(P-ISSN 0972-3099)
(e-ISSN 2278-5124)

Environment Conservation Journal

Volume 24, Number (3), 2023

An International Journal Devoted to Conservation of Environment
(A Peer Reviewed Journal)

Action for Sustainable, Efficacious Development and Awareness (ASEA), India
www.environcj.in

Environment Conservation Journal

(P-ISSN 0972-3099) (e-ISSN 2278-5124)

An International Journal Devoted to Conservation of Environment

(A Peer Reviewed Journal)

Volume 24, Number (3), 2023

Issue DOI: https://doi.org/10.36953/ECJ.2023.2403

NAAS Rating: 5.66

Editorial Head Office

405, VivekVihar, Ranipur More,

Opposite Hotel Vinayak, Haridwar- 249407

Uttarakhand, India

Published by: Action for Sustainable Efficacious Development and Awareness (ASEA)

Phone: 09897020147, 09412072917 www.environcj.in E-mail: environcj@gmail.com

Environment Conservation Journal

ISSN 0972-3099 (Print) ISSN 2278-5124 (Online)

Abstracted/Indexed in

- **DOAJ (DIRECTORY OF OPEN ACCESS JOURNALS)**
- **Chemical Abstracts Services (U.S.A.)**
- **Aquatic Science and Fisheries Abstracts (U.S.A.)**
- **NATIONAL ACADEMY OF AGRICULTURAL SCIENCE (NAAS)**
- **EBSCO (U.S.)**
- **Indian Science Abstracts (India)**
- **CAB Abstracts (U.K.)**
- **J-Gate (India)**
- **World Cat (USA)**
- **Scilit (Switzerland)**
- **PKP Index (Canada)**
- **BASE (Bielefeld Academic Search Engine) Germany**
- **Euro Pub (U.K.)**
- **Scope database, India**
- **Index Copernicus (Poland)**
- **Google Scholar (U.S.A.)**
- **Indian Citation Index (India)**
- **IP indexing (India)**

DISCLAIMER: Though we try our best to get abstracted/ indexed/ enlisted each and every article in the above repositories but we cannot guarantee the inclusion of each and every published articles in these websites.

INSTRUCTIONS TO AUTHORS

Aims and Scope: Environment Conservation Journal aims to publish original research/ review papers/ Book reviews/ Reports on conferences/ seminars/ important events, news of interest/ information on forthcoming seminar/ books on the environment related aspects. It encourages submission of two categories of papers. The first category comprises scientific papers and second category comprises engineering papers. The study of environment is inherently multidisciplinary.

Authors Guidelines

Submission, revisions and publication:

Manuscripts should be submitted online as a Microsoft Word file in a single column format on our website through the submission portal.

- The manuscript should be in English
- Use a normal, plain font (12-point Times new Roman) for text with 1.5 space.
- Use italics for emphasis.
- Use the automatic line numbering and page numbering function to number the pages and lines.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Use the equation editor or MathType for equations.
- Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).
- Abbreviations should be defined at first mention and used consistently hereafter.
- Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full.

Once the manuscript is submitted online on our website, our editorial team will do an initial assessment (Plagiarism and Quality Check) of the submitted manuscript to ascertain its eligibility to be sent for review. After passing the plagiarism and quality check stage the manuscript will be sent for review, Authors are also encouraged to provide the names of three referees/reviewers along with the manuscript.

The authors are given reasonable time and opportunities to revise the paper to address the comments of the reviewers and editorial team. If the author is unable to revise the manuscript as requested, the manuscript will be rejected. Also, if the revisions are not received within the requested dates of the revision, the manuscript will not be processed further and the authors will be requested to submit the manuscript again and will be treated as a new submission for re-review. Any manuscript which has been dormant for more than a year due to any reason whatsoever will be deleted from our system.

After a thorough review and revision process, if the paper is accepted for publication then, Article Processing charges would be charged. Please refer to the Payments and Subscriptions section of our website for the current fee structure.

The decision of the Editor-in-Chief would be final for the acceptance of the manuscript for publication in the journal.

Manuscript Preparation

The manuscript should be in English in Times new roman (font size 12, space 1.5) with wide margins on high quality white paper. Subdivision of the paper into Abstract (Not more than 300 words), Introduction, Materials and Method, Results and Discussion, Conclusion, Acknowledgements and References is recommended.

Page 1: of the manuscript should contain Short and informative Title of paper, Article type, Keywords for computer aided searching, Author(s) and Co-authors name(s), Affiliation(s), complete address for correspondence including electronic address (Email id), telephone and Fax number.
Page 2: of the manuscript should contain the Abstract (Not more than 300 words) and at least six keywords in alphabetical order.

Consecutive pages: of the manuscript should contain Introduction, Materials and Method, Results and Discussion, Acknowledgement, Conflict of Interest, funding if any, References.

Tables

All the tables/figures/histogram/photographs should be consecutively numbered with a brief caption below and should be placed at the end of the manuscript. The illustrations should be of good quality. Illustration should be designed to allow 50 % reduction. These should be numbered sequentially.

- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

References

The list of references should only include works that are cited in the text and that have been published or accepted for publication.

Reference list entries should be alphabetized by the last names of the first author of each work.

Journal names and book titles should be italicized.

If available, please always include DOIs as full DOI links in your reference list (e.g. "https://doi.org/abc").

Reference Citations in text

For single author

Cite last name every time the reference appears in the text. For example: (Khanna, 2018) or Khanna (2018)

For two authors

Cite both names every time the reference appears in the text. For example: (Khanna and Bhutiani, 2018) or Khanna and Bhutiani (2018)

For more than two authors

Cite the last name followed by et al. in italic. For example: (Khanna et al., 2018) or Khanna et al. (2018)

Citing authors with multiple works from one year

Cite the multiple works with a, b, c and so on. Assign these letters within the reference list also, which is sorted alphabetically by the surname of the first author. For example: (Khanna, 2017a,b,c) or Khanna, (2017a,b,c)

If these works are by the same author, cite the surname once followed by the years in chronological order. For example: (Bhutiani, 2007, 2013, 2017) or Bhutiani (2007, 2013, 2017)

No author

If there is a title of a book, periodical, brochure or report, it should be italicised. For example: (A guide to citation, 2017).

Citing a group or organisation

Cite the full name of the group. For example: (Food and Agriculture Organization, 2017) or Food and Agriculture Organization (2017)

Citing an entire website

When you refer to a website in your text without quoting or paraphrasing from a specific part of it, you do not need a formal citation. Use the same format as you use for print, with a URL added at the end. For example: www.environcj.in or (www.environcj.in)

For this kind of citation, you do not need to include the website in the list of Reference sections.

Citing a specific page of the entire website

If you are citing a specific page or article from a website, you will need a formal citation in the text and also in the reference list of the Reference section.

For example: (Centers for Disease Control and Prevention, 2021) or Centers for Disease Control and Prevention (2021)

All references cited in the text should be listed at the end of the manuscript alphabetically in the following style:

References in the Reference list

For paper

Bhutiani, R., Ram, K. & Ahamad, F. (2019). Assessment of suitability of ground water quality in and around Laksar, Haridwar, Uttarakhand on the basis Water Quality Index (WQI). Environment Conservation Journal, 20 (1), 41–46. https://doi.org/10.36953/ECJ.2019.1008.1207

For book

Khanna, D.R. & Bhutiani, R. (2017): Water Biology. Discovery Publishing House, New Delhi.

Society, association, or institution as author and publisher

American Public Health Association (2012). Standard methods for examination of water and waste water.23th Ed. Washington DC, USA.

Chapter, essay, or article by author in a book or encyclopedia edited by another

Priyanka, Tiwari, Ramesh Chandra and Bhutiani, Rakesh (2021): Green tea and its effects with special reference to ayurvedic concept about tea and rasayana. In: Green Tea (pp: 99-109) Nova Publications.

Ph.D. Thesis, Dissertation and Reports

Bhutiani, R., (2004). Limnological status of river Suswa with reference to its mathematical modeling, Ph.D. Thesis submitted to Gurukul Kangri University, Haridwar, Uttaranchal, India.

For webpage

Centers for Disease Control and Prevention (2021). Water treatment. Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID), Division of Foodborne, Waterborne, and Environmental Diseases (DFWED). Retrieved March 3, 2021, https://www.cdc.gov/healthywater/drinking/public/water_treatment.html

Annual report

United States Department of Agriculture (2016). World Rice Production, Consumption, and Stocks. United States Department of Agriculture. Foreign Agricultural Service. Retrieved from http://apps.fas.usda.gov/psdonline/psdHome.aspx)

Permissions

If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s) for both the print and online format. Please be aware that some publishers do not grant electronic rights for free.

Animal Ethics and Informed Consent for Human Participants:

The author should ensure that appropriate permission are taken from the concerned Animal Ethics Committee for the conduct of the research using animals. The research involving human participants proper guidelines should be followed to protect their privacy and written consent should be taken informing the participants about the data to be used in the research.

Author contributions

The Publisher recommends authors to include contribution statements in the work that specifies the contribution of every author in order to promote transparency. These contributions should be listed at the separate title page.

Changes to authorship

Authors are strongly advised to ensure the correct author group, the Corresponding Author, and the order of authors at submission. Changes of authorship by adding or deleting authors, and/or changes in Corresponding Author, and/or changes in the sequence of authors are not accepted after acceptance of a manuscript.

- Please note that author names will be published exactly as they appear on the accepted submission

Please make sure that the names of all authors are present and correctly spelled, and that addresses and affiliations are current.

Adding and/or deleting authors at revision stage are generally not permitted, but in some cases it may be warranted. Reasons for these changes in authorship should be explained. Approval of the change during revision is at the discretion of the Editor-in-Chief.

If there is suspicion of misbehavior or alleged fraud the Journal and/or Publisher will carry out an investigation following COPE guidelines. If, after investigation, there are valid concerns, the author(s) concerned will be contacted under their given e-mail address and given an opportunity to address the issue.

Proofs

Galley proofs will be sent to the corresponding author by e-mail, your response, with or without corrections, should be sent within 72 hours. However, on non-receipt of the proof, the care would be taken by the publisher to get the papers corrected and published at the earliest possible.

As part of our Go Green initiative, ECJ has decided not to provide hard copies. This will help us fulfil our environmental commitment to care of the earth for ourselves and generations to come. A secured pdf file of the published research paper/review article would be provided by e-mail to the corresponding author. Authors will be able to view the manuscript on the journal’s website.

Article Processing Charges: Article processing charges of INR 7500 (with in India) and USD 225 (Outside India) up to 12 print pages of the journal and there-after INR 500 (within India)/ USD 15 (outside India) for additional each print page, will be charged for publication of the MS. For any subsequent MS, separate Article processing charges would be charged. The Article processing charges cover the costs including those of publication management, journal production, online hosting and archiving, abstracting and indexing services, online distribution to discovery services, content aggregators, Digital Object Identifier (DOI) numbers and other related services.

Print Copies: As part of our Go Green policy we print very limited hard copies of the issues on special request only. It's INR 1500/USD 150 for 1 issue, which includes postal charges.

Volume-24, Number (3), 2023
Contents

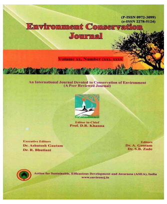
Page no.

Environment Conservation Journal 24 (3):1-7, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Genetic parameters and association analysis for grain yield and yield attributing traits in rice (*Oryza sativa* L.) germplasm lines

Yeshala Chandra Mohan
Rice Research Centre, ARI, PJTSAU, Rajendranagar. Hyderabad, Telangana, India
Kasanaboina Krishna ✉
Department of Genetics and Plant Breeding, PJTSAU, College of Agriculture, Rajendranagar. Hyderabad, Telangana, India
Lavuri Krishna
Rice Research Centre, ARI, PJTSAU, Rajendranagar. Hyderabad, Telangana, India.
Thakur Veerendar Jeet Singh
Rice Research Centre, ARI, PJTSAU, Rajendranagar. Hyderabad, Telangana, India.
R. Jagadeeshwar
Administrative Building, PJTSAU, Rajendranagar. Hyderabad, Telangana, India.

ARTICLE INFO

Received: 27 July 2022
Revised : 10 December 2022
Accepted: 03 January 2023

Available online: 11 April 2023

Key Words:
Additive Gene Action
Direct Effect
Indirect Effect
Inheritance and Selection

ABSTRACT

The intensity of trait association and genetic variability of yield attributing variables in 217 rice genotypes was investigated during *kharif* 2018. The existence of genetic variability among the genotypes was demonstrated by analysis of variance, which recorded significant differences for all the seven studied parameters. The estimation of variability indicated that The full grain number per panicle (37.2 % and 34.1 %) & single plant yield (24.7 % and 20.55 %) had the highest intensity of phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV), and High heritability along with high genetic advance as a per cent of mean (GAM) was found in Plant height (98.9 % and 20.8 %), panicle number per plant (95.4 % and 36 %), panicle length(96.8 % and 35.9 %), full grain number per panicle(99.5 % and 61.6 %), thousand seed weight (98.1 % and 40.25 %) and single plant yield (69.2 % and 35.2 %) , depicting additive gene action in inheritance of these parameters. A simple selection procedure can help to enhance these characteristics even further. Correlation and regression coefficient findings indicated that plant height (0.193) and the full grain number per panicle (0.177**) had a significant impact on single plant yield. The full grain number per panicle (0.265**), followed by thousand seed weight (0.194**) and plant height (0.110**), had the maximum direct positive effect on single plant yield, as per path coefficient analysis. As a result, accessions with a higher full grain number per panicle, thousand seed weight and plant height would be suitable for yield enhancement programme.**

Introduction

The world's population is expected to exceed nine billion and food insecurity might become a major issue worldwide by 2050 (Alexandratos and Bruinsma 2012). As a consequence, increasing the output of essential cereal crops such as rice is critical to meet expanding population need (Fitzgerald *et al.,* 2009). Rice accounts for roughly 20 % of the calories consumed by humans. It is known in India as "Prana," which means "breath of life." Rice, like other cereal grains, has a high biological value and substantial protein content. Successful parent selection necessitates knowledge of the kind and degree of population diversity, trait conglomeration with yield and its attributes, as well as the degree of the environmental effect on the manifestation of the attributes. Correlation and path coefficient analysis may be one of the useful strategies in accurately assessing cause and conglomeration between yield and agronomic traits (Khan *et al.,* 2003). Seed yield is a multifaceted

Corresponding author E-mail: *kasanaboinakrishna@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14032416

parameter that is influenced by a wide range of factors that can have favorable or negative consequences. Assessing each trait's contribution is essential in order to place greater attention on those that have the greatest impact on seed yield. As a result, data on the confederation between characteristics and seed production is critical for defining yield-based selection criteria for rice breeding. Genetic advancement is another term for the predicted response to selection (GA). Significant genetic advancement paired with high heritability estimates is the most successful selection condition (Shalini *et al.,* 2000). The focus of this research was to identify rice germplasm with high yielding potential and to see the conglomeration between morphological traits and yield. This morphological analysis will aid in discovering the relationships between these traits, which will ultimately assist in the production of a desirable plant type that combines the expression of numerous desired traits.

Material and Methods

The germplasm used in this investigation consisted of 210 accessions of *O. sativa,* The trial was conducted in *kharif* 2018 at Rice Research Centre, Agriculture Research Institute, Rajendranagar, Hyderabad, Telangana State, by utilizing Federer's (1956, 1961, 1991) augmented design with seven checks. Thirty-one days old seedlings were placed into a well prepared main field after establishing a healthy nursery. Each genotype has two rows of 4m length, consisting 25 plants in each row. For each genotype, plant height, panicle number per plant, panicle length, full grain number per panicle, thousand seed weight, and single plant yield, were all determined on randomly selected five plants. On a full plot basis, days to 50% heading was recorded. ANOVA was used to compare the mean data of each character. Burton (1952) and Shafique, *et al.,* 2016) approach was used to quantify the genotypic and phenotypic variances, as well as the genotypic (GCV) and phenotypic (PCV) coefficients of variation. The genetic advance (GA) being determined using Johnson *et al.* (1955) method and heritability in the broad sense [h2 (b)] was estimated utilising the formulae provided by Lush (1940). correlations as per Singh and Chaudhary (1985) and path analysis as outlined by Dewey and Lu (1959), and INDOSTAT software ver 9.2 was used to perform regression analysis.

Results and Discussion

Genetic variation among parameters is vital for breeding and selecting desirable types, an investigation of the correlation between seed yield and yield components is critical for determining selection criteria. Since seed yield is a polygenic and complex trait that is influenced by a huge range of other factors, direct selection based solely on an association pattern between two variables may occasionally mislead the breeder; therefore, direct and indirect effects should be differentiated for effective selection. (Awol and Alise, 2018).

The correlation coefficient reflects the degree of relationship of various yield component characteristics among themselves and with the yield. Correlation studies between various yield attributes and yield provide a foundation for future breeding programmes. Path coefficient analysis determines the direct effect of one variable on another and allows the correlation coefficient to be divided into components of direct and indirect effects (Swetha *et al.,* 2019). Information on the variability and correlation studies among the economic characters of the crop. is of great value to plant breeders (Shedge *et al.,* 2019). It will not only, help to understand the desirable and undesirable relationship of economic characters but also help in assessing the scope of simultaneous improvement of two or more attributes (Shanmugam and Kalaimagal, 2019).

Genetic parameters: variability, heritability, and genetic advance

All the seven parameters in the current investigation showed significant differences between the genotypes as illustrated in the ANOVA (Table 1). The minimal genotypic coefficient of variation (GCV) (5.59 %) and phenotypic coefficient of variation (PCV) (5.69 %) were observed for the days to 50 % heading. The estimated heritability for this parameter was high (96.5%), while GA (genetic advance as per cent of mean) was moderate (11.7%) (Table 2). These results were akin to the findings of Prasannakumari *et al.* (2020) for minimal GCV and PCV, Pragnya *et al*. (2018) for high heritability and Sandeep *et al*. (2018) for moderate GA. For plant height, the GCV and PCV estimates were moderate, 10.19 and 10.24

Table 1: ANOVA for yield and its attributing parameters in rice (*Oryza sativa* L.)

	DF	DFF	PH	PNP	PL	NFGP	TW	SPY
Entries (ignoring Blocks)	216	51.171**	154.589**	7.432**	25.646**	7031.833 **	26.252**	77.007**
Checks	6	151.581**	300.224**	2.77**	11.252**	28421.38 **	265.643**	119.537**
Varieties	209	47.989 **	144.046**	7.42**	25.635**	6120.859 **	19.466**	62.848**
Checks vs.Germplasm	1	113.668**	1484.308**	36.567**	114.206**	69088.190 **	8.318**	2781.070**
ERROR	54	1.285	1.139	0.262	0.639	22.477	0.283	16.097

DFF: Days to 50% flowering, PH: Plant height (cm), PNP: Panicle number per plant, PL: Panicle length (cm), NFGP: Full grain number per panicle, TW: 1000-seed weight, SPY; single plant yield(g).
**** Significant at 1 level of probability**

Table 2: Amplitude of variability, heritability and genetic advance for yield and it's component parameters in rice

S N	Characters	Phenotypic Variance	Genotypic Variance	Environmental variance	PCV (%)	GCV (%)	Heritability in broad sense (h^2) (%)	Genetic Advance as % mean
1	**DFF**	37.43	36.15	1.28	5.69	5.59	96.5	11.3
2	**PH**	111.75	110.62	1.13	10.24	10.19	98.9	20.8
3	**PNP**	5.80	5.54	0.26	18.82	17.86	95.4	36
4	**PL**	19.98	19.34	0.63	18.05	17.76	96.8	35.9
5	**NFG/P**	4743.0	4720.5	22.47	30.06	29.99	99.5	61.6
6	**TSW**	15.13	14.84	0.28	19.91	19.72	98.1	40.25
7	**SPY**	52.28	36.18	16.09	24.70	20.55	69.21	35.2

per cent, respectively. This character had a high heritability estimate (98.90%) and a high GA (20.8 %). Similar results have been reported by Prasannakumari *et al.* (2020) for high heritability, Rachana (2018) for high GA for plant height.

Panicle number per plant had moderate GCV and PCV *i.e*., 17.86 % and 18.82% respectively. The recorded heritability was high for this trait (95.4 %) with high GA (36 %) which are in accordance with the reports of Edukondalu *et al.* (2017) for moderate GCV and PCV, Nikhitha *et al.* (2020) for high heritability and high GA. The moderate GCV and PCV were recorded (*i.e.,* 17.76% and 18.05% respectively) for panicle length (cm). The estimated heritability (96.8%) and GA (35.9 %) were high for this trait. The results are in agreement with findings of Mishu *et al.* (2016) for moderate GCV and PCV, Rachana (2018) for high GA and heritability.

High GCV (29.99%) and PCV (30.06%) were recorded for the full grain number per panicle. This trait's heritability was correspondingly high (99.5%), with a high GA (61.6 %) and these results were akin with the reports of Rukmini Devi *et al.* 2017 and Fathima *et al.* (2021). 1000-grain weight exhibited moderate GCV (19.72%) and PCV (19.91%) with high heritability estimate (98.1%), as well as high GA (40.25 %). Similar findings were reported by Hema *et al.* (2019) for high heritability and GA. Single plant yield recorded high GCV (20.55%), PCV (24.70 %) heritability (69.2 %) and GA (35.2 %) as reported earlier by Dhurai *et al*. (2014). Similarly to our findings, the above-mentioned observations for high GCV and PCV estimates in various genotypes, including early segregating and advanced generation for important yield component traits, suggest the possibility of genetic improvement through direct selection for these traits.

Correlation analysis

If a plant having high vegetative growth or plant height, usually flowering is delayed, and excess vegetative growth / plant height, istelf is an indication of translocating high amount of nutrients, which eventually lead to filling of grains and high exerting panicle. There was a substantial and positive interaction of days to 50 per cent flowering with the plant height (0.152*) and negative, significant interaction with panicle length (-0.185**) (Table 3 and Figure 1) Significant and positive interaction was shown by plant height with panicle length (0.275**) and full grain number per panicle (0.224*). Similar findings were reported by Begum *et al.* (2021). The conglomeration of full grain number per panicle revealed a significant and negative phenotypic interrelation with 1000seed weight (-0.571**). Positive and significant

Table 3: Phenotypic (P) correlation coefficients of yield and it's component traits in rice

	DFF	PH	EBT	PL	NFG/ P	TW	SPY
DFF	**1.0000**	0.152 *	-0.037	-0.185 **	0.086	-0.109	0.049
PH	0.152 *	**1.000**	-0.031	0.275 **	0.224 **	0.097	0.193**
PNP	-0.037	-0.031	**1.000**	-0.113	-0.072	-0.078	0.034
PL	-0.185 **	0.275**	-0.113	**1.000**	0.067	0.091	0.056
NG/P	0.086	0.224 ***	-0.072	0.067	**1.000**	-0.571 ***	0.177**
TSW	-0.109	0.097	-0.078	0.091	-0.571 ***	**1.000**	0.044

*** Significant at 5 per cent level; ** Significant at 1 per cent level**

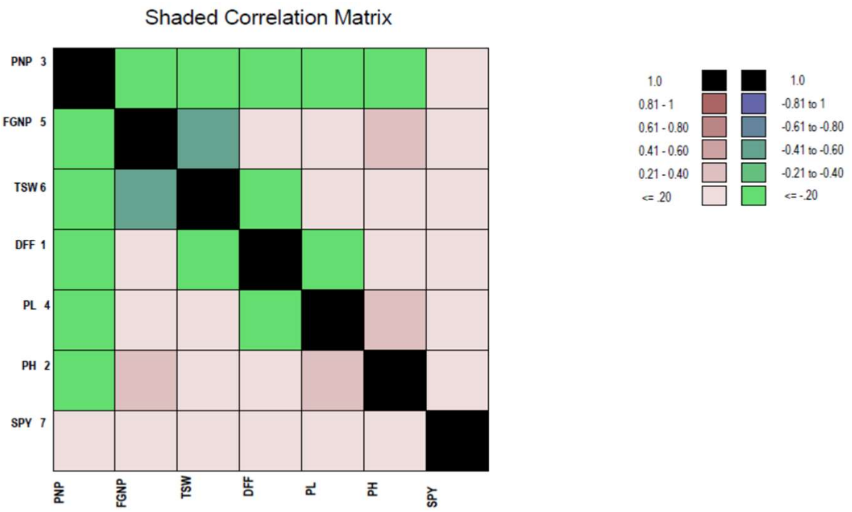


Figure 1: C*orrelogram* visualizing the correlation in yield and its attributing traits rice

conglomeration of single plant yield with full grain number per panicle (0.193**) and plant height (0.177**), indicated that these two characteristics were essential for improvement of yield. Similar findings were found by Saleh *et al.* (2020) for full grain number per panicle.

Path coefficient analysis

The highest significant, positive direct phenotypic influence was exhibited by full grain number per panicle (0.265) on single plant yield (Table 4. and Fig.2) and it also contributed significant negative indirect effects *via* 1000-seed weight (-0.151). Saleh *et al.* (2020) found similar findings of positive direct effect of full grain number per panicle on single plant yield. Thousand seed weight (0. 196) showed a greater direct phenotypic positive effect on single plant yield and this trait also contributed negative indirect effects through full grain number per panicle (-0.1108). Plant height (0.110) recorded a significant positive direct phenotypic influence on single plant yield. Other traits i.e. days to 50% heading (0.034), panicle number per plant (0.074), and panicle length (0.005) had a negligible direct positive phenotypic effect on single plant yield. The full grain number per panicle had the greatest positive direct effect on single plant yield, followed by 1000-seed weight and plant height, according to path coefficient analysis. These characteristics should be emphasized in the selection process to isolate superior rice genotypes with higher yield potential.

Multiple linear regressions

Regression coefficients and the likelihood of the calculated variables in predicting single plant yield are displayed in table 3. Based on these findings, the following model equations for estimating grain yield/plant (Y) are developed.

$Y = +0.06157x_1 DFF + 0.14020x_2\ PH + 0.11325x_3\ EBT + 0.10110x_4 PL + 0.01909x_5\ NGP + 0.07731x_6\ TW$

The t-test for the parameters revealed that the plant height (0.5752) and full grain number per panicle, (0.7344) have contributed significantly to single plant yield as reported earlier by Begum *et al.*(2021).

Table 4: Phenotypic (P) path coefficients of yield and it's component traits in rice

	DFF	PH	EBT	PL	NFG/ P	TW	SPY
DFF	**0.034**	0.005	-0.001	-0.006	0.003	-0.003	0.049
PH	0.016	**0.110***	-0.003	0.030	0.024	0.010	0.193**
PNP	-0.002	-0.002	**0.074**	-0.008	-0.005	-0.005	0.034
PL	-0.001	0.001	-0.002	**0.005**	0.002	0.003	0.056
FGNP	0.022	0.059	-0.019	0.017	**0.265****	-0.151	0.177**
TSW	-0.021	0.0188	-0.015	0.017	-0.1108	**0.194****	0.0440

Phenotypic Residual effect = 0.365 Bold values are direct effects

Table 5: Multiple linear regression in predicting rice grain yield

	Beta Wt.	Simple R^2	Reg. Coeff.	Std.Err.	t-value	t Prob.	Partial R^2
INTERCEPT a		0.0000	1.90780	10.2164	0.8180	0.852	0.000
DFF	0.0344	0.0017	0.04318	0.0766	3.2793	0.4141	0.001
PH	0.1103	0.0213	0.08016	0.0476	0.5752	0.0012 **	0.010
PNP	0.0744	0.0026	0.24438	0.1946	0.9481	0.5656	0.006
PL	0.0057	0.0003	0.01010	0.1116	2.9995	0.3439	0.000
FGNP	0.2652	0.0469	0.02859	0.0082	0.7344	0.0029 **	0.043
TSW	0.1939	0.0085	0.34059	0.1320	0.8180	0.4633	0.024
*** Significant at 5 per cent level; ** Significant at 1 per cent level**							

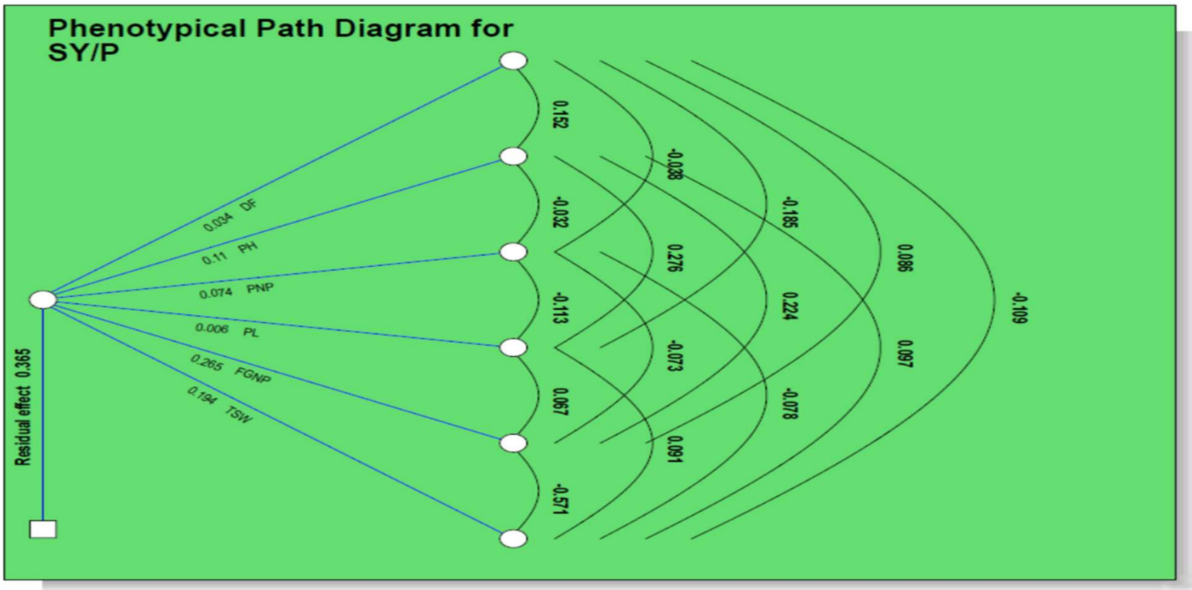


Figure 2: Phenotypical path diagram indicating direct and indirect effect of various traits on grain yield of rice.

Conclusion

The genetic organization of grain yield is the final net impact of multiple yield components interacting with one another. The present findings showed that the materials under investigation had substantial genetic variability. Plant height, panicle number per plant, panicle length, full grain number per panicle, 1000 seed weight, and single plant yield had high heritability and genetic advance as per cent of mean, , showing that the characters were governed by additive gene effects, where selection can be practiced for these traits. High heritability estimates along with moderate genetic advance as per cent of mean for days to 50% heading, suggests the existence of non-additive gene effects, as well as environmental influence. As per correlation and regression coefficient analysis, plant height and the full grain number per panicle contributed significantly to single plant yield. The full grain number per panicle had the greatest positive direct influence on single plant yield, followed by 1000-seed weight and plant height, according to path coefficient analysis. As a result, accessions with a larger full grain number per panicle with higher 1000-seed weight and plant height would be ideal for yield enhancement scheme.

Acknowledgement
The authors appreciate the facilities provided by the Post Graduate School and Director, ICAR- Indian Agricultural Research Institute (IARI), New Delhi, and ICAR- Research Complex for the North Eastern Himalayan Region (ICAR–RCNEH), Barapani, Meghalaya, India.

Conflict of interest
The authors declare that they have no conflict of interest.

References
Alexandratos, N., & Bruinsma, J. (2012) World Agriculture towards 2030/2050. (2013). Variability in quasi cms lines of aromatic rice (*Oryza sativa* L.) in BC 3 generation and their phenotypic acceptability. *Eco-friendly Agriculture Journal*. (6), 78-82.

Awol, M., & Alise, F. (2018). Correlation and path analysis in yield and yield components in Ethiopian chick pea land races. *Journal of food and agriculture* 12(6), 35-37.

Begum, S., Srinivas, B., Reddy, V. R., & Kumari, C. A. (2021). Multiple Regression, Correlation and Path Analysis of Gall Midge Incidence, Yield and Yield Components in Rice (*Oryza sativa* L.) Hybrids. *Current Journal of Applied Science and Technology*, 40(2), 33-45.

Burton, G. W. 1952. Quantitative inheritance in grasses. *Proceedings of 6th Grassland Congress J.* (1), 277-281.

Dhurai, S.Y., Bhati, P.K. & Saroj, S.K., (2014). Studies on genetic variability for yield and quality characters in rice (*Oryza sativa* L.) under integrated fertilizer management. *The Bioscan*, 9(2),745-748.

Edukondalu, B., Reddy, V.R., Rani, T.S., Kumari, C.A. & Soundharya, B. (2017). Studies on variability, heritability, correlation and path analysis for yield, yield attributes in rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences*. 6 (10), 2369-2376.

Fathima, M.A., Geetha, S., Amudha, K. & Uma, D., (2021). Genetic variability, frequency distribution and association analysis in ADT (R) 48 x Kavuni derived F2 population of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*(1956). Augmented designs. Hawaiian Planter's Rec.55:191–208.

Federer, W.T. (1961). Augmented designs with one-way elimination of heterogeneity. *Biometrics* 20, 540–552.

Federer, W.T. (1991). Statistic and society. Section 7.11. 2nd ed.Marcel Dekker, New York, NY.

Fitzgerald, M. A., Bergman, C. J., Resurreccion, A. P., Moller, J., Jimenez, R., Reinke, R. F., Martin, M., Blanco, P., Molina, F., Chen, M. H., Kuri, V., Romero, M. V., Habibi, F., Umemoto, T., Jongdee, S., Graterol, E., Reddy, K. R., Bassinello, P. Z., Sivakami, R., Rani, N. S., Das, S., Wang, Y. J., Indrasari, S. D., Ramli, A., Ahmad, R., Dipti, S. S., Xie, L., Lang, N. T., Singh, P., Toro, D. C., Tavasoli, F. & Mestres, C. (2009a). Addressing the dilemmas of measuring amylose in rice. *Cereal Chemistry*, Vol. 86 (5). 492–498

Hema, T., Saravanan, S., Kannan, R., Shoba, D. and Pillai, M. A. (2019). Studies on genetic variability, association and path coefficient analysis in F2 derivatives of CR 1009× WP 22-2 for earliness and semi-dwarfism in rice (Oryza sativa L.). *Electronic Journal of Plant Breeding*, 10(2): 585-591

Johnson, H.W., Robinson, H.F. & Comstock, R.E. (1955). Estimates of genetic and environmental variability of Soybeans. *Agronomy Journal*. 47: 314-318.

Khan, A.S., Ashfaq, M, & Asad, M, A. (2003).A correlation and path coefficient tanalysis for some yield components in bread wheat. *Asian Journal of Plant Sciences*, 2(8): 582-584.

Lush, J.L. (1940). Correlation and regression of offspring in rams as a method of estimating heritability of characters. *Proceedings of American Society of Animal Production*. (33): 292-301

Mishu, M.F.K., Rahman, M.W., Azad, M.A.K., Biswas, B.K., Talukder, M.A.I., Kayess, M.O., Md. Rafiqul Islam, M.R & Alam, M.R. (2016). Study on Genetic Variability and Character Association of Aromatic Rice (*Oryza sativa* L.) Cultivars. *International Journal of Plant and Soil Science*., 9(1), 1-8.

Nikhitha, T. C., Pushpham, R., Raveendran, M. & Manonmani, S. (2020). Genetic variability and frequency distribution studies in F2 population involving traditional variety mappillai samba. *Electronic Journal of Plant Breeding*, 11(3), 933-938

Pragnya K., Radha Krishna, K. V., Subba Rao, L, V., & Suneetha, K. (2018). Estimation of Genetic Variability Parameters in Soft Rice (*Oryza sativa* L.) Genotypes.

International Journal of Current Microbiology and Applied Sciences. 7(06), 2029-2042.

Prasannakumari, M., Akilan, M., Kalaiselvan, S., Subramanian, A., Janaki, P. & Jeyaprakash, P. (2020). Studies on genetic parameters, correlation and path analysis for yield attributes and Iron content in a backcross population of rice [(*Oryza sativa*. L.)]. *Electron. Journal of Plant Breeding*, 11(3), 881- 886.

Rachana B., (2018). Variability, heritability and genetic advance for yield and its component traits in NPT core set of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, *9*(4), 1545-1551.

Rukmini Devi, K., Parimala, K., Venkanna, V. & Cheralu, C. (2014). Genetic variability, heritability, correlation and path analysis for yield and quality traits in rice (*Oryza sativa* L.). *The Journal of Research PJTSAU*. 42(4), 7- 14.

Rukmini Devi, K., Satish Chandra, B., Lingaiah, N., Hari, Y. & Venkanna, V. (2017). Analysis of variability, correlation and path coefficient studies for yield and quality traits in rice (*Oryza sativa* L.). *Agriculture Science Digest*. 37(1), 1-9.

Saleh, M.M., Salem, K.F.M. & Elabd, A.B. (2020). Definition of selection criterion using correlation and path coefficient analysis in rice (*Oryza sativa* L.) genotypes. *Bull Natl Res Cent* 44, 143.

Sandeep, S., M. Sujatha, L.V. Subbarao & Neeraja, C.N. (2018). Genetic Variability, Heritability and Genetic Advance Studies in Rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences.* 7(12), 3719-372

Shafique, M. S., Muhammad, A., Zafar, M., Muhammad, A., Awais, S., & Ahmad, M. I. (2016). Genetic variability and interrelationship of various agronomic traits using correlation and path *analysis in chickpea (Cicer arietinum L.). Academia Journal of Agricultural Research*, 4(2), 82-85.

Shalini, S., R.A. Sheriff, R.S. Kulkami & P.Venkantarmana, (2000). Correlation and path analysis of lndian mustard germplasm. *Research on Crops in India*, 1(2), 226-229.

Shanmugam, M., & Kalaimagal T. (2019). Genetic Variability, Correlation and Path Coefficient Analysis in Chickpea (Cicer arietinum L.) for Yield and its Component Traits. *International Journal of Current Microbiology and Applied Sciences* 8(5),1801-1808.

Shedge, P.J., Patil, D.K., & Dawane, J.K. (2019). Correlation and Path Coefficient Analysis of Yield and Yield Components in Chickpea (Cicer arietinum L.) *International Journal of Current Microbiology and Applied Sciences*, 8(5), 82-85.

Singh, N. & Verma, O.P., (2018). Genetic variability, heritability and genetic advance in rice (*Oryza sativa* L.) under salt stressed soil. *Journal of Pharmacognosy and Phytochemistry,* 7(3),3114-3117.

Singh, R.K. & Chaudhary, B.D. (1985). Biometrical methods inquantitative genetic analysis. Kalyani Publishers, New Delhi, Ludhiana, India: 205-215.

Swetha, P. B., & Lavanya, G. R. (2019). Genetic variability, heritability and character association for yield and component characters in chickpea (Cicer arietinum L.). *Journal of Pharmacognosy and Phytochemistry*, 8(5), 161-163.

Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3):8-13, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Diversification of traditional rice – wheat system with vegetables for sustainable productivity, profitability and energy efficiency

Avnee ✉
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, District Kangra (HP)
SC Negi
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, District Kangra (HP)
Puneet Kaur
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, District Kangra (HP)
Navneet Kaur
Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, District Kangra (HP)

ARTICLE INFO

Received : 28 July 2022
Revised : 10 December 2022
Accepted : 03 January 2023

Available online: 11 April 2023

Key Words:
Cropping system
Energy
Food security
Productivity
Profitability
Sustainability

ABSTRACT

Rice – wheat cropping system is backbone of agriculture and responsible for achieving food security in the country. However, because of threat to sustainability of this system there is urgent need of crop diversification. A field experiment to diversify the rice – wheat system in wet zone of Himachal Pradesh was carried out during the year 2017-18 at Bhadiarkhar research farm, Department of Agronomy, CSK HPKV, Palampur to evaluate productivity, profitability and energy pattern of eight different rice-based cropping systems. Results revealed that rice – palak – cucumber system resulted in significantly higher rice grain equivalent yield (16477 kg/ha), profitability (₹ 848.76/ha/day), productivity (63.62 kg/ha/day), net returns (₹ 219828/ha) and benefit cost ratio than other crop sequences whereas lowest rice grain equivalent yield (6259 kg/ha) and productivity (21.44 kg/ha/day) was recorded from traditional rice – wheat system. However, land utilization ratio and duration were found to be maximum from turmeric – pea – summer squash system (86.85) followed by rice – wheat. Energy utilization was noticed highest from rice – lettuce – potato + coriander system followed by turmeric – pea – summer squash. Maximum energy output (280.42×10^{3}MJ/ha) and energy efficiency (10.58) were observed in rice – palak – cucumber system.

Introduction

Cereal-based cropping systems have significant role in attaining self-sufficiency in food-grain production in India. One of the most important cropping systems in country is rice – wheat system which is considered to be the major contributor to the national food basket. Maximum area of country is covered by this system (about 10.5 M ha area) (Sarkar, 2015). However, concern has been raised over the sustainability of this system due to natural resource degradation (declining soil fertility and lowering of groundwater tables), climate variability, reduction in profitability, and decelerating yield growth rates of both the crops (Lohan *et al.*, 2017; Jat *et al.*, 2021). As much of the food and economic security has been dependent on this cropping system, the low production level needs urgent attention. So, to maintain sustainability it is imperative to intensify and diversify rice – wheat system with other crops of high economic value. Crop diversification is a useful means to increase crop output, achieve stability and sustainability in production and stabilizing farm income. It is significant tool in minimizing the risk in farming (Hedge *et al.*, 2003). Diversified farms are resilient to shocks and stresses thus are economically and ecologically stable. Diversification is responsible for yield maximization owing to high cropping intensity. It

Corresponding author E-mail: *avneemandial@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14082418

provides large scale boost to Indian agricultural economy in terms of income, employment and nutritional improvement. Intensification in rice – wheat system can be achieved through either adding or replacing rice or wheat crop with some high value crops like vegetables which will not only increase production and profitability, but it also maintains sustainability to meet requirement of future generation (Samui *et al.*, 2004). It also improves socio-economic condition of farmers and provide year-round income and employment to them. Agriculture in Himachal is characterized by presence of large number of small and marginal farmers. The wet zone is bestowed upon with plenty of rainfall congenial for vegetable production. Also, hilly area of the state is famous for production of high-quality vegetables which are major driving force behind diversifying cereal-based cropping systems with high value vegetables. Therefore, to increase income of small households, alternative cropping systems suited to the region for efficient utilization of resources need to be selected for higher system productivity, economic returns and benefit cost ratio.

Material and Methods

Experimental site

A field investigation on diversification of rice – wheat cropping system was carried out in the year 2017-18 under All India Coordinated Research Project to evaluate productivity, profitability and energy auditing of diversified cropping systems at Bhadiarkar research farm of department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The research site was located at latitude of 32°04′ N and longitude of 76°35′ E and at an elevation of 1100 m amsl in the Palam valley of Kangra region.

Soil and Climate

Soil of experimental farm was silty clay loam in texture, slightly acidic (pH 5.5) with high organic carbon (0.95%), available nitrogen (295.12 kg/ha), phosphorus (68.58 kg/ha) and potassium (123.35 kg/ha) at the start of investigation. The total rainfall recorded was 2851mm from June 2017-June 2018. The minimum and maximum temperature varied from 3.06 – 20.78 and 15.71 – 32.89 during the cropping period. The climate of region is classified as humid sub-tropical with cool winters and mild summers.

Treatment details

The experiment was laid out in randomized block design with eight treatments (T_1: Rice – Wheat, T_2: Rice – Pea – Summer squash, T_3: Okra – Radish – Onion, T_4: Turmeric – Pea – Summer squash, T_5: Rice – Lettuce –Potato + Coriander, T_6: Rice – Palak – Cucumber, T_7: Rice – Broccoli – Radish and T_8: Colocasia – Pea + Coriander) which were replicated four times. All the crops were provided with full recommended dose of fertilizes. All the intercultural operations were according to recommended package of practices for the region. The varieties, seed rate and fertilizer doses for each crop is given in table 1.Economic yield of all the crops were converted to rice grain equivalent yield (RGEY) as per the price of the respective crop at a local market and was calculated as follows-

$$\textbf{RGEY (kg/ha)= Economical yield of a crop (kg/ha) x } \frac{\text{Price (₹/kg) of same crop}}{\text{Price (₹/kg) of rice}}$$

Land use efficiency (LUE) was measured by dividing actual duration of crop sequence with 365 and expressed as percentage.Energy input (MJ/ha) was calculated by summing up all the energy expenditures used for raising the component crops. Energy output (MJ/ha) was determined by adding the energy equivalents (MJ) for main and by products of crops.

$$E_0 = \{\sum(M_y * E_m)\} + \{\sum(B_y * E_b)\}$$

E_0 is the energy output
M_y and B_y are the economic and by-product yield, respectively
E_m and E_b are energy equivalents for main crop and by-products, respectively

$$\textbf{Energy use efficiency, EUE} = \frac{\text{Energy Output (MJ/ha)}}{\text{Energy Input (MJ/ha)}}$$

$$\textbf{Energy productivity} = \frac{\text{Grain Output (kg/ha)}}{\text{Energy Input (MJ/ha)}}$$

Results and Discussion

Rice grain equivalent yield, productivity, land use efficiency and duration

The rice equivalent yield (RGEY) was recorded highest in rice – palak – cucumber (table 2) which was followed by okra – radish – onion and turmeric – pea – summer squash which might be due to high market price of vegetables compared to cereals and also high cropping intensity than cereal-based system. Lowest RGEY was recorded from traditional rice – wheat system (Jat *et al*., 2012) which was 2.6 times less than rice – palak – cucumber. Productivity also followed almost similar trend as rice equivalent yield. Maximum productivity was observed in rice – palak – cucumber sequence because of higher production and market price of cucumber. Tandel *et al*. (2014) and Kachroo *et al*. (2014) also reported similar results where maximum rice grain equivalent yield and productivity was observed from diversified vegetable-based sequence compared to cereal-based system. Total duration and land utilization efficiency was maximum for turmeric – pea – summer squash system which was followed by rice – wheat and rice – pea – summer squash. Lowest land use efficiency was recorded from rice – broccoli – radish and rice – palak – cucumber sequence (table 2).

Table 1: Varieties, seed rate and fertilizer doses of all the crops

Sequence	Crop	Variety	Seed rate (kg/ha)	Fertilizer dose		
				N	P2O5	K2O
Kharif						
T_1	Rice	HPR-2143	15	90	20	40
T_2	Rice	HPR-2143	15	90	20	40
T_3	Okra	P-8	15	75	25	55
T_4	Turmeric	Palam pitamber	2250	30	15	60
T_5	Rice	HPR-2143	15	90	20	40
T_6	Rice	HPR-2143	15	90	20	40
T_7	Rice	HPR-2143	15	90	20	40
T_8	Colocasia	Local	2000	75	25	50
Rabi						
T_1	Wheat	HPW-155	100	120	60	30
T_2	Pea	Palam Priya	75	25	30	60
T_3	Radish	Japanese white	8	100	25	35
T_4	Pea	Palam Priya	75	25	30	60
T_5	Lettuce	Avej wonder	0.5	60	20	40
T_6	Palak	Pusaharit	30	74	25	30
T_7	Broccoli	Palam samridhi	0.5	150	50	55
T_8	Pea + Coriander	Palampriya+Local	75+10	25	30	60
Summer						
T_1	-	-	-	-	-	-
T_2	Summer squash	Pusaalankar	8	100	25	55
T_3	Onion	Nasik red	10	125	37	60
T_4	Summer squash	Pusaalankar	8	100	25	55
T_5	Potato + Coriander	Kufrijyoti + Local	2250 + 10	120	40	60
T_6	Cucumber	Palam sanjog	10	100	25	60
T_7	Radish	Marvel white	4	100	25	35
T_8	-	-	-	-	-	-

Table 2: Rice grain equivalent yield, LUE and productivity of rice-based cropping systems

	Cropping sequence	Biological yield (kg/ha)	RGEY (kg/ha)	Duration (days)	LUE (%)	Productivity (kg/ha/day)
T_1	Rice – Wheat	4072 + 2273	6259	96 + 196 (292)	80.00	21.44
T_2	Rice – Pea – Summer squash	3598 + 2273 + 7292	13163	96 + 132 + 54 (282)	77.26	46.68
T_3	Okra – Radish – Onion	1098 + 5398 + 13636	14025	63 + 83 + 123 (269)	73.70	52.14
T_4	Turmeric – Pea – Summer squash	2794 + 1610 + 7008	13506	131 + 132 + 54 (317)	86.85	42.61
T_5	Rice – Lettuce – Potato + Coriander	3930 + 3409 + 8523 + 379	12547	96 + 58 + 119 (273)	74.79	45.96
T_6	Rice – Palak – Cucumber	3409 + 1420 + 11648	16477	96 + 113 + 50 (259)	70.96	63.62
T_7	Rice – Broccoli – Radish	2841 + 2367 + 3598	7599	96 + 103 + 59 (258)	70.68	29.46
T_8	Colocasia – Pea + Coriander	8144 + 1894 + 237	10630	131 + 133 (264)	72.33	40.26
	CD		1737			6.61

This was due to presence of more fallow period between harvest and sowing of successive crop. These cropping systems need more intensification to get more profit per unit area per unit time. Among the crops, wheat crop remained in field for longest followed by pea, turmeric and onion while cucumber, summer squash, lettuce and radish covered the field for very short duration i.e for less than 60 days.

Energy pattern

Energy pattern of different rice-based cropping systems were evaluated (table 3). Rice – lettuce – potato + coriander cropping system utilized maximum amount of energy which is attributed to labour intensive nature of potato crop and high cropping intensity of this system. This sequence was followed by turmeric – pea – summer squash and rice – broccoli – radish. However, rice – wheat sequence utilized the lowest amount of energy. Similar results were reported by Sharma *et al*. (2004). In case of energy output, rice – pea – summer squash system was reported to had significantly higher energy output followed by rice – wheat, rice – broccoli – radish, rice – lettuce – potato + coriander, colocasia – pea + coriander, rice – palak – cucumber, turmeric – pea – summer squash and least for okra – radish – onion (127.71). Net energy was also recorded maximum for rice – pea – summer squash system followed by rice – wheat. This was due to more output of energy as compared to energy use in these systems. Least net energy was from okra – radish – onion sequence.

The energy use efficiency was recorded maximum in rice – pea – summer squash. However, this sequence was at par with rice – wheat system. This was due to production of maximum energy with low energy input in this system. Similar results were also reported by Kacharoo *et al (2012).* Significantly lower energy efficiency was observed in okra – radish – onion which was at par with turmeric – pea – summer squash. Among all the cropping systems, rice – lettuce – potato + coriander was found to be most productive (9.95 kg/MJ) followed by Colocasia – pea + coriander whereas traditional rice – wheat system was reported to be least productive (0.64 kg/MJ).

Table 3:Energy pattern of different rice-based cropping systems

	Cropping systems	Energy input (MJ/ha)	Energy output (MJ/ha)	Net Energy (MJ/ha)	Energy Efficiency	Energy productivity
T_1	Rice – Wheat	23478.37	240113.64	216635.27	10.23	0.64
T_2	Rice – Pea – Summer squash	26513.69	280421.40	253907.71	10.58	1.49
T_3	Okra – Radish – Onion	29505.84	127712.12	98206.28	4.33	1.90
T_4	Turmeric – Pea – Summer squash	33780.22	159308.71	125528.49	4.72	1.16
T_5	Rice – Lettuce – Potato + Coriander	39804.19	205118.37	165314.18	5.15	9.95
T_6	Rice – Palak – Cucumber	27857.43	168522.73	140665.30	6.05	1.84
T_7	Rice – Broccoli – Radish	33102.41	215250.95	182148.54	6.50	0.88
T_8	Colocasia – Pea + Coriander	26616.72	197500.00	170883.28	7.42	6.14
	CD	-	28814.98	28814.98	0.98	0.06

Economic analysis

It is evident from table 4 that maximum cost for cultivation of crops was involved in turmeric – pea – summer squash system (₹ 168 040/ha) followed by rice – lettuce – potato + coriander and okra – radish – onion. However, least cost was involved in rice – wheat sequence. Rice – palak – cucumber system generated highest gross and net returns (₹ 344 488 and 219 828/ha, respectively) which was followed by rice – pea – summer squash and okra – radish – onion. Lowest gross returns were obtained from rice – wheat system (₹ 163 542/ha) whereas net returns were lowest from rice – broccoli – radish (₹ 80 163/ha) followed by rice – wheat (₹ 80163/ha). Similar results were reported by Prasad and Urkurkar (2010). Benefit cost ratio followed the similar trend being highest from rice – palak – cucumber system (5.64) and lowest from rice – wheat (1.88). Returns and benefit cost ratio was higher from the systems including vegetables compared to cereal-based system. These results corroborate the findings of Prasad (2016). Moreover, all the cropping systems are intensified than rice – wheat system. Rice – palak – cucumber cropping system generated maximum income (848.76 ₹/ha/day) mainly because of higher production which ultimately fetch more returns from cucumber. This system was followed by rice – pea – summer squash and okra – radish – onion whereas rice – broccoli – radish (176.78 ₹/ha/day) and rice – wheat (274.53 ₹/ha/day) were least profitable. Economic efficiency of rice – palak – cucumber was recorded 380% and 209% higher over rice – broccoli – radish and rice – wheat system. Prasad *et al*. (2013) and Ray *et al*. (2016) also reported similar results in rice-based cropping system.

Table 4: Economic analysis of various rice-based cropping systems

	Cropping sequence	Cost of cultivation	Returns (₹/ha)		B:C	Profitability (₹/ha/day)
			Gross	Net		
T_1	Rice – Wheat	82014	163542	80163	1.88	274.53
T_2	Rice – Pea – Summer squash	127646	285914	156903	4.06	556.39
T_3	Okra – Radish – Onion	130003	282395	152392	2.91	566.51
T_4	Turmeric – Pea – Summer squash	168040	275846	107806	2.67	340.08
T_5	Rice – Lettuce – Potato + Coriander	162534	266004	93075	3.07	340.93
T_6	Rice – Palak – Cucumber	123295	344488	219828	5.64	848.76
T_7	Rice – Broccoli – Radish	121222	168196	45609	1.04	176.78
T_8	Colocasia – Pea + Coriander	129373	224091	94718	1.58	358.78
	CD		35295	35295	0.29	134.26

Conclusion

From the research it can be concluded that rice – palak – cucumber cropping sequence resulted in higher rice grain equivalent yield, economic and production efficiency, net and gross returns and benefit cost ratio whereas energy efficiency and energy output were recorded highest from rice – pea – summer squash system. Inclusion of legume crop in system was found to increase dry matter production and yield of succeeding crop i.e summer squash. Land use efficiency was maximum from turmeric – pea – summer squash which utilized the land for maximum period. Overall, it can be concluded that vegetable-based systems are superior in almost all aspects over traditional rice – wheat system. So, it is advisable to farmers to substitute cereal-based system with diversified crops so as to provide additional sources of revenue, making farming more resilient, promoting a diverse ecosystem for the long-term viability of the farm, sustainable production and for better resource use efficiency.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Hedge, D.M., Tiwari, S.P. and Rai, M. (2003). Crop diversification in Indian agriculture. *Agricultural Situation in India,*351-354.

Jat, H.S., Kumar, V., Kakraliya, S.K., Abdallah, A.M., Datta, A., Choudhary, M., Gathala, M.K., McDonald, A.J., Jat, M.L. and Sharma, P.C. (2021). Climate-smart agriculture practices influence weed density and divesity in cereal-based agri-food systems of western Indo-Gangetic plains. *Scientific Reports,* 11, 15901.

Jat, R.A., Dungrani, R.A., Arvadia, M.K. and Sahrawat, K.L. (2012). Diversification of rice (*Oryza sativa* L.) based cropping systems for higher productivity, resource-use efficiency and economic returns in South Gujarat of India. *Archives of Agronomy and Soil Science,* 58(6), 561-572.

Kachroo, D., Thakur, N.P., Kaur, M., Kumar, P., and Sharma, R. (2012). Productivity and energetic of rice (*Oryza sativa*) based cropping systems under sub-tropical condition of Jammu. *Indian Journal of Agronomy,* 57: 117-121.

Kachroo, D., Thakur, N.P., Kaur, M., Kumar, P., Sharma, R. & Khajuria, V. (2014). Diversification of rice-based cropping system for enhancing productivity and employment. *Indian Journal of Agronomy,* 59, 21-25.

Lohan, S.K., Jat, H.S., Yadav, A., Sidhu, H.S., Jat, M., Choudhary, M., Peter, J.& Sharma, P. (2017). Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews,* 81, 693-706.

Prasad, A. (2016). Diversification of existing rice–based cropping system for sustainable productivity under assured irrigation condition for Chhattisgarh plains. *International Journal of Multidisciplinary Education and Research,* 1(3), 85-88.

Prasad, D., and Urkurkar, J.S. (2010). Economic evaluation of rice based cropping sequences in plain areas of Chhattisgarh. *Journal of Soils and Crops*, 20: 229-232.

Prasad, D., Yadava, M.S.& Singh, C.S. (2013). Diversification of rice-based cropping systems for higher productivity, profitability and resource-use efficiency under irrigated ecosystem of Jharkhand. *Indian Journal of Agronomy,* 58, 264-270.

Ray, M., Roy, D.C.&Zaman, A. (2016). Evaluation of rice (*Oryza sativa*)-based cropping systems for increasing productivity, resource use efficiency and energy productivity in coastal West Bengal. *Indian Journal of Agronomy,* 61(2), 131-137.

Samui, R., Kundu, A., Mazumdar, D., Mani, P.&Sahu, P. (2004). Diversification of rice (*Oryza sativa*)-based cropping system in new alluvial zone of West Bengal. *Indian Journal of Agronomy,* 49,71-73.

Sarkar, S. (2015). Management practices for enhancing fertilizer use efficiency under rice-wheat cropping system in the Indo-Gangetic Plains. *Innovare Journal of Agricultural Science,* 3(2), 5–10.

Sharma, R.P., Pathak, S.K., Haque, M.& Raman, K.R. (2004). Diversification of traditional rice (*Oryza sativa*) based cropping system for sustainable production in South Bihar alluvial plains. *Indian Journal of Agronomy,* 49(4), 218-222.

Tandel, B.M., Patel, N.N. &Tandel, Y.N. (2014). Economic production on rice based vegetable cropping system. *Indian Journal of Agronomy,* 79, 233-236.

Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3):14-20, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Genetic divergence studies for yield and its component traits in Mung bean (*Vigna radiata* L. Wilczek)

Sindoora Nalajala ✉

Department of Genetics and Plant breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur, India.

N. Brajendra Singh

Department of Genetics and Plant breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur, India.

M. Samuel Jeberson

Department of Genetics and Plant breeding, Agriculture University Jodhpur, Mandor, Jodhpur, Rajasthan, India.

Sonika Yumnam

Department of Genetics and Plant breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur, India.

Bireshwar Sinha

Department of Plant Pathology, College of Agriculture, Central Agricultural University, Imphal, Manipur, India.

ARTICLE INFO

Received : 16 August 2022
Revised : 22 January 2023
Accepted : 13 February 2023

Available online: 11April 2023

Key Words:
Genetic divergence
Inter and intra cluster distance
Mahalanobis D^2
Mung bean

ABSTRACT

The present investigation was carried out at Genetics and Plant Breeding (GPB) farm, College of Agriculture, Central Agricultural University, Imphal, Manipur during kharif 2021 using 60 genotypes of Mung bean. Mahalanobis D^2 statistics was used to evaluate the diversity. A total of fourteen clusters were formed with maximum number of genotypes in cluster I *i.e.*, 29 genotypes followed by cluster II with 17 genotypes, cluster XII with 3 genotypes, all the remaining clusters were mono genotypic. It was found that the pattern of genotype distribution into different clusters was random and unrelated to geographic diversity. Results on genotype diversity between clusters IV and IX revealed the greatest inter-cluster distances, whereas cluster XII had the greatest intra-cluster distances. The largest cluster mean for seed yield per plant was found in cluster IX. Further, maximum contribution towards divergence was by number of seeds per plant (52.49%) followed by seed yield (17.8%) and days to 50% flowering (7.34%), while minimum by pod length which had shown 0% contribution.

Introduction

In South and South-East Asia, the mung bean (*Vigna radiata* (L.) Wilczek) is one of the most significant food legumes. Pedigree analysis of the majority of the released cultivars showed that only a small number of parents with a close degree of relatedness were regularly used in breeding programmes. Amplified Fragment Length Polymorphism analysis, which is used to analyse genetic diversity, also reveals a high degree of similarity among mung bean varieties (Ghat *et al.*, 2005). ISSR research demonstrates that Indian cultivars have a small genetic foundation due to the continuous adoption of identical cultivars in their genealogy (Saini *et al.*,2004). So, Genetic divergence studies are essential for understanding the genetic variety among genotypes and are helpful in the selection of heterogeneous parents to achieve higher degrees of heterosis as well as a wide range of variability for efficient selection. When numerous traits are considered simultaneously, multivariate analysis, such as the Mahalanobis D^2 statistic, is a useful tool for determining the genetic diversity within a population. The difficulty of selecting various parents for hybridization programmes is brought into sharper focus by the discovery of the features important for genotype discrimination. In order to use these genotypes in crop improvement initiatives aiming at creating high yielding mung bean genotypes, it was decided to quantify the genetic diversity of the mung bean genotypes under study.

Corresponding author E-mail: *nalajalasindoora1@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14422436

Material and Methods

The experiment was carried out on 60 genotypes of mung bean, the genotypes are selected based on visual diversity for seed shape, seed colour and seed lustre, at GPB Farm, College of Agriculture, Central Agricultural University, Imphal, Manipur during kharif 2021, following Randomized Block Design with three replications. Each row was 4 m × 30 cm size with a spacing of 30 cm x 10 cm between and within rows. All the other recommended package of practices were followed during the study for a good crop growth and the genotypes are harvested as and when pods matured. Ten randomly selected plants from each genotype in each replication were taken and observed for several traits i.e., days to 50 % flowering (number of days from sowing until 50% of plants in a genotype plot per replication had atleast one open flower), days to maturity (number of days was taken from sowing to 80% pods maturation on a plant), plant height (cm) (it was measured at maturity from ground level to tip of the main axis), number of primary branches (number of branches emerging directly from the main shoot), primary branch length (cm), number of clusters per plant (number of pod bearing clusters in a plant was calculated), number of pods per plant, Pod length (cm) (it was measured at the time of maturity), number of seeds per pod, number of seeds per plant, 100 seed weight (g), biological yield (g) (weight of all the above ground parts along with the roots was calculated after harvest), harvest index (%) (calculated by dividing total seed yield by biological yield per plant which is expressed as percentage) and seed yield per plant (g), the mean of all ten sampled plants from each genotype is drawn and used for further calculations. Using the D^2 statistics of Mahalanobis (1936), genetic divergence was assessed, and Tocher's approach was used to divide genotypes into several groups (Rao, 1952). The experimental data was analysed statistically by the method of analysis of variance for single factor and lastly to find out the significance mean difference between varieties different genetic parameters were estimated.

Results and Discussion

In the present investigation 60 genotypes of mung bean were grouped into fourteen different clusters using Tocher’s clustering method.

Clustering pattern

The 60 mung bean genotypes used for the genetic divergence analysis varied greatly in terms of the 14 morphological traits examined. The cluster I contained maximum number of genotypes i.e., 29 followed by cluster II with 17 genotypes, cluster XII with 3 genotypes and one genotype in each of other eleven clusters which depicts a large amount of variation between and among the genotypes. Wide diversity was also reported by Das *et al.* (2010) grouped 23 genotypes in 8 clusters. The clusters and the contributing genotypes were presented in Table 1 and the dendrogram depicting the cluster pattern in Figure 1.

Table 1: **Showing clustering pattern of 60 genotypes of mung bean on the basis of D^2 statistics**

Cluster	Number of genotypes	Genotypes included
I	29	OBGG 109, BCM 18-2, DGGV 91, MH 1468, MH 1772, BCM 18-1, RVSM 18-1, SML 2015, KM 2241, CAU- GG-1, COGG 16-10, IPM 1610-1, Pusa BM6, RMG 1139, PM 1609, IIPM 20-2, Pusa M 2072, GM 6, IIPM 20-1, Pusa M 2071, Pusa 0672, KM 2419, MI 750-1, MGG 453, Pusa 1371, SML 1839, Pusa M 2132, VGG 17-049 and PM 504-20-27
II	17	RMG 1166, MH 1830, Pusa M 2131, Virat (IPM 205-7), IPMD 1604, IPM 99-125, TBMB 17-2, MHBC 20-7, MI 181-1, IPM 1604-1, SKNM 1705, RMG 1154, TCADM 20-5, SML 1115, PM 1624, Pusa BM 16 and IPMD 101-2
III	1	VGG 15-013
IV	1	IPM 604-1-2
V	1	IPM 1603-1
VI	1	PM 1603
VII	1	IPM 1103-1
VIII	1	Pant M6
IX	1	RMG 1132
X	1	TBMB 117-5
XI	1	IGKM 06-18-3
XII	3	PM 1605, MLS and SKNM 1514
XIII	1	MML 2568
XIV	1	LGG 600

Inter and intra cluster distances

Table 2 lists the typical inter and intra cluster distances between and within the fourteen clusters. In the majority of cases, the inter-cluster distances

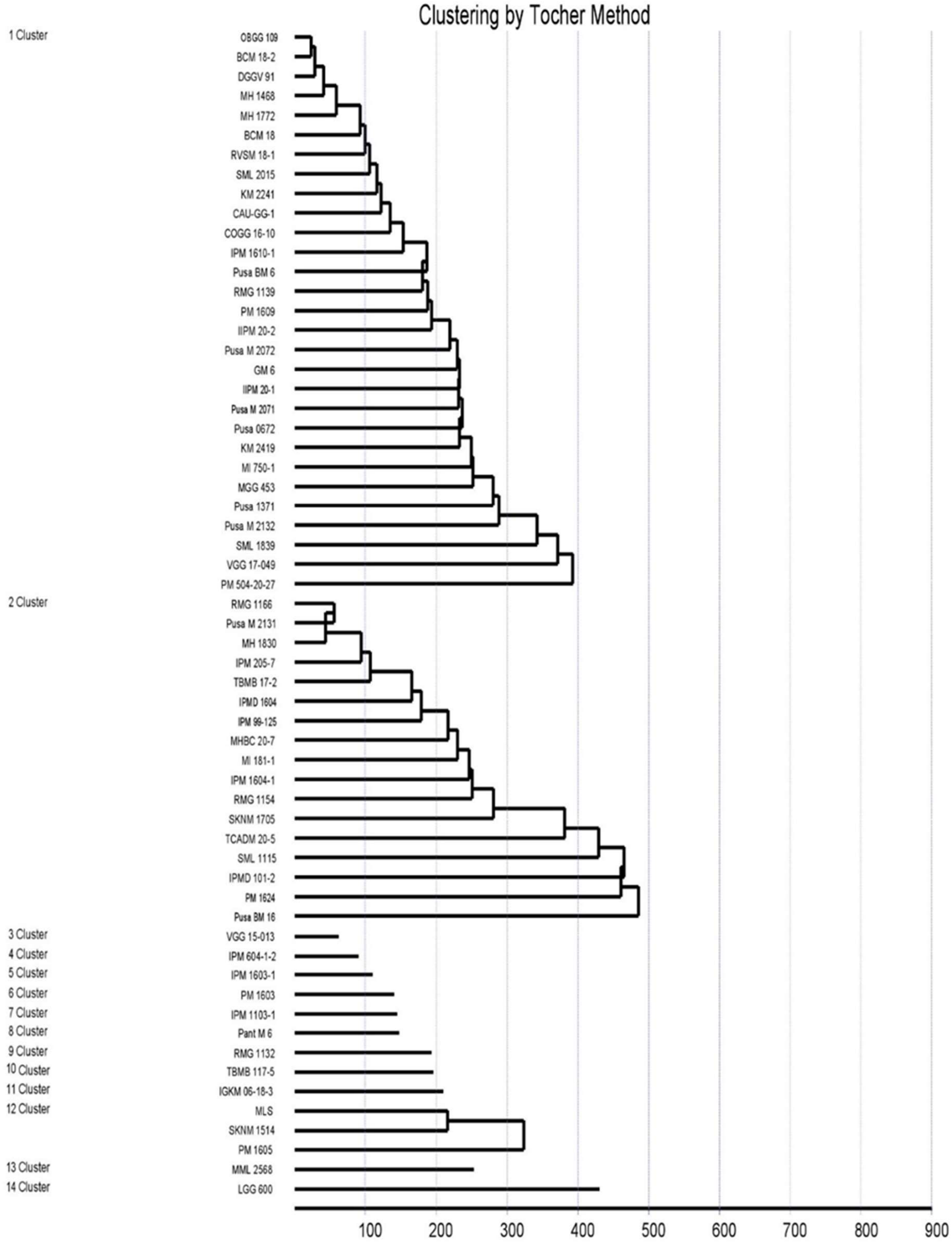


Figure 1: Dendrogram showing the cluster pattern of 60 genotypes of Mung bean

Table 2: Showing average intra & inter cluster distance among fourteen clusters of mung bean.

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
I	255.07	897.74	596.21	430.62	1800.82	478.72	1894.85	517.79	2196.17	852.45	536.23	620.61	1273.52	998.82
II		362.67	564.80	1793.12	650.70	1108.13	619.31	840.7	812.66	594.31	1152.62	802.31	645.6	1651.57
III			0	1144.51	1444.0	605.19	1401.53	147.11	1578.3	359.45	334.83	572.67	926.97	531.15
IV				0	3254.59	825.02	3340.27	78881	3718.04	1385.52	635.83	1209.72	2519.79	1160.75
V					0	1759.93	145.14	2060.57	193.06	1673.23	2450.31	1374.85	374.84	2930.3
VI						0	1921.47	646.14	1931.27	1382.23	655.78	401.91	845.24	515.77
VII							0	1915.77	197.55	1462.21	2489.09	1608.88	421.58	2918.85
VIII								0	2242.48	409.24	210.3	695.45	1363.79	504.41
IX									0	1934.56	2669.51	1499.89	426.34	2957.72
X										0	734.80	1104.08	1492.3	1246.61
XI											0	682.86	1613.74	430.33
XII												395.48	812.33	900.06
XIII													0	1703.41
XIV														0

Table 3: Cluster means for seed yield and its component traits in 60 genotypes of mung bean in 14 clusters.

	DF	DM	PH	PB	PBL	NC	NPP	PLN	SPP	SPPL	TW	BY	HI	SY
I	33.74	64.51	30.62	1.88	14.34	3.66	8.25	7.27	11.14	97.51	3.14	7.61	44.03	3.22
II	35.14	64.78	39.14	1.57	19.06	5.47	16.78	7.46	11.70	218.10	3.24	12.96	52.18	6.53
III	42.00	70.00	48.90	1.37	16.31	4.53	13.73	6.55	10.47	167.53	2.19	13.27	32.95	4.37
IV	32.00	62.67	23.27	2.60	17.10	2.17	5.23	5.55	10.27	43.53	2.08	2.87	32.67	0.93
V	34.33	64.33	30.33	1.20	13.20	7.13	18.47	8.47	13.73	265.43	3.39	21.27	45.94	9.77
VI	40.33	70.00	25.53	3.33	16.60	2.70	5.17	6.10	9.33	87.33	3.52	9.00	43.03	3.87
VII	36.00	64.67	25.73	1.00	11.20	6.73	15.10	7.89	11.93	285.47	3.65	13.93	68.80	9.60
VIII	40.33	69.33	36.35	1.00	27.20	4.27	11.33	6.27	6.40	132.60	2.21	6.67	45.14	2.97
IX	38.33	64.33	46.10	2.63	20.85	6.20	17.40	7.57	12.07	283.40	3.15	15.00	68.49	10.27
X	36.33	65.00	36.59	1.23	18.07	6.73	19.40	7.74	10.77	208.40	3.81	12.27	32.41	3.97
XI	40.00	69.67	49.10	1.30	42.33	5.67	6.87	6.95	12.20	90.07	2.39	6.30	31.76	2.00
XII	37.22	67.44	48.98	2.96	32.76	5.94	14.78	7.90	9.19	116.90	3.52	10.59	50.98	4.63
XIII	40.00	70.00	33.03	1.53	18.36	4.40	9.27	8.87	12.60	193.23	4.58	12.20	63.68	7.77
XIV	45.67	78.00	40.91	3.33	21.38	7.00	9.67	6.53	10.33	93.27	2.41	6.60	31.84	2.10

DF-Days to 50% flowering, DM- days to Maturity, PH-plant height, PB-number of Primary branches, PBL-primary branch length, NC-number of Clusters per plant, NPP-number of Pods per plant, PLN-Pod length, SPP-number of Seeds per pod, SPPL-number of Seeds per plant, TW-100 Seed weight, BY-biological yield, HI-harvest index and SY-seed yield per plant.

were greater than the intra-cluster distances, showing a significant amount of genetic variation. Maximum values at the intra-cluster level were found for cluster XII (395.48), cluster II (362.67), and cluster I (255.07), indicating that there is a significant genetic diversity among the genotypes of these clusters. Due to the presence of a single genotype in the other eleven clusters, intra cluster distances in these clusters were zero (0). The average inter-cluster values were minimum between cluster V and VI (145.14) and maximum between cluster IV and IX (3718.04). The cluster pairs exhibiting very high inter-cluster distance were between IV and IX (3718.04) followed by cluster IV and VII (3340.27) and cluster IV and V (3254.59) when crosses are made between genotypes of these clusters there may be increased chance of heterosis, So, it is desirable to attempt crosses between genotypes belonging to distant clusters for getting highly heterotic crosses which are likely to yield wide range of segregants on which selection can be done. While least inter-cluster distances were between cluster V and VII (145.14), cluster III and VIII (147.11), cluster V and IX (193.06), cluster VII and IX (197.55), cluster VIII and XI (210.3). The inter and intra-cluster distances were depicted in Figure 2.

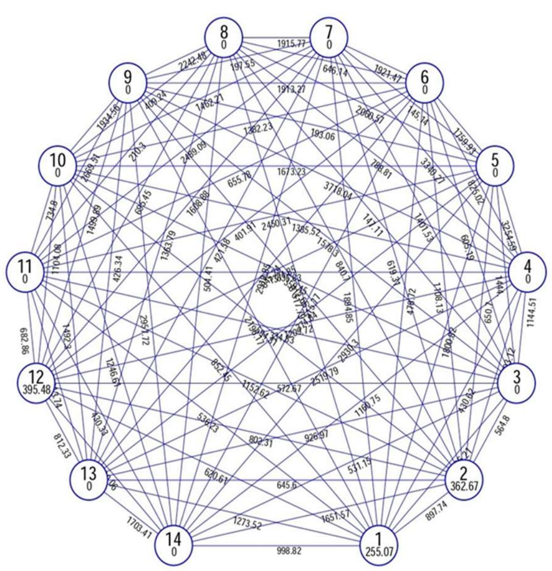


Figure 2: Average inter and intra cluster distance between fourteen clusters of 60 genotypes of Mung bean

Cluster means for different characters

Table 3 displays the cluster means for the fourteen morphological characters. For several features, there was a wide range in cluster mean values among the clusters. Cluster V had maximum cluster mean for number of clusters per plant (7.13), number of seeds per pod (13.73) and biological yield (21.27), whereas cluster XIV had maximum cluster means for days to 50% flowering (45.67), days to maturity (78.00) and number of primary branches (3.33). maximum cluster mean value for traits number of seeds per plant (285.47) and harvest index (68.8) was observed in cluster VII. While plant height (49.10) and primary branch length (42.33) in cluster XI and pod length (8.87) and 100 seed weight (4.58) had their highest means in cluster XIII. Cluster IX had maximum cluster mean for seed yield per plant (10.27) and cluster X had maximum cluster mean for number of pods per plant (19.4). Same trend was observed by Raje and Rao (2001) where cluster III had highest values for number of primary branches, number of clusters, number of pods per plant and number of seeds per plant., Haritha and Reddy (2002) observed maximum values in cluster VII, Yimram *et al*. (2009), Gokulakrishnan *et al*. (2012) observed cluster V recorded the highest mean for seed yield per plant, number of pods per plant, number of branches per plant, number of seeds per pod and 100 seed weight, Gadakh *et al*. (2013) reported cluster V had highest cluster mean for number of seeds per pod and biological yield, while cluster VII had highest cluster mean for pod length and 100 seed weight. Razzaque *et al*. (2016) cluster III had the highest cluster mean for pods per plant, seeds per pod, 1000 seed weight and seed yield, Sarkar and Kundagrami (2016) Cluster V showed the maximum mean value for plant height, number of pods per plant, seed per pod, seed yield and lowest values for days to 50% maturity and days to maturity, and Tiwari *et al*. (2022) reported similar results for clusters I to VII.

Relative contribution of the traits towards divergence

Percent contribution of 14 quantitative traits towards divergence by clustering is depicted in tabulated form Table 4 and pictorially in the Figure 3. Highest percentage contribution towards divergence was shown by trait number of seeds per

Table 4: Relative contribution of the fourteen characters studied towards the divergence

SN	Character	Percent contribution
1	Days to 50 % flowering	7.34
2	Days to maturity	1.07
3	Plant height (cm)	0.34
4	Number of primary branches	6.84
5	Primary branch length (cm)	3.95
6	Number of clusters per plant	0.11
7	Number of pods per plant	0.85
8	Pod length (cm)	0.00
9	Number of seeds per pod	0.51
10	Number of seeds per plant	52.49
11	100 seed weight (g)	1.53
12	Biological yield (g)	0.68
13	Harvest index (%)	6.5
14	Seed yield per plant (g)	17.8

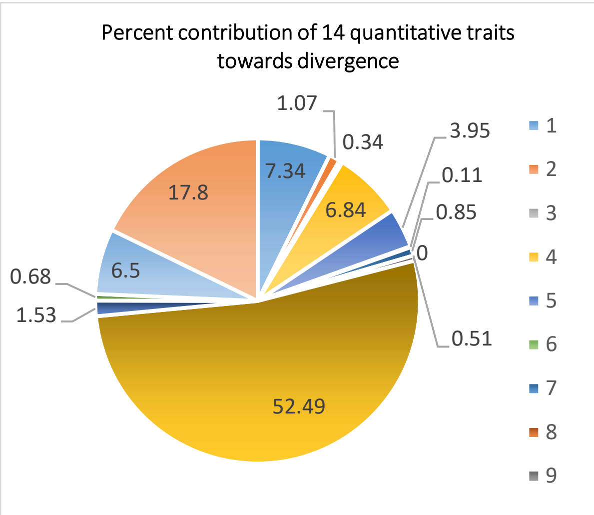


Figure 3: Percentage contribution of individual character towards divergence

plant (52.49%) followed by seed yield per plant (17.8%), days to 50% flowering (7.34%), number of primary branches (6.84%), harvest index (6.5%),primary branch length (3.95%), 100 seed weight (1.53%), days to maturity (1.07%), number of pods per plant (0.85), biological yield (0.68%), number of seeds per pod (0.51%) and plant height (0.34%). While lowest percentage contribution towards divergence was shown by number of clusters per plant (0.11%) and pod length had shown (0%) no contribution towards the divergence. Same trend was observed with the results of Jadhav *et al*. (2021) for PC1 TO PC7. The traits with more percentage contribution can be highlighted like number of seeds per plant and seed yield per plant to understand the variation between genotypes.

Conclusion

The 60 mung bean genotypes used in the current study were split into 14 clusters, with Clusters V and XIV having the highest cluster means for most of the variables and Clusters IV and IX having the maximum inter-cluster distance. According to the D^2 analysis of genetic diversity, which is based on significant inter-cluster distances, the genotypes were found to be diverse for most of the characters and it is advised to cross the genotypes from clusters IV and IX and cluster IV and VII, which may lead to a wide spectrum of favourable genetic variability for improving yield in mung bean.

Acknowledgement

The facilities needed to conduct my research were generously provided by the Department of Genetic and Plant Breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur. I am extremely thankful to the members of my advisory committee for their continuous support and encouragement.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Das, A.M., Biswas and Dastidar, K.K.G. 2010. Genetic divergence in greengram (*Vigna radiate* L. Wilczek). *Scialert.net/abstract/doi: Journal*, 126-30.

Gadakh, S.S., Dethe, A.M., Kathale, M.N., & Kahate, N.S. (2013). Genetic diversity for yield and its component traits in green gram [*Vigna radiata* (L.) Wilczek]. *Journal of Crop and Weed*, 9(1), 106-109.

Ghat, K.V., Lakhanpaul, S., & Chandha, S. (2005). Amplified fragment length polymorphism (AFLP) analysis of genetic diversity in Indian mungbean (*Vigna radiata* (L.) Wilczek) cultivars. *Indian Journal of Biotechnology*, 4, 56-64.

Gokulakrishnan, J., Kumar, S.B., & Prakash, M. (2012). Studies on genetic diversity in mung bean (*Vigna radiata* L.). *Legume Research*, 35(1), 50-52.

Haritha, S., & Reddy, S.M. (2002). Clustering of mung bean genotypes by complete linkage dendrogam. *Legume Research*, 25 (4), 288-291.

Jadhav, R.A., Mehtre, S.P., Patil, D.K., & Gite, V.K.,2021. Multivariate Analysis using D2 and Principal Component Analysis in Mung bean [*Vigna radiata* (L.) Wilczek] for Study of Genetic Diversity. *Legume Research-An International Journal*, *1*, p.8.

Mahalanobis, P.C. (1936). On the generalized distance in statistics. *National Institute of Science*, 18, 49-51.

Raje, R.S., & Rao, S.K. (2001). Genetic diversity in germplasm collections of mung bean [*Vigna radiata* (L.) Wilczek]. *Indian Journal of Genetics*, 61(1), 50-52.

Rao, C.R. (1952). Advanced Statistical Methods in Biometry, John Wiley Publishers, New York.

Razzaque, M.A., Haque, M.M., Rahman, M.M., Bazzaz, M.M., & Khan, M.S.A. (2016). Screening of mung bean [*Vigna radiata* (L.) Wilczek] genotypes under nutrient stress in soil. *Bangladesh Journal of Agricultural Research,* 41(2), 377-386.

Saini, A., Reddy, S.K., & Jawali, N. (2004) Evaluation of long primers for AP-PCR analysis of mungbean (*Vigna radiata* (L.) Wilczek): Genetic relationships and fingerprinting of some genotypes. *Indian journal of Biotechnology*, 3, 511-518.

Sarkar, M., & Kundagrami, S. (2016). Multivariate analysis in some genotypes of mung bean [*Vigna radiata* (L.) Wilczek] on the basis of agronomic traits of two consecutive growing cycles. *Legume Research*, 39(4), 523-527.

Tiwari, P., Sharma, S., & Thakur, S. (2022). Diversity analysis of mungbean (*Vigna radiata* L.) germplasm under different seasons. *The Pharma Innovation Journal*, 11(1), 52-57.

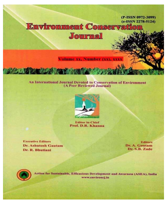
Yimram, T., Somta, P., & Srinives, P. (2009). Genetic variation in cultivated mung bean germplasm and its implication in breeding for high yield. *Field Crops Research*, 112, 260-266.

Environment Conservation Journal 24 (3):21-24, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Addition of *Frerea indica* Dalzell to the flora of Nashik district, Maharashtra, India

Balasaheb Shantilal Kale ✉
Department of Botany, S.V. K. T. Arts, Science and Commerce College, Deolali Camp, Nashik, Maharashtra, India
Sanjay Appaji Khairnar
Department of Botany, S.V. K. T. Arts, Science and Commerce College, Deolali Camp, Nashik, Maharashtra, India
Mangesh Shankar Bhale
Department of Chemistry, Arts, Commerce and Science College, Jawhar, Palghar, Maharashtra, India

ARTICLE INFO

Received : 31 August 2022
Revised : 16 January 2023
Accepted : 22 January 2023

Available online: 09 April 2023

Key Words:
Endemic
Critically endangered
Frerea indica
Nashik district
New additions
Maharashtra

ABSTRACT

In the Indian subcontinent, the Western Ghats are a biodiversity hotspot. The Western Ghats mountain range runs for more than 1,600 kilometers along India's western coast, from 8.3188890 N to 21.273330 E. The Western Ghats biodiversity hill range is divided into three sub-regions: the Northern Western Ghats (NWG), Central Western Ghats (CWG), and Southern Western Ghats (SWG). The studied area of Nashik district is a part of the Northern Western Ghats of India. The current botanical investigation explored the rich plant biodiversity area of Nashik district. During floral exploration in the Nashik district, we explored critically endangered, endemic, and monotypic genus of the *Frerea indica* Dalzell flowering plant species reported for the first time from the studied area. *F. indica* is a jeopardized limited to Maharashtra state only in the Western Ghats of India.This significance plant species was first time located at Shivneri fort, Junnar tehsil, Pune district. In presence conditions, 9 regions of the northern Western Ghats of Maharashtra, India are reported only.

Introduction

The Western Ghats along with Sri Lanka it is one of the 34th mega biodiversity hotspot region of interest assigned in view of high plant species endemism and furthermore serious level of danger because of habitat loss (Myers *et al.*, 2000). The *Frerea indica* is a critically endangered, endemic, and monotypic genus of the Western Ghats of India (Oldfield, 1997; Nandikar *et al.*, 2018). *F. indica* Dalzell belongs to the family Apocynaceae (Dalzell, 1865). *F. indica* is a jeopardized limited to Maharashtra in the Western Ghats of India (Umdale *et al.*, 2021).This plant taxa first time found on the hill (Shivneri fort- birthplace of Chhatrapati Shivaji Maharaj) near Junnar in the Pune district (Dalzell, 1865; Irwin and Narasimhan, 2011), were some reported localities such as Ahmednagar (Radha falls), Pune (Junnar and Purandar), Raigad (Shivthar Ghal), Satara (Mahabaleshwar, Sajjan gadh) districts (Hemadri, 1970; Mishra and Singh, 2000; Selvam *et al.*, 2009).It is an attractive succulent plant species that grows on steep hill slopes at high altitudes. In the present conditions this plant species has critically endangered because of its unique and small habitat (Umdale *et al.*, 2021). During the field study, we observed *F. indica* naturally lives with *Euphorbia neriifolia* L. as a strong and positive association (Tetali *et al.*, 1997). This pretty flower species is recorded from Kalmuste hills ranges of Trimbakeshwar Taluka, Nashik district (red colored arrow and circle indicating the specimen collection site) (Figure 1). This species was observed at 883 meters above mean sea level along the Kalmuste hills (N19.931599, E73.478387 GPS location recorded). The floral exploration of Nashik district has been carried out by Lakshminarasimhan and Sharma in 1991 year published the flora of Nashik district. The flora of the Nashik district has no taxonomical records of studied taxa (Lakshminarasimhan and Sharma, (1991). *F. indica* is proposed as an

Corresponding author E-mail: *kaleunipune@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14752458

addition to the flora of Nashik district, based on the collections from different localities in Nashik district. During a field exploration for locating *F. indica* along the steep hill slopes of Kalmuste hills range noticed during the year 2020 to 2022, after exploration studied site we noticed about less than 10 individual plants, not a single specimen was collected from the site because of species coming under critically endangered IUCN status. We just click some photographs of this species, with the help of specimens photographs, deposited herbarium and identified the species using some standard floras such as Flora of the Presidency of Bombay by Cooke (1958), Flora of Nasik district by Lakshminarasimhan and Sharma (1991), Flora of British India: Vol. IV. Asclepiadeae to Amaranthaceae by Hooker (1890) and Flora of Maharashtra by Singh *et al*. (2000).

(a) (b)

Figure 1: Morphology of *Frerea indica* Dalzell

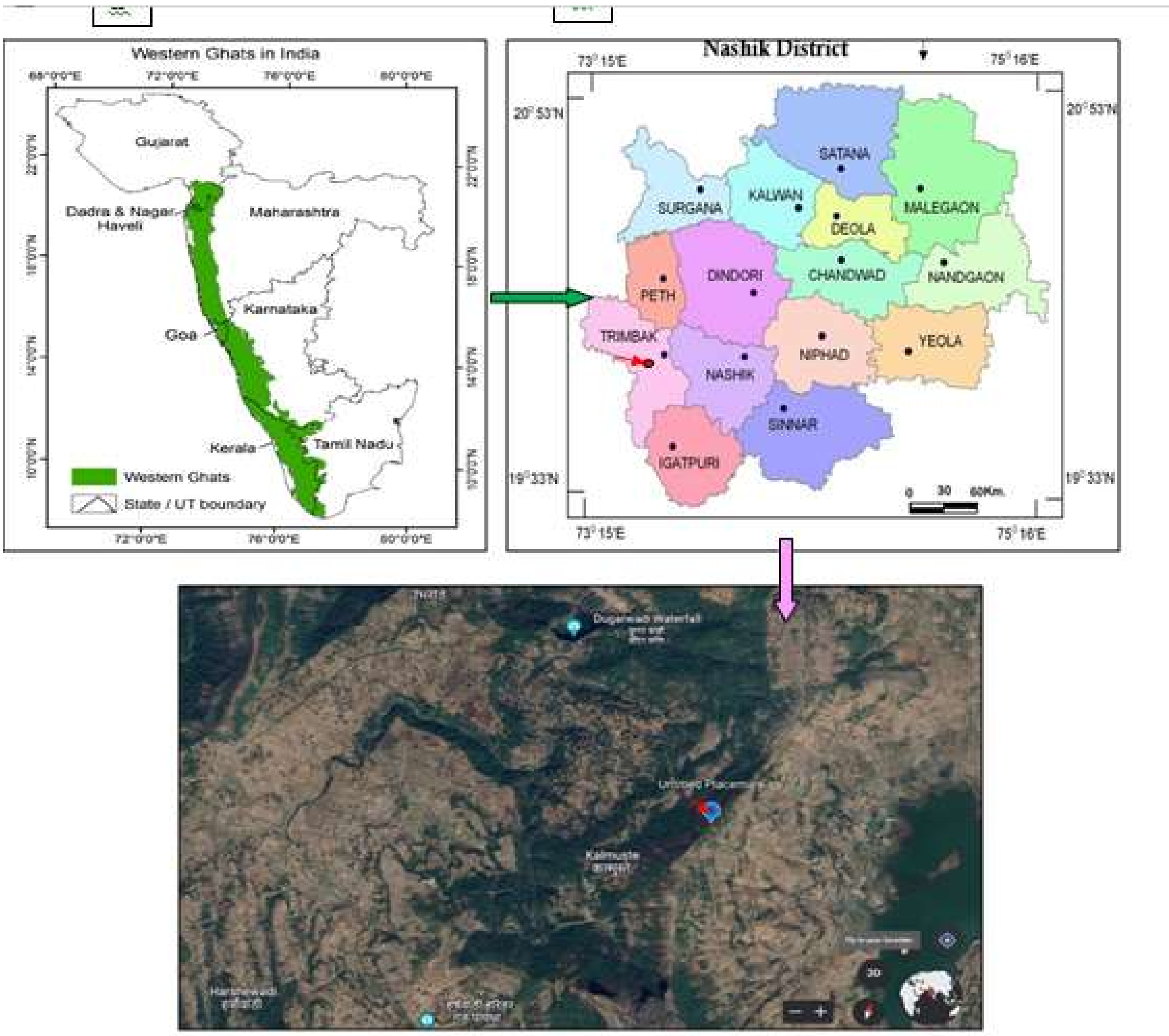


Figure 2: Map showing *F. indica* collected from Nashik district

Material and Methods

Study area:

The *F. indica* specimen was locality recorded during floral exploration in the Trimbakeshwar tehsil, slopes of Kalmuste hills ranges of Nashik district (Maharashtra), India (N19.931599, E73.478387 GPS location recorded) (Figure 2). The studied site was explored during the years 2020–2022. The studied living plant specimen recorded its livingness during the monsoon, winter, and summer seasons of the year. During the monsoon and winter seasons, plants show their actual livingness, i.e., specimen have leaves, flowers, and stems, but during the summer season, plant specimen have only succulent stems. *F. indica*specimen identification by using Flora of the Presidency of Bombay and Flora of Maharashtra (Dalzell, 1865; Singh *et al*., 2000). Repeated survey of the some area under study using Global Positioning System (G.P.S.).

Taxonomy & Morphology: Identification and classification of *F. indica* using different available local Floras and other available literature. During filed exploration studied specimen photographs, with the help of specimens photographs, deposited herbarium and identified the species using some standard floras such as Flora of the Presidency of Bombay by Cooke (1958), Flora of British India: Vol. IV. Asclepiadeae to Amaranthaceae by Hooker (1890) and Flora of Maharashtra by Singh *et al*.. (2000).

Herbarium consultation: The *F. indica* identified by using different deposited herbarium voucher specimen No. 17540, K000911102, 27510.000, 33586.000, and 62981.000 of BSI, Western Circle, Pune herbaria. This plant database gathered from Western Ghats of India (Datar & Watve, 2018; Naoroji Godrej Centre for Plant Research, 2022).

Results and Discussion

Studied taxa explored during the year 2021-2022 record of beautiful plant taxa belonging to endemic, critically endangered, and monotypic *Frerea* genus of family Apocynaceae. The plant was correctly identified using Flora of Maharashtra and Flora of Bombay Presidency and authenticated by BSI accession numbers K000911102, 27510.000, 33586.000, and 62981.000. The critical literature survey of available scientific literature was studied taxa not been added in the Flora of Nashik district. It can be claimed that these are new records for the Flora of Nashik district, Maharashtra state (India).

Family: Apocynaceae

***Frerea indica* Dalz.**in J. Linn. Soc. Lond. 8:10, t. 3. 1865 (Dalzell, 1865); Hook.f. Fl. Brit. India 4: 76 (Hooker, 1885); Cooke, Fl. Pres. Bombay 2: 243.1958 (Repr.) pp. 178 (Cooke, 1908); Flora of Maharashtra state. pp. 361-362 (Singh *et al*., 2000).

Synoname:*Desmidorchisdal zellii* M.R. Almeida, *Boucerosia frerei* (G.D.Rowley) Meve & Liede, *Caralluma frerea* Dazell, *Ceropegia frerei* (G.D.Rowley) Bruyns

Description: Studied species is a fleshy glabrous herb 4-6 in; stems and branches green, fleshy, quadrangular, marked with scars of fallen leaves. Leaves 3-6 cm long. Flowers solitary, extra axillary; pedicels curved; corolla 2.0 to 2.5 cm across, fleshy, yellowish green on the outer side, deep purple on the inner, with an irregularly shaped yellow spot at the center of each lobe, divided less than 1/2 way down, fringed with fine, deep purple hairs on the edges; corona staminal, outer bowl-shaped, with five, short, broad, sinuate truncate lobes, inner arising from the inner margin of the outer corona, 5 linear, truncate lobes, incurved at the apex (Figure 1).

Common names: Shiv Suman and ShindalMakadi.

Flowering and fruiting: September to January.

Distribution: Endemic to the northern Western Ghats of Maharashtra (Nashik, Ahmednagar, Pune, Raigad, Satara).

Ecology: The studied plant specimen associated with *Euphorbia neriifolia*. Mostlythis taxa grown on the rocky crevices of hill cliffs from an altitude 600 to 1347 m.

This plant taxa first time reported on the top of hill (Shivneri fort) near Junnartehsil in the Pune district of Maharashtra (Dalzell, 1865; Irwin and Narasimhan, 2011), were some other localities reported like Ahmednagar (Radha falls), Pune

(Junnar and Purandar), Raigad (Shivthar Ghal), Satara (Mahabaleshwar, Sajjan gadh) districts (Hemadri, 1970; Mishra and Singh, 2000; DST, 2004;Selvam *et al.*, 2009). Studied significance plant species in presence conditions, 9 regions of the northern Western Ghats of Maharashtra, India are reported only. Studied plant species we reported first time in Nashik district of Maharshtra state, India for addition of Flora of Nashik district (Umdale *et al.*, 2021).

Conclusion

During floral exploration in the Nashik district, we explored *F. indica* flowering plant species reported for the first time from the studied area. *F. indica* is a new addition of the Flora of Nashik district.

Acknowledgement

The authors appreciate the facilities provided by the Department of Botany, S.V. K. T. Arts, Science and Commerce College, Deolali Camp, Nashik-422401, Maharashtra, India, Savitribai Phule Pune University, Pune and Gaurav Lotan Hyalij and Hiraman Gaikwad.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Cooke, T. (1958). Flora of the Presidency of Bombay. In *London: Taylor and Francis: Vol. II.*

Dalzell, N. A. (1865). A new genus of Asclepiadeae. *The Journal of the Linnean Society of London ., VIII*, 10.

Datar, M. N., & Watve, A. V. (2018). Vascular plant assemblage of cliffs in Northern Western Ghats, India. *Journal of Threatened Taxa*, *10*(2), 11271–11284. https://doi.org/10.11609/jott.3611.10.2.11271-11284

Hemadri, K. (1970). The Flora of Junnar and Its Surroundings , Poona District, (Maharashtra State). *Botanical Survey of India*, 1–1079.

Hooker, J. D. (1890). Flora of British India: Vol. IV. Asclepiadeae to Amaranthaceae. *London: L. Reeve and Co., 5, Henrietta Street, Covent Garden*, 1–784.

Irwin, S. J., & Narasimhan, D. (2011). Endemic genera of Angiosperms in India : A Review. *Rheedea*, *21*(1), 87–104.

Lakshminarasimhan, P., & Sharma, B. D. (1991). Flora of Nasik District. *Botanical Survey of India*, 01–370.

Mishra, D. K., & Singh, N. P. (2000). Frerea indica Dalz. (Asclepiadaceae)- a Critically endangered plant, now collected from Ahmednagar district, Maharashtra. *Bulletin of Botanical Survey of India*, *42*(1–4), 157–159.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*, 853–858.

Nandikar, M. D., Giranje, P. T., & Jadhav, D. C. (2018). Floristic enumeration of Torna Fort (Western Ghats , India): a storehouse of endemic plants. *Journal of Threatened Taxa*, *10*(7), 11895–11915.

Naoroji Godrej Centre for Plant Research, P. (2022). *Haritarium Frerea indica Dalzell* (pp. 1–6).

Oldfield, S. (1997). Status Survey and Conservation on Action Plan: Cactus and Succulant Plants. *IUCN, Gland, Switzerland and Cambridge, UK*, 1–226.

Selvam, A. B. D., Bandyopadhyay, S., & Pillai, B. (2009). Studies on Frerea indica Dalz .: A Critically Endangered and Endemic Species from Maharashtra , India. In *Emerging trends in biological sciences* (Issue 1, pp. 199–204).

Singh, N. P., Lakshminarasimhan, P., Karthikeyan, S., & Prasanna, P. V. (2000). Flora of Maharashtra State, Dicotyledons. *Flora of India Series 2*, *1*(1), 1–871.

Tetali, P., Tetali, S., & Kumbhojkar, M. S. (1997). Association of Frerea indica Dalz ., an endangered plant species with Euphorbia neriifolia L . and its importance in habitat conservation. *Current Science*, *73*(7), 563–565.

Umdale, S., Mahadik, R., Otari, P., Gore, N., Mundada, P., & Ahire, M. (2021). Phytochemical composition , and antioxidant potential of Frerea indica Dalz .: A critically endangered , endemic and monotypic genus of the Western Ghats of India. *Biocatalysis and Agricultural Biotechnology*, *35*, 1–11.

Environment Conservation Journal 24 (3): 25-30, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

A comparison of apple varieties based on yield and production efficiency under north western plain zones of Uttar Pradesh

Arvind Kumar
College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, India
Vibhu Pandey ✉
College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, India
Khushboo Sharma
Faculty of Horticulture, Sher-e-Kasmir University of Agriculture Sciences & Technology, Srinagar, India
Anuj Pal
College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, India
Devendra Pal
College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, India
Amit Kumar
College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, India

ARTICLE INFO

Received : 05 September 2022
Revised : 22 January 2023
Accepted : 13 February 2023

Available online: 09 April 2023

Key Words:
Quality Attributes
Apple
Fruit Quality
Yield

ABSTRACT

Apple is largely cultivated in India's northwestern Himalayan area, which also encompasses the nation's mountainous north-eastern regions as well as the union territory of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Uttar Pradesh. This research was conducted during 2019-2020 and 2020-21 at Horticultural Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut. The experiment was laid out in Randomized Block Design (RBD) and the number of treatments was 3, each replicated 4 times. Each treatment consists of one plant. Total 12 plants were selected for study. The plants were planted at spacing of 5x5 m. The obtained results showed that the no. of fruits per plant (176.62), no. of branches per plant (28.5) was found to be significant. On the other side canopy spread (4.84 m), stem girth (33.87 cm), plant height (4.06 m), number of flowers (1020.75), fruit size (length) (57.12 mm), fruit size (width) (52.61 mm), fruit weight per fruit (76.62 gm),), fruit weight (5 fruits) (383.12) were found to be non-significant. The results of present study indicate that the basis of their vegetative behavior, Dorsett Golden appeared to be superior variety in terms of tree morphology and other as moderate. Further, it can be concluded that variety Dorsett Golden had more productivity and the fruits of ANNA and HRMN-99 were having more marketable fruit traits. The current study revealed the diversity of the apple cultivars analyzed in this experiment, highlighting the significance of safeguarding these precious genetic resources and pursuing additional study to ensure their conservation, exchange, and utilization in upcoming breeding initiatives for the development of novel, improved apple varieties.

Introduction

Apple is one of the finest table fruit of the world and has been under cultivation since time immemorial. Apple trees are believed to have originated in South Eastern Europe and the Tien Shan Mountains of Kazakhstan in Asia [Gasteir, 2000], where enormous forests of untamed apple trees still remain. The top ten apple-producing nations, which together produce 63 million tonnes of apples annually, are the USA, China, France, Italy, Turkey, Argentina, West Germany, Spain, Japan, and the former USSR [Snowdon, 1990]. With an annual production and productivity of 2890.6 thousand metric tonnes and 11 metric tonnes per hectare, respectively, apple is primarily

Corresponding author E-mail: *pandey.vibhu007@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14802460

grown in India's northwestern Himalayan region, which includes the union territory of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand in addition to the north-eastern hilly states of the nation on an average area of 320 thousand hectares [Anonymous, 2017].

In case of Uttar Pradesh, horticulture is one of the critical sectors in the economy. The horticulture crops are grown in around 30 lakh hectares area which accounts 12% of the total cultivated area of the State (State Horticultural Mission Report, 2013). Expansion of area horticulture can promote economic diversification and thus create additional employment opportunities in the state. Fruits, vegetables, tuber crops, mushrooms, floriculture, medicinal and aromatic plants, spices, food processing, and beekeeping are all included in the broad category of horticulture crops. Uttar Pradesh is being covered by 9 agro climatic zones mainly, Bhabar and terai, Bundelkhand, central, Eastern plain, Mid-Western plain, North Eastern plain, South west semi-arid, Vindhya, Western plain. Because of the diverse agro-climate of U.P., a number of crops may be grown all year long, ensuring year-round availability. The state holds a vast potential for the development of various horticulture crops as it has diverse climatic conditions for growing different categories of fruits and off-season vegetables in its different agro zones [Nomita *et al*., 2020]. Agriculture, horticulture, and related industries make up the majority of the state's workforce. Fruits from the temperate to subtropical zones can be grown in a hospitable environment due to topographical changes and altitudinal variances [Basannagari *et al*., 2013].

The cultivated apple (*Malus* X *domestica* Borkh) belonging to family Rosaceae, sub-family Pomoideae, order Rosales, is considered as one of the most important and widely grown fruit in temperate zones of the world with regard to its acreage, production, economic returns, nutritive value and popularity. Apple is believed to have originated in the temperate regions of Western Asia between Black and Caspian Sea [Beceanu, 2002]. The high value of apple cultivation is a result of the fruit's nutritional, preventative, and therapeutic benefits as well as the biological and technological characteristics of apple trees and value-added cropping. In the diet of the modern human, apples are one of the staple foods. They can be found all year round as a raw produce and are processed in various ways. The apple tree being one of the most important species of trees in temperate regions of the world, holds a prominent position in the production of fruit [Braniste and Uncheasu 2011]. Apple storage capacity is crucial for the new varieties that have been introduced to the market, and a typical biochemical and sensory examination should be included in an impartial assessment of their commercial value [Stănică *et al.,* 2008]. Achieving a good level of quality that is comparable to the susceptible variety for the scab resistant cultivars is a key objective. This study contains findings from numerous scab-resistant cultivars [Stănică *et al.,* 2010], focusing on the fruit's properties and how they evolve during storage.

Material and Methods

The Horticulture Research Center of the Sardar Vallabhbhai Patel University of Agriculture & Technology, Modipuram, Meerut, Uttar Pradesh, conducted the investigation titled "To Find the Suitable Variety of Apple for North Western Plain Zones of Uttar Pradesh" during the years 2019–2020 and 2020–21. At a height of 237.75 metres above mean sea level, the experimental field is located at 29°04 North latitude and 77°42 East longitude. In order to avoid pruning during the experiment, all 12 apple trees that were chosen as the experimental material were subjected to the same cultural practises. Using a Randomized Block Design (RBD) layout, the experiment was conducted on a five-year-old apple orchard, and its parameters were recorded. There were three different varieties, each replicated four times.

The three apple cultivars studied were HRMN-99, Dorsett Golden, and ANNA. The cultivars were taken into consideration as a factor, and each plant under study served as a replication. The dates of the first flowering and the full bloom, which occurred in February and March, respectively, were determined by daily observations (Table 1). By calculating the number of days it took the plant to go from the anthesis of the first flower to the last, the Date to First Flowering and the Date to Full Bloom durations emerged. In terms of the overall number of flowers per plant, the number of flowers produced by each apple variety replication was recorded.

Throughout the trial period, the number of branches per plant was manually tallied. The average value of each branch was then computed by dividing the total number of branches by the number of plants in each replication of apple types. Measurements of the canopy spread were made in the North-South and East-West directions, and the diameter was calculated using the mean diameter (m). A height of 50 cm was used to gauge the mature tree's trunk girth (cm). By using a long, straight, measured, and marked stick, we were able to assess plant height by measuring the distance between the tree's base and the topmost shoot.

Their measurements were given in metres. Each Apple variety replication's fruit production was measured in terms of the total quantity of fruits produced by each plant. The length, breadth (in mm), weight per fruit (gm), and total weight of five fruits from each cultivar were measured from each replication (gm). To determine the length of the fruit in each replication, Vernier callipers were used to measure the average length of five fruits from their base to their tip. Each replication's fruit width was measured using Vernier callipers, with the average width of five fruits being measured at their widest point.

To measure the fruit weight per fruit using a digital balance, five randomly chosen fruits from each marked tree were averaged in each replication. The fruit weight per fruit data were then computed for each replication by dividing the total fruit weight by the total fruit number. To get the total weight of fruit weight (5 fruit), add the weights of the five randomly chosen mango fruits from each marked tree in each replication (5 fruit). The acquired observations were statistically assessed utilising the recommended Panse & Sukhatme (1967) standard technique.

Results and Discussion

The 10 more relevant quantitative characters were measured in plant samples and are summarized in table 2, 3 and 4. Among the three cultivars studied, earliest flower initiation occurred in cv. Dorsett Golden and ANNA (13 February), while the latest flower initiation was also observed in cv. Dorsett Golden (24 February) in the year 2019-20 (table 1). In the year 2020-21, the earliest flower initiation occurred in cv. HRMN-99 (11 February), followed by ANNA (12 February) and Dorsett Golden (18 February) while the latest flower initiation was observed in cv. Dorsett Golden (23 February) in the year 2020-21. Data further revealed that maximum number of flowers per plant was born in cv. ANNA (911.5) and was followed by HRNM 99 (846.5) and Dorsett Golden (654.5) in the year 2019-20. In the year 2020-21, maximum number of flowers per plant was borne in cv. Dorsett Golden (1283), and was followed by cv. ANNA (1130) and cv. HRMN-99 (1028). Depending on the cultivar's propensity as well as environmental and cultural factors, the flowering date and duration may vary. According to [Mratinic and Aksic 2011], the earliest initial bloom was observed in some apple cultivars on April 22 and persisted until May 6. They also noted a roughly 16-day gap between the earliest and last cultivars' entire bloom dates. Among the three cultivars studied, earliest full blossom was observed in cv. Dorsett Golden (20 February), while the latest full blossom was observed in cv. HRMN-99 (1 Mar) in the year 2019-20 (table 1). In the year 2020-21, the earliest full blossom occurred in cv. ANNA (26 February), while the latest full blossom was observed in both cv. Dorsett Golden and cv. HRMN-99 (6 March) in the year 2020-21.

No. of branches per plant were found significantly maximum in HRMN-99 (28) in the year 2019-20 as compared to Dorsett Golden (9) and ANNA (7.750). Whereas, in the year 2020-21 also HRMN-99 (29) was found to be having significantly higher number of branches per plant compared to ANNA (15) and Dorsett Golden (14). Canopy spread of a plant was found to be non-significant in both 2019-20 and 2020-21 years. In the year 2019-20, cv. Dorsett Golden (4.543m) was having maximum area cover under its canopy, followed by ANNA (4.312m) and HRMN-99 (4.198m). In the year 2020-21 also cv. Dorsett Golden (5.15m) was having maximum area cover under its canopy and was followed by ANNA (4.94m) and HRMN-99 (4.37m). Stem girth of HRMN-99 (33cm) was found maximum among all the three cultivars used in the experiment in the year 2019-20. This was followed by ANNA (29.50cm) and Dorsett Golden (29.25cm). In the year 2020-21, cv. Dorsett Golden (35.00cm) was found to have maximum stem girth and was followed by HRMN-99 (34.75cm) and

Table 1: Date of flower initiation and full blossom in the year 2019-20 and 2020-21

SN	Cultivars	Date of flower initiation								Date of Full blossom							
		R1		R2		R3		R4		R1		R2		R3		R4	
		19-20	20-21	19-20	20-21	19-20	20-21	19-20	20-21	19-20	20-21	19-20	20-21	19-20	20-21	19-20	20-21
1	HRMN-99	14 Feb	11 Feb	14 Feb	12 Feb	14 Feb	16 Feb	14 Feb	12 Feb	28 Feb	5 Mar	28 Feb	4 Mar	1 Mar	6 Mar	1 Mar	5 Mar
2	Dorsett Golden	13 Feb	18 Feb	15 Feb	20 Feb	25 Feb	20 Feb	13 Feb	23 Feb	24 Feb	2 Mar	24 Feb	1 Mar	22 Feb	2 Mar	20 Feb	6 Mar
3	ANNA	13 Feb	12 Feb	13 Feb	15 Feb	13 Feb	18 Feb	13 Feb	12 Feb	25 Feb	28 Feb	25 Feb	28 Feb	26 Feb	26 Feb	26 Feb	26 Feb

Table 2: Mean values of different traits of three apple varieties the year 2019-20 and 2020-21

SN	Character	2019-20						2020-21					
		HRMN-99	Dorsett Golden	ANNA	SE Mean	CD	CV	HRMN-99	Dorsett Golden	ANNA	SE Mean	CD	CV
1	No. of flowers	846.5	654.5	911.5	60.02	N.S.	14.93	1028	1283	1130	128.71	N.S.	22.58
2	No. of branches per plant	28	9	7.750	1.41	4.872	18.92	29	14	15	4.97	N.S.	52.83
3	Canopy spread (m)	4.198	4.543	4.312	0.41	N.S.	18.84	4.37	5.15	4.94	0.38	N.S.	15.30
4	Stem Girth (cm)	33.00	29.25	29.50	2.67	N.S.	17.48	34.75	35.00	33.75	2.46	N.S.	13.37
5	Plant Height (m)	3.258	3.220	2.91	0.22	N.S.	13.99	3.66	4.91	4.00	0.42	N.S.	19.97
6	No. of fruits per plant	67.50	92.50	81.25	3.82	13.17	9.50	174.00	288.00	272.00	19.99	68.99	17.38
7	Fruit size (length) (mm)	55.75	54.375	54.243	1.91	N.S.	6.55	55.98	56.11	60.00	1.79	N.S.	6.27
8	Fruit size (width) (mm)	57.583	52.99	52.53	2.52	N.S.	9.25	43.22	47.46	52.69	4.01	N.S.	17.08
9	Fruit weight per fruit (gm)	71.5	71.75	73.25	7.21	N.S.	20.22	80	73	80	4.87	N.S.	12.80
10	Fruit weight (5 fruit) (gm)	357.50	358.75	366.25	36.05	N.S.	19.98	400.00	365.00	400.00	24.32	N.S.	12.94

Table 3: Pool data values of different traits of three apple varieties the year 2019-20 and 2020-21

SN	Character	HRMN-99	Dorsett Golden	ANNA	Mean
1	No. of flowers	937.25	968.75	1020.75	975.58
2	No. of branches per plant	28.5	11.5	11.37	17.12
3	Canopy spread (m)	4.28	4.84	4.62	4.58
4	Stem Girth (cm)	33.87	32.12	31.62	32.53
5	Plant Height (m)	3.45	4.06	3.45	3.65
6	No. of fruits per plant	120.75	190.25	176.62	162.54
7	Fruit size (length) (mm)	55.86	55.24	57.12	56.07
8	Fruit size (width) (mm)	50.40	50.22	52.61	51.07
9	Fruit weight per fruit (gm)	75.75	72.37	76.62	74.91
10	Fruit weight (5 fruit) (gm)	378.75	361.87	383.12	374.58

ANNA (33.75cm). The data was found to be non-significant.HRMN-99 (3.258m) showed highest plant height in the year 2019-20, while ANNA (2.91m) showed shortest plant height in the same year. Dorsett Golden showed vertical plant growth of 3.220m. In the year 2020-21, Dorsett Golden (4.91m) showed highest plant height and was followed by ANNA (4.00m) and HRMN-99 (3.66m). The data was found to be non-significant. In the year 2019-20, maximum number of fruits per plant was produced by Dorsett Golden (92.50) and was followed by ANNA (81.25) and HRMN-99 (67.50). Dorsett Golden in the year 2020-21 produced maximum number of fruits per plant i.e., 288 and was followed by ANNA (272) and HRMN (67.50). The data was found to be non-significant. The obtained data in this experiment was found to be significant. Fruit size is another crucial factor in the breeding programmes that are used to select the best genotypes [Westwood and Blaney, 1963]. Fruit size in length was measured longest in HRMN-99 (55.75 mm) in the year 2019-20. In the same year, other two cultivars, Dorsett Golden and ANNA showed 54.375 mm and 54.243 mm of fruit size in length, respectively. In the year 2020-21, the cv. ANNA (60.00 mm) produced longest fruit size in length and was followed by Dorsett Golden (56.11 mm) and HRMN-99 (55.98 mm). The data was found to be non-significant. The results were close to results found by [Reim *et al*. 2013] who recorded the fruit size between 1.8-5.1 cm and [Reim *et al*. 2013] also reported that the majority of the trees had fruit size under 3.5cm thus indicating a true type *Malus sylvestris*. Fruit size in width was measured longest in HRMN-99 (57.583 mm) in the year 2019-20. In the same year other two cultivars, Dorsett Golden and ANNA showed 52.99 mm and 52.53 mm of fruit size in length respectively. In the year 2020-21, the cv. ANNA (52.69 mm) produced longest fruit size in length and was followed by Dorsett Golden (47.46 mm) and HRMN-99 (43.22 mm). The obtained data in this experiment was found to be non-significant. Phylogenic behavior-related genetic variables may be in charge of controlling variation in fruit size and weight [Harda *et al*., 2005]. Fruit weight per fruit was measured and it revealed that in the year 2019-20, cv. ANNA (73.25 gm) produced the heaviest fruit. This was followed by cv. Dorsett Golden (71.75 gm) and HRMN-99 (71.5 gm) which produced almost similar fruit weight. In the year 2020-21, cv. ANNA and HRMN-99 produced similar and heaviest fruit among the three cultivars used in this experiment and weighed 80 gm, whereas, cv. Dorsett Golden weighed 73 gm and produced lower weight as compared to other two cultivars used in this experiment. It is common knowledge that factors including genetics, environment, and cultural practices all affect fruit weight. Using resources effectively to reach a specific fruit size may represent a genotype's innate ability to produce bigger fruits. The findings of this study were consistent with those of [Mratinic and Aksic 2011], who noted that several Turkish Malus species' fruits ranged in weight from 70.00g to 193.33g and that some wild apples' fruits weighed between 3.828g and 3.668g. Fruit weight (5 fruits were chosen randomly) was measured highest in ANNA showed 366.25 gm in the year 2019-20. The same year other two cultivars, Dorsett Golden and HRMN-99 showed 358.75 gm and 357.50 gm of fruit size in length. In the year 2020-21, the cv. ANNA and HRMN-99 produced highest fruit weight of 400.00 gm and Dorsett Golden (365 gm) produced lowest weight among all the cultivars used in the experiment. The data was found to be non-significant.

Conclusion

All the varieties appeared to be promising under the conditions of North-West plain zone of Uttar Pradesh and can be recommended for further research, mass multiplication and ultimate adoption by orchardists. On the basis of their vegetative behavior, Dorsett Golden appeared to be superior variety in terms of tree morphology and other was found to be moderate. Further, it can be concluded that variety Dorsett Golden had more productivity and the fruits of ANNA and HRMN-99 were having more marketable fruit traits. The current study demonstrated the diversity of the apple cultivars investigated in this experiment, demonstrating the importance of protecting these rare genetic resources and pursuing further research to ensure their conservation, exchange, and utilisation in upcoming breeding programmes for the creation of novel, commercially focused cultivars.

Acknowledgement

We thank Department of Horticulture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (UP, India) for providing laboratory, research field facilities and encouragement.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Anonymous (2017) Indian Horticulture Database, Area and production statistics. Ministry of Agriculture and Cooperableatives, Government of India, New Delhi. (http://nhb.gov.in/area%20_production.html).

Basannagari, B., & Kala, C. P. (2013). Climate change and apple farming in Indian Himalayas: a study of local perceptions and responses. *Plos one*, *8*(10), e77976.

Beceanu, D. (2002) Tehnologia produselor horticole vol. I. Aspecte generale (Technology of horticultural products, vol. I. General aspects).

Braniste N., Uncheasu G. (2011) Determined for apple varieties.

Gasteir, T. N. (2000). Great moments in apple history. *The Ohio ICM News*, *4*, 24.

Harada, T., Kurahashi, W., Yanai, M., Wakasa, Y., & Satoh, T. (2005). Involvement of cell proliferation and cell enlargement in increasing the fruit size of Malus species. *Scientia horticulturae*, *105*(4), 447-456.

Mratinić, E., & Fotirić-Akšić, M. (2011). Evaluation of phenotypic diversity of apple (*Malus sp.*) germplasm through the principle component analysis. *Genetika*, *43*(2), 331-340.

Nomita P. Kumar and Kavita Baliyan. *(2020)* Benchmark Survey of Horticulture Crops in Uttar Pradesh Area and Production Estimation. *Giri Institute of Development Studies.pp-3-4*

Panse VC and Sukhatme PV 1967. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi.

Reim, S., Proft, A., Heinz, S., & Höfer, M. (2012). Diversity of the European indigenous wild apple *Malus sylvestris* (L.) MILL. in the East Ore Mountains (Osterzgebirge), Germany: I. Morphological characterization. *Genetic Resources and Crop Evolution*, *59*(6), 1101-1114.

Reim, S., Höltken, A., & Höfer, M. (2013). Diversity of the European indigenous wild apple (*Malus sylvestris* (L.) Mill.) in the East Ore Mountains (Osterzgebirge), Germany: II. Genetic characterization. *Genetic resources and crop evolution*, *60*(3), 879-892.

Snowdon, A. L. (1990) A colour atlas of postharvest diseases and disorders of fruits and vegetables. Vol. 1 and 2. CRC Press, Boca Raton, Florida, USA. pp302.

Stănică F. and Plato I. (2008) Effects of Three Apple Tree Planting System on Growth and Productivity, IX International 4Stănică F. 2008. Behavior of new resistant apple varieties in different planting. Works. St. U.S.A.M.V.B. Series B, Vol LI.

Stănică F., Davidescu V., A. Madjar, Dumitraúcu M., Ilie I. (2010) Influence of the organic Cultural Practices on the Productivity and Efficiency of the year Apple Orchard Varieties Resistant Scabies. International Horticultural Congress, Lisbon, August 22 to 27.

State Horticultural Mission Report, 2013, http://agricoop.nic.in/statistics/state-level

Westwood, M. N., & Blaney, L. T. (1963). Non-climatic factors affecting the shape of apple fruits. *Nature*, *200* (4908), 802-803.

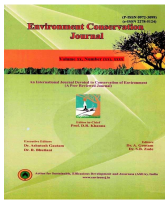
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 31-39, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



The long-term impact of the integrated crop-livestock system on carbon emission, sustainability and livelihood security of small and medium farmers

Kumara, O. ✉
University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India
Kumar Naik, A. H.
University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India
Rajashekhar, L.
University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India
Shivanand Goudra
University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

ARTICLE INFO

Received : 17 October 2022
Revised : 04 January 2023
Accepted : 22 January 2023

Available online: 12 April 2023

Key Words:
Agricultural enterprises
Carbon sequestration
IFS, Livestock
Sustainability index

ABSTRACT

In India, 80 per cent of the farmers are small and marginal farmers. They primarily depend on agriculture and allied activities for their livelihood security. The rice-rice cropping system reduces farm income, declined soil fertility and other soil degradation problems. The farming system approach is a holistic tool to address the problems of mono-cropping through diversification that enhances farm income, production and employment. A field study was conducted during 2011–2018 to study the impact of the rice-based integrated crop-livestock system (ICLS) for profitability, carbon emission and sustainability. Recycling of resources and residues led to higher productivity (58.9 %) and net profit (48.5 %) over the initial year by adopting rice-based ICLS. This system had a net profit of $ 3097/year and generated 776 man T days/ha/year employments. In ICLS, the recyclable farm waste material of 28.98 tons is converted into organic manures of 16.03 tons and saves the fertilizer's cost of $ 504 per year. It can be a sustainable model with a sustainable yield index (0.11) of for wet situations with less carbon-emitting and profitable.

Introduction

To meet the demand for food and nutrition over the same period of time, the farmers use a variety of agricultural enterprises, including crops, dairy, poultry, pigeons, fish, sericulture, apiculture, and others that are appropriate for the size, agro-climate, and socioeconomic conditions of their farms. The integrated crop-livestock system (ICLS) is a common term for the development of a more comprehensive, resource-based, client-oriented, and collaborative strategy to address various and risk-prone environmental issues (Kumar *et al.,* 2011). IFS idea reduces reliance on outside resources by effectively using and recycling all agricultural resources. (Hilimire, 2011). Similarly, crop residues of preceding crops are recycled for succeeding crops to maintain soil's physicochemical properties, increase the crops nutrient uptake, and ensure a better soil environment for crop growth (Behera and Mahapatra, 1999). Enhancing productivity, profitability, and agriculture sustainable production methods all need efficient energy usage (Paramesh *et al.,* 2014). Integrated farming system is using farm produced energy like organic manure and reduced external use of energy thereby it is more efficient system for energy usage (Devasenapathy, 2009). Crop residue, conservation tillage, crop rotations, integrated nutrient management, and efficient irrigation all contribute to soil fertility and environmental quality by effectively managing soil carbon in agricultural fields (Gebeyehu and

Corresponding author E-mail: *kumarabar@gmail.com*
Doi:https://doi.org/10.36953/ECJ.15452493

Soromessa, 2018). All of these beneficial farming techniques are part of ICLS, which also decreases soil erosion and boosts soil organic matter to slow down climate change (Paramesh *et al.,* 2014). Thus, ICLS provides scope for minimum tillage operations, reduced soil disturbances, recycling of crop residue and consequently improves soil fertility, crop productivity and environmental quality. In this regard, the study was conducted to identify a technically feasible, economically viable, and eco-friendly integrated crop-livestock system by integrating cropping with allied enterprises.

Material and Methods

Experimental site and soil characteristics

The study was carried out as a part of All India Coordinated Research Project on the Integrated Farming System at Agricultural and Horticultural Research Station, Kathalagere, Davanagere district of Karnataka, India, under canal irrigation of Bhadra command area. The experiment was established in 2011-2018 under the semi-arid tropic of wetland ecology, involving crops (rice, arecanut and vegetables), dairy and sheep as the livestock component. The present study was carried out in one hectare area to assess the effect of different components of ICLS on productivity and profitability. The experiment site had a semi-arid tropic climate with rainfall ranging from 600 mm to 1100 mm, with the received from June to October which is from the southwest monsoon rains. The soils of the experimental site are classified under Alfisols (sandy clay loam) and those re acidic to neutral in reaction (6.80), medium in soil organic carbon (0.52 %), high in available nitrogen (355 kg/ha), medium in available phosphorus (22.56 kg/ha) and potassium (234 kg/ha).

Farming and cropping system

The one hectare integrated crop-livestock system comprises of 0.50 ha of rice-rice cropping system, 0.34 ha for Arecanut, Coconut, Banana, Vegetables and Drumstick which horticulture crops, as additional enterprises Diary and Sheep components were also introduced HF cow (3+1) and sheep (12+1). Green fodder block was fixed in an area of 0.03 ha (Figure 1).

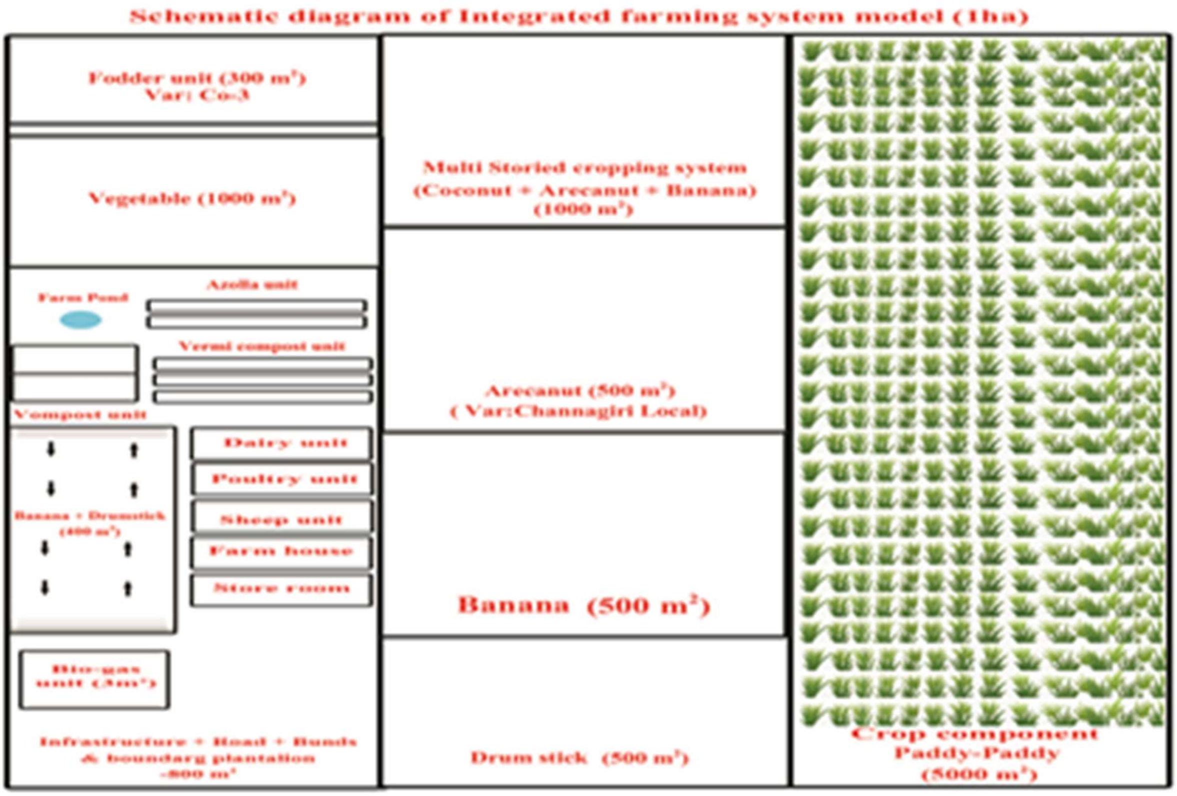


Figure 1: Schematic daigram of integrated farming system model (1 ha)

Additional components *viz*., compost (2 units), vermicompost (3 units), Azolla (2 units) and border planting of forest trees (teak, drumstick, *Glyricidia sepium*) were included in the system. The model details were depicted in Table 1 and Figure 1.

Table 1: Component-wise farming system model (1.0 ha)

Components of the integrated farming system model	Area (m^2)	% share
Crop Components:		
Rice-Rice	5000	50
Horticulture Components:		
Vegetable	1000	10
Arecanut garden	500	05
Arecanut+banana intercropping	1000	10
Banana (Sole Crop)	500	05
Drumstick	500	05
Banana + drum stick	400	04
Fodder (CO-3)	300	03
Farmhouse	800	08
Sheep		
Dairy		
Vermicompost unit (3-Nos.)		
Azolla (2-Nos.)		
Compost (1-No.)		
Road and bunds		
Border planting (Teak-74 no's and *Glyricidia*-12 no's)		
Total	10000	100

Animal and fodder component

In an area of 66 m^2, a low-cost cowshed and sheep shed were built with enough light and a hard floor, and three milch crossbreed cows and one calf, as well as sheep (12 +1), were kept under stall feeding. In order to meet the livestock unit's needs for feed, 300 m^2 of multi-cut Napier hybrid (CO-3) was planted.

Productivity (Rice equivalent yield)

The economic yield of vegetables, arecanut, coconut, banana, milk yield and meat were converted in to rice equivalent yield (REY) based on their prevailing marketable price including rice and expressed in kg per unit area.

$$REY\,(kg) = \frac{Yield\ of\ component\ crops\ (kg) \times Price\ of\ component\ crops\ (\$/kg)}{Price\ of\ rice\ \ (\$/kg)}$$

Sustainability indicators

IFS models were assessed as by Vittal *et al*. (2002) on sustainability indices (S.I.). The sustainable yield index (SYI), sustainable value index (SVI) and sustainable economic efficiency (SEE) may all be used to calculate the S.I. for any IFS model . These indicators were estimated by using the following formulae.

Sustainable yield index (SYI)

$$SYI = \frac{Grain\ yield - Standard\ deviation}{Maximum\ yield\ attained\ under\ any\ component}$$

Sustainable value index (SVI)

$$SVI = \frac{Net\ returns - Standard\ deviation}{Maximum\ yield\ attained\ under\ any\ component}$$

Sustainable economic efficiency (SEE)

$$SEE = \frac{Net\ returns}{365\ days}$$

On farm bioresource flow

Using Perionyx excavates species of earthworms in the ICLS modules, compost and vermicompost production operations were started during the lean time to recycle the farm's animal waste, agricultural leftovers, grass, fodder, weeds, and tree wastes, among other things. These byproducts provide useful manure to agricultural activities and lessen reliance on market-purchased inputs and external chemical fertilizers.

Employment generation

Employment generation was calculated for various components of the integrated crop-livestock system. Farm Family member engaged in various activities throughout year with eight working hour is considered as a 1 man day by using formula (Anup *et al.,* 2021).

$$Man\ days\ (man\ days) = \frac{Working\ hours}{8}$$

Economic analysis

The Agriculture Produce Market Committee used market rates for inputs and outputs to calculate the cost of cultivation and gross returns for each firm. Chemical fertilizers, micronutrients, FYM, pesticides, seeds, feed, concentrate, mineral mixture, labour, and equipment costs are all included in the input cost. The crop's economic value was used to assess the gross returns. Cost of cultivation and gross returns were worked out for all the enterprises by taking into considering the market rates of inputs and outputs at the Agriculture Produce Market Committee. The input cost includes the cost of FYM, fertilizers, micronutrients, seeds, pesticides, feed, concentrate, mineral mixture, labor, and machines. The total gross returns was computed from the economic value of the crop. The net returns was computed for all the components.

$$Net\ returns\ (\$/ha) = (Gross\ returns\ (\$/ha)) - (\text{Cost of cultivation (\$/ha)})$$

$$Benefit\ cost\ ratio = \frac{Gross\ returns\ (\$/ha)}{\text{Cost of cultivation (\$/ha)}}$$

Analysis of soil

Soil samples were collected at 0-30 cm depth from the field after the completion of each cropping sequence. Soil pH determined through glass electrode by pH meter and EC through Conductivity Bridge as per the method by using a soil water suspension at ratio of 1:2.5 (Sparks, 1996). The soil organic carbon was determined by wet digestion method (Sparks, 1996) and expressed in percentage. Soil available nitrogen (Sharawat and Buford, 1982), phosphorus and potassium was estimated as per standard method explained by Sparks (1996) and expressed in kg/ha.

Soil Carbon Stock Determination

The soil samples were collected at interval of 15 cm from 0-105 cm depth of the soil, from all the components of IFS model, for soil organic carbon estimation a specific volume of soil samples were collected, air-dried, processed and sieved through 2 mm diameter sieve. 5 grams of the sieved soil was used for SOC determination, whereas core sampling method was used for B.D estimation (Black, 1973). Based on the soil analysed data, considering soil organic carbon concentration, bulk density (BD) and soil depth (Manjunath *et al.,* 2014) soil organic carbon was estimated using the following formula.

$$Carbon\ (Mg\ C/ha) = \frac{\text{Soil Organic carbon (g/kg)} \times \text{Soli bulk density (Mg/m}^3\text{)} \times \text{Depth of soil (cm)} \times 10}{100}$$

Greenhouse gas emission

Work has been started to identify the sources and sinks of greenhouse gases such as methane, nitrous oxide, and carbon dioxide in the current IFS model of Southern Transitional Zone of Karnataka. The model consists of different cropping systems such as rice-rice (5000 m^2), vegetable (1000 m^2), arecanut sole (500 m^2), arecanut + coconut + banana (1000 m^2), drumstick + banana (400 m^2), banana (500 m^2), drumstick (500 m^2), sheep (12+1), dairy (3+1), fodder unit (300 m^2), vermicompost (3 no.) etc. also maintained in the boarder teak, drumstick and glyricidia were established. The Indian Institute of Farming System Research, Modipuram, Meerut, Uttar Pradesh released an excel application that predicts the greenhouse gas emissions from several IFS model components using the IPCC guidelines

$$Emission = A \times EF$$

Where,
emission = annual emission in units of kg of CO_2 eq. per farm
A = Activity data (kg of N used, liters of fuel used etc.)
EF - Emission factor = IPCC default emission factors of country specific emission factors.

Data analysis

The gathered information was tallied, and relevant graphs and tables with the mean and standard deviation were created (S.D.) (Gomez and Gomez, 1984). The data of average of eight years from 2011 to 2018 on production, productivity and income presented in this manuscript.

Results and Discussion

Productivity and economics of ICLS model

In ICLS model, the different components were compared based on the REY (Table 2). The REY of the different components ranged from 833 to 6188 kg/ha/year. The results revealed that maximum REY was achieved in rice–rice cropping system (6188 kg/ha/year) followed by dairy (4501 kg/ha/year) and vegetables (4107 kg/ha/year). Among the animal components, dairy produced 46 % higher REY compared to sheep and in horticulture component arecanut showed higher REY (2711 kg/ha/year) fallowed by arecanut + coconut + banana (2323 kg/ha/year) than drumstick and banana. The cost of cultivation, net returns and benfit cost ratio had been assesed for each component of ICLS model (Table 2 and Figure 2). The cost of cultivation ranged from (13 to 410 $/ha/year) from different farm enterprises, results revealed that the rice-rice system yielded the maximum cost of cultivation followed by the vegetable unit. Among the animal components, the dairy component recorded higher cost of cultivation followed by sheep (Table 2). The total net returns realized from the ICLS model were $ 3097 and it also highest in rice-rice cropping system (1125 $/ha/year) fallowed by vegetable (552 $/ha/year) and the lowest net returns was obtained from arecanut + coconut + banana cropping system (26 $/ha/year). Benfit cost ration was maximum in rice-rice cropping system (3.66) fallowed by vegetable (3.35) and lowest was observed in arecanut + coconut + banana (1.74) and in animal component sheep component resulted in higher B:C ratio (3.82) than dairy unit (3.79).

Table 2: Productivity and Economics of integrated crop-livestock system (2011-2018)

Treatments	Productivity (kg/ha/year)	Cost of Cultivation ($/ha)	Net returns ($/ha)	B:C ratio
Rice-Rice	6188	410	1125	3.66
Vegetables	4107	217	552	3.35
Banana sole crop	2014	63	87	2.36
Banana + Drumstick intercropping	1910	68	65	2.68
Drumstick	833	84	151	2.80
Fodder	1007	15	-	-
Areca nut (64No's)	2711	37	117	2.98
Areca nut + Coconut (18No's) + Banana	2323	27	26	1.74
Boundary plantation	0	13	0	0.00
Dairy (Milk)	4501	218	641	3.79
Sheep	2397	93	269	3.82
Vermicompost	1293	35	-	-
Mean	2662.2	106.7	309.7	3.07
SD	472.7	32.7	107.1	0.20

The integration of rice with dairy and sheep resulted in higher REY due to the significant contribution of cow and sheep with higher milk and meat production over monocropping. Higher monetary efficiency and net returns was observed in rice-rice system due to use of high yielding cultivars and improved cultivation practices. The ICLS approach aims at increasing farm income

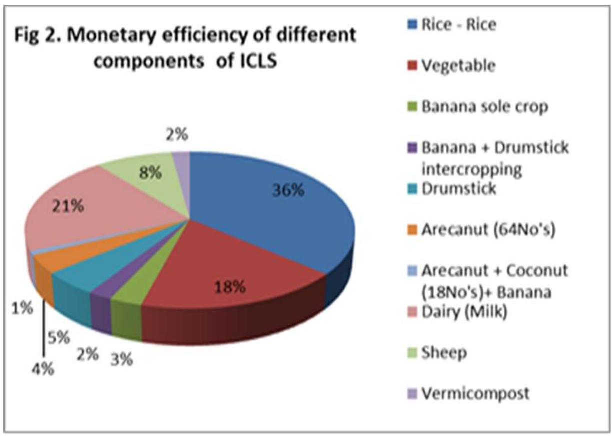


Figure 2: Monetary efficiency of different components of ICLS

from small and marginal farmers by integrating the various farm enterprises within the farm itself. Rearing of sheep recorded the highest benefit-cost ratio, followed by dairy due to lesser management cost mainly use of on farm resources via paddy straw and green fodder. The overall system more intensive cultivation of vegetables and crop production activities around the year under irrigated conditions may add profit to the system. The risk is reduced in a rice-based farming system due to diversification of the system with low-risk enterprises and vegetable cultivation (Paramesh *et al.,* 2014) ICLS would positively influence the economic viability of the system.

Sustainability indices

Existing ICLS is a fusion of animal with crop component help to achieve higher sustainable yield index (0.11), sustainable value index (0.78) and system economic efficiency (464) (Table 3). Existing ICLS is fusions of animal with crop component help to achieve higher sustainability indices like sustainable yield index, sustainable value index and system economic efficiency. Higher the, yield, benefit cost ratio and net returns and also maintained sustainability index, economic efficiency and sustainability value index (Vittal *et al.,* 2002).

Bio-resource flow

Integrated crop-livestock system provides chance for efficient utilization of farm waste or by products from one component as input for another (Figure 3).

Table 3: Sustainable yield index (SYI), sustainable value index (SVI) and sustainable economic efficiency (SEE) of ICLS system. (2014-2018)

Year	REY	Net returns ($./ha)	Sys. Economic Efficiency
2014-15	56.64	2220	452
2015-16	9.73	1928	392
2016-17	12.73	2507	510
2017-18	73.13	2136	435
2018-19	16.85	2603	530
Indices	SYI	SVI	SE
	0.11	0.78	464

The compost and vermicompost was prepared from the left-over straw, weed waste along with the livestock waste (dung, urine) after the decomposition it was applied to crops as a source of nutrients. In rice-rice cropping system after the harvest of the rice, the straw is feed to the dairy animals and the azolla grown on the surface of the pond is also fed to the animals which in-turn increases the milk yield (Hilimire, 2011). In this way there is an efficient way for resources recycling in ICLS model to reduce the overall cost of cultivation or to increase the net returns of the system along with it maintains the soil health status (Yadav *et al*., 2019).

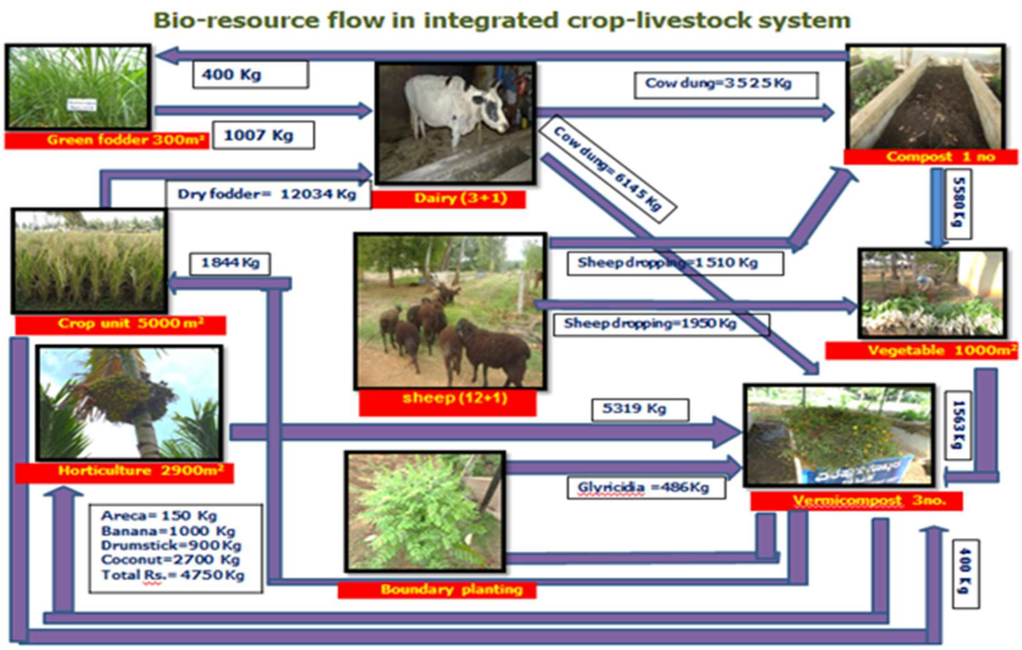


Figure 3: Bio-resource flow in integrated crop livestock system

Employment generation

An integrated crop livestock system is a labor-intensive model; in ICLS model multiple components are maintained throughout the year as against monocropping of rice. Hence, it provides higher employment opportunities for family labor than rice-rice cropping systems (Table 4).

The average employment generation in the 1.0 ha integrated crop livestock system was 776 man-day per year. The labor involvement was higher in dairy (205 man days/year) fallowed by sheep rearing (200 man days/ year) and lesser employment generation was seen in fodder (5 man days/year).

An integrated crop - livestock system is a labor-intensive model provides higher employment opportunities for family labor than rice-rice cropping systems (Ansari *et al.,* 2014). A multi-enterprise agricultural system evenly distributes employment creation throughout the year (Paramesh *et al.,* 2014). Due to the intensification of crops and other businesses, it also boosts productivity and income per unit area and time. Adoption of pond base IFS with vegetable and livestock components generated more employment (434 man days/ha) than the traditional system of rice–rice cropping system. The average employment generation in the 1.0 ha integrated crop livestock system was more than that of the rice-rice Cropping System (Anup *et al.,* 2021).

Table 4: Employment generation of the integrated crop-livestock system (mean of 2011- 2018)

Treatments	Employment generation (man days)
Rice-Rice	132
Vegetables	103
Banana sole crop	12
Banana + Drumstick intercropping	13
Drumstick	10
Fodder	5
Areca nut (64No's)	12
Areca nut + Coconut (18No's)+ Banana	17
Boundary plantation	
Dairy (Milk)	205
Sheep	200
Vermicompost	67
Mean	**70.6**
SD	**22.4**

On farm bio resources flow in integrated crop livestock system

In integrated farming system by–product of one component was input for other components. Similarly, the excreta of livestock (Dairy and sheep) were used for compost and vermicompost and applied to the crops after decomposition. The manure production in different livestock components were presented (Table 5). On an average dung production from dairy (13-15 kg dung/day/cow) and sheep dropping (600-700 g/day/sheep) and total farm waste produced in the various activities of ICLS model was 28.98 tons which was converted in to 16.03 tons of organic manure and it saves chemical fertilizers cost $ 504 per year.

Greenhouse gas emission

Results of greenhouse gas emissions during 2018 from different bio-energy cropping systems are presented (Table 6). The present ICLS has shown sequestration of CO_2 into the system mainly through above-ground biomass of the agroforestry system and residue recycling greenhouse gas

Table 5: Bio-resource production from crop-livestock system (mean of 2011 – 2018)

Components	Pooled data of total produce recycled (kg/lit./Nos.)	Pooled data of total value of the recycled product ($)
Crops (Paddy straw, Weeds and crop residue)	12434	200
Horticulture (Crop residue & Banana waste)	5319	39
Dairy (Dung, urine & shed waste)	9670	4
Other units (Dried leaves & coconut plant debris)	1563	4
Total	**28986**	**247**
Vermicompost	6594	293
Compost	5980	81
Sheep dropping	3460	130
Total	**16,034**	**504**

Table 6: Net greenhouse gas emission (GHG) in integrated crop- livestock system (CO_2-e in kg) during 2018-19

Components	CO_2-e (kg)
Carbon sources- Rice-Rice cropping system	4253.8
Vegetable Unit	865.2
Banana Sole	511.6
Banana + Drumstick intercrop	495.8
Drumstick	358.2
Arecanut Sole (64 No.s)	661.4
Arecanut (69 No.)+ Coconut (8 No.)+ Banana (60 No.) intercrop	364.9
Dairy (3+1)	1655.8
Sheep (12+1)	473.1
Fodder crop	210.1
Pond	18.4
Carbon sinks- Border plantation and agroforestry	0.0
Agroforestry- SINK	1121.9
Total Biomass/compost added – SINK	13876.0
Total SOURCE	9868.3
Total SINK	14998.0
GHG-Integrated farming system	-5,129.7

emission (-5129.7 CO_2^{-e} in kg). The total source for GHG emission noticed from the integrated model was 9868.3 CO_2-e in kg and the total sink from the model was 14998 CO_2^{-e} in kg. Higher greenhouse gas emission was from rice-rice cropping system (4253.8 CO_2^{-e} in kg) fallowed by dairy (1655.8 CO_2^{-e} in kg) and lowest was from pond (18.4 CO_2^{-e} in kg).Crop rotations with green manure improve soil structure, reduce N_2O emissions and improve soil aeration, according to a study by the International Council on Crop Solutre (ICCS) and the Netherlands Institute for Climate, Land and Soil Sciences (NCLS) (Kumar *et al.,* 2006). The amount of CO_2 emission caused by agricultural practices equal 20-25 per cent of the whole CO_2 flux of the atmosphere (Devasenapathy *et al.,* 2009). Rice-Rice cropping system contributed more CO_2 due to use of more fertilizer, which release higher CO_2 and cultivation (puddling) of soils resulting in the loss of soil organic matter (Nadelhoffer, 1995).

Carbon sequestration

Any system's soil carbon stock is determined by the long-term equilibrium between ex-situ carbon addition, in situ organic matter degradation, soil management, soil biota and soil carbon losses due to biological processes such decomposition, erosion, and leaching (Table 7).

Table 7: Carbon sequestration in various components of the integrated crop- livestock system (2011- 2018)

Cropping systems	Bulk Density (Mg/m3)	Soil organic carbon (g/kg)	Carbon Stock (Mg C/ha)
Rice-Rice	1.20	4.16	8.20
Vegetables	1.23	4.53	8.24
Banana sole crop	1.17	4.56	8.08
Banana+ Drumstick intercropping	1.14	4.68	8.06
Drumstick	1.15	4.25	8.23
Fodder	1.18	4.74	8.38
Arecanut (64 No.s)	1.22	4.85	8.91
Arecanut + Coconut (18 No.s) + Banana	1.21	4.69	8.56
Mean	1.19	4.56	8.33
SD	0.01	0.08	0.09

Summarizes the SOC, bulk density (BD) and soil carbon stock in the IFS model. The results revealed that higher soil organic carbon levels were showed in Arecanut (4.85 g/kg) followed by fodder component (4.74 g/kg) and reduced BD were observed with banana + drumstick cropping system (1.14 Mg/m^3) fallowed by drumstick (1.15 Mg/m^3). Green manure crops, leguminous crops and low tillage operations have been shown to increase soil carbon uptake. Legumes reduce atmospheric carbon by absorbing and translocation of these carbons to soil through leaf fall and higher root biomass (Devasenapathy *et al*., 2008). The carbon inputs from crop residues might have contributed to the improvement of carbon stocks. The lower carbon sequestration was observed in the banana + drumstick cropping system, which were nutrient exhaustive. Similarly, proper integration of cereal, legumes and livestock enriches soil quality and sustainability (Wilkins *et al.,* 2008 and Hilimire *et al.,* 2012).

Conclusion

An ICLS is a location and demand specific integration of diary, sheep, arecanut, coconut, vegetable, rice, banana and drumstick and it was found suitable and performance was encouraging. The most notable advantage is that utilizing low-cost or no-cost material at the farm level for recycling certainly reduces the production cost and ultimately improves the farm income. Therefore, it is imperative that integrated farming system concepts and expertise be spread throughout the nation's many agroclimatic regions in order to advance the national mission of improving the economic standing of low-income rural households and providing for their nutritional needs. ICLS model helps to achieve higher sustainable yield index, sustainable value index and system economic efficiency and reduced atmospheric carbon by absorbing and translocation of these carbons to soil through leaf fall and higher root biomass by legumes.

Acknowledgement

The authors extend their appreciation to King Saud University, Researcher Supporting Project (RSP-2021/118) for their financial support of the present research.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ansari, M. A., Prakash, N., Baishya, L. K., Punitha, P., Sharma, P. K., Yadav, J. S., Kabuei, G. P. & Levis, C. K. (2014). Integrated Farming System: an ideal approach for developing more economically and environmentally sustainable farming systems for the Eastern Himalayan Region. *Indian Journal of Agricultural Sciences, 84*, 356–362.

Anup, D., Debashis, D., Tanmay, S., Ramkrushna, G. I., Mokidul, I., Burhan, U. C., Kamal, P. M., Jayanta, L., Subhash, B. & Gulab, S. Y. (2021). Livelihood security of small holder farmers in eastern himalayan, India: Pond basedd integratd farming sytem a sustainable apporach. Curr. *Research in Enivonmental Sustainability, 3,* 1-14.

Behera, U. K. & Mahapatra, I. C. (1999). Income and employment generation for small and marginal farmers through integrated farming systems. *Indian Jounal of Agronomy, 44*, 431–439.

Black, C. A., (1973). *Methods of Soil Analysis,* Part I Agronomy Monograph No. 9, American Society of Agronomy, Madison, Wisconsin, 148.

JayanthiDevasenapathy, P., Ramesh, T. & Gangwar, B. (2008). Efficiency indices for agriculture management research. New Delhi: New India Publishing Agency, *43,* 87.

Devasenapathy, P., Senthilkumar, G., Shanmugam, P. M. (2009). Energy management in crop production. *Indian Journal of Agronomy, 54*(1), 80–90.

Gebeyehu, G. & Soromessa, T. (2018). Status of soil organic carbon and nitrogen stocks in Koga Watershed Area, Northwest Ethiopian Agriculture and Food Security. *7*, 9.

Gomez, K. A. & Gomez, A. A. (1984). Statistical procedures for agricultural research, An International Rice Research Institute Book, Wiley- Inter Science Publication, New York, USA.

Hilimire, K. (2011). Integrated Crop/Livestock Agriculture in the United States: A Review. *Journal of Sustainable Agriculture, 35*, 376–393.

Kumar, R., Pandey, S. & Pandey (2006). A Plant roots and carbon sequestration. *Current Science, 91*, 885–890.

Kumar, S., Singh, S. S. & Dey, A. (2011). Integrated farming systems for Eastern India. *Indian Journal of Agronomy, 56*, 297–304.

Manjunath, B. L., Paramesh, V., Mahajan, G. R., Das, B., Reddy, K. V., Chakurkar, E. B. & Singh, N. P. (2017). Sustainability through resource recycling, soil fertility and carbon sequestration from integrated farming systems in west coast India. *The Bioscan, 12*, 1-6.

Nadelhoffer, Knute, Raich & James (1992). Fine Root Production Estimates and Belowground Carbon Allocation in Forest Ecosystems. Ecology. *73*, 1139.

Paramesh, V., Sridhara, C. J., Shashidhar, K. S. & Bhuvaneswari, S. (2014). Effect of integrated nutrient management and planting geometry on growth and yield of aerobic rice. *International Journal of Agricultural Sciences, 10*(1), 49–52.

Sharawat, K. L. & Burford, J. R., 1982, Modification of alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. *Soil Science, 133*, 53-57.

Sparks (1996). Methods of Soil Analysis Part-3: Chemical methods. Soil Science Society of America, USA.

Vittal, K. P. R., Maruthi, S. G. R., Singh, H. P. & Samra, J. S. (2002). Sustainability of practices of dryland agriculture: Methodology and assessment. All India Coordinated Research Project on Dryland Agriculture, Centeral Research Institute for Dryland Agriculture, ICAR. *59,* 3-4.

Wilkins, R. (2008). Eco-efficient approaches to land management: a case for increased integration of crop and animal production systems. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*, 517-525.

Yadav, A. K., Nalini, R. & Singh, D. (2019). Integrated Farming Systems Approach: Increase Food Security, Agricultural Farm Income and Rural Economy. *International Journal of Current Microbiology and Applied Sciences, 8*, 2-3.

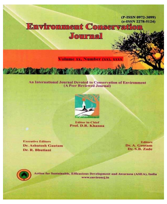
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 40-46, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Multivariate analysis for study of genetic divergence in mungbean [*Vigna radiata* (L.) Wilczek] genotypes

Shivangi Rahangdale ✉
Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India

J. P. Lakhani
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India

S.K. Singh
Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India.

Akash Barela
Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India.

Pratik Kumar
Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India.

S. S. Prajapati
Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.), India.

ARTICLE INFO

Received: 17 October 2022
Revised : 16 January 2023
Accepted : 22 January 2023

Available online: 12 April 2023

Key Words:
Cluster analysis
Greengram
Mahalanobis D^2
PCA
Tocher method

ABSTRACT

Forty mungbean genotypes were evaluated for fourteen quantitative traits, planted in Randomized Complete Block Design with three replications. Mahalanobis' generalised distance D^2 was used to assess the character data and Principal Component Analysis for estimating genetic diversity and identification of superior mungbean genotypes. Following Tocher's technique, the 40 genotypes were divided into 7 clusters in accordance with their genetic distance. Among them four clusters were polygenotypic and three were monogenotypic. The genotypes of cluster IV and VII showed highest (40.51) inter cluster distance followed by cluster III and VII (39.04). Cluster V has been discovered to have the largest intra-cluster distance. In order to increase the genetic diversity of *Vigna radiata*, genotypes from these clusters may be crossed. Based on Principal Component Analysis results, 5 PCs explained 75.87% of the variation among the 14 parameters and had eigen values greater than unit. Only six genotypes—TJM-37, TJM-134, TJM-140, TJM-235, Shikha, and PM-1632—contained with favourable yield and quality associated PCs, and had outstanding remark for yield traits—out of all genotypes contributing their existence in more than one PC with high PC score. These lines may be used in hybridization programmes to transmit desirable features, such as high yield and high quality, to recipient mungbean genotypes, resulting in the creation of promising cultivars.

Introduction

The mungbean (*Vigna radiata* (L.) Wilczek), which is indigenous to India or the Indo-Burman region, is the third-largest self-pollinated, short-duration grain legume crop, trailing chickpea and pigeonpea. Central Asia is regarded to be the main source of the genetic variety found in mungbeans (Kumar and Kumar, 2014). Mungbean has 22 chromosomes in the 2n set and a relatively modest (579 Mb) genome (Kang *et al.,* 2014). The names greensoy, greengram, greenbean, mashbean, and goldengram are also used to describe it (Markam *et al*., 2018). In Asia, mungbean is a vital and reasonably priced source of food protein, especially for the impoverished. It also plays a critical role in lowering protein insufficiency, particularly in developing countries. It is a great option for balanced diets because it contains a lot of readily digestible, high-quality protein (24%) that causes less flatulence and has a high iron level (40-70 ppm) (Vairam *et al.*, 2016). Central Asia is thought to be the main source of mungbean genetic diversity. The majority of the world's greengram

Corresponding author E-mail: *shivangirahangdale@gmail.com*
Doi:https://doi.org/10.36953/ECJ.15472494

comes from India, and it is grown in almost every states of India. According to 3rd advance estimates-2021-2022, the overall production of pulses in India to be 27.75 million tonnes. In India, total 2.85mt mungbean productions including 1.48mt in kharif and 1.37mt in *rabi*, accounting for 10% of all pulse production (Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, 2022). The mungbean crop grows quickly in warm weather, requires little water, and nitrogen fixation provides good soil fertility enhancement (Yagoob and Yagoob, 2014).

Any crop improvement programme must have genetic diversity since it aids in the finding of outstanding segregants and makes their usage and control easier. Divergent lines from diverse, distant clusters are more likely to result in heterotic hybrids or superior offspring than parental lines from the same cluster or cluster with close genetic proximity. To comprehend the useful variation that exists among genotypes, it is crucial to organise or classify them using an appropriate scale. Principle component analysis is a widely used data reduction method. Finding the fewest possible components that could explain the most variability is the goal of principal component analysis (Rahangdale *et al.,* 2021). Given the significance of multivariate analysis, a study was conducted on 40 genotypes of Vigna radiata with the aim of analysing yield and yield-related inter-componential variables to gain specific data about the impact of character to genetic variability and to order the genotypes as per PC Score.

Material and Methods

This study was carried out at Breeder Seed Production Unit, Department of Plant Breeding and Genetics, College of Agriculture, JNKVV, Jabalpur (M.P) during summer season of 2021. Regarding geography and fertility, the trial region was quite uniform. The experimental material consists of 40 genotypes of mungbean obtained from BARC Project- Mutation breeding for mung and urd improvement, were planted in Randomized Complete Block Design with three replications. Each plot was consisted of four rows of two meter length with a spacing 30 cm row to row and 10 cm plant to plant. To record quantitative traits, middle five competitive plants from each plot were randomly selected and recorded the data at specific growth stage. Days to 50% flowering and days to maturity were recorded on whole plot basis.

Statistical analysis

Utilizing mean values, statistical analysis was performed using INDOSTAT 8.1 and XLSTAT 2021.2.2 software. Mahalanobis' generalised distance D^2 was used to assess the character data. Tocher's method (Rao, 1952) was used to divide the populations into several clusters. In the present investigation, the principal components were extracted using a correlation matrix.

Results and Discussion

Genetic divergence:

The percentage contribution of all the characters towards genetic divergence is graphically presented in figure 1. The trait seed index (78.46%) contributed maximum to the genetic divergence followed by days to maturity, plant height, pod length, number of pods per plant, biological yield per plant, days to flowering, harvest index, number of seed per pod, seed yield per plant, leaf length, number of cluster per plant, number of primary branches. The trait number of pods per cluster had no contribution towards genetic divergence. In contrast to this result the findings of Gokulakrishnan *et al.* (2012) reported seed yield per plant had maximum contribution (63.67%) towards genetic divergence. These results were consonance by the findings of Win *et al.* (2020).The 40 genotypes were divided into 7 groups according to Tocher's technique based on genetic distance (table 1). The cluster I, II, IV and V were poly genotypic, while clusters III, VI and VII were mono genotypic (1 genotype in each). The average intra- and inter-cluster D^2 values determined using INDOSTAT software are shown in table 2, and the cluster mean values of several variables are reported in table 3. The average intra-cluster distance (D^2) values showed that Cluster V had the greatest intra-cluster distance ($D^2 = 10.72$), followed by Cluster IV ($D^2 = 9.62$), Cluster II ($D^2 = 9.58$), and Cluster I ($D^2 = 7.63$). Clusters IV and VII had the greatest intercluster distance ($D^2 = 40.51$) indicating, wide diversity between them and the hybridization between genotypes belonging to cluster IV and cluster VII (Hum-1) may lead to formation of superior recombinants. Findings of Goyal *et al.* (2021) showed highest inter cluster distance in cluster II and cluster IV. Gadakh *et al.*

Table 1: Clustering pattern of forty *Vigna radiata* genotypes as per Tocher Method

Cluster No.	Intra-Cluster Distance	No. of genotypes	Genotypes
I	7.63	10	TJM-37, TJM-111, TJM-160, TJM-236, PDM-11, PDM-139, LGG-460, Shikha, Kanika, Ganga-8
II	9.58	17	TJM-115, TJM-124, TJM-136, TJM-137, TJM-140, TJM-143, TJM-144, TJM-145, TJM-146, TJM-155, TJM-196, TJM-232, SML-668, Virat, MH-421, MH-903, PM-1623
III	0.00	1	TJM-37
IV	9.62	6	TJM-134, TJM-141, TJM-231, TJM-235, Pusa Vishal, Pusa B-51
V	10.72	4	IPM-430-1, PKVAM-4, TM-96-25, Urdi Local
VI	0.00	1	Yellow Mung
VII	0.00	1	Hum-1

Table 2: Average intra and inter cluster distance (D^2) among seven cluster in *Vigna radiata*

Clusters	I	II	III	IV	V	VI	VII
I	**7.63**	18.39	30.14	31.18	17.07	11.52	12.49
II		**9.58**	15.34	16.54	13.37	21.42	27.38
III			**0.00**	8.34	21.04	33.03	39.04
IV				**9.62**	21.96	33.56	40.51
V					**10.72**	16.45	23.38
VI						**0.00**	12.09
VII							**0.00**

Table 3: Cluster mean values showing performance of different traits

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII
DF	42.37	42.71	**44.67**	42.78	43.67	40.67	43.67
DM	70.77	71.25	73.00	71.11	**77.08**	76.00	74.67
PH	35.70	35.80	40.00	37.94	42.38	**48.00**	44.33
LL	9.19	8.96	**10.77**	8.11	6.83	6.57	10.17
PL	7.40	7.58	7.87	**8.36**	6.07	7.23	7.17
NPB	2.07	2.25	1.67	2.28	**2.92**	2.67	2.00
NCPP	7.77	8.00	7.33	6.67	**8.67**	6.33	7.33
NPPC	**4.73**	3.92	4.00	4.06	3.58	3.67	4.33
NPPP	27.43	24.14	23.00	22.89	27.58	17.67	**29.00**
NSPP	10.70	10.86	**11.67**	10.50	8.50	8.67	9.00
SI	3.44	4.45	**5.32**	5.31	4.09	3.12	2.83
HI	23.34	21.61	24.71	21.71	27.36	21.31	**29.52**
BYPP	41.29	40.29	**42.40**	39.34	22.57	19.47	34.60
SYPP	9.16	8.41	**10.47**	7.80	6.20	4.13	10.20

DF (days to 50% flowering), DM (days to maturity), LL (leaf length), PH (plant height), PL (pod length), NPB (number of primary branch), NCPP (number of clusters per plant), NPPC (number of pods per cluster), NPPP (number of pods per plant), NSPP (number of seeds per pod), SI (seed index), HI (harvest index), BYPP (biological yield per plant), SYPP (seed yield per plant)

(2013) reported that the genotypes from cluster III and cluster IV may be utilized in hybridization programme as they had highest intercluster distance. Garg *et al.* (2017) reported cluster I and V were highest cluster distance followed by cluster III and VI and cluster II and IV. Cluster mean values showing performance of different characters on particular cluster present in table 3. Cluster I define high value for number of pods per cluster whereas lowest cluster mean for days to maturity and plant height. Similarly, cluster III and cluster V recorded highest mean values of many yield related traits such as number of seeds per pod, seed index, biological yield per plant, seed yield per plant, number of primary branches and number of cluster per plant. Phenological traits such as days to

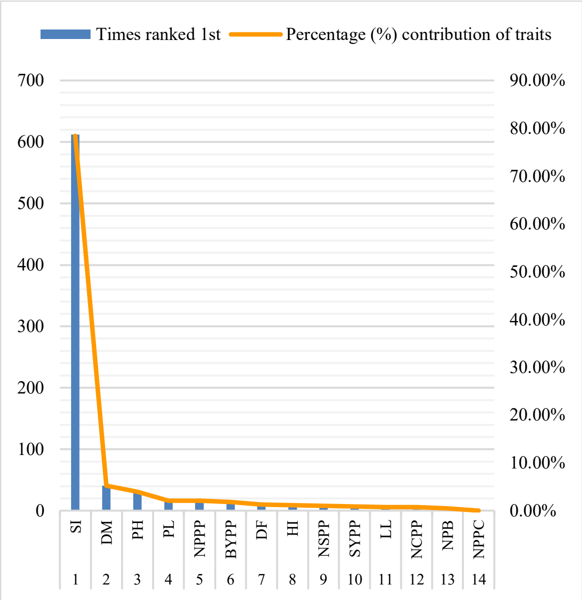


Figure 1: Graphical Representation of Contribution of Different Characters towards Divergence

Notations: SI (seed index), DM (days to maturity), PH (plant height), PL (pod length), NPPP (number of pods per plant), BYPP (biological yield per plant), DF (days to 50% flowering), HI (harvest index), NSPP (number of seeds per pod), SYPP (seed yield per plant), LL (leaf length), NCPP (number of clusters per plant), NPB (number of primary branch), NPPC (number of pods per cluster)

flowering and days to maturity were highest in cluster III and cluster V, respectively. Mostly, yield related traits had lowest performance in cluster VI, consequently, genotypes associated with this cluster may not be used in a hybridization programme as a donner for yield contribution. As per the high mean value of yield related traits recorded on cluster III, IV and V, the genotypes belonging to these clusters can be utilized for improvement in yield through selection for the characters having highest cluster mean values. Gupta *et al.* (2021) reported similar result and these results were also supported by the findings of Gokulakrishnan *et al.* (2012) recorded highest mean value of yield related traits in cluster IV and V.

Variability on the basis of PCA analysis:

Utilizing yield and yield attributing components on greengram genotypes, principal component analysis was carried out. Only five of the forty investigated traits' principal components (PCs) had an Eigen value greater than 1.0 and represented 75.87% of all the cumulative variability among the traits (figure-2). Among the genotypes under research, the PC1 displayed 26.74% variability, while the PC2, PC3, PC4, and PC5 shown 19.05%, 12.35%, 10.41%, and 7.33% variability, respectively. PC1 exhibited highest eigen value 3.74 which then declined gradually as 2.67, 1.73, 1.46 and 1.03 so on with successive PCs. Out of the eleven PCs, Gupta *et al.* (2021) found that the first three accounted for 78.80% of the overall variation among genotypes for various characteristics. Divyaramakrishnan and Savithramma (2014) reported that, out of twelve PCs, four displayed more than 1.0 eigenvalues and shown a total variability of 63.86% among twelve characters of 374 mungbean germplasm (Fig. 3). According to Fetemeh *et al.* (2012), three factors accounted for about 79% of the total variability among 20 genotypes.

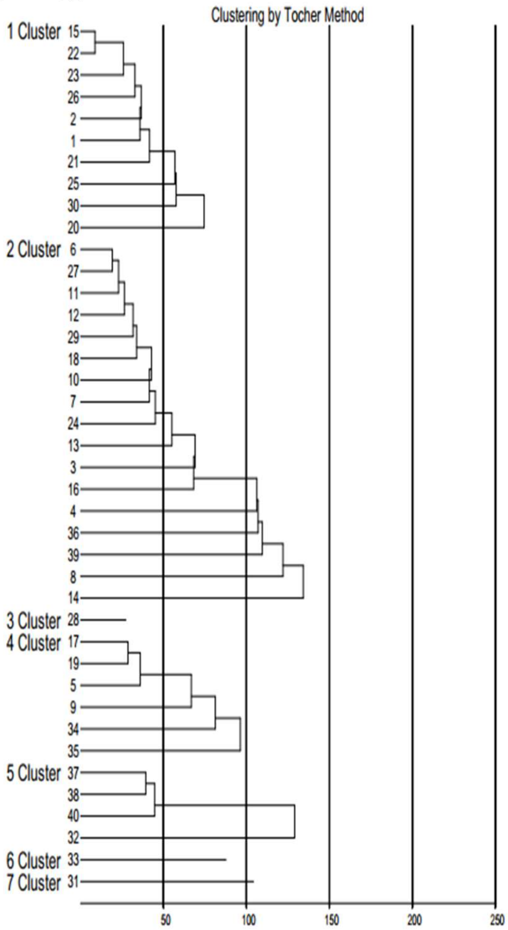


Figure 2: Dendrogram of forty genotypes of *Vigna radiate* based on Euclidean distance using quantitative traits

Rotated component matrix:
Rotated component matrix for fourteen yield attributing traits is depicted in Table 4 and figure 4, represented that the PC 1 which reported maximum variability (26.74%) was associated with yield related traits like number of seeds per pod, biological yield per plant and morphological trait leaf length. The PC 2 was dominated by yield related traits like number of pods per plant, number of clusters per plant, number of pods per cluster and number of primary branch. The PC3 was dominated by phenological traits such as days to flowering, days to maturity, plant height and pod length. The PC 4 contributed to grain quality character seed index. Similarly, PC5 was dominated by seed yield traits like seed yield per plant and harvest index. These findings were in partial consonance with the results of Gupta *et al.* (2021) and Jadhav *et al.* (2021). As per Mahalingam *et al.* (2020), the traits found in the first four PCs—such as pod length, number of seeds per pod (PC 2), number of pods per cluster (PC 3), and single plant yield (PC 4)—were a significant factor in the diversity between germplasm collections.

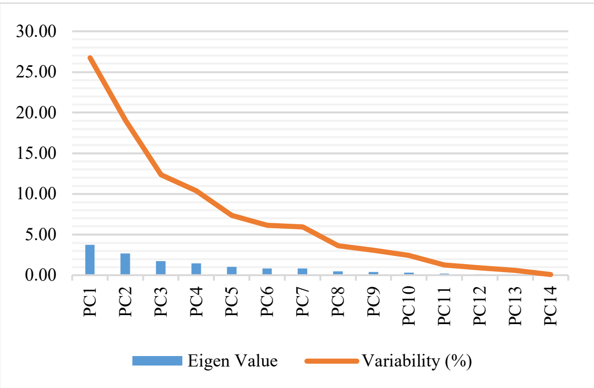


Figure 3: Graphical representation of eigen value and variance percentage of principle component

In this study, the genotypes contributing their presence in more than one principal components and also have >1.5 PC score were selected here for further consideration (table 5). PCA Scores of forty genotypes of *Vigna radiata* is schematically presented in figure 5.
From this study, it was reported that PC2 and PC5 were constituted by most of the yield attributing traits, hence genotypes belonging to these PCs like

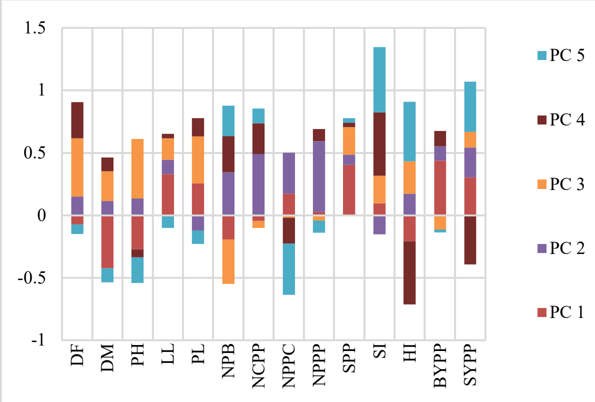


Figure 4: Rotated component matrix for fourteen yield attributing traits of *Vigna radiata*

Table 4: Interpretation of rotated component matrix for the traits having highest value in each PCs

	PC1	PC2	PC3	PC4	PC5
Traits	Number of seeds per pod	Number of pods per plant	Days to 50% flowering	Seed index	Seed yield per plant
	Biological yield per plant	Number of clusters per plant	Days to maturity		Harvest index
	Leaf length	Number of pods per cluster	Plant height		
		Number of primary branch	Pod length		

Table 5: Genotypes selected on the basis of high PC score (>1.5) in each component contributing positive values

PC 1	PC 2	PC 3	PC 4	PC 5
TJM-37	TJM-37	TJM-140	TJM-144	TJM-134
TJM-134	Shikha	GAM-5	TJM-145	PM-1623
TJM-140	Ganga-8	Pusa Vishal	TJM-231	
TJM-146	Virat	Pusa B-51	TJM-235	
TJM-155	TM-96-25	IPM-430-1	Urdi Local	
TJM-196	PM-1623	PKVAM-4		
TJM-232				
TJM-235				
Kanika				
Shikha				

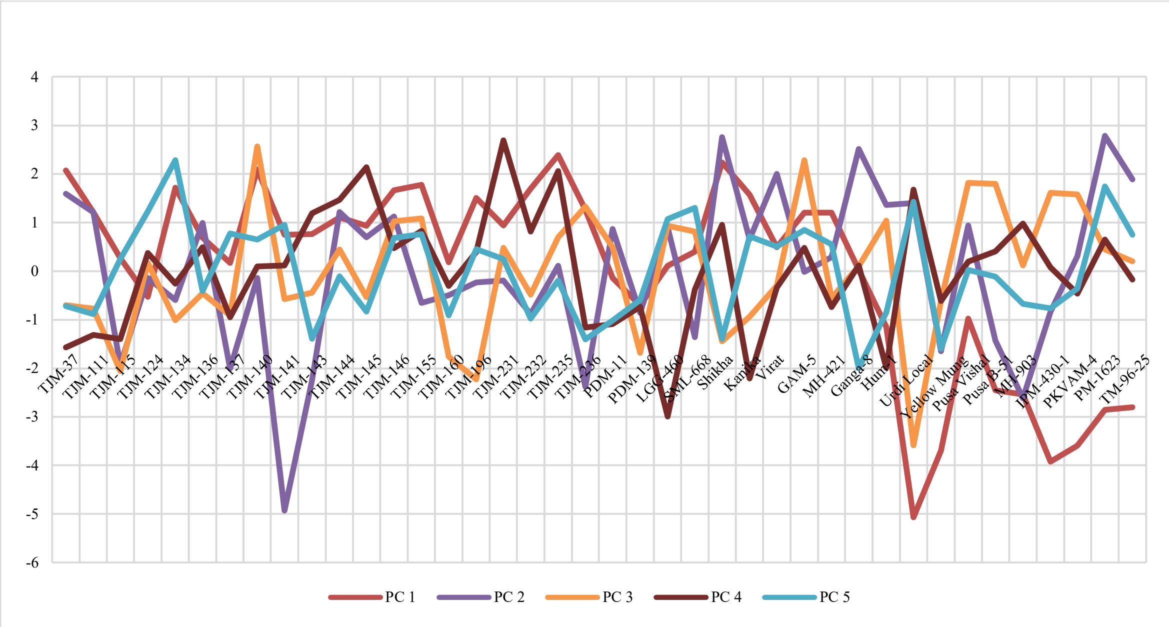


Figure 5: PCA Scores of forty genotypes of *Vigna radiate*

TJM-37, TJM-134, Shikha, Ganga-8, Virat, TM-96-25 and PM-1623 should be used for development of high yielding promising genotypes. Similarly, PC4 reported for the seed quality attributing trait seed index, hence genotypes like TJM-144, TJM-145, TJM-231, TJM-235 and Urdi Local should be selected from these PCs can be utilized for quality improvement programme. Genotypes recorded common share of presence in more than one PCs are TJM-37, TJM-134, TJM-140, TJM-235, Shikha and PM-1632 (table-5). The characters with the most variability are highlighted by PC analysis, it can be concluded. Therefore, rigorous selection techniques can be created to quickly increase yield and quality defining traits.

Conclusion

The trend of grouping generated using PCA was comparable to the analysis based on the Tocher's method and readily and successfully differentiated the groups. Additionally, the results of PCA and cluster analysis were quite comparable. Genotypes from diverse groups will increase thelikelihood of obtaining transgressive segregants because different genotypes are more likely to contribute favourable, unique alleles at different loci. Genetic divergence and clustering trend of forty genotypes of *Vigna radiata* concluded that the genotypes of cluster IV (TJM-134, TJM-141, TJM-231, TJM-235, Pusa Vishal, Pusa B-51) and cluster VII (Hum-1) can be crossed to utilized in hybridization programme as they showed highest inter cluster distance in order to increase the genetic diversity of mungbean. The selection of genotypes on the basis of PCA ranking and contributing their presence in more than one PC dominated with yield and quality traits, the genotypes TJM-37, TJM-134, TJM-140, TJM-235, Shikha and PM-1632 will be selected as donor for improving the yield and yield related trait in mungbean. These studies also suggest that improved genetic recombinants for yield and yield-attributing qualities in mungbean may result via indirect selection for seed yield based on component traits.

Acknowledgement

The authors declare no known conflict of interests that could have appeared to influence the work reported in this paper.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Directorate of Economics and Statistics (2022). Third advance estimates of Production of Food grains for 2021-22. Department of Agriculture and Farmers Welfare, Government of India.

Divyaramakrishnan, C.K. & Savithramma, D.L. (2014). Tailoring genetic diversity of mungbean [Vigna radiata (L). Wilczek] germplasm through principal component and cluster analysis for yield and yield related traits. *International Journal of Agronomy and Agricultural Research,* 5(2), 94-102.

Fetemeh, A., Faruq, G. & Subha, B. (2012). Estimation of genetic diversity of mungbean (Vigna radiata L. Wilczek) in Malaysian tropical environment. *African Journal of Microbiology Research*, 6(8), 1770-1775.

Gadakh, S.S., Dethe, A.M., Kathale, M.N. & Kahate, N.S. (2013). Genetic diversity for yield and its component traits in green gram [Vigna radiata (L.) Wilczek]. *Journal of crop and weed*, 9(1), 106-109.

Garg, G.K., Verma, P.K., Kesh, H. & Kumar, A. (2017). Genetic variability, character association and genetic divergence for seed quality traits in mungbean [Vigna radiata (L.) Wilczek]. *Indian Journal of Agricultural Research*, 51(6).

Gokulakrishnan, J., Sunil Kumar, B. & Prakash, M. (2012). Studies on genetic diversity in mung bean (*Vigna radiata* L.). *Legume Research: An International Journal*, 35(1).

Goyal, L., Intwala, C.G., Modha, K.G. & Acharya, V.R. (2021). Association and diversity analysis for yield attributing traits in advance generation of green gram (*Vigna radiata* (L.) Wilczek). *International Journal of Chemical Studies*, 9(1), 1934-1939.

Gupta, D., Muralia, S., Gupta, N.K., Gupta, S., Jakhar, M.L. & Sandhu, J.S. (2021). Genetic Diversity and Principal Component Analysis in Mungbean [*Vigna radiata* (L.) Wilczek] under Rainfed Condition. *Legume Research-An International Journal*, 1, 8.

Jadhav, R.A., Mehtre, S.P., Patil, D.K. & Gite, V.K. (2021). Multivariate Analysis using D^2 and Principal Component Analysis in Mung bean [*Vigna radiata* (L.) Wilczek] for Study of Genetic Diversity. *Legume Research-An International Journal,* 1, 8.

Kang, Y.J., Kim, S.K., Kim, M.Y., Lestari, P., Kim, K.H., Ha, B.K., Jun, T.H., Hwang, W.J., Lee, T., Lee, J. & Shim, S. (2014). Genome sequence of mungbean and insights into evolution within Vigna species. *Nature communications*, 5(1), 1-9.

Kumar, S. & Kumar, R. (2014). Genetic improvement of mungbean for yield, nutrition and resistance to stresses-A review. *International Journal of Tropical Agriculture,* 32(3/4), 683–687.

Mahalingam, A., Manivanan, N., Kumar, K.B., Ramakrishnan, P. & Vadivel, K. (2020). Character association and principal component analysis for seed yield and its contributing characters in greengram (*Vigna radiata* (L.) Wilczek). *Electronic Journal of Plant Breeding*, 11(01), 259-262.

Markam, N.K., Nair, S.K., Nanda, H.C. & Lakpale, N. (2018). Studies on allelic relationship for resistance to mungbean yellow mosaic virus disease in mungbean genotypes. *International Journal of Chemical Studies*, 6(2), 2401-2403.

Rahangdale, S., Singh, Y., Upadhyay, P.K. & Koutu, G.K. (2021). Principal component analysis of JNPT lines of rice for the important traits responsible for yield and quality. *Indian Journal of Genetics and Plant Breeding*, 81(01), 127-131.

Rao, C.R. (1952). Advanced statistical methods in biometrical research. John Wiley and Sons Inc NY.

Vairam, N., Lavanya, S.A., Muthamilan, M. & Vanniarajan, C. (2016). Screening of M3 mutants for yellow vein mosaic virus resistance in greengram [*Vigna radiata* (L.) wilczek]. *International Journal of Plant Science*, 11(2), 265–269. doi: 10.15740/HAS/IJPS/11.2/265-269.

Win, K.S., Win, S., Htun, T.M. & Win, N.K.K. (2020). Characterization and evaluation of mungbean [Vigna radiata (L.) Wilczek] germplasm through morphological and agronomic characters. *Indian Journal of Agricultural Research*, 54(3), 308-314.

Yagoob, H. & Yagoob, M. (2014). The effects of water deficit stress on protein yield of mungbean genotypes. *Peak Journal of Agricultural Science*, 2(3), 30-35.

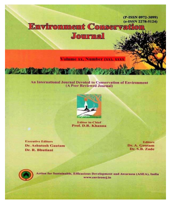
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3):47-53, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Traditional uses of ethno-medicinal plants for the treatment of skin ailments in district Pithoragarh, Uttarakhand, India

Renu
Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, Uttarakhand, India
Bharti ✉
Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, Uttarakhand, India
Deepak Kumar
Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, Uttarakhand, India
Pankaj Arya
Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, Uttarakhand, India

ARTICLE INFO

Received : 10 September 2022
Revised : 29 December 2022
Accepted : 22 January 2023

Available online: 09 April 2023

Key Words:
Allergies
Ethnomedicine
Skin diseases
Therapeutics

ABSTRACT

This study was conducted among the local people of Pithoragarh district (Uttarakhand) to document the ethnomedicinal plants used as remedies for various skin diseases. A total of 52 plant species from 36 families were listed for curing skin ailments such as allergies, infections, pigmentation, acne, pimples, burns, wounds, etc. It is noted that most of the plant formulations were applied externally in the form of paste. However, phytochemical analysis and pharmacognostic research on these recorded plants should be conducted to determine their therapeutic potential as a first step toward the development of effective drugs. This valuable knowledge about indigenous uses of the reported plant species must be conserved for sustainable use and future generations.

Introduction

India is known for its traditional medicinal system for primary health care from ancient times. In the Charak Samhita, approximately '340' herbal medicines with their traditional uses were documented (Mehra *et al.,* 2014). It is observed that the traditional knowledge of curing human ailments by ethnic communities relies on the Ayurveda, Unani, and Siddha systems of medicine (Bhat *et al.,* 2014). However, approximately 80% of the population worldwide believes in traditional medicinal systems due to their fewer side effects (Ojha *et al.,* 2020). Plants are rich in many bioactive molecules extracted from different parts of the plant, i.e., "roots, stems, leaves, flowers, fruits, and seeds". These components exhibit antiseptic, anti-inflammatory, antimicrobial, anticancer, anti-diabetic, and other properties (Gordon and David, 2001). Therefore, modern medical science also depends on secondary metabolites derived from plant resources for drug development (Kebede *et al.,* 2021). Kumaun Himalayan region provides a variety of climates that sustain the growth of plant species used by conventional healers in folk medicine. Its more than two-thirds of the population depends on a variety of natural resources for food, fuel, timber, oil, fodder, and herbal medicine (Kapkoti *et al.,* 2014). Human skin is the largest sensory organ, forming the body's outer covering and making contact with the external environment. It also protects against pathogens like bacteria, fungi, and viruses that are the causative agents of skin diseases such as itching, acne, pimples, dermatitis, allergies, psoriasis, etc. (Sharma *et al.,* 2014). Skin diseases are common problems for all age groups and sexes that affect human health in various ways. People in developing countries are still facing skin-related issues despite the development of medical science because of a lack of hygiene, sanitation, awareness, and adequate guidance among health workers (Sharma *et al.,* 2014; Sharif *et al.,* 2018). Ethnomedicinal plants play a pivotal role in herbal

Corresponding author E-mail: *bhartirautela77@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14922464

therapy and are used to manage dermatological conditions throughout the world (Abbasi *et al.,* 2010). Therefore, the present study focuses on documenting ethnomedicinal knowledge of plants applied to skin disorders by the traditional herbalists (vaidyas) or local people in the district Pithoragarh (Uttarakhand).

Material and Methods

Pithoragarh district is situated within the Kumaun division of Uttarakhand state, with a total geographic area of 7110 sq. km and is bordered by the districts of Almora, Champawat, Bageshwar, and Chamoli. The area is located between latitudes 29.54587-29.62587° North and longitudes 80.17517-80.25517° East. Regular field visits were carried out for plant collection. Plants were identified by using regional flora and available literature. The data on documented plants were collected from the local people residing in the Pithoragarh district through discussion to explore the traditional knowledge about skin health. Later, the data were also compared to the related literature.

Results and Discussion

In the present study, 52 plant species (46 genera and 36 families) were listed, which were traditionally used by the local inhabitants of district Pithoragarh (Uttarakhand) for the treatment of various skin ailments (Table 1). Different habits of plant species have been recorded, such as herbs (54%), undershrubs (4%), shrubs (10%), climbers (11%), and trees (21%) (Figure 1). In this data, herbs were generally used by traditional healers because they are readily available for preparing herbal formulations (Parthiban *et al.,* 2016).

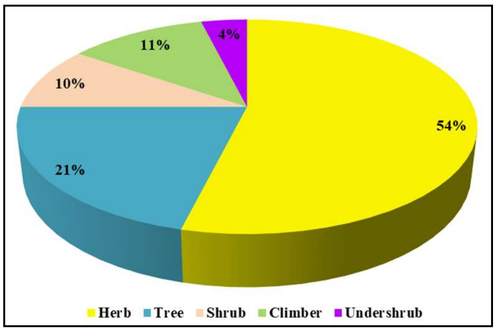


Figure 1: Habit of ethnomedicinal plants reported from study area

The most commonly used plant part was the leaves (32%), followed by the fruits (19%), seeds (13%), flowers (9%), roots (7%), whole plant (6%), stem (4%), tuber (4%), rhizome (4%), and bulb (2%) (Figure 2).

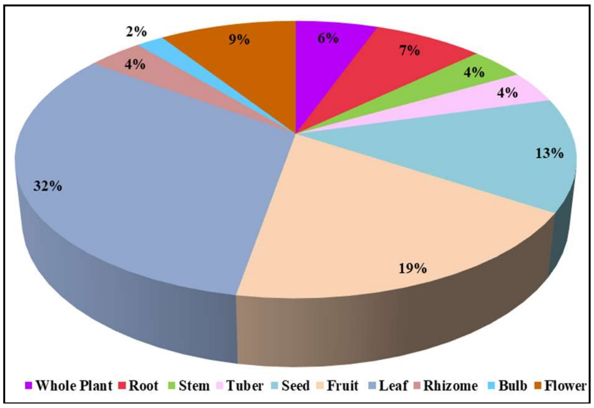


Figure 2: Percentage of plant part used for dermatological problems

It was depicted from the data that the leaves are valued for plant-based therapy because they are considered a rich source of easily extractable secondary metabolites and show maximum efficacy against skin illness (Ghorbani, 2005; Kayani *et al.,* 2015). Data also suggested that Asteraceae and Rosaceae (4 spp. each) were the dominant families, followed by Rutaceae and Solanaceae (3 spp. each). Besides these, 6 families were di-typic (two species each) and 26 families were monotypic (one species each) (Figure 3).

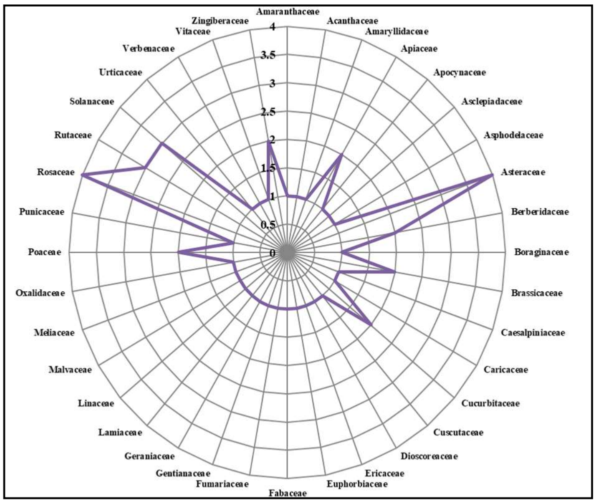


Figure 3: Families of ethnomedicinal plants reported from study area

Figure 4: A) ***Lagenaria siceraria*** **B)** ***Oxalis corniculata*** **C)** ***Coriandrum sativum*** **D)** ***Curcuma longa*** **E)** ***Catharanthus roseus*** **F)** ***Prunus persica*** **G)** ***Vitis vinifera*** **H)** ***Rhododendron arboreum***

Ethnomedicinal plant species mentioned in this study have also shown their importance in indigenous systems of medicine like Ayurveda, Homoeopathy, Unani, and Siddha. In Ayurveda, gel obtained from the leaves of aloe vera is used to relieve sun tan, wounds, eczema, stretch marks, acne, burns, boils, etc. (Joseph and Raj, 2010). It also has anti-ageing properties as it stimulates collagen production in skin cells. *Curcuma longa* paste is traditionally applied to cuts, bruises, wounds, abrasions, skin eruptions, insect bites, bumps, and itches (Kumar and Sakhya, 2013; Sabale *et al.,* 2013). The native use of *Melia azadirach* for scabies, pustules, ringworm, allergy, and other skin diseases is documented in Ayurveda (Brishty *et al.,* 2020; Sharma *et al.,* 2013, Sultana *et al.,* 2014). The fruits, seeds, leaves, and pulp of *Cucumis sativus* have long been used extensively in traditional healthcare systems for a variety of skin problems like sunburn, itching, irritated skin, hyperpigmentation, and skin toning (Nema *et al.,* 2011). Therefore, these plants are currently advised on a global scale for preparing cosmetic items (Sotiroudis *et al.,* 2010).

Further, modern research has also proved the importance of recorded plants for the treatment of skin ailments. Parameshwaraiah and Shivakumar (1998) have evaluated the ethanolic extract of Brahmi (*Centella asiatica*) increases the rate of epithelization and enhances the growth of collagen content in the skin. The extract of *Murraya koeingii* has a wide range of applications in treating skin irritations (Abeysinghe *et al.,* 2021). Sumathi *et al.,* (2008) found that the fresh extract of *Cucumis sativus* contains many beneficial constituents that can be used in a variety of skin care products consisting of packs, toners, and others.

Conclusion

The ethnic groups of Pithoragarh district (Uttarakhand) possess remarkable ethnomedicinal knowledge to treat common skin problems in their daily lives by utilizing regional plants according to the current study. The study demonstrates that herbal treatments are considered important among rural people as plants are an excellent source of bioactive compounds and can be a safer and more affordable way to treat skin conditions. However, the traditional knowledge on plant usage is under threat due to urbanization and habitat destruction. Therefore, urgent attention is required for the resurgence of interest in traditional folk medicine by screening therapeutic phytochemicals and performing clinical research.

Acknowledgement

The authors are thankful to the Head (Department of Botany) and Principal of the L.S.M. Govt. P.G. College, Pithoragarh, Uttarakhand for providing necessary research facilities.

Table 1: Ethnomedicinal plants for the treatment of skin ailments in district Pithoragarh (Uttarakhand)

SN	Botanical Name	Common Name	Family	Habit	Plant Part Used	Traditional use
1.	*Achyranthes aspera* L.	Chirchita	Amaranthaceae	H	Leaf	Leaf powder is used for itchy skin.
2.	*Ajuga bracteosa* Wall. ex Benth.	Neelkanthi	Lamiaceae	H	Leaf	Leaf juice is applied on wounds.
3.	*Allium cepa* L.	Pyaj	Amaryllidaceae	H	Bulb	Its bulb paste is applied to skin allergies.
4.	*Aloe vera* (L.) Burm. f.	Ghrit kumari	Asphodelaceae	H	Leaf	Leaf gel is used for wrinkles and blemishes on the skin.
5.	*Artemisia nilagirica* (Clarke) Pamp.	Duana	Asteraceae	H	Leaf	Leaf paste is used for pigmentation.
6.	*Bauhinia variegata* L.	Kachnar	Caesalpiniaceae	T	Stem bark	Paste made from bark powder effectively treats acne and pimples.
7.	*Berberis aristata* DC.	Daru haldi	Berberidaceae	S	Root	Paste made from its root powder is used to manage acne and tan.
8.	*Berberis chitria* Buch.-Ham. ex Lindl.	Totar	Berberidaceae	S	Root	Root extract is useful for inflammation.
9.	*Bidens pilosa* L.	Kumar	Asteraceae	H	Whole plant	Plant paste is effective on burns and cuts.
10.	*Brassica campestris* L.	Sarson	Brassicaceae	H	Seed	Its seed oil is effective on itchy rashes and scratches.
11.	*Brassica juncea* (L.) Czern.	Lai	Brassicaceae	H	Seed	Its seed paste is applied for boils and baldness.
12.	*Calotropis procera* (Aiton) Dryan.	Aak	Asclepiadaceae	S	Root	Root bark decoction is used externally for eczema, leprosy.
13.	*Carica papaya* L.	Papita	Caricaceae	T	Fruit	Fruit is beneficial for pigmentation, acne, wrinkles, and tan.
14.	*Catharanthus roseus* (L.) G.Don	Sadabahar	Apocynaceae	H	Flower	Flower juice is applied to acne, dermatitis, and wounds. (Fig 4E)
15.	*Centella asiatica* (L.) Urb.	Brahmi	Apiaceae	H	Leaf	Paste made from leaves is used to manage acne, burns, wounds, and skin infections.
16.	*Citrus pseudolimon* Tanaka	Pahari nimbu	Rutaceae	T	Fruit	Fruit juice is good for skin health and its peel is used for pigmentation.
17.	*Citrus sinensis* (L.) Osbeck	Malta	Rutaceae	T	Fruit	Powder of fruit peel is used for blemishes and acne on skin.
18.	*Coriandrum sativum* L.	Dhaniya	Apiaceae	H	Leaf	Mixture of its leaf and lemon juice is effective on dry skin, acne, and pimples. (Fig 4 C).
19.	*Cucumis sativus* L.	Kakdi	Cucurbitaceae	Cl	Fruit	Fruit extract is used for skin hydration and to reduce pores.
20.	*Curcuma longa* L.	Haldi	Zingiberaceae	H	Rhizome	Its rhizome powder is used for skin diseases like dermatitis, eczema, psoriasis, alopecia, acne, and wounds. (Fig. 4D)
21.	*Cuscuta reflexa* Roxb.	Amarbel	Cuscutaceae	Cl	Stem	Stem paste is used as an ointment to treat itchy skin and infections.
22.	*Cynoglossum lanceolatum* Forssk.	Kuro	Boraginaceae	H	Leaf	Leaf paste is used for healing skin wounds.
23.	*Dicliptera bupleuroides* Nees	Somni	Acanthaceae	H	Leaf	Paste made from leaves is applied to skin wounds.
24.	*Dioscorea bulbifera* L.	Genthi	Dioscoreaceae	Cl	Tuber	Paste made from powdered dried tubers is employed on wounds.
25.	*Eleusine coracana* (L.) Gaertn.	Mandwa	Poaceae	H	Seed	Seed powder softens the skin and protects it from dullness and damage.
26.	*Eupatorium adenophorum* Sprengel	Kala bansa	Asteraceae	US	Leaf	Leaves are crushed and applied on wounds.
27.	*Fumaria indica* (Haus.) Pugs.	Pit-papra	Fumariaceae	H	Leaf	Leaf paste is used for healing skin wounds.
28.	*Geranium nepalense* Sweet	Bhand	Geraniaceae	H	Root	Paste made from root is used in itching and eczema.
29.	*Hibiscus rosa-sinensis* L.	Gudhal	Malvaceae	S	Flower, Leaf	Leaves and flower paste are good for hydrating and soothing

						skin.
30.	*Lagenaria siceraria* (Molina) Standl.	Lauki	Cucurbitaceae	Cl	Fruit	Fruit juice is beneficial for skin health and reduces wrinkles and premature aging. (Fig 4A)
31.	*Linum usitatissimum* L.	Alsi	Linaceae	H	Seed	Paste of seeds is used to tighten and hydrate the skin.
32.	*Lycopersicon esculentum* Mill.	Tamatar	Solanaceae	H	Whole Plant	Fruit juice is effective for sunburns, acne, scars, pores, and glow.
33.	*Melia azedarach* L.	Bakain	Meliaceae	T	Leaf	Leaf paste is used for wounds, pimples, itching, allergies, and other skin diseases.
34.	*Murraya koenigii* (L.) Spreng.	Kari patta	Rutaceae	S	Leaf	Leaf paste is beneficial for skin health, pigmentation, and irritation.
35.	*Oryza sativa* L.	Chawal	Poaceae	H	Seed	Rice water is used to brighten, tighten, and nourish the skin.
36.	*Oxalis corniculata* L.	Khati buti	Oxalidaceae	H	Leaf	Leaf paste is beneficial for wounds, warts and, inflammation. (Fig 4B)
37.	*Phyllanthus emblica* L.	Amla	Euphorbiaceae	T	Fruit	Fruit juice is beneficial to skin health and can reduce acne, wrinkles and pigmentation.
38.	*Prunus armeniaca* L.	Khubani	Rosaceae	T	Fruit	Fruit nourishes the skin and keeps it hydrated.
39.	*Prunus domestica* L.	Plum	Rosaceae	T	Fruit	Fruit is beneficial for skin health and reduces wrinkles, dark circles, acne and scars
40.	*Prunus persica* (L.) Batsch	Aadoo	Rosaceae	T	Fruit	Fruit is beneficial for skin health and reduces wrinkles and blemishes.(Fig 4F)
41.	*Punica granatum* L.	Darim	Punicaceae	T	Seed	Juice of seeds nourishes the skin and reduces wrinkles and ageing.
42.	*Rhododendron arboreum* Sm.	Burans	Ericaceae	T	Flower	Flower juice is used for skin health. (Fig 4H)
43.	*Rosa brunonii* Lind.	Kunja	Rosaceae	Cl	Flower	Flower juice is applied to skin irritations and wounds.
44.	*Solanum nigrum* L.	Makoi	Solanaceae	H	Leaf	Leaf paste is applied to itchy skin.
45.	*Solanum tuberosum* L.	Aaloo	Solanaceae	H	Tuber	Tuber juice is used for cuts, wounds, acne, and blemishes.
46.	*Swertia chirayita* (Roxb. ex Fleming) Karst.	Chiraita	Gentianaceae	US	Whole plant	Its decoction is used for skin rashes and itches.
47.	*Tagetes erecta* L.	Genda	Asteraceae	H	Flower	Flower paste is effective on burns, eczema, and wounds.
48.	*Trigonella foenum-graecum* L.	Methi	Fabaceae	H	Seed	Its seed paste is effective on acne, scars, and blemishes on the skin.
49.	*Urtica dioica* L.	Bichu ghas	Urticaceae	H	Leaf	Leaf extract is beneficial for skin allergies.
50.	*Verbena officinalis* L.	Vervain	Verbenaceae	H	Leaf	Leaf juice is effective remedy for burns and wounds.
51.	*Vitis vinifera* L.	Angoor	Vitaceae	Cl	Fruit	Grape fruit is good for skin health.
52.	*Zingiber officinale* Roscoe	Adrak	Zingiberaceae	H	Rhizome	Juice of rhizome is used for acne, scars and wrinkles.

Abbreviations: H- Herbs, US- Undershrubs, S- Shrubs, T- Trees, Cl- Climber

Conflict of interest

The authors declare that they have no conflict of interest.

References

Abbasi, A. M., Khan, M. A., Ahmad, M., Zafar, M., Jahan, S. & Sultana, S. (2010). Ethnopharmacological application of medicinal plants to cure skin diseases and in folk cosmetics among the tribal communities of North-West Frontier Province, Pakistan. *Journal of Ethnopharmacology*, *128*(2), 322–335.

Abeysinghe, D. T., Kumara, K. A., Kaushalya, K. A., Chandrika, U. G. & Alwis, D. D. (2021). Phytochemical screening, total polyphenol, flavonoid content, in vitro antioxidant and antibacterial activities of Sri Lankan varieties of *Murraya koenigii* and *Micromelum minutum* leaves. *Heliyon*, *7*(7), e07449.

Bhat, P., Hegde, G. R., Hegde, G. & Mulgund, G. S. (2014). Ethnomedicinal plants to cure skin diseases-an account of the traditional knowledge in the coastal parts of Central Western Ghats, Karnataka, India. *Journal of Ethnopharmacology*, *151*(1), 493–502.

Brishty, S. R., Islam Setu, N., Anwar, M. R., Jahan, R., Mia, M. M. K., Fahim Kadir, M. & Islam, M. R. (2020). Ethnobotanical study on medicinal plants for dermatological disorders at Chittagong Hill Tracts, Bangladesh. *Pharmaceutical and Biomedical Research*, *6*(1), 61–90.

Ghorbani, A. (2005). Studies on pharmaceutical ethnobotany in the region of Turkmen Sahra, north of Iran:(Part 1): General results. *Journal of Ethnopharmacology*, *102*(1), 58–68.

Gordon, M. C. & David, J. N. (2001). Natural product drug discovery in the next millennium. *Pharmaceutical Biology*, *39*(Sup1), 8–17.

Joseph, B. & Raj, S. J. (2010). Pharmacognostic and phytochemical properties of *Aloe vera* Linn.- an overview. *International Journal of Pharmaceutical Sciences Review and Research*, *4*(2), 106–110.

Kapkoti, B., Lodhiyal, N. & Lodhiyal, L. S. (2014). Ethno-medicinal plants and their uses by van panchayat people in Nainital of Kumaun Region, Uttarakhand. *Biolife Journal of Biology and Life Science*, *2*(2), 526–532.

Kayani, S., Ahmad, M., Sultana, S., Shinwari, Z. K., Zafar, M., Yaseen, G., Hussain, M. & Bibi, T. (2015). Ethnobotany of medicinal plants among the communities of alpine and sub-alpine regions of Pakistan. *Journal of Ethnopharmacology*, *164*, 186–202.

Kebede, T., Gadisa, E. & Tufa, A. (2021). Antimicrobial activities evaluation and phytochemical screening of some selected medicinal plants: A possible alternative in the treatment of multidrug-resistant microbes. *PLoS One*, *16*(3), e0249253.

Kumar, N. & Sakhya, S. K. (2013). Ethnopharmacological properties of *Curcuma longa*: a review. *International Journal of Pharmaceutical Sciences and Research*, *4*(1), 103–112.

Mehra, A., Bajpai, O., & Joshi, H. (2014). Diversity, utilization and sacred values of ethno-medicinal plants of Kumaun Himalaya. *Tropical Plant Research*, *1*(3), 80–86.

Nema, N. K., Maity, N., Sarkar, B. & Mukherjee, P. K. (2011). *Cucumis sativus* fruit-potential antioxidant, anti-hyaluronidase, and anti-elastase agent. *Archives of Dermatological Research*, *303*(4), 247–252.

Ojha, S. N., Tiwari, D., Anand, A. & Sundriyal, R. C. (2020). Ethnomedicinal knowledge of a marginal hill community of Central Himalaya: diversity, usage pattern, and conservation concerns. *Journal of Ethnobiology and Ethnomedicine*, *16*(1), 1–21.

Parameshwaraiah, S. & Shivakumar, H. G. (1998). Evaluation of topical formulations of aqueous extract of *Centella asiatica* on open wounds in rats. *Indian Journal of Experimental Biology*, *36*(6), 569–572.

Parthiban, R., Vijayakumar, S., Prabhu, S. & Yabesh, J. G. E. M. (2016). Quantitative traditional knowledge of medicinal plants used to treat livestock diseases from Kudavasal taluk of Thiruvarur district, Tamil Nadu, India. *Revista Brasileira de Farmacognosia*, *26*(1), 109–121.

Sabale, P., Modi, A. & Sabale, V. (2013). *Curcuma longa* Linn. A phytochemical and phytopharmacological review. *Research Journal of Pharmacognosy and Phytochemistry*, *5*(2), 59–68.

Sharif, A., Asif, H., Younis, W., Riaz, H., Bukhari, I. A. & Assiri, A. M. (2018). Indigenous medicinal plants of Pakistan used to treat skin diseases: a review. *Chinese Medicine*, *13*(1), 1–26.

Sharma, J., Gairola, S., Sharma, Y. P. & Gaur, R. D. (2014). Ethnomedicinal plants used to treat skin diseases by Tharu community of district Udham Singh Nagar, Uttarakhand, India. *Journal of Ethnopharmacology*, *158*, 140–206.

Sharma, J., Gaur, R. D., Gairola, S., Painuli, R. M. & Siddiqi, T. O. (2013). Traditional herbal medicines used for the treatment of skin disorders by the Gujjar tribe of Sub-Himalayan tract, Uttarakhand. *Indian Journal of Traditional Knowledge*, *12*(4), 736–746.

Sotiroudis, G., Melliou, E., Sotiroudis, T. G. & Chinou, I. (2010). Chemical analysis, antioxidant and antimicrobial activity of three Greek cucumber (*Cucumis sativus*) cultivars. *Journal of Food Biochemistry*, *34*, 61–78.

Sultana, S., Asif, H. M., Akhtar, N., Waqas, M. & Rehman, S. U. (2014). Comprehensive review on ethanobotanical uses, phytochemistry and pharmacological properties of *Melia azedarach* Linn. *Asian Journal of Pharmaceutical Research and Health Care*, *6*(1), 26–32.

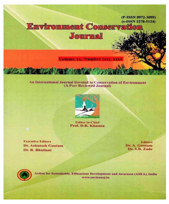
Sumathi, T., Ponnuswami, V. & Senthamizh, B. S. (2008). Anatomical changes of cucumber (*Cucumis sativus* L.) leaves and roots as influenced by shade and fertigation. *Research Journal of Agriculture and Biological Sciences*, *4*(6), 630–638.

Environment Conservation Journal 24 (3): 54-62, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Disease incidence, larval parameters and mortality of mulberry silkworm, *Bombyx mori* L. effected by bed disinfectants

Pompi Konwar
Department of Sericulture, Assam Agricultural University, Jorhat, Assam, India
Monimala Saikia ✉
Department of Sericulture, Faculty of Agriculture, Assam Agricultural University, Jorhat, Assam, India
Surajit Kalita
Directorate of Research (Agri.), Assam Agricultural University, Jorhat, Assam, India
Hemanta Saikia
Department of Basic Science and Humanities, College of Sericulture, AAU, Jorhat, Assam, India
Aparupa Borgohain
Department of Sericulture, College of Sericulture, AAU, Jorhat, Assam, India

ARTICLE INFO

Received : 12 September 2022
Revised : 13 November 2022
Accepted : 03 January 2023

Available online: 09 April 2023

Key Words:
Bed disinfectant
Bombyx mori
Disease incidence
Larval mortality
Growth parameters

ABSTRACT

With an aim to find out an effective bed disinfectant regulating disease incidence, larval growth parameters and mortality of mulberry silkworm, *Bombyx mori* L. revealed a positive influence on the disease incidence, and larval growth of mulberry silkworm race, (CSR6 × CSR26) × (CSR2 × CSR27). The commercial bed disinfectant, Ankush manifested better result in terms of reduction in disease incidence (1.833 %) and larval parameters (larval duration, 21.888 days; full grown larval weight, 4.596 g; silk gland weight, 0.889 g and 24.181% SGTSI) compared to the control (22.667 days, 3.976 g, 0.817 g and 20.726 %, respectively) followed by Sericillin and Turmeric rhizome powder alone or in combinations. However, a combination of bed disinfectants *viz*., Ankush + Sericillin, Ankush + Turmeric rhizome powder and Sericillin + Turmeric rhizome powder recorded better results compared to Turmeric rhizome powder alone. Though bed disinfectants did not show any significant effect on mortality percentage but Ankush resulted highest reduction of mortality over control (46.933 %). The performance of all the bed disinfectants was found to be better during the late spring season.

Introduction

Mulberry silkworm, *Bombyx mori* (Lepidoptera: Bombycidae) is a domesticated monophagous silkworm and completely reared under indoor condition. China is the leading producer of silk with a production of 53, 359 MT mulberry raw silk (Anon., 2022). Contribution of India is next to China in silk production (33,770 MT). Among the four varieties of silk produced in India, mulberry silk accounted for 70.76 per cent of the total raw silk production. Mulberry silk occupies an important place in Assam's sericulture covering an area of 2,653.00 ha with a total production of about 16 metric tonnes of mulberry silk (Anon., 2021). Various factors like quality silkworm layings, incubation of silkworm eggs, disinfection of rearing house, maintenance of hygiene and rearing environment, quality of mulberry leaf, disease and pest management, mounting etc. are considered to be the most important for healthy and vigorous growth of silkworm and its successive higher production. Moreover, mulberry silkworm is sensitive and susceptible to various diseases caused by microsporidia, bacteria, viruses and fungi (Doreswamy *et al*., 2004) sharing about 30 per cent of total loss and estimated loss due to disease incidence is about 15-20 kg per unit of 100 disease free layings (Selvakumar *et al*. 2002). Silkworm rearing bed or seat always acts as a major source for infection and multiplication with some secondary infection. Hence, proper bed disinfection

Corresponding author E-mail: *dr.moni1980@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14952465

is considered as an essential precautionary measure in mulberry silkworm culture. In mulberry silkworm culture, several workers had already revealed efficacy of different bed disinfectants in preventing contamination, spread and multiplication of various silkworm diseases *viz*., grasserie, flacherie, muscardine and pebrine, which ultimately helps in increasing the larval growth parameters of silkworm and thereby silk production (Singhvi *et al*., 2004). In silkworm rearing, reports can be obtained on indiscriminate use of various bed disinfectants *viz*., Vijetha, Lime, Captan, Dithane M-45, Resham Keet Oushad, Ankush, Vijetha Green, Resham Jyothi, Formalin Chaff and Labex etc. in large quantities (Swathi *et al*., 2014; Shashidhar *et al*., 2018). Thus, selection and proper use of bed disinfectant could help the farmers in achieving the success in mulberry silkworm culture. Therefore, the present study was undertaken with the objective to evaluate existing chemical bed disinfectants and also formulation of new botanical disinfectant alone or in combination to reduce the silkworm disease effectively for good larval growth and quality cocoon production suitable for the prevailing very high relative humidity induced environmental condition of Assam.

Material and Methods

Silkworm rearing

The present investigation to find out the effect of botanical and chemical bed disinfectants on larval characters and disease incidence of mulberry silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae) was conducted at the Department of Sericulture, Assam Agricultural University, Jorhat during the year 2019-20 under ambient environmental condition. Seeds of double hybrid mulberry silkworm race, (CSR6×CSR26) × (CSR2×CSR27) were collected from Silkworm Seed Production Centre, Central Silk Board, Bangalore and were reared (Fig. 1) separately during the late spring (May-June, 2019-20) and the autumn season (September-October, 2019-20). The newly hatched silkworms were reared on mulberry leaves (variety: S1635) under ambient room temperature and relative humidity following standard rearing technique suggested by Kumar *et al*. (2015).

Treatments and method of use

Altogether 3 (three) bed disinfectants *viz*., Ankush, Sericillin, and Turmeric rhizome powder were selected and utilized @ 3g/sq.ft bed area based on earlier scientific reports (Balavenkatasubbaiah *et al*., 2014), and were tested at various treatment combinations (Table 1) by dusting on the body as well as rearing seat of mulberry silkworm so reared with the help of a muslin cloth. Treatments were repeated once after every moult at 30-40 minutes before the resumption of feed from first to fifth instars. Moreover, one additional dusting with the selected bed disinfectants was done on the 4th day of fifth instar after bed cleaning. Each treatment was replicated three times with 100 numbers of larvae per replication. The data on total larval duration and instarwise larval weight (from 2nd instar onward) were recorded. Silk gland weight, silk gland tissue somatic index were calculated during the fifth instar. Disease incidence and larval mortality were observed during the larval period as a whole. All the treatments alone or in combinations were tested in both the late spring (May-June, 2019-20) and the autumn season (September-October, 2019-20)

Statistical Analysis

The data on different seasonal growth parameters, diseases incidence and mortality percentage were subjected to Analysis of variance (ANOVA) following Completely Randomized Design (CRD) and interaction effects of both season and bed disinfectants were calculated following the method proposed by Sahu and Das (2009).

The percent of Disease Incidence (%) was calculated by the following method of Zagar (2010) as mentioned below –

$$\text{Disease Incidence (\%)} = \frac{\text{Number of diseased larvae}}{\text{Total number of healthy larvae}} \times \mathbf{100}$$

The per cent of disease reduction was calculated by the following method of Abbott (1925) as mentioned below-

$$\text{Per cent disease reduction (\%)} = \frac{\text{C- T}}{\text{C}} \times \mathbf{100}$$

Where,
C = Mortality per cent of control batch
T = Mortality per cent of treatment batch

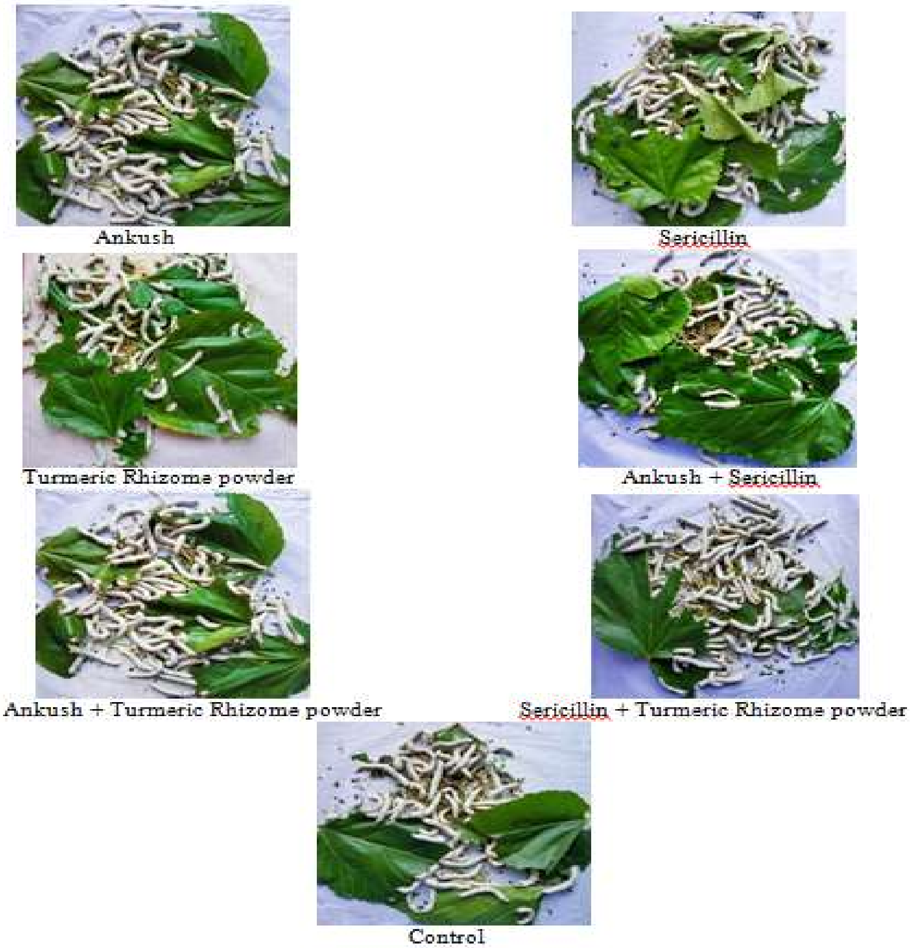


Figure 1: 5th instar mulberry silkworm larvae in different treatments.

Table 1: Treatment details and dosage

Treatment No	Treatment details	Dosage (g/sq.ft bed area)
T_1	Ankush	3
T_2	Sericillin	3
T_3	Turmeric rhizome powder	2
T_4	Ankush + Sericillin	3 (1.5+1.5)
T_5	Ankush + Turmeric rhizome powder	2.5 (1.5+1)
T_6	Sericillin + Turmeric rhizome powder	2.5 (1.5+1)
T_7	Control	No application

The Silk Gland Tissue Somatic Index (SGTSI) expressed in percentage (%) was determined by using the standard formula described by Venkata Rai Reddy and Benchamin (1989) as mentioned below –

$$\text{SGTSI (\%)} = \frac{\text{Weight of the silk gland tissue } (g)}{\text{Weight of larval body } (g)} \times 100$$

Larval mortality (%) was calculated with the data on numbers of larvae died out of total number of larvae brushed, which is represented below –

$$\text{Larval mortality (\%)} = \frac{\text{Total number of larvae died}}{\text{Total number of larvae brushed}} \times 100$$

Results and Discussion

Table 2 represents the data on effect of selected bed disinfectants on disease incidence (%) of double hybrid mulberry silkworm and the data revealed a higher disease incidence during autumn season (2.000 to 5.333%) as compared to late spring season (1.667 to 5.000%). The data on disease

Table 2: Effect of bed disinfectants on disease incidence (%) of double hybrid mulberry silkworm race in late spring and autumn season

Treatment	Season		Mean
	Late spring	Autumn	
T_1	1.667	2.000	1.833
T_2	2.000	2.333	2.167
T_3	4.000	4.333	4.167
T_4	2.333	2.667	2.500
T_5	2.667	3.333	3.000
T_6	3.000	4.000	3.500
T_7	5.000	5.333	5.167
Mean	2.952	3.429	
	S. Ed (±)	C.D (5%)	
Season	0.471	NS	
Bed disinfectant	0.882	1.816	
Season × Bed disinfectant	1.247	NS	

Data are mean of three replications
NS = Non Significant

incidence revealed that all the treatments showed better performance over control and season had non-significant effect but bed disinfectants had significant effect on disease incidence of mulberry silkworm larvae. Among the different treatments of bed disinfectants, significantly the lowest disease incidence of 1.833% was recorded with the application of Ankush @ 3 g/sq. feet as compared to 5.167% disease incidence in the control. Mulberry silkworm, being an indoor reared and completely domesticated insect is susceptible to various diseases caused by bacteria, virus, microsporidia and fungus mainly due to fluctuation of environmental conditions during different seasons. The larva after each moult has the newly formed skin which is thin, loose and delicate; and pathogen finds it easy to infect. Bed disinfectant helps to keep the silkworm bed dry during moulting. Further, once the disease occurs, management is difficult due to very short larval life and spreads within a short period of time causing heavy crop loss. There are several research reports of using bed disinfectants as a preventive measure to protect the life of mulberry silkworms. Earlier Reddy and Rao (2009) recorded the higher incidence of diseases in summer and winter seasons and was suppressed by applying disinfectant of 2% bleaching powder in 0.3% slaked lime solution and Ankush@3g/sq. feet in young age silkworms and 5g/ sq. feet in late age silkworms. Shashidhar *et al.* (2018) also reported that application of Ankush Vijetha green and slaked lime powder as per recommended schedule in combination leads to low incidence of silkworm diseases like grasserie, flacherie and muscardine during post rainy and *rabi* season which supports present findings. It was also reported that Sericillin treated larvae showed significantly less (8.4%) incidence of grasserie disease compared to control (13.10%) (Mohanan *et al.* 2009). Manimegalai and Subramaniam (1999) observed that dusting of Turmeric powder + Chalk powder and Vijetha resulted in 63.16 per cent reduction in grasserie infection during summer season. Sujatha *et al.* (2007) showed that turmeric powder at lower concentration resulted in 17.00 % reduction of diseases. In the present investigation, incidence of grasserie and muscardine were mostly observed and their incidences were lowered down by the application of all the bed disinfectants either alone or in combination compared to control might be due to lowering down the humidity. Ankush + Turmeric rhizome powder, Sericillin + Turmeric rhizome powder could not able to suppress the disease incidence as much as Ankush or Sericillin might be because of lower dose (2.5 g/sq.ft) and efficacy of Ankush or Sericillin was more than Turmeric rhizome powder. Among Ankush, Sericillin and Turmeric rhizome powder; Ankush might be more effective to reduce the humidity compared to other two bed disinfectants. Therefore, Ankush could able to lower down the disease incidence more efficiently than Sericillin, Turmeric rhizome powder and Ankush + Sericillin.The data on effect of bed disinfectants on larval duration are presented in Table 3, which revealed a larval duration ranging between 21.933 to 22.733 days in late spring season and 21.833 to 22.600 days in autumn season. All the bed disinfectants had significant effect causing lower larval duration of the tested mulberry silkworms. Significantly the lowest larval duration (21.888 days) was observed with the treatment with Ankush, as compared to the highest of 22.667 days in the control. During the experimentation, the effect of seasons on larval duration was found to be non-significant. Shorter larval duration is preferred for commercial exploitation. The larval duration generally varies with the quality of mulberry leaves and other environmental conditions (Kamili and Masoodi, 2000).

Table 3: Effect of bed disinfectants on larval duration (days) of double hybrid mulberry silkworm race in late spring and autumn season

Treatment	Season		Mean
	Late spring	Autumn	
T_1	21.933	21.833	21.888
T_2	21.967	21.900	21.933
T_3	22.433	22.367	22.400
T_4	22.233	22.167	22.200
T_5	22.267	22.200	22.233
T_6	22.333	22.233	22.283
T_7	22.733	22.600	22.667
Mean	22.271	22.186	
	S. Ed (±)	C.D (5%)	
Season	0.084	NS	
Bed disinfectant	0.156	0.322	
Season × Bed disinfectant	0.221	NS	

Data are mean of three replications
NS = Non Significant

Present findings are in conformity with Thakur (2010) who recorded shortest larval duration (21.91 days) due to application Ankush powder @50, 100, 600, 1250 and 2000 g per 100 dfls at the time of 1st, 2nd, 3rd and 4th day old 5th instar mulberry silkworm larvae, which however found *at par* with other bed disinfectants like Sanitech, Bleaching powder, Slaked lime powder, Neem powder, Serichlor-20, Turmeric powder. Manjunath *et al*. (2020) recorded extended larval duration in 5th instar mulberry silkworm over control with application of turmeric extract but shorter than Amruthaballi, Tulasi and Asparagus. Present results also revealed that Turmeric rhizome powder alone or in combination exhibited longer larval duration compared to all the treatments. However, longest larval duration was recorded in control.The data on effect of different bed disinfectants on larval weight of mulberry silkworm are presented in Table 4 and the data revealed a significant effect with respect to larval weight increase in all the instars was observed across the seasons. It was apparent from the table that all the bed disinfectants recorded significantly higher larval weight over control. A significantly higher larval weight of II, III, IV instar, full grown and matured (0.039g, 0.308g, 0.941g, 4.596g and 3.393g) was observed in treatment with Ankush @ 3 g/sq. feet, which followed by Sericilin @ 3 g/sq. feet, Ankush + Sericillin @ 3 g/sq. feet, Ankush + Turmeric rhizome powder @ 2.5 g/sq. feet, Sericillin + Turmeric rhizome powder @ 2.5 g/sq. feet, Turmeric rhizome powder @ 2.0 g/sq. feet and the lowest of 0.035g, 0.257g, 0.842g, 3.976g and 2.931g in the control. Irrespective of the treatments, late spring reared larvae showed higher larval weight (0.038g, 0.281g, 0.886g, 4.388g and 3.189g) than autumn reared larvae (0.036g, 0.272g, 0.879g, 4.227g and 3.074g) in all the instars. It was revealed from the data of each instar that the larval weight was gradually increased in each of successive instar i.e. from 2nd instar to 5th instar. Sericillin is a mixture of lime, bleaching powder and fungicide whereas Ankush is the mixture of

Table 4: Effect of bed disinfectants on instar wise larval weight (g) of double hybrid mulberry silkworm race in late spring and autumn season

Treatment	2nd Instar			3rd Instar			4th Instar			5th Instar					
										Full Grown weight			Matured weight		
	Late Spring	Autumn	Mean	Late Spring	Autumn	Mean	Late Spring	Autumn	Mean	Late Spring	Autumn	Mean	Late Spring	Autumn	Mean
T_1	0.039	0.038	0.039	0.316	0.300	0.308	0.944	0.939	0.941	4.605	4.587	4.596	3.483	3.303	3.393
T_2	0.039	0.038	0.038	0.295	0.287	0.291	0.925	0.917	0.921	4.534	4.482	4.508	3.375	3.219	3.297
T_3	0.037	0.035	0.036	0.264	0.259	0.262	0.856	0.845	0.850	4.182	4.021	4.102	3.013	2.932	2.973
T_4	0.038	0.036	0.037	0.284	0.273	0.279	0.893	0.882	0.888	4.481	4.279	4.380	3.274	3.185	3.230
T_5	0.038	0.035	0.037	0.275	0.269	0.272	0.873	0.870	0.871	4.471	4.194	4.333	3.140	3.077	3.108
T_6	0.038	0.035	0.037	0.273	0.264	0.268	0.864	0.860	0.862	4.413	4.105	4.259	3.040	2.943	2.991
T_7	0.036	0.033	0.035	0.264	0.250	0.257	0.846	0.839	0.842	4.027	3.924	3.976	3.000	2.861	2.931
Mean	0.038	0.036		0.281	0.272		0.886	0.879		4.388	4.227		3.189	3.074	
		S.Ed(±)	C.D(5%)		S.Ed(±)	C.D(5%)		S.Ed(±)	C.D(5%)		S.Ed(±)	C.D(5%)		S.Ed(±)	C.D(5%)
Season		2.4×10^{-4}	4.8×10^{-4}		0.001	0.001		0.001	0.001		0.026	0.053		0.010	0.021
Bed Disinfectant		4.4×10^{-4}	9.0×10^{-4}		0.001	0.002		0.001	0.002		0.048	0.099		0.019	0.039
Season × Bed Disinfectant		6.2×10^{-4}	1.2×10^{-4}		0.002	0.003		0.002	0.003		0.068	0.139		0.027	0.056

indigenously available eco-friendly chemicals and botanicals.That may be the reason of the better performance of these two bed disinfectants alone or in combination compared to Turmeric rhizome powder alone or in combination which might positively affect the growth and development of silkworm. An increase in larval weight on applying Ankush was also found by Thakur (2010), which might be because of the fact that effective regulation of rearing bed humidity and thereby providing optimum condition for growth of silkworm. Similar results were recorded by several workers by applying different chemical bed disinfectants (Jagannatha, 1996; Swathi *et al.*, 2014). However, results of Thakur (2010), Mohanan *et al*. (2009), which corroborate our findings. Karuppasamy *et al*. (2013) stated that mean larval weight of the final instar larvae increased as compared to the control due to Turmeric powder extracts at different concentrations (0.2%, 0.4%, 0.6%, 0.8% and 1% along with sugar solution). Sujatha *et al*. (2007) showed that the higher larval weight was obtained at lower dose of Turmeric powder as compared to higher dose.The growth and development of silk gland depends on the healthy growth of silkworm and is important to the sericulture industry because silk glands are responsible for synthesis of silk protein (Akai, 1983; Sailaja and Sivaprasad, 2010). The Silk Gland Tissue Somatic Index (SGTSI) is the ratio between silk gland weight and the body weight (Vijayakumar *et al*., 2007), which gives us an idea about the potential productivity of silkworms.During our experimentation, season and bed disinfectant were found to be having significant effect on silk gland weight and Silk Gland Tissue Somatic Index (Table 5, 6) of mulberry silkworm larvae. Application of Ankush @ 3 g/sq. feet at late spring season registered higher values compared to other treatments and season. Vallaanchira *et al*. (2013) observed that the higher weight of silk gland could be achieved when larvae were reared under the environmental condition of 25°C and 70% RH. Again, between the seasons, both the parameters exhibited better result in late spring season. Silk gland weight is positively correlated with larval weight (Singh and Kumar, 1996). Higher larval weight in all the instars in Ankush dusted larvae and maximum weight of silk gland in the same observed in the present study confirmed the statement. Application of all the bed disinfectants performed better results over control may be due to disease free environment and vigorous growth of the silkworm. Our experiments on possible effect of bed disinfectants on larval mortality (Table 7) revealed the highest mortality ranging from 3.667 to 6.667 % and 5.000 to 9.667% in late spring and autumn season, respectively.

Table 5: Effect of bed disinfectants on silk gland weight (g) of double hybrid mulberry silkworm race in late spring and autumn season

Treatment	Season		Mean
	Late spring	Autumn	
T_1	0.895	0.883	0.889
T_2	0.883	0.872	0.877
T_3	0.844	0.832	0.838
T_4	0.872	0.861	0.867
T_5	0.859	0.850	0.855
T_6	0.853	0.839	0.846
T_7	0.825	0.809	0.817
Mean	0.861	0.849	
	S. Ed (±)	C.D (5%)	
Season	0.003	0.006	
Bed disinfectant	0.005	0.011	
Season × Bed disinfectant	0.007	NS	

Data are mean of three replications
NS = Non Significant

Table 6: Effect of bed disinfectants on Silk Gland Tissue Somatic Index (SGTSI) (%) of double hybrid mulberry silkworm race in late spring and autumn season

Treatment	Season		Mean
	Late spring	Autumn	
T_1	24.782	23.579	24.181
T_2	24.373	23.261	23.817
T_3	22.390	21.109	21.755
T_4	23.642	22.467	23.055
T_5	23.461	22.346	22.904
T_6	23.402	22.137	22.769
T_7	21.273	20.178	20.726
Mean	23.333	22.154	
	S. Ed (±)	C.D (5%)	
Season	0.005	0.114	
Bed disinfectant	0.104	0.213	
Season × Bed disinfectant	0.147	NS	

Data are mean of three replications
NS = Non Significant

Table 7: Effect of bed disinfectants on larval mortality (%) of double hybrid mulberry silkworm race in late spring and autumn season

Treatment	Season		Mean	Reduction over control
	Late spring	Autumn		
T_1	3.667	5.000	4.334	46.933
T_2	4.333	6.000	5.167	36.733
T_3	6.000	8.000	7.000	14.289
T_4	4.667	6.667	5.667	30.611
T_5	4.667	7.000	5.834	28.566
T_6	5.000	7.667	6.334	22.444
T_7	6.667	9.667	8.167	
Mean	5.000	7.143		
	S.Ed (±)	C.D (5%)		
Season	1.012	2.091		
Bed disinfectant	1.900	NS		
Season ×Bed disinfectant	2.687	NS		

Data are mean of three replications
NS = Non Significant

Control. It was apparent from the table that though the effect of bed disinfectant was non significant, however,the lowest larval mortality (4.334%) was observed ni the treatment with Ankush @3g/Sq. ft. as compared to 8.167% in the conntrol. Irrespective of all the treatments, season had significant effect ($P<0.05$) on larval mortality of mulberry silkworm. Treatment with Ankush recorded maximum (46.933%) reduction of mortality over control and the lowest (14.289%) reduction of mortality was observed in treatments with turmeric rhizome powder @ 2 g/sq. feet. Late spring reared larvae recorded minimum larval mortality (5.000%) while autumn reared larvaerecorded maximum (7.143%). There was no significant effect due to interaction of season and bed disinfectant on larval mortality of mulberry silkworm. Singh (2012) reported that Vijetha dusted batches found more effective in the parameters of larval mortality than the RKO dusted batches in spring season. Dusting of Lime: Paraformaldehyde: Sodium benzonate (94: 3: 3) and Lime: Paraformaldehyde: Benzoic acid (95: 3: 2) mixture on rearing bed resulted in decreased larval mortality (16.5% and 15.4%, respectively) over control (68.30%) (Barman, 1991). Rasool *et al.* (2018) stated that the lowest mortality (55.00%) was registered by Vijetha followed by Lime + Captan + Walnut hull (59.77%), Lime + Cefixime + Turmeric (66.77%), Lime + Turmeric + Bavistin (68.95%) and Lime + Turmeric (72.42%). The disinfectant such as Turmeric + RKO (1:1 ratio), pure Turmeric and RKO produced 12, 16 and 20 per cent larval mortality respectively (Dhirwani *et al.*, 2015).

Conclusion

Sericulture industry has a significant contribution to the economy of the developing countries like India and this industry suffers a huge loss due to incidence of different infectious diseases caused by pathogen. In this case, the silkworm bed disinfectants play an important role in preventing the spread of various diseases through secondary contamination. From our present investigation, it could be concluded that all the bed disinfectants showed better results compared to untreated larvae, but the performance of Ankush was better compared to others, which might be due to its constituents as it is a mixture of plant product and non-hazardous chemicals. In future, dissemination of information on possible use of eco-friendly bed disinfectants like Ankush, Sericilin and turmeric at proper dose and method of application to the extension personnel and mulberry silkworm rearers through home visits, field days, discussions, training and demonstrations could help to cater the full benefits in silk industry.

Acknowledgement

Authors are thankful to Assam Agricultural University, Jorhat for providing necessary support to conduct the experiment.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Abbott, W. S. (1925). A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, *18*(2): 265-267.

Akai, H. (1983). The structure and ultra structure of the silk gland. *Cellular and Molecular Life Sciences*, *39*(5): 443-449.

Anonymous (2022). Retrieved from http://www.inserco.org/en/statistics on 31st May, 2022.

Anonymous (2021). State wise silk production during 2020-21, p. 88. In: *Annual Report*, Central Silk Board, Ministry of Textiles, Government of India.

Balavenkatasubbaiah, M., Chandrasekharan, K., Sharma, S.D., Nayaka A. R. N., & Bindroo, B.B. (2014). Disinfection and hygiene technology using Asthra and Ankush for the management of silkworm diseases. *International Journal of Plant, Animal and Environmental Sciences*, *4*(1): 100-106.

Barman, A. C. (1991). Effect of some formulated chemical composites for controlling bacterial and viral diseases of silkworm, *Bombyx mori* L. *Bulletin of Sericulture Research*, *2*: 62-66.

Dhirwani, H., Rathod, M. K., & Rai Manoj, M. (2015). Evaluation of different bed disinfectant against the diseases of silkworm, Bombyx mori. *International Journal of Researches in Biosciences*, *Agriculture & Technology*, *6*: 154-155.

Doreswamy, C., Govindan, R., Devaiah, M.C., & Muniswamappa M.V. (2004). Deterioration of cocoon traits of silkworm, *Bombyx mori* L. by the synergistic infection with larval flacherie pathogens. *Karnataka Journal of Agricultural Sciences*, *17*: 345-348.

Jagannatha, K. R. (1996). Evaluation of commercial germicides for their utility as disinfectants in silkworm rearing [Unpublished M.Sc. (Agri.) Thesis]. University of Agricultural Sciences, Bangalore.

Kamili, A. S., & Masoodi, M. A. (2000). *Principles of Temperate Sericulture*. Kalyani Publishers, New Delhi.

Karuppasamy, K., Palsamy, S., & Isaiarasu, L. (2013). Influence of turmeric extract on the growth and commercial parameters of *Bombyx mori* L. (Lepidoptera: Bombycidae). *African Journal of Basic and Applied Sciences*, *5*(5): 228-231.

Kumar, N. S., Singh, H., & Saha, A. K. (2015). *Textbook on Silkworm Rearing Technology*. Dominant Publishers & Distributors Pvt Ltd, New Delhi-110002, India.

Manimegalai, S., Subramanian, A., & Chandramohan, N. (2000). Efficacy of bed disinfectants and botanicals against Grasserie disease of silkworm *Bombyx mori* L. *Sericologia*, *40*(4): 585-590.

Manjunath, G. C., Doreswamy, C., & Bhaskar, R. N. (2020). Evaluation of certain medicinal plant extracts for the management of late larval flacherie disease of silkworm, *Bombyx mori* L. *Journal of Entomology and Zoology Studies*, *8*(4): 260-264.

Mohanan, N. M., Krishan, N., Mitra, P., & Saratchandra, B. (2009). Sericillin: A new silkworm bed disinfectant. *Indian Silk*, *48*(7): 16.

Rasool, S., Ganie, N. A., Wani, M. Y., Dar, K. A., Khan, I. L., & Mehraj, S. (2018). Evaluation of a suitable silkworm bed disinfectant against silkworm diseases and survivability under temperate conditions of Kashmir. *International Journal of Chemical Studies*, *6*(1): 1571-1574.

Reddy, B. K., & Rao, J. V. K. (2009). Seasonal occurrence and control of silkworm diseases, grasserie, flacherie and muscardine and insect pest uzi fly in Andhra Pradesh, India. *International Journal of Industrial Entomology*, *18*(2): 57-61.

Sailaja, B., & Sivaprasad, S. (2010). Photoperiodic modulation of circadian protein rhythm in the silk gland of *Bombyx mori* during fourth instar development. *The Bioscan*, *5*(2): 177-183.

Sahu, P. K., & Das, A. K. (2009). *Agriculture and Applied Statistics-II*. Kalyani Publishers, Ludhiana-141008, India.

Selvakumar,T.,Nataraju,B.,Balavenkatesh Subbaih, M. ,Siva prasad, V.,Baig,M.,Kumar, V.,Sharma, S.D.,Thiagrajan,V., & Datta, R.K. (2002). A reort on prevalance on silkworm diseases and estimated crop loss, In: Proceedings of National conference on stategies for sericulture research and development (Dandwa S.P. and Gupta V.P. Ed., CSRTI Mysore ,India pp:354-357.

Shashidhar, K. R., Thulasiram, K., & Haveri N. (2018). Effectiveness of bed disinfectants on silkworm diseases and cocoon yield under tropical conditions of Kolar district, Karnataka. *Journal of Pharmacognosy and Phytochemistry*, *7*(5): 2720-2724.

Singh, A. (2012). Effect of two different bed disinfectants on cocoon productivity in spring rearing of silkworm, *Bombyx mori*. *Green Farming*, *3*(1): 123-124.

Singh, G. P., & Kumar, V. (1996). Correlation study on the larval silk gland and shell weight in the silkworm *Bombyx mori L. Entomon*, *21*(3&4): 277-279.

Singhvi, N. R., Kushwaha, R.V., Mathur, S. K., Lochan, R., Rekha, M., & Sinha, B. R. (2004). Comparative efficacy of bed disinfectant TKO, Resham Jyothi and Vijetha and protecting tasar silkworm from invasion of pathogens. *Journal of Experimental Zoology*, *7*(1): 165-168.

Swathi, H. C., Vijayendra, M., & Nagaraj, S. B. (2014). Revalidation of bed disinfectant practices followed by farmers in the rearing of silkworm, *Bombyx mori* L. *Journal of Agriculture and Veterinary Science, 7*(1): 1-7.

Thakur, D. R. (2010). Efficacy of different disinfectants on rearing of mulberry silkworm. [Unpublished M.Sc. (Agri) Thesis]. Marathwada Agricultural University, Prabhani, Maharasthra.

Vallaanchira; Rahmathulla, V. K., & Suresh, H. M. (2013). Influence of temperature and humidity on growth and development of silk gland of a bivoltine silkworm hybrid. *Iranian Journal of Entomology*, *3*: 24-29

Venkata Rai Reddy, K., & Benchamin, K. V. (1989). Studies on Tissue Somatic Index (TSI) of silk gland and gonads of silkworm *B. mori* L. during Vth instar development. *Sericologia*, *28*(4): 463-476.

Vijayakumar, P. B., Katti, S. R., Venkatesh, H., & Sekharappa B. M. (2007). Silk gland somatic index in some pure races of *Bombyx mori* L. *The Bioscan*, *2*(4): 297-299.

Zagar, M. A. (2010). Studies on pathogenicity of *Nosema bombycis* Nageli to silkworm, *Bombyx mori*, L. and its management [Unpublished Ph.D. Thesis]. Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar.

Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 63-66, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Preparation and evaluation of fresh pineapple, passion fruit and ginger blended ready-to-serve drink

Thejangulie Angami ✉
ICAR (RC) for NEH Region, AP Centre, Basar, Arunachal Pradesh, India
S.R. Assumi
ICAR (RC) for NEH Region, Umiam, Meghalaya, India
H. Kalita
ICAR (RC) for NEH Region, AP Centre, Basar, Arunachal Pradesh, India
Bharati Saloi
ICAR-KVK West Siang, Arunachal Pradesh, India
K. Suraj Singh
ICAR-KVK West Siang, Arunachal Pradesh, India
LetngamTouthang
ICAR (RC) for NEH Region, AP Centre, Basar, Arunachal Pradesh, India
BadapmainMakdoh
ICAR (RC) for NEH Region, AP Centre, Basar, Arunachal Pradesh, India
AmpeeTasung
ICAR (RC) for NEH Region, AP Centre, Basar, Arunachal Pradesh, India

ARTICLE INFO

Received : 21 November 2022
Revised : 29 January 2023
Accepted : 05 February 2023

Available online: 13 April 2023

Key Words:
Pineapple
Passion fruit
Ginger
Juice
Ready-to Serve
Beverage

ABSTRACT

Preliminary work was executed at the processing laboratory of ICAR (Research complex) for NEH Region, Arunachal Pradesh Centre, Basar, to prepare and assess the physico-chemical properties of fresh juice blends. The experiment comprised of nine treatments consisting of fresh pineapple, passion fruit and ginger juice blends in different ratios following CRD with three replications. It was found that the treatment (T_5) passion fruit-ginger juice at the ratio of 90:10 blended RTS beverage exhibited the highest pH (4.33), ascorbic acid (18.73 mg per 100 ml) and beta carotene (245.33 µg per 100 ml). The TSS and acidity percent were non-significant as all the sample treatments were maintained almost uniform at 15 °Brix and 0.30 percent. Further, it also revealed that both the sugar i.e. reducing and total sugar of the fresh mixed RTS drink was recorded maximum in (T_2) pineapple-passion fruit juice ratio of 70:30. Organoleptic traits of freshly mixed ready to serve drinks after evaluated by a member of juries based on 9 Points Hedonic Scale vividly indicated that treatment (T_1) pineapple-passion fruit RTS at 50:50 ratio recorded the most favoured taste, colour, flavour ultimately attributing to the highest overall acceptability.

Introduction

Fruits are important constituents for a healthy diet and well being for human health beyond doubt for all age groups as it provides notable amount of nutrition particularly minerals, vitamins and other important phytochemicals including primary and secondary metabolites. It is noteworthy to state that regular fruit consumption lower the risk of numerous ailments like certain cancer, premature ageing, heart diseases etc. chiefly due to the overall combine action of oxygen radical scavengers like vitamin C (ascorbic acid), carotenoids (β-carotene), anthocyanin etc.(Perera *et al.*, 2022; Sindumathi *et al.*, 2013). However, because of the perishable nature of the fruits they call for instant processing to get rid of post harvest losses such as fruit beverages which are an important value added products known for its thirst quenching, pleasant, refreshing, appetizing, and nutritionally quality drink and also owing to the presence of acidity, astringency, unfavourable mouth feel and few other such unpleasant factors in fruits, the utility of such fruits for the preparation and conversion of various

Corresponding author E-mail: *thejaangami@yahoo.com*
Doi:https://doi.org/10.36953/ECJ.16252518

processed and value added products becomes restricted, inspite of possessing superior nutritional values. Thus, development of new process product by blending of fresh fruit juices along with suitable spice extracts at right proportion in order to achieve acceptable health drinks are thought to be a suitable and convenient choice for its utility to attain certain value added beverages (Amaravathi *et al.*, 2014).The use of soft drinks due to their thirst quenching potential and taste is well-known and its demand has an increasing trend propelling potential for preparation of naturally nutritionally rich drinks. Animesh and Jimi (2017) reported on blending of two or more fruit juices in certain quantities and proportions for the development of tasty and nutritionally quality drinks enhancing an apparition and flavour of the result product leading to development of new original product. Studies also divulged that the inclusion of spice extracts like mint, ginger, turmeric, cumin, black pepper, cardamom etc. enhanced the organoleptic quality of RTS fruit beverages (Sindumathi *et al.*, 2013) with high nutritional and health promoting components which could serve as functional juice ingredients (Russo *et al.*, 2020).

Availability of different fruits according to season also influences the economics of fruit production. So, fruits can be processed into different products not only to make available to the consumers throughout the year but also to fetch continuous income. Pineapple, passion fruit and ginger are commonly grown in the mid hills of Arunachal Pradesh which are readily available at the same time but the fruits being acid flavour, there is a need for processing for development of new flavours further avoiding the losses after harvest of crops. Therefore, considering the points in mind, preliminary study was performed to prepare and assess physico-chemical properties of fresh juice blends.

Material and Methods

The experiment was conducted in the Processing laboratory at ICAR (Research complex) for NEH Region, Arunachal Pradesh Centre, Basar during 2017-18. Kew pineapple, yellow passion fruit and ginger of optimum maturity were harvested and collected. Fruits and rhizomes were washed and peeled using stainless steel knives. Pineapple pulp and ginger rhizomes were sliced into smaller pieces and pulp of passion fruit were scooped out with spoon and juices were extracted with an assistance of mixer further, juice were filtered with the help of muslin cloth.The RTS beverages were prepared with 15 percent juice content, acidity of 0.3 percent and TSS of 15°Brix. The RTS drink was made in different ratios with a total of nine treatments replicated thrice as shown in Table 1 following Completely Randomized Design. The prepared beverage was filled into 200 ml sterilized glass bottles of capacity leaving 1" head space on the top further sealing the cap with the help of crown corking machine. Sterilization of bottles was done at boiling water for 20 minutes. The bottles were immediately cooled to room temperature and taken for analysis.

Table 1: Treatment details

Treatment Notations	Blending ratios
T_1	50:50 (Pineapple : Passion fruit)
T_2	70:30 (Pineapple : Passion fruit)
T_3	30:70 (Pineapple : Passion fruit)
T_4	90:10 (Pineapple : Ginger)
T_5	90:10 (Passion fruit : Ginger)
T_6	80:20 (Pineapple : Ginger)
T_7	80:20 (Passion fruit : Ginger)
T_8	70:30 (Pineapple : Ginger)
T_9	70:30 (Passion fruit : Ginger)

The different ratios of blended juices were examined for pH, titratable acidity, TSS, vitamin C, sugars and β-carotene. The pH values were estimated with the assistance of digital pH meter, hand held refractometer (0–32 °Brix) was used to measure the TSS (total soluble solids) in which the values were expressed as °Brix.Titratable acidity of the product was estimated by titrating the blended fruit juice against 0.1N sodium hydroxide using phenolphthalein as indicator (AOAC, 2000). Sugars *viz.* reducing and total sugar were analyzed by methodology proposed by Ranganna (2001). Vitamin C content (ascorbic acid) was estimated by titration process by using 2,6-dichlorophenol indophenol dye as directed by Ranganna (2001). β-carotene was ascertained through colorimetric methodology proposed by Srivastava and Kumar (2002). The sensory score of the blended drinks were evaluated by the 10 semi-trained members of the institute and it was based on 9 point hedonic scale i.e. dislike extremely to like extremely with score value as 1-9 (Amerine *et al.,* 1965). The acceptability of the beverage was evaluated with respect to colour, taste, flavour and all round acceptability. The data recorded were tabulated and subjected to statistical analysis using Statistical Analysis System 9.3 computer software (SAS Institute Inc., 13). DMRT procedure was used at P = 0.05 level to determine if there were significant differences among the means.

Results and Discussion

The nutritional parameters of fresh blended RTS were analyzed and presented in Table 2. From the preliminary experiment, it was found that passion fruit-ginger at the ratio of 90:10 blended RTS beverage exhibited the highest pH (4.33), ascorbic acid (18.73 mg per 100 ml) and beta carotene (245.33 µg per 100 ml). The higher ascorbic acid and beta carotene content recorded in the treatment may be due to more concentrations of ascorbic acid and beta carotene present in passion fruit which must have boosted the nutritional quality with respect to β-carotene and ascorbic acid content simultaneously blending of ginger juice also might have aid in reducing the oxidation process resulting in higher ascorbic acid content (Bhardwaj and Mukherjee, 2011). The TSS (total soluble solids) in ready to serve formulations is designated as ºBrix.

Table 2: Physico-chemical characteristics of freshly prepared Pineapple, Passion fruit and Ginger Blended Ready-to-Serve Drink

Treatments	pH	TSS (°B)	Acidity (%)	Ascorbic acid (mg/100 ml)	Total sugar (%)	Reducing sugar (%)	Beta carotene µg/100 ml
T_1	3.80^{c}	15.03	0.31	14.94^{c}	12.63	7.35^{a}	220.00^{c}
T_2	3.71^{c}	15.07	0.31	14.20^{cd}	13.00	7.93^{a}	161.67^{d}
T_3	4.02^{b}	15.00	0.33	16.94^{b}	11.44	5.32^{c}	223.00^{bc}
T_4	3.66^{c}	14.97	0.31	14.25^{cd}	12.91	7.65^{a}	219.67^{c}
T_5	4.33^{a}	15.00	0.30	18.73^{a}	12.15	5.46^{bc}	245.33^{a}
T_6	3.68^{c}	15.00	0.29	13.41^{d}	12.84	7.76^{a}	216.00^{c}
T_7	4.12^{b}	15.07	0.31	17.03^{b}	11.67	5.53^{bc}	237.33^{ab}
T_8	3.72^{c}	15.10	0.29	12.26^{e}	12.16	6.14^{b}	174.33^{d}
T_9	4.04^{b}	15.07	0.31	15.13^{c}	11.52	5.40^{c}	226.67^{bc}
SEm(±)	0.05	0.15	0.02	0.33	0.46	0.23	5.72
CD (0.05)	0.15	NS	NS	0.99	NS	0.70	17.11

TSS ascertains the presence of sugars in the RTS blends which chiefly results caused by constituents of fructose, sucrose and glucose (Sangma *et al*., 2016). The TSS and acidity percent were found non-significant as all the sample treatment were maintained almost uniform at 15 ºBrix and 0.30 percent.Similarly, it was noted that total sugar (13.00 %) and reducing sugar content (7.93 %) of the fresh blended RTS beverage was recorded maximum in pineapple-passion fruit ratio of 70:30. The sugar content was observed to elevate when the volume of pineapple juice was added to the passion fruit juice. Rise in sugar level indicates that when pineapple juice was added, it has led to rise in sugar:acid ratio in the RTS blends which ascertains a positive parallel relation between TSS (total soluble solids) and sugar constituents (Ravi *et al*., 2010).Addition of pineapple juice to passion fruit juice could also be attributed to the conversion of polysaccharides, organic acids and other juice components to sugar constituents (Borghani *et al*., 2012). The colour, flavour and taste are a crucial ground for all round acceptability of processed fruit products (Devra *et al*., 2017).Organoleptic traits of freshly mixed ready to serve drinks were assessed by jury of members based on 9 Points Hedonic Scale and depicted in Table 3 and Fig. 1.

Table 3: Organoleptic characteristics of Fresh pineapple, passion fruit and ginger blended Ready-to-Serve Drink (on 9 point hedonic scale)

Treatments	Taste	Colour	Flavour	Overall acceptability
T_1	8.2	8.3	8.2	8.2
T_2	7.8	8.0	8.1	8.0
T_3	7.9	8.2	8.2	8.0
T_4	7.8	7.6	7.8	7.5
T_5	8.0	7.6	8.0	7.6
T_6	7.5	7.2	7.2	7.4
T_7	7.6	7.3	7.9	7.5
T_8	7.2	7.0	7.4	7.1
T_9	7.3	7.3	7.8	7.5

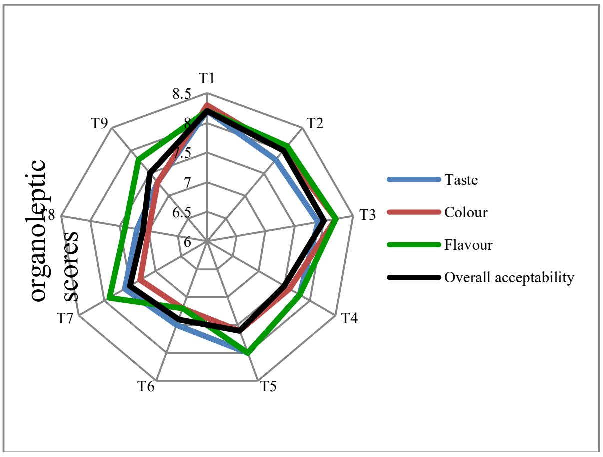


Figure 1: Organoleptic score

Conclusion

With regard to the final results examined, the study revealed the possibility of preparing blended pineapple-passion fruit RTS (ready to serve) beverages with inclusion of ginger extracts. Further at the same time, the flavored pineapple-passion fruit blended RTS drinks ascertains important nutrients like β-carotene and vitamin C (ascorbic acid), an important antioxidant necessary for well being of human. However, further studies on the period of storage as a future line of work is crucial to understand the nutritional status and overall acceptability of the product.

Acknowledgement

The authors acknowledge the Director, ICAR (Research Complex) for NEH Region, Umiam, Meghalaya, India, PIMS code: IXX 08906

Conflict of interest

The authors declare that they have no conflict of interest.

References

Amaravathi, T., Vennila, P., Hemalatha, G., &Parimalan, P.(2014). Spiced Pineapple Ready-To-Serve Beverages. *Indian Journal of Science andTechnology,7*(11), 1827-1831.

Amerine, M.A., Pangbron, R.M., &Roessler, E. A.(1965). *Principles of sensory evaluation of food*. Academic Press, New York.

Animesh, S., & Jimi, B.(2017). Standardization of Blending of Guava Pulp with Pineapple Juice for Preparation of Ready-To-Serve (RTS). *International Journal Current Microbiology and Applied Science, 6*(11), 395-401.

AOAC. (2000). *Official Methods of Analysis*. 17th Ed. Association of Official Analytical Chemists, Washington DC, USA.

Bhardwaj, R.L., &Mukherjee, S.(2011). Effects of fruit juice blending ratios on kinnow juice preservation at ambient storage condition. *African Journalof Food Science,5*(5), 281-286.

Borghani, A.R., Abdul, R., &Syed, I. H.(2012). Development and storage of blended papaya-*Aloe vera* ready to serve (RTS) beverages. *Journal of Food Processing and Technology,3*(10), 1-4.

Devra, N.S., Kaushik, R.A., & Meena, H. R.(2017). Standardization and Storage Study of Aonla (*Emblica officinalis* Gaertn.) based Blended Ready-To-Serve Beverages. *International Journal of Current Microbiology and Applied Science, 6*(5), 1275-1284.

Perera, S., Silva, A.B.G., Amarathunga, Y., De Silva, S., Jayatissa, R., Gamage, A., Merah, O., & Madhujith, T. (2022). *Agronomy*, *12*, 1073.

Ranganna, S.(2001). *Handbook of analysis and quality control of fruit and vegetable products*, Tata McGraw Hill Pub. Co. Ltd., New Delhi.

Ravi, U., Menon, L., Aruna, M., & Jananni,B. K.(2010). Development of orange-white pumpkin crush and analysis of its physicochemical, nutritional and sensory properties. *American-Eurasian Journal ofAgricultural andEnvironmentalScience, 8*(1), 44-49.

Russo, M., Bonaccorsi, I., Torre, G., Saro, M., Dugoab, P., & Mondelloa, L. (2020). Underestimated sources of flavonoids, limonoids and dietary fibre: availability in lemon's byproducts. *Journal of Functional Foods*, *9*, 18-26.

Sangma, D.C.M., Sarkar, S.,&Mishra, L. K.(2016). Preparation and evaluation of ready to serve drink made from blend of *Aloe vera*, Sweet lime, Amla and Ginger. *International Journalof Food Fermentation and Technology, 6*(2), 457-465.

Sindumathi, G.,&Premalatha, M. R.(2013). Development and Storage Studies of Naturally Flavored Papaya-Pineapple Blended Ready-to-Serve (RTS) Beverages. *International Journal of Science and Research,4*(2), 856-860.

Srivastava, R. P., &Kumar, S.(2002). *Fruit and vegetable preservation - principles and practices*. International Book Distributing Company, Lucknow.

Environment Conservation Journal 24 (3): 67-78, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Energy budgeting and life cycle assessment of cashew cultivation under different planting densities

Krishnappa Manjunatha ✉
ICAR- Directorate of Cashew Research, Puttur 574202, Dakshina Kannada, Karnataka, India
Mundakochi Gangadhara Nayak
ICAR- Directorate of Cashew Research, Puttur 574202, Dakshina Kannada, Karnataka, India
Shamsudheen Mangalassery
ICAR- Directorate of Cashew Research, Puttur 574202, Dakshina Kannada, Karnataka, India
Palpandian Preethi
ICAR- Indian Institute of Horticultural Research, Bengaluru, Karnataka, India
Bommanahalli Munivenkata Muralidhara
ICAR- Indian Institute of Horticultural Research, Bengaluru, Karnataka, India
Siddanna Savadi
ICAR- Directorate of Cashew Research, Puttur 574202, Dakshina Kannada, Karnataka, India

ARTICLE INFO

Received : 24 August 2022
Revised : 10 December 2022
Accepted : 03 January 2023

Available online: 11 April 2023

Key Words:
Cashew
Energy input
Energy analysis
Energy equivalents
Specific energy

ABSTRACT

Energy budgeting is important for determining the sustainability and vulnerability of a crop production system. In the present study, an assessment of the energy requirements for cashew cultivation under three different planting densities was carried out during 2015-20. The study revealed that the total input energy consumption for cashew cultivation ranged from 75292.68 to 120903.58 MJ/ha. The energy productivity from 0.04 to 0.13 kg/MJ and energy use efficiency varied from 8.46 to 24.61% under three planting densities. The highest energy was consumed in terms of chemical fertilizers for all the planting densities followed by fuel (diesel), machinery, farmyard manure (FYM), pesticides, petrol and human energy. The analysis revealed the need to implement improved management practices to enhance the energy efficiency by reducing the energy consumption in inputs, by optimizing energy consumption and/or improving the crop yield by optimizing the cultivation methods and switching from non-renewable sources to renewable sources of energy. Among the three different planting densities, 2.5x2.5 m spacing consumed the highest energy followed by 5x5 m and 7.5x7.5m spacing. However, the planting density of 2.5x2.5 m spacing was more energy efficient over the years due to more yields per unit area.

Introduction

Cashew (*Anacardium occidentale* L.) is a nut crop native to Brazil. Currently, cashew is cultivated in over 30 countries and has emerged as a potential foreign-exchange earning crop in the developing countries. Cashew is good source of carbohydrates (22%), proteins (21%), fat (47%) and minerals (calcium, iron and phosphorous) (Sharma, 2004) and offers 575 kcal of energy per 100 g (Sathe, 1994). Historically India dominated the global cashew market (Nayak and Savadi, 2019) (Anonymous, 2014). Currently, Vietnam, India and Ivory Coast are the major cashew producers in the world (FAOSTAT, 2018). Cultivation of cashew in India is mainly confined to the coastal areas and in recent times it has been spread to plains of Chhattisgarh, Jharkhand and hills of the North Eastern States. Energy is the basic driver of agricultural crop production and practices (Ozkan *et al.*, 2004). Limited agricultural land availability due to urbanization has necessitated the need for intensive agriculture. The success of sustainable agriculture depends on the utilization of energy

Corresponding author E-mail: *manjunathtech07@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14622444

sources in an efficient manner (Fadavi *et al*., 2011). For agriculture, the energy needs are split into two categories, viz. direct and indirect. The crop production activities such as land preparation, irrigation, weeding, harvesting, and threshing and transportation of various inputs for agricultural production come under the direct energy category (Singh, 2000). The energy for activities such as packaging of agricultural produce and transportation of the seeds, fertilizers, farm machines, insecticides and pesticides are regarded as indirect energy. Yet another classification of the energy is as non-renewable or renewable energy sources based on the capability of being renewed (Rajesh *et al*., 2018).

An energy assessment of the crop production system and practices is required to determine the optimal energy input for achieving different productivity levels. Minimizing or combining machinery operations may minimize the energy input, time and labour (Esengun *et al*., 2007; Karale *et al*., 2008). Analysis of energy involved in agricultural production is often used as the basic components for life cycle assessments. (Piringer & Steinberg, 2006). Several investigations have been done on energy usage in different agricultural systems including fruit and nut crops (Strapatsa *et al*., 2006; Demircan *et al*., 2006; Fadavi *et al*., 2011; Paramesh *et al*., 2018; Bartzas and Komnitsas, 2018). The energy indicators and the energy expenditure per unit of apple production was estimated in West Azarbaijan, Iran by Fadavi *et al*. (2011). The values of energy productivity, net energy and output-input energy were estimated to be 101.50 MJ/ha, 0.23 kg/MJ, –56.32 MJ/ha and 0.44, respectively. The study findings indicated that 96.7% of total energy input was in the form of non-renewable sources. Hatirli *et al*. (2006) analysed the correlation between energy inputs and crop yields for greenhouse tomato cultivation in Turkey and developed an economic model. Likewise, in sweet cherry production, Demircan *et al*. (2006) showed that the fertilizers (45.35%) were the foremost energy-consuming input source followed by diesel oil (21.53%). In pistachio production, the total energy intake under irrigated conditions in Greece was found to be 41.9 GJ/ha, while the ratio of energy productivity and energy efficiency rate was 0.06 kg/MJ and 70%, respectively (Bartzas and Komnitsas, 2018). Paramesh *et al*. (2019) reported an improved energy efficiency of 1.72 and net energy of 19625 MJ/ha under the organic nutrient management due to lower energy intake (30722MJ/ha) and higher energy output (50347MJ/ha), compared to the no-manuring and integrated nutrient management practices.

In India, cashew is generally grown as rainfed crop under wider spacing of 7.5 x 7.5 m with 178 trees per hectare. However, under wider spacing system, the plants take 7-8 years to cover the allotted space as a result the resources such as land, sunlight, chemical inputs *etc* go wasted (Nayak *et al*., 2019). The adoption of high density and ultra-density planting systems in cashew helps to utilise the land and input resources more effectively in the initial years of plantation establishment and as consequence, increased productivity per unit area. The energy budgeting in cashew production systems has received little attention and there are no reports energy budgeting in cashew. The present study was undertaken to find out the energy requirement and life cycle assessment of cashew cultivation under different planting densities in coastal India. This is first report of energy budgeting in cashew crop production, which can facilitate effective utilization inputs and energy resource to attain better productivity with little energy wastage and environmental damage.

Material and Methods

Experimental site

The investigation was carried out at the ICAR-Directorate of Cashew Research Puttur, Karnataka, India. The study area has hot and humid climate with annual average precipitation of 3500 mm and the soil is sandy clay loam with a pH of 5.25. The present study was conducted from 2015 to 2020 to assess the life cycle and energy budgeting of cashew cultivation under three planting densities [2.5 x 2.5 m, 5 x 5 m and 7.5 x 7.5 m] under rainfed condition. The experiment was designed in a randomized block design (RBD) with three replications. The jumbo nut cashew hybrid, H-130, a pruning responsive cultivar planted during 2013 at the three different spacings was chosen for the study.

Computation of parameters

The energy assessment was carried out on the basis of various farm operations (planting, weeding, harvesting) as well as on the direct (human labour and fuel) and indirect (farm machines, chemical fertilizers and pesticides) energy resources used in the crop production process. Information on the duration, quantity and frequency of the unit operations and energy inputs was collected and quantified using the energy coefficient in order to estimate energy usage in a particular unit operation (Table 1).

Table 1: Resource input, outputs, and their energy equivalents

Input	Energy Equivalent	Unit	Reference
Human labour	1.96	MJ/man h	Paramesh *et al.* (2019); Erdal *et al.* (2007); Nassiri & Singh (2009); Mohammadi *et al.* (2008)
Machinery	62.7	MJ/kg	Paramesh *et al.* (2019); Mohammadi *et al.* (2008); Singh & Mittal (1992); Gündoğmuş (2006)
FYM	0.3	MJ/kg	Paramesh *et al.* (2019); Taki *et al.* (2012); Hatirli *et al.* (2006); Demircan *et al.* (2006)
Fertilizers			
N	60.6	MJ/kg	Singh & Mittal (1992); Gündoğmuş (2006)
P	11.1	MJ/kg	Singh & Mittal (1992); Gündoğmuş (2006)
K	6.7	MJ/kg	Singh & Mittal (1992); Gündoğmuş (2006)
Chemicals			
Insecticide	184.63	MJ/kg	Pimentel (1980)
Petrol	48.23	MJ/l	Singh & Mittal (1992)
Diesel	56.31	MJ/l	Paramesh *et al.* (2019); Gündoğmuş (2006); Mohammadi *et al.* (2008)
Self-Propelled Machines	68.4	MJ/kg	Singh & Mittal (1992)
Cashew fruit	1.9	MJ/kg	Singh & Mittal (1992)

The methodology adopted for the analysis for assessing the energy inputs used in cashewnut production is as follows.

1. The use of human energy was calculated by taking into account the time of labour-intensive activity and the total number of people involved in that particular farm operation. The gross human energy expenditure was estimated by multiplying the energy coefficient of the human power for unit man-hour by the total number of hours of human activity in the particular unit operation (Sharma *et al*., 2020).
2. In the case of the tractor, diesel engine or other machinery, the volume of fuel used for a specific field operation was determined using the top-fill method. The energy consumption to manufacture machineries such as tractors, weeders and other farm equipment was determined based on their weight, useful life and average annual working hours.
3. The quantity of input materials like farmyard manure (FYM), chemical fertilizers and insecticides/pesticides utilized in cashew production has been converted to energy equivalent by multiplying the amount of the input material used in the plots with the energy content of each input sources(Azam & Singh, 1996; Khan & Singh, 1997).

In the present study, useful life and average annual working hours were used as perIS:9164 (1979). The following equation was used to calculate the energy expenditure from farm machines (Rajesh *et al*., 2018).

$$\mathbf{E_M = (E_{qm} \times W_m \times W_{hm}) / (L_m \times W_{hym})} \quad (1)$$

Where,
E_M = Energy from farm machines
E_{qm}= Energy equivalent for machinery
W_m= Weight of machine
W_{hm}= Machine working hours
L_m= Life of machine
W_{hym}= Machine working hours/year

Energy indicators

The identified set of indicators was calculated based on the energy equivalents of inputs and outputs to determine the energy efficiency as follows (Balogh & Hall, 2016; Hall, 2011; Martin *et al*., 2014; Mohammadi & Omid, 2010; Singh *et al*., 1997).

Energy use efficiency

The energy use efficiency shows the effectiveness of a crop production system. It is important to remember that the energy consumed in input can be minimized by optimizing energy consumption or to increase the crop yield by optimizing farming practices in order to enhance energy use efficiency during the cultivation cycle.

$$\text{Energy use efficiency} = \frac{\text{Total energy output (MJ/ha)}}{\text{Total energy input (MJ/ha)}} \quad (2)$$

Net energy

Net energy is one of the key performance indices that show the relationship between the gross energy produced from the main and by-product and the total input energy required for crop production.

$$\text{Net Energy} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)} \quad (3)$$

Energy productivity

It defines the amount of product obtained per unit of input energy used. The input energy sources like human labour and FYM comes under renewable energy sources; while non-renewable energy consists of energy inputs from machines, fuel, chemical fertilizers and chemicals.

$$\text{Energy productivity} = \frac{\text{Crop yield (kg/ha)}}{\text{Total energy input (MJ/ha)}} \quad (4)$$

Specific energy

This index represents how much of energy is used by a product to produce 1 kg and is typically used to compare various product categories. The entire crop production process is more effective when the specific energy is less.

$$\text{Specific energy} = \frac{\text{Total energy input (MJ/ha)}}{\text{Crop yield (kg/ha)}} \quad (5)$$

Results and discussion

Analysis of input-output energy use for cashew production and energy indicators

The total energy expenditure and different energy indices for the production of cashew at 2.5 x 2.5 m spacing showed that the overall energy used in various unit operations in cashew production was 120903 MJ/ha (Table 2). The maximum energy intake was utilized by chemical fertilizers (55788 MJ/ha) followed by the fuel (diesel) (27479 MJ/ha) (Table 2). The fuel energy (diesel oil) was used mainly to run earth moving machines for the initial land development activities. Therefore, exact chemical fertilizer management, taking the amount and frequency of fertilization into account, as well as proper selection and management of machinery to reduce direct use of diesel fuel are required to save non-renewable energy sources without compromising the yield or profitability and to increase the energy use efficiency of cashew production. Proebsting (1980) estimated that the energy expenditure for fuel (diesel oil) was 14.87% and 14.75% of the overall energy intake for the red tart and sweet cherry respectively. The energy consumption for machinery, farmyard manure (FYM) chemicals, petrol and human energy were found to be 22405, 6000, 5760, 1746 and 1724 MJ/ha, respectively.

A cashew tree starts bearing two years after planting in closer spacing but widely spaced planting takes six to seven years for commercial production. The energy efficiency, specific energy, energy productivity and net energy of cashew production were also estimated for 2.5x2.5 m spacing (Table 2). The mean yield of cashew crop was determined to be 1248 kg/ha in the second year and it was significantly increased to 2432 kg/ha during the fourth year. The energy ratio (also known as energy use efficiency) varied from 12.2 to 24.6% in the cashew orchards, showing the ineffective utilization of energy in the cashew production. It is important to note that the proportion can be maximized by enhancing the crop yield (the cashew apple energy coefficient is relatively less) and/or by reducing input energy expenditure (input management). The specific energy for cashew production varied from 8.22 to 4.06 MJ/kg. The study findings showed that energy productivity and net energy varied from 0.06 to 0.13 kg/MJ and -17,126.66 to -14,158.49 MJ/ha respectively. This means an average output of 0.10 units per unit of energy was achieved. The net energy calculated was negative inferring that in cashew production, the energy was wasted. Fadavi *et al.* (2011) observed that net energy and energy productivity for apples were –64,556 MJ/ha and 0.19 kg/MJ, respectively. The net energy of tangerine (-8201 MJ/ha) and plum (-116,219 and -125,788 MJ/ha) was reported by

Table 2: Energy consumption and different energy indices for cashew production (2.5 x 2.5 m spacing)

Inputs	Total Energy Equivalent (MJ/ha)					Total Energy MJ/ha	Percentage of total energy input (%)
	Initial establishment	I Year	II Year	III Year	IV Year		
Human labour	295.96	226.07	339.72	451.02	411.45	1724.22	1.43
Machinery	22366.80	16.11	13.45	4.48	4.48	22405.33	18.53
FYM	1200	1200	1200	1200	1200	6000.00	4.96
Chemical fertilizer	914.64	9977.62	14965.37	14965.37	14965.37	55788.38	46.14
Insecticides	354.49	1683.83	1240.71	1240.71	1240.71	5760.46	4.76
Petrol		964.6	781.326			1745.93	1.44
Diesel	23650.2	957.27	957.27	957.27	957.27	27479.28	22.73
Total Energy Consumption	48782.09	15025.49	19497.86	18818.86	18779.29	120903.58	100.00
Yield (kg/ha)			1248	2240	2432	5920	
Total Energy output (MJ/ha)			2371.2	4256	4620.8	11248.00	
Energy use efficiency (%)			12.16	22.62	24.61	9.30	
Specific energy (MJ/kg)			8.22	4.42	4.06	10.75	
Energy productivity (kg/MJ)			0.06	0.12	0.13		
Net energy yield (MJ/ha)			-17126.66	-14562.86	-14158.49	-109655.58	

FYM: Farm yard manure

Mohammadshirazi *et al.* (2012), and Tabatabaie *et al.* (2012). The low energy output may be due to the low yields during the second year and higher energy consumption during the initial establishment of cashew orchard (less output, with increased input). The different inputs utilized in cashew production and their energy coefficients; output energy equivalents and energy indicators are represented in Table 3. The overall energy equivalent of inputs was determined to be 98532 MJ/ha. Out of total energy input, energy from human labour accounts for 1021.32 MJ/ha whereas machinery, FYM, chemical fertilizers, chemicals petrol and diesel energy were found to be 14738.71, 4200.00, 55788.86, 2570.05, 2749.11 and 17463.98 MJ/ha, respectively. It was observed that in cashew production much energy was consumed from fertilizers followed by the fuel energy (diesel oil) and farm machines. The energy inputs utilized in production such as FYM, fuel, chemicals (insecticide/pesticide) and human labour were considered to be comparatively less than the other inputs. The average yield of cashew under 5 x 5m spacing varied from 880 to 1212 kg/ha and its energy value was found to be 1672 to 2302MJ/ha. The calculated mean values of energy productivity and energy use efficiency varied from 0.05 to 0.07 kg/MJ and 9.32 to 12.95 %, respectively. These findings suggest that there is considerable potential in the study region for improving the energy efficiency of cashew production. Energy efficiency was different from other orchard plants like cherry (0.96) (Kizilaslan, 2009) and apple (0.97) (Hasanzadeh & Rahbar, 2005) due to the different growth rates and phenology of the crops and operations involved in the crop production. The calculation of energy productivity for various crops such as potato (0.35) (Mohammadi *et al*., 2008) and cherry (0.51) (Kizilaslan, 2009) is well documented. The average specific energy of cashew production at 5 x 5 m spacing varied 10.73 to 7.72 MJ/kg, indicating that per unit of cashew production, an average of 9.07 MJ of energy was ingested. The findings revealed that net energy varied from -16275.00 to -15482.18 MJ/ha. The net energy calculated is negative inferring that more energy is consumed during the cashew production. Similarly, Fadavi *et al*. (2011) found that net energy for apple production was about –64,556 MJ/ha while the energy productivity was 0.19 kg/MJ.The unit operation wise energy requirements in cashew production under wider spacing of 7.5 x 7.5 m were monitored and evaluated for studying different patterns of energy usage and results are reported in Table 4. Out of all the energy inputs, chemical fertilizer application recorded the largest energy usage among the input variables used in cashew production, reaching 42215 MJ/ha (56.07%) in overall energy expenditure. The

Table 3: Energy consumption and different energy indices for cashew production (5 x 5 m spacing)

Inputs	Total Energy Equivalent (MJ/ha)					Total Energy MJ/ha	Percentage of total energy input (%)
	0 Year	I Year	II Year	III Year	IV Year		
Human labour	137.20	145.04	237.14	261.41	240.54	1021.32	1.04
Machinery	14698.18	18.29	16.63	2.80	2.80	14738.71	14.96
FYM	600	600	600	1200	1200	4200.00	4.26
Chemical fertilizer	914.64	9978.11	14965.37	14965.37	14965.37	55788.86	56.62
Chemicals	88.62	465.27	465.27	775.45	775.45	2570.05	2.61
Petrol		1446.9	1302.21			2749.11	2.79
Diesel	15541.56	360.384	360.384	600.83	600.83	17463.98	17.72
Total Energy Consumption	31980.21	13013.99	17947.00	17805.86	17784.98	98532.04	100.00
Yield (kg/ha)			880	1068	1212	3160	
Total Energy output (MJ/ha)			1672	2029.2	2302.8	6004.00	
Energy use efficiency (%)			9.32	11.40	12.95	6.09	
Specific energy (MJ/kg)			10.73	8.77	7.72	16.41	
Energy productivity (kg/MJ)			0.05	0.06	0.07		
Net energy yield (MJ/ha)			-16275.00	-15776.66	-15482.18	-92528.04	

Table 4: Energy consumption and different energy indices for cashew production (7.5 x 7.5 m spacing)

Inputs	Total Energy Equivalent (MJ/ha)					Total Energy MJ/ha	Percentage of total energy input (%)
	0 Year	I Year	II Year	III Year	IV Year		
Human labour	97.06	128.62	188.93	197.62	205.48	817.71	1.09
Machinery	12429.55	16.36	17.33	1.24	1.24	12465.71	16.56
FYM	265.5	265.5	265.5	531	531	1858.50	2.47
Chemical fertilizer	545.79	5952.39	8929.02	11905.19	14882.87	42215.26	56.07
Chemicals	38.77	206.79	206.79	341.57	341.57	1135.47	1.51
Petrol		1360.086	1446.9			2806.99	3.73
Diesel	13142.75	159.3573	159.3573	265.7832	265.7832	13993.04	18.58
Total Energy Consumption	26519.42	8089.10	11213.83	13242.39	16227.94	75292.68	100.00
Yield (kg/ha)			499.14	663.75	723.93	1886.82	
Total Energy output (MJ/ha)			948.366	1261.125	1375.467	3584.96	
Energy use efficiency (%)			8.46	9.52	8.48	4.76	
Specific energy (MJ/kg)			11.82	10.50	11.80	21.00	
Energy productivity (kg/MJ)			0.04	0.05	0.04		
Net energy yield (MJ/ha)			-10265.46	-11981.27	-14852.47	-71707.72	

second-largest contribution to energy consumption was the use of diesel energy (13993.04 MJ/ha) followed by machinery (12465.71 MJ/ha). Diesel oil is primarily used for operating earth moving machines and tiller operated sprayers engaged in different farming activities such as land preparation and spraying of plant protection chemicals. The share of electricity was only 2806.99 MJ/ha (3.73% of the overall energy intake). The FYM contributed 2.47%, while chemicals and human labour contributed even less i.e., 1.51% and 1.09%, respectively. The various energy indicators *viz*., energy use efficiency, specific energy, energy productivity and net energy were determined based on the energy output from the cashew (Table 4). The calculated average energy use efficiency and energy productivity values varied from 8.46 to 9.52% and 0.04 to 0.05 kg/MJ respectively. Energy productivity is low compared to the results reported in other fruits such as apricot (0.24 kg/MJ) (Esengun *et al*., 2007), and apple (0.49 kg/MJ)(Rafiee *et al*., 2010). It implies that extra energy should be spent to increase the crop yield. It was also observed that energy consumption has a positive correlation with crop yield. Specific energy shows the amount of energy spent to produce a unit of product. It was slightly higher (11.82 to 10.50 MJ/kg). Bartzas and Komnitsas (2018) found that the average specific energy of pistachios production was 16.97 MJ/kg, implying that 16.97 MJ of energy was consumed in pistachios for the production per unit of dry in-shell pistachios. The net energy in cashew production system varied from -14852.47 to -10265.46 MJ/ha indicating that the present production system is not energy efficient.

In this study, the total energy expenditure in cashew production for different plant densities during 4 years in coastal India was assessed and presented in Table 5. The calculated energy consumption for different plant densities varied from 75292.68 to 120903.58 MJ/ha.

The study showed that energy consumption in cashew production increases with an increase in the number of plants per unit area. The energy use efficiency gap recommends improving the crop yield by optimizing the farming practices or minimizing the input energy utilized by optimizing energy consumption. In cashew production, chemical fertilizer is one of the most significant energy input sources followed by diesel oil and machinery. Therefore, we need to focus more on efficient use of chemical fertilizers, fuel (diesel) for various operations and energy for different machinery to reduce energy expenditure in cashew production compared to other factors. Special crop management practices and application procedures should be followed to minimize the inputs. Mangalassery *et al*. (2019) reported the biomass generated in mature cashew plantation can be converted to compost with 65% recovery and about 50% of the nutrient requirement of cashew plantation can be met by proper recycling of biomass generated in cashew plantations (Mangalassery *et al*., 2019; Rupa, 2017). Other means for reducing the reliance on chemical fertilizers without compromising on soil quality is to go for green manuring, application of bio fertilizers and organic farming (Kalaivanan & Rupa, 2017; Yadukumar *et al*., 2008). Proper management of critical inputs can reduce energy use on cashew production and can improve energy efficiency.

Table 5: Total energy equivalents (MJ/ha) in 4 years under different plant densities

Inputs	Spacing (m)		
	2.5 x 2.5	**5 x 5**	**7.5 x 7.5**
Human labour	1724.22	1021.32	817.71
Machinery	22405.33	14738.71	12465.71
FYM	6000.00	4200.00	1858.50
Chemical fertilizer	55788.38	55788.86	42215.26
Chemicals	5760.46	2570.05	1135.47
Petrol	1745.93	2749.11	2806.99
Diesel	27479.28	17463.98	13993.04
Total Energy Consumption (MJ/ha)	120903.58	98532.04	75292.68
Yield (kg/ha)	5920.00	3160.00	1886.82
Total Energy output (MJ/ha)	11248	6004	3584.958
Energy use efficiency	9.30	6.09	4.76
Specific energy (MJ/kg)	10.75	16.41	21.00
Energy productivity (kg/MJ)	0.05	0.03	0.03
Net energy yield (MJ/ha)	-109655.58	-92528.04	-71707.72

Source-wise Energy Distribution Pattern

The percentage shares of total input energy for cashew production for 2.5x2.5m spacing are depicted in Figure 1. The energy expenditure of fertilizers ranked first among the energy inputs and accounted for 46 percent followed by diesel (23%) and machinery (19%). The contribution of farmyard manure (5%), chemicals (5%), petrol (1%) and human energy (1%) remained at a low level. In order to bring down the energy consumption in cashew production the management of input consumption is more important. Among the overall

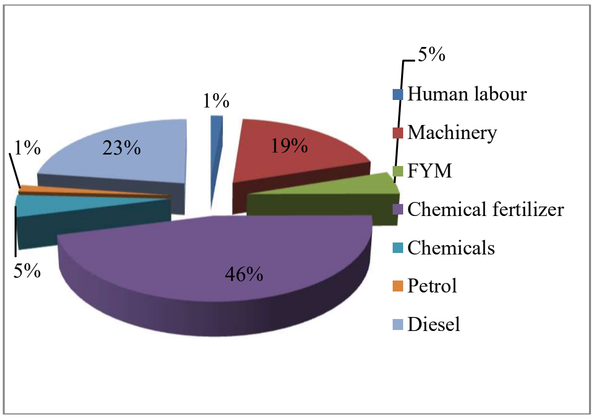


Figure 1: Percentages of total energy input for cashew production (2.5 x 2.5 m spacing)

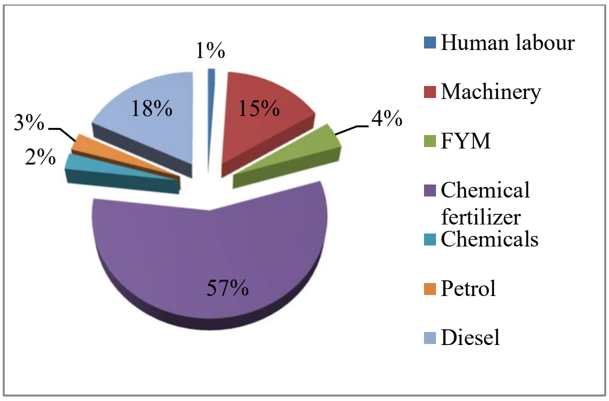


Figure 2: The anthropogenic energy inputs in the production of cashew (5 x 5 m spacing)

energy utilized, 25.60% was direct energy and 74.40% was indirect energy sources whereas, non-renewable form and renewable form of energy sources were recorded as 93.61% and 6.39%, respectively (Table 6). It was also noted that the impact of indirect energy was proved to be more effective than compared to direct energy sources. Hatirli *et al*. (2006) observed the effect of indirect energy's on yield was more significant than direct energy's. Hatirli *et al*. (2005) also observed a greater impact of non-renewable energy sources on crop yield compared to renewable sources.

In 5 x 5 m spacing, the energy consumption by crop management accounted for 57% of overall energy usage (Figure 2). The increased energy inputs used in the management of crops are due to the higher energy content of fertilizers. The fuel (diesel) energy has ranked second place in energy consumption accounting for about 18.0% of the overall input energy followed by energy from machinery (15 %). However, energy from FYM, chemicals, petrol and human labour consumed about 4, 2, 3 and 1%of the overall input energy respectively. Similarly, in ultra-density planting (2.5 x 2.5 m spacing), the indirect energy (77297.62 MJ/ha), sources were much greater in cashew production contrast to direct energy (21234.42 MJ/ha). The indirect energy input persisted at 78.45% of the total energy input compared with 21.60% of the direct energy. There was greater consumption of non-renewable sources (94.7%) than renewable form (5.3%) (Table 6). Consumption of both non-renewable sources and renewable sources of energy varied with various inputs used in crop production. The decrease in the usage of non-renewable sources has a direct impact on the cultivation cost. The non-renewable energy component is high in cashew production. The maximum contribution of non-renewable energy sources comes from the use of fertilizers, diesel, farm machines, chemical and petrol. The findings of the energy distribution in the present study are in close agreement with reports of Bartzas and Komnitsas (2018) for the production of irrigated pistachio and they also reported non-renewable sources and indirect energy sources accounts for about 81% and 66% of the overall energy expenditure.Source-wise energy analysis for cashew production at normal planting system (7.5 x 7.5 m) showed that the chemical fertilizers took a larger share of energy consumption (55.6% of overall energy intake), followed by diesel energy (19% of overall energy intake) (Figure3). The contribution of energy from machinery sources was determined to be 17% of the total energy requirements. However, energy sources like FYM,chemicals, petrol and human labour consumed about 2, 1, 4 and 1% of the total input energy. Under normal planting system, 93.45% and 76.60% of the overall input energy utilized for cashew production is non-renewable energy and indirect energy sources whereas, the amount of renewable and direct energy sources was found to be 3.55 and 23.40%, respectively (Table 6). Similar results were observed by Afshar *et al*. (2013) for pistachio production in irrigated condition and showed 86 % of total energy consumption for non-renewable energy sources. Likewise, the distribution of sources of energy has been recorded in several other fruit tree production, like apple (Fadavi *et al*., 2011) and almonds (Beigi *et al*., 2016).

Table 6: Quantification of various energy sources under different plant densities

SN	Energy Sources	Unit	Total energy consumption for different plant density (MJ/ha)		
			2.5 x 2.5	5 x 5	7.5 x 7.5
1.	Direct Energy (DE)	MJ/ha	30949.42 (25.60%)	21234.42 (21.55%)	17617.73 (23.40%)
2.	Indirect Energy (IDE)	MJ/ha	89954.16 (74.40%)	77297.62 78.45%)	57674.95 76.60%)
3.	Renewable Energy (RE)	MJ/ha	7724.21 (6.39%)	5221.323 (5.30 %)	2676.205 (3.55%)
4.	Non-Renewable Energy (NRE)	MJ/ha	113179.36 (93.61%)	93310.72(94.70 %)	72616.47 93.45%)

The source wise energy expenditure pattern for the production of cashew under various plant densities are depicted in Figure 4. Among the different plant densities, chemical fertilizer consumed the maximum energy, followed by diesel fuel. As regards to the share of the total energy, expenditure is concerned the energy consumption per unit area was slightly higher for ultra-density plantation (2.5x2.5 m) as compared to other two spacing (i.e., 5x5 and 7.5x7.5 m). The higher energy expenditure in ultra-density and high-density cashew orchards is mainly due to more number of plants per unit area and increased need for resources for the initial establishment. Comparative analyses of the findings obtained in the present study in terms of energy requirements under different plant densities indicated that the overall energy requirement is decreased over the years, for all planting densities and the yield was increased significantly which in turn increases the total output energy. Forms of renewable/non-renewable and direct/indirect energy sources used in cashew production are also studied for different plant densities and presented in Figure 5. The outcomes indicated that the contribution of direct input energy for different plant densities varied from 21.55 to 25.60% compared to 74.40 to 78.45% for indirect energy sources. Also, non-renewable and renewable energy sources contributed to 93.45 to 94.70% and 3.55 to 6.39% of the overall energy intake, respectively. It is evident that the amount of non-renewable and indirect input energy usage in cashew production is very much high. Energy analysis showed that cashew production is relatively energy efficient in coastal India and is heavily reliant on non-renewable energy and indirect energy sources.

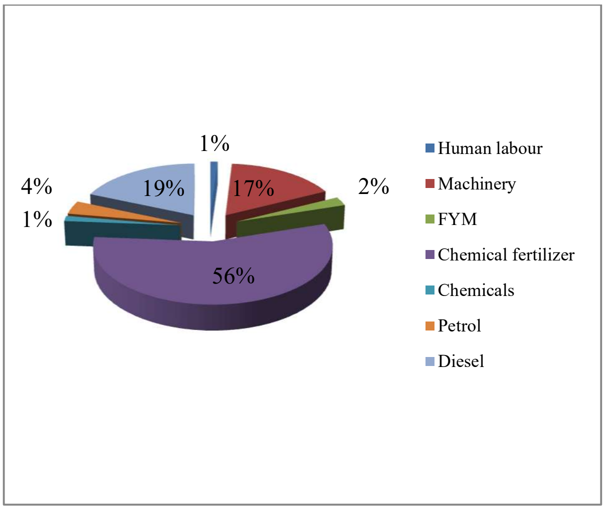


Figure 3: Percentages of total energy input for cashew production (7.5 x 7.5 m spacing)

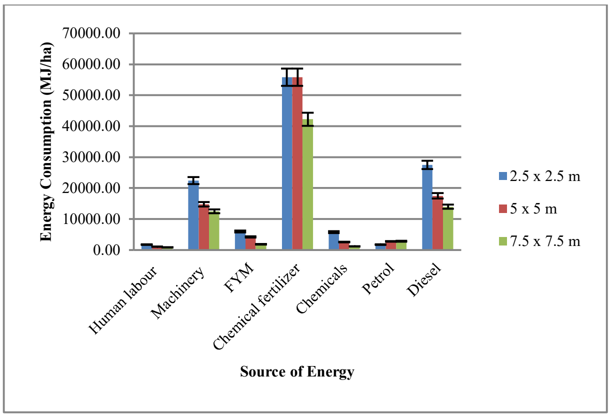


Figure 4: Source wise energy consumption pattern for cashew production under different plant densities.

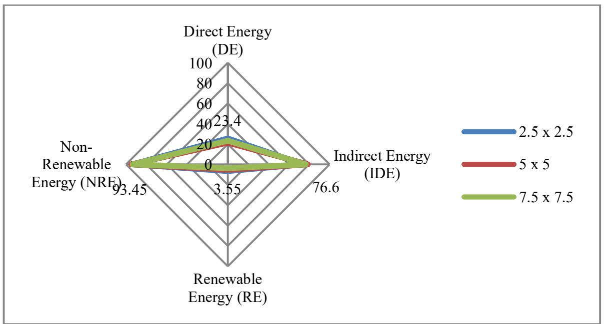


Figure 5: Distribution pattern of total energy input (MJ/ha) in the form of direct energy (DE), indirect energy (IDE), renewable (RE) and non-renewable (NRE) for Cashew cultivation.

The expenditure analysis suggested that the overall energy consumption involved in the current production of cashew in the study area is primarily due to the increased usage of commercial energy sources. These results are in accordance with the energy sources distribution in other fruit crops production *viz*., almond (Beigi *et al*., 2016), pear (Tabatabaie *et al*., 2013), strawberry (Banaeian *et al*., 2011), apple (Rafiee *et al*., 2010) and prune (Tabatabaie *et al*., 2013).

Conclusion

The rate of energy expenditure for input and output energies in cashew production were investigated in this study under different plant densities in coastal India. In this perspective, a set of four energy indices*viz*., energy use efficiency, specific energy, energy productivity and net energy in conjunction with various energy forms, i.e. non-renewable/renewable and direct/indirect were analysed to identify the process of energy input which causes the greatest impact in the life cycle of cashew production. In conclusion, assessment of the energy flow indicated that cashew production is relatively less energy-efficient and is largely dependent on non-renewable and indirect energy sources. The source wise energy contribution indicated that overall energy expenditure related to the current cashew production in the study region is primarily attributed to the management of nutrients (fertilizers) followed by energy from diesel fuel, machinery, FYM, chemicals, petrol and human energy. In this context, different strategies have been suggested to improve the energy efficiency, including the reasonable use of chemical fertilizers, alternatives to minimise the use of chemical fertilizers, and reducing diesel fuel and agricultural machinery to the extent possible as well as the encouragement of the use of renewable energy sources.

Acknowledgement

The authors are thankful to Dr. P.L. Saroj, Former Director, ICAR-Directorate of Cashew Research, Puttur, India and other staff of ICAR-DCR, Puttur for the support provided in conducting this experiment.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Afshar, R. K., Alipour, A., Hashemi, M., Jovini, M. A., & Pimentel, D. (2013). Energy inputs-yield relationship and sensitivity analysis of pistachio (Pistacia vera L.) production in Markazi Region of Iran. *Spanish journal of agricultural research*(3), 661-669.

Anonymous. (2014). *Cashew Handbook - Global Perspective. 4th edition, Copyright, Foretell Business Solutions Private Limited. Available at* www.cashewinfo.com. Retrieved from

Azam Khan, M., & Singh, G. (1996). Energy inputs and crop production in Western Pakistan. *Energy, 21*(1), 45-53.

Balogh, S. B., & Hall, C. A. S. (2016). Food and Energy. In G. Steier & K. K. Patel (Eds.), *International Food Law and Policy* (pp. 321-358). Cham: Springer International Publishing.

Banaeian, N., Omid, M., & Ahmadi, H. (2011). Energy and economic analysis of greenhouse strawberry production in Tehran province of Iran. *Energy Conversion and Management, 52*(2), 1020-1025.

Bartzas, G., & Komnitsas, K. (2018). Energy flow analysis in agriculture; the case of irrigated pistachio production in Greece. *Sustainable Energy Technologies and Assessments, 28*, 73-80.

Beigi, M., Torki-Harchegani, M., & Ebrahimi, R. (2016). Sensitivity analysis of energy inputs and cost assessment for almond production in Iran. *Environmental Progress & Sustainable Energy, 35*(2), 582-588.

Demircan, V., Ekinci, K., Keener, H. M., Akbolat, D., & Ekinci, C. (2006). Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. *Energy Conversion and Management, 47*(13), 1761-1769.

Erdal, G., Esengün, K., Erdal, H., & Gündüz, O. (2007). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. *Energy, 32*(1), 35-41. doi:https://doi.org/10.1016/j.energy.2006.01.007

Esengun, K., Gündüz, O., & Erdal, G. (2007). Input–output energy analysis in dry apricot production of Turkey. *Energy Conversion and Management, 48*(2), 592-598. doi:https://doi.org/10.1016/j.enconman.2006.06.006

Fadavi, R., Keyhani, A., & Mohtasebi, S. (2011). An analysis of energy use, input costs and relation between energy inputs and yield of apple orchard. *Research in Agricultural Engineering, 57*(3), 88-96.

FAOSTAT. (2018). Available at: http://www.fao.org/faostat/en/#data/QC(accessed 25/03/2020).

Hall, C. A. (2011). Introduction to special issue on new studies in EROI (Energy Return on Investment). *Sustainability, 3*(10), 1773-1777.

Hasanzadeh, A., & Rahbar, S. (2005). *Study of energy flow in apple orchards Azarbaijane Gharbi Province*. Paper presented at the The 4th Iranian Congress on Horticultural Science, Ferdosi Mashad University, Mashad, Iran.

Hatirli, S. A., Ozkan, B., & Fert, C. (2005). An econometric analysis of energy input–output in Turkish agriculture. *Renewable and Sustainable Energy Reviews, 9*(6), 608-623. doi:https://doi.org/10.1016/j.rser.2004.07.001

Hatirli, S. A., Ozkan, B., & Fert, C. (2006). Energy inputs and crop yield relationship in greenhouse tomato production. *Renewable Energy, 31*(4), 427-438. doi:https://doi.org/10.1016/j.renene.2005.04.007

IS:9164. (1979). *Indian Standard IS 9164, Guide for estimating cost of farm machinery operation*.

Kalaivanan, D., & Rupa, T. R. (2017). Organic cultivation of cashew. In P. L. Saroj (Ed.), *Cashew: improvement, production and processing* (pp. 295-322). New Delhi: Astral International Pvt Ltd.

Karale, D., Khambalkar, V., Bhende, S., Amle, S. B., & Wankhede, P. S. (2008). Energy economic of small farming crop production operations. *World Journal of Agricultural Sciences, 4*(4), 476-482.

Khan, M. A., & Singh, G. (1997). Energy inputs and potential for agricultural production in western Pakistan. *Agricultural Systems, 54*(3), 341-356. doi:https://doi.org/10.1016/S0308-521X(96)00067-4

Kizilaslan, H. (2009). Input–output energy analysis of cherries production in Tokat Province of Turkey. *Applied Energy, 86*(7), 1354-1358. doi:https://doi.org/10.1016/j.apenergy.2008.07.009

Mangalassery, S., Kalaivanan, D., & Philip, S. P. (2019). Effect of inorganic fertilisers and organic amendments on soil aggregation and biochemical characteristics in a weathered tropical soil. *Soil and Tillage Research, 187*, 144-151. doi:10.1016/j.still.2018.12.008

Mangalassery, S., Nayak, M. G., Adiga, J. D., Preethi, P., & Muralidhara, B. M. (2019). *Nutrient management in cashew, Technical bulletin No. 1/2019*. Retrieved from

Martin-Gorriz, B., Soto-García, M., & Martínez-Alvarez, V. (2014). Energy and greenhouse-gas emissions in irrigated agriculture of SE (southeast) Spain. Effects of alternative water supply scenarios. *Energy, 77*, 478-488. doi:https://doi.org/10.1016/j.energy.2014.09.031

Mohammadi, A., & Omid, M. (2010). Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. *Applied Energy, 87*(1), 191-196. doi:https://doi.org/10.1016/j.apenergy.2009.07.021

Mohammadi, A., Tabatabaeefar, A., Shahin, S., Rafiee, S., & Keyhani, A. (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. *Energy Conversion and Management, 49*(12), 3566-3570. doi:https://doi.org/10.1016/j.enconman.2008.07.003

Mohammadshirazi, A., Akram, A., Rafiee, S., Mousavi Avval, S. H., & Bagheri Kalhor, E. (2012). An analysis of energy use and relation between energy inputs and yield in tangerine production. *Renewable and Sustainable Energy Reviews, 16*(7), 4515-4521. doi:https://doi.org/10.1016/j.rser.2012.04.047

Nassiri, S. M., & Singh, S. (2009). Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. *Applied Energy, 86*(7), 1320-1325. doi:https://doi.org/10.1016/j.apenergy.2008.10.007

Nayak, M. G., Mangalassery, S., & Preethi, P. (2019). Innovative production technologies to enhance productivity and income of cashew farmers. *The Cashew and Cocoa Journal, VIII*(3), 8-18.

Nayak, M. G., & Savadi, S. (2019). Global status of cashew production and Trade: Challenges and strategies for India to regain world leadership. Agriculture Today: The National Agriculture Magazine.

Ozkan, B., Akcaoz, H., & Karadeniz, F. (2004). Energy requirement and economic analysis of citrus production in Turkey. *Energy Conversion and Management, 45*(11), 1821-1830. doi:https://doi.org/10.1016/j.enconman.2003.10.002

Paramesh, V., Arunachalam, V., & Nath, A. J. (2019). Enhancing ecosystem services and energy use efficiency under organic and conventional nutrient management system to a sustainable arecanut based cropping system. *Energy, 187*, 115902. doi:https://doi.org/10.1016/j.energy.2019.115902

Pimentel, D. (1980). Energy inputs in corn production. *Handbook of energy utilization in agriculture*, 67-84.

Piringer, G., & Steinberg, L. J. (2006). Reevaluation of energy use in wheat production in the United States. *Journal of Industrial Ecology, 10*(1-2), 149-167.

Proebsting, E. L. (1980). Energy inputs in cherry production. In D. Pimentel (Ed.), *Handbook of energy utilization in agriculture* (pp. 251-254): CRC Press Boca Raton, FL.

Rafiee, S., Mousavi Avval, S. H., & Mohammadi, A. (2010). Modeling and sensitivity analysis of energy inputs for apple production in Iran. *Energy, 35*(8), 3301-3306. doi:https://doi.org/10.1016/j.energy.2010.04.015

Rajesh, U. M., Mudasir, A., Raghuvirsinh, P. P., & Sharad, K. N. (2018). Energy audit application for rice-wheat croppingsystem. *Oriental Journal of Computer Science and Technology, 11*(4), 209-218.

Rupa, T. R. (2017). Nutrient and water management. In P. L. Saroj (Ed.), *Cashew: improvement, production and processing* (pp. 233-252). New Delhi: Astral International Pvt Ltd.

Sathe, S. K. (1994). Solubilization and electrophoretic characterization of cashew nut (Anacardium occidentale) proteins. *Food Chemistry, 51*(3), 319-324. doi:https://doi.org/10.1016/0308-8146(94)90033-7

Sharma, R. K., Bhattacharya, T. K., Akanksha, K., Priyanka, C., Sandip, M., & Deepshikha, A. (2020). Energy use pattern in wheat crop production system among different farmer groups of the Himalayan Tarai region. *Current Science, 118*(3), 444-448.

Sharma, V. K. (2004). *Trees and protection of environment*. New Delhi, India: Deep and Deep Publications.

Singh, J. M. (2000). *On farm energy use pattern in different cropping systems in Haryana, India.* (Master of Science), International Institute of Management, University of Flensburg, Germany,

Singh, M., Pal, S., Thakur, R., & Verma, U. (1997). Energy input-output relationship of cropping systems. *Indian Journal of Agricultural Sciences, 67*(6), 262-264.

Singh, S., & Mittal, J. P. (1992). *Energy in production agriculture*. New Delhi, India: Mittal Publications.

Strapatsa, A. V., Nanos, G. D., & Tsatsarelis, C. A. (2006). Energy flow for integrated apple production in Greece. *Agriculture, Ecosystems & Environment, 116*(3), 176-180. doi:https://doi.org/10.1016/j.agee.2006.02.003

Tabatabaie, S. M. H., Rafiee, S., & Keyhani, A. (2012). Energy consumption flow and econometric models of two plum cultivars productions in Tehran province of Iran. *Energy, 44*(1), 211-216. doi:https://doi.org/10.1016/j.energy.2012.06.036

Tabatabaie, S. M. H., Rafiee, S., Keyhani, A., & Ebrahimi, A. (2013). Energy and economic assessment of prune production in Tehran province of Iran. *Journal of Cleaner Production, 39*, 280-284. doi:https://doi.org/10.1016/j.jclepro.2012.07.052

Tabatabaie, S. M. H., Rafiee, S., Keyhani, A., & Heidari, M. D. (2013). Energy use pattern and sensitivity analysis of energy inputs and input costs for pear production in Iran. *Renewable Energy, 51*, 7-12. doi:https://doi.org/10.1016/j.renene.2012.08.077

Taki, M., Ajabshirchi, Y., Mobtaker, H. G., & Abdi, R. (2012). Energy consumption, input–output relationship and cost analysis for greenhouse productions in Esfahan Province of Iran. *Journal of Experimental Agriculture International*, 485-501.

Yadukumar, N., Rejani, R., & Nandan, S. L. (2008). Studies on green manuring in high density cashew orchards. *Journal of Plantation Crops, 36*(3), 265-269.

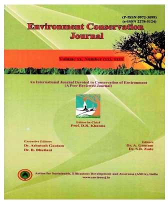
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 79-86, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Principal component analysis among vegetable soybean genotypes (*Glycine max* L. Merrill)

Devi Sri Dunna ✉
Department of Genetics and Plant Breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur, India
Nanita Devi Heisnam
Department of Genetics and Plant Breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur, India
Renuka Devi Thokchom
Department of Genetics and Plant Breeding, College of Agriculture, Central Agricultural University, Imphal, Manipur, India
Bireswar Sinha
Department of Plant Pathology, College of Agriculture, Central Agricultural University, Imphal, Manipur, India
Okendro Singh
Department of Basic Sciences, College of Agriculture, Central Agricultural University, Imphal, Manipur, India

ARTICLE INFO

Received : 18 August 2022
Revised : 29 December 2022
Accepted : 22 January 2023

Available online: 11 April 2023

Key Words:
Eigen values
Genotypes
Miracle crop
Screeplot

ABSTRACT

In the present study, 33 soybean genotypes were selected to study the association between the fourteen quantitative characters under study and to assess the magnitude of divergence between 33 genotypes for 14 traits during *Kharif,* 2021. For all measured traits, the results revealed significant variation among tested entries. The principal component analysis (PCA) was conducted for the 1quantitative characters and only 7 showed > 1 Eigen value and showed about 81.748% of total variation and remaining 7 components having a eigen value less than 1.00 and contributed only 18.252% of total Variation. Among the traits studied PC1 showed 20.7235 while, PC2 to PC 14 exhibited 15.205%, 12.69%, 9.476%, 9.142%,7.271%, 7.241%, 6.171%, 4.089%, 2.865%, 2.185%, 1.506%, 0.897% and 0.536% variability, respectively. Scree plots explained the percentage of variance. A high PC score for a specific genotype shows high value for those variables like EC 915989, EC 915900, EC 915993, EC 915975, EC 915903, EC 915898 and EC 915959 in PC1 and this indicated that these genotypes have high values for traits such as 100 Fresh pod weight and 100 Fresh seed weight.

Introduction

Protein malnutrition is common among the poor in India, and it is expected to worsen as the population grows by 2025. There is a need for a versatile crop that can alleviate protein malnutrition while also being suitable for the Indian cropping system. Glycine max (vegetable soybean) (L.) Merill is known in Japan as edamame and in China as maodou. Edamane is a large-seeded vegetable soybean with a sweet flavour, bright green colour, light hilum, and a soft texture. While the pods and plants are still green, the pods are harvested when they are completely seeded. Samuel Bowen, a sailor, introduced soybean to the United States in 1765, and it quickly became a popular crop in the south by the twentieth century (Brachfeld and Choate, 2007). Farmers in Asia, where edamame is a popular vegetable, is harvested at the full-seed stage, with a larger, sweet, nutty, and mildly flavoured seed (Zhang *et al.,* 2015). Soybean was consumed as a vegetable in the Far East as early as the second century BCE because of its nutritional and medicinal properties (Shanmugasundaram, 2001; Shurtleff and Aoyagi, 2009). The current challenge in Edamame breeding is to develop improved cultivars that outperform in terms of vegetable pod yield. At present varieties that are bred for vegetable purpose are limited in India. In any crop improvement effort, the first step is the collection of germplasm and the evaluation for magnitude variability of economic traits of interest.

Corresponding author E-mail: *dunna.devisri@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14532442

To overcome the scarcity of resources I used the IISR's elite vegetable soybean varieties with the assistance of AICRP, soybean. Soybean, as a promising vegetable legume crop in India, has a lot of room for genetic improvement in terms of different quantitative and qualitative traits besides widening the genetic base of the crop through mutagenesis. Vegetable Soybean is one of the most nutritious leguminous crop. It is also known as the "miracle crop" because of its exceptional qualities. The magnitude of the association between yield and other components is very crucial.

Material and Methods

R studio with R software version 4.2.1 was used to perform the analysis in which different packages like princomp, promp, FactoMineR were used in the process. First the data structure was prepared in excel and later the data was imported , scaled and adjusted, The scaled data then using princomp and prcomp packages PCA structures was concluded and 3D plots were prepared, later on using FactoMineR rotated component were prepared and the conclusions were drawn. In the present study, 33 soybean genotypes were selected to study the association between the fourteen quantitative characters under study and to assess the magnitude of divergence between 33 genotypes for 14 traits during *Kharif,* 2021. Catell suggests using a stree plot (PCA) to calculate the eigenvalue. Jeffers proposed the selection of PCs with eigen values >1. R utilised to perform PCA by equation given here under. PCA is a well-known dimension reduction method that seeks linear combinations of X columns with the lowest variance, or equivalently, the highest information (Massy, 1965; Jolliffe, 1986). It is frequently used in chemo metrics to provide the most concise data representation. The singular value decomposition of X is one of several standard approaches for determining the principal components. In chemometrics, the nonlinear iterative partial least-squares (NIPALS) algorithm is commonly used to estimate the principal components (Wold, 1966). This experiment was carried out at Andro research farm, CAU, Imphal East during kharif 2021. Geographically the CAU Research Farm, Andro is situated in the Imphal East district of Manipur at the 24° 76.42' North latitude and 94° 05.19' East longitudes at an altitude of 808m above Mean Sea Level which comes under the Eastern Himalayan Region (*II*) and the agro-climatic zone Sub-Tropical Zone (NEH-4) of Manipur (Agro meteorological observatory, ICAR-RC NEH Region, Manipur Centre, Lamphelphet, Imphal). The soil type of the experimental field was clay in texture with acidic soil reaction having pH value ranging from 5.5 to 5.6. It has high available potassium but low available nitrogen and phosphorous.

Results and Discussion

Principle Component Analysis (PCA) is a well-known data analysis technique that is the most commonly used multivariate technique for reducing the dimensionality of a data set. According to Rotaru *et al*. (2012), using the PCA method in agricultural studies is beneficial. The present investigation was performed for 14 traits of vegetable soybean. Out of 14 principal components in which 7 components showed > 1.00 Eigen value and showed about 81.748% of total variation. However, remaining 7 components having a eigen value less than 1.00 and contributed only 18.252% of total Variation. Among the traits studied PC1 showed 20.7235 while, PC2 to PC 14 exhibited 15.205%, 12.69%, 9.476%, 9.142%,7.271%, 7.241%, 6.171%, 4.089%, 2.865%, 2.185%, 1.506%, 0.897% and 0.536% variability, respectively. Among Seven principal components first four components showed major contribution (58.093%) towards total variation. Eigen value and variance associated with each principal component decreased gradually and cumulative variability increase gradually which is shown as screen plot. The result or principal components are depicted as a factor loading score. A more or less same trend was observed by Srikanth Thippani *et al*. (2017), Jakhar and Arjun (2018). These results are presented in the Table 1 and depicted for Variables in Fig. 1, Individuals in Fig.2 and Biplot in Fig.3.Scree plots are created by graphing the principal component numbers (X-axis) and the percentage of variation explained (Y-axis).The Principal Component 1 showed 20.7 percent variability with eigen value 2.901 which then declined gradually. From the graph, it is clear that the maximum variation was observed in Principal Component 1(Fig. 4). In PC1 the traits that had high positive component were 100 fresh

Table 1: Principal components (PCs) analysis for metric traits in soybean genotypes

Characters	Principal component	Eigen values	percentage of variance	cumulative % of variance
Days to 50% flowering	PC1	**2.901**	20.723	20.723
Plant height(cm)	PC2	**2.129**	15.205	35.928
Days to Harvest	PC3	**1.777**	12.69	48.617
Pod length(cm)	PC4	**1.327**	9.476	58.093
No. of seeds/pod	PC5	**1.28**	9.142	67.236
No. of pods/plant	PC6	**1.018**	7.271	74.506
Fresh pod yield/plant(g)	PC7	**1.014**	7.242	81.748
100 Fresh pod weight(g)	PC8	0.864	6.172	87.92
100 Fresh seed weight(g)	PC9	0.572	4.089	92.009
100 Dry seed weight(g)	PC10	0.401	2.866	94.875
Crude sugar content	PC11	0.306	2.185	97.06
Crude protein content	PC12	0.211	1.506	98.566
Hydration rate	PC13	0.126	0.897	99.463
Cooking time(min)	PC14	0.075	0.537	100

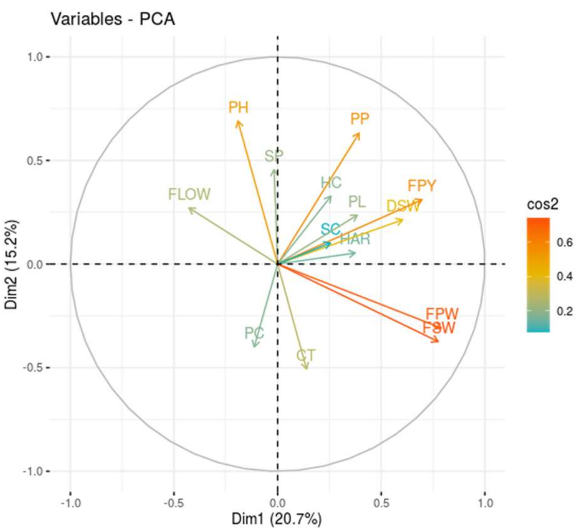


Figure 1: PCA graph of different traits for first two principal components

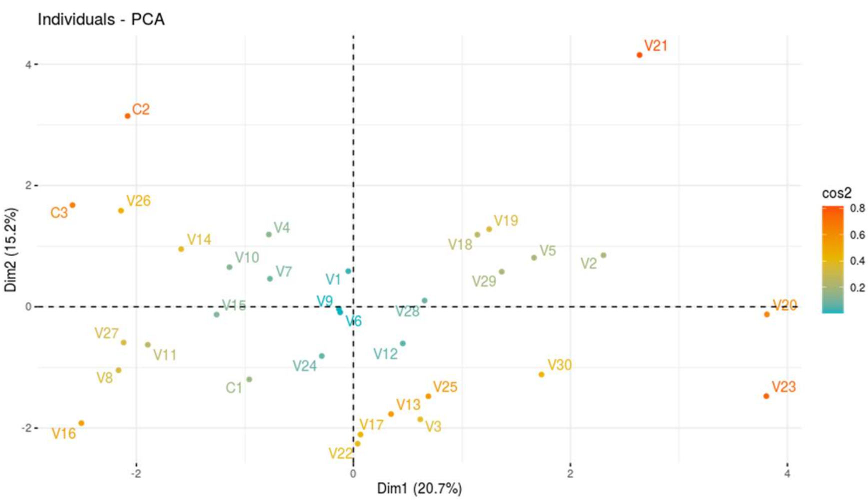


Figure 2: PCA graph for germplasm lines across first two principal components

seed weight (0.952) followed by 100 fresh pod weight(0.920), that accounted that these traits were mostly related to PC1. In PC2 the traits that had high positive component were No. of pods/plant(0.933) and Fresh pod yield/plant (0.865). In PC3 that had high positive component were Days to 50% flowering (0.730) and plant height (0.548). In PC4 that had high positive component were 100 Dry seed weight(0.614) and Hydration rate(0.883). In PC5 that had high positive component were No. of seeds/plant (0.890) and days to Harvest(0.590) . In PC6 that had high positive component was Crude sugar content(0.904), In PC7 that had high positive component was pod length (0.849). The rotated component matrix components were presented in Table 2 and the traits having eigen values for each PC were represented in Table 3 and Figure 5.

Table 2: Principal Components for yield and its contributing characters of Vegetable soybean

	RC1	RC2	RC3	RC4	RC5	RC6	RC7
Days to 50% flowering	-0.071	0.016	**0.730**	-0.373	0.144	-0.179	-0.154
Plant height(cm)	-0.433	0.312	**0.548**	0.183	-0.219	0.136	0.256
Days to Harvest	0.303	-0.085	-0.048	0.250	**0.590**	-0.142	0.241
Pod length(cm)	0.066	0.103	-0.014	0.074	0.168	0.125	**0.849**
No. of seeds/pod	-0.192	0.108	0.080	-0.038	**0.890**	0.050	0.040
No. of pods/plant	-0.034	**0.933**	0.080	0.035	0.127	-0.038	0.069
Fresh pod yield/plant(g)	0.413	**0.865**	-0.006	0.041	-0.069	0.057	0.032
100 Fresh pod weight(g)	**0.920**	0.124	-0.044	0.070	0.009	0.039	0.131
100 Fresh seed weight(g)	**0.952**	0.132	-0.060	0.047	-0.085	0.061	0.010
100 Dry seed weight(g)	0.107	0.229	-0.338	**0.614**	0.098	0.166	0.333
Crude sugar content	0.122	-0.049	0.024	-0.021	-0.084	**0.904**	0.179
Crude protein content	0.215	-0.245	0.168	-0.279	-0.381	-0.558	0.443
Hydration rate	0.037	-0.020	0.160	**0.883**	0.060	-0.038	-0.053
Cooking time(min)	-0.009	-0.013	-0.868	-0.186	-0.002	-0.064	-0.042

Rotated Component Matrix; Extraction by Principal Component Analysis; Rotation by Varimax with Kaiser Normalization

Table 3: Rotated component matrix interpretation for the traits having values >0.5 in each PCs

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
TRAITS	100 Fresh pod weight (g)	No. of Pods /plant	Days to 50% Flowering	100 Dry seed weight(g)	Days to Harvest	Crude Sugar Content	Pod length(cm)
	100 Fresh seed weight(g)	Fresh Pod Yield /plant(g)	Plant Height(cm)	Hydration Rate	No. of seeds/pod		

The table shows the top PC scores for all traits and all 33 soybean genotypes in these seven components. These scores, the intensity of which can be determined by the variability explained by each of the principal components, can be used to suggest precise selection indices. A high PC score in a specific component for a specific genotype indicates that the variables in that genotype have high values. EC 915989, EC 915900, EC 915993, EC 915975, EC 915903, EC 915898 and EC 915959 in PC1 and this indicated that these genotypes have high values for traits such as 100 Fresh pod weight and 100 Fresh seed weight. The highest PC score of EC 915898 followed by EC 915978, EC 915975 and EC 915974 in PC2 was mainly related with No. of pods/plant and Fresh Pod yield/plant which are mainly yield attributing traits. A more or less same trend was observed by Bello *et al.* (2012) where he obtained comparable results by using principal component analysis to

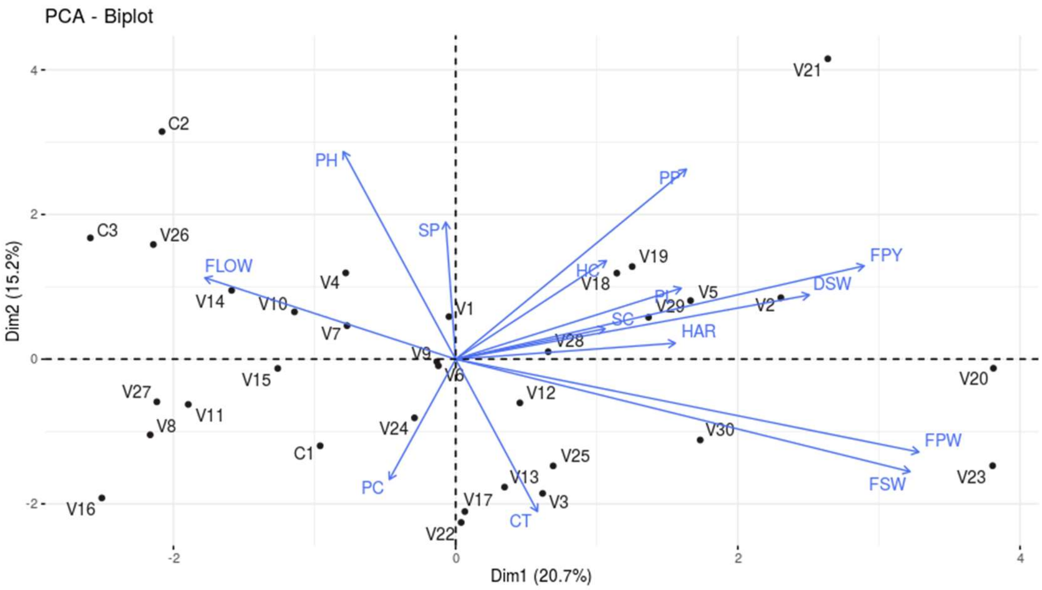


Figure 3: Distribution and grouping of germplasm lines across first two principal components.

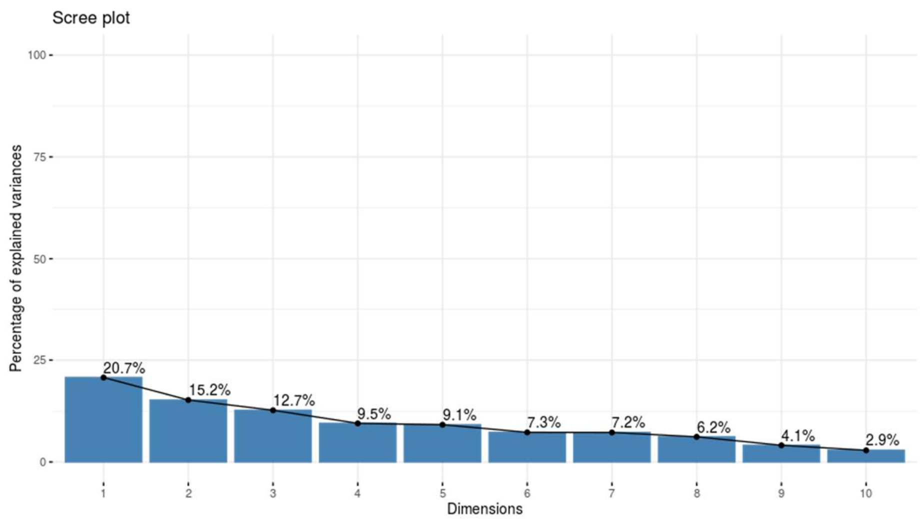


Figure 4: Scree Plot

evaluate 56 soybean genotypes to determine the percent contribution of variation by each trait to seed yield. The most important factors in genotype variation were discovered to be days to Harvest, plant height, and No. of pods/plant. Days to Harvest, plant height, and No. of pods/plant are all variables with a high weighting in the first PC, which accounted for 39.83% of total variation. PC2 explained an additional 20.52% of the total variation. These two factors accounted for 60.36% of all variable variation. As a result, genetic improvement of these traits will eventually result in higher seed yield and more or less same trend was observed by Ojo *et al*. (2012) where he investigated and reported three major components: PC1 had 52% variability, PC2 had 26% variability, and PC3 had 10% variability among genotypes for the traits studied. The No. of pods/plant, pod length, pod yield/plant, 100-seed weight, and seed yield/plot were all highly correlated with the first principal component. Days to 50% flowering and days to Harvest were the two components that were most

Table 4: Principle component scores of soybean genotypes

Genotypes	RC1	RC2	RC3	RC4	RC5	RC6	RC7
AGS-ACC	-0.034936266	-0.379835128	-0.467201909	-0.007735112	-1.117690966	**1.479109168**	-2.429748321
Karune	-1.769132537	0.960255876	**1.297266461**	-0.221807336	0.903606341	-0.328352164	0.164778903
NRC 105	-0.966812829	-0.264202699	**1.902818963**	-0.307204623	-0.149691149	0.798211927	-0.73811453
EC 915895	-0.446972606	-0.068169658	0.806440466	**1.128795093**	-2.248440251	-0.325948877	**1.673123674**
EC 915898	**1.07578808**	**2.997804337**	0.192475565	0.350291669	-1.38676415	-0.844012357	-1.919461732
EC 915900	**1.363486211**	-1.344361777	-0.026359629	-0.216408623	0.795493399	-0.218135888	-0.037426951
EC 915902	-1.59657889	-0.601153726	-0.428118991	**1.915537538**	0.15313189	-0.761906867	**1.164923006**
EC 915903	**1.106227369**	-0.898520134	**1.050558202**	0.063047482	**1.47926242**	**2.0392975**	**1.174943156**
EC 915908	-1.000668843	-0.285914648	-1.086688415	0.755091374	-0.937076293	0.757942136	0.653304897
EC 915909	-0.258439847	0.004712798	0.598476403	0.0449178	0.238422026	-1.08850357	0.219813443
EC 915910	-1.473336901	-0.282943278	-1.741754841	-1.294384486	0.612558905	-0.316078698	-0.44992662
EC 915913	0.298515533	-0.196840527	0.60209444	-1.410144618	0.54903056	-0.008837286	**1.437404564**
EC 915919	-1.149498287	-0.669979485	0.163803645	0.645493199	-1.247133923	**1.883033343**	0.240839458
EC 915923	0.098047376	-0.161963542	**1.318050678**	-1.534888122	-1.21039105	-0.465513686	-0.046830658
EC 915924	-0.320028755	-0.21723012	-1.135074507	**1.357971156**	-1.007563275	0.5386164	-0.67301945
EC 915926	0.566775447	-0.353364205	-0.828100863	-0.977254738	-0.385581909	0.344363432	0.107241867
EC 915933	-0.37442973	0.083554796	**1.479172542**	-0.048700622	-0.270350176	-0.763271126	-0.380608327
EC 915937	-0.113553486	0.711816547	0.799200896	-1.780233709	-0.865852719	-0.916687314	0.432203382
EC 915945	-0.881236355	-0.731194447	-1.044196048	-2.172353589	-0.774492903	**1.29370759**	-0.793771441
EC 915949	0.279425072	0.047741601	-1.22123404	-1.254246128	-0.620977732	-1.280718723	0.750685155
EC 915959	**1.000638448**	-0.081931258	**1.673470675**	0.047368994	0.468984202	**1.14378003**	0.638458025
EC 915974	0.45145444	**1.078074466**	0.15210382	0.180848295	**1.688104553**	-0.480732331	-0.631596913
EC 915975	**1.229244739**	**1.652171045**	-0.944252016	-0.530489897	-0.385272809	-0.217104803	**2.287670891**
EC 915978	-0.644085431	**2.615079176**	-0.093589366	**1.145877072**	**1.344311578**	**1.648575087**	0.033829023
EC 915983	**1.004980277**	-1.293798241	-0.275675882	**1.051511108**	-0.109960249	-2.095959501	-0.666331928
EC 915989	**2.168505837**	-0.006629361	-0.93535979	**1.010066419**	-0.026584073	0.907789773	-0.391560195
EC 915993	**1.310893064**	-0.985048535	**1.253142594**	0.26805993	0.54224033	-0.237953307	-1.648451464
EC 916000	0.639809924	-0.313563948	-0.849909787	0.234459825	-0.002465246	-0.655825632	-0.432816595
EC 916009	-1.45619745	-0.186345578	0.707036369	**1.247736982**	0.457340155	-1.333178508	-0.566585375
EC 916022	-0.846913635	-1.30444743	-0.562801952	-0.366015819	**1.88872081**	-0.683925384	-0.563568824
EC 916025	0.042030113	0.543444518	-0.600400953	-0.654649725	0.520485728	0.597787118	0.041572639
EC 916032	-0.284459508	0.82785335	-1.484181466	0.125032737	**1.669256453**	-0.210284224	0.219169705
EC 916039	0.981459423	-0.895070786	-0.271211261	**1.204410473**	-0.564660475	-0.199283257	**1.129857535**

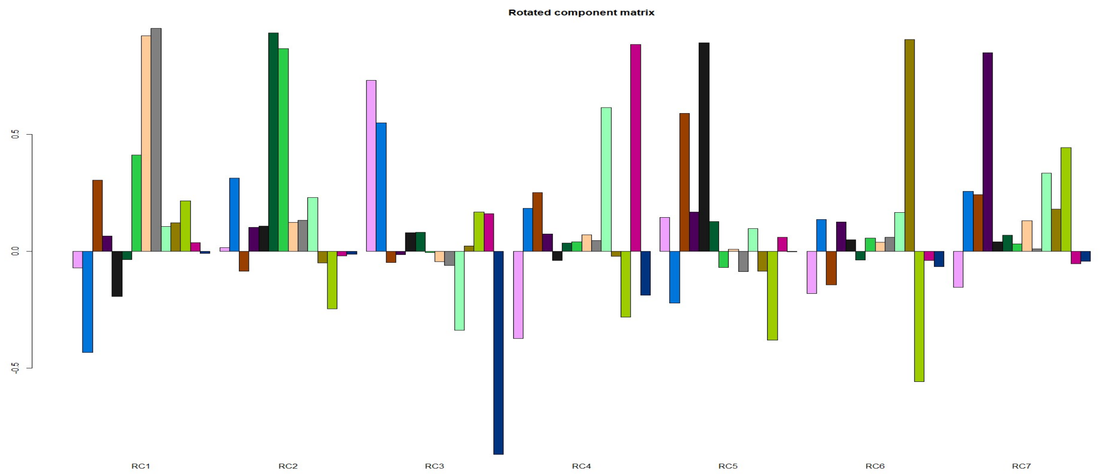


Figure 5: Rotated Component Matrix for 15 yield contributing traits of soybean.

closely related to the second main component. The highest PC score of NRC 105 followed by EC 915959, EC 915933, EC 915923, Karune, EC 915993 and EC 915903 in PC3 was mainly related with days to 50% flowering and plant height. More or less same trend was observed by Iqbal et al. (2008) where he investigated three major components, the first three of which accounted for 67.77% of the total variance. PC1 included seed yield and biological yield/plant, while PC2 included 100-seed weight and harvest index and PC3 included days to Harvest and No. of branches/plant. The highest PC score of EC 915902 followed by EC 915924, EC 916009, EC 916039, EC 915978, EC 915895, EC 915983 and EC 915989 in PC4 was mainly related with 100 dry seed weight and Hydration Rate. The highest PC score of EC 916022 followed by EC 915974, EC 916032, EC 915903 and EC 915978 in PC6 was mainly related with Days to Harvest and No. of seeds/pod. The highest PC score of EC 915903, EC 915919, EC 915978, AGS-ACC, EC 915945 and EC 915959 in PC5 was mainly related with Crude Sugar content. The highest PC score of EC 915975, EC 915895, EC 915913, EC 915903, EC 915902 and EC 916039 in PC7 was mainly related with Pod length. More or less same trend was observed by Dubey *et al*. (2018) where he investigated fifty soybean accession for PCA in order to assess economic traits. Only five of the eighteen principal components (PCs) had more than one eigenvalue and revealed 73.44% variability among the observed traits. The variation in the first principal component was 37.13%, followed by 13.02% in the second principal component, 10.17% in the third principal component, 6.88% in the fourth principal component, and 6.24% in the fourth principal component (PC). These results are represented in the table 4.

Conclusion

The principal component analysis sorted out of total fourteen traits into seven main principal components. They had more than one Eigen value and a cumulative variance of about 81.748% was identified through all seven components, with PC1 explaining the most variance. AGS-ACC, Karune, NRC 105, EC 915895, EC 915898, EC 915900, EC 915902, EC 915903, EC 915923, EC 915924, EC 915933, EC 915945, EC 915959, EC 915974, EC 915975, EC 915978, EC 915983, EC 915989, EC 915993, EC 916009, EC 916022, EC 916032, EC 916039 were identified as putative genotypes based on principle component analysis and per se performance. However, EC 915903 was found to be the best because it had a higher value for a greater number of important traits.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Bello, L. L., Aondover, S., & Terkimbi, V. (2012). Studies on relationship between seed yield and yield components in soybean [*Glycine max* (L.) Merrill]. *Electronic Journal of Plant Breeding*, *3*(4), 1012-1017.

Brachfeld, A., & Choate, M. (2007). *Eat your food! Gastronomical glory from garden to gut: a Coastalfields cookbook, nutrition textbook, farming manual and sports manual.* Coastal fields. Arvada, CO, USA, pp. 275.

Dubey, N., Avinashe, H. A., & Shrivasthava, A. N. (2018). Principal component analysis in advanced genotypes of soybean [*Glycine max* (L.) Merrill]. *Plant Archives, 18*(1), 501-506.

Fehr, W. R., Caviness, C. E., Burmood, D. T., & Pennington, J. S. (1971). Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. *Crops Science*, *11*, 929-931.

Iqbal, Z., Arshad, M., Ashraf, M., Mahmood, T., & Waheed, A. (2008). Valuation of soybean [*Glycine max* (L.) Merrill] germplasm for some important morphological traits using multivariate analysis. *Pakistan Journal of Botany*, *40*(6): 2323-2328.

Jakhar, N. K., & Arjun, K. (2018). Principal component analysis and character association for yield components in greengram [*Vigna radiata* (L.) Wilczek] genotypes. *Journal Pharmacogn Phytochem*istry, *7* (2): 3665-3669.

Jolliffie, I.T. (1986). *Principal Component Analysis*. Springer.

Massay, W.F. (1965). Principal components regression in exploratory statistical research. *Journal of the American Statistical Association*, *60*, 234-246.

Ojo, D. K., Ajayi, A. O., & Oduwaye, A. O. (2012). Genetic relationships among soybean accessions based on morphological and RAPDs techniques. *Pertanika Journal of Tropical Agriculture Science, 35*(2), 237 – 248.

Shanmugasundaram, S. (2001). Global extension and diversification of fresh and frozen vegetable soybean. In: Lumpkin TA and Shanmugasundaram S (Compilers), 2nd International Vegetable Soybean Conference, Washington State University, Pullman, p. 161-165.

Shurtleff, W., & Aoyagi, A. (2009). History of edamame, green vegetable soybeans, and vegetable-type soybeans (1275-2009): Extensively annotated bibliography and sourcebook. Soybean information Center, Lafayette, CA.

Srikanth, T., Eshwari, K.B., & Bhave, M. H. V. (2017). Principal component analysis for yield components in Greengram Accessions (*Vigna radiate* L.). *International Journal on Pure Applied Biosciences,* ***5*** (4), 246-253.

Wold, H. (1966). Estimation of Principal Components and Related Models by Iterative Least Squares. In: Multivariate Analysis, Krisnaiaah P.R. (Eds). Academic Press, New York, pp. 391-420.

Zhang, Q.Y., Li, Y.S., & Liu, X. B. (2015). Edible quality and its regulation in vegetable soybean (Glycine max (L.) Merril).2015 ASA, CSSA, SSSA International Annual Meetings November 15-18, 2015, Minneapolis, MN.

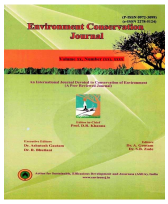
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 87-97, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Interactive effects of non-fodder litter and fungal species on soil enzymes: A microcosm temporal assessment from Indian arid zone

Manohar Singh Suthar
Department of Botany, Jai Naryan Vyas University, Jodhpur, Rajasthan, India
Manish Mathur ✉
ICAR-Central Arid Zone Research Institute, Jodhpur, India
Praveen Gehlot
Department of Botany, Jai Naryan Vyas University, Jodhpur, Rajasthan, India
Swami Sundaramoorthy
Department of Botany, Jai Naryan Vyas University, Jodhpur, Rajasthan, India

ARTICLE INFO

Received : 27 November 2022
Revised : 17 January 2023
Accepted : 22 January 2023

Available online: 13April 2023

Key Words:
Indian arid region
Plant litter
Aspergillus
Soil enzymes
Soil quality index

ABSTRACT

The interactive effects of three non-fodder Indian arid plant species, *Tephrosia purpurea, Aerva persica,* and *Calotropis procera*, and four *Aspergillus* fungal species on soil enzymes (acid and alkaline phosphatase, -glucosidase, dehydrogenase, urease, and amidase activities) were temporally assessed (15 and 30 days withdrawals). The results were statistically analysed using ANOVA, Principal Component Analysis (PCA), and Canonical Correlation Analysis (CCoA). Aside from these, a biochemical soil quality index was created by assigning a weighted score to each enzyme and analysing it using PCA. This study found that various litter-fungal species complexes acted differently and that their effects changed over time, specifically for acid phosphatase, alkaline phosphatase, beta-glucosidase, and amidase. Dehydrogenase and urease activities increased with predictors over time. With temporal backwash, all four fungal species with *C. procera* inhibit acid phosphatase, alkaline phosphatase, and beta-glucosidase activities (i.e., more at 15 days and lesser after 30 days). Our current findings suggest that (a) urease activities were modulated by *A. persica* in cooperation with fungi like *A. terreus, A. niger*, and *A. flavus* at specific enzyme levels; (b) In assistance with fungi such as *A. fumigatus, A. niger, and A. persica*, amidase concentration was successfully managed through litter of the legume plant species *T. purpuria*. (c) When *C. procera* and *A. fumigatus, A. niger*, and *A. flavus* worked together, they were most effective at supporting beta-glucosidase and dehydrogenase (d) Alkaline phosphatase and (e) acid phosphatase was more responsive to *T. purpurea-A. terreus* complexes than were *T. purpurea-A. flavus* and *C. procera-A. terreus* complexes.

Introduction

Soil health is the net result of ongoing conservation and degradation processes; which is heavily dependent on the biological elements of the soil ecosystem and affects plant health, environmental health, food safety, and quality (Laishram *et al.,* 2012). Numerous indicators can be used to gauge this, but soil enzymes are among the most significant because they are essential for preserving soil fertility, soil health, and soil ecology (Mathur and Sundarmoorthy, 2019). They react quickly to changes in environmental circumstances and soil management practices. Because of this, they are used as sensors, and they have been researched all over the world as a measure of soil fertility (Utobo & Tewari, 2015), a measure of microbial biomass (Ren *et al.,* 2018), as indicators of vegetation effects and capability to conduct bio-geochemical cycling, total microbial activity (Luo *et al.*, 2018), as a predictor of bio-remediation (Basak *et al.,* 2016), and to understand the consequence of

Corresponding author E-mail: *eco5320@gmail.com*
Doi:https://doi.org/10.36953/ECJ.16392522

degradation (Pajares *et al.,* 2011; Samuel, 2017). Their responses have also been assessed in terms of litter type (Xiang *et al.,* 2018; Jagadish *et al.,* 2001), soil fungi (Oseni, 2011), soil management practises (Maharjan *et al.,* 2017), and temporal variations (Ren *et al.,* 2018; Veeraragavan *et al.,* 2018). Some of the above attributes have been addressed in Indian arid and semi-arid zones by Tarafdar *et al.* (2002) and Gaur *et al.* (2012).

Few studies have been done on the interactions between different types of plant litter and different fungi species and extracellular soil enzymes in hot dry region of India. In light of this, our study closes a knowledge gap regarding the impact of fungus species and litter type on extracellular soil enzymes. We hypothesized in this work that the effects of particular plant litter and fungus species on soil enzymes would vary from their combined effects and that these variances would change over time. The objectives of this study were (a) to evaluate the temporal effects of litter from three wild arid plant species on acid phosphatase, alkaline phosphatase, beta-glucosidase, dehydrogenase, urease, and amidase, i.e. after 15 and 30 days withdrawal periods. (b) to visualise the studied enzymes in a cumulative approach that takes into account the interactive effects of the litter-fungi-time complex, and (c) to develop a biochemical soil quality index.

Material and Methods

Species and experimental setup

As litter source species, three non-fodder arid wild plant species were used: *Tephrosia purpurea* (L.) Pers, *Aerva persica* (Burm.f.) Shult, and *Calotropis procera* (Aiton) W.T.Aiton. These species can be found in abundance in wastelands, fallow lands, crop-fences, and community grazing lands (Mathur and Pandey, 2016). As litter, total aboveground biomass of *T. purpurea* and *A. persica*, as well as a mixture of stem (1 cm width) and leaves of *C. procera*, were used. These species were collected in and around natural agroforestry field located at six different provinces of arid eco-regions, namely Shergarh (Site 1; 26^0 19' 32.66" N and 72^0 17' 13.16" E), Balesar (Site 2: 26^0 24.0' 69" N and 72^0 28' 59.83" E), Osiyan (Site 3: 26^0 43' 53.46" N and 72^0 54' 30.79" E), Chawa (Site 4: 26^0 22.06' 62" N and 72^0 09.05' 58" E), Baitu (Site 5: 25^0 54' 13.72" N and 71^0 46' 15.69" E) and Kalyanpur (Site 6: $26.^0$ 0.1' 19.67" N and 72^0 34' 34.21" E). After being collected, each plant material was air dried in comparable climatic conditions. After achieving a homogeneous moisture level, they were completely blended to create homogeneous material. For a microcosm experiment, four different fungi—*Aspergillus flavus, Aspergillus fumigates, Aspergillus niger*, and *Aspergillus terreus*—were chosen and inoculated with plant litter from non-fodder plants. The plant pathology lab of the Department of Botany at Jai Narain Vyas University in Jodhpur, India, provided these fungal cultures. The same department's experimental field of ecology laboratory provided the soil, which was then pulverized and sieved through a 2 mm mesh size in preparation for the microsom experiment. Then, over the course of three days, this natural soil was tyndalized by autoclaving at 121^0 C for an hour and overnight oven drying at 80^0 C. (Eivazi and Tabatabai, 1988).

100g tyndalized soil was placed in 250ml cotton plugged conical flasks, followed by litter at a fertility level of 2000 kg N h^{-1} and the fungal culture (on the basis of colony forming unit 3 X 10^9 per treatment). After 15 and 30 days of laboratory incubation, this microcosm experiment setup was recovered, and six different extracellular enzymes were quantified. Acid and alkaline phosphatase (Eivazi and Tabatabai, 1977), glucosidase (Eivazi and Tabatabai 1988), dehydrogenase (Tabatabai, 1982), urease (Douglas and Bremner, 1977a and b), and amidase (Frankenberger and Tabatabai, 1980) were all quantified using standard methodologies. After incubation and enzyme reaction termination, each enzyme activity was kept under control by adding substrate to blank samples (Mathur, 2005). All the experiments were conducted in triplicates.

Statistical analysis

To analyze the effects of three major sources of variation (litter types, fungal species, and withdrawal time) and their interactions on the concentration of the examined enzymatic activities, we utilized Statsoft's (2011 Version 10) three-way ANOVA (Strip-Split design) tool. The intersection plot is divided into subplots in the strip-split-plot design to accommodate a third element, extending the capabilities of the strip-plot design. This design stands out due to the use of four levels of precision for measuring the effects of various factors, with the highest level corresponding to the sub-plot factor and its interactions with other factors, as well as more than three plot sizes (such as horizontal, vertical strip, intersection plot, and subplot). The percentage temporal deviation in various soil enzymes was calculated in relation to litter type and fungal species by using the following formula.

$$\%\,\boldsymbol{Temporal\ Deviation} = \left(\frac{W_2 - W_1}{W_1}\right) \boldsymbol{x}\ \mathbf{100} \quad (1)$$

Where W_1 and W_2 are first and second withdrawal periods. In this study, principal component analysis (PCA) was used for two distinct purposes: (a) to visualize the litter-fungal complex with reference to their proximity or distance with withdrawal periods for each studied enzyme; and (b) to develop a soil quality index with weighted scores assigned to each enzyme. The distance of each litter-fungal complex from the centroid of the PCA bi-blot developed in earlier steps was calculated. A cumulative data set that includes the litter-fungi complex for each enzyme under consideration was produced using these centroid distances. This cumulative data set was used to create the PCA bi-plot, which graphically depicts the overall scenario for various enzymes that is naturally adjusted by litter-fungal-withdrawal as well as their interactions. Such PCA strategies have been supported by many researchers (Laliberte and Legendre, 2010, Mathur and Sundaramoorthy, 2018). The connections between soil enzymes detected during the first and second withdrawal periods, as well as between these two periods, were established using Canonical Correlation Analysis (CCoA). Correlation matrices were converted into a network-like structure for ease of graphical interface. PCA was used to quantify correlations among enzymes with weighted scores using the PAST (Hammar *et al.* 2001) and XLSTAT (2017) software.

Weights in the soil quality index were determined by dividing the percent of variation in the data set explained by the principal component analysis that contributed the indicated variable by the total percentage of variance explained by all the PCs with more than one eigenvector (Mathur and Sundaramoorthy, 2018).

$$\boldsymbol{SQI} = \sum_{i=1}^{n} \boldsymbol{W_i\, x S_i} \qquad (2)$$

W_i = weighting factor of soil enzyme *i* and S_i value of soil enzyme *i*.

Results and Discussion

Acid phosphatase (µg p-Nitrophenol released h^{-1} g^{-1} of soil)

This enzyme had a higher concentration (0.97) with *C. procera* + *A. terreus* after 15 days, but it had a lower concentration (0.65) after 30 days with a different plant-fungal complex (i.e., *A.persica* + *A. niger* Table 1). Except for *A. persica* + *A. niger* and *T. purpurea* + *A. fumigatus*, we found higher concentrations of this enzyme during 15 days withdrawal compared to 30 days with most treatments. We noticed +7.40 and +5.41 percent temporal deviation with these two complexes. (Table 2).

Alkaline phosphatase (µg p-Nitrophenol released h^{-1} g^{-1} of soil)

Higher concentrations were found in *C. procera* + *A. fumigatus* (1.87) and *C. procera* + *A. terreus* (1.38), respectively, at 15 and 30 day intervals (Table 1). While its minimum concentration was recorded at 15 and 30 day intervals with *A. persica* + *A. niger* (0.58) and *A. persica* + *A. fumigatus* (0.87), respectively. With the exception of *C. procera* and *T. purpurea* + *A. terreus*, all four fungal species showed negative temporal deviation (Table 2), indicating that they were recorded more during the first sampling period

Beta-glucosidase (µg p-Nitrophenol released h^{-1} g^{-1} of soil)

During the two sampling periods, higher concentrations of this enzyme (1.19 and 1.14) were detected with the *C. procera* + *A. fumigatus* complex (Table 1). Its minimum concentrations with *T. purpurea* + *A. flavus* (0.35 at 15 days) and *T. purpurea* + *A. fumigatus* (0.35 at 15 days) were determined (0.42 at 30 days). Similar to Alkaline Phosphatase, all four fungal species with *C. procera* and *T. purpura* + *A. fumigatus* exhibited negative temporal deviations (Table 2).

Dehydrogenase (µg TPF released h^{-1} g^{-1} of soil)

Calotropis procera was found to be more conducive for this enzyme with four studied fungi, with higher concentrations recorded with *C. procera-A flavus* (12.68) and *C. procera- A. fumigatus* (12.67) during second sampling periods (i.e., 30 day). During the first sampling period (15

Table 1: Effects of soil fungi and litter types on various soil enzymes during two sampling times.

Variables	AcP		AlP		BG		De		Ur		Am	
	1	2	1	2	1	2	1	2	1	2	1	2
Control	0.39	0.23	0.6	0.46	0.16	0.34	1.74	1.52	164.51	158.24	0.16	0.17
T. purpurea+ A. flavus	0.64	0.54	1.11	1.16	0.35	0.64	3.54	5.33	193.72	286.92	0.25	0.27
T. purpurea+ A. fumigatus	0.47	0.50	0.61	0.91	0.49	0.42	1.84	4.44	202.47	257.71	0.24	0.12
T. purpurea+ A. niger	0.59	0.44	1.07	1.21	0.42	0.43	1.78	8.72	240.76	277.42	0.25	0.08
T. purpurea+ A. terreus	0.64	0.63	1.25	1.21	0.39	0.56	1.54	10.51	249.61	275.81	0.25	0.40
A. persica +A. flavus	0.67	0.44	0.98	1.03	0.40	0.69	1.73	8.19	240.38	338.53	0.24	0.26
A. persica +A. fumigatus	0.59	0.50	0.62	0.87	0.52	0.68	2.01	9.85	240.88	272.76	0.27	0.09
A. persica +A. niger	0.61	0.65	0.58	1.16	0.52	0.87	2.60	10.05	231.31	406.45	0.26	0.24
A. persica +A. terreus	0.72	0.60	0.62	1.17	0.56	0.74	2.51	10.11	254.67	365.23	0.28	0.32
C. procera +A. flavus	0.73	0.50	1.50	0.89	0.97	0.69	3.86	12.68	186.87	293.55	0.34	0.16
C. procera +A. fumigatus	0.88	0.47	1.87	1.12	1.19	1.14	4.49	12.67	235.45	330.11	0.32	0.18
C. procera +A. niger	0.91	0.54	1.70	0.90	1.08	0.75	5.84	10.90	214.09	305.38	0.36	0.13
C. procera +A. terreus	0.97	0.53	1.40	1.38	0.98	0.78	7.52	12.26	236.60	346.77	0.32	0.35

AcP = Acid Phosphatase, AlP = Alkaline Phosphatase, BG = Beta-glucosidase, De = Dehydrogenase, Ur = Urease, Am = Amidase. 1 and 2 are = 15 and 30th days withdrawal, respectively.

Table 2:. Percent temporal deviation in various soil enzymes with Litter types and fungal species

Variables	AcP	AlP	BG	De	Ur	Am
Control	-40.19	-22.67	109.13	-12.91	-3.81	5.14
T. purpurea+ A. flavus	-15.81	5.39	80.16	50.66	48.11	6.34
T. purpurea+ A. fumigatus	5.41	48.77	-14.52	140.64	27.28	-51.16
T. purpurea+ A. niger	-26.40	13.65	2.43	390.87	15.23	-67.68
T. purpurea+ A. terreus	-1.96	-2.95	43.05	580.23	10.49	63.02
A. persica +A. flavus	-33.30	4.40	75.09	372.13	40.83	10.77
A. persica +A. fumigatus	-15.72	40.42	30.50	390.71	13.23	-65.46
A. persica +A. niger	7.40	100.09	67.42	287.11	75.71	-8.52
A. persica +A. terreus	-16.57	89.30	31.32	302.87	43.42	11.16
C. procera +A. flavus	-31.22	-40.57	-29.18	228.40	57.09	-53.16
C. procera +A. fumigatus	-46.41	-39.97	-4.75	182.30	40.21	-45.31
C. procera +A. niger	-40.82	-47.05	-30.02	86.68	42.64	-62.56
C. procera +A. terreus	-45.55	-1.80	-20.83	63.06	46.57	9.48

AcP = Acid Phosphatase, AlP = Alkaline Phosphatase, BG = Beta-glucosidase, De = Dehydrogenase, Ur = Urease, Am = Amidase days), the concentration of this enzyme was lower with *T. purpurea - A. terreus* (1.54) and with *A. persica-A. flavus, T. purpurea - A. niger*, and *T. purpurea-A. fumigatus* (Table 1). *T. purpuria-A. terreus* had the highest percent positive deviation (580.23) over two sampling periods (Table 2). Such findings imply that the efficacy of this litter-fungi complex is time-dependent.

Urease (µg urea hydrolyzed released $h^{-1}g^{-1}$ of soil)

The effects of litter type and fungal species on this enzyme were more pronounced during the second sampling period (Table 1). The highest concentration (406.45) was obtained *with A. persica-A. niger*, while the complex of *C. procera-A. flavus* after 15 days withdrawal was the least effective (186.87) for this enzyme, and the highest positive deviation (75.82) was obtained with *A. persica-A. niger* (Table 2).

Amidase (µg NH_4^+ released h^{-1} g^{-1} of soil)

The effects of litter types and soil fungi on the concentration of this enzyme were greatest (0.40) with *T. purpurea -A. terreus*, but the least (0.08) with the same litter type but with A. niger (Table 1). Impacts of *C. procera* with different soil fungi were recorded more during 15 days withdrawal compared to 30 days. Both positive and negative temporal deviations were recorded for this enzyme and *T. purpurea - A. flavus, T. purpura-A. terreus , A. persica-A. terreus , C. procera-A. terreus* supports concentration of this enzyme with time advancement. However, effect of *T. purpuria-A. niger, T. purpurea-A. fumigatus, A. persica-A. flavus, A. persica-A. niger,* and *C. procera* with *A. flavus, A. fumigatus, A. niger* on enzyme concentration held back with time advancement (Table 2).The results of the analysis of variance (ANOVA) revealed that all of the studied variables, including litter type, fungal species, and sampling time, as well as their interactions, caused significant variations in alkaline phosphatase, dehydrogenase, and urease enzymes. Significant differences in acid phosphatase were brought about by litter and fungal species, as well as sampling time. Their interactions, however, were insignificant. For beta-glucosidase, neither the sampling factor nor its interaction with fungal species were significant. For amidase, litter types and their interactions with sampling time were not significant.The effects of predictors on enzyme activities are clearly visible as we have got many fold increase in concentration of studied enzyme (Table 1) in comparison to control. However, treatments like *T. purpurea-A terreus* (15 days) for dehydrogenase (-10.70%) and *T. purpurea-A. fumigatus* (-25.47%), *T. purpurea – A. niger* (-49.74%), *A. persica-A. fumigatus* (-41.07%) and *C. procera-A. niger* (-16.81%) for amidase (30 days) revealed their negative impacts on these enzymes with compared to control. Bi-plots of all the soil enzymes showed that first two axes (F1 and F2) together accounted 100 per cent variabilities (69.41 and 30.58, 64.06 and 35.79, 86.11 and 13.88, 75.86 and 24.12, 81.96 and 18.03, 51.60 and 48.39 for acid phosphatase, alkaline phosphatase, beta-glucosidase, dehydrogenase, urease and amidase, respectively). Such results indicated the appropriate use of this tool as the cumulative percentage of variance for each enzyme approached >80 per cent. Certain specific trends were visualized that were pertains to litter-fungal complex and with withdrawal time (a) *C. procera* with *A. fumigatus*, *A. niger* and with *A. flavus,* was more conducive for acid phosphatase, alkaline phosphatase, beta-glucosidase and for amidase with 15 days period, (b) *A. niger* and *A. terreus* with litter like *T. purpurea , A. persica* and *A. fumigatus*, *A. terreus* with *A. persica* and with *C. procera* were more effective for dehydrogenase enzyme with 30 days, while *C. procera* with *A. niger* and with *A terreus* having an intermediate temporal positive impact for this enzyme (c) *T. purpurea* with *A. fumigatus, A. niger, A. terreus* showed a temporal progressive pace for urease and a decreased temporal pace were showed by *T. purpurea* with *A. fumigatus, niger* and with *A. persica - A. fumigatus* for amidase enzyme.Further with these PCA analysis, the factorial score (distance from centroid) for each litter-fungi complexes along with control and for enzymes were calculated and are presented in (Table 3). With this data set a bi-plot was further constructed (Figure 1) representing all the studied enzymes and litter-fungal complex along with accommodated withdrawal period.

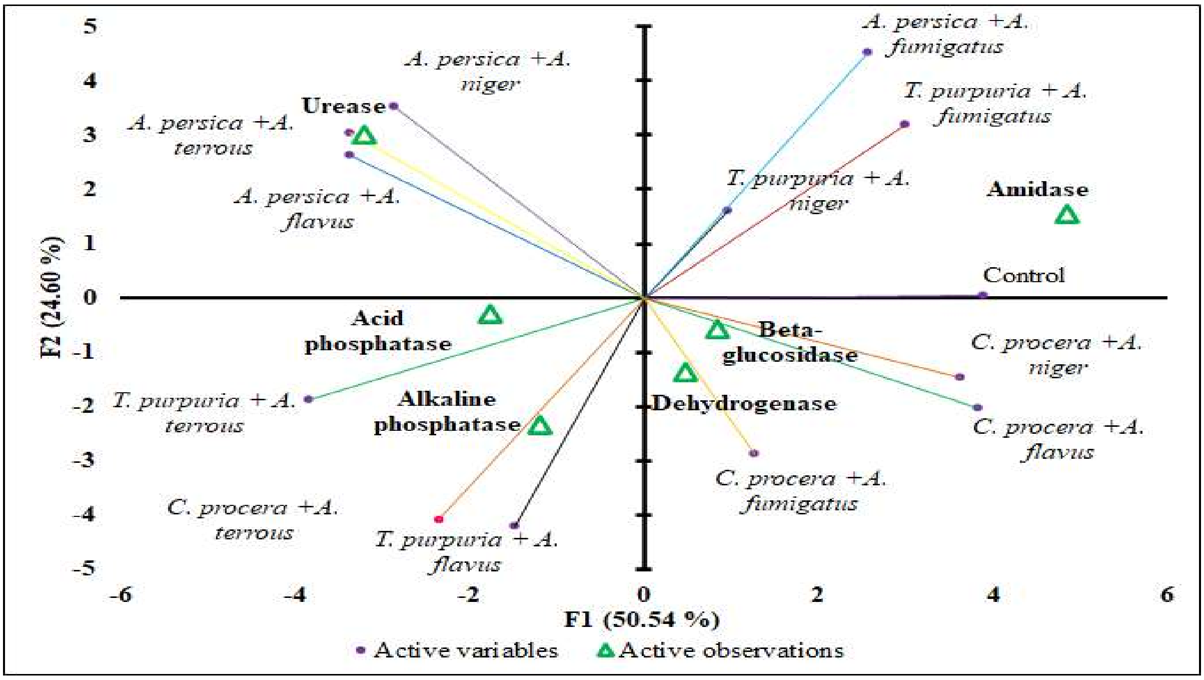


Figure 1: PCA Bi-plot with Factorial Score of Different Enzymes with different treatments.

For this the per cent variability explained by first four axes were, 50.54, 24.60, 13.15 and 7.7 with their eigen value, 6.5, 3.19, 1.7 and 1.0, respectively. This approach suggested a more cumulative relationship among enzyme-litter-fungi complex and revealed that (a) *A. persica* with fungi like *A. terreus* , *A. niger, A. flavus* are crucial one for the urease (b) *T. purpurea* with *A. fumigatus* and *A. niger* and *A. persica- A. fumigatus* were more effective for amidase, (c) *C. procera* with *A. fumigatus, A. niger* and with *A. flavus* were more supportive for beta-glucosidase and dehydrogenase, (d) *C. procera-A. terreus* and *T. purpurea- A. flavus* found to be effective with alkaline phosphatase and (e) Acid phosphatase having more proximity with *T. purpurea -A. terreus* . With this tool our biochemical soil quality equation was developed which can be equate as

$$SQI = \sum_{i=1}^{n} -0.68 \text{ Acid Phosphatase} - 0.46 \text{ Alkaline Phosphatase} + 0.32 \text{ Beta} - \text{glucosidase} + 0.18 \text{ Dehydrogenase} + 1.89 \text{ Amidase} - 1.25 \text{ Urease} \quad (3)$$

Here, the numbers represent the distance of each enzyme from the centroid and sign represent their relative position on PCA bi-plot (Figure 1). Use of PCA in the development of a soil quality index are provided by many workers also (Laishram *et al.,* 2012; *Cherubin et al.,* 2016; Guo *et al.,* 2018). Significant correlations among enzymes (studied during first and second withdrawal and between enzymes quantified during these two sampling periods and among enzymes) are depicted in Figure 2. CCoA revealed that urease during the first withdrawal period not related to any other studied enzymes, however, it showed correlation with almost all enzymes during second sampling period except amidase.

Significant intra-relationship was also recorded between BG_1 and BG_2 (r^2 = 0.72). Interestingly, amidase during the first sampling period was significantly correlated with all studied enzymes except urease, however, during the second sampling period, it was linked with alkaline phosphatase (AlP_2) only (r^2 = 0.54). Correlations among weighted enzymes (Figure 3) suggested that both acid phosphatase as well as alkaline phosphatase related to all other enzymes except amidase. Amidase (r^2 = 0.55) and urease (r^2 = 0.56) were correlated with beta-glucosidase and with alkaline phosphatase, respectively. The strongest relationships were presented between BG_1-Am_1 (r^2 = 0.92) and between BG_w – De_w (r^2 = 0.87).

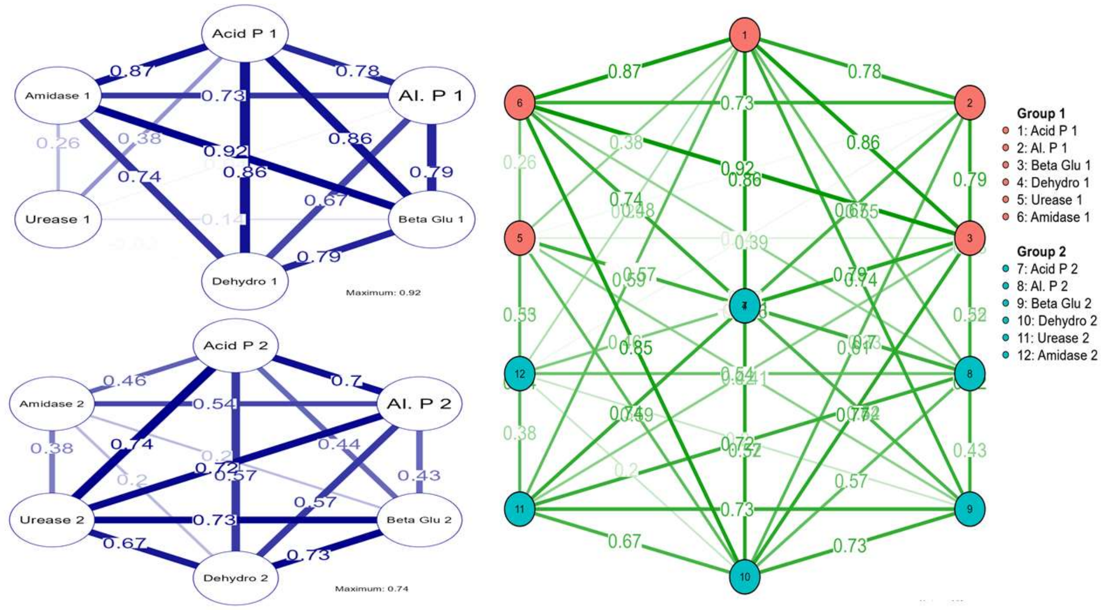


Figure 2: Correlation matrix for different soil enzymes (temporal, and combined)
Significant relationships are indicated by bold lines). Acid P = Acid Phosphatase; Al P = Alkaline Phosphatase; Beta Glu = Beta-glucosidase; Dehydro = Dehydrogenase. 1, 2, represents the 15 and 30th days withdrawals.

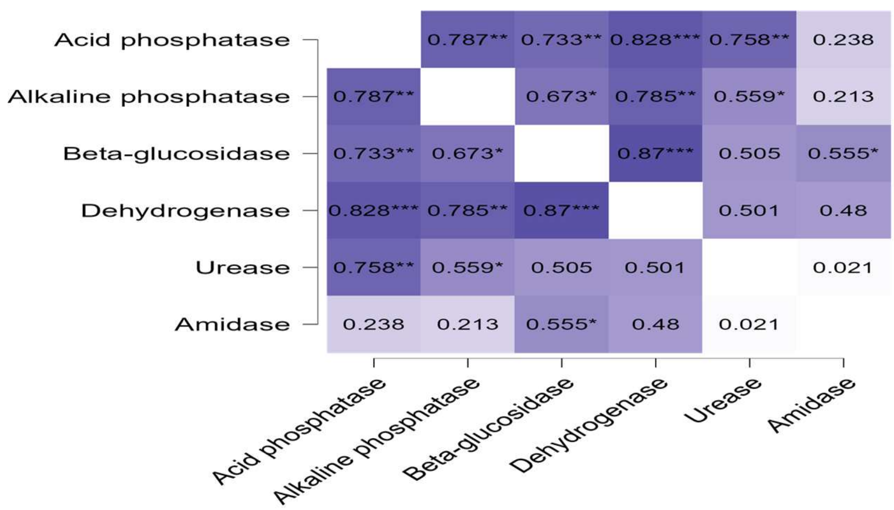


Figure 3: orrelation matrix for different soil enzymes (weighted)

Extracellular enzyme activities (EEAs) are indicators of both soil microbial activity and nutrient availability for plants. However, it is unclear how EEAs change in response to litter and micro-organism inputs particularly in the Indian hot desert. The effects of the desertic environment on soil enzymes have been explored with different predictors like plantation regime of *Caragana microphylla* (Cao *et al.* 2008), soil properties (Stursova and Sinsabaugh, 2008; Buscardo *et al.* 2021), biological soil crust (Liu *et al.* 2014), effects of rainfall treatments (Laura *et al.* 2015), long term restoration of desertified land (Zhang *et al.* 2015a), effects of grazing and cultivation (He *et al.* 2017). The temporal dynamics of enzyme activities should reflect the availability of substrates (Zhang *et al.* 2015b). Our findings address this discrepancy by indicating that soil enzyme activities vary with litter

Table 3. Factorial Score for different enzymes and treatments calculated with PCA

Variables	AcP	AlP	BG	De	Ur	Am
Control	-2.69	-2.27	-1.68	-1.78	-2.5	-1.23
T. purpurea+ A. flavus	0.09	0.4	-0.54	-0.52	-0.73	-0.68
T. purpurea+ A. fumigatus	-0.81	-1.02	-0.88	-1.23	-0.82	0.27
T. purpurea+ A. niger	-0.73	0.48	-0.99	-0.49	0.15	0.62
T. purpurea+ A. terreus	0.56	0.74	-0.68	-0.25	0.32	-1.7
A. persica +A. flavus	-0.4	-0.15	-0.33	-0.6	0.72	-0.85
A. persica +A. fumigatus	-0.36	-1.1	-0.15	-0.22	0.11	0.85
A. persica +A. niger	0.62	-0.36	0.35	0	1.12	-0.32
A. persica +A. terreus	0.73	-0.29	0.08	-0.01	1.27	-0.57
C. procera +A. flavus	0.15	0.2	0.65	0.87	-0.81	1.33
C. procera +A. fumigatus	0.52	1.39	2.24	1.07	0.54	0.96
C. procera +A. niger	1.04	0.52	1.02	1.2	-0.13	1.7
C. procera +A. terreus	1.26	1.43	0.92	1.98	0.72	-0.35

AcP = Acid Phosphatase, AlP = Alkaline Phosphatase, BG = Beta-glucosidase, De = Dehydrogenase, Ur = Urease, Am = Amidase

and fungal species types, as well as their combined actions. In this study, the temporal increase in enzyme activities such as dehydrogenase and urease could be attributed to litter's dual role in (a) providing suitable substrate for microbial activities and (b) contributing to the formation and stability of soil aggregates. These findings are consistent with those of Acosta-Martinez *et al.* (2003) and Fang *et al.* (2013).Using saline plant species like *Asteriscus maritimus, Arthrocnemum macrostachyum, Frankenia corymbosa, Halimione portulacoides, Limonium cossonianum, Limonium caesium, Lygeum spartum*, and *Suaeda vera*, Caravaca *et al.* (2005) reported significant variations in dehydrogenase, urease, phosphatase, and beta-glucosidase. They also came to the conclusion that this alteration may be attributable to various microbial communities connected to the rhizosphere soil or to various quantities of microbial biomass carbon.Effects of monoculture and polyculture practices on rhizosphere enzyme activities were studied by Yang *et al.* (2007), Fang *et al.* (2013) and Bogat and Walczak (2022). They concluded that cause -effect relationships between type of cultural practices and modification in rhizosphere enzyme concentration cannot be generalized and they are region and species specific. The seasonal dynamics of soil enzyme activities in response to leaf litter of *Cassia siamea, Shorea robusta, Eucalyptus citriodora, Acacia auriculiformis, Anacardium occidentale, Dalbergia sissoo* was reported by Venu *et al.* (2016). Two fundamental lines of thought can be contributed in light of the recent findings: (a) different litter-fungal species complexes functioned differently at the level of the specific enzyme. Particularly for beta-glucosidase, amidase, acid phosphatase, and alkaline phosphatase, their effects evolved with time. The aforementioned factors led to an increase in dehydrogenase and urease activity over time. All four fungi containing *C. procera* suppress the activities of acid phosphatase, alkaline phosphatase, and beta-glucosidase with temporal backwash (i.e., more at 15 days and lesser after 30 days). Such patterns were seen for amidase except with C. procera-A. terreus. As a result of this study, a litter-fungi species specific complex can be recommended for the studied enzyme, (b) all enzyme predictors: We created a bio-chemical soil quality index using PCA and CCoA, in which each enzyme was weighted with numerical values based on their relationships with litter type (plant species), fungi species types, and withdrawal period (temporal factor). As a result, faith in studied enzymes with litter-fungi-time complex is provided.At specific enzyme levels, our current findings suggest that (a) urease activities were modulated by *Aerva persica* in collaboration with fungi such as *A. terreus, A. niger*, and A. *flavus* (b) amidase concentration was effectively controlled through litter of a legume plant species *T. purpuria* in collaboration with fungi such as *A. fumigatus, A. niger*, and *A. persica* (c) Beta-glucosidase and dehydrogenase were most supportive by combined action of *C. procera* with *A. fumigatus, A. niger, A. flavus* (d) *C. procera-A. terreus* and *T. purpurea-A. flavus* complexes, on the other hand, were more effective for alkaline phosphatase and (e) acid phosphatase having more proximity with *T. purpurea-A. terreus*.Our correlation analysis revealed the complex relationships between enzymes using an enzyme-specific approach. Canonical Correlation Analysis (CCoA) revealed that urease did not correlate with any other enzymes studied during the first withdrawal period, but it did correlate with almost all enzymes except amidase during the second sampling period. Surprisingly, amidase was significantly correlated with all studied enzymes except urease during the first sampling period, but only alkaline phosphatase (AlP_2 $r^2 = 0.54$) during the second sampling period. Correlations among weighted enzymes revealed that acid phosphatase and alkaline phosphatase were both related to all other enzymes except amidase. These findings are consistent with those of Acosta-Martinez *et al.* (2003) and Mathur (2020).The region's first compressive effort employing locally accessible desert plant species and fungus resulted in the development of a soil quality index. This index considers how time, litter, and different fungal species behave. This index, however, may not be applicable to other scenarios such as cultural practices (addition of fertilizers, irrigation types, soil tillage, fallow land practice, and so on), land use (forest land, agricultural land, orchid, and so on), mining, and rehabilitation practices because the studied data set is restricted to controlled conditions. Such practices unquestionably have a unique interaction with the biochemical properties of soil.Future work will therefore involve validating and improving this index using numerous scenarios.

Conclusion

The current study is the first from the hot, arid region of India to look at the interaction and temporal effects of diverse fungus species and wild plant species used as litter sources on soil enzyme concentrations. Using PCA and CCoA, we developed a bio-chemical soil quality index, where each enzyme was weighted with numerical values based on their associations with the kind of litter (plant species), fungal species types, and withdrawal period (temporal factor). The idea of sustainable utilization of arid wild species that are neither cultivated nor have direct market potential can be used to determine the importance of the current study (provisional ecosystem services). They can therefore be utilized as regular litter for a variety of crops to maintain soil fertility.

Acknowledgement

The authors are thankful to the Head, Department of Botany for facilities, UGC-CAS and DST-FIST are acknowledged for instrumental facilities. The corresponding author is thankful to the Director, CAZRI for granting study leave during the research period.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Acosta-Martinez, V., Zobeck, T.M., Gill, T.E., & Kennedy, A.C. (2003) Enzyme activities and microbial community structure in semiarid agricultural soils. *Biology and Fertility of Soils*, 38, 216-227.

Basak, B., & Dey, A. (2016) Bioremediation approaches for recalcitrant pollutants: potentiality, successes and limitation. In: Ashok KR, Vindo KD, Editors. Toxicity and Waste Management Using Bioremediation. IGI Global Engineer Science, Series Advances in Environmental Engineering and Green Technologies. Hershey PA, USA. 178-197.

Bogati, K., & Walczak, M. (2022) The Impact of Drought Stress on Soil Microbial Community, Enzyme Activities and Plants. *Agronomy*, 12, 189. https://doi.org/10.3390/agronomy12010189

Buscardo, E., Souza, R.C., Meir, P., Gemi, J., Schmidt, S.K., da Costa, A.C.L. & Nagy, L. (2021). Effects of natural and experimental drought on soil fungi and biogeochemistry in an Amazon rain forest. *Communications Earth and Environment* 2, 55 https://doi.org/10.1038/s43247-021-00124-8

Cao, C., Jian, D., Teng, X., Jiang, Y., Liang, W., & Cui, Z. (2008) Soil chemical and mircrobiogical properties along a chronsequence of *Caragana microphylla* Lam. Plantations in the Horqin sandy land of northeast china. *Applied Soil Ecology,* 40, 78-85.

Caravaca, F., Alguacil, M.M., Torres, P., & Roldan, A. (2005) Plant type mediates rhizospheric microbial activities and soil aggregation in a semiarid Mediterranean salt marsh. *Geoderma*, 124**,** 375-382.

Cherubin, M.R., Karlen, D.L., Cerri, C.E.P., Franco, A.L.C., Tormena, C.A., & Davies, C.A. (2016) Soil Quality Indexing Strategies for Evaluating Sugarcane Expansion in Brazil. *PLoS ONE*, 11(3), 1-26.

Douglas, L.A., & Bremner, J.M. (1970b). Colorimetric determination of microgram quantities of urea. *Analytical Letters*, 3,79-87.

Douglas, L.A., & Bremner, J.M. (1970a). Extraction and colorimetric determination or urea in soils. *Soil Science Society of America Proceeding: Soil Science*, 859-862.

Eivazi, F., & Tabatabai, M.A. (1977) Phosphatases in soils. *Soil Biology and Biochemistry* 9, 167-172.

Eivazi, F., & Tabatabai, M.A. (1988) Glucosidases and glactosidases in soils. *Soil Biology and Biochemistry*, 20(5), 601-606.

Fang, S., Liu, D., Tian, Y., Deng, S., & Shang, X. (2013) Tree Species Composition Influences Enzyme Activities and Microbial Biomass in the Rhizosphere: A Rhizobox Approach. *PLoS ONE*, 8(4),1-11

Frankenberger, JrW.T., & Tabatabai, M.A. (1980) Amidase activity in soils: Method of Assay. *Soil Science Society of America Journal*, 44, 282-287.

Gaur, D., Jain, P.K., & Bajpai, V. (2012). Production of extracellular α amylase by thermophilic *Bacillus* sp. isolated from arid and semi-arid region of the Rajasthan, India. *Journal of Microbiology and Biotechnology Research,* 2(5), 675-684.

Guo X.M., Tong-qian, Z., Wen-ke, C., Chun-yan, X., & Yu-xiao, H. (2018) Evaluating the effect of coal mining subsidence on the agricultural soil quality using principal component analysis. *Chilean Journal of Agricultural Research*, 78(2),173-182.

Hammar, O., Harper, D.A.T., & Ryan. P.D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologica Electronica*, 4 (1), 9pp.

Jagadish, C.T., Subhash, C.M., & Shyam, K. (2001) Influence of straw size on activity and biomass of soil microorganisms during decomposition. *European Journal of Soil Biology*, 37,157–160.

Laishram, J., Saxcena, K.G., Maikhuri, R.K., & Rao, K.S. (2012). Soil quality and soil health: a review. *International Journal of Ecology and Environmental Sciences*, 38(1), 19-37.

Laliberte, E., & Legendre, P. (2010) A distance-based framework for measuring functional diversity from multiple traits. *Ecology*, 9(1), 299-305.

Laura, M.L., Sinsabaugh, R.L., Collins, S.L., & Thomey, M.L. (2015) Soil enzyme responses to varying rainfall regimes in chihuahuan desert soils. *Ecosphere,* 6(3), 40.1-10

Liu, Y., Yang, H., Li, X., & Xing, Z. (2014) Effects of biological soil crust on soil enzymes activities in revegetated areas of the tengger desert, China. *Applied Soil Ecology,* 80, 6-14.

Luo, L., Meng, H., & Gu, J. (2018). Microbial extracellular enzymes in biogeochemical cycling of ecosystems. *Journal of Environmental Management*, 175:539-549.

Maharjan, M., Sanaullah, M., Razavi, B.S., & Kuzykov, Y. (2017). Effect of land use and management practices on microbial biomass and enzyme activities in subtropical top-and sub-soils. *Applied Soil Ecology*, 113:22-28.

Mathur, M. (2005). Ecology and prospecting of some medicinal plants of aphrodisiac potential. Ph.D. thesis. Jai Narain Vyas University, Jodhpur, Rajasthan, India.

Mathur, M. (2020). Comportments of arid grazing land plant diversity: a temporal assessment with bottom-up and top-down factors. *Range Management and Agroforestry*, 41 (2), 200-208.

Mathur, M., & Pandey, C.B. (2016). Vegetation ecology of hot arid and semi arid grazing lands of India. In: Gaur M, Pandey CB, Goyal RK (eds) Remote sensing for natural resources monitoring and management. Scientific Publishers, Jodhpur, pp 213–242

Mathur, M., & Sundaramoorthy, S. (2009). Mineral Composition in *Corchorus depressus* at hHeterogeneous environmental conditions and their relationships with bottom-up, top-down, and plant metabolite factors. *Communications in Soil Science and Plant Analysis*, 40(13), 2028-2043.

Mathur, M., Suthar, M.S., Gehlot, P., & Sundaramoorthy, S.S. (2019) Assessment of litter availability and its quality plasticity of four wild species of the Indian arid environment. *Tropical Ecology*, https://doi.org/10.1007/s42965-019-00034-z

Mathur. M., & Sundaramoorthy, S. (2018) Appraisal of arid land status: a holistic assessment pertains to bio-physical indicators and ecosystem values. *Ecological Processes*, 7(41), 1-15.

Oseni, O.A. (2011) Production of microbial protease from selected soil fungal isolates. *Nigerian Journal of Biotechnology*, 23, 28-34.

Pajares, S., Gallardo, J.F., Masciandaro, G., Ceccanti, B., & Etchevers, J.D. 2(011) Enzyme activity as an indicator of soil quality changes in degraded cultivated acrisols in the Mexican trans-volcanic belt. *Land Degradation and Development*, 22, 373-381.

Ren, Q., Song, H., Yuan, Z., Ni, X., & Li, C. (2018). Changes in soil enzyme activities and microbial biomass after re-vegetation in the three gorges reservoir, China. *Forests,* 9, 249:

Samuel, A. D., Brejea, R., Domuta, C., Bungau, S., Cenusa, N., & Tit, D. M. (2017). Enzymatic indicators of soil quality. *Journal of Environmental Protection and Ecology*, 18(3), 871-878.

StatSoft, Inc. (2011) STATISTICA (Data Analysis Software System), Version 10. http://www.statsoft.com

Stursova, M., & Sinsabaugh, R.L. (2008). Stabilization of oxidative enzymes in desert soil may limit organic matter accumulation. *Soil Biology and Biochemistry*, 40, 550-553.

Tabatabai. M. A. (1982) Soil enzymes In: Page A.L., Miller R.H., Keeney D.R. (eds.): Methods of Soil Analysis, Part 2. American Society of Agronomy and Soil Science Society of America, Madison.

Tarafdar, J.C., Yadav, R.S, & Niwas, R. (2002). Relative efficiency of fungal intra-and extracellular phosphatases and phytase. *Journal of Plant Nutrition and Soil Sciences*, 165, 17-19.

Utobo, E.B., & Tewari, L. (2015). Soil enzymes as bio-indicators of soil ecosystem status. *Applied Ecology and Environmental Sciences*, 13(1), 147-169.

Veeraragavan, S., Duraisamy, R., & Mani, S. (2018) Seasonal variation of soil enzyme activities in relation to nutrient and carbon cycling in Senna alata (L.) Roxb invaded sites of Puducherry region, India. *Geology Ecology and Landscapes*, 2(3), 155-168.

Venu, N., Reddy, S.V., & Reddy, M. (2016). Estimation of soil enzyme activity with respect to decomposition of leaf litter types. *Biolife*, 4 (1), 155-163.

Xiang, Y., An, S., Cheng, M., Liu, L., & Xie, Y. (2018). Changes of soil microbiology properties during grass litter decomposition in loess hilly region, China. *International Journal of Environmental Research and Public Health*, 15, 1797.

XLSTAT. 2017. Data Analysis and Statistical Solution for Microsoft Excel, Addinsoft, Paris, France.

Yang, R., Tang, J., Chen, X., & Hu, S. (2007) Effects of coexisting plant species on soil microbes and soil enzymes in metal lead contaminated soils. *Applied Soil Ecology*, 37, 240-246.

Zhang, S., Li, J., Yang, X., & Sun, B. (2015a). Effects of soil management regimes on biochemical properties of loess soil. *Journal of Soil Science and Plant Nutrtion,* 15(3), 711-725.

Zhang, Y.L., Chen, L.J., Chen, X.H., Tan, M.L., Duan, Z.H., & Wu, Z. J. (2015b). Response of soil enzyme activity to long-term restoration of desertified land. *Catena*, 33, 64-70.

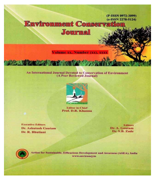
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 98-104, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Geospatial mapping of ecoraces of tasar silkworm (*Antheraea mylitta* Drury) using remote sensing and geographic information system techniques

Priti Pragyan Ray ✉

Department of Zoology, Shailabala Women's Autonomous College, Cuttack, Odisha, India

Barsha Barala

Department of Zoology, Shailabala Women's Autonomous College, Cuttack, Odisha, India

ARTICLE INFO

Received : 16 September 2022
Revised : 29 December 2022
Accepted : 03 January 2023

Available online: 09 April 2023

Key Words:
Bombyx sp.,
GDS
GPS
Lepidoptera

ABSTRACT

Tropical Tasar silkworm *Antheraea mylitta* Drury (Family: Saturniidae) produces Tasar silk which has very high demand globally and because of their wide range of distribution in tropical regions, they have adapted to different niches forming different ecoraces. In Odisha, alone seven types of ecoraces of *A. mylitta* have been reported, namely Modal, Sukinda, Nalia, Jata-Daba, Adaba, Umerkote, and Boudh. These ecoraces show differences in their phenotypes, genetic constitution, fecundity, voltinism, etc. In the past few decades, there is the substantial deterioration of habitats due to many anthropogenic activities. This has resulted in a large decline in wild Tasar cocoon production. Lepidopterans are accepted as ecological indicators of ecosystem health and it is apprehended that through anthropogenic and climatic factors this precious genetic resource, which took millions of years to evolve, may face the threat of extinction shortly if adequate conservation measures are not taken. This paper attempts the geospatial mapping of these ecoraces in the state of Odisha through RS and GIS tools, which will provide a greater scenario for their conservation.

Introduction

The Tasar (tussah/tussor/tussore) silkworm is a semi-domesticated wild silkworm that belongs to the family Saturniidae. Almost 35 species of *Antheraea* are responsible for the production of wild silk. Out of those 35 species, 3 species are exploited in India for wild silk culture, i.e. Tropical Tasar silkworm (*A. mylitta*), Temperate Tasar silkworm (*A. proylei*), and Muga silkworm *(A. assama)* (Jolly, 1985). The *A.mylitta* wild distribution is spread over West Bengal, Odisha, Andhra Pradesh, Jharkhand, Bihar, Chhattisgarh, Madhya Pradesh, and Maharashtra states of India (Sinha, 2003). Observations indicated that the distribution of *A. mylitta* Drury is almost between 12-31°N latitude and 72-96°E longitude. To date almost 64 ecoraces have been reported (Rao *et al.* 2003). In the state of Odisha total number of 7 ecoraces have been reported, namely Modal, Sukinda, Nalia, Jata-Daba, Adaba, Omarkote, and Boadh/Boudh (Table-1). These ecoraces are mainly restricted to tropical moist deciduous forest areas (Sinha and Prasad, 2011). Geospatial technology includes GIS (Geographical Information System), GPS (Global Positioning System), and satellite-based technologies such as RS (Remote sensing). GIS mostly captures image data, its input, update, transformation, manipulation, query, modeling, analysis, and visualisation of geographically referenced information through a set of computer programs (Bonham Carter, 2014). GPS provides positioning, navigation, and timing (PNT) services by capturing data from satellites (Eldredge *et al.* 2010). RS is an earth observation instrument that delivers regional information on climatic factors and landscape features (Saran *et al.,* 2020). For regional and spatial information, GPS and RS are useful. But for geospatial data integration as well as accurate geospatial analysis in a real-time manner,

Corresponding author E-mail: *wonderpriti@gmail.com*
Doi:https://doi.org/10.36953/ECJ.15052468

Table 1: Ecoraces found in Odisha and their preferred host plant (Vijayan *et al.,* 2010)

SN	ECORACE	PREDOMINANT FOOD TYPE	SOIL TYPE	FOREST TYPE
01	Modal	*Shorea robusta*	Red Loamy	Tropical moist deciduous
02	Sukinda	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
03	Jata-Daba	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
04	Umerkote	*Shorea robusta*	Red Loamy	Tropical moist deciduous
05	Boudh	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
06	Adaba	*Terminalia arjuna, Terminalia tomentosa*	Red Loamy	Tropical moist deciduous
07	Nalia	*Shorea robusta*	Red Loamy	Tropical moist deciduous

GIS has been proven very useful (Zhen *et al.,* 2010). In order to preserve the natural biodiversity present in the *Antheraea mylitta* species population, attempts are made to understand and conserve their ecoraces. These ecoraces conservation (in-situ and ex-situ) links genetic diversity to utilisation, protecting diverse gene pools, habitats, and ecosystems for human socio-economic needs (Metzler and Zebold, 1995). Through their ecorace conservation, we can utilise their valuable genes in enhancing productivity (Mirhosein *et al.,* 2004) and building their new population through the genetic hybridisation technique (Kumaresan *et al.,* 2004). The increasing international demand for Tasar silk, their abundance of host plants, and the limited option of productivity of ecoraces for commercial rearing demand the exploration of these ecoraces (Ojha *et al.,* 2009). Previously, Sinha and Prasad (2011) mapped the distribution of all 44 ecoraces of *A. mylitta*. Sahay *et al.* (2011), have identified the Tasar culture growing regions of Odisha. Renuka and Shamitha (2015) have also mapped the location of Daba, Bhandara, Andhra local, Modal, Sukinda, and Railey ecoraces in India. But there is no particular map available for all the ecorace found in Odisha yet. Hence the need for a map showing the location of different ecoraces in Odisha is a must for further development of sericulture in the state. In this current paper, an attempt has been made to map all the available ecoraces of Tasar silkworm (i.e. Modal, Sukinda, Jata-daba, Omarkote, Boudh, Adaba, and Nalia) and their geographical locations in different regions of Odisha (Table 2).

Material and Methods

Study area:

Odisha is a state of Eastern coastal India, situated between latitude 17°78'N and 22°73'N and longitude 81°37'E and 87°53'E, covering an area of 1,55,707km^2, which is 4.87% of the total area of India, with a coastline of 450 km. According to the 2021 forest cover estimation published by Odisha State Forest Department (https://www.odisha forest.in), the total forest cover of Odisha is almost 61,204km^2, which makes up 39.31% of the total land of the state. Out of 30 districts of Odisha, most of the ecoraces of Tasar silkworm *A. mylitta* are confined to Mayurbhanj, Boudh, Gajapati, Jajpur, Kalahandi, Nawarangpur, and Sundergarh districts.

Non spatial data collection:

For individual location identification of different ecoraces and their cultivation grounds, both primary and secondary data have been used. Secondary data have been derived from different research papers available about ecoraces and their endemic locations from different authors. For Modal, Nalia, Sukinda, and Jata-Daba both primary and secondary data have been utilised. For Boudh, Umerkote, and Adaba, only primary data have been collected from forest personnel of those regions and regional TRCS (Tasar Rearers Cooperative Societies) centers.

Map plotting:

The mapping has been done with intensive use of Geo-information technology like RS (Remote Sensing), and GIS (Geo Information Systems) (Fig-1).The source political map of Odisha with its 30 districts has been obtained from https://gisodisha .nic.in. The Forest boundary map of Odisha was collected from official website of the Odisha state forest Department (https://www.odisha forest.in). The forest map data belongs to the 2021 official data record issued by the government of Odisha, mapped with IRS-Resourcesat 2- LIS III, with a spatial resolution of23.5m and a scale of 1:50,000. For the protected areas and their spatial data collection the official boundary map of different sanctuaries and national parks has been obtained from the Forest and Environment Department of Odisha http://odishawildlife.org/map.html. Shapefiles of

Table 2: Ecoraces and their geographical distribution in Odisha

Ecorace Name	Location Name	Location On Map	Average Elevation Asl (In Meters)	District
MODAL	Gudgudia	21°52'59"N 86°15'19"E	379	Mayurbhanj (Similpal National Forest)
	Sarat	21°26’39”N 86°20’38”E	203	Mayurbhanj (Similpal National Forest)
	Lulung	21°56’42”N 86°33’20”E	300	Mayurbhanj (Similpal National Forest)
	Arjunvilla Village	22°06’14”N 86°15’24”E	335	Mayurbhanj (Similpal National Forest)
	Khadambeda	22°10’55”N 86°25’34”E	358	Mayurbhanj (Similpal National Forest)
	Kitabeda	22°10'07"N 86°25'16"E	350	Mayurbhanj (Similpal National Forest)
SUKINDA	2.1 Ankurpali	22°19'21"N 84°53'36"E	242	Jajpur
	2.2 Sukaran	20°57'30"N 85°57'57"E	223	Jajpur
	2.3 Kundal	20°39'52"N 86°10'28"E	72	Jajpur
	2.4 Kansa	21°91'54"N 85°56'53"E	63	Jajpur
NALIA	3. Raghubeda Forest Range	21°28'52"N 85°46'33"E	434	Keonjhar
JATA-DABA	4.1 Thakurmunda	21°31'24"N 86°09'39"E	329	Mayurbhanj
	4.2 Kendujuiani	21°39'03"N 86°07'03"E	346	Mayurbhanj
	4.3 Mahuldiha	21°26'55"N 86°10'39"E	268	Mayurbhanj
	4.4 Kuldiha	21°27'04"N 86°42'56"E	91	Mayurbhanj
ADABA	5. Adaba	19°40'21"N 84°10'25"E	386	Gajapati
UMERKOTE	6. Umerkote/Umarkote	19°40'21"N 82°12'09"E	612	Nabarangpur
BOUDH	7. Satkosia Range	20°35'12"N 84°27'06"E	320	Boudh

district boundary and forest boundary were converted to KML to find the locations on Google Earth in order to see the present status of the forest in the state. The shape files have been converted to UTM (Universal Transverse Mercator) to calculate areas of cultivation ground and for correct placements of scale bones. The next step was to pin mark different villages of Tasar silkworm Ecoraces. For this purpose individual village or area location was pinned using Google Earth-9 software. The GIS of google earth is supported by Google Landsat 8 with Copernicus sentinel (Data SIO, NOAA, U.S. Navy, NGA, GEBCO). For individual precise pinning of different villages that are located within 60 km^2 of area of each other, Maxar technologies, CNES/Airbus and Terrametrics source help of same Google Earth-9 software has been taken. The project file of pinned locations with georeferences of ecorace clusters in different districts of Odisha that has been done with Google Earth 9 software. The forest cover map and pinned location map have been overlaid together to create a new more informative map of our interest cultivation grounds, nearby forest covers, along with to which district or range the villages belong to can be shown together in a single map image. Area calculation of different cultivation ground or forest ranges in different districts has been done through ISRO- CHAMAN

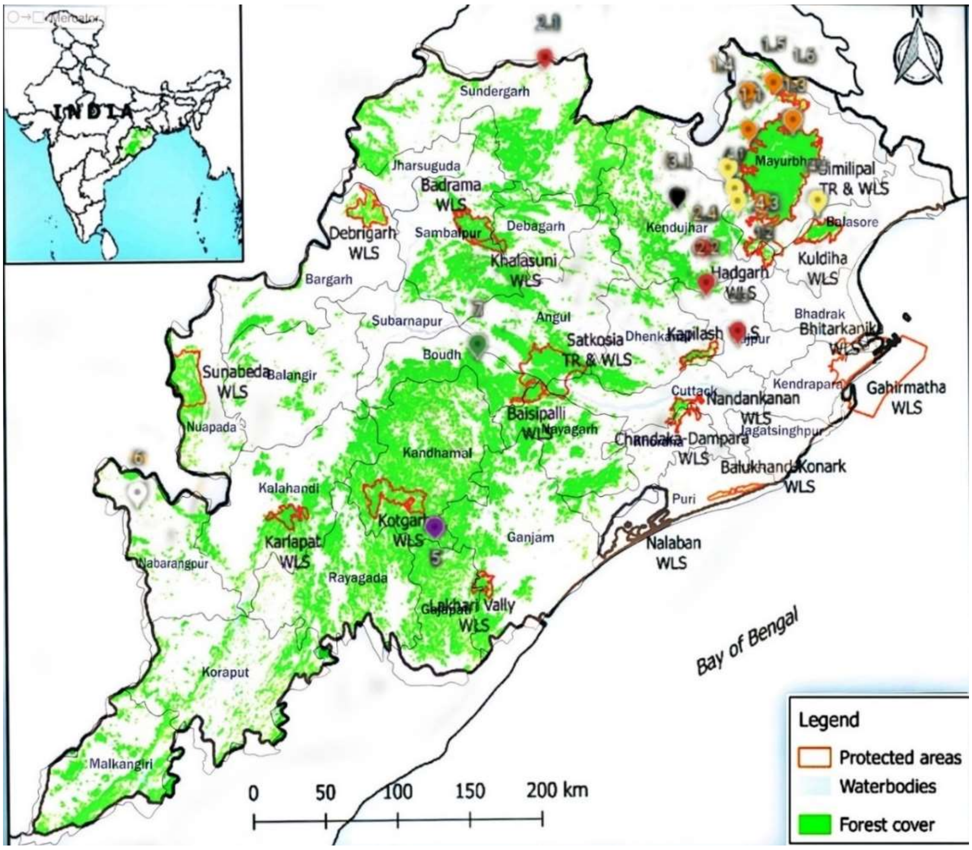


Figure 1: Location mapping of different ecoraces of Tasar silkworm *A.mylitta*

(Coordinated Programme on Horticulture Assessment and Management using Geoinformatics) and Bhuvan-2D and Bhuvan-3D websites. After this appropriate band combination, necessary contrast enhancement has applied to make the image more interpretable.

Results and Discussion

The 7 ecoraces of Tasar silkworm *Antheraea mylitta* found in Odisha are Modal, Sukinda, Nalia, Jata-Daba, Boudh, Omerkote, Adaba.

Modal: The modal ecorace is endemic to the Similpal National Park and Biosphere Reserve and to nearby regions of Mayurbhanj. It is one of the largest and highest-yielding Tasar ecorace. This ecorace is exclusively wild, univoltine, almost disease free, and produces the heaviest cocoons. This ecorace alone contributes to 19% of raw silk production in India and this area of almost 823sq.km is covered by semi-deciduous forest. The Similpal National Park is spread over an area of 2750sq.km area out of which the core region is 303sq.km area (Sahu and Debta, 2020). The abundance of Arjun, Asan, and Sal plants in the forest region is responsible for the good habitat of the Modal Tasar silkworms.

Sukinda: The trivoltine Sukinda ecorace is economically profiting for the sericulture. State Department of Sericulture collected this ecorace from the Kundal, Ankurapa, Sukaran, and Kans areas of Sukindagarh of Jajpur district, in the 1970s and then introduced them to other regions for cultivation (Sahay *et al.,* 2011). For our mapping purpose, these regions have been selected. The cocoons are yellow or grey in colour, having a silk ratio varying between 10.5-13.1%. This race particularly is semi-domesticated and they perform better in semi-domesticated environments than in wild. Sukindagarh used to be the main hub for

Sukinda ecorace cultivation but since this region is full of ore mines and industries, which are constantly being over exploited, the negative impact of this over-exploitation, mining, and industrialisation are affecting the natural habitat of Sukinda tasar ecorace.

Nalia: A bivoltine ecorace of *A. mylitta* found in near forest area of the Keonjhar district of Odisha. Early multiplication, short larval period, and better quality commercial character make this ecorace more desirable by Sericulturist (Rout *et al.,* 2009). The availability of this ecorace is in the range of Raghubeda Forest range of Keonjhar and the forest patch between the borders of Sundergarh and Keonjhar district of Odisha.

Jata-Daba: Another bivoltine ecorace of *A. mylitta* is found in almost 35 villages of the Thakurmuda region of Mayurbhanj (Rout *et al.,* 2008). For our mapping purpose, we have taken Thakurmuda, Kendujiani, Mahuldiha, and Kuldiha of the Mayurbhanj district. This ecorace is preferable because of its higher percentage silk content.

Adaba: Adaba ecorace is one of the most unexplored ecoraces of Odisha found in the Adaba forest Gajapati district. Since Adaba is also one of the wild ecoraces, almost all of its life stages are spent in the wild on its host plant. The Naxal issues in the Adaba forest have always been a greater hindrance to the biological exploration of local fauna and flora including its endemic Tasar silkworm ecorace and its host plant. This is the same reason why the Adaba ecorace is unknown to many sericulturists and researchers of this field.

Umerkote: Umerkote/Omarkote is one of the endemic ecoraces found in Kalahandi and Nawarangpur forest cover regions of Odisha. The forest area is mostly covered with moist deciduous forest of 298km^2.

Boudh: Although not many reports have been published about this ecorace, but some papers do claim that this Boudh/Boadh Ecorace is also found in the Phulbani region i.e. new Boudh and Kalahandi district (Sinha and Prasad, 2011). This ecorace is suspected to be endemic to the moist deciduous forest range of these two districts and some parts of nearby regions. Sinha and Prasad (2011), have proven that the morphological difference between different ecoraces is relevant to their biochemical constitutions like protein content, lipid content, and carbohydrate content, including genetic constitutions, which makes each ecorace genetically unique from their sister ecorace. It also has been noticed by them that the *Shorea*-based ecoraces (Modal, Nalia, Umerkote) have greater shell weight as compared to *Terminalia*-based ecoraces like (Sukinda, Boudh, Jata-Daba, Adaba). In some research papers, Bogei is also considered as a separate ecorace of *A. mylitta*, but in reality, it's the rearing (commercial) variety of Modal and Nalia that are called Bogei by local people.

The evolution of GIS, GPS, and RS technologies has enabled the collection and analysis of spatial, non-spatial, and field data in such a sophisticated manner that was not possible before the arrival of these software technologies. The use of these technologies in India increased after the 1990s IT revolution. Since the 2000s these technologies have been actively in use by both Government and Non-government authorities worldwide for Resource management such as agriculture, soil, water, land cover, forest cover estimation, mining area detection, Wildlife management, and agricultural land detection, etc. Currently, the advancement of mobile technology also has enabled to use the GPS via satellite imaging for regular use without any expensive handset use. In 2011, Sinha and Prasad mapped all the 44 ecoraces of *A. mylitta* Drury documented officially, using imagery techniques of GIS data. The horizontal accuracy within a map depend mostly on the Ground Sampling Distance or GSD i.e., number of pixels per centimetre. Inaccurate maps will lead the investigator astray because the critical data point of the problem might not be there at the moment on the Map. Hence accuracy of the map is very critical for right investigation of the project. In India ISRO Bhuvan (2014) and ISRO-CHAMAN (2014) are in use for the estimation of area of land forest cover, coast line, and Plantation cover, etc. CHAMAN GIS is exclusively used for agricultural, horticultural and forest assessment. Banana, Citrus fruit, and Mango plantation cover of different states is already in the data base of CHAMAN. Similarly, we can implement the GIS and GPS along with data from Imagery RS to create locational plantation planning for A. mylitta Drury host plants such as Arjun, Asan, and Sal in corresponding regions where the availability of different ecorace prevails. By doing so, more host plants will be available for Tasar silkworm culture to the local tribe people which in turn will improve the economy of the region.

Conclusion
The potential use of RS and GIS has been very satisfactory for the study of forest cover and locations in required places. RS, GIS, and GPS techniques have been very crucial in our field for geospatial mapping of Tasar silkworm (*A. mylitta*) ecoraces throughout Odisha. As for spatial data collection, there is still a lot of knowledge gap among professionals regarding the availability of ecoraces and their geographical distribution. The LANDSAT 9 images have been very useful for the identification of individual villages and nearby forest range. In Odisha, mostly Modal, Sukinda, and Nalia are commercially exploited for Tasar production. Other Jata-Daba, Umerkote, Boudh, and Adaba don't have that much commercial importance yet because they yet have to be explored properly in their endemic places. Geospatial mapping technique has long been in our country mapping system. This technique has been used for forest area and forest cover mapping, census mapping, cluster mapping of plantations, coastal erosion checking, etc. Many states including Odisha have been collaborating with ISRO (Indian Space Research Organisation) for all GIS, GPS, and RS data for different censuses like tiger reserves, elephant reserves, etc. But for Tasar silkworm (*Antheraea mylitta* Drury) ecoraces and their mapping, no organised map have ever been in the picture. Hence to fulfil such a demand for the growth of the economic status of Tasar silk production and available ecorace genetic pool diversity maintenance, the Geospatial technique of mapping might be proven a greater success.

Acknowledgement
The authors are grateful to Department of Science and Technology, Govt. of Odisha for providing financial support to carry out the research work.

Conflict of interest
The authors declare that they have no conflict of interest.

References
Bonham-Carter, G. (2014*). Geographic information systems for geoscientists: Modelling with GIS.*

Eldredge, L., Enge, P., Harrison, M., Kenagy, R., Lo, S., Loh, R., & Niles, R. (2010, May). Alternative positioning, navigation & timing (PNT) study. In *International civil aviation organisation navigation systems panel (NSP), Working Group Meetings, Montreal, Canada.*

In International civil aviation organisation navigation systems panel (NSP). Working Group Meetings (2010). Alternative positioning, navigation & timing (PNT) study. *Montreal, Canada.*

Jolly, M.S. (1985). Species differentiation in the genus *Antheraea, Sericologia, 25(1),* 84-94.

Kumaresan, P., Sinha, P.K., Mohan, B., and Thangavel, K. (2004). Conservation of multivolatine silkworm Bombyx mori L., germplasm in India: An overview. *International Journal of Industrial Entomology. 9*(1), 1-13.

Metzler, E.H. and Zebold, R.A. (1995). Twenty eight species of moths new to Ohio from Huffman Prairie, Green County (Lepidoptera). *Ohio Journal of Sci. 95,* 240-242.

Mirhoseini, S.Z., Seydavi, A.R., Ghanipoor, M., and K. Etebari, (2004). General and special combining ability estimation and heterosis in new varieties of silkworm *Bombyx mori. Journal of Biological Sc., 4*, 725-730.

Ojha, N.G., Reddy, R.M., Hansda, G., Sinha, M.K., Suryanarayan, N., Vijayaprakash, N.B., (2009). Status and potential of Jata, a new ecorace of Indian Tasar Silkworm (*Antheraea mylitta* Drury). *Academic journal of entomology. 2(2),* 80-84.

Rao, J.V.K., Singh, R.N., Shetty, K.K. (2003). Catalogue of wild silkworms and their host plants in India. *Proceedings of the national workshop on Vanyasilk culture and Forestry.* 1-9.

Renuka, G. and ShamithA, G (2015). Studies on the biodiversity of tasar ecoraces Antherae mylitta Drury. *Journal of Entomology and Zoology studies*. *3(6)*, 241-245.

Rout, J.K., Mohanty, B., Dash, C.S., and Rao, B.R. (2008). Jata-Daba another Tropical Tasar Ecorace. *Indian silk.* 47**,** 16-18.

Rout, J.K., Dash, C.S., Mohanty, B., and Behere, M.R., (2009). Nalia ecorace in Mayurbhanj. *Indian silk*. 22-24.

Sahay, A., Satapathy, S., and Sharan, S.K. (2011). Characterisation and Rejuvenation of local ecorace Sukinda in Odisha state. *Nature preceedings*. doi:10.1038/npre.2011.6210.1.

Saratchandra, B. (2003). Forestry and culture of vanyasilks. *Proceedings of the national workshop on "vanya silk culture and forestry".* 37-42.

Sahu, A., Debta, Dr. P.R. (2020). Behavioural Analysis Of Genetic Variants Of Drury In A Natural Population: Similpal Biosphere Reserve A Case Study. *International Journal of Creative Research Thoughts (IJCRT). 8,* 3998-4008.

Saran, S., Singh, P., Kumar, V., and Chauhan, P., (2020). Review of Geospatial technology for Infectious disease Surveillance: Use case on COVID 19. *Journal Indian SOC Remote Sense. 48*(8), 1121-1138.

Sinha, A.K. and Prasad, B.C. (2011) Variability in the ecoraces of Tasar silkworm *Antheraea mylitta* Drury. *Nat Prec*. https://doi.org/10.1038/npre.2011.6161.1

Vijayan, K., Singh, R.N., and Saratchandra, B. (2010). Prospects of application of linkage Disequilibrium mapping for crop improvement in wild silkworm *Antheraea mylitta* Drury. *International Journal of Industrial Entomology. 20*(2), 37-43.

Zhen, Z., Jin, J. M., & Liu, F. (2010). The application of geographic information system (GIS) in the field of public health. In 2010 2nd IITA international conference on geoscience and remote sensing, *IITA-GRS 2010*.

Environment Conservation Journal 24 (3): 105-108, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Management of pod fly, *Melanagromyza obtusa* (Malloch) through newer insecticides

Marri Sravanthi
Department of Entomology, Dr. RPCAU, Pusa, Samastipur, Bihar, India
Sangita Limma ✉
Department of Entomology, School of Agriculture, GIETU, Gunupur, Odisha, India
Kollu Praveen Kumar
Department of Entomology, Dr. RPCAU, Pusa, Samastipur, Bihar, India

ARTICLE INFO

Received : 28 September 2022
Revised : 17 January 2023
Accepted : 05 February 2023

Available online: 10 April 2023

Key Words:
Chlorantraniliprole
Flubendiamide
Pigeon pea
Pod damage

ABSTRACT

A field experiment was carried out at research farm of T.C.A., Dholi (Muzaffarpur) during *Kharif* season 2019-2020 to manage the pod fly *Melanagromyza obtusa* (Malloch) through newer insecticides. All eight novel insecticides were substantially potential over control in lowering the damage caused by pod fly and also recorded increased yields. Minimal pod and grain damage was recorded in chlorantraniliprole 18.5 SC (11.63 % and 8.42 % respectively) followed by flubendiamide 480 SC (14.66% and 15.37%). The highest yield (1945 kg/ha) was recorded in chlorantraniliprole 18.5 SC as against 682 kg/ha in untreated control with a Cost Benefit Ratio (CBR) of 1:41.8.

Introduction

In India several crops are grown among them pulses are very important and responsible for producing higher financial benefits through large quantities of exports. Pigeon pea is one of the crops among the pulses which are grown mostly next to chick pea in India. It is a multipurpose legume. Red gram, tur and arhar are the few other names for Pigeon pea [*Cajanus cajan* (L.) Mill sp.]. Arhar leads to 80% of world's food production and it contains higher amounts of proteins (20% to 22%), carbohydrates (65%), fat (1.2%) and ash (3.9%) (Food and Agriculture Organization, 2005). Its fiber quality is very great (7g/100g of seeds) (Kandhare, 2014). Due to its good taste, several insect pests are also attacking pigeon pea beyond human consumption (Prasad and Singh, 2004). Red gram is attacked by several insect pests regularly and among all the insect pests attacking red gram, Pod fly (*Melanagromyza obtusa*) is notorious and serious pest that causes more than 20% to 80% damage to grains (Subharani and Singh, 2009). Pod fly attacks the crop during pod maturity also starting from pod filling stage. They lay eggs (oviposition) on inner walls of pod. Adult females oviposit single eggs inside the epidermis and after the larvae emerge out, it will feed on pods by mining in to it and causes damage because of which the pod is not fit for consumption and seed value also decreases.The control of the pest complex associated with pigeon pea has been attempted through various chemical management practices. Several crop pests have established maximum resistance to the various insecticides that are available. Hence it reduces the faith over insecticide control. The problem of controlling species which are resistant to chemicals and using different methods for reducing harmful effects on useful insects has provided support for increasing production of red gram. Actually the method to handle pigeon pea pod fly with following eco friendly norms is using target specific novel chemicals.

Material and Methods

Field trial was conducted in 2019-2020 at T.C.A Research Farm, Dholi, Muzaffarpur, a campus of

Corresponding author E-mail: sangita.limma@gmail.com
Doi: https://doi.org/10.36953/ECJ.15172473

Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar to determine effectiveness of new insecticides against pod fly, *M. obtusa* with the Bahar pigeon pea cultivar. Experiment was laid out in a Randomized Block Design with seven treatments viz., Buprofezin 25 SC (1ml l^{-1}), Diafenthiuron 50 WP (1 g/l),Dinotefuron 20SG (0.3 g/l), Flubendiamide 480 SC (0.3 ml/l), Indoxacarb 15.8EC (1ml/l), Chlorantraniliprole 18.5 SC (0.4 ml l^{-1}), Quinolphos 25EC (2 ml/l) including control. Treatments were repeated thrice with an individual plot size of 36 m^2 under standard agronomic practices. The spacing between rows and plants was 60 × 20 cm. Spacing of 1.5 m between treatment plots was followed in order to maintain distance between treatments.

The insecticides were sprayed twice, first at the time of the development of 50 per cent of pods and 2nd at 10 days after the 1st spray. Insecticides were applied with the help of foot sprayer. For each treatment spray mixtures were prepared freshly.

Observations were made on

a. **Counts of pod fly maggot population -** Count was done on randomly selected and labeled five plants per replication before spray and after ten days of 1st and 2nd spray. Plain water was sprayed in the control plot, and counts of pod fly were taken similar to those of insecticidal treatments.
b. **Grain and pod damage-** Randomly 200 pods and 100 grains were selected from every replication during harvest. And percent grain and pod damage was calculated using the formulae.

$$\text{Per cent pod/grain damage (\%)} = \frac{\text{No. of damaged pods or grain}}{\text{Total no. of pods}} \times 100$$

c. **Yield (kg/ ha)-** After pods ripening, harvesting was done treatment wise and dried for six to seven days and then thrashing was done. To determine effect of different treatments on yield, total yield per treatment was reported separately and afterward converted to kg/ha and subjected to statistical analysis and the yield gain was also determined using variations between yields of the sprayed and the unsprayed.
d. **Incremental Cost Benefit Ratio-** So as to calculate the ICBR ratio the net profit generated by deduction of cost of plant protection from the value of extra yield will be divided with cost of plant protection.

Results and Discussion

The effectiveness of various insecticides is depicted in fig 1 and discussed below.

a. Number of maggots

The data on maggot population of pod fly is presented on Table 1. Maggot population did not show any significant difference between treatments at one day before the first spray, which vary from 12.90 to 13.74 (Table 1) indicating uniform distribution of pest. Among the treatments, the less number of maggots per 100 pods was registered in Chlorantraniliprole (8.68) at ten days after first spray, which was substantially better than remaining insecticidal treatments while the larval population was high in untreated control (Table 1).

Table 1: Efficacy of insecticides against maggots of pod flies

Sl. No	Treatments	Dosage	Number of maggots per 100 pods		
			First spraying		Second spraying
			1 DBS	10 DAS	10DAS
T_1	Buprofezin 25 SC	200gm/ha	13.67	10.81	9.34
T_2	Difenthiuron 50 WP	350gm/ha	13.74	11.34	9.82
T_3	Dinotefuron 20SG	40gm/ha	12.90	10.00	9.00
T_4	Flubendiamide 480 SC	30gm/ha	13.45	9.1	7.32
T_5	Indoxacarb 15.8 EC	75gm/ha	13.44	9.35	7.84
T_6	Chlorantraniliprole 18.5 SC	30gm/ha	13.35	8.68	6.92
T_7	Quinolphos 25 EC	350gm/ha	12.97	13.2	11.64
T_8	Control	200gm/ha	13.0	29	32.94
	SEm ±		NS	**0.33**	**0.34**
	CD at 5%			**0.85**	**0.82**
	CV(%)			**12.11**	**12.94**

DBS- Days Before Sowing, DAS- Days After Sowing

Present findings are also in consistence with Chiranjeevi and Sarnaik (2017) who evaluated the effectiveness of different insecticide treatments on pod fly population. The analysis showed that chlorantraniliprole 18.5 SC @ 30 g a.i. was recorded as effective insecticide on 1, 3, 7, 10 and 14 days after 1st application, i.e. 46.33, 25.33, 16.67, 14.00 and 28.00 pod flies (larvae+pupae) per hundred pods respectively. The results is in relation to maggot population of *M. obtusa* is in accordance with Patel and patel (2013) who reported that chlorantraniliprole was the most effective insecticide against pod borer complex.

b. Grain or pod damage

The data on grain and pod damage is represented in Table 2 and illustrated in Figure 1 graphically. The observations reported on damage of pod caused by *M. obtusa* ranged from 11.63 to 64.66 percent in various insecticidal treatments. The data showed that damage of pod was substantially lower in chlorantraniliprole treated plots and was reported to be effective with 11.63 per cent pod damage across all treatments. Fluebendiamide and dinotefuron were found to be the next best treatments by reporting 14.66 and 15.66 per cent of damage of pod and were statistically parallel with one other and substantially superior to untreated control (64.66 per cent). Observations of grain damage due to *M. obtusa* varied between various treatments from 8.42 to 57.63 per cent (Table 2). The current results showed that infestation to grain was substantially reduced in insecticidal treated plots among them chlorantraniliprole was reported to be superior of all treatments with less percentage of grain damage (8.42%). Indoxacarb and flubendiamide were identified as next best treatments by recording grain damage of 14.25 and 15.37 per cent and were statistically equivalent to one other and substantially superior to untreated control (Table 2).

Table 2: Economics of different insecticidal treatments against pod fly on pigeon pea.

Treatments	Dose /ha	Per cent pod damage	(%) grain damage	Yield Kg/ha	Yield increased over control	Gross income over control	Cost of application (Rs/ha)	Net income (Rs/ha)	CBR
Buprofezin 25 SC	200gm/ha	20.33	15.53	1196	514	46,260	2,724	43,536	1:15.9
Difenthiuron 50 WP	350gm/ha	19.33	18.34	1159	477	42,930	3,174	39,756	1:12.5
Dinotefuron 20SG	40gm/ha	15.66	16.62	1228	546	49,140	2,744	46,396	1:16.9
Flubendiamide 480 SC	30gm/ha	14.66	15.37	1350	668	60,120	2,634	57,486	1:21
Indoxacarb 15.8EC	75gm/ha	28.83	14.25	1258	576	51,840	2,712	49,128	1:18.1
Chlorantraniliprole 18.5 SC	30gm/ha	11.63	8.42	1945	1263	113,670	2,652	111,018	1:41.8
Quinolphos 25EC	350gm/ha	21.3	17.65	1023	341	30,690	2,740	27,950	1:10.2
Control	-----	64.66	57.63	682			----		

c. The results are in consistence with Patel and Patel (2013) who performed experiment on bio-efficacy of various novel insecticides towards pod borer complex on the crop pigeon pea and reported that chlorantraniliprole @30 g a.i./ ha showed minimal percentage of pod damage (18.5%) caused by *H. armigera* and *M. obtusa* and maximum yield of pigeon pea.

d. Yield

Grain yields from various insecticidal treatments and their economics are displayed in Table 2. The data showed that all insecticide treatments had substantially more yields than untreated control. Between treatments, the maximum yield of 1945 kg/ha was recorded in Chlorantraniliprole, this may be due to its effectiveness for reducing the grain infestation and increasing the yield. Quinolphos recorded the minimum yield among the treatments (1023 kg/ha) (Table 2).

The present findings were in relation with the findings of Sreekanth *et al*., (2014) who reported that highest grain yield was in Chlorantraniliprole (686.1 kg/ha), followed by Flubendiamide (595.8 kg/ha).

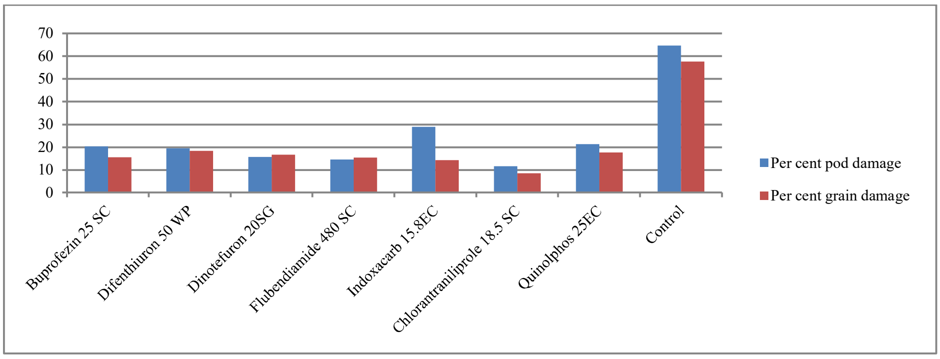


Figure 1: Effectiveness of insecticides towards percent pod and grain damage caused by *Melanoagrmyza obtusa* in pigeon pea

e. Incremental Cost Benefit Ratio (CBR)

The CBR ratio varied from 1:41.8 to 1:21. The highest CBR ratio was recorded with Chlorantraniliprole (1:41.8), proceeded by Flubendiamide (1:21), Indoxacarb (1:18.1). This is in accordance with the result of earlier worker Singh (2014) where in highest cost benefit ratio (1: 4.24) was obtained from chlorantraniliprole.

Conclusion

The chemical control method minimizes the pest population, pod and grain damage with higher yield. Keeping in view of the data of all the parameters, viz. number of larvae per plant, per cent pod damage and grain yield in different treatments, the new generation novel insecticides like such as Chlorantraniliprole, Flubendiamide and Indoxacarb were found to be efficient towards *M. obtusa* with the more percentage of pod damage reduction and increased yields compare to control. In addition to these, cost-effectiveness of Chlorantraniliprole and Flubendiamide was more and favorable with a CBR ratio of 1:41.8 and 1:21. Therefore, chemical management with new insecticides popularizes as an effective, practical alternative to avoid the development of resistance to pod borer complexes in pigeon pea and makes profitable cultivation of pigeon pea crop.

Acknowledgement

The authors are grateful to Head, Department of Entomology and Dean of Agriculture, Dr. RPCAU, Pusa, Samastipur, Bihar for providing essential facilities and support to carry out the experiment.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Chiranjeevi, B. & Sarnaik, S. V. (2017). Efficacy of different insecticidal treatments on population of pod fly, *Melanagromyza obtusa* (Malloch). *Journal of Entomology and Zoology Studies, 5*(4), 1812-1815.

Food and Agriculture Organization (2005). Food and Agriculture Data. FAOSTAT Data. http:/www. Faostat.fao.org/.

Kandhare, A. S. (2014). Different seed categories of pigeon pea and its seed mycoflora. *International Research Journal of Biological Science, 3*(7), 74-75.

Patel, S. A. & Patel, R. K. (2013). Bio-efficacy of newer insecticides against pod borer complex of pigeon pea (*Cajanus cajan* (L) Millspaugh). *An International e-Journal, 2*(3), 398-404.

Prasad, D. & Singh, A. (2004). *Advances in Plant Protection Sciences*. Akansha Publishing House, New Delhi, 6(3), 45-47.

Singh, A. K. (2014). Evaluation of new molecule of insecticides against pod fly (*Melanagromyza obtusa*) of pigeonpea. *SAARC Journal of Agriculture, 12*(1), 89-95.

Sreekanth, M., Lakshmi, M. S. M. & Rao, Y. K. (2014). Bio-efficacy and economics of certain new insecticides against gram pod borer, *Helicoverpa armigera* (Hub.) infesting pigeon pea (*Cajanus cajan* L.). *International Journal of Plant, Animal and Environmental Science*, 4, 11-15.

Subharani, S. & Singh, T. K. (2009). Yield loss assessment and economic injury level of pod borer complex in pigeonpea. *Annals of Plant Protection Sciences*, 17, 299-302.

Environment Conservation Journal 24 (3): 109-115, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Influence of biostimulants on growth and productivity of foxtail millet (*Setaria italica* L.) genotypes

Chethan G S ✉

Department of Agronomy, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

Hugar A Y

Department of Agronomy, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

Sarvajna B Salimath

Department of Soil science and Agricultural Chemistry, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

Girijesh G K

Department of Agronomy, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

Dushyantha Kumar B M

Department of Genetics and Plant Breeding, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

ARTICLE INFO

Received : 11 October 2022
Revised : 20 January 2023
Accepted : 13 February 2023

Available online: 10 April 2023

Key Words:
Foxtail millet
Foliar application
Genotypes
Humic acid
Panchagavya

ABSTRACT

A field experiment was carried out at AHRS, Bavikere, Karnataka during late *kharif* season of 2021to find out the "Influence of biostimulants on growth and productivity of foxtail millet (*Setaria italica* L.) genotypes''. The field trial was laid out in split plot design with 12 treatment combinations. The study involves three genotypes in the main plot *viz.*, SiA-3156 (G_1), HMT-100-1 (G_2) and DHFt-109-3 (G_3). Foliar application of biostimulants in sub plots *viz.*, 0.1 % humic acid (F_1), 3 % panchagavya (F_2), 0.1 % humic acid and 3 %panchagavya (F_3) at 30 and 60 days after sowing (DAS) and recommended dose of fertilizer (RDF) as control (F_4). Genotypes and Foliar application of biostimulants exhibited significant variation in growth and yield components of foxtail millet. Among the different genotypes, HMT-100-1 recorded significantly higher plant height (142.00 cm), number of tillers per meter (81.87) and leaf area (18.40 dm^2/plant) at harvest and also yield components like panicle length (16.60 cm), grain weight per panicle (4.02 g) and grain yield (1701.0 kg/ha) compared to DHFt-109-3 and SiA -3156. In biostimulants, Foliar application of 0.1 % humic acid and 3 % panchagavya recorded significantly higher plant height (142.32 cm), number of tillers per metre (83.75) and leaf area (18.51 dm^2/plant) at harvest and also yield components like panicle length (16.99 cm), grain weight per panicle (4.33 g) and grain yield (1781.2 kg/ha). While, they were found to be at their lowest with application of RDF alone. Interaction between genotypes and biostimulants was also found to be significant in which combination of HMT-100-1 with foliar application of 0.1 % humic acid and 3 %panchagavya recorded significantly higher growth and yield compared to other treatment combinations.

Introduction

The global climate change and extreme weather fluctuations have emerged as the most threatening challenge to agriculture. Under such situation, cultivation of climate smart crops and adaptions of climate resilient practices are the need of the hour. Millets have been discussed as potential alternatives to cereals due to their inherent ability to grow in adverse conditions like low-quality soils, lack of irrigation facilities and abbarent weather conditions. Since, there has been stagnation in the yield of cereals in recent years, it's the time to exploit the underutilized crops *viz.*, finger millet, foxtail millet, barnyard millet, little millet, proso millet and brown top millet and kodo millet.

Corresponding author E-mail: *chethangs6016@gmail.com*
Doi:https://doi.org/10.36953/ECJ.15332480

Among minor millets, foxtail millet (*Setaria italica* L.) is one of the oldest cultivated crop for grain, hay and pasture. It is adapted to a wide range of elevation, soils, and climatic conditions. However, the potentiality of this crop is not fully exploited. The productivity of foxtail millet in India is very low due to the insufficient application of fertilizers, conventional cultivation of low yielding cultivars and lack of good management practices In India, the area under small millets is 4.44 lakh hectare with the production of 3.46 lakh tonnes and productivity of 781 kg/ha. In Karnataka, the area under small millets account for 0.26 lakh hectares with production of 0.20 lakh tonnes and productivity of 778 kg/ha.Agronomic practices *viz*., use of growth regulators, PGPR and biostimulants *etc*., are known to improve the yield and quality of the produce in several crops. Further, biostimulants are eco-friendly and it's usage in millets is very meagre.

Hence, they are one of the most innovative and capable solution to address the challenge of increasing foxtail millet productivity. Biostimulants are the materials which contain substances or microorganisms, whose function when applied to plants or the rhizosphere is to boost natural processes to enhance nutrient uptake, nutrient efficiency, tolerance to abiotic stress and crop quality, independent of its nutrient content. Humic substances are heterogeneous organic molecules that form in the soil as by-products of microbial metabolism of dead organic matter. Use of such particles either to the soil or by foliar application alongside sufficient quantity of conventional fertilizers enhances the proficiency of applied chemical fertilizers. Panchagavya is an organic product produced by using different by-products of cow namely dung, urine, milk, ghee, curd and other ingredients.

It is rich in N, P, K, micronutrients and contains various amino acids, vitamins, growth regulators like auxins, gibberellins along with beneficial microorganisms. Foliar application of biostimulants like humic acid, panchagavya *etc*., at critical growth stages like tillering and flowering stage not only improves the physiological efficiency and plays a significant role in raising the productivity of the crop. The present investigation was taken to study the role of bio stimulants in increasing productivity of foxtail millet.

Material and Methods

The experiment was laid out in split plot design included twelve treatment combinations which are replicated thrice. Genotypes SiA-3156 (G_1), HMT-100-1 (G_2) and DHFt-109-3 (G_3) in main plots. Subplot treatment includes foliar application of biostimulants *viz*., 0.1 %humic acid(F_1), 3 %panchagavya(F_2), 0.1 %humic acid and 3 %panchagavya(F_3) at 30 and 60 DAS and RDF as control (F_4). The land was well ploughed and harrowed to make a fine seed bed and foxtail millet was sown with spacing of 30 × 10 cm. The crop was commonly supplied with recommended dose of fertilizer in the form of urea (N), Di ammonium phosphate (DAP) and Muriate of potash (MOP) as per the calculated amount to each plot as basal dose at the time of sowing to all the treatments. Foliar application of the biostimulants *viz*., humic acid and panchagavya was done at 30 and 60 DAS. Protective irrigation was done as per the need of the crop and two hand weeding at 30 and 45 DAS were done to reduce crop-weed competition. Growth parameters *viz*., plant height(cm), number of leaves per plant, number of tillers per metre row length, leaf area (dm^2/plant) and total dry matter production (g/plant) were recorded at 30, 60 DAS and at harvest in the randomly selected 5 plants in the net plot area. Yield parameters like panicle length (cm), panicle weight (g), grain weight per panicle (g) and test weight (g) are also recorded from those randomly tagged five plants. Panicles in each treatment plots were harvested separately and sun dried for 4 - 5 days in threshing yard. Later panicles from net plot were threshed and grain weight was recorded in kilogram and later converted to kg/ha. The data recorded on various observations on growth, yield and soil parameters were subjected to analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). The level of significance used in 'F' test was at 5 %.

Study area

The experiment was conducted at Agricultural and Horticultural Research Station, Bavikere, Chikkamagalur district during late *kharif* 2021. It is situated in the Southern Transition Zone (Zone-7) of Karnataka state at 13°42` N latitude and 75°51` E longitude, with an altitude of 695 meters above the mean sea level.The soil of the experimental site was sandy loam in texture with acidic in reaction (6.12), medium organic carbon (0.52%), medium available nitrogen (315.64 kg/ha), medium available phosphorus (50.56 kg/ha) and medium in available potassium (340.58 kg/ha). During the crop growth period *i.e.,* from September 2021 to December 2021 highest rainfall occurred during October (207.6mm) lowest in the December (0 mm). The mean monthly maximum temperature was highest during October (30.5°C), while it was lowest in November (28.2°C). The maximum relative humidity was observed in September (82.7%) and minimum during December (57.3%). The sunshine hours were higher in November (7.9 hrs), while it was lowest in (6.3 hrs).

Results and Discussion

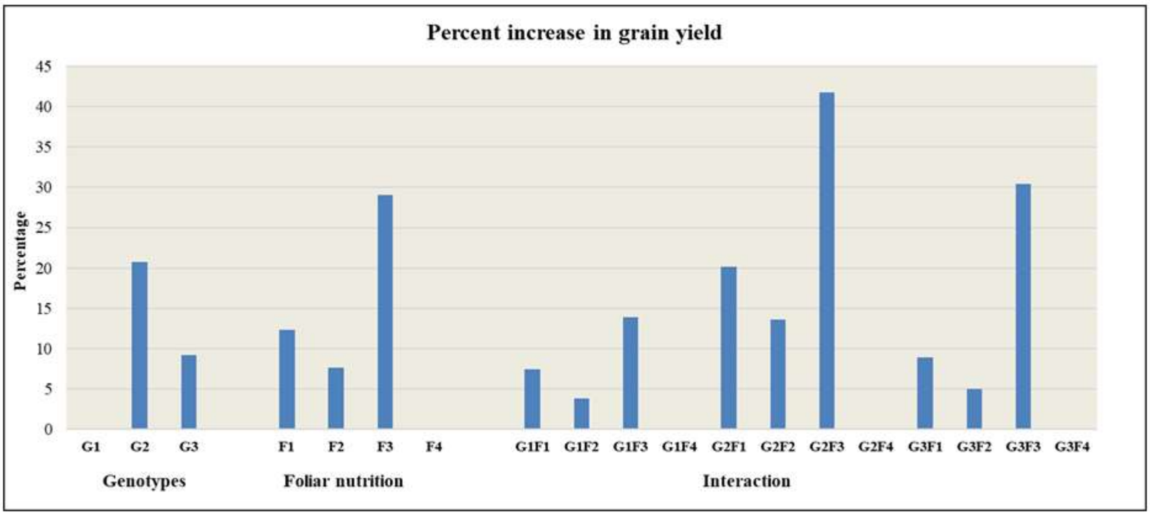
The results of the various growth, yield parameters and productivity of the foxtail millet are tabulated in table 1 - 3 and figure 1.

Table 1: Growth parameters of foxtail millet at harvest as influenced by genotypes and foliar application of biostimulants

Treatments	Plant height (cm)	Number of leaves per plant	Number of tillers per meter row length	Leaf area (dm^2/plant)	Total dry matter production (g/plant)
Main plots – Genotypes(G)					
G_1	131.57	21.17	73.96	15.02	18.03
G_2	142.00	24.20	81.87	18.40	22.33
G_3	136.06	22.24	77.46	16.78	19.08
S. Em. ±	1.86	0.57	1.31	0.35	0.38
C. D. at 5%	7.49	2.25	5.16	1.39	1.52
Sub plots – Foliar nutrition(F)					
F1	136.92	23.27	80.46	17.19	20.64
F2	134.23	20.94	76.67	16.23	18.76
F3	142.32	25.62	83.75	18.51	23.00
F4	132.70	20.32	70.73	15.00	16.85
S. Em. ±	2.12	1.04	0.67	0.41	0.27
C. D. at 5%	6.36	3.10	2.00	1.21	0.81
Interaction (G x F)					
G_1F_1	133.67	23.00	78.37	15.81	17.97
G_1F_2	130.53	20.87	71.22	14.38	17.14
G_1F_3	134.33	26.00	78.93	16.72	21.36
G_1F_4	129.60	20.00	67.23	13.18	15.67
G_2F_1	141.93	28.00	81.18	18.68	23.15
G_2F_2	137.67	25.67	83.00	17.84	22.06
G_2F_3	152.33	31.07	88.98	20.34	25.30
G_2F_4	136.07	24.27	74.41	16.73	18.79
G_3F_1	137.02	27.27	81.65	17.08	20.81
G_3F_2	134.49	23.00	75.52	16.48	17.07
G_3F_3	140.29	30.00	83.53	18.46	22.33
G_3F_4	132.42	22.93	70.53	15.09	16.09
S. Em. ±	3.68	2.26	1.167	0.71	0.47
C. D. at 5%	NS	NS	3.46	NS	1.41

G_1: SiA 3156
G_2: HMT-100-1
G_3: DHFt-109-3

F_1: RDF + Foliar application of humic acid @ 0.1 % at 30 and 60 DAS
F_2: RDF + Foliar application of panchagavya @ 3 % at 30 and 60 DAS
F_3: RDF + Foliar application of humic acid @ 0.1 % and panchagavya @ 3% at 30 and 60 DAS
F_4: RDF (Control)



G_1: SiA 3156
G_2: HMT-100-1
G_3: DHFt-109-3

F_1: RDF + Foliar application of humic acid @ 0.1 % at 30 and 60 DAS
F_2: RDF + Foliar application of panchagavya @ 3 % at 30 and 60 DAS
F_3: RDF + Foliar application of humic acid @ 0.1 % and panchagavya @ 3% at 30 and 60 DAS
F_4: RDF (Control)

Figure 1: Per cent increases in grain yield as influenced genotypes and foliar nutrition of biostimulants.

Among the genotypes, HMT-100-1 recorded significantly higher plant height (142.00 cm), number of leaves/plant (24.20), number of tillers/meter row length (81.67), leaf area (18.40 dm^2/plant) and total dry matter production (22.33 g/plant) at harvest compared to genotype DHFt-109-3 and SiA-3156 (Table 1). Foliar application of biostimulants shown significant variation with respect to growth parameters. Among different treatments, foliar application of 0.1 % humic acid and 3 % panchagavya along with RDF recorded significantly higher plant height (142.32 cm), number of leaves/plant (25.62), number of tillers/meter row length (83.75), leaf area (18.51 dm^2/plant) and total dry matter production (23.00 g/plant) at harvest compared to application of RDF alone (Table 1).

Among the interaction effects, combination of genotype HMT-100-1 with foliar application of humic acid @ 0.1% and panchagavya @ 3% along with RDF among the interaction has recorded significantly higher plant height (152.33 cm), number of leaves/plant (31.07), number of tillers/meter row length (88.98), leaf area (20.34 dm^2/plant) and total dry matter production (25.30 g/plant) at harvest compared to other treatment combinations.

Experimental results clearly indicated the differential response of treatments with respect to different yield parameters, grain and straw yield due to genotypes and foliar nutrition of biostimulants. Among genotypes, HMT-100-1 recorded significantly higher grain and straw yield (1701.0 and 4066.0 kg/ha respectively) compared to DHFt-109-3 and SiA-3156. Significant increase in yield was due to increase in yield attributing characters of the genotype HMT-100-1. which recorded significantly higher number of panicles per meter row length (64.18), panicle length (16.60 cm), panicle weight (4.47 g), grain weight per panicle (4.02 g) and test weight (3.95 g) (Table 2).

As far as different biostimulants is concerned foliar application of 0.1 % humic acid and 3 % panchagavya along with RDF significantly influenced the yield and yield attributing characteristics by recording higher grain and straw yield (1781.2 kg/ha and 4139.5 kg/ha, respectively). It was mainly attributed to superior yield parameters such as higher number of panicles

Table 2: Yield attributes of foxtail millet as influenced by genotypes and foliar application of biostimulants

Treatments	Number of panicles/m row length	Panicle length (cm)	Panicle weight (g)	Grain weight per panicle (g)	Test weight (g)
Main plots – Genotypes (G)					
G_1	54.12	14.92	4.00	3.63	3.84
G_2	64.18	16.60	4.47	4.02	3.95
G_3	57.45	15.20	4.14	3.73	3.89
S. Em. ±	1.31	0.32	0.06	0.05	0.030
C. D. at 5%	5.29	1.26	0.25	0.22	NS
Sub plots – Foliar nutrition (F)					
F1	62.68	16.28	4.29	3.90	3.88
F2	57.85	15.25	4.22	3.79	3.87
F3	68.69	16.99	4.61	4.33	3.95
F4	45.10	13.77	3.60	3.25	3.87
S. Em. ±	0.86	0.29	0.08	0.07	0.073
C. D. at 5%	2.58	0.87	0.24	0.21	NS
Interaction (G x F)					
G_1F_1	58.64	15.97	3.94	3.55	3.77
G_1F_2	55.36	14.33	3.96	3.56	3.80
G_1F_3	61.17	16.22	4.74	4.27	3.84
G_1F_4	40.95	13.16	3.50	3.15	3.80
G_2F_1	67.41	17.50	4.83	4.34	3.81
G_2F_2	60.44	16.53	4.67	4.21	4.00
G_2F_3	76.83	18.32	4.91	4.42	4.03
G_2F_4	52.03	14.05	3.68	3.33	3.97
G_3F_1	61.64	15.37	4.24	3.82	3.93
G_3F_2	57.76	14.89	4.01	3.61	3.82
G_3F_3	68.07	16.41	4.80	4.32	3.97
G_3F_4	42.32	14.12	3.52	3.17	3.83
S. Em. ±	1.49	0.50	0.13	0.12	0.127
C. D. at 5%	4.44	1.51	0.40	0.36	NS

per meter row length (68.69), panicle weight (4.61 g), panicle length (16.99 cm), grain weight per panicle (4.33 g) and test weight (3.95 g) (Table 2). compared to application of RDF alone without any foliar nutrition of biostimulants (1380.1 kg/ha and 3531.8 kg/ha, respectively). Interaction between genotypes and foliar nutrition of biostimulants showed significant variation in yield and yield parameters. This indicated that the genotypes differed in their phenotypic characters to their interaction with foliar nutrition of biostimulants. Combination of HMT-100-1 with 0.1 % humic acid and 3 % panchagavya along with RDF recorded significantly higher number of panicles per meter row length (76.83), panicle length (18.32 cm), panicle weight (4.42 g), grain weight per panicle (4.42 g), test weight (3.95g), grain and straw yield (2028.1 kg/ha and 4666.6 kg/ha, respectively) (Table 2 and Table 3). Growth parameters are important in deciding the grain yield of any crop.

Table 3: Productivity of foxtail millet as in influenced by genotypes and foliar application of biostimulants

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index
Main plots – Genotypes (G)			
G_1	1408.2	3525.4	0.286
G_2	1701.0	4066.0	0.295
G_3	1538.7	3731.7	0.291
S. Em. ±	39.57	55.69	0.003
C. D. at 5%	159.54	224.57	NS
Sub plots – Foliar nutrition(F)			
F1	1550.6	3791.6	0.290
F2	1485.4	3634.6	0.290
F3	1781.2	4139.5	0.299
F4	1380.1	3531.8	0.283
S. Em. ±	31.77	55.67	0.005
C. D. at 5%	95.39	166.71	NS
Interaction (G x F)			
G_1F_1	1423.5	3532.0	0.288
G_1F_2	1376.2	3460.2	0.284
G_1F_3	1508.5	3710.3	0.287
G_1F_4	1324.7	3399.7	0.283
G_2F_1	1719.2	4111.7	0.295
G_2F_2	1626.0	3840.1	0.297
G_2F_3	2028.1	4666.6	0.303
G_2F_4	1430.6	3645.6	0.284
G_3F_1	1509.2	3731.2	0.288
G_3F_2	1453.8	3603.8	0.287
G_3F_3	1806.9	4041.9	0.307
G_3F_4	1385.0	3550.0	0.282
S. Em. ±	55.03	96.43	0.009

Plant height, number of tillers and leaf area are effectively able to increase the total dry matter accumulation as it is the essential parameter for increasing grain yield. Genotypes and foliar application of biostimulants significantly influenced the growth parameters at all the stages of the crop growth.
The variation in the growth parameters among the genotypes might be due to the variation in their genetic character like higher inter nodal length, high tillering ability which resulted in higher plant height and number of tillers. The increase in the leaf area enhanced the photosynthetic rate which in turn increased its biomass. The results are in accordance with the findings of Reddy *et al*. (2018) in foxtail millet, Sivashankar *et al*. (2020) in finger millet and Kabse *et al*. (2014) in paddy.
Among the foliar nutrition of biostimulants, the development of sound vegetative growth was because of sufficient and liberal availability of nutrients through inorganic sources by RDF and organic sources by biostimulants in soil and foliar application, respectively have resulted in higher metabolic activity in the plant. Humic acid and panchagavya have direct influence on plant growth by inducing metabolic process such as ion uptake, nucleic acid synthesis and regulation of hormone levels resulted in increasing cell division, cell elongation enabled increased growth and development of crop. Similar findings were in line with the findings Manal *et al*. (2016) in wheat, Suruthi *et al*. (2020) in barnyard millet, Ashoka *et al*. (2020) and Naik *et al*. (2018) in foxtail millet.
Yield depends upon various factors related to the plant and environment. Maximization of the grain yield of any crop genotypes mainly depends upon processes associated with uptake of nutrients, their mobilization, translocation, partitioning and assimilation during different crop growth stages. These processes are mainly influenced by genetic potential of the genotypes, soil and climatic factors and cultural practices followed during cultivation.
The magnitude of increase in grain and straw yield with the superior genotype HMT-100-1 was to an extent of 20.80 % grain yield and 15.42 % straw yield over low yielding genotype SiA-3156 (Table 3 and Figure 1). It might be due to the fact that gen0types are different in their yielding potential depending on many physiological processes taking place in different plant parts, and are controlled by both the genetic makeup of the plant and the environment. These results are in agreement with the findings of Brunda *et al*. (2014), Srikanya *et al*. (2020) and Jyothi *et al*. (2016) in foxtail millet.
Among the foliar application treatments, there was an improvement in grain and straw yield to an extent of 29.05 % in grain and 16.28 % respectively over control (Table 3 and Figure 1). Soil application of nutrients provide scope for the development of the plant but is also subjected to various losses due to climate abnormalities like heavy or deficit rainfall *etc.* Hence, providing additional nutrient supply through the foliar application of biostimulants *viz*., humic acid and panchagavya which facilitate easy and quick nutrient absorption through their stomata and epidermis. They contain growth promoting substances like Indole acetic acid (IAA), gibberellins and auxins in its structure along with beneficial microorganisms. When these liquid manures applied twice at critical stages of the plant growth and development, they act as a stimulus in the plant system increases the translocation of the photosynthates from source to sink and nutrient uptake by the crop ultimately leads to higher yield. These results are in conformity with the findings of Kumaran and Parasuraman. (2019) in foxtail millet, Patel *et al.* (2021) in pearl millet, Vanitha and Mohandas (2014) in paddy and Gokul and Senthilkumar (2019) in finger millet.
Combined effect of the genetic potential of the genotype to adopt for the climate of that area and additional supply of nutrient through the biostimulants along with the RDF made significant increase in the yield of the crop. The results are in conformity with the findings of Atish *et al*. (2019) in foxtail millet and Ahmed *et al*. (2016) in proso millet.

Conclusion
The results of the present investigation clearly indicated that providing additional supply of nutrients along with soil application of recommended dose of fertilizers increase the growth and yield of foxtail millet. It has the potential to improve the productivity of the foxtail millet grown in medium to low fertile soils also. Hence, cultivation of HMT-100-1 with foliar application of 0.1 % humic acid and 3 % panchagavya along with soil application of RDF

becomes more suitable practice when compare to cultivation of other genotypes and application of RDF alone for growing foxtail millet under late sown condition of *Kharif* season in Southern Transition Zone of Karnataka.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ahmed, M., Nadeem, S.M., Naveed, M., & Zahir, Z.A. (2016). Potassium solubilizing bacteria and their application in agriculture. *Springer India*, 293-313.

Ashoka, P., & Rajkumar, G. R.(2020).Effect of nutrient management on growth and yield attributes of brown top millet (*Brachiaria ramose*). *Journal of Pharmacognosy and Phytochemistry*, 9(6), 1298-1301.

Atish., Bharamaraj, B., Shivmurty, D., & Hunje, R. (2019). Effect of foliar organic nutrients and time of application on seed yield and yield attributes of foxtail millet (*Setaria italica* L.). *International Journal of Chemical Studies*, 8(1),1718-1721.

Brunda, S. M., Kamatar, M. Y., Naveenkumar, K.L., & Hundekar, R. (2014). Study of genetic variability, heritability and genetic advance in foxtail millet in both rainy and post rainy season. *Journal of Agriculture and Veternary Sciences,* 7(11), 34-37.

Gokul, G., & Senthilkumar, N. (2019). Effect of water soluble fertilizer and humic acid on growth parameters and yield of finger millet (*Elusinecarocona* L.). *plant Arch*., 20(2): 5817-5822.

Gomez, K. A., & Gomez, A. A. (1984). Statistical procedures agricultural research, (2/e) an international rice research institute book, A Willey Inter Science Publication, John Willey and Sons, New York.

Jyothi, K.N., Sumathi, V., & Sunitha, N. (2016). Productivity, nutrient balance and profitability of foxtail millet (*Setariaitalica* L.) varieties as influenced by levels of nitrogen. *Journal of Agriculture and Veternary Sciences*,9(4), 18-22.

Kasbe, S. S. (2008). Characterization and evaluation of jeevamrutha formulations on aerobic rice.*M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Bangalore, Karnataka, India.

Kumaran, & Parasuraman, P. (2019). Effect of Panchagavya foliar spray on the plant metabolism and grain yield of Tenai under rainfed condition. *Journal of Pharmacognosy and Phytochemistry*, 2(7), 32-34.

Manal, F. M., Thalooth, A. T., Amal., Ahmed, G., Magda, H. M., & Elewa, T. A. (2016). Evaluation of the effect of chemical fertilizer and humic Acid on yield and yield components of wheat plants (*Triticum aestivum*) grown under newly reclaimed sandy soil. *International Journal of Chem Tech research,* 9(8), 154-161.

Naik, U. P., Rao, S., Desai, B.K., Krishnamurty, D., &Yadahalli, V.G. (2018). Effect of Different Sources of Organic Manures on Growth and Yield of Foxtail Millet (*Setaria italica* L.) under Integrated Organic Farming System. *Advaced research*, 13(2), 1-6.

Patel, S. P., Malve, S.H., Chavda, M.H., & Vala, Y.B. (2021). Effect of Panchagavya and Jeevamrutha on growth, yield attributes and yield of summer pearl millet. *The Pharma Innovation,*10(12), 105-109.

Reddy, B. H., Bulbule, A. V., Gajbhije., P. N &Patil, D. S. (2018). Effect of foliar application of plant nutrients on growth and yield and economics of Finger millet (*Eleusine coracana* L.) *International Journal of Current Microbiology and Applied Sciences,* 7(3), 2203-2209.

Sivashankar, M., Paulpandi, V.K., Durai, S. &Thangaraj, N. (2020). Studies on the Effect of Establishment Methods and Foliar Nutrition on Productivity of Transplanted Finger Millet (*Eleusine coracana*) under Irrigated Condition. *International Journal of Current Microbiology and Applied Sciences*, 9(10), 2446-2451.

Srikanya, B., Revathi, P., Reddy, M.M., & Chandrashaker, K. (2020). Effect of Sowing Dates on Growth and Yield of Foxtail Millet (*Setariaitalica* L.)Varieties. *International Journal of Current Microbiology and Applied Sciences*, 9(4), 3243-3251.

Suruthi, S., Sujatha, K., & Menaka, C. (2020). Effect of organic and inorganic foliar nutrition on growth and yield attributes of barnyard millet (*Echinochloa frumentacea* L.). *International Journal of Chemical Stu*dies, 7(3), 851-853.

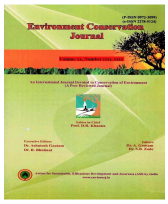
Vanitha., K. &Mohandas, S. (2014). Effect of humic acid on plant growth characters and grain yield of drip fertigated aerobic rice (*Oryza sativa* L.). *The Bioresearch*,9(1), 45-50.

Environment Conservation Journal 24 (3): 116-125, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Water stress influence of Rajendrasonia and Pitamber turmeric varieties

Sambeta Kedarini ✉

Department of Botany, Osmania University, Hyderabad, Telangana, India

Singisala Nageswara Rao

Department of Botany, Osmania University, Hyderabad, Telangana, India

ARTICLE INFO

Received : 18 October 2022

Revised : 17 January 2023

Accepted : 05 February 2023

Available online: 10 April 2023

Key Words:

Pitamber

Rajendrasonia

Water stress

ABSTRACT

Turmeric varieties viz., Rajendrasonia and Pitamber were subjected to water stress by irrigating at different intervals. Impact of water stress on morphological, physiological and yield parameters of both the varieties were investigated. In this study irrigation treatments divided into three groups. Group A, control receives water weekly once. For every two weeks once group B was irrigated and for every three weeks once group C was irrigated. Plants which are under heavy water stress showed gradual reduction in morphological, physiological and yield parameters, i.e. plant height, number of leaves, leaf area, leaf area index, Net Assimilation rate, Relative Growth rate , fresh and dry weight of rhizome. Pitamber and Rajendrasonia growth parameters, physiological and yield parameters were slightly affected in moderate stress compared to control. In heavy stress condition the two varieties severely affected compared to control and moderate stress. Among the two selected varieties Pitamber was less affected in all parameters except in leaves number, tuberous roots length and in dry weight in moderate and heavy stress.

Introduction

Among the oldest spices turmeric is one of them. Increased demand on turmeric use as natural-dye, spice, flavorant led to increase in cultivation and production across the globe. Curcumin , de methoxy curcumin , bis de methoxy curcumin are the important active components present in turmeric. Among these components curcumin is the pivotal component. Curcumin has numerous properties like " anti-inflammatory, anticancer, antitumor, antibacterial, antioxidant, antidiabetic, antiallergic properties". (Singh *et al.*, 2012: Shehzad *et al.*, 2013: Devassy *et al.*, 2015: Deogade and Ghate 2015). Water supply can be considered as the major factor that affects plant growth , it also affects production of second-ary metabolites . (Randhawa *et al.*, 1992, 1996). Lack of water supply to plants leads to drastic changes in growth and in photosynthesis rate . However, some reports confirmed that providing limited water to plants enhances the secondary metabolites biosynthesis, accumulation of solutes and enzyme related activities (Singh-Sangwan *et al.*, 2001). Depletion in leaf area, leaf -senescence & reduced cell development were developed due to water undersupply conditions (Kafi and Damghani, 2001). Metabolic responses and physiological actions are significantly decreased due to lack of moisture (Flevas *et al.*, 2002). Under supply of water may be primarily influence "the primary, secondary metabolites biosynthesis, plant -lipids, plasma- membrane". Fatty-acids components undergo modifications in several crops due to lack of water. Essential- oil biosynthesis is also affected by water stress. (Laribi *et al.*, 2009; Bourgou *et al.*, 2011 Bettaieb *et al.*, 2011, 2012;). The main goal of this study was to analyze the resistance level and productivity of improved varieties of Curcuma plants (Pitamber, Rajendrasonia) under different water stress conditions.

Corresponding author E-mail: *kedarinikeni@gmail.com*

Doi:https://doi.org/10.36953/ECJ.15482486

Material and Methods

A field study was conducted during the year 2019-20 at the University College of Science, Saifabad, Hyderabad. Arid type of climate was recorded in the Hyderabad. Latitude and longitude of the study area is 17.4074º N, 78.4536º E. Black soil was used for the study and its analysis were conducted by using Digital Soil Testing Mini Lab in Coromandel International Limited located in Center of Excellence (Vegetables and Flowers) Jeedimetla, Hyderabad and the data collected as follows, soil composed of clay (56.5%), silt (23.4%), Fine sand (15.1 %), Coarse sand (4.9 %), pH of the soil was 6.8. Nitrogen content was high in the soil viz., 560.0 kg/ha. Available moisture percentage of the soil was 28.5 mm (0-15 cm depth).The rhizomes of both the categories - control and treatments were planted in pots by using randomized complete block design method with three replications, in order to study the morphological, physiological and yield parameters of turmeric. Two short duration varieties of turmeric, Pitamber, Rajendrasonia were used for the study. The healthy rhizomes of turmeric varieties were collected from Horticulture & Sericulture Department, Nizamabad, Telangana, India. The rhizomes were sterilized by metaloxin mancozeb (150g/150ml concentration) by soaking for 30 minutes. After 30 minutes, the turmeric rhizomes were dried in shade for around one and a half hour and planted in the pots. After 60 days of sowing, the saplings were exogenously treated with 70% thiophanate methyl.

The two treatments provided were treatment A-Moderate water stress giving water in 14 days interval and treatment B-Heavy water stress giving water in 21 days interval, where control includes watering plants weekly once. At each irrigation, 800 ml of water per pot was applied.

Plants for observation were randomly selected from control and treatments to study experimental parameters according to the chapman and pratt method (1978). The parameters choosed for the study is germination percentage where, germination counts were made at 10 days interval upto 90 days after subjecting the rhizomes to the soils of control and treatment categories, when the germination rate becomes almost constant in each pot. However, germination percentage was calculated only at 50 days after sowing, height of the plant where, the main shoot was taken to represent the height of the plant. The plant height was measured in centimeters at 60,120, 180 and 240 days after plantation. The measurement was taken from the soil surface to the shoot apex and the average mean was taken from three plants selected from control and treatment categories randomly, total numbers of thin and tuberous adventitious roots count were made at various growth stages and average mean was taken from three sample plants selected from control and treatment categories randomly at 60,120,180 and 240 days after plantation, number of functional leaves per plant of treatments and control categories were counted at 60,120,180 and 240 days after plantation. Average mean was taken from three sample plants, leaf length, leaf width per plant of treatments and control groups were measured in centimeters at 60,120,180 and 240 days after plantation, Leaf Area was measured by Portable Area Meter (LI-COR) Model LI-3,000 in cm^2. Average mean of leaf area was taken from three plants selected from control and treatment categories respectively at the 60,120,180 and 240 days after plantation.

Net Assimilation Rate measured by Radford method (1967), fresh weight of mother rhizome was measured in grams at 180 and 240 days after plantation by using the electrical balance**,** length of mother rhizome was measured in centimeters at 60,120,180, 240 days after plantation, width of mother Rhizome was measured in centimeters at 240 days after plantation. Dry weight of mother rhizome was measured in grams at 240 days after plantation by using electrical balance. Radford (1967) method was followed to measure the plant Relative Growth Rate at 240 days after plantation. SPSS 16.0 soft ware used to determine the least significant difference ($P \leq 0.05$) and other calculations were carried out using MS Excel 2010.

Results and Discussion

Water stress greatly influences the germination percentage of turmeric. At 50^{th} day after planting Pitamber in the control showed highest germination rate. Rajendrasonia and Pitamber showed 100 percent germination from 70^{th} day onwards in control where water was given 7 days once. In moderate stress condition least germination percentage was recorded in Rajendrasonia than

Pitamber (figure 1 and 2). In the heavy stress condition 0nly 33 percent germination on 50th day was recorded in both varieties. In the heavy stress condition highest germination percentage was recorded in Pitamber compared to Rajendrasonia. Plants are particularly vulnerable to water deficit stress in the course of the key periods of germination of seed and initial development of seedling (Li *et al.*, 2011). The lack of free water availability in the early stages of seeds may be the cause of the reduced seed germination . This would render the hydrolytic enzymes inactive (C. B. Shah *et al.*,1975 , A. Hadas *et al.*, 1976).

Figure 1: Reduction in germination percentage in turmeric varieties

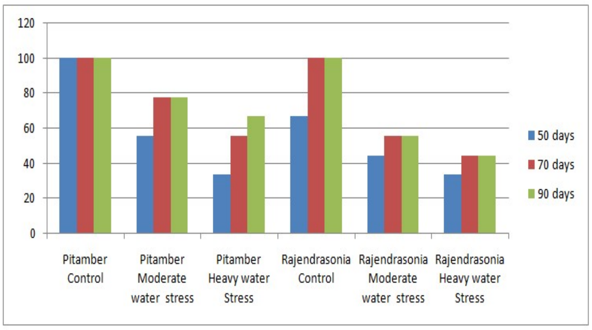


Figure 2: Effect of irrigation intervals on Germination percentage of Mother Rhizome of Rajendrasonia and Pitamber after 50,70,90 days after plantation (mean of sea son 2019 - 2020)

Plant height varied at different stages of growth of turmeric significantly differed among treatments (figure 3). Plant height was noted highest in Pitamber control viz., 110 cm at 240 days after plantation compared to Rajendrasonia(95.4 cm). Pitamber showed highest Plant height (80 cm) than the Rajendrasonia (69.2 cm) in case of moderate water stress condition at 240 days after plantation. Compared to control , plants which exposed to moderate water stress showed reduced plant height. In case of heavy water stress reduced plant height was noted in Rajendrasonia (45.4 cm) compared to Pitamber (50.1 cm).Heavy water stress reduced Plant height. Due to the water deficit condition, mitosis divisions was compromised, and elongation of cell and expansion of cell led to slower plant- growth and development (Hussain *et al.*, 2008).

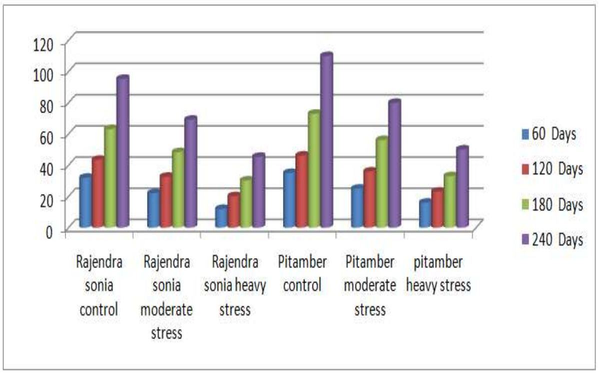


Figure 3: Effect of irrigation intervals on Plant height of Mother Rhizome of selected varieties after 60, 120, 180, 240 days after plantation (mean of season 2019 - 2020)

Number of thin and tuberous adventious roots at different stages of growth of turmeric significantly differed among treatments (figure 4). Highest number of thin and tuberous adventious roots was noted in Pitamber (32) in control at 240 days after plantation compared to Rajendrasonia (30). Pitamber (29) showed maximum number of thin and tuberous adventious roots than the Rajendrasonia(21) in case of moderate water stress condition at 240 days after plantation. Compared to control, the plants which faced moderate stress showed less number of thin and tuberous adventious roots . In case of heavy water stress few number of thin and tuberous adventious roots noted in Rajendrasonia(15) compared to Pitamber (18).Heavy stress reduced number of thin and tuberous adventious roots . According to Dhole and Reddy (2010), as the water potential decreases, the number of roots per plant decreases. Number of leaves per plant at different stages of growth of turmeric significantly differed among treatments (figure 5). The number of leaves slightly reduced in the plants which were undergone moderate water stress compared to control.

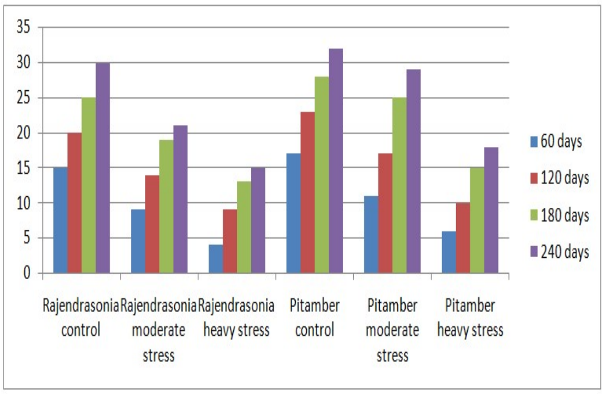


Figure 4: Effect of irrigation intervals on number of thin and tuberous adventious roots of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (Mean of season 2019 - 2020)

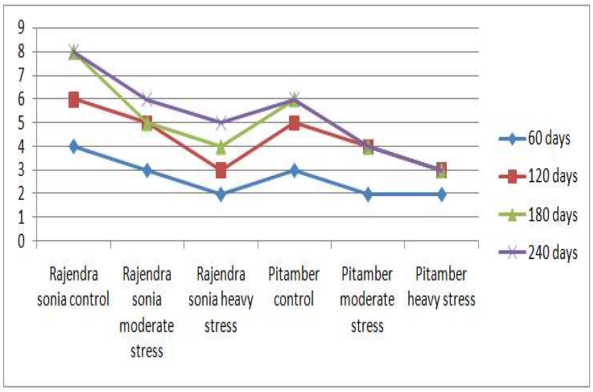


Figure 5: Effect of irrigation intervals on Number of leaves of Mother Rhizome of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (mean of season 2019 - 2020)

Among the two varieties Rajendrasonia (6) leaves was less affected than Pitamber (4) leaves. 5 leaves were recorded in Rajendrasonia and 3 leaves were recorded in Pitamber at 240 days after plantation in case of heavy water stress condition compared to control. Among the two varieties Rajendrasonia is less affected than Pitamber. Compared to control Pitamber more affected than Rajendrasonia. The number of leaves observed under the severely stressed treatment (CG 80–85% MAD) are in agreement with the findings on the response of water stress on essential oil of oregano by, Said-A l Ahl *et al.*(2009), Auges Gatabazi *et al* . (2019). Leaf length of mother rhizome (cm) at different stages of growth of turmeric significantly differed among treatments (figure 6) In control maximum leaf Length was noted in Pitamber(45.5 cm) . In moderate water stress condition leaf length was less affected in pitamber (20.5,27.2,35.3,40) than Rajendrasonia (20,26,30,35 cm) at 60, 120,180,240 days after plantation. Compared to control both are slightly reduced. In heavy water stress condition leaf length was more affected in pitamber and Rajendrasonia at 60, 120,180,240 days after plantation, compared to control and moderate stress .Among the two leaf length was less affected in Pitamber(30.5 cm) than Rajendrasonia (25 cm) at 240 days after plantation. Leaf width of mother rhizome (cm) at different stages of growth of turmeric significantly differed among treatments (figure 7) In control maxium leaf width was noted in Pitamber(9.9 cm) at 240 days after plantation .In moderate water stress condition leaf width was less affected in Pitamber than Rajendrasonia at 60, 120,180,240 days after plantation. Compared to control, Pitamber (7.9 cm) and Rajendrasonia (7.7 cm) are slightly reduced at 240 days after plantation. In heavy water stress condition leaf width was more affected in pitamber and Rajendrasonia compared to control and moderate stress .Among the two varieties leaf width was less affected in Pitamber (6.1 cm) than Rajendrasonia (5.9 cm) at 240 days after plantation. Both the total number of leaves and the size of each individual leaf diminish during a drought. The amount that the leaf expands is frequently governed by the turgor pressure and the availability of assimilates. Reduced turgor pressure and a slow rate of photosynthesis, largely restrict leaves from expanding in dry conditions (Rucker *et al.*, 1995)

Leaf Area of mother rhizome plant (cm^2) at different stages of growth of turmeric significantly differed among treatments (figure 8). In control maxium leaf area was noted in Pitamber (150.5 cm^2) at 240 days after plantation .In moderate water stress condition leaf area was less affected in Pitamber than Rajendrasonia at 60, 120,180,240 DAP. Compared to control, Pitamber (124.5 cm^2) and Rajendrasonia (114 cm^2) are slightly reduced. In heavy water stress condition leaf area was more affected in Pitamber and Rajendrasonia compared to control and moderate water stress. Among the two, leaf area was less affected in Pitamber (79.5 cm^2) than Rajendrasonia (66 cm^2). The results are agreed with the Bittimen.s *et al* (1987).

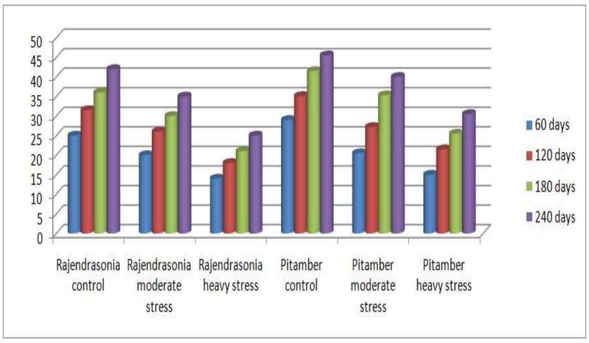


Figure 6: Effect of irrigation intervals on leaf length of mother rhizome in cm of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (mean of season 2019 - 2020)

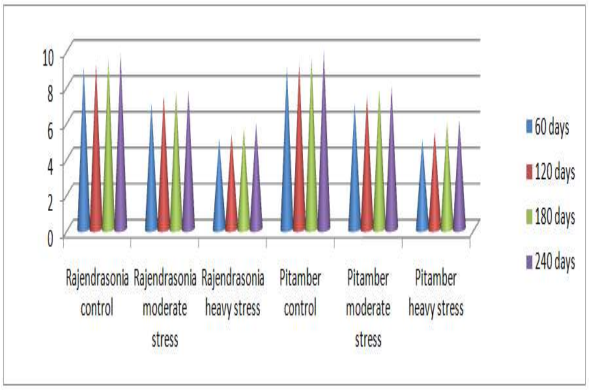


Figure 7: Effect of irrigation intervals on leaf width of mother rhizome in cm of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (mean of season 2019 - 2020)

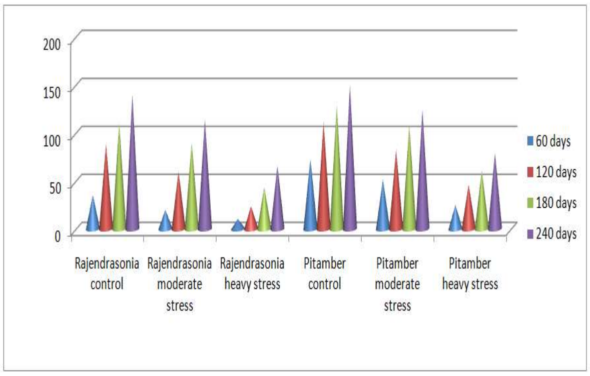


Figure 8: Effect of irrigation intervals on leaf area of mother rhizome in cm^2 of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (mean of season 2019 - 2020)

Physiological aspects:

Leaf Area Index of mother rhizome plant at different stages of growth of turmeric significantly differed among treatments (figure 9). In control

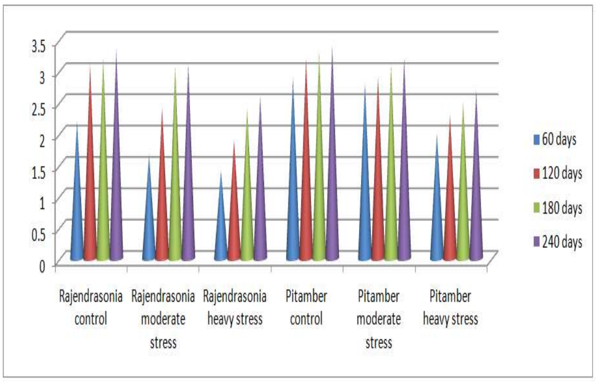


Figure 9: Effect of irrigation intervals on Leaf Area Index of Mother rhizome of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (mean of season 2019 - 2020)

maxium leaf area index was noted in Pitamber (3.4) .In moderate water stress condition leaf area index was less affected in Pitamber than Rajendrasonia at 60, 120,180,240 DAP. Compared to control both are slightly reduced. In heavy water stress condition leaf area index was more affected in Pitamber(2.7) and Rajendrasonia(2.6) compared to control and moderate stress .Among the two varieties leaf area index was less affected in Pitamber than Rajendrasonia. The reduced leaf area index value under stress is due to fewer and smaller leaves, as well as a well-documented drought response in many crops. The leaf area index responds to physiological activities that are necessary for dry matter generation, such as leaf expansion and photosynthesis (Blum 2005) A prior investigation of *Pelargonium sidoides* growth in response to water and nitrogen levels demonstrated a decrease in leaf area with water stress. Similarly, Acreche et al (2009), found that well-watered commercial ginger had the highest leaf area index when compared to stress given treatments.

Net Assimilation Rate of mother rhizome was measured after 240 DAP. It Was observed that Pitamber (0.0041) net assimilation rate was less affected than Rajendrasonia (0.002)in control (figure 10).In moderate water stress condition net assimilation rate of mother rhizome were affected more in Pitamber(0.003) and Rajendrasonia (0.001) compared to control. Among the two selected varieties Pitamber performance is good than the variety Rajendrasonia at 240 DAP. In heavy water stress condition net assimilation rate was more affected in Pitamber (0.002) and Rajendrasonia (0.00064) compared to control and moderate stress. Among the two net assimilation rate was less affected in Pitamber than Rajendrasonia. The results are similar with Moradi et al (2008), who discovered that water deficit stress during the vegetative development phase significantly reduced NAR and came to the conclusion that irrigation should be extended throughout all growth stages, particularly during the reproductive phase, to maximise Net Assimilation Rate. Relative Growth Rate of mother rhizome was measured after 240 DAP. It Was observed that Pitamber (0.0194) Relative Growth Rate was less affected than Rajendrasonia (0.01) in control (figure 11).

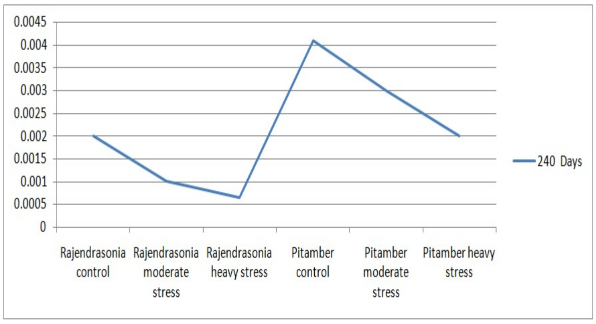


Figure10: Effect of irrigation intervals on Net Assimilation Rate of Mother rhizome of Rajendrasonia and Pitamber after 240 days after plantation (mean of season 2019 - 2020)

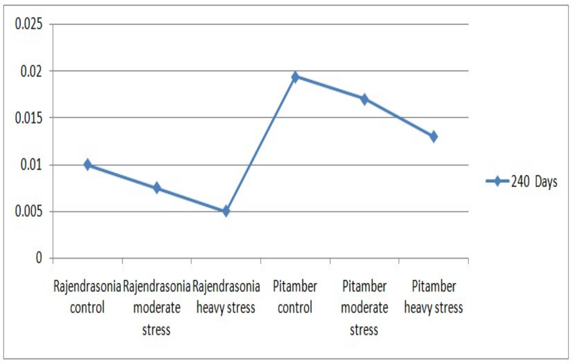


Figure 11: Effect of irrigation intervals on Relative Growth Rate of mother rhizome of Rajendrasonia and Pitamber after 240 days after plantation (mean of season2019 and 2020)

In moderate water stress condition Relative Growth Rate of mother rhizome were affected more in Pitamber (0.017) and Rajendrasonia (0.0075) compared to control. Among the two selected varieties Pitamaber performance is good than the variety Rajendrasonia at 240 DAP. In heavy water stress condition Relative Growth Rate was more affected in Pitamber (0.013) and Rajendrasonia (0.005) compared to control and moderate stress .Among the two Relative Growth Rate was less affected in Pitamber than Rajendrasonia. The results are agreed with Shihab Uddin et al (2013) ,who mentioned lack of water significantly lowers RGR in mung variety.Concerning the combination between irrigation and the two species of *Curcuma* plants it can be noticed that there were no significant effect on the growth and physiological parameters. The results obtained are agreed with the results of Leithy *et al.* 2006 on rosemary and El-Mekawy (2013) on Achillea santolina. Under supply of water had modified the rosemary plants morphology, i.e declined height of the plant and the shoot development according to Nicola´s *et al.* (2008).According to L. El-Tahir *et al.* (2011), this may be due to the vital functions of water supply at adequate amount of diverse physiological processes such as photosynthesis, respiration, transpiration, translocation, enzyme reaction, and cell turgidity occurring concurrently. Furthermore, rising levels of water stress impair growth and yield due to decreased photosynthesis due to decreased stomata and mesophyll conductivity. Studies on *Catharanthus roseus* seedlings by Amirjani (2013) reported that subjecting seedlings to four varied water- treatments i.e irrigating once in every week, every two weeks and once in three weeks, where plants in control were given water daily. The activity of photosynthesis and rate of transpiration were significantly declined with drought level enhancement.

Yield aspects

Fresh weight of mother rhizome (gms) at different stages of growth of turmeric significantly differed among treatments (figure 12). In control maxium fresh weight was noted in Pitamber (60.2 grams) at 240 days after plantation .In moderate water stress condition fresh weight was less affected in

Pitamber (22,42 grams) than Rajendrasonia (19,28 grams) at 180,240 days after plantation. Compared to control both are slightly reduced. In heavy water stress condition fresh weight was more affected in Pitamber and Rajendrasonia compared to control and moderate stress .Among the two fresh weight was less affected in Pitamber (28 grams) than Rajendrasonia (19.8 grams). The results similar with Auges Gatabazi *et al.*, 2019, who found that fresh weight of commercial ginger was more negatively impacted by extreme water stress than that of African ginger. Length of mother rhizome in cms at different stages of growth of turmeric significantly differed among treatments (figure 13).

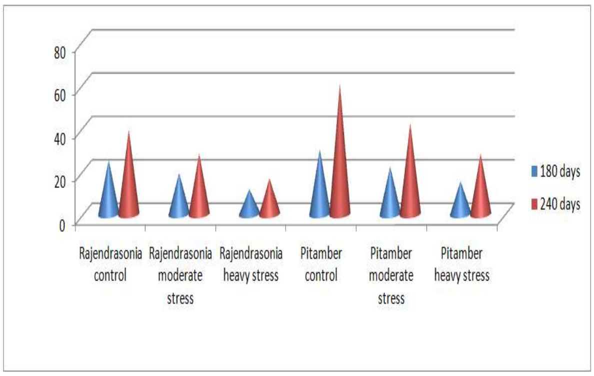


Figure 12: Effect of irrigation intervals on Fresh weight of Mother rhizome in grams of Rajendrasonia and Pitamber after 180,240 days after plantation (mean of season 2019 - 2020).

In control maximum length of mother rhizome was noted in Pitamber(6.9 cm) .In moderate water stress condition length of mother rhizome was less affected in Pitamber (4.9,5.2,5.7,5.9 cm) than Rajendrasonia (4.1,4.4,4.7,4.9 cm) at 60, 120,180,240 days after plantation. Compared to control both are slightly reduced. In heavy water stress condition length of mother rhizome was more affected in Pitamber and Rajendrasonia compared to control and moderate stress .Among the two length of mother rhizome was less affected in Pitamber (5.1 cm) than Rajendrasonia (4.6 cm) at 240 days after plantation. The differences between the irrigation intervals were significant in most cases. Width of mother rhizome in cms at different stages of growth of turmeric significantly differed among treatments (figure 14). In control maxium Width of mother rhizome was noted in Pitamber (4.3 cm) .In moderate water stress condition Width of mother rhizome was less affected in Pitamber (3.3 cm) than Rajendrasonia (2.2 cm) at 240 days after plantation.

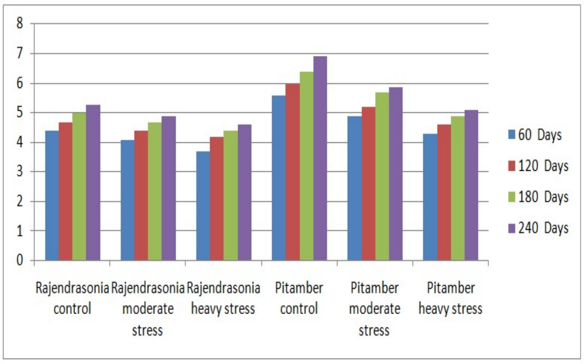


Figure13: Effect of irrigation intervals on length of Mother rhizome in cm of Rajendrasonia and Pitamber after 60,120,180,240 days after plantation (mean of season 2019 - 2020)

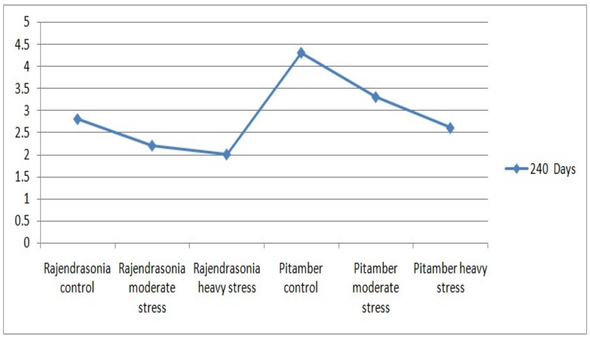


Figure 14: Effect of irrigation intervals on width of mother rhizome in cms of Rajendrasonia and Pitamber after 240 days after plantation (mean of season 2019 and 2020)

Compared to control both are slightly reduced. In heavy water stress condition Width of mother rhizome was more affected in Pitamber and Rajendrasonia compared to control and moderate stress .Among the two Width of mother rhizome was less affected in Pitamber (2.6 cm) than Rajendrasonia (2 cm). Dry weight of mother rhizome(gms) at different stages of growth of turmeric significantly differed among treatments (figure 15). In control maximum dryweight was noted in Rajendrasonia (8.0 grams). In moderate water stress condition dry weight was maximum in Rajendrasonia than Pitamber at 180,240 days after plantation. Compared to control both are slightly reduced. In heavy water stress condition dryweight was more affected in Pitamber and Rajendrasonia compared to control and moderate stress .

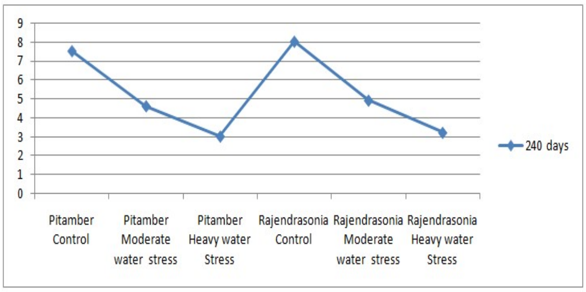


Figure 15: Effect of irrigation intervals on Dry weight of mother rhizome in gms of Rajendrasonia and Pitamber after 240 days after plantation (mean of season 2019 and 2020)

Among the two dry weight was maximum noted in Rajendrasonia (3.2 grams) than Pitamber (3.0 grams) at 240 days after plantation. According to earlier findings, when there is a water deficit, the dry weight reduces due to a decrease in chlorophyll concentration, which lowers the effectiveness of photosynthesis, as noted by Khalid (2006). The results were similar with this.

Mean of weight of whole rhizome in kgs per plant of selected varieties after 240 Days After Plantation (DAP) were recorded. It Was observed that Pitamber rhizome (0.123 kg) whole weight was maximum than Rajendrasonia (0.079 kg) in control (figure 16). In moderate stress condition weight of whole rhizome were affected more in Pitamber and Rajendrasonia compared to control.

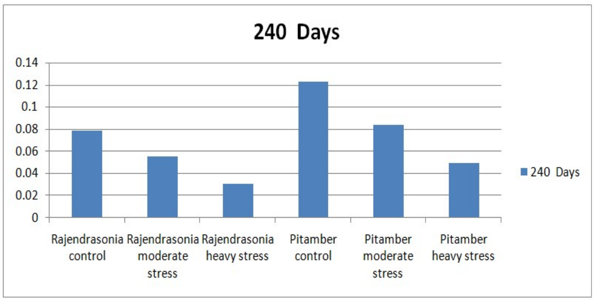


Figure 16: Effect of irrigation intervals on weight of whole rhizome of Rajendrasonia and Pitamber after 240 days after plantation (mean of season 2019 and 2020).

Among the two selected varieties Pitamber rhizome (0.084 kg) weight was maximum than the variety Rajendrasonia (0.056 kg) at 240 days after plantation. In heavy stress condition rhizome whole weight was more affected in Pitamber and Rajendrasonia compared to control and moderate stress .Among the two whole rhizome weight was less affected in Pitamber (0.050 kg) than Rajendrasonia (0.031 kg). The results are agreed with the findings mentioned.Water plays a crucial role in plant growth and its production of several crops & medicinal plants was prooved by several researchers. Nutrients absorption drastically reduced as a result of reduction in vegetative development of plants as per Pascale *et al.* (2001). A study of several irrigation regimes on potato development and production found that total fresh and marketable tuber output improved with increasing irrigation (Yuan, B.Z. *et al.*,2003).Total plant fresh weight, Total dry weight of plant "*Satureja hortensis*" (summer savory) was awfully reduced under soil water debt conditions. (Baher *et al.*, 2002).A Study on "*Eragrostis curvula"* plant cultivated under water stress showed that plant number, stem number, dry weight was affected adversely (Colom and Vazzana, 2002). Dry weight of the plant was reduced drastically because of decrease in the content of chlorophyll as reports mentioned under deficit water condition satisfied with the data of Khalid (2006). The results mentioned are satisfied with the results obtained by Farooq (2009) who mentioned that morphological parameters and yield parameters of plant was severely reduced by drought stress, which mainly affects biochemical functions and physiological aspects i.e photosynthesis, trans-location, respiration, uptake of ions, carbohydrates, nutrient- metabolism and promoters of growth. Reduced plant biomass recorded in *Salvia officinalis* (Bettaieb, I *et al.*, 2009) Jyotsna et al (2012) found similar results in ginger, reporting that water stress reduced growth and yield. Mulu et al (2012) conducted studies on onion crop and found that well-watered treatments given better yields than stressed ones.

Conclusion

Pitamber showed good germination percentage, highest number of thin and tuberous roots, maximum leaf length, leaf area, leaf area index, plant height, plant fresh weight and also resulted in highest relative growth rate, net assimilation rate in control than Rajendrasonia. In moderate stress these parameters

was slightly reduced in Pitamber and Rajendrasonia compared to control. Among the two Pitamber was less affected at 60, 120,180,240 DAP. In heavy water stress condition, where water given 21 days once showed more impact on all the parameters of pitamber and Rajendrasonia compared to control and moderate water stress. Among the two, pitamber was less affected than Rajendrasonia. Rajendrasonia leaves number, leaf width, dry weight was maximum in control than Pitamber and its leaves number, leaf width, dry weight were less affected in moderate and in heavy
stress condition than Pitamber. Irrigating turmeric two weeks once showed minor impact on plants than irrigating those three weeks once. In heavy water stress, plants were affected in all morphological, physiological and yield parameters. Thus, irrigation intervals every one week improved growth characteristics and yield of selected *Curcuma* varieties. Pitamber produced the higher values as compared to Rajendrasonia.

Conflict of interest

The authors declare that they have no conflict of interest.

References

A. Hadas, (1976).“Water Uptake and Germination of Leguminous Seeds under Changing External Water Potential in Osmoticum Solution,” *Journal of Experimental Botany*, Vol. 27, No. 3, pp. 480-489.

Acreche, M.M.; Briceño-Félix, G.; Sánchez, J.A.M.; Slafer, G.A.(2009). Radiation interception and use efficiency as affected by breeding in Mediterranean wheat. *Field Crops Res*., 110, 91–97.

Amirjani MR. (2013). Effects of drought stress on the alkaloid contents and growth parameters of *Catharanthus roseus.* ARPN J Agric Bio Sci 8 (11): 745-750

Auges Gatabazi , Diana Marais , Martin J. Steyn ,HintT. Araya , Motiki M. Mofokeng and Salmina N. Mokgehle, (2019). Evaluating Growth, Yield, and Water Use Efficiency of African and Commercial Ginger Species in South Africa. *Water: 11:* 548.

Baher ZF, MuzaM, GhorbanliM, Rezaii MB.(2002). The influence of water stress on plant height, herbal and essential oil yield an decomposition in Satureja hortensis L. *Flav Frag*. 6: 127-32.

Bettaieb I, Knioua S, Hamrouni I, Limam F, Marzouk B., (2011). Waterdeficit impact on fatty acid and essential oil composition and antioxidant activities of cumin (Cuminum cyminum L.) aerial parts. *J Agric Food Chem.* 59: 328-334.

Bettaieb IR, Jabri-uroul I, Hamrouni-Sellami I, Bourgou S, Limam F, Murzouk B. (2012). Effect of drought on the biochemical compositon and antioxidant activities of cumin (Cuminum cyminum L.) Seeds*. Ind Crop Prod*. 36 (1): 238-245.

Bettaieb, I.; Zakhama, N.; Wannes, W.A.; Kchouk, M.E.; Marzouk, B.(2009). Water deficit effects on Salvia officinalis fatty acids and essential oils composition. *Sci. Hortic*., 120, 271–275.

Blum, A. (2005).Drought resistance, water-use efficiency, and yield potential—Are they compatible, dissonant, or mutually exclusive. *Crop Pasture Sci*., 56, 1159–1168.

Bourgou S, Bettaieb I, Saidani M, Marzouk B. (2011). Fatty acids, essential oil and phenolics modifications of black cumin fruit under NaCl stress conditions. *J. Agric Food Chem.* 59: 3428-3434.

C. B. Shah and R. S. Loomis, (1975).“Ribonucleic Acid and Protein Metabolism in Sugar Beet during Drought,” *Plant Physiology*, Vol. 18, pp. 240-254.

Chapman, H.D. and Pratt, P.F. (1978) Methods of Analysis for Soils, Plants and Water. Univ. of California, *Prical Publication*, Vol. 4030, 12-19.

Colom MR, Vazzana C.(2002). Water stress effect on three cultivars of Eragrostis curvula. *Ita J Agron.* 6: 127-32.

Deogade, S., Ghate, S.,(2015). Curcumın: therapeutıc applıcatıons in systemıc and oral health. *Int. J. Biol. Pharm. Res.* 6 (4): 281–290.

Devassy, J., Nwachukwu, I., Jones, P.,(2015). Curcumin and cancer: barriers to obtain inga health claim. *Nutr. Rev.* 73(3): 155–165.

Dhole, V. J. & Reddy, K. S. (2010). Gamma rays induced moisture stress tolerant long root mutant in mungbean (*Vigna radiata* L Wilczek). *Electronic Journal of Plant Breeding*, 1(5):1299-1305.

El-Tahir B, El-Hawary A, Yagaub SO. (2011). Effect of different irrigation intervals on wheat (*Triticum aestivum*) in semiarid regions of Sudan. *J Sci Tech* 12 (3): 75.

Farooq M, Wahid A, Kobayashi N.(2009). Plant drought stress: effects,mechanisms and management. *Agron Sustain Dev* 29 (1): 185-212.

Flevas J, MedranoH. (2002). Drought-inhibition of photosynthesis in plants: stomatal and non stomatal limitation revisited. *Ann Bot.* 89: 183-189.

Hussain M., Malik M.A., Farooq M., Ashraf M.Y., Cheema M.A. (2008). Improving Drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower, *J. Agron. Crop Sc*i. 194, 193–199.

Jyotsna, N.; Ghosh, C.; Meitei, W.I.(2012). Study of growth, yield and quality of organically grown ginger varieties under rainfed condition of Manipur. *J. Crop Weed*, 8, 17–21.

Kafi M, Damghan MM. (2001). Mechanisms of Environmental Stress Resistance in plants Publicaton Ferdowsi University, Mashha Khalid, K.A., 2006. Influence of water stress on growth, essential oil and chemical composition of herbs (Ocimum sp.). *Int. Agrophys*. 20 (4), 289–296

Kh.A. Khalid,(2006). Influence of water stress on growth, essential oil, and chemical composition of herbs (Ocimum sp.), *Int. Agrophysics*, 289-296

Laribi B, Bettaieb I, Kouki K, Sahli A, Mougou A, Marzouk B. (2009). Water deficit effect on caraway (Carum carvi L.) growth, essential oil and fatty acid composition. *Ind Crop Prod*. 31: 34-42.

Leithy S, El-Meseiry TA, Abdallah EF. (2006). Effect of/biofertilizer, cell stabilizer and irrigation regime on rosemary herbage oil yield and quality. *J App Sci Res.* 2 (10): 773-779.

Li FL, Bao WK, Wu N. (2011). Morphological, anatomical and physiological responses of Campylotropis polyantha (Franch.) Schindl. seedlings to progressive water stress. *Sci Hortic-Amsterdam*;127:436-43.

Moradi, A., Ahmadi, A., & Zadeh, A. H. (2008). The effects of different timings and severity of drought stress on gas exchange parameters of mungbean. *Desert,* 13(1): 59-66.

Mulu, A.; Alamirew, T.(2012). Deficit irrigation application using center pivot sprinkler irrigation for Onion production. *Int. J. Basic Appl. Sci.*, 1, 148–159.

Nicola´s E., Ferrandez T., Rubio J.S., Alarco´n J.J., Sa´nchez-Blanco, M. (2008). Annual Water Status, Development, and Flowering Patterns for Rosmarinus officinalis Plants under Different Irrigation Conditions. *HORTSCIENCE* 43(5):1580– 1585.

Pascale, S. D., Paradiso, R., Barbieri, G. (2001). Recovery of physiological parameters in Gladiolus under water stress. *Colture Protette*. 30 (7):65-69.

Radford, P.J.(1967). Growth analysis formulae - their use and abuse. *Crop Science, Madison*, v.7, p. 171-175.

Randhawa GS, Gill BS, Raychanudhuri SP. (1992). Optimizing agronomic requirements of anise (Pimpinella anisum L. in the Punjab. Rescent Advances in Medicinal, Aromatic and Spice Crops. Vol 2. *International Conference*, 28-31. January 1989, New Delhi, India.

Randhawa, G.S., Mahey, R.K. (1996). Advances in the agronomy and production of in India. Herbs, Spices Med. Plants. 3: 71–100.

Rucker, K.S., Kvien, C.K., Holbrook, C.C. and Hook, J.E. (1995). Identification of peanut genotypes with improved drought avoidance traits. *Peanut Sci*., 24: 14-18

Said-A lAhl, H.A.H.; Omer, E.A.; Naguib, N.Y. (2009). Effect of water stress and nitrogen fertilizer on herb and essential oil of oregano. *Int. Agrophys.23*: 269–275.

Shehzad, A., Rehman, G., Lee, Y. (2013). Curcumin in inflammatory diseases. Int.Union Biochem. *Mol. Biology, Inc.* 39 (1): 69–77.

Shihab Uddin, Shahnaj Parvin & M. A. Awal. (2013). Morpho-Physiological Aspects Of Mungbean (*Vigna Radiata* L.) In Response To Water Stress, *International Journal Of Agricultural Science*, Vol. 3, Issue 2, 137-148

Singh, S., Panda, M.K., Nayak, S. (2012). Evaluation of genetic diversity in turmeric (Curcuma longa L.) using RAPD and ISSR markers. *Ind. Crops Prod* 37: 284–291. 10.1016/j. indcrop. 2011. 12. 022.

Singh-Sangwan N, Farrooqi AHA, Shabih F, Sangwan RS. (2001). Resultation of essential oil production in plants. *Plant Growth Reg.* 34: 3-21.

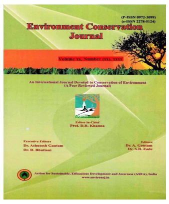
Yuan, B.Z.; Nishiyama, S.; Kang, Y. (2003). Effects of different irrigation regimes on the growth and yield of drip-irrigated potato. *Agric. Water Manag*. 63, 153–167.

Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 126-135, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal
ISSN 0972-3099 (Print) 2278-5124 (Online)



Comparative evaluation of low-cost natural farming, organic farming and conventional farming in major crops of South Saurashtra region at Junagadh, Gujarat, India

Hiteshvari Korat ✉
Agricultural Research Station, Anand Agricultural University, Arnej, Gujarat, India
RatilalMathukia
Department of Agronomy, Junagadh Agricultural University, Junagadh, Gujarat, India
HarshangTalaviya
Division of Agricultural Chemical, ICAR-Indian Agricultural Research Institute, New Delhi, India

ARTICLE INFO

Received :09 September 2022
Revised :10 December 2022
Accepted :03 January 2023

Available online: 10 May 2023

Key Words:
Calcareous
DTPA
Junagadh
Experimental economic
natural farming
organic

ABSTRACT

Conventional farming always modifying by good innovation in agriculture, while the holistic idea of organic farming checks the use of synthetic inputs where in opposite side, the concept of natural farming allowing farming with few traditional and locally available inputs. The all three farming concepts are fundamentally different, to check it on real field, a experiment was conducted on medium black calcareous clayey soil at Junagadh (Gujarat) during *rabi* 2019-20 to *kharif* 2020 in order to evaluate low cost natural farming, organic farming and conventional farming in major six crops of Gujarat. The experimental results revealed that conventional farming module significantly increased yields of crops as compared to organic farming and low cost natural farming. Significantly higher available nitrogen, phosphorous and potassium after harvest was found under conventional farming, while organic farming module registered significantly higher organic carbon, heat soluble S; DTPA-extractable Fe, Zn, Cu and Mn after harvest, which was found at par with conventional farming. Economic analysis showed that maximum net returns gross returns, and B:C ratio were observed under conventional farming module.

Introduction

Since human evolution, farming practices concept has been changing with new innovations and connectivity with other continental peoples. the concept has totally changed from its core ideas, which is also favourable in point of meet the current demand form society. that point of view conventional farming walk with innovations. During 19th century and earlier time farmers of thorough world of are capable to meets the demand of food by producing food in organic farming. In current scenario, growing organic food was no longer a viable way to feed the world's population as the world's population grew. As a result, advancements and technology were introduced innovative, resource efficient and sustainable productive ways to feed a population that had nearly doubled in size. Mechanized farming, fertilizers, and chemically pest control system have contributed to higher yields for a larger population. These farming methods became ingrained in what we now refer to as "conventional" farming (Melissa, 2003).Green putsch transformed the country from a food-deficit state to self-sufficiency during early 1970's but the avails of green putsch were reviewed and found that it has led to serious negative impacts on genetic diversity, incidence of pests, soil erosion, soil fertility, water shortage, micronutrient deficiencies, soil contamination, and availability of nutritious food for the local population. Ultimately farming society of the Indian has been experiencing rural impoverishment the displacement of huge numbers of small farmers from their land and increased tensions and disputes (Sebby, 2010).Government of India has committed

Corresponding author E-mail: *korathiteshvari@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14912463

to double farmers' income by 2022 and all efforts are being made to execute the pledge. After perceiving the harmful effects of chemical farming, newly introduced agriculture farming technique among the farmers is Low Cost Natural Farming means for all the crops, thereby decreased in the cost of production. The economic survey of 2018-19 made fervent appeal for adoption of Low Cost Natural Farming (LCNF) in a big way to double farmer's income and it was subsequently endorsed by the Hon'ble Finance Minister during her budget speech in the parliament. Organic farming, Biodynamic farming, *Homa Jaivik Krishi, Rishi Krishi, Panchagavya Krishi,* Natural farming, Permaculture, LEISA farming, Natueco farming, *Homa* Farming, *Yogic* farming and other eco-friendly and farmer-friendly alternative farming systems are based on nature and implemented to protect soil and environment degradation, protection from the hazardous side effects of chemical methods, such as magnification, pollution, carcinogenic elements, food poisoning and so on.

In Current scenario,scientific community, ecologist, policy makers and economist making special affords to reduce the environmental burden of agricultural productionand direct it toward more sustainable practices.To serve the purpose we have conducted comparative study between CF, OF and LCNF. It is first study in Indian continent to check the available resource efficiency and economical output of fundamentally different agricultural practices

Material and Methods

Our research study was conducted on non-organic fixed plot with large plot technique and five samples collected from each of 2.7 m x 4.8 m plot. The observations were recorded on five randomly selected plants for each net plot and mean values were computed for each net plot and mean of all the plots represent the result of each module. Some of the parameters were analysed in the field immediately after collection of samples. Soil samples were directly taken in the lab and analysed for various soil physico-chemical parameters like, bulk density, porosity, water holding capacity, organic carbon (walkley and black's process), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al.*, 1954), available potassium (Jackson, 1974), available sulphur (Williams and Steinbergs, 1959) and micronutrients (Lindsay and Norvell, 1978). The details of the farming module are presented in Table 1. The present experiment included wheat and chickpea during *rabi* season 2019-20; groundnut and sesame during summer season 2020; groundnut and sweet corn during *kharif* season 2020. Only Module-I (Low cost natural farming) included intercropping of wheat and chickpea (4:1 replacement series); groundnut and sesame (3:1 replacement series); groundnut and sweet corn (2:1 replacement series). The detail technical programme presented in Table 2. For data analysis, the experiment has followed Large plot technique model.The benefit:cost ratio was calculated by using the following formulae.

$$B:C = \frac{\text{Gross returns (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

Table 1: Package of various treatments of different farming systems

Treatments	Module details
Module-I	**Low cost natural farming (LCNF)** • Intercropping of crops • Seed treatment with *Beejamrut* by spraying on seed, mix well and dry before sowing • Soil application of *GhanJeevamrut* @ 250 kg/ha along with FYM @ 250 kg/ha at sowing as well assoil application of *Jeevamrut* with irrigation at sowing, 30, 60 & 90 DAS • *Achhadan*: Wheat straw mulch @ 5 t/ha • Plant protection: *Agniastra*, *Brahmastra, Neemastra*, *etc.,* if required
Module-II	**Organic farming (OF)** • Sole cropping of crops as per area covered in LCNF • Seed treatment with biofertilizer by spraying on seed, respectively; mix well and dry before sowing • Soil application of vermicompost @ 2 t/ha, FYM and foliar application of *Panchagavya*at 30, 45 and 60 DAS • Plant protection: Pheromone trap, *Trichoderma*, *Beauveria*, *Metarhizium*, NPV, *etc*., if required
Module-III	**Conventional farming (CF)** • Sole cropping of crops as per area covered in LCNF • Seed treated with recommended fungicide before sowing of seed • Soil application of recommended dose of mineral fertilizer (Urea and DAP) and manures (Farmyard Manures) • Plant protection: Recommended fungicides, insecticides and herbicides, if required

Table 2: Technical programme of present experimentation

Season-1	*Rabi*	
Crop and variety	Wheat, GJW 496 (Wheat Research Station, Junagadh)	Chickpea, GG 5 (Main Pulse Research Station Junagadh)
Spacing	22.5 cm	45 cm × 10 cm
Seed rate	100 kg/ha	60 kg/ha
Manures and fertilizer	FYM 10 t/ha 120-60-60 kg N-P-K/ha	FYM 5 t/ha 20-40-0 kg N-P-K/ha
Season-2	**Summer**	
Crop and variety	Groundnut, GJG 31 (Oil Seed Research Station Junagadh)	Sesame, GJT 5(Oil Seed Research Station Junagadh)
Spacing	30 cm × 10 cm	30 cm × 10 cm
Seed rate	100 kg/ha	3 kg/ha
Manures and fertilizer	FYM 10 t/ha 25-50-50 kg N-P-K/ha	FYM 5 t/ha 50-25-40 kg N-P-K/ha
Season-3	***Kharif***	
Crop and variety	Groundnut, GJG 22 (Oil Seed Research Station Junagadh)	Sweet corn, Sugar 75 (Collected form privet vendors of seeds, "Syngenta")
Spacing	60 cm × 15 cm	60 cm × 20 cm
Seed rate	120 kg/ha	12 kg/ha
Manures and fertilizer	FYM 7.5 t/ha 12.5-25-25 kg N-P-K/ha	FYM 5 t/ha 120-60-60 kg N-P-K/ha

FYM – Farmyard Manure

Study area

The experiment was set up at western state of India (Gujarat) at Instructional Farm, Department of Agronomy, JAU, Junagadh, for the period agricultural year 2019-20.The land from of Southern Saurashtra region of Gujarat have developed from basaltic and Gaj bed milliolitic lime stone parent materials from hill slope to piedmont and alluvium in piedmont plain and coastal plain. The soils have clay loam to clayey in texture, moderate to strong sub angular blocky structure and very dark greyish to brown colour. Before starting the experiment, soil chemical parameters shows that the soil of the plot was calcareous and slightly alkaline in reaction with pH 8.34, 7.97 and 7.74 and EC 0.54, 0.50 and 0.47 dS/m in *rabi* 2019-20, summer 2020 and *kharif* 2020, respectively. The soil was low in available nitrogen (239.88 kg/ha, 236.39 kg/ha and 242.32 kg/ha), medium in available phosphorus (32.14 kg/ha, 32.48 kg/ha and 34.77 kg/ha) and medium in available potassium (254.06 kg/ha, 249.51 kg/ha and 254.11 kg/ha) in *rabi* 2019-20, summer 2020 and *kharif* 2020, respectively.This region comprises of arid and semi-arid type of climate with average annual rainfall widely varied from 400-800 mm. Junagadh located at the periphery boundary of south west monsoon.

The mean maximum and minimum temperatures during *rabi* 2019-20 ranged from 25.4 to 34.3 °C and 9.7 to 19.4 °C, respectively, during crop growth and development. During crop period the relative humidity was in the range of 56 to 80%. There were no occurrences of winter rainfall during life span of crops. During the crop growth and development cycle in summer 2020, the mean maximum and minimum temperatures were 31.6 to 42.4 °C and 16.9 to 27.7 °C, respectively. Average relative humidity was varied between 24.25 & 33.65% and no rainfall during the period. The meteorological parameters for the period of investigation during *kharif* 2020 includes maximum and minimum temperature range from 28.6 to 36.9 °C and 24.5 to 26.7 °C, respectively. The relative humidity ranged from 83 to 96% during crop period. Total rainfall received during crop growing season was 60 mm.In the experiment we have just included only major cropping system of Junagadh, Gujarat, the comparative evaluation can be strengthen by including diverse spectrum of crop with different agro ecological conditions.

Preparation of bio-enhancers

Beejamrut, Jeevamrut, Ghan Jeevamrut and Panchagavya used in present experiment was prepared on farm by using following ingredients (Bisnoi and Bhati, 2017). Till date, there is not standard evolution of major component for the ingredients.

Beejamrut

Beejamrut, an organic, was used to treat seeds prior to sowing in order to improve germination and protect young roots from fungi, as well as soil-borne and seed-borne diseases. Local cow dung- a powerful natural fungicide, cow urine- a potent anti-bacterial liquid, lime, water, and soil are among the ingredients.

Jeevamrut

In the plant system*, Jeevamrut,* an organic product, has the ability to promote growth and provide immunity. *Jeevamrut* is made up of four different ingredients: cow dung, cow urine, chickpea flour, and jaggery. These have miraculous effects when properly combined and used.

Ghan Jeevamrut
Ghan Jeevamrut is dry or solid *Jeevamrut* that acts as a natural fertilizer for the crop plants. *Ghan Jeevamrut* prepared from desi cow dung, cow urine, jaggery and pulse flour.
Panchagavya
Panchagavya is a Sanskrit word that means "five cow items." The fermentation process uses five cow products, as well as a few other natural ingredients, as the name implies. It is important to note that all cow products must come from a desi cow. Cow dung, cow urine, milk, curd, jaggery, ghee, ripe banana, tender coconut, and water were used in the experiment to make *Panchagavya.* When suitably mixed and used, these have miraculous effects.

Results and Discussion

Yields
In the comparative evaluation, in the *rabi* season, results showed that various farming modules manifested considerable influence on crop yields (Table 3). Remarkably higher grain yield (4930 kg/ha) and straw yield (6704 kg/ha) of wheat were recorded under conventional farming in comparison to organic farming and significantly the lowest wheat yields were recorded under low cost natural farming. The result was supported by long term experiment study as well as divers cultivars of wheat in all wheat growing continent under the similar treatment condition.(Mäder *et al* 2007, Kitchen *et al* 2003, Van Stappen et al 2015, De Ponti *et al* 2012 and Fagnano *et al* 2012) In the case of chickpea the numbers revealed thatdifferent farming modules had a substantial impact on yields (Table 3). In the conventional farming recorded higher chickpea seed yield (2415 kg/ha) and stover yield (3609 kg/ha), which was statistically at per to the organic farming module. On the contrary, the Module-I (LCNF) recorded the lowest seed yield (1737 kg/ha) and stover (2794 kg/ha) of chickpea. Which is supported by De santis 2021 study on chickpea. Glimpse of the data on groundnut yields differed significantly among different modules (Table 4). Impressively the highest pod yield (3027 kg/ha) and haulm yield (3837 kg/ha) was recorded CF, which was found at par with the organic farming of to the tune of 2830 and 3586 kg/ha, respectively and the LCNF recorded significantly lowest yields of groundnut. The data presented in Table 6 revealed that 100CF significantly promote the seed yield (1233 kg/ha) and stalk yield (1898 kg/ha) of sesame, succeeded by module OF and followed by LCNF.In *kharif* season, the concerned data (Table 5) indicated that different farming modules significantly influenced the haulm yield and pod yield during the research year. A critical scanning of the data showed that strikingly higher pod yield (1759 kg/ha) and haulm yield (2415 kg/ha) was recorded with whole package of conventional farming practices (CF), which was found statistically at per with to 100% nutrition through bio fertilizers, vermicompost, FYM and *Panchagavya* as well as biopesticides (OF) and *Beejamrut*, *Jeevamrut*, *Ghan Jeevamrut,* FYM, *Achhadan, Agniastra*, *Brahmastra* and *Neemastra*(LCNF) recorded significantly lowest pod yield of (1298 kg/ha) and haulm yield (1821 kg/ha) of groundnut. The data about yields of sweet corn are presented in Table 9 revealed that impressively maximum green cob yield (6802 kg/ha) and green fodder yield (18143 kg/ha) was recorded under the Module-III that included supply of mineral fertilizers along with FYM and pesticides (CF), followed by organic farming (OF) and significantly the lowest yields was analyzed under the module that included growing of crops with cow based bioenhancers, botanicals and FYM (LCNF).Yield potential is a complicated function of biochemical and metabolic processes occurring in a plant system, which can be influenced by the environment and appropriate crop cultivation practises. The highest grain yield of crop recorded with the supply of inorganic sources of nutrient due to the availability of nutrients and immediate release as compared to organic source of nutrient, which release the nutrient slowly (Banik and Sharma, 2009).Therefore, combined use of inorganic and organic sources of nutrients could be resulted of the better synchrony of nutrient availability (Mwale *et al*., 1997) that would be reflected in higher total yield and nutrient use efficiency. Higher yield of chickpea and groundnut was due to beneficial effect of conjunctive use of organic and inorganic supplements which increased the availability ofnutrients considerably resultingin improvement of nodule development, energy transformation, metabolic process and root growth causing more dry matter production and number of

Table 3: Yields of wheat and chickpea under low cost natural farming, organic farming and conventional farming (*Rabi*)

Particulars	LCNF	OF	CF	S.Em.±	C. D. at 5%	C.V.%
Wheat						
Grain yield (kg/ha)	3123	3983	4930	96	296	11.98
Straw yield (kg/ha)	4453	5481	6704	140	433	12.66
Chickpea						
Seed yield (kg/ha)	1737	2257	2415	54	166	12.58
Stover yield (kg/ha)	2794	3377	3609	86	266	13.26

LCNF – Low cost natural farming; OF – Oganic Farming; CF – Conventional Farming

nodule (Chaturvedi*et al*., 2010) These results are in accordance with findings of Chaurasia*et al.* (2014), Manjunatha*et al*. (2009), Jat*et al*. (2013), Baskar *et al.* (2017), Chaudhary *et al*. (2017), Pradeep *et al*. (2018) and Sikka *et al.* (2018).

Green Revolution transformed the country from a food-deficit state to self-sufficiency during early 1970's. The Green Revolution technology aimed to boost agriculture production by replacing conventional hardy crop varieties with high response varieties and hybrids, increasing fertiliserand plant protection chemical use, putting more cultivated land under irrigation, particularly through large investments in major irrigationsystems and consolidating land holdings to make agriculture amenable for mechanization. The initialresponse to these technological innovations was very dramatic and it resulted in quantum jump in agricultural production.

Post-harvest soil status

By just seeing yield results of single year we cannot conclude the whole farming system potential, another dimension we have evaluated the major element of agricultural production system in the form of post harvest soil status. In the time of *rabi* season, the data refer to the effect of variousmodules on physical properties of soil were furnished in Table 6. When looking about different modules, none of them exerted significant impacton bulk density, porosity and water holding capacity of soil after harvest of crops. An assessment of the data (Table 6) mentioned that different crop growing modules taken under experimentation exerted considerable influence on of soil available nutrients after harvestof the crops.Appreciably the highest available N, P and K after harvest of wheat and chickpea were recorded underthe conventional farming module (CF), while, module-II that included application vermicompost, FYM and *Panchagavya* (OF) significantly increased organic carbon, heat soluble S; DTPA-extractable Fe, Zn, Cu and Mn, which was statistically comparable to application of 100% RDF through fertilizers along with FYM (CF). Nevertheless, significantly the lowest available micro, macro nutrients and organic carbon after harvest of wheat intercropped with chickpea was recorded under the LCNF.

During summer season, the critical scanning of the data presented in Table 7 indicated that various farming modules like, low cost natural farming, organic farming and conventional farming had no significant impact on porosity, water holding capacity and bulk density after harvest of groundnut and sesame. The close look to the data on post-harvest chemical properties data in Table 7 indicated that considerably the highest available nitrogen, phosphorus and potassium were reported with approved dose of chemicals for plant nutrition and management of weed, insect-pests and diseases (CF). Module-II that included treatment of biofertilizer, vermicompost, FYM, *Panchagavya* and biopesticides (OF) having highest organic carbon (0.611%), S (19.606 mg/kg), Fe (5.429 mg/kg), Zn (0.635 mg/kg), Cu (0.287 mg/kg) and Mn (13.530 mg/kg), statistically followed by conventional farming (CF) and notably the lowest organic carbon and available nutrients was recorded with the natural farming module (LCNF).The data furnished in Table 8 illumined that effect of varied modules on porosity, bulk density and water holding capacity later the harvest of crop was significant during the study due to residual effect of previous season. It is explicit from the data that significantly the lowest bulk density after harvest (1.334 Mg/m^3); and maximum porosity (48.989%) and water holding capacity (44.586%) was recorded with organic farming (OF), which was found at par with conventional farming (CF). An evaluation of the data (Table 8) mentioned that different crop growing modules taken under experimentation exerted serious influence on post-harvest available nutrients in soil. Significantly the highest available

N (140.17 mg/kg), P (23.47mg/kg) and K (147.40 mg/kg) after harvest was recorded with use of 100% RDF + FYM and pesticides (CF). OF recorded significantly highest organic carbon, S, DTPA-extractable Fe, Zn, Cu and Mn, which was found at par with CF. Nevertheless, notably the lowest organic carbon and available nutrients after harvest was observed when crops grown under the LCNF.The results showed that during first and second season of experiment, non-significant improvement in porosity, bulk density and water holding capacity. But continuous supply of FYM in the Module-III and vermicompost along with FYM in the Module-II improved physical properties of soil. This was possible because of enrichment of soil organic matter resulting in aggregation of soil particles and good pore geometry in soil, reduced bulk density; increased porosity and water holding capacity. The findings confirm the reports of Brar *et al.* (2015). Organic additives, such as FYM and vermicompost, control soil fertility in agricultural systems. The addition of organic manures to agricultural soil has a number of effects on enzyme activity, which are critical for nutrient mineralization (Gopinath *et al*., 2008).The higher available nutrients and organic carbon in soil after harvest in the CF and the OF due to addition of more organic matter and production of organic acids and carbon dioxide released during the process of decomposition of FYM which improve the availability of nutrients from native supplied with help of fertilizers during crop cycle(Mere *et al*., 2013). Vermicompost itself contains more quantity of micronutrients and also increase available cationic micronutrient concentration in soil solution by soil microbes. Poorer results under the natural farming might be due to addition of smaller quantity of supplements. Similar results were also reported by Katkar*et al.* (2011), Sudhakaran*et al*. (2013), Arbad*et al.* (2014), Nagar (2017), Sikka *et al.* (2018), Jadhao*et al*. (2019) and Kumar *et al*. (2020). Many experts in the field of agriculture have voiced concern that any more efforts to persist with this model of chemical agriculture will only prove counter productive in the long run and cause irreparable damage to soil health and environment. Restoring soil health by reverting to non-chemical agriculture has assumed great importance to attain sustainability in production.

Economics

As earlier mentions, the experiment was conducted in conventional farming plot, that's why we haven't consider premier price for LCNF and OF, but after conversion period production form OF and LCNF should get higher prices. The findings of *rabi* season presented in Table 9 shows that maximum gross returns (USD 1354.33/ha), net returns (USD781.79/ha) and B:C ratio (2.37) were accrued with conventional (CF) due to sufficiently supply of essential nutrients and proper pest and disease control helps get higher output as compared toorganic (OF) and cow based supplements (LCNF).

Table 4: Yield of groundnut and sesame under low cost natural farming, organic farming and conventional farming (Summer)

Particulars	LCNF	OF	CF	S.Em.±	C. D. at 5%	C.V.%
Groundnut						
Pod yield (kg/ha)	2137	2830	3027	71	219	13.34
Haulm yield (kg/ha)	2789	3586	3837	92	284	13.52
Sesame						
Seed yield (kg/ha)	769	1008	1233	25	77	12.48
Stalk yield (kg/ha)	1197	1558	1898	42	131	13.67

Table 5: Yield of groundnut and sweet corn under low cost natural farming, organic farming and conventional farming (*Kharif*)

Particulars	LCNF	OF	CF	S.Em.±	C. D. at 5%	C.V.%
Groundnut						
Pod yield (kg/ha)	1298	1647	1759	40	125	12.89
Haulm yield (kg/ha)	1821	2273	2415	60	185	13.81
Sweet corn						
Green cob yield (kg/ha)	4543	5651	6802	147	451	12.93
Green fodder yield (kg/ha)	12578	15402	18143	418	1287	13.58

Table 6: Physical and chemical properties of soil under low cost natural farming, organic farming and conventional farming (*Rabi*)

Particulars	LCNF	OF	CF	S.Em.±	C. D. at 5%	C.V.%
Bulk density (Mg/m³)	1.474	1.451	1.464	0.016	NS	5.48
Porosity (%)	44.494	45.115	44.656	0.495	NS	5.53
Water holding capacity (%)	41.128	41.453	41.361	0.485	NS	5.87
Organic carbon (%)	0.485	0.547	0.529	0.007	0.021	6.60
Available N (mg/kg)	114.94	118.34	130.38	3.586	11.05	7.59
Available P(mg/kg)	14.73	16.34	18.89	0.570	1.76	8.78
Available K (mg/kg)	121.25	124.88	137.72	3.827	11.79	7.67
Available S (mg/kg)	16.120	18.275	17.982	0.265	0.817	7.59
Available Fe (mg/kg)	4.503	5.124	5.031	0.075	0.232	7.71
Available Zn (mg/kg)	0.506	0.586	0.558	0.009	0.028	8.31
Available Cu (mg/kg)	0.218	0.258	0.253	0.004	0.014	9.19
Available Mn (mg/kg)	10.939	12.645	12.167	0.200	0.615	8.37

N – Nitrogen, P– Phosphorus; K –Potassium; S – Sulphur; Fe – Iron, Zn – Zinc; Cu – Copper; Mn – Manganese

Table 7: Physical and chemical properties of soil under low cost natural farming, organic farming and conventional farming (Summer)

Particulars	LCNF	OF	CF	S.Em.±	C. D. at 5%	C.V.%
Bulk density (Mg/m^3)	1.463	1.406	1.433	0.016	NS	5.49
Porosity (%)	44.854	46.629	45.742	0.555	NS	6.07
Water holding capacity (%)	41.240	42.842	42.081	0.406	NS	4.83
Organic carbon (%)	0.506	0.611	0.584	0.009	0.028	8.12
Available N (mg/kg)	116.34	120.57	135.88	4.144	12.77	8.55
Available P(mg/kg)	15.30	17.22	20.97	0.606	1.868	8.72
Available K (mg/kg)	122.03	126.60	142.31	4.545	14.01	8.94
Available S (mg/kg)	16.647	19.606	19.057	0.329	1.013	8.92
Available Fe (mg/kg)	4.605	5.429	5.246	0.083	0.257	8.19
Available Zn (mg/kg)	0.519	0.635	0.603	0.011	0.033	9.18
Available Cu (mg/kg)	0.227	0.287	0.274	0.005	0.016	10.09
Available Mn (mg/kg)	11.416	13.530	13.286	0.230	0.709	9.02

Table 8: Physical and chemical properties of soil under low cost natural farming, organic farming and conventional farming (*Kharif*)

Particulars	LCNF	OF	CF	S.Em.±	C. D. at 5%	C.V.%
Bulk density (Mg m^3)	1.454	1.334	1.375	0.014	0.042	4.87
Porosity (%)	45.230	48.989	47.916	0.434	1.337	4.58
Water holding capacity (%)	41.355	44.586	43.644	0.371	1.142	4.29
Organic carbon (%)	0.533	0.689	0.658	0.010	0.031	8.02
Available N (mg/kg)	117.07	122.39	140.17	4.397	13.550	8.91
Available P(mg/kg)	16.09	18.17	23.47	0.752	2.316	10.02
Available K (mg/kg)	123.14	128.66	147.40	4.323	13.320	8.33
Available S (mg/kg)	17.240	20.937	20.124	0.356	1.097	9.16
Available Fe (mg/kg)	4.849	5.930	5.665	0.095	0.294	8.69
Available Zn (mg/kg)	0.539	0.694	0.663	0.011	0.035	9.05
Available Cu (mg/kg)	0.243	0.329	0.312	0.006	0.019	10.54
Available Mn (mg/kg)	11.757	14.807	14.291	0.281	0.866	10.32

Table 9: Economics of crops grown under low cost natural farming, organic farming and conventional farming (*Rabi*)

Particular	LCNF	OF	CF	S.Em.±	C.D. at 5%	C.V. %
Gross returns (USD/ha)	886.73	1133.97	1354.33	1680	5176	9.61
Cost of cultivation (USD/ha)	472.21	681.55	572.54	-	-	-
Net returns (USD/ha)	414.52	452.42	781.79	1680	5176	19.68
B:C ratio	1.88	1.66	2.37	-	-	-

However, the net returns, minimum gross returns and B:C ratio were achieved with the Module-I (LCNF).During summer, an evaluation of the data (Table 10) showed that maximum gross returns (USD 1928.04/ha) and net realization (USD1381.76 /ha) were obtained under growing of chemically treated sole groundnut and sesame (CF), followed by the Module-II which included biofertilizer, vermicompost, FYM, *Panchagavya* and biopesticides (OF). Whereas, the lowest gross returns and net returns (USD1341.04/ha and USD 843.87/ha) was observed with crops grown under the low cost natural farming (LCNF). in the course of *kharif* season, the findings (Table 11) demonstrated that the module-III that involved application of industrial chemicals like, NPK fertilizers, fungicides, insecticides and herbicides (CF) resulted in higher gross returns (USD 2395.97/ha), net returns (USD 1782.27/ha) and B:C ratio (3.90), followed by application of biofertilizer, *Panchagavya*, FYM, vermicompost and biopesticides (OF) and application of cow based bioenhancers and botanicals (LCNF). Maximum gross and net returns were obtained under the CF.

Table 10: Economics of crops grown under low cost natural farming, organic farming and conventional farming (Summer)

Particular	LCNF	OF	CF	S.Em.±	C.D. at 5%	C.V. %
Gross returns (USD/ha)	1341.04	1770.21	1928.04	2879	8870	11.03
Cost of cultivation (USD/ha)	497.17	694.03	546.28	-	-	-
Net returns (USD/ha)	843.87	1076.18	1381.76	2879	8870	16.84
B:C ratio	2.70	2.55	3.53	-	-	-

Table 11: Economics of crops grown under low cost natural farming, organic farming and conventional farming (*Kharif*)

Particular	LCNF	OF	CF	S.Em.±	C.D. at 5%	C.V. %
Gross returns (USD/ha)	1663.16	2082.72	2395.97	2793	8607	8.78
Cost of cultivation (USD/ha)	606.74	749.83	613.70	-	-	-
Net returns (USD/ha)	1056.42	1332.89	1782.27	2793	8607	12.93
B:C ratio	2.74	2.78	3.90	-	-	-

This might be attributed to higher economical yield and biological yield of crops withcomparatively less cost than additional income under this module. The minimum gross returns andnet returns were achieved under the LCNF which might be due to variation in the economical and biological yields of crops. These results are similar with results of Chaurasia*et al.* (2014), Behera and Rautaray (2010), Singh *et al.* (2018) and Lyngdoh *et al.* (2019).

Conclusion

With the evident of three-season field experimentation, it may be finalized that conventional farming system comprised of mineral fertilizers, FYM and pesticides was found superior as compared to organic farming and low cost natural farming for obtaining higher yield of major field crops along with higher net returns shows slight improvement in soil physical and chemical properties although it is just one year experiment which is conducted under medium black calcareous clayey soil of South Saurashtra Agro-climatic Zone of Gujarat.

Acknowledgement

The authors are grateful to College of Agriculture, Junagadh Agricultural University, Junagadh for providing necessary field and laboratory facilities during Ph.D. research work.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Arbad, B. K., Ismail, S., & Dhawan, A. S. (2014). Influence of long term use of farmyard manure and inorganic fertilizer on grain yield and nutrient availability in vertisols under soyabean-safflower sequence cropping. *Legume Research*, *37*(6), 600-606.

Banik, P., & Sharma, R. C. (2009). Effect of organic and inorganic sources of nutrients on the winter crops-rice cropping system in sub-humid tropics of India. *Archives of Agronomy and Soil Science*, *55*(3), 285-294.

Baskar, M., Solaimalai, A., Kumar, A., & Palanisamy, A. (2017). Residual effect of fly ash, farmy yard manure and fertilizers applied to groundnut on growth parameters, nutrient uptake, yield of sesame and post-harvest soil available fertility status in groundnut-sesame cropping system in northeastern zone of Tamil Nadu. *International Journal of Current Microbiology and Applied Sciences*, *6*(6), 2917-2923.

Behera, U. K., & Rautaray, S. K. (2010). Effect of biofertilizers and chemical fertilizers on productivity and quality parameters of durum wheat (Triticum turgidum) on a Vertisol of Central India. *Archives of Agronomy and Soil Science*, *56*(1), 65-72.

Bishnoi, R., & Bhati, A. (2017). An Overview: Zero budget natural farming. *Trends in Biosciences*, *10*(46), 9314-9316.

Brar, B. S., Singh, J., Singh, G., & Kaur, G. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Agronomy*, *5*(2), 220-238.

Chaturvedi, S., Chandel, A. S., Dhyani, V. C., & Singh, A. P. (2010). Productivity, profitability and quality of soybean (Glycine max) and residual soil fertility as influenced by integrated nutrient management. *Indian Journal of Agronomy*, *55*(2), 133-137.

Chaudhary, G. L.; Sharma, S. K.; Singh, K. P.; Chaudhary, S. and Bazaya, B. R. (2017a). Effect of *Panchagavya* on growth and yield of organic blackgram [*Vigna mungo* L. (Hepper)]. *International Journal of Current Microbiology and Applied Sciences*, *6*(10), 1627-1632.

Chaurasia, S. K., Jain, N., & Jain, N. (2014). Effect of integrated use of fertilizers, organic manures and micronutrients on productivity of sesame (Sesamum indicum). *Annals of Agricultural Research*, *30*(3&4).

De Ponti, T., Rijk, B., & Van Ittersum, M. K. (2012). The crop yield gap between organic and conventional agriculture. *Agricultural systems*, *108*, 1-9.De Santis, M. A., Rinaldi, M., Menga, V., Codianni, P., Giuzio, L., Fares, C., & Flagella, Z. (2021). Influence of organic and conventional farming on grain yield and protein composition of chickpea genotypes. *Agronomy*, *11*(2), 191.

De Santis, M. A., Rinaldi, M., Menga, V., Codianni, P., Giuzio, L., Fares, C., & Flagella, Z. (2021). Influence of organic and conventional farming on grain yield and protein composition of chickpea genotypes. *Agronomy*, *11*(2), 191.

Fagnano, M., Fiorentino, N., D'Egidio, M. G., Quaranta, F., Ritieni, A., Ferracane, R., & Raimondi, G. (2012). Durum wheat in conventional and organic farming: yield amount and pasta quality in Southern Italy. *The Scientific World Journal*, *2012*.

Gopinath, K. A., Saha, S., Mina, B. L., Pande, H., Kundu, S., & Gupta, H. S. (2008). Influence of organic amendments on growth, yield and quality of wheat and on soil properties during transition to organic production. *Nutrient Cycling in Agroecosystems*, *82*(1), 51-60.

Jackson, M. L. (1974). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp. 301-325.

Jadhao, S. D., Mali, D. V., Kharche, V. K., Singh, M., Bhoyar, S. M., Kadu, P. R., & Sonune, B. A. (2019). Impact of Continuous Manuring and Fertilization on Changes in Soil Quality under Sorghum-Wheat Sequence on a Vertisols. *Journal of the Indian society of soil science*, *67*(1), 55-64.

Jat, L. K., Singh, S. K., Latare, A. M., Singh, R. S., & Patel, C. B. (2013). Effect of dates of sowing and fertilizer on growth and yield of wheat (Triticum aestivum) in an Inceptisol of Varanasi. *Indian Journal of Agronomy*, *58*(4), 611-614.

Katkar, R. N., Sonune, B. A., & Kadu, P. R. (2011). Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (Sorghum bicolor)-wheat (Triticum aestivum) system in Vertisol. *Indian journal of agricultural sciences*, *81*(8), 734.

Kitchen, J. L., McDonald, G. K., Shepherd, K. W., Lorimer, M. F., & Graham, R. D. (2003). Comparing wheat grown in South Australian organic and conventional farming systems. 1. Growth and grain yield. *Australian journal of agricultural research*, *54*(9), 889-901.

Kumar, R., Kumar, S., Yashavanth, B. S., Meena, P. C., Ramesh, P., Indoria, A. K., & Manjunath, M. (2020). Adoption of Natural Farming and its Effect on Crop Yield and Farmers' Livelihood in India.

Lindsay, W. L. and Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, *42*, 421-428.

Lyngdoh, B., Krishnamurthy, N., Jayadeva, H. M., Gowda, J., & Seenappa, C. (2019). Influence of foliar nutrition on the performance of soybean [Glycine max (L.) Merrill]. *Mysore Journal of Agricultural Sciences*, *53*(2), 57-61.

Mäder, P., Hahn, D., Dubois, D., Gunst, L., Alföldi, T., Bergmann, H., ... & Niggli, U. (2007). Wheat quality in organic and conventional farming: results of a 21 year field experiment. *Journal of the Science of Food and Agriculture*, *87*(10), 1826-1835.

Manjunatha, G. S., Upperi, S. N., Pujari, B. T., Yeledahalli, N. A., & Kuligod, V. B. (2009). Effect of farm yard manure treated with jeevamrutha on yield attributes, yield and economics of sunflower (Helianthus annuus L.). *Karnataka Journal of Agricultural Sciences*, *22*(1), 198-199.

Melissa, V. (2003). Converting to an Organic Farming System.

Mere, V., Singh, A. K., Singh, M., Jamir, Z., & Gupta, R. C. (2013). Effect of nutritional schedule on productivity and quality of soybean varieties and soil fertility. *Legume Research-An International Journal*, *36*(6), 528-534.

Mwale, M., Mapiki, A., & Phiri, L. K. (1997). To synchronize nutrient availability with plant uptake. *The Biology and Fertility of Tropical Soils: A TSBF Report*, *1998*, 40-41.

Nagar, U. S. (2017). Long-term effects of inorganic fertilizers and FYM on soil chemical properties and yield of wheat under rice-wheat cropping system. *HIMALAYAN ECOLOGY*, *25*, 28.

Olsen, S. R.; Cole, C. V.; Watanabe, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with $NaHCO_3$. Circular USDA, 939.

Pradeep, S., Ullasa, M. Y., Naik, A. H., Ganapathi & Divya, M. (2018). Effect of different organic nutrient management practices on growth, yield of pigeonpea (Cajanus cajan L. Millsp.) and soil properties. *Research Journal of Agricultural Sciences*, *9*(2), 352-357.

Sebby, K. (2010). The green revolution of the 1960's and its impact on small farmers in India.

Sikka, R., Singh, D., Deol, J. S., & Kumar, N. (2018). Effect of integrated nutrient and agronomic management on growth, productivity, nutrient uptake and soil residual fertility status of soybean. *Agricultural Science Digest*, *38*(2), 103-107.

Singh, N., Joshi, E., Sasode, D. S., Sikarwar, R. S., & Rawat, G. S. (2018). Liquid Biofertilizer and Inorganic Nutrients Effect on Physiological, Quality Parameters, and Productivity of Kharif Groundnut (Arachis hypogaea L.). *International Journal of Current Microbiology and Applied Sciences*, *7*(9), 729-735.

Subbiah, B. V. and Asija, G. C. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, *25*(2), 259-260.

Sudhakaran, M., Ramamoorthy, D., & Kumar, S. R. (2013). Impacts of conventional, sustainable and organic farming system on soil microbial population and soil biochemical properties, Puducherry, India. *International Journal of Environmental Sciences*, *4*(1), 28-41.

Van Stappen, F., Loriers, A., Mathot, M., Planchon, V., Stilmant, D., & Debode, F. (2015). Organic versus conventional farming: the case of wheat production in Wallonia (Belgium). *Agriculture and Agricultural Science Procedia*, *7*, 272-279.

Williams, C. H. and Steinbergs, A. (1959). Soil sulphur fraction as chemical indices of available sulphur in some Australian soils. *Australian Journal Agricultural Research*, *10*, 340-352.

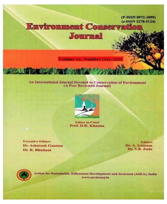
Publisher's Note:ASEA remains neutral with regard to jurisdictional claims in published maps andfigures.

Environment Conservation Journal 24 (3): 136-143, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Comparing the economics of hemp (*Cannabis sativa* ssp. *sativa*) cultivation for fiber and seed yield as influenced by spacing and nutrition

Meghana, H. R ✉

Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, University of Horticulture Sciences, Karnataka, India.

Maruthi Prasad, B. N

Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, University of Horticulture Sciences, Karnataka, India.

Dhananjaya, B. N

Department of Soil Science and Agricultural Chemistry, College of Horticulture, Kolar, University of Horticulture Sciences, Karnataka, India.

Shankarappa, T. H

Department of Natural Resource Management, College of Horticulture, Bengaluru, University of Horticulture Sciences, Karnataka, India.

Harshaavardhan redi sirupa

Managing Director of Namratha Hemp Company, Bengaluru, Karnataka, India.

ARTICLE INFO

Received : 14 December 2022
Revised : 19 March 2023
Accepted : 01 April 2023

Available online: 25 June 2023

Key Words:
Cost of cultivation
Gross returns
Net returns
BC ratio

ABSTRACT

Hemp is dual purpose crop, where fibers and seeds have found its place in textile and food industry due to its strong fiber and nutrition content in seed. The cultivation of hemp is a new venture in India where farmers get dual income by both fibers and seeds hence, optimizing spacing and nutrient management to harness maximum yield of fiber and seed can double the income of farmers. The present investigation on economics of hemp cultivation revealed that the, maximum gross returns (Rs. 5,74,000/ ha) were obtained from plants grown at 10 cm × 5 cm spacing and supplied with 125 per cent RDF plus PGPR consortia but highest B:C ratio of 4.68 was observed in plants grown at spacing of 20 cm × 10 cm and nourished with 100 per cent of RDF plus PGPR consortia for fiber purposes. Upon considering seed economics maximum gross returns (Rs. 12,58,200/ ha) was recorded in the treatment combination of 10 cm × 10 cm spacing and supplied with 125 per cent RDF plus PGPR consortia while, maximum B:C ratio of 13.17 was noted from plots where plants were spaced at 15 cm × 10 cm and supplied with nutrition of 100 per cent RDF plus PGPR consortia for seed purposes.

Introduction

Hemp (*Cannabis sativa* ssp. *sativa*), a member of Cannabaceae family and native to Western and Central Asia (Zatta *et al*., 2012). The crop is under cultivation worldwide for fiber, seeds and medicinal importance hence it is considered as incredibly versatile plant with thousands of documented uses and has the capability to produce more than 25,000 crucial products, so it is often praised as trillion-dollar crop (Papastylianou *et al*., 2017). Hemp fibers served mankind for thousands of years and always been valued for its strength and durability. Fibers is used to manufacture countless products such as fibers, textiles, paper, construction materials, automobile parts, bricks, particle board, duck, wall insulator panels, fiber glasses, concrete, car parts, bricks, bio fuel, bioplastic preparations and pharmaceutical industries (Aubin *et al*., 2015). Hemp seed considered as powerhouse of good health due to its amazing nutrition profile, unsaturated fats and protein, while containing little to no cholesterol (Carus *et al*., 2013). Seeds are reputed as vegetarian meat, as it contains nine

Corresponding author E-mail: meghanahhr@gmail.com
Doi:https://doi.org/10.36953/ECJ.16612528

essential amino acid that human body can't produce naturally but which are necessary for vegetarians (https://iihaindia.org/). In India, agriculture is the major source of livelihood for over 85% of the rural population but small land holdings, low soil productivity, lack of assured irrigation, scientific knowledge, cultivation of only traditional crops, low return, price fluctuation, pest and diseases problems are the prime reason for less income to Indian farmers. Hemp is one such crop which can address all above problem as it is short duration (90 days), lower cultivation costs coupled with less water demand, largely untouched by pests, diseases, animals and high returns are the primary reasons for its acceptance among Indian farmers. Since it is a new crop and renders income to farmers from both fiber and seed but the information on agronomic practices is meager and the technologies with less use of fertilizers are much needed since the demand is more for the fibers are escalating in international market (Prasanna *et al*., 2021). Among agronomic practices, spacing plays important role in determining the yield per unit area as it facilitate aeration and light penetration into canopy for optimum plant growth (Campiglia *et al*., 2017). Unscientific use of chemical fertilizer in crop production not only caused low yield and waste of fertilizer but also lead to increased production costs apart from contaminating the soil and water. In order to promote environment-friendly and sustainable agricultural systems, the concept of ecofriendly agriculture through application of PGPR consortia is a new field of interest without compromising the yield and quality of crop (Pagnania *et al*., 2018). Hence, study was framed with the intention to assess the influence of spacing and nutrients plus PGPR consortia on economics of cultivation of hemp for both fiber and seed purposes.

Material and Methods

The study was carried out in factorial randomized complete block design with twenty-four treatment combination and replicated thrice by considering spacing as factor one and nutrition along with PGPR consortia as factor two at Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, University of Horticultural Sciences campus, Gandhi Krishi Vignana Kendra, Bengaluru during *kharif* season of 2019-2020. One week old, healthy and uniform seedlings of NHEMPCO Vijaya -I fiber strain has been transplanted in plot having dimension of one square meter and were separated by a distance of two meter from each other. Seedlings were transplanted at six different spacings such as, S_1: 10 cm × 5 cm (200 plants/ m^2), S_2: 10 cm × 10 cm (100 plants/ m^2), S_3: 15 cm × 5 cm (133 plants/ m^2), S_4: 15 cm × 10 cm (66 plants/ m^2), S_5: 20 cm × 5 cm (100 plants/ m^2) and S_6: 20 cm × 10 cm (50 plants/ m^2) and applied with four different levels of nutrition *viz*., N_1: 10 t FYM/ ha + 150:75:150 kg N, P_2O_5, K_2O/ ha (75% RDF) + PGPR consortia, N_2: 10 t FYM/ ha + 200:100:200 kg N, P_2O_5, K_2O /ha (100% RDF) + PGPR consortia, N_3: 10 t FYM/ ha + 250:125:250 kg N, P_2O_5, K_2O/ ha (125% RDF) + PGPR consortia and N_4: FYM 10 t/ ha + 200:100:200 kg N, P_2O_5, K_2O/ ha (100% RDF) without PGPR consortia (Control). Fifty per cent of nitrogen and full dose of phosphorous and potassium were applied 15 days after transplanting and the remaining fifty per cent of nitrogen was applied 30 days after transplanting. After 10 days of transplanting PGPR consortia of *Azospirillum brasilense*, *Bacillus megaterium* and *Pseudomonas fluorescens* were applied by mixing at the rate of five kilo gram each. As the crop was dioicous in nature plants were harvested separately for male and female (after shedding of pollens and after harvesting seed respectively) stalks according to treatment by cutting above the soil surface and shade dried stalks were used for fiber extraction by decortication process (Jankauskiene *et al*., 2017). Seeds are harvested from female plants when seeds turns to brown from green, which coincide from 70 days after transplanting and extended up to 90 days. Later, female stems were uprooted, tied and dried under shade for fiber extraction.The cost incurred towards inputs and farm labours charges that were prevailed during the study period in Bengaluru region are considered and computed per hectare cultivation cost are presented in Table 1. The total cost of cultivation (in Rs./ha) incurred towards cultivation hemp for fiber and seed purposes are presented separately in Table 2 and Table 3 respectively. Gross income was calculated based on the market price prevailed for fiber and seed at the time of harvest according to hemp foundation.

Market price for extracted hemp fiber was Rs. 200 kg^{-1} and hemp seeds was Rs. 150/kg. The net income per hectare was calculated by subtracting total costs in the gross income. The benefit cost ratio was worked out using the following formula.

$$\textbf{Benefit : Cost ratio} = \frac{\textbf{Net returns (Rs./ ha)}}{\textbf{Total costs (Rs./ ha)}}$$

Table 1: Cost of inputs and labour used for raising hemp crop per hectare

Particulars	Quantity	Unit cost	Total cost (Rs.)
Land preparation (Tractor)	8 hours	Rs. 600/hour	4,800
FYM	10 t/ ha	Rs.1750/ t	17,500
Seedlings	S_1-20,00,000 S_2-10,00,000 S_3-13,30,000 S_4-6,60,000 S_5-10,00,000 S_6-5,00,000	Rs.10 200/ seedlings	1,00,000 50,000 66,500 33,000 50,000 25,000
Fertilizers (200:100:200 kg NPK ha^{-1}) Urea SSP MOP	434.78 kg 625 kg 333.33 kg	Rs. 6.5/ kg Rs. 7.2/ kg Rs. 16.04/ kg	2,826.07 4,500.00 5,346.61
Transplanting	10 labours	Rs.250/ labour	2,500
Weeding	5 labours	Rs. 250/ labour	1,250
Plant protection chemicals: Chlorpyriphos Ridomil- gold	1liter 100 g	Rs. 600/ liter Rs. 1,350/ kg	600 135
Harvesting and processing	30 labours	Rs. 250 /labour	7,500
Fiber extraction			5,000/ ha
PGPR consortia	5 kg	360/ kg	1,800
Miscellaneous	Transportation and others	1,500	1,500
Total			11,53,613.4

Results and Discussion

The perusal of data in Table 4 for fiber production indicates that, cost of cultivation was maximum (Rs. 1,58,426/ ha) with the spacing of 10 cm × 5 cm and application of 125 per cent RDF plus PGPR consortia. Whereas, plants spaced at 20 cm × 10 cm and nourished with 75 per cent RDF plus PGPR consortia registered least cost of cultivation (Rs. 77,090/ ha). The maximum gross return of Rs. 5,74,000/ ha was obtained from plants grown at 10 cm × 5 cm spacing and supplied with 125 per cent RDF plus PGPR consortia but highest net returns of Rs. 4,65,910/ ha was obtained from plots where plants were placed 20 cm × 5 cm spacing and supplied with 75 per cent RDF plus PGPR consortia. However, highest B:C ratio of 4.68 was obtained from plants grown at 20 cm × 10 cm and nourished with 100 per cent RDF plus PGPR consortia.The data on economics of hemp cultivation for seed yield documented in Table 5 indicated that, spacing of 10 cm × 5 cm supplied with 125 per cent RDF plus PGPR consortia resulted in maximum cost of cultivation (Rs. 1,51,926/ ha). The maximum gross returns (Rs. 12,58,200/ ha) and net returns (Rs. 11,56,274/ ha) were obtained in the treatment combination of 10 cm × 10 cm spacing and application of 125 per cent RDF with PGPR consortia. While, highest B:C ratio (13.17) was realized from plots where plants were spaced at 15 cm × 10 cm and supplied with nutrition of 100 per cent RDF and PGPR consortia. The least gross returns (Rs. 5,43,000/ ha), net returns (Rs. 3,96,062/ ha) as well as B:C ratio (2.70) were obtained in the treatment combination of 10 cm × 5 cm spacing along with 100 per cent RDF.The probable reason for maximum cost involved for cultivating hemp for fiber production due to high cost incurred towards the purchase of a greater number of seedlings per unit area and also cost incurred towards purchase of higher doses of chemical fertilizer and PGPR consortia in treatment comprise of higher density with maximum level of nutrition along with PGPR consortia. Whereas, least cost of cultivation was found at widely spaced plants coupled with low dose of fertilizers without PGPR consortia as there was reduction in number of seedlings coupled with reduced dose of fertilizer devoid of PGPR consortia. Kubsad, (2009) also reported increased production cost for ashwagandha production in closer spacing and highest dose of fertilizers. Increased benefit cost ratio for fiber purpose in widely spaced plants (20 cm × 10 cm) with 100 per cent RDF plus PGPR consortia may be attributed to lower cost of planting material, optimum usage of nutrition and good yield. Though maximum yield and gross returns was noticed in other treatment but due to increases cost of

Table 2: Cost of cultivation (Rs./ ha) as influenced by different spacing and nutrition for fiber yield of hemp

Treatments	FYM	Land Preparation	Seedlings	Transplanting	Fertilizers	PGPR consortia	Weeding	Plant Protection	Harvesting and processing	Fiber extraction & Miscellaneous	Total Cost
S_1N_1	17,500	4,800	1,00,000	2,500	9,505	1,800	1,250	735	7,500	6,500	1,52,090
S_1N_2	17,500	4,800	1,00,000	2,500	12,653	1,800	1,250	735	7,500	6,500	1,55,238
S_1N_3	17,500	4,800	1,00,000	2,500	15,841	1,800	1,250	735	7,500	6,500	1,58,426
S_1N_4	17,500	4,800	1,00,000	2,500	12,653	-	1,250	735	7,500	6,500	1,53,438
S_2N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	6,500	1,02,090
S_2N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	6,500	1,05,238
S_2N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	6,500	1,08,426
S_2N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	6,500	1,03,438
S_3N_1	17,500	4,800	66,500	2,500	9,505	1,800	1,250	735	7,500	6,500	1,18,590
S_3N_2	17,500	4,800	66,500	2,500	12,653	1,800	1,250	735	7,500	6,500	1,21,738
S_3N_3	17,500	4,800	66,500	2,500	15,841	1,800	1,250	735	7,500	6,500	1,24,926
S_3N_4	17,500	4,800	66,500	2,500	12,653	-	1,250	735	7,500	6,500	1,19,938
S_4N_1	17,500	4,800	33,000	2,500	9,505	1,800	1,250	735	7,500	6,500	85,090
S_4N_2	17,500	4,800	33,000	2,500	12,653	1,800	1,250	735	7,500	6,500	88,238
S_4N_3	17,500	4,800	33,000	2,500	15,841	1,800	1,250	735	7,500	6,500	91,426
S_4N_4	17,500	4,800	33,000	2,500	12,653	-	1,250	735	7,500	6,500	86,438
S_5N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	6,500	1,02,090
S_5N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	6,500	1,05,238
S_5N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	6,500	1,08,426
S_5N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	6,500	1,03,438
S_6N_1	17,500	4,800	25,000	2,500	9,505	1,800	1,250	735	7,500	6,500	77,090
S_6N_2	17,500	4,800	25,000	2,500	12,653	1,800	1,250	735	7,500	6,500	80,238
S_6N_3	17,500	4,800	25,000	2,500	15,841	1,800	1,250	735	7,500	6,500	83,426
S_6N_4	17,500	4,800	25,000	2,500	12,653	-	1,250	735	7,500	6,500	78,438

Table 3: Cost of cultivation (Rs./ ha) as influenced by different spacing and nutrition for seed yield of hemp

Treatments	FYM	Land Preparation	Seedlings	Transplanting	Fertilizers	PGPR consortia	Weeding	Plant Protection	Harvesting and processing	Total Cost
S_1N_1	17,500	4,800	1,00,000	2,500	9,505	1,800	1,250	735	7,500	1,45,590
S_1N_2	17,500	4,800	1,00,000	2,500	12,653	1,800	1,250	735	7,500	1,48,738
S_1N_3	17,500	4,800	1,00,000	2,500	15,841	1,800	1,250	735	7,500	1,51,926
S_1N_4	17,500	4,800	1,00,000	2,500	12,653	-	1,250	735	7,500	1,46,938
S_2N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	95,590
S_2N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	98,738
S_2N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	1,01,926
S_2N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	96,938
S_3N_1	17,500	4,800	66,500	2,500	9,505	1,800	1,250	735	7,500	1,12,090
S_3N_2	17,500	4,800	66,500	2,500	12,653	1,800	1,250	735	7,500	1,15,238
S_3N_3	17,500	4,800	66,500	2,500	15,841	1,800	1,250	735	7,500	1,18,426
S_3N_4	17,500	4,800	66,500	2,500	12,653	-	1,250	735	7,500	1,13,438
S_4N_1	17,500	4,800	33,000	2,500	9,505	1,800	1,250	735	7,500	78,590
S_4N_2	17,500	4,800	33,000	2,500	12,653	1,800	1,250	735	7,500	81,738
S_4N_3	17,500	4,800	33,000	2,500	15,841	1,800	1,250	735	7,500	84,926
S_4N_4	17,500	4,800	33,000	2,500	12,653	-	1,250	735	7,500	79,938
S_5N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	95,590
S_5N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	98,738
S_5N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	1,01,926
S_5N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	96,938
S_6N_1	17,500	4,800	25,000	2,500	9,505	1,800	1,250	735	7,500	70,590
S_6N_2	17,500	4,800	25,000	2,500	12,653	1,800	1,250	735	7,500	73,738
S_6N_3	17,500	4,800	25,000	2,500	15,841	1,800	1,250	735	7,500	76,926
S_6N_4	17,500	4,800	25,000	2,500	12,653	-	1,250	735	7,500	71,938

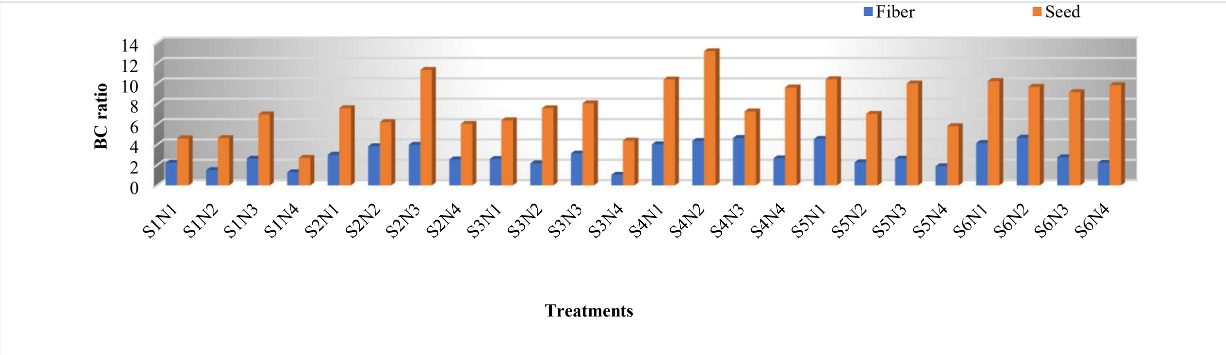


Figure 1: Comparing the BC ratio for fiber and seed yield purpose as affected by spacing and nutrition

Table 4: Economics of hemp as influenced by spacing and nutrition on fiber yield basis

Treatments	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)	Net returns (Rs./ ha)	B:C ratio
S_1N_1	1,52,090	4,92,000	3,39,910	2.23
S_1N_2	1,55,238	3,88,000	2,32,762	1.50
S_1N_3	1,58,426	5,74,000	4,15,574	2.62
S_1N_4	1,53,438	3,50,000	1,96,562	1.28
S_2N_1	1,02,090	4,08,000	3,05,910	3.00
S_2N_2	1,05,238	5,10,000	4,04,762	3.85
S_2N_3	1,08,426	5,40,000	4,31,574	3.98
S_2N_4	1,03,438	3,66,000	2,62,562	2.54
S_3N_1	1,18,590	4,26,000	3,07,410	2.59
S_3N_2	1,21,738	3,85,000	2,63,262	2.16
S_3N_3	1,24,926	5,16,000	3,91,074	3.13
S_3N_4	1,19,938	2,44,000	1,24,062	1.03
S_4N_1	85,090	4,28,000	3,42,910	4.03
S_4N_2	88,238	4,74,000	3,85,762	4.37
S_4N_3	91,426	5,17,000	4,25,574	4.65
S_4N_4	86,438	3,16,000	2,29,562	2.66
S_5N_1	1,02,090	5,68,000	4,65,910	4.56
S_5N_2	1,05,238	3,43,000	2,37,762	2.26
S_5N_3	1,08,426	3,92,000	2,83,574	2.62
S_5N_4	1,03,438	2,98,000	1,94,562	1.88
S_6N_1	77,090	3,98,000	3,20,910	4.16
S_6N_2	80,238	4,56,120	3,75,882	4.68
S_6N_3	83,426	3,13,000	2,29,574	2.75
S_6N_4	78,438	2,52,000	1,73,562	2.21

S1: 10 cm × 5 cm, S2: 10 cm × 10 cm, S3: 15 cm × 5 cm, S4: 15 cm × 10 cm, S5: 20 cm × 5 cm, S6: 20 cm × 10 cm
N_1: 75 % RDF + PGPR consortia N_2: 100 % RDF + PGPR consortia
N_3: 125 % RDF + PGPR consortia N_4: 100 % RDF

cultivation, net returns shown slight decline, this finding were supported by Shivani and Gautam, (2019). With respect to seed yield, maximum gross returns and net returns were obtained from plots which received 125 per cent RDF plus PGPR consortia and spaced at 10 cm × 10 cm. However, greatest B:C ratio (13.75) was realized when hemp plants were spaced at 15 cm × 10 cm and nourished with 100 per cent RDF plus PGPR consortia might be due to optimum plant population coupled with maximum seed yield and minimum cost of inputs incurred towards purchase of seedlings and nutrients.

The findings are in line with Lothe *et al*. (2021). Upon comparing the benefit cost ratio between fiber and seed, highest net return and BC ratio was recorded with the intention of seed purpose compared to fiber purpose. This might be due to reduced fiber yield and less cost per unit weight of fiber compared to seed. Increased cost of cultivation when grown for fiber purpose is due to additional cost incurred for fiber extraction. However, hemp can be exploited for both purposes by utilizing the same stem after seed harvesting which ensures double income for farmers

Table 5: Economics of hemp as influenced by spacing and nutrition on seed yield basis

Treatments	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)	Net returns (Rs./ha)	B:C ratio
S_1N_1	1,45,590	8,17,950	6,72,360	4.62
S_1N_2	1,48,738	8,38,500	6,89,762	4.64
S_1N_3	1,51,926	12,10,500	10,58,574	6.97
S_1N_4	1,46,938	5,43,000	3,96,062	2.70
S_2N_1	95,590	8,20,200	7,24,610	7.58
S_2N_2	98,738	7,12,200	6,13,462	6.21
S_2N_3	1,01,926	12,58,200	11,56,274	11.34
S_2N_4	96,938	6,82,500	5,85,562	6.04
S_3N_1	1,12,090	8,28,750	7,16,660	6.39
S_3N_2	1,15,238	9,87,450	8,72,212	7.57
S_3N_3	1,18,426	10,71,750	9,53,324	8.05
S_3N_4	1,13,438	6,12,750	4,99,312	4.40
S_4N_1	78,590	8,94,750	8,16,160	10.39
S_4N_2	81,738	11,58,450	10,76,712	13.17
S_4N_3	84,926	7,01,250	6,16,324	7.26
S_4N_4	79,938	8,49,000	7,69,062	9.62
S_5N_1	95,590	10,91,700	9,96,110	10.42
S_5N_2	98,738	7,92,000	6,93,262	7.02
S_5N_3	1,01,926	11,22,450	10,20,524	10.01
S_5N_4	96,938	6,60,000	5,63,062	5.81
S_6N_1	70,590	7,93,950	7,23,360	10.25
S_6N_2	73,738	7,86,750	7,13,012	9.67
S_6N_3	76,926	7,81,200	7,04,274	9.16
S_6N_4	71,938	7,80,450	7,08,512	9.85

S1: 10 cm × 5 cm, S2: 10 cm × 10 cm, S3: 15 cm × 5 cm, S4: 15 cm × 10 cm, S5: 20 cm × 5 cm, S6: 20 cm × 10 cm
N_1: 75 % RDF + PGPR consortia N_2: 100 % RDF + PGPR consortia
N_3: 125 % RDF + PGPR consortia N_4: 100 % RDF

Conclusion

Hemp is a multipurpose crop where both seed and fiber are of economic importance hence, it gives dual advantage for the farmers. Results suggest cultivating hemp either at spacing of 20 cm × 10 cm or 15 cm × 10 cm and supplied with nutrition of 100 per cent RDF plus PGPR consortia in order to obtain dual income from both fiber and seed. After harvesting of seeds, same stems can be used to extract fiber without much comprising in yield is added advantage of cultivating hemp.

Acknowledgement

The authors are greatly thankful to the Parents, Chairperson (Dr. Maruthi Prasad, B. N.), Advisory committee, Namratha Hemp Company and College of Horticulture, Bengaluru for providing facilities for conduct of this research.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Aubin, M. P., Seguin, P., Vanasse, A., Tremblay, G. F., Mustafa, A. F. & Charron, J. B. (2015). Industrial hemp response to nitrogen, phosphorus and potassium fertilization. *Crop forage turfgrass manag. 1*: 1-10.

Campiglia, E., Radicetti E. & Mancinelli, R. (2017). Plant density and nitrogen fertilization affect agronomic performance of industrial hemp (*Cannabis sativa* L.) in Mediterranean environment. *Industrial Crops and Products*, *100:* 246–254.

Carus, M., Karst, S., Kauffmann, A., Hobson, J. & Bertucelli, S. (2013). The European Hemp Industry: Cultivation, processing and applications for fibres, shives and seeds. *EIHA*, 1-9.

Jankauskiene, Z., Gruzdeviene, E., Maumevicius, E. & Layko, I. M. (2017). Investigation of hemp (*Cannabis sativa* L.) fibre quantity and quality as influenced by genotype and seed rate. *Proc. 11th Int. Scientific and Pract. Conference on Envir. Tech. Resources,* 15-17 June, Latvia*, 1*: 125-128.

Kubsad, V.S., Palled, Y.B. & Mansur, C.P. (2009). Productivity, quality and economics of rainfed Ashwagandha (*Withania somnifera*) as influenced by spacing and fertilizer levels. *Indian Journal of Agronomy*, *54*(4): 449-453.

Lothe, N.B., Mazeed, A., Pandey, J., Patairiya, V., Verma, K., Semwal, M., Verma, R.S. & Verma, R.K. (2021). Maximizing yields and economics by supplementing additional nutrients for commercially grown menthol mint (*Mentha arvensis* L.) cultivars. *Industrial Crops and Products*, *160*: 113-110.

Pagnania, G., Pellegrinia, M., Galienia, A., Egidioa, S. D., Matteuccic, F., Riccia, A., Stagnaria, F., Sergia, M., Sterzoa, C. L., Pisantea, M. & Galloc, M. D. (2018). Plant growth-promoting rhizobacteria (PGPR) in *Cannabis sativa* 'Finola' cultivation: an alternative fertilization strategy to improve plant growth and quality characteristics. *Industrial Crops Products*. *123*: 75–83.

Papastylianou, P., Kakabouki, I. & Travlos, I. (2017). Effect of nitrogen fertilization on growth and yield of industrial hemp (*Cannabis sativa* L.). *Not Bot HortiAgrobo*. *46*(1): 197.

Prasanna, H.S., Maruthi Prasad, B.N., Shankarappa, T.H. & Vishnuvardhana, S.M. (2021). Economics of chia (*Salvia hispanica*) cultivation as influenced by foliar application of different elicitors. *10*(4): 245-249.

Shivani, K. & Gautam, G. (2019). Influence of different levels of nitrogen on yield and economics of stevia (*Stevia rebaudiana* Bertoni) under different planting geometry. *International Journal of Chemical Studies*, *7*(3): 806-809.

Zatta, A., Monti, A. & Venturi, G. (2012). Eighty years of studies on industrial hemp in the Po Valley (1930-2010). *J. Nat.Fibers*. *9*(3):180-196.

Environment Conservation Journal 24 (3): 144-151, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Genetic diversity for morphophysiological character studies in rainfed sorghum (*Sorghum bicolor* [L.] Moench) parental lines

Manish Vishnudas Chavhan ✉
Discipline of Plant Physiology, Sorghum Research Station, Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra, India
Laxman Jawale
Sorghum Research Station, Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra, India
Ambika More
Sorghum Research Station, Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra, India

ARTICLE INFO

Received : 17 August 2022
Revised : 22 January 2023
Accepted : 06 March 2023

Available online: 25 June 2023

Key Words:
Diversity
Genetic Advance
Heritability
Parental lines
Variability
Coefficient of variance

ABSTRACT

The experimental trial was conducted at Sorghum Research Centre, Marathwada Agricultural University, Parbhani during *kharif* 2021 in randomized design with 3 replications. Eighteen parental (B & R) lines were evaluated to study genetic diversities and variability for fifteen yield contributing characters. Among all the eighteen genotypes of parental lines significant differences were observed for yield and its yield contributing traits except total chlorophyll content. Coefficient of variance at phenotypic level showed higher values than at genotypic level among all traits. Coefficient of variance for the traits like chlorophyll stability index (G=23.035, P=23.714), leaf area (G=21.064, P=21.673), 1000 grain weight (G=28.845, P=29.929), fodder yield (G=21.858, P=22.458), grain number per panicle (G=29.564, P=30.158), leaf dry weight (G=29.044, P=29.903) was observed high at both level. Traits like plant height (H=90, GAM=21.041), grain yield (H=86, GAM=29.074), leaf dry weight (H=94, GAM=23.664), leaf area (H=94, GAM=42.17), chlorophyll stability index (H=94, GAM=46.093), grain number per panicle (H=96, GAM=59.703), fodder yield (H=94, GAM=43.823),1000 grain weight (H=92, GAM=52.270) and harvest index (H=84, GAM=32.321) were recorded high heritability with high genetic advancement. Genotype AKR 504, NR 39-15, KR 218, KR 219, PMS 100B, AKMS 90 B and INDORE 12 showed the better performance for all characters thus, should be used for development of hybrids and inbreds in breeding programmes by DUS (Distinctness, Uniformity and Stability) testing.

Introduction

Sorghum bicolor [L.] Moench is an angiospermic crop plant that belongs to poaceae family. It is often cross pollinated crop. In various regions it has several names like Jowar, Indian millet, great millet etc. It is rich in protein, carbohydrates, fat, vitamins, calcium and little quantity of iron.It is a C_4plant having high water use efficiency and photosynthetic efficiency. It can withstand in extreme drought condition for long period and have ability to tolerate drought stress, therefore sorghum is also called as 'camel of desert'. After wheat and rice, Sorghum is the fifth most extensive and beneficial crop in the world, with its nutritional quality and potential use in agriculture. Most of the poor and rural people lived in village prefer jowar bhakri than wheat chapati.According to Department of Agriculture, Cooperation & Farmers Welfare (2020-21), All India estimates for sorghum in terms of area, production and yield during 2020-21 was 1.66 million hectares, 1.75 million tones and 1053 kg/hectare. And according to U.S. Department of Agriculture the area and production of sorghum crop in world for year 2020-21 was 40 million hectare and 60 million tones respectively.Selection of the superior parents to be used in hybridization is one of the main decisions faced by the plant physiologists and plant breeders that will accelerate the exploitation of maximum variability in crops

Corresponding author E-mail: *manishchavhan34@gmail.com*
Doi:https://doi.org/10.36953/ECJ.14462439

and production of superior new genotypes. (Bertan*et al*., 2007). For this reason, utilization of genetic variability and selection of genotypes is very necessary. Knowledge of interrelationship among all the characters which influence the yield of crop to greater extent enables the researcher to plan field trial accordingly. Efforts were made to assess the genetic variability in parental (B and R) lines of *kharif* sorghum for utilizing cytoplasmic genetic male sterility to develop high yielding hybrids. (Godbharle *et al*., 2010)

Material and Methods

Analysis of variance was performed according to standard methods prescribed by panse and sukhatme (1985) for fifteen yield contributing characters of 18 parental genotypes. Experiment was laid out in randomized block design with three replications at Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* 2021. Total 18 (7B and 11R) parental lines were used which were collected from IIMR Hyderabad, ICRISAT Hyderabad, Indore, Parbhani and Akola listed in table 1. Some of the parameters were analysed in the field at 50 % flowering stage of collected sample. Then those samples were taken to laboratory for analysis of relative water content by Barrs and Weatherley (1962) and chlorophyll stability index by Arnon (1949). Most of the samples were analysed at 50 % flowering and flowering stage those are as; Days to 50% flowering, days to maturity, plant height at physiological maturity, leaf dry weight at flowering, stem dry weight at flowering, leaf area at flowering, SPAD value at 50 % flowering (SPAD meter), total chlorophyll content, 1000 grain weight, grain number per panicle , grain yield, fodder yield and harvest index.

Table 1: List of parental (B and R) lines used for study

B-line	Source	R-line	Source
AKMS 30B	Akola	AKR 456	Akola
AKMS 33B	Akola	AKR 504	Akola
AKMS 70B	Akola	AKR 524	Akola
AKMS 90B	Akola	KR 192-2	Parbhani
PMS 100B	Parbhani	KR 218	Parbhani
PMS 237B	Parbhani	KR 219	Parbhani
PMS 28B	parbhani	C 85	Hyderabad
		NR 10-15	Hyderabad
		NR 12-15	Hyderabad
		NR 39-15	Hyderabad
		INDORE 12	INDORE

Results and Discussion

Analysis of variance for fifteen characters in parental lines (B and R) of *kharif* sorghum and mean performances of fifteen characters studied in *kharif* sorghum parental (B and R) lines are presented in table 2 and 3. Traits like days to 50% flowering , days to maturity, plant height, leaf dry weight, stem dry weight, leaf area, relative water content, SPAD value, chlorophyll stability index, 1000 grain weight, grain no per panicle, grain yield, fodder yield and harvest index showed significant differences among all genotypes while total chlorophyll content (TCC) showed non significant difference. Differences among all the genotypes in respect of all yield contributing characters (traits) studied showed significant values at 5% level of significance indicating the presence of variability and diversities of these characters which provides ample scope for selection of superior and desirable genotypes for physiologists and breeders for further genetic improvement and for selection of parents for hybrid development.WASP-Web Agri Stat Package version 2.0 statistical software were used for analysis of variance and mean performance. Grain yield is important character to find out the best physiological trait by its productivity and to choose higher grain yield trait in selecting for crossing. The best performance for grain yield (q/ha) was observed in genotypes PMS 100B (29.88) q/ha, INDORE 12 (23.57) q/ha, KR 218 (23.06) q/ha, KR 192-2 (22.73) q/ha, KR 219 (22.73) q/ha, and AKR 504 (22.39) q/ha. While C-85 (17.26) q/ha showed lowest grain yield among all genotypes. Tirkey *et al.* (2021) has earlier reported similar result higher grain yield in PMS 100 B genotype while similar least yield was observed in PMS 237B reported by Gangaiah *et al.*(2020).Days to fifty percent flowering is recorded until 50 % of plant had atleast one open flower in plot. Less required the days to reach fifty percent flowering results less days to reach maturity within time. Genotypes AKR 524 (76.6), AKMS 70B (79.66) and PMS 100B (80.00) required less days to reach for fifty percent flowering while genotype INDORE 12 (83.00) required higher days to 50 % flowering. Rao *et al.* (2019) has earlier reported similar result required less days to reach 50 % flowering in genotypes AKMS 70B and AKR 524.

Table 2 : Analysis of variance for fifteen characters in parental lines (B and R) of *kharif* sorghum

SN	Sources of variation	Degrees of freedom	Dfif	Days to maturity	Plant height at physiological maturity (cm)	Leaf dry wt at flowering (g/m^2)	Stem dry wt at flowering (g/m^2)	Leaf area at flowering (cm^2)	RWC (%) at 50% flowering
1	Replication	2	4.57	1.500	29.685	10.167	7330.907	1352.519	16.074
2	Treatment	17	6.63*	12.431*	853.11*	428.049*	48893.028*	85931.983*	40.780*
3	Error	34	1.96	1.912	29.038	8.402	12007.770	1650.166	16.917

Contd..

SN	Sources of variation	Degrees of freedom	SPAD value at 50% flowering	TCC (mg/ml)	CSI (%)	1000 grain wt (g)	Grain no/panicle	Grain yield (q/ha)	Fodder yield (q/ha)	HI (%)
1	Replication	2	12.519	0.000	5.352	0.310	2602.463	2.743	12.878	4.019
2	Treatment	17	22.623*	0.002^{NS}	851.198*	24.229*	511247.849*	30.358*	1124.83*	33.02*
3	Error	34	6.362	0.001	16.646	0.603	6816.110	1.531	20.508	1.920

*** Significant at 5% level ,^{NS}non significant**

A similar or different value in days to fifty percent flowering was observed by Rao *et al.* (2016, 2017, 2018, 2019), Gangaiah *et al.*(2020) also observed significant differences among genotypes. They observed B line AKMS 33B and R line AKR 456 and NR 12 15 to be the quickest flowering.Days to maturity tells the number of days required from transplanting to reach its physiological maturity. Less no of days to fifty percent flowering results in less days to reach maturity. Genotypes AKR 524 (117.33), AKMS 70B (120.33), required less days to reach physiological maturity while genotypes NR 10-15 (126.33), INDORE 12 (125.33), required higher days to reach physiological maturity. Rao *et al.* (2019) has earlier reported similar result required less days to reach physiological maturity in B line containing genotype AKMS 70B and R line containing AKR 524. A different trend in days to fifty percent flowering was reported by Rao *et al.* (2016,2017,2018). Gangaiah *et al.* (2020) reported significant differences and observed B line AKMS 33B and R line AKR 456 and NR 12 15 to be the quickest maturity as well.

Plant height is very important character as it is correlated with the lifespan, mass of seeds, days required for maturity and have the ability to compete with other plants in population having higher length for light, CO_2.Plant height at physiological maturity was observed superior highest in genotypes AKR 504 (190cm) and PMS 100B (186.33cm), higher in KR 192-2 (176.67cm) and KR 219 (169.33cm), moderate in AKMS 30B (158.67cm) and AKMS 70B (157.67cm) and lowest height was observed in genotype AKMS 90B (134.67cm) and KR 218 (138cm). Similar result superior plant height in R line containing genotype AKR 504, KR 192-2 and B line containing PMS 100B was earlier reported by Rao *et al.* (2019) and Gangaiah *et al.* (2020). A similar or different value was reported for plant height in inbred lines by Chavhan *et al.* (2022). Leaf dry weight indicates the biomass of leaf and ability to photosynthesize for storing food. The best performance for leaf dry weight was observed in genotype AKR 504 (62.66) g/m^2, followed by AKMS 70B (56.33) g/m^2, NR 39-15 (53.66) g/m^2, AKMS 90B (52.00) $g/m^2$and INDORE 12 (51.66) g/m^2, while the lowest dry weight observed in AKR 524 (19.67) g/m^2. Rao *et al.* (2019) has earlier reported similar result higher leaf dry weight for R line containing genotype NR 39-15.Results for leaf dry weight is in accordance with earlier worker Chavhan *et al.* (2022), Gangaiah *et al.* (2020).

Stem dry weight is dependent on the weight of dry leaf biomass. Increase in photosynthesis in leaf increases in biomass of leaf and transport of organic solutes from leaf to stem results in increase in dry matter of stem. The best performance for stem dry weight was observed in genotype KR 192-2 (1108.667) g/m^2, followed by AKR 504 (982.67) g/m^2, NR 10-15 (927.0) g/m^2 and lowest in genotype AKMS 90B (635.67) g/m^2.These results are in accordance with the earlier findings by Gangaiah *et al.* (2020).Leaf area of plant is important to determine environmental impacts on plant biomass production and describes the measurement of canopy structure of plant. The highest leaf area was observed in genotypes AKR 504 (1115.33) cm^2 and NR 39-15 (1058.0) cm^2, while lowest leaf area observed in KR 218

Table 3: The Mean performances of fifteen characters studied in *kharif* sorghum parental (B and R) lines

SN	Genotypes	Dfif	Days to maturity	Plant height at physiological maturity (cm)	Leaf dry wt at flowering (g/m^2)	Stem dry wt at flowering (g/m^2)	Leaf area at flowering (cm^2)	RWC (%) at 50% flowering	SPAD value at 50% flowering	TCC (mg/ml)	CSI (%)	1000 grain wt (g)	Grain no/panicle	Grain yield (q/ha)	Fodder yield (q/ha)	HI (%)
1	AKMS 30B	81.67	122.00	158.67	56.33	710.67	1001.33	79.00	55.00	0.11	96.33	9.59	1191.33	17.85	80.81	18.00
2	AKMS 33B	80.67	122.00	149.00	46.00	894.67	589.33	84.67	48.00	0.14	68.00	11.45	1195.00	18.01	67.34	21.00
3	AKMS 70B	79.67	120.33	152.67	44.67	679.00	725.33	88.67	56.33	0.11	87.67	6.04	2191.33	20.20	67.34	22.67
4	AKMS 90B	81.67	125.00	134.67	52.00	635.67	820.33	87.00	58.33	0.14	93.67	6.49	764.67	17.93	67.34	20.33
5	PMS 100B	80.00	121.67	186.33	35.67	801.00	615.00	85.33	57.00	0.09	71.67	8.27	1184.67	29.88	106.90	21.67
6	PMS 237B	80.67	121.67	147.67	34.67	646.33	619.00	88.33	56.00	0.09	41.00	5.67	564.67	17.85	67.34	20.33
7	PMS 28B	82.67	124.00	142.33	26.67	674.67	731.67	93.33	53.67	0.11	47.33	8.34	1275.67	19.61	69.87	21.67
8	AKR 456	82.33	124.33	160.33	29.33	848.00	785.67	83.67	52.67	0.15	84.33	8.80	1426.00	17.93	65.66	21.00
9	AKR 504	81.33	123.33	190.00	62.67	982.67	1115.33	83.67	58.33	0.13	81.33	8.17	1512.33	22.39	63.97	25.33
10	AKR 524	76.67	117.33	144.67	19.67	726.33	631.33	86.67	57.00	0.14	55.33	9.21	1329.33	19.70	88.38	17.67
11	KR 192-2	81.33	123.33	176.67	24.33	1108.6	678.00	87.67	57.67	0.13	71.33	8.67	1621.67	22.73	111.95	16.33
12	KR 218	82.33	124.33	138.00	33.67	844.00	583.67	93.33	58.67	0.10	81.33	10.20	1964.67	23.06	106.90	17.33
13	KR 219	80.00	122.33	169.33	40.67	894.67	922.67	81.00	58.00	0.14	90.00	10.07	1263.00	22.73	105.22	17.33
14	C 85	82.33	123.00	134.33	44.00	716.67	831.33	83.67	56.67	0.07	85.00	16.70	1374.00	17.26	110.27	13.00
15	NR 10-15	81.33	126.33	160.33	44.67	927.00	840.00	89.33	53.33	0.09	65.00	10.27	1275.00	19.53	115.32	14.00
16	NR 12-15	81.67	123.00	141.67	32.67	816.00	754.67	84.67	58.33	0.14	78.33	9.45	1333.33	18.27	92.59	16.00
17	NR 39-15	82.33	122.67	141.00	53.67	737.33	1058.00	87.67	58.00	0.08	50.33	14.68	1326.33	18.69	106.90	14.67
18	INDORE 12	83.00	125.33	150.00	51.67	873.33	1020.67	87.00	54.33	0.11	55.33	13.07	2170.67	23.57	85.86	21.00
	General mean	81.20	122.89	154.31	40.72	806.48	795.74	86.37	55.96	0.11	72.41	9.73	1386.87	20.40	87.78	18.85
	SE (m)	0.810	0.798	3.111	1.674	63.266	23.453	2.375	1.456	0.019	2.356	0.448	47.666	0.714	2.614	0.800
	CD at 5%	2.326	2.294	8.941	4.809	181.80	67.397	6.824	4.185	N/A	6.769	1.288	136.977	2.062	7.546	2.299
	C.V	1.727	1.125	3.492	7.118	13.587	5.105	4.762	4.507	28.95	5.635	7.981	5.953	6.066	5.159	5.185

Table 4: Mean and genetic variability parameters for fifteen characters in parental (B and R) lines of *kharif* sorghum

Characters	Range		Mean	GCV	PCV	Heritability %	Genetic advance	Genetic Advance value % means
	Min	Max						
Dfif	76.67	83	81.20	1.536	2.311	44.170	1.708	2.103
Days to maturity	117.33	126.33	122.89	1.524	1.894	64.717	3.103	2.525
Plant height at physiological maturity (cm)	134.33	190	154.32	10.740	11.294	90.440	32.469	21.041
Leaf dry wt at flowering (g/m^2)	19.67	62.67	40.72	29.044	29.903	94.334	23.664	58.110
Stem dry wt at flowering (g/m^2)	635.67	1108.67	806.48	13.749	19.330	50.591	162.469	20.145
Leaf area at flowering (cm^2)	583.67	1115.33	795.74	21.064	21.673	94.452	335.567	42.170
RWC (%) at 50% flowering	79	93.33	86.37	3.265	5.774	31.981	3.286	3.804
SPAD value at 50% flowering	48	58.67	55.96	4.160	6.134	46.006	3.253	5.813
TCC (mg/ml)	0.07	0.15	0.12	11.480	31.160	13.573	0.010	8.713
CSI (%)	41	93.67	72.41	23.035	23.714	94.354	33.374	46.093
1000 grain wt (g)	5.67	16.7	9.73	28.845	29.929	92.889	5.572	52.270
Grain no/panicle	564.67	2191.33	1386.87	29.564	30.158	96.101	828.108	59.703
Grain yield (q/ha)	17.26	29.88	20.40	15.200	16.364	86.278	5.931	29.074
Fodder yield (q/ha)	63.97	115.32	87.78	21.858	22.458	94.725	38.467	43.823
HI (%)	13	25.33	18.85	17.081	18.596	84.373	6.093	32.321

(583.661) cm^2, AKMS 33B (589.33) cm^2, followed by PMS 100B (615.0) cm^2, PMS 237B (619.0) cm^2. These results are in accordance with the earlier findings by Chavhan *et al.* (2022), Gangaiah *et al.* (2020). Rao *et al.* (2019) has earlier reported similar result highest leaf area in R line containing genotypes NR 39-15 and AKR 504 .

Relative water content means that how much amount of water leaf can hold, also is an indicator of plant water status in crops. The best genotypes for relative water content (RWC) was observed in PMS 28B and KR 218 (93.33%), followed by NR 10-15 (89.33%), AKMS 70B (88.67%) and lowest values observed in AKMS 30B (79.0%) respectively. Chavhan *et al.* (2022) reported high water content in inbred line PVK 1025 and lowest in CSV 39.

SPAD is accurate and non destructive method of measurement of leaf chlorophyll concentration widely used in estimation of status of chlorophyll in crop plants. Significant differences were observed among the genotypes for SPAD at 50 % flowering. Among KR 218 (58.67), AKMS 90B (58.33), NR 12-15 (58.33), AKR 504 (58.33) observed superior higher values while least in genotype AKMS 33B (48.00). These results are in accordance with the earlier findings by Gangaiah *et al.* (2020), Rao *et al.*(2019), Chavhan *et al.* (2022).

Differences in total chlorophyll content (TCC) was observed non significant for all the genotypes.

Chlorophyll stability index also is an indicator of plant that indicates the ability of tolerance/resistance capacity of plants when an external abiotic stress like temperature, drought is influenced on it. Chlorophyll stability index (CSI) was observed significant differences among all the genotypes. Highest stability was observed in genotype AKMS 30B (96.33%), AKMS 90B (93.67%), KR 219 (90.00%) followed moderately by AKMS 70B (87.67%), C 85 (85.00 %), AKR 504 (81.33%) and lowest stability observed in PMS 237B (41.00%) and PMS 28B (47.33%).Similar results significant differences among all the genotypes in inbred lines were earlier reported by Chavhan *et al.* (2022). They observed high stability in CSV 34, PDKV Kalyani and lowest in CSV 31.

Test weight is the weight of 1000 grain seeds and is used in grain quality indicator. The test weight i.e; 1000 grain weight was observed higher in C 85 (16.70 g), NR 39-15 (14.68g), INDORE 12 (13.07g) and lowest weight in AKMS 90B (6.49g), AKMS 70B (6.04g) and PMS 237B (5.67g). A similar results higher 1000 grain weight in C 85 and least in PMS 237B was reported by Gangaiah *et al.*(2020). Chavhan *et al.* (2022) reported higher 1000 grain weight in inbred line PDKV Kalyani, AKSV 346 and lowest weight in SPV 2510, AKSV 318.

Fodder yield consists of weight of dry matter biomass and depend on various factors. The best performance for fodder yield was found in genotypes NR 10-15 (115.32q/ha), KR 192-2 (111.95q/ha), C 85 (110.27q/ha) and poor performance was observed in PMS 237B , AKMS 90B, AKMS 70B (67.34q/ha), AKR 456 (65.66q/ha) and AKR 504 (63.97q/ha). The best performance for fodder yield in genotype PVK 1025, SPV 2510 and poor in AKSV 318 was earlier reported by Chavhan *et al.* (2022). Harvest index is the ratio of grain yield to its biological yield and used to describe dry matter partitioning in crop plants. Genotypes AKR 504 (25.33%), AKMS 70B (22.67%) showed highest harvest index and lowest in C 85 (13.00%) followed by NR 12-15 (16.00%), NR 39-15 (14.67%), NR 10-15 (14.00%) and KR 192-2 (16.33%).Results are in accordance with Chavhan *et al.* (2022) reported highest index in inbred lines SPV 2504 and lowest in PDKV Kalyani.

Genotypic and phenotypic coefficient variance matrix.

The results of estimated genetic parameters are represented in table no 4.

Genotypic and phenotypic coefficient variance matrix indicates whether the traits are influenced by environmental factors or genetic factor which leads to select appropriate trait in order for breeding programme for crop improvement. Coefficient variance matrix for both level (phenotypic and genotypic) were classified into three level <10 as low, 11-21 as moderate and > 21 high in accordance with Sivasubramanian and Menon (1973).Coefficient variance matrix at phenotypic level showed higher values than at genotypic level among all traits. Similar results high phenotypic variance than genotypic variance was earlier reported by Godbharle *et al.* (2010) and Chavhan *et al.* (2022). Traits like grain no per panicle, leaf dry weight, 1000 grain weight, fodder yield, chlorophyll stability index (CSI), leaf area were recorded high coefficient variance matrix at both genotypic and phenotypic level. Similar results higher values of GCV and PCV for grain no per panicle, leaf dry weight, 1000 grain weight were earlier reported by Chavhan *et al.* (2022).Moderate coefficient variance matrix at both genotypic and phenotypic were observed for plant height at physiological maturity, dry weight of stem and grain yield. Similar results observed moderate values of GCV and PCV for plant height by Chavhan *et al.* (2022) in his earlier findings. While low coefficient variance matrix at both genotypic and phenotypic were recorded for traits like days to fifty percentflowering, days to maturity, relative water content (RWC) and SPAD value. Similar results observed low values of GCV and PCV for days to fifty percent flowering, days to maturity, relative water content (RWC) and SPAD value by Chavhan *et al.* (2022) in his earlier findings. Higher values of phenotypic matrix indicate that the traits are influence by several environmental factors, hence traits showing higher genotypic values should be select and use in crop improvement programme.

Heritability and genetic advance

Heritabilty is transmission of characters from its parents to its offsprings. Heritability estimation helps in selection of best genotypes from diverse genetic group. High heritability indicates that traits are low influenced by environmental factor. The heritability percentage to determine its level of heredity classified as low (0-31), medium (31-61) and high (61 and above) in accordance with Johnson *et al* (1955). Grain yield, plant height at maturity, grain number per panicle, leaf dry weight at flowering, chlorophyll stability index, 1000 grain weight, fodder yield, leaf area and harvest index recorded high heritability and high genetic advance. Similar results high heritability with high genetic advance for grain yield and fodder yield were earlier reported by Tirkey *et al.* (2021). These traits are beneficient and important to researcher for better selection in crop improvement programme. High percentage of heritability with low genetic advance were observed in days to reach physiological maturity. Similar results high heritability with low genetic advance for days to reach physiological maturity was earlier reported by Chavhan *et al.* (2022).Traits which showing high heritability percentage are likely to inherit maximum genes or characters from its parent to offsprings. So, traits which showing high heritability percentage should used for hybrid seed development.

Conclusion

From the above suggestion it is concluded that the variability and diversities in parental lines helps in selecting the appropriate genotype need for production of hybrids or new cultivars. Therefore the study of physiological parameters for genetic diversity in parental sorghum lines is very essential in order to choose better quantitative and qualitative trait (drought resistant, heat resistant, stress tolerance, water logged resistant) for exploitation of inbred and hybrids in hybrid development programme. As sorghum is the fifth most important crop in the world for its various uses for consumption, feed and fodder, ethanol production etc, the development of hybrid through selection of desirable trait for increased productivity with qualitative features enhance in crop improvement globally all over the world.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Aron D. (1949) Copper enzymes in isolated chloroplasts, polyphenoloxidase in *Beta vulgaris.* Plant Physiology., 24:1-15.

Barr, H.D. and Weatherley, P.E. (1962). A re-examination of the relative turgidity technique for estimating water deficit in leaves. *Aust. J. Biol. Sci*. 15:413-428.

Bertan, I., de Carvalho, F. I., & Oliveira, A. C. D. (2007). Parental selection strategies in plant breeding programs. *Journal of crop science and biotechnology*, *10*(4), 211-222.

Chavhan, M., Jawale, L. N., & Pardhi, D. S. (2022). Genetic diversity and variability for morphophysiological yield and yield contributing traits in kharif sorghum (Sorghum bicolor L. Moench) inbred lines. *The Pharma Innovation Journal 2022; 11(7): 1025-1029.*

Department of Agriculture, Cooperation & Farmers Welfare (2020-21) Annual Report.

Gangaiah, B. *et al.* (2020). Sorghum Physiology Kharif Report. Millets research publicationAICRP on Sorghum, Hyderabad 8- Sorghum Physiology kharif report-agm 21. *Kharif* vanakalam (2020-21) sorghum report.

Godbharle, A.R., & More, A.W.(2010). Genetic variability an correlation studies in elite 'B' and 'R' lines in *Kharif* sorghum. *Electronic Journal of Plant Breeding ;1(4):989-993.*

Johnson, H.W., Robinson, H.F.,& Comstock.(1955). Estimation of genetic and environmental variability in soybeans.*Agron.J;47:314-318.*

Rao, S.S., S Srividhya, PS Kamble, R.B. Ghorade, Satpal and KR Kamble (2019). Sorghum Physiology Kharif Report. Millets research publicationAICRP on Sorghum, Hyderabad 8- Sorghum Physiology *kharif* report-agm20.

Sivasubramanian, S., & Menon, M. (1973).Heterosis and inbreeding depression in rice.*Madras Agricultural Journal ;60*:11-39.

Tirkey, S., Jawale, L.N., & More, A.W. (2021).Genetic variability, correlation and path analysis studies in B parental lines of *kharif* sorghum (*Sorghum bicolor* (L.) Moench). *The Pharma Innovation Journal 2021; 10(8): 624-628*

Environment Conservation Journal 24 (3): 152-156, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Trait association studies in diverse genotypes of rice for their utilization in biofortification

Caleb Vanlalrinngama
Department of Genetics and Plant Breeding, RPCAU, Pusa (Samastipur), Bihar, India
Banshidhar Jha
Department of Genetics and Plant Breeding, LPU, Phagwara (Jalandhar), Punjab, India
S. K. Singh
Department of Genetics and Plant Breeding, RPCAU, Pusa (Samastipur), Bihar, India
A. Tigga
Department of Genetics and Plant Breeding, RPCAU, Pusa (Samastipur), Bihar, India
Bishawajit Kumar
Department of Genetics and Plant Breeding, RPCAU, Pusa (Samastipur), Bihar, India
Namata Kumari
Department of Genetics and Plant Breeding, RPCAU, Pusa (Samastipur), Bihar, India
M. K. Singh ✉
Department of Genetics and Plant Breeding, RPCAU, Pusa (Samastipur), Bihar, India

ARTICLE INFO

Received : 17 August 2022
Revised : 26 February 2023
Accepted : 20 March 2023

Available online: 27 June 2023

Key Words:
Rice
Micronutrients
Biofortification
Correlation
Correlation coefficient
Phenotype
Genotype

ABSTRACT

Rice is the staple food crop for more than half of the world population. Thus, rice varieties enriched with various micronutrients qualifies as a better alternative to combat micronutrient deficiency. The present investigation was undertaken to study the degree and direction of association for grain characters especially grain Zinc (Zn) content and grain Iron (Fe) content in 30 genotypes of rice. The correlation coefficient analysis findings at the phenotypic level were used to determine whether the various traits were correlated with yield and the significance of the relationship among them. This data shows significant positive correlation at the phenotypic and genotypic level for grain yield per plant with days to 50% flowering (0.356 & 0.373), number of panicles per plant (0.340 & 0.522), panicle length (0.293 & 0.356), test weight (0.307 & 0.346) and kernel breadth (0.283 & 0.339). The signs (positive or negative) reflect the consequence of increasing or decreasing one variable over the other. The traits plant height ((-0.399 & -0.410) and kernel L/B ratio (-0.237 & -0.291) showed negative correlation with yield indicating that shorter plants as well as grains having shorter length with more breadth are more likely to produce more yield thus selection should be carried out against height . One possible reason for this could be that in plants with shorter stature have higher nutrient use efficiency and are resistant to lodging. The traits days to 50% flowering, number of panicles per plant, panicle length, and test weight and kernel breadth showed positive correlation indicating that selection towards higher values for these traits would consequently improve the yield. It was also found that the traits Zn and Fe content were positively correlated with each other implying that simultaneous selection of these traits could be done for the purpose of biofortification.

Introduction

Rice (*Oryza sativa L.*) is the single most important staple crop of the world. Asia is second to none in terms of production and constitutes 90% of the global rice cultivation area (Singh *et al.*, 2017). India produced an estimated 117.94 Mt of grain with a productivity of 2.7 t/ha during the 2019-2020 season. Although rice production is high in India, productivity is meager compared to other major producers such as China (6.5 t/ha) and Indonesia (5.2 t/ha) (MoA& FW, GoI,2019-2020).Though the

Corresponding author E-mail: *mithileshgpb@gmail.com*
Doi: **https://doi.org/10.36953/ECJ.14472440**

progress in production of rice has moved forward by leaps and bounds, there is still a necessity to increase production and productivity to meet the needs of the growing population. However, feeding the growing population is not the only concern but we should also ensure the nutritional security especially with respect to essential micronutrients, vitamins and proteins as micronutrient deficiency is a major issue plaguing developing countries such as India (Bain *et al.*, 2013). According to a survey by the WHO, more than two billion people are afflicted with micronutrient deficiencies. Development of rice cultivars that possess substantial yield with ample amount of micronutrients could create an avenue for solving two problems with a single solution. Yield is a very complex trait as this does not depend on a single factor; rather it is a function of the combination of several attributing factors in the form of different traits (Moosavi *et al.*, 2015). Thus, selection procedures in crop improvement must take into consideration these factors or traits that. Therefore, the association studies between grain yield and its contributing trait is very much essential in making indirect selection. It aims at initiation of effective selection programme to achieve genetic improvement in crops so as to enhance their economic value and utility. It provides a statistical measure about the strength of association between two variables and also the direction in which they are associated.

Material and Methods

The present investigation was conducted at Research farm, RPCAU, Pusa, Bihar during *Kharif* 2019-2020. The experimental materials comprised of 29 rice genotypes acquired from HarvestPlus programme, ICRISAT, Hyderabad. The local check was taken from Rice breeding section, Department of Plant Breeding and Genetics, RPCAU, Pusa, Bihar. 21 days old seedlings were transplanted in an experimental unit of 5m^2 adopting a spacing of 20cm between rows and 15cm between plants. Randomized Complete Block Design was followed with three replications. Eleven quantitative traits were taken into consideration for the present study. The observations on quantitative traits *viz* plant height, number of panicles per plants, panicle length and grain yield per plant were taken by selecting 5 random plants from each plot while days to 50% flowering was recorded on plot basis. Observation on test weight, kernel length, kernel breadth, kernel L/B ratio, grain Iron content and grain Zinc content was recorded from seeds taken from bulk harvest of individual plot. An instrument known as Energy Dispersive X-Ray Fluorescence(ED-XRF) was used for estimation of the grain Iron and Zinc content. Trait association between the various characters under study was analyzed using methods proposed by Galton (1889); Fisher (1918) and Falconer (1964) for computation of correlation coefficient which gives an insight into the magnitude and direction of relationship between the various traits. The cause-&-effect relationship was established by dividing the correlation coefficient into measures of direct & indirect effects using the path analysis, as proposed by Wright (1921) and further illustrated by Dewey and Lu (1959). Computation of data was done using R software.

Results and Discussion

The correlation coefficient provides information on the nature of relationship between various traits. It gives the magnitude and direction of the relationships thereby making the process of selection more precise and efficient. The data on correlation for this research which has been presented in Table 1 shows significant positive correlation at the phenotypic and genotypic level for grain yield per plant with days to 50% flowering (0.356 & 0.373), number of panicles per plant (0.340 & 0.522), panicle length (0.293 & 0.356), test weight (0.307 & 0.346) and kernel breadth (0.283 & 0.339) suggesting that these component trait can be used as in indirect selection for grain yield per plant. Similar findings were also reported by previous workers such as Bhargava *et al.* (2021); Yadav *et al.* (2010) and Veni *et al.* (2013). Significant negative association of grain yield per plant with plant height (-0.399 & -0.410) and kernel L/B ratio (-0.237 & -0.291) suggests that these component trait can also be used in indirect selection for grain yield per plant wherein exercising selection for lower values for this trait can lead to an increment in yield per plant. These traits may be utilized in crop improvement to obtain yield increases *via* indirect selection.

Table 1: Correlation coefficient among 11 quantitative traits of rice

Traits		PH	DFF	NPP	PL	1000-GW	KL	KB	L/B	FeC	ZnC
PH	P	**-0.357**	0.062	0.139	0.001	0.051	-0.030	-0.062	0.025	0.020	-0.054
	G	**-0.2347**	0.0416	0.1208	-0.0064	0.0343	-0.0213	-0.0368	0.0082	0.0190	-0.0386
DFF	P	-0.036	**0.206**	0.078	-0.025	0.042	0.013	0.021	-0.010	-0.006	-0.032
	G	-0.0244	**0.1380**	0.0650	-0.0185	0.0287	0.0085	0.0195	-0.0090	-0.0042	-0.0228
NPP	P	-0.053	0.052	**0.136**	-0.026	0.020	0.006	0.004	-0.001	-0.023	-0.044
	G	-0.1853	0.1696	**0.3601**	-0.0806	0.0557	0.0530	0.0632	-0.0113	-0.0621	-0.1590
PL	P	-0.001	-0.030	-0.047	**0.249**	0.043	-0.082	0.061	-0.111	-0.034	0.075
	G	0.0083	-0.0405	-0.0674	**0.3013**	0.0531	-0.1130	0.1470	-0.2046	-0.0480	0.1105
1000-GW	P	-0.025	0.036	0.026	0.031	**0.176**	-0.034	-0.026	0.001	-0.042	-0.020
	G	-0.0311	0.0443	0.0329	0.0375	**0.2128**	-0.0413	-0.0399	0.0027	-0.0541	-0.0277
KL	P	-0.049	-0.037	-0.027	0.196	0.115	**-0.593**	-0.146	-0.314	0.064	0.073
	G	-0.0406	-0.0274	-0.0659	0.1677	0.0867	**-0.4471**	-0.1293	-0.2640	0.0548	0.0528
KB	P	0.182	0.108	0.032	0.252	-0.156	0.255	**1.037**	-0.714	-0.070	-0.168
	G	0.1073	0.0964	0.1199	0.3333	-0.1280	0.1977	**0.6834**	-0.4107	-0.0755	-0.1533
L/B	P	-0.063	-0.040	-0.005	-0.393	0.004	0.469	-0.608	**0.884**	-0.015	0.055
	G	-0.0207	-0.0387	-0.0186	-0.4017	0.0076	0.3492	-0.3554	**0.5914**	-0.0054	0.0564
FeC	P	0.003	0.002	0.008	0.007	0.012	0.005	0.003	0.001	**-0.049**	-0.015
	G	0.0009	0.0003	0.0019	0.0018	0.0028	0.0014	0.0012	0.0001	**-0.0111**	-0.0036
ZnC	P	0.001	-0.001	-0.001	0.001	-0.0004	-0.0004	-0.001	0.0002	0.001	**0.003**
	G	0.0097	-0.0098	-0.0261	0.0217	-0.0077	-0.0070	-0.0133	0.0056	0.0193	**0.0592**
YPP	P	**-0.399****	**0.356****	**0.340****	**0.293***	**0.307***	**0.01**	**0.283***	**-0.237**	**-0.154**	**-0.127**
	G	**-0.410****	**0.373****	**0.522****	**0.356****	**0.346****	**-0.019**	**0.339****	**-0.291**	**-0.167**	**-0.126**

The negative correlation of plant height with yield was supported by the findings of workers *viz.* Singh *et al.* (2017) and Patil and Sarawgi (2005). Non significant association of the traits kernel length (0.01 & -0.019), grain Iron content (0.154 & -0.167) and grain Zinc content (0.127 & -0.126) with yield suggests that they play no role in yield determination. However if for any reason one wishes to combine high yield with any of these traits, one may have to independently select for the two traits in a single genotype. The traits grain Zn and Iron (0.301 & 0.326) content showed significant positive correlation between each other indicating that simultaneous selection could be done to improve nutritional quality in crop improvement programmes to enrich the rice grain with both these micronutrient serving as a potent weapon against the battle on malnutrition. The probable reason for this association may be attributed to common transporters involved in absorption of these micronutrients from soil to the plant system. Path analysis separates the correlation coefficient into measurements of direct and indirect effects of aset of independent variables on the dependent variable using the standardized partial regression coefficient. If the correlation between yield and trait is due to the trait's direct effects, it represents the true relationship between them, and selection may be used to improve yield. If, on the other hand, the link is due to the trait's indirect effects through another component trait, the breeder must choose the latter trait. This knowledge gives a better insight into the nature of relationship between traits and thus helps to make selection more effective. The perusal of data on path coefficient analysis (Table 2) from this research revealed that the following traits *viz.* days to 50% flowering (0.206 & 0.138), panicle length (0.249 & 0.301), test weight (0.176 & 0.212), number of panicles per plant (0.136 & 0.360), kernel breadth (1.037 & 0.683), kernel L/B ratio (0.884 & 0.591), and grain Zn content (0.003 & 0.059) were all observed to exert positive direct effect on the dependent variable *i.e.* grain yield per plant, indicating a strong positive association between these traits. This implies that selection for these

Table 2: Path analysis coefficient analysis among 11 quantitative traits of rice

Traits		PH	DFF	NPP	PL	1000-GW	KL	KB	L/B	FeC	ZnC
PH	**P**	**-0.357**	0.062	0.139	0.001	0.051	-0.030	-0.062	0.025	0.020	-0.054
	G	**-0.2347**	0.0416	0.1208	-0.0064	0.0343	-0.0213	-0.0368	0.0082	0.0190	-0.0386
DFF	**P**	-0.036	**0.206**	0.078	-0.025	0.042	0.013	0.021	-0.010	-0.006	-0.032
	G	-0.0244	**0.1380**	0.0650	-0.0185	0.0287	0.0085	0.0195	-0.0090	-0.0042	-0.0228
NPP	**P**	-0.053	0.052	**0.136**	-0.026	0.020	0.006	0.004	-0.001	-0.023	-0.044
	G	-0.1853	0.1696	**0.3601**	-0.0806	0.0557	0.0530	0.0632	-0.0113	-0.0621	-0.1590
PL	**P**	-0.001	-0.030	-0.047	**0.249**	0.043	-0.082	0.061	-0.111	-0.034	0.075
	G	0.0083	-0.0405	-0.0674	**0.3013**	0.0531	-0.1130	0.1470	-0.2046	-0.0480	0.1105
1000-GW	**P**	-0.025	0.036	0.026	0.031	**0.176**	-0.034	-0.026	0.001	-0.042	-0.020
	G	-0.0311	0.0443	0.0329	0.0375	**0.2128**	-0.0413	-0.0399	0.0027	-0.0541	-0.0277
KL	**P**	-0.049	-0.037	-0.027	0.196	0.115	**-0.593**	-0.146	-0.314	0.064	0.073
	G	-0.0406	-0.0274	-0.0659	0.1677	0.0867	**-0.4471**	-0.1293	-0.2640	0.0548	0.0528
KB	**P**	0.182	0.108	0.032	0.252	-0.156	0.255	**1.037**	-0.714	-0.070	-0.168
	G	0.1073	0.0964	0.1199	0.3333	-0.1280	0.1977	**0.6834**	-0.4107	-0.0755	-0.1533
L/B	**P**	-0.063	-0.040	-0.005	-0.393	0.004	0.469	-0.608	**0.884**	-0.015	0.055
	G	-0.0207	-0.0387	-0.0186	-0.4017	0.0076	0.3492	-0.3554	**0.5914**	-0.0054	0.0564
FeC	**P**	0.003	0.002	0.008	0.007	0.012	0.005	0.003	0.001	**-0.049**	-0.015
	G	0.0009	0.0003	0.0019	0.0018	0.0028	0.0014	0.0012	0.0001	**-0.0111**	-0.0036
ZnC	**P**	0.001	-0.001	-0.001	0.001	-0.0004	-0.0004	-0.001	0.0002	0.001	**0.003**
	G	0.0097	-0.0098	-0.0261	0.0217	-0.0077	-0.0070	-0.0133	0.0056	0.0193	**0.0592**
YPP	**P**	**-0.399****	**0.356****	**0.340****	**0.293***	**0.307***	**0.01**	**0.283***	**-0.237**	**-0.154**	**-0.127**
	G	**-0.410****	**0.373****	**0.522****	**0.356****	**0.346****	**-0.019**	**0.339****	**-0.291**	**-0.167**	**-0.126**

traits in the positive direction could directly lead to an increase in yield. These results were similar to those of Lakshmi *et al*. (2014); Sadeghi (2011) and Sankar *et al*. (2006) who also found that traits such as test weight, and number of panicles per plant had large positive association with grain yield and apart from these traits, the results of the present investigation imply that traits such as panicle length, kernel breadth and kernel L/B ratio have a direct positive association with grain yield. Negative direct effect was exerted by the traits plant height (-0.357 & -0.234), kernel length (-0.593 & -0.447), and grain Fe content (-0.049 & -0.011). Negative direct effect implies that these traits have a direct negative effect on the dependant variable *i.e* grain yield, implying that selection for these traits should be done in negative direction to increase grain yield. This could be attributed to the fact that plants with short stature have been found to exhibit higher nutrient use efficiency and are resistant to lodging. These findings were in conjunction with the findings of Babu *et al*. (2012) and Nayak *et al*. (2001) who also reported a negative direct effect of plant height on grain yield.

Conclusion

The analysis of trait association and subsequent path analysis revealed that the traits, plant height, days to 50% flowering, number of panicles per plant, panicle length, test weight and kernel breadth are the major determinant of grain yield per plant as they showed significant association as well as high direct effect on the latter. These traits could be utilized in the selection for improvement of yield in crop breeding programmes. Further the grain Iron(Fn) and Zinc(Zn) content while not showing any significant association with grain yield displayed a significant positive association with each other signifying that improvement of these two traits could be done simultaneously in biofortification programmes.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Babu, V. R., Shreya, K., Dangi, K. S., Usharani, G., & Shankar, A. S. (2012). Correlation and path analysis studies in popular rice hybrids of India. *International Journal of Scientific and Research Publications*, *2*(3), 1-5.

Bain, L.E., Awah, P.K., Geraldine, N., Kindong, N.P., Siga, Y., Bernard, N. & Tanjeko, A.T. (2013). Malnutrition in Sub-Saharan Africa: burden, causes and prospects. *Pan African Medical Journal*, 15(1),120

Bhargava, K., Shivani, D., Pushpavalli, S. N. C. V. L., Sundaram, R. M., Beulah, P., & Senguttuvel, P. (2021). Genetic variability, correlation and path coefficient analysis in segregating population of rice. *Electronic Journal of Plant Breeding*, 12(2), 549-555.

Dewey, D.R. & Lu, K.H. (1959). A Correlation and Path Coefficient Analysis of Components of Crested Wheatgrass Seed Production. *Agronomy journal*, 57(9), 515-518.

Fisher, R. A. (1918). The correlation between relatives on the supposition of Mendelian inheritance. *Transactions of the Royal Society of Edinbergh*, 52, 399-433.

Falconer, D.S. 1960**.** Introduction to quantitative genetics. *Ronald Press, New York*. pp. 247-281.

Galton, F. (1889). I. Co-relations and their measurement, chiefly from anthropometric data. *Proceedings of the Royal Society of London*, *45*(273-279), 135-145.

Lakshmi, M. V., Suneetha, Y., Yugandhar, G., & Lakshmi, N. V. (2014). Correlation studies in rice (Oryza sativa L.). *International Journal of Genetic Engineering and Biotechnology*, 5(2), 121-126.

Ministry of Agriculture and Farmers Welfare, Government of India, 2020. Available at http://www.indiastat.com

Moosavi, M., Ranjbar, G., Zarrini, H.N. & Gilani, A. (2015). Correlation between morphological and physiological traits and path analysis of grain yield in rice genotypes under Khuzestan conditions. *Biological Forum*, 7(1), 43-47.

Nayak, A. R., Chaudhury, D., & Reddy, J. N. (2001). Correlation and path analysis in scented rice (Oryza satna L.). *Indian Journal of Agricultural Research*, 35(3), 186-189.

Patil, P. V., & Sarawgi, A. K. (2005). Studies on genetic variability, correlation and path analysis in traditional aromatic rice accessions. *Annals of plant physiology*, 19(1), 92.

Singh, M. K., Singh, S., Nautiyal, M. K., Pandey, I. D., & Gaur, A. K. (2017). Variability, heritability and correlation among grain quality traits in basmati rice (Oryza sativa L.). *International Journal of Chemical Studies*, *5*(5), 309-312.

Sadeghi, S.M. (2011). Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in land race rice varieties. *World Applied Sciences Journal*. 13(5), 1229-1233.

Sankar, P. D., Sheeba, A., & Anbumalarmathi, J. (2006). Variability and character association studies in rice (Oryza sativa L.). *Agricultural Science Digest*, *26*(3), 182-184.

Veni, B. K., Lakshmi, B. V. & Ramana, J. V. (2013). Variability and association studies for yield components and quality parameters in rice genotypes. *Journal of rice research*, 6(2), 16-23.

Wright, S. (1921). Systems of mating. I. The biometric relations between parent and offspring. *Genetics*, **6**(2): 111.

Yadav, S. K., Suresh, B. G., Pandey, P. & Kumar, B. (2010). Assessment of genetic variability, correlation and path association in rice (*Oryza sativa* L.). *Journal of bio-science*, 18, 1-8.

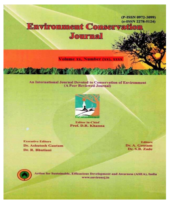
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 157-166, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Detecting air pollutants trends using Mann-Kendall tests and Sen's slope estimates

Gowthaman T. ✉
Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, West Bengal, India
Sathees Kumar K.
Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, West Bengal, India
Banjul Bhattacharyya
Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, West Bengal, India

ARTICLE INFO

Received : 17 September 2022
Revised : 20 January 2023
Accepted : 06 March 2023

Available online: 26 June 2023

Key Words:
Air Quality
NO_2
Particulate matter
SO_2
Trend analysis

ABSTRACT

Recently, trend detection in ambient air pollutants has received a lot of interest, particularly in relation to climatic changes. Air pollutants data that were acquired from monitoring stations from 2015 to 2021 were used in the current investigation. The direction and size of the monotonic trend were determined using the Mann-Kendall test and Sen's slope estimator. The findings showed that there was significant fluctuation in different parameters over time. According to the study, SO_2 and NO_2 indicate a slightly increasing tendency with approximate annual concentrations of 6µg/m^3 and 40µg/m^3, respectively, whereas PM2.5 shows a decreasing trend with an approximate annual concentration of 130µg/m^3. For all of Odisha's districts, PM10 exhibits no trend, with annual concentrations of about 90µg/m^3. The study found that while NO_2, PM2.5, and PM10 concentrations were significantly over the standard allowed limits while SO_2 concentrations were significantly below them. Specific actions are needed to reduce these pollutants' emissions in Odisha.

Introduction

Environmental deterioration now largely depends on air pollution. The main causes of air pollution today are rising industrialization and the use of automobiles for transportation to meet the demands of an expanding human population (Sharma *et al.,* 2018; Bhutiani*et al.,* 2021). The most significant pollutant in terms of phytotoxicity is air particulate matter, which is one of the criterion pollutants. Air pollution in cities and peri-urban areas is a major global environmental concern (Gupta *et al.,* 2016; Ruhela *et al.,* 2022a). The main causes of particulate matter (PM) pollution are activities related to agriculture, road dust, power plants powered by vehicle emissions, construction activities, etc. (Kumar *et al.,* 2018; Ruhela *et al.,* 2022b). In general, atmospheric aerosols are dominated by crustal components in the Indian region mainly because of their origin from suspended soil-dust and road dust (Bhaskar and Sharma, 2008). Because of this, ambient suspended particulate matter levels have frequently been found to be above National Ambient Air Quality Standards (NAAQS) guidelines (CPCB, 2012).

In the fields of climatology, water quality, air quality, and other time series, trend detection is an important topic. A statistical test is used to determine whether there is a trend in a time series of air quality measurements; the test's power is the likelihood that it would reject the null hypothesis in the presence of a trend or fail to do so in the absence of a significant trend (Karpouzos *et al.,* 2010). Because most projects are planned, developed, and operated based on the historical pattern of environmental behaviour, detection of temporal trend is one of the most crucial environmental monitoring goals (Abdul *et al.,* 2006).In its annual report, India's Central Pollution Control Board (CPCB) stated that 67 monitoring stations for NO_2 and 295 stations for PM10 exceeded national ambient air quality limits. The

Corresponding author E-mail: *agrigowtham77@gmail.com*
Doi: https://doi.org/10.36953/ECJ.15062470

concentration of SO_2 has been reported to be below acceptable limits (NAQ, 2010). Air pollution in a city demands rapid attention because the city has a huge population, and so air pollution may affect more individuals. A fundamental component of an air pollution management system is strict rules, ongoing monitoring of air pollutants, and trend analysis (Chelini *et al.,* 2010: Box *et al.,* 2015).

Odisha is fortunate to have a wealth of mineral resources, including 24% of India's coal reserves, 17% of iron ore, 98% of chromite, 51% of bauxite, 35% of manganese, and 92% of nickel ore (Odisha Economic Survey 2014–15). The coal belts of the state have been deemed the most hazardous for human health and living circumstances, according to a State of Environment study from 2008. The coal belt's surrounding areas experience shockingly high concentrations of suspended particulate matter (SPM) and respirable particle matter (RPM), which are many times higher than the national acceptable threshold. Furthermore, according to WHO (2010), harmful chemicals released during the coal mining process may have a negative impact on the air quality in the area. Because coal is a significant source of energy and fuel, it is crucial for the expansion and development of a transitional economy like Odisha. In addition, coal has the strongest forward connections with other industries.

Human population increase is becoming a contentious problem, and this overpopulation has had numerous negative repercussions on the ecosystem. Numerous social and economic issues negatively impact the environment. As a result of this negative influence, dangerous pollutants like SO_2, NO_2, RSPM, SPM, etc. are released into the atmosphere (Ahamad *et al.,* 2022; Ruela *et al.,* 2022b). The amount of suspended particle matter (SPM) in the air in Bhubaneswar is alarming, according to a report from the Odisha State Pollution Control Board. It increases the chance of premature death and causes substantial deterioration of heart and lung conditions. In addition, cardio-respiratory problems may result. In order to assess the health effects of pollutants, health care data for Odisha was analysed, and it was shown that respiratory disorders were responsible for 4.80 percent of deaths per 100,000 people in Odisha in 2014 (Samal *et al.,* 2019).

The environmental time-series data can be analysed using a variety of statistical approaches to find trends and seasonal variations. There are two mathematical methods for calculating trend analysis: parametric methods, which are more efficient but they require the data be in depended and normally distributed, and non-parametric methods, which presuppose dependent observations. One of the often employed non-parametric techniques to identify significant trends in time series data is the Mann-Kendall test. It is feasible to detect if a rising or decreasing trend exists using the Mann-Kendall test (Jaiswal *et al.,* 2018).

The present study's objective is to use the Mann-Kendall test and Sen's slope estimator (1968) to identify and quantify the trend in air quality in five districts of Odisha. The objective is to have a deeper understanding of the air quality trend from 2015 to 2021.

Material and Methods

Study area and data collection

Odisha State comprises 30 districts and a geographical area of roughly 156,077 km^2. About 1438 mm of rain falls on the state each year. The weather in Odisha State is generally tropical, brief winter with mild temperatures, and highly humid with medium-to-high rainfall. In the majority of the districts, cyclones, droughts, and floods of varied intensities happen virtually annually. In western areas, the summertime maximum temperature rises beyond 40°C and fluctuates between 40°C and 46°C.

Through the National Ambient Air Quality Monitoring Program (NAMP) and State Ambient Air Quality Monitoring Program (SAMP), which are both supported by the CPCB, the Central Pollution Control Board monitors ambient air quality at 38 stations in seventeen different areas of the State. At all monitoring stations, variables including respirable suspended particulate matter (PM10 and PM2.5), SO_2, NO_2, NH_3, O_3, CO, Pb & Ni are routinely analysed. Except for Brahamanagar in Berhampur and Konark Police Station in Konark, all 10 monitoring locations consistently had Respirable Suspended Particulate Matter (RSPM or PM2.5) concentrations above the prescribed limit of 60 g/m^3, while at 21 locations, the average annual value of PM remained 2.5 g/m^3 below the limit (out of 30 locations monitored). The 102 most polluted cities in India include six in the state of Odisha. The national ambient air quality requirements established by the Central Pollution Control Board (CPCB) have not been met by Cuttack, Bhubaneswar, Balasore, Angul, Talcher, or Rourkela (Anonymous, 2019). The study areas that selected for trend analysis is shown in the figure 1.

The Odisha State Pollution Control Board in Bhubaneswar provided the monthly air quality statistics for five districts over a six-year period (2015–2021). Data was retrieved for Angul, Bhubaneswar, Cuttack, Talcher, and Rourkela in the state of Odisha. The air quality indices used in the study include Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Particulate matter 2.5 (PM2.5), and Particulate matter 10 (PM10).

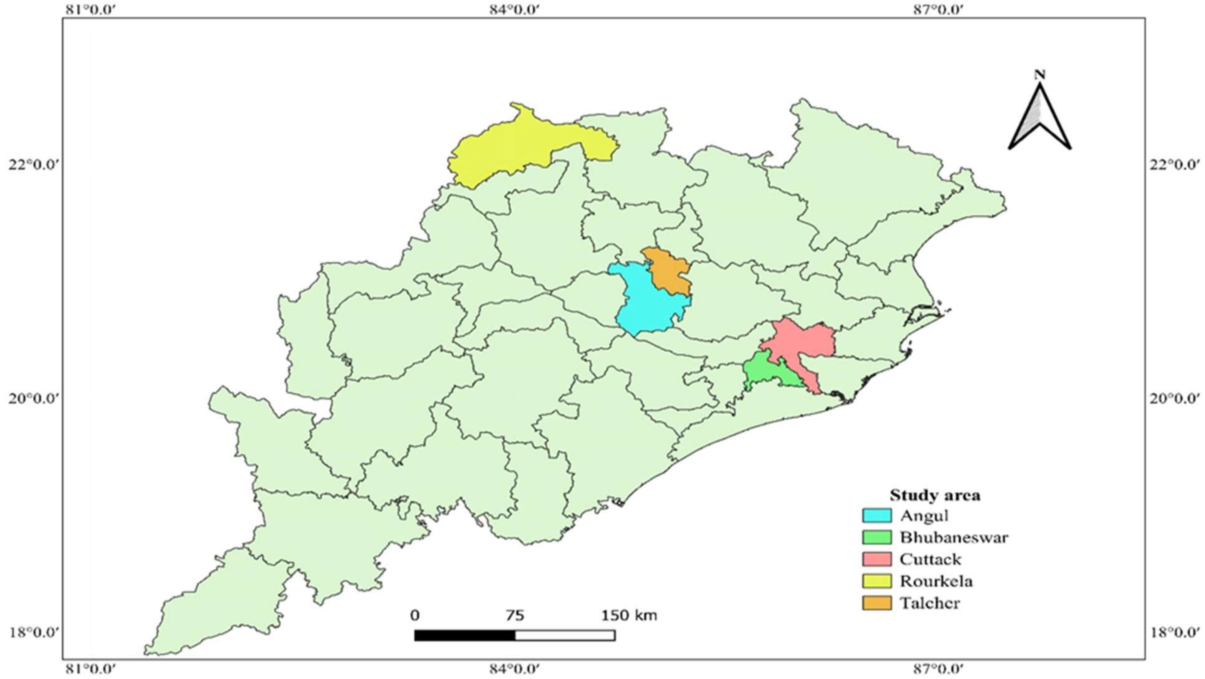


Figure 1: Study areas of Air pollutants in Odisha state

Shaprio-Wilk test

The Shaprio Wilk test is used to determine the normality of a data. Null Hypothesis(H_0) of the test is that the data follows a normal distribution and alternative hypothesis(H_1) is the data does not follow normal distribution.

The Shaprio-Wilk test statistics,

$$\boldsymbol{W} = \frac{(\sum_{i=1}^{n} a_i x_{(i)})^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Where, $x_{(i)}$ are the ordered of the sample values and a_i is the constant

Mann-Kendall Test

The Mann-Kendall (MK) test is a non-parametric trend analysis for locating the increasing and decreasing pattern in time series of the data. Instead than comparing the actual values of the sampled data, it compares the relative magnitudes of the data. Introduced by Mann (1945) and reworked by Kendell (1975) and The MK test is initially applied using the null hypothesis (H_0) of trend testing against the alternative hypothesis (H_1) of a monotonically increasing or decreasing trend, in which the observations x_i is arranged in time randomly. All following data values are contrasted with the data values evaluated as ordered time series. The statistic S is increased by one if a data value from a later period is higher than a data value from an earlier period. However, S is decreased by one if the data value from a later period is lower than a data value sampled earlier. (Da silva *et al.,* 2015). The final value of S is the sum of all these increments and decrements. Calculated as follows is the MK test statistic S:

$$S = \sum_{k=1}^{n=1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k) \qquad (1)$$

$$Sgn(x_j - x_k) = \begin{cases} -1 & if\ (x_j - x_k) < 0 \\ 0 & if\ (x_j - x_k) = 0 \\ +1 & if\ (x_j - x_k) > 0 \end{cases} \qquad (2)$$

Where x_j and x_k are, respectively, the annual values in the years' j and k, j>k. If n 10, the Mann-Kendall test is used to compare the value of |S| directly to the theoretical distribution of S. If the absolute value of S equals or exceeds a given value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S having the probability smaller than $\alpha/2$, H_0 is, at some level of probability, discarded in favour of H_1. S values that are positive or negative suggest an upward or downward trend. (Chaudhuri and Dutta, 2014). For n≥10, the statistic S is approximately normally distributed with the mean and variance as follows:

$$E(S) = 0$$

$$Var\,(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)\,(2t_p + 2)\right] \qquad (3)$$

t_p is the total amount of data values in the p^{th} group, and q is the total number of tied groups. Calculating the standard test statistic Z is as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(s)}} & ; if\ S > 0 \\ 0 & ; if\ S = 0 \\ \frac{S+1}{\sqrt{Var(s)}} & ; if\ S < 0 \end{cases} \qquad (4)$$

The Z value is used to assess if a statistically significant trend exists. An upward (downward) trend is indicated by a positive (negative) Z value. H_0 is rejected if $|Z|>Z_{1-\alpha/2}$ when testing for either an upward or downward monotonic trend (a two-tailed test) at level of significance, where $Z_{1-\alpha/2}$ is derived from the common normal cumulative distribution tables. Equation 5 is used to calculate the Kendall's values.

$$\tau = 2\frac{S^*}{z(z-1)} \qquad (5)$$

S* stands for Kendall's sum, which is calculated as S* = A-B, where A is the number of chances that the difference between x_b and x_a will be larger than zero and B is the number of chances that it will be less than zero. (Chattopadhyay *et al.,* 2012; Gowthaman *et al.,* 2022).

Sen's slope estimator test

In non-parametric data, this test, also known as the Theil-Sen slope test, is frequently used to calculate the strength of a trend that was discovered using the M-K test (Eymen and Köylü, 2018). This method, which is median-based and uses a linear model to assess the trend's slope, was created by Theil and Sen in (1950) and (1968), respectively. The variance of the residual is calculated using Equations 6 and 7 if there are m pollutant data points in the time series (X_1, X_2, X_3,... X_m) and X_a and X_b are the pollutant values at time instance a and b such that b > a.

$$T_i = \frac{X_b - X_a}{b-a}\ \ for\ i = 1, 2, 3, \dots\dots\dots m \qquad (6)$$

Equation 7 is used to calculate the Sen's slope estimator, which is the median of all T_i values and is indicated as T_{med}. The sign of T_{med} indicates whether the data are trending upward or downward, and its numeral indicates how steep the trend is.

$$T_{med} = \begin{cases} T_{\frac{m+1}{2}} & if\ m = odd \\ \dfrac{T_{\frac{m}{2}} + T_{\frac{(m+2)}{2}}}{2} & if\ m = even \end{cases} \qquad (7)$$

The M-K test's ability to predict pollution trends is dependent on the significance level α, and other significant levels may also indicate the presence of trends. Sen's slope estimator can therefore be used to determine the changing rates for contaminants that display no trend in the M-K Test.

Results and Discussion

The descriptive statistics for the variables under consideration are shown in Table 1. Prior to analysis, the data must undergo quality check because incorrect outliers can have a significant impact on trends. The measured variables, the limit of detection, the mean, and the standard deviations are all summarised in Table 1. If the data are from a normal distribution, it can be determined using the standardised skewness and kurtosis. The data demonstrated that skewness values varied from -

0.17 to 2.98 and kurtosis values ranged from -0.49 to 10.87, indicating data were from a population with a non-normal distribution (Brown, 2006).Both the Mann-Kendall test and the Sen's slope test are non-parametric tests. Shaprio Wilks test was applied to determine whether the data were normal. The findings are shown in Table 2, and the test shows that none of the time series data for air pollutants follow a normal distribution. As a result, the methodology used for the study is suitable.

Trend analysis using Mann-Kendall test

In this section of the study, time series data on pollutants from several districts of Odisha are estimated using the Mann-Kendall test and Sen's slope estimator, and its findings are examined. The six-year monthly data were used to calculate the Mann-Kendal S and Z statistics (2015-2021). Table 3 includes a Mann Kendall's test statistics and associated p-value are listed next to each test name and figure 2 shows the trend graph of different air pollutants for selected locations. P-values less than 0.05 are considered significant, and at these levels, the null hypothesis would be proven incorrect. The null hypothesis for this investigation is that there is no trend in the data that is currently available.The p-value is below the significant level for the obtained data of sulphur dioxide (SO_2) in the districts of Angul and Bhubaneswar, with positive (0.270) and negative (-0.224) Kendall's Tau values, respectively. This values indicates that increasing trend for Angul and decreasing trend for Bhubaneswar. The equivalent p-values for the remaining districts, Cuttack, Talcher, and Rourkela, are 0.280, 0.228, and 0.962, respectively, which are more than the significant valueof 0.05 and indicate that there is no trend in the data. The table 3 for the pollutant NO_2 indicates a trend with a positive orientation for the districts of Angul and Talcher

Table 1: Descriptive statistics of air pollutants

Variables	Locations	Min	Max	Mean	Variance	SD	Skewness	Kurtosis
SO2 (µg/m3)	Angul	7	23	11.7	4.62	2.15	1.54	7.93
	Bhubaneswar	2	7	3.21	1.01	1.00	1.43	2.76
	Cuttack	2	8	3.98	1.93	1.39	1.03	0.41
	Talcher	10	15	12.3	1.01	1.00	-0.078	0.267
	Rourkela	3	20	10.75	10.79	3.28	0.621	0.415
NO2 (µg/m3)	Angul	21	36	31.14	7.13	2.67	-0.92	1.35
	Bhubaneswar	13	40	22.55	31.91	5.64	1.27	1.12
	Cuttack	19	45	32.11	60.90	7.80	-0.21	-1.59
	Talcher	26	42	34	10.72	3.27	-0.183	-0.082
	Rourkela	6	24	16.13	9.58	3.09	-0.25	1.83
PM2.5 (µg/m3)	Angul	45	143	76.01	450.97	21.2	1.10	1.32
	Bhubaneswar	28	133	55.40	426.36	20.6	1.25	1.82
	Cuttack	26	207	70.82	816.84	28.5	2.19	-0.49
	Talcher	30	173	77.3	978.81	31.2	1.052	0.924
	Rourkela	40	223	80.25	897.61	29.9	2.98	10.87
PM10 (µg/m3)	Angul	57	124	93.71	285.50	16.8	-0.17	-0.99
	Bhubaneswar	45	137	90.10	632.94	25.1	0.06	-1.10
	Cuttack	49	167	88.29	694.62	26.3	0.55	7.44
	Talcher	45	153	98.6	562.02	23.7	-0.191	0.740
	Rourkela	51	158	106.2	526.30	22.9	-0.17	-0.01

Table 2: Results of Shaprio-Wilks test for normality

Locations	Angul		Cuttack		Bhubaneswar		Talcher		Rourkela	
Pollutants	Statistic	P	Statistic	P	Statistic	P	Statistic	P	Statistic	P
SO_2	0.87	<0.001	0.84	<0.001	0.79	<0.001	0.90	<0.001	0.95	0.008
NO_2	0.93	<0.001	0.87	<0.001	0.85	<0.001	0.96	0.02	0.94	0.002
PM10	0.96	0.025	0.94	0.001	0.96	0.012	0.97	0.012	0.97	0.02
PM2.5	0.91	<0.001	0.83	<0.001	0.84	<0.001	0.91	<0.001	0.67	<0.001

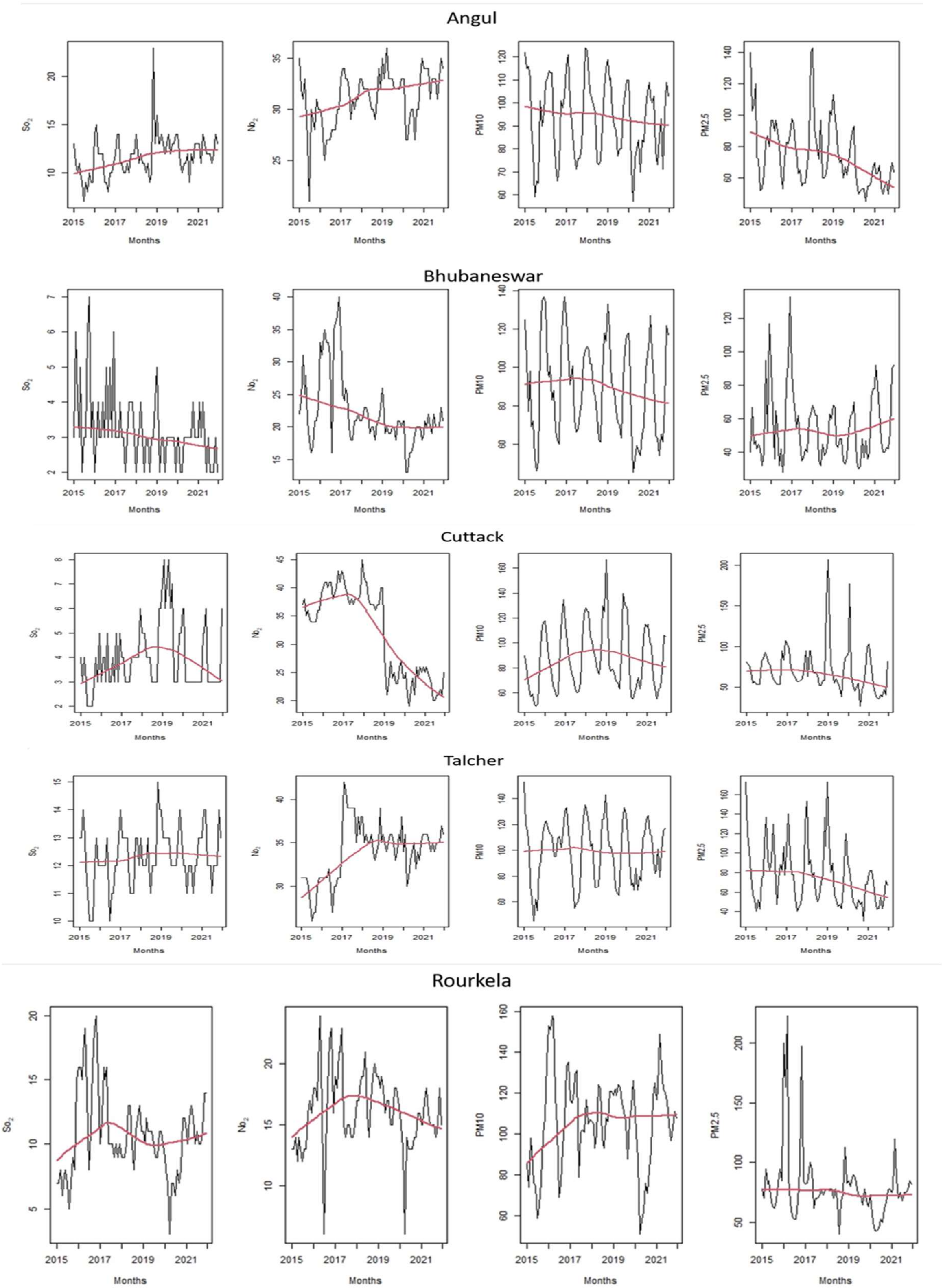


Figure 2: Trend graph of different air pollutants for the period from 2015 to 2021

and a trend with a negative orientation for the districts of Bhubaneswar and Cuttack. No trend is predicted for Rourkela due to the higher p value of 0.697. H_0 is rejected for the districts of Angul, Cuttack, and Talcher for particulate matter particle size up to 2.5 (PM2.5), demonstrating the existence of a trend with a negative orientation in the pollutant data. Due to higher p values of 0.232 and 0.062, no trend is estimated in the other two districts. Table 3's findings for PM10 show that for every district, p values are closer to the significant level of 0.05, and H_0 is accepted, demonstrating that there is no trend in the data.

Sen's slope estimation

The results of the Sen's slope test validate the M-K test findings, and the values of the Sen's Slope estimator are also reported in Table 3. Sen's slope values are also obtained for pollution data in which no trend exists. This is because the hypothesis in the M-K test is formed above the significant level, and there is a chance that a trend may exist and, therefore, that a trend slope may exist beyond. In the proposed study, significant level is kept at 5% for the findings calculation. The M-K test findings can be explained by the Sen's slope data shown in Table 3 that also show similar slope orientations. For the trends, the Sen's slope value of SO_2 for Angul displays a positive slope (0.02) and a negative slope (-0.01) for Bhubaneswar. The NO_2 slope estimator results for Bhubaneswar and Cuttack (-0.068 and -0.235) show a negative slope for the trends, whereas those for Angul and Talcher show positive slopes for the trends (0.04 and 0.053). In prior years, the Angul, Cuttack, and Talcher districts' PM2.5 slope estimate data showed a negative slope. The Mann-Kendall test for the PM10 data reveals no trend, and the Sen's slope estimator values predicted a positive slope for the districts of Cuttack and Rourkela with 0.083 and 0.100 respectively, and a negative slope for the districts of Angul, Bhubaneswar, and Talcher with -0.086, -0.154, and -0.027 respectively.

Table 3: Results of M-K and Sen's slope estimator test on different pollutants

Variables	Locations	Kendall's Tau	S	Z	Sen's Slope	Trend	P Value
SO_2 (µg/m^3)	Angul	0.270	943	3.69	0.02	↑ Trend	0.002
	Bhubaneswar	-0.224	-782	-3.35	-0.01	↓ Trend	<0.008
	Cuttack	0.075	264	1.078	0.001	No Trend	0.280
	Talcher	0.084	295	1.204	0.001	No Trend	0.228
	Rourkela	0.03	13	0.04	0.001	No Trend	0.962
NO_2 (µg/m^3)	Angul	0.288	1006	3.92	0.04	↑ Trend	<0.001
	Bhubaneswar	-0.304	-1062	-4.128	-0.068	↓ Trend	<0.001
	Cuttack	-0.479	-1671	-6.468	-0.235	↓ Trend	<0.009
	Talcher	0.251	878	3.424	0.053	↑ Trend	<0.001
	Rourkela	-0.02	-101	-0.38	0.001	No Trend	0.697
PM2.5 (µg/m^3)	Angul	-0.331	-1155	-4.46	-0.37	↓ Trend	<0.001
	Bhubaneswar	0.010	-310	0.139	0.001	No Trend	0.232
	Cuttack	-0.193	-676	-2.609	-0.230	↓ Trend	0.009
	Talcher	-0.225	-785	-3.03	-0.385	↓ Trend	0.002
	Rourkela	-0.138	-482	-1.861	-0.11	No Trend	0.062
PM10 (µg/m^3)	Angul	-0.089	-311	-1.198	-0.086	No Trend	0.231
	Bhubaneswar	-0.088	-310	-1.193	-0.154	No Trend	0.889
	Cuttack	0.057	199	0.765	0.083	No Trend	0.444
	Talcher	-0.021	-75	-0.285	-0.027	No Trend	0.774
	Rourkela	0.069	243	0.93	0.100	No Trend	0.349

The study's findings help in evaluating the levels of various pollutants in various districts of Odisha during the previous few years. In this period, the lower concentration values of SO_2& NO_2 are

2μg/m^3 and 6μg/m^3& the higher concentration values are 23μg/m^3& 45μg/m^3 respectively. Similarly, SO_2 and NO_2 concentration were found to be little higher in the township areas and industrial areas (Mohapatra and Biswal, 2014). The PM2.5 value ranged from 26μg/m^3 to 223μg/m^3 and PM10 value ranged from 45μg/m^3 to 158μg/m^3. Both PM2.5 and PM10 values were higher in Rourkela district followed by Cuttack. In all the other sampling station it was found that PM2.5 and PM10 values were nearly close or slightly exceeding the standard values set by the CPCB. But the SO_2 and NO_2 concentration were not in the permissible limit as stated by CPCB (NAAQS-2004) for the district of Angul, Bhubaneswar and Cuttack. The average AQI value gives us an idea that selected stations are moderately polluted but it is nearer to the range of heavy air polluted region. The SO_2 and NO_2 concentration for the district of Angul shows increasing trend and for the district of Bhubaneswar shows decreasing trend over the years. The concentration of PM2.5 shows decreasing trend for Angul, Cuttack and Talcher, and for remaining district it shows no trend. Similarly, PM10 values are shows no trend but still are very close to permissible limits. More control measures are needed for pollutants, especially for PM2.5 and nitrogen dioxide, according to the M-K test and Sen's slope estimator test shown in the table 3 (Pal *et al.,* 2018). Results indicate that nitrogen oxide levels in Talcher and Angul have

been rising in recent years. Odisha's PM2.5 and PM10 concentrations are above the annual permissible limits 40μg/m^{3}and 60μg/m^3, respectively (National Air Quality Index, 2014; Permissible threshold for pollutants, 2017). Since these are the primary pollutants, new restrictions are required, including improving road traffic conditions and limiting vehicular pollution through better vehicle types (Lenschow *et al.,* 2001). The studies mentioned above showed that there was no trend or a negative trend in the levels of PM10 and PM2.5 for any of the cities. The global lockdown brought on by COVID-19 has reduced air pollution and raised the Air Quality Index. One of the biggest issues in Cuttack and Bhubaneswar is the traffic. There are thousands of moving automobiles every day. Traffic is under tremendous pressure as a result. However, because of lockdown, this problem has been somewhat under control (Das *et al.,*2021). While ambient aerosol, including PM10, has a lowering trend globally, it has a significant negative impact in India (Dey *et al.,* 2012). Since the introduction of BSES VI environment standard automobiles, the Indian government has somewhat restrained the rise of traffic-related NO_2 and PM10 emissions (Bansal and Bandivadekar, 2013: Hilboll *et al.,* 2017), but the positive trend in the data still refers to the need for better strategies to combat such pollutants.

Conclusion

The present study used the Mann-Kendall test and Sen's Slope estimates methodologies to identify the monotonic trends in air quality variables between 2015 and 2021. The M-K test results show a trend in some pollution data across districts, and the Sen's Slope estimator test result determined the strength of the trends. It may be concluded that SO_2 and NO_2 were under the permissible limit for some districts, however PM2.5 and PM10 throughout the entire research area are close to or above the CPCB's permissible limit. In most places, PM2.5 and PM10 concentrations are observed to be greater in μg/m^3. Due to industrial activity, rising urbanisation, and vehicular traffic, Odisha's air quality has substantially declined. The air quality is significantly worsened by an excessive amount of pollution, which has detrimental effects on the exposed population.

Acknowledgement

The author wish to thank Odisha state pollution control board for providing data used in this study.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ahamad, F. Bhutiani, R. & Ruhela, M. (2022). Environmental Quality Monitoring Using Environmental Quality Indices (EQI), Geographic Information System (GIS), and Remote Sensing: A Review. *GIScience for the Sustainable Management of Water Resources*, 331. (Chapter number-18, pp.331-348, ISBN ebook: 9781003284512).

Anonymous (2019). Poison in the Air: Six Odisha Cities most polluted among 102 cities in India.

[https://aqli.epic.uchicago.edu/news/poison-in-the-air-six-odisha-cities-most-polluted-among-102-in-india/].

Bansal, G., Bandivadekar, A., (2013). Overview of India's vehicle emissions control program. ICCT, Beijing, Berlin, Brussels, San Francisco, Washington.

Bhaskar, V. S., & Sharma, M. (2008). Assessment of fugitive road dust emissions in Kanpur, India: A note. *Transportation Research Part D: Transport and Environment*, *13*(6), 400-403. https://doi.org/10.1016/j.trd.2008.06.003.

Bhutiani, R., Kulkarni, D. B., Khanna, D. R., Tyagi, V., & Ahamad, F. (2021). Spatial and seasonal variations in particulate matter and gaseous pollutants around integrated industrial estate (IIE), SIDCUL, Haridwar: a case study. *Environment, Development and Sustainability*, *23*(10), 15619-15638.

Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). *Time series analysis: forecasting and control*. John Wiley & Sons.

Brown, T. A. (2006). Confirmatory factor analysis for applied research. New York: Guilford Press.

Chattopadhyay, G., Chakraborthy, P., & Chattopadhyay, S. (2012). Mann–Kendall trend analysis of tropospheric ozone and its modeling using ARIMA. *Theoretical and Applied Climatology*, *110*(3), 321-328. https://doi.org/10.1007/s00704-012-0617-y

Chaudhuri, S., & Dutta, D. (2014). Mann–Kendall trend of pollutants, temperature and humidity over an urban station of India with forecast verification using different ARIMA models. *Environmental monitoring and assessment*, *186*(8), 4719-4742. https://doi.org/10.1007/s10661-014-3733-6

Chelani, A. B., Gajghate, D. G., & Hasan, M. Z. (2002). Prediction of ambient PM10 and toxic metals using artificial neural networks. *Journal of the Air & Waste Management Association*, *52*(7), 805-810.

Das, N., Sutradhar, S., Ghosh, R., & Mondal, P. (2021). Asymmetric nexus between air quality index and nationwide lockdown for COVID-19 pandemic in a part of Kolkata metropolitan, India. *Urban Climate*, *36*, 100789.

Da Silva, R. M., Santos, C. A., Moreira, M., Corte-Real, J., Silva, V. C., & Medeiros, I. C. (2015). Rainfall and river flow trends using Mann–Kendall and Sen's slope estimator statistical tests in the Cobres River basin. *Natural Hazards*, *77*(2), 1205-1221. https://doi.org/10.1007/s11069-015-1644-7

Dey, S., Di Girolamo, L., van Donkelaar, A., Tripathi, S. N., Gupta, T., & Mohan, M. (2012). Variability of outdoor fine particulate (PM2. 5) concentration in the Indian Subcontinent: A remote sensing approach. *Remote sensing of environment*, *127*, 153-161.

Eymen, A., & Köylü, Ü. (2019). Seasonal trend analysis and ARIMA modeling of relative humidity and wind speed time series around Yamula Dam. *Meteorology and Atmospheric Physics*, *131*(3), 601-612.

Gupta, G. P., Kumar, B., Singh, S., & Kulshrestha, U. C. (2016). Deposition and impact of urban atmospheric dust on two medicinal plants during different seasons in NCR Delhi. *Aerosol and Air Quality Research*, *16*(11), 2920-2932.

Gowthaman, T., Kumar, K. S., Adarsh, V. S., & Bhattacharyya, B. (2022). Trend Analysis and ARIMA Models for Water Quality Parameters of Brahmani River, Odisha, India. *Int. J. Environ. Clim. Change*, *12*(12), 219-228.

Hilboll, A., Richter, A., & Burrows, J. P. (2017). NO_2 pollution over India observed from space–the impact of rapid economic growth, and a recent decline. *Atmospheric Chemistry and Physics Discussions*, 1-18. https://doi.org/10.5194/acp-2017-101

Jaiswal, A., Samuel, C., & Kadabgaon, V. M. (2018). Statistical trend analysis and forecast modeling of air pollutants. *Global Journal of Environmental Science and Management*, *4*(4), 427-438. https://dx.doi.org/10.22034/gjesm.2018.04.004

Karpouzos, D. K., Kavalieratou, S., & Babajimopoulos, C. (2010). Trend analysis of precipitation data in Pieria Region (Greece). *European Water*, *30*(30), 30-40.

Kendall, M. G. (1975). Rank correlation methods. Griffin, London.

Kumar, D. S., Bhushan, S. H., & Kishore, D. A. (2018). Atmospheric dispersion model to predict the impact of gaseous pollutant in an industrial and mining cluster. *Global Journal of Environmental Science and Management*, *4*(3), 351-358. https://dx.doi.org/10.22034/GJESM.2018.03.008

Lenschow, P., Abraham, H. J., Kutzner, K., Lutz, M., Preuß, J. D., & Reichenbächer, W. (2001). Some ideas about the sources of PM10. *Atmospheric Environment*, *35*, S23-S33.

Mann, H. B. (1945). Nonparametric tests against trend. *Econometrica: Journal of the econometric society*, 245-259.

Mohapatra, K. & Biswal, K. S. (2014). Assessment of Ambient Air Quality Index (AQI) In Bhubaneswar, the Capital City of Odisha. *International Journal of Advance Research in Science and Engineering*, 3(6), 190-196.

National Ambient Air Quality Status & Trends. In India-2010, NAAQMS/ 35/2011-2012, CPCB.

National Air Quality Index (2014). CPCB, Ministry of environment, forests & climate Change, GoI.

Pal, R., Chowdhury, S., Dey, S., & Sharma, A. R. (2018). 18-Year Ambient PM2.5 Exposure and Night Light Trends in Indian Cities: Vulnerability Assessment. *Aerosol and Air Quality Research*, 18: 2332–2342.

Permissible level for pollutants (2017). Ministry of environment, forest and climate change, GoI.

Ruhela, M., Sharma, K., Bhutiani, R., Chandniha, S. K., Kumar, V., Tyagi, K., ... & Tyagi, I. (2022a). GIS-based impact assessment and spatial distribution of air and water pollutants in mining area. *Environmental Science and Pollution Research*, 1-15.

Ruhela, M., Maheshwari, V., Ahamad, F., & Kamboj, V. (2022b). Air quality assessment of Jaipur city Rajasthan after the COVID-19 lockdown. *Spatial Information Research*, *30*(5), 597-605

Samal, K. K. R., Babu, K. S., Das, S. K., & Acharaya, A. (2019, August). Time series based air pollution forecasting using SARIMA and prophet model. In *proceedings of the 2019 international conference on information technology and computer communications* (pp. 80-85).

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American statistical association*, *63*(324), 1379-1389.

Sharma, B., Vaish, B., Srivastava, V., Singh, S., Singh, P., & Singh, R. P. (2018). An insight to atmospheric pollution-improper waste management and climate change nexus. In *Modern age environmental problems and their remediation* (pp. 23-47). Springer, Cham.

Theil, H. (1950). A rank-invariant method of linear and polynomial regression analysis. *Indagationes mathematicae*, *12*(85), 173.

World Health Organisation. (2010). Quantifying the Burden of Disease from Mortality and Morbidity‖. World Health Organisation.

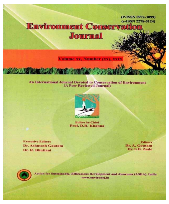
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 167-173, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Evaluation of some promising indigenous brinjal genotypes under terai region of West Bengal

Amar Biradar
Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal, India
Taru Dumi
Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal, India
Subhamoy Sikder ✉
Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal, India
Shibnath Basfore
Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal, India
Ranjit Chatterjee
Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal, India

ARTICLE INFO

Received : 13 November 2022
Revised : 27 February 2023
Accepted : 06 March 2023

Available online: 26 June 2023

Key Words:
Brinjal
Character association
Genetic advance
Heritability
Path coefficient
Variability
Yield

ABSTRACT

Present experiment was implemented under the Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Coochbehar which situated at terai region of West Bengal during the autumn-winter season of 2019-20 and 2020-21 on 28 highly diversified brinjal genotypes on ten highly important yield and yield attributing traits to assess the extent of involvement of different genetic phenomena in manifestation of important yield related traits and to understand the inter relationship among them to design better selection criteria. Result revealed that there was close proximity in the magnitude among the component of coefficient of variation and these component exhibited high estimates coupled with high heritability for almost all the characters excepting days to first flowers and days to fruit maturity indicated less interference of the environmental factors in the manifestation of these traits. High magnitude of heritability coupled with genetic advance of mean for those character suggested possibility for selecting these characters based on phenotypic performance for further improvement at desired direction. Residual effect from path analysis was 0.1367 at genotypic level which suggested that contribution of the traits under study was approximately 86.5% on yield, argued for appropriate selection of traits for success of present experimental study. From character associationship and path coefficient it was found that expected yield was highly correlated in positive direction with average fruits per plant (0.68 and 0.801), average fruit weight (0.48 and 0.565), numbers of primary branches per plant (0.51 and 0.113); hence, these yield attributing traits were significantly positively related with each other which suggested that simultaneous selective breeding strategy considering these characters for improvement of yield could be rewarding due to their probable conditioning by additive gene action.

Introduction

Brinjal (*Solanum melangena* L.), with diploid chromosome numbers (2n=24) belonged to the Solanaceae family, considered as one of the most common and popular vegetable crop in Indian subcontinent. It is also called as *Eggplant, Garden egg, Melangena* and *Aubergine*. The name '*Egg plant*' given due to some of brinjal varieties having round shape with white colour which looks like chicken eggs. In terms of area and production India ranks second after China with approximately 741 thousand hectare of land coverage and 13000 thousand metric tonnes of production (NHB 2019-2020). However, West Bengal is first in both area and production with 162.93 thousand hectares of

Corresponding author E-mail: *subhamoy.sms@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16052507

land coverage and 3 thousand metric tonnes of production, respectively. Brinjal is known as poor man's vegetable as because it comprises of highest production potential quality coupled with ease availability to consumers (Kumar *et al*., 2013). Hence, it is a stable vegetable in our diet since ancient time, considered as reliable source of income for marginal farmers. Brinjal fruits are rich source of vitamins, minerals *viz*., magnesium, calcium, phosphorus and fatty acids. Brinjal has medicinal use like curing asthma, diabetes and liver complaints (Santhosha *et al*., 2017). There is a high demand for brinjal for its nutritional and medicinal values like decholestrolizing property primarily due to presence of linoleic and linoleic fatty acid which are present abundant in flesh and seeds. Because of its low sugar content and high chlorogenic acid content, white brinjal is considered beneficial for diabetic people. (Bajaj *et al*., 1979). These also contributes to brinjal's antioxidant and anti-cancer capabilities (Gonthier *et al*., 2003). It is well-known for treating liver problems and toothaches (Dakone *et al*., 2016) as well as used in improvement of cardiovascular and liver health (Patel *et al*., 2004).

India being a much diversified country with respect to agro-climate, ecology, culture, society and local preferences, provides ample scope for genotypic manipulation and/or modification of brinjal. Hence, throughout the India still there is high demand for improved zone-specific varieties of brinjal. However, again being primary center of origin, India exhibits a greater degree of variability with diverse range of local landraces to many advanced cultivars bring forth greater opportunity for effective selection for desirable kinds.Coupled with the discussed facts, due to global warming and day by day narrow genetic approach towards development of improved brinjal cultivars resulting in loss of variability up to a greater extent. Target specific selective breeding approach always associated with overlooking of useful important traits by mistake that also provide opportunity for further evaluation. Greater extent of variability exist in indigenous germplasm of brinjal with respect to plant morphology, quantitative attributes, yield potential, fruit quality, processing aspects and tolerance to biotic or abiotic stresses (Ullah *et al.,* 2014). For improvement of any desired trait by means of any breeding strategy is comprises with consideration of multiple sub-traits those remain directly and/or indirectly interrelated with principal trait and misjudging may lead negative effect on end product. Specifically, yield components of any crop are complicated being governed by polygenes in their manner of inheritance and also heavily influenced by the environment factors (Kumar *et al*, 2012). For this reason, evaluation of genetic diversified population is paramount important for the assessment of nature of trait and relative breeding potential of the genitors or identifies best combiners. Considering all these information, present experiment was laid out to estimate the magnitude of involvement of different genetic phenomena in manifestation of important yield related traits and to understand the inter relationship among them to design better selection criteria.

Material and Methods

Present experiment was organized at the Instructional Farm under the Department of Vegetable and Spice Crops, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal, India during the Autumn-Winter season (September to March) of 2019-20 and 2020-21. The farm is situated at terai agro climatic region of West Bengal (latitude 26 ^{0}19'86" N and longitude 89^{0} 23'53" E) at 43 meter above mean sea level. The soil of the experimental site is characterized by sandy loam in nature, poor in water holding capacity due to course in texture, with low pH (5.2-5.6) and high soil moisture content. Hence, the weather condition is typically sub-tropical humid climate that specified by extreme rainfall coupled with high relative humidity, medium temperature and extended winter season. The experimental material was consisted of twenty eight highly diversified genotypes, out of which twenty seven local genotypes collected from different reputed institutes and agricultural universities of India and national released variety Pusa Purple Long collected from IARI, Pusa, New Delhi, India to be used as check variety in the present experiment. Present investigation was outlined following the randomized complete block design that included three replications for each treatment. Each replication was raised in 3m x 3m plots consisted of 16 plants in each plot maintaining the plant spacing of 75 cm row to row and 75 cm plant to plant; recommended cultivation practice was followed for raising seedling and maintaining germplasm. The observation was recorded on ten important growths and yield related traits *viz.*, average height of height (cm), numbers of primary branches per plant, calyx length (cm), days to first flowering, days to fruit maturity, fruit diameter (cm), fruit length (cm), average weight of fruit (g), number of fruits per plant and yield per hectare of land (t/ha); where metric data were recorded by using vernier calipers (Mitutoyo, 0-150mm) and digital weight machine (Mettler Toledo PBD659). For collection of data, 10 healthy mature plants of almost 60 days old from each plot was selected, average performance under each plot was considered as individual replication. After completion of record keeping process, pooled data over two successive years were statistically analyzed and discussed elaborately. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense and genetic advance for different characters were worked out according to Lush (2010) and the estimates were classified into hierarchical groups as suggested by Nadarajan and Gunasekaran (2008). Phenotypic (r_p) and genotypic (r_g) correlation coefficients of important quantitative traits were estimated as suggested by Saini *et al.* (2018). To know the direct and indirect effects of the important quantitative traits path coefficient analysis was carried out following Rauf *et al.*, (2004).

Results and Discussion

Genetic variability, Heritability and Genetic advance

In any crop species, variability observed in different important characters among genotypes are generally due to the sole or combined effect of genotype as well as environment, the reason why estimation of the genotypic and phenotypic coefficients of variation were of immense important to determine the magnitude of genotypic and phenotypic variation to have an idea about real value of variation due to genotype. In present experiment, there was higher magnitude of phenotypic coefficients of variation were recorded as compared to the than genotypic coefficients of variation for all the traits studied with negligible difference in most of the cases (Table 1) indicated that there was minimal influence of environmental factors in the manifestation of the traits. The extent of the coefficients of variation for the both due to phenotype and genotype highly varied from character to character from low to high which was evident of prevailing high degree of variation principally due to genetic potentiality among the genotypes under study. High GCV (24.34%) and PCV (24.46%) coupled with heritability (99.09%) and GAM (49.92%) was recorded for plant height. Similar results were found by Shilpa *et al.* (2018) for high GCV and PCV. High estimate for GCV (40.51%), PCV (40.69%), heritability (99.12%) and high GAM (83.07%) was recorded in number of primary branches per plant which were in conformity with the finding of Kumar *et al.* (2012). In case of calyx length, similar high estimated in present investigation which was also reported earlier by Kumar *et al.* (2013). The average fruit diameter was observed 6.28 cm, ranging from 3.16 to 11.88 cm with high estimates for all the genetic parameters and this high GCV and PCV was also reported by the Yadav *et al.* (2016). High GCV (28.64%) and PCV (28.65%) coupled with high heritability (99.91%) and GAM (58.97%) was recorded for fruit length. Kumar *et al.* (2013) and Lokesh *et al.* (2013) in earlier also reported high GCV and PCV for fruit length in brinjal in their experiment. For fruit weight, high GCV (60.25%), PCV (60.25%),heritability (99.98%) and high GAM (124.10%) was observed which were in conformity with the earlier finding of Kumar *et al.* (2012) and Yadav *et al.* (2016). Whereas, high heritability coupled with GAM was reported by Muniappan *et al.* (2010). Numbers of fruit per plant exhibited high estimatesfor all the genetic parameters which were in accordance with the findings of Madhavi *et al.* (2015). Also, high heritability coupled with GAM for fruit numbers per plant was obtained earlier by Lokesh *et al.* (2013) and Yadav *et al.* (2016). The mean varietal performance of fruit yield was 18.48 tonnes per hectare ranged from 5.28 to 42.31 tonnes per hectare. High GCV (64.21%) and PCV (64.22%) couple with high heritability (99.98%), high genetic advance (37.74) and GAM (132.26%). Similar results were also reported by Kumar *et al.* (2013) and Shilpa *et al.* (2018). Estimated components of variation for all these characters were statistically at per as well as towards high heritability which was indicative of presence of

Table 1: Genetic variability parameters for different important traits of brinjal

Characters	Mean	Range		GCV (%)	PCV (%)	Heritability (h^2%)	Genetic Advance (GA)	Genetic Advance (% of Mean)
		Maximum	Minimum					
Plant height (cm)	60.17	92.67	35.17	24.34	24.46	99.09	30.04	49.92
Number of primary branches	4.94	9.03	1.37	40.51	40.69	99.12	4.10	83.07
Calyx length (cm)	3.21	4.97	1.38	28.66	28.68	99.87	1.90	59.00
Days to first flower	55.75	63.38	47.64	6.20	6.35	95.19	6.94	12.46
Days to fruit maturity	36.21	44.39	23.31	14.68	14.97	96.07	10.73	29.63
Fruit diameter (cm)	6.28	11.88	3.16	40.85	40.88	99.82	5.28	84.07
Fruit length (cm)	15.91	25.07	6.41	28.64	28.65	99.91	9.38	58.97
Fruit weight (g)	286.86	709.36	92.15	60.25	60.25	99.98	356.00	124.10
Number of fruits per plant	10.90	39.56	3.21	72.63	72.65	99.95	16.31	149.57
Yield ha^{-1} (t/ha)	18.48	42.31	5.28	64.21	64.22	99.98	37.74	132.26

sufficient variation among the genotype for these character as well as manifestation was more due to genetic potentiality of individual genotypes. Also, high genetic gain suggested improvement of this character could be done by pure line or bulk selection *i.e.*, selection of these characters based on phenotypic performance could be rewarding breeding strategy for further improvement at desired direction. Moderate GCV (14.68%) and PCV (14.97%) for days to fruit maturity and low GCV (6.20%) and PCV (6.35%) for days to first flower indicated negligible genotypic variation for these traits.Kumar *et al*. (2013) and Shilpa *et al*. (2018) in their investigation reported similar finding for these characters. Also, low genetic gain suggested there might be dominance of non-additive genetic factor for the trait that could possibility be improved at desired direction by heterosis or transgressive breeding strategy.

Character association analysis

Table 2 revealed that plant height which was significant and positively correlated with primary branches (Gr=0.36) and fruit length (Gr=0.29). Similar findings results were found by Gupta *et al*. (2017) and Mohanty (2003) in which plant height was significantly and positively correlated with number of primary branches. Plant height showed significant and negatively correlated with fruit weight (Gr= -0.23). Number of primary branches showed significant and positive correlation with calyx length (Gr = 0.35), days to first flower (Gr = 0.26), fruit diameter (Gr = 0.42) and yield (Gr = 0.51). Positive association with fruit yield, fruit diameter and fruit weight was also reported by Banerjee *et al*. (2018). Again, number of primary branches showed significant negative relation with days to fruit maturity.Calyx length which was significant and positive correlation with days to first flower (Gr = 0.33), fruit diameter (Gr = 0.61) and fruit weight (Gr = 0.46). This positive relation with fruit weight and fruit diameter was also reported by Kumar *et al*. (2016). However, calyx length showed significant negative relation with days to fruit maturity (Gr = -0.38). Days to first flower found to be significant positive correlated with numbersof fruits per plant (Gr = 0.27) and yield (Gr = 0.29). Dharwad *et al*. (2009) and Mohanty *et al*. (2020) also found positive correlation among days to first flowering and fruit weight. Days to fruit maturity showed significant positive correlation with fruit length (Gr = 0.57) and number of fruits per plant (Gr = 0.31). However, it showed significant negative correlation with fruit diameter (Gr = -0.76), fruit weight (Gr = -0.57) and yield (Gr=-0.25). The negative relationship among days to fruit maturity and yield per hectare was also reported by Mohanty *et al*. (2020). Fruit diameter showed significant positive correlation with fruit weight (Gr = 0.91) and yield (Gr = 0.41). Similar results found by Mohanty *et al*. (2020) and Kumar *et al*. (2016). Whereas, it exhibited significant negative correlation with fruit length (Gr = -0.35) and number of fruits per plant (Gr = -0.31).Fruit length did not exhibited any significant relationship. Fruit weight showed significant positive correlation with yield (Gr = 0.48), but significant negative correlation with number of fruits per plant (Gr = -0.27). Positive association between fruit weight and total yield per hectare was also reported by Dharwad *et al*. (2009). Number of fruits per plant showed significantly positive correlation with yield (Gr = 0.68) and this

Table 2: Genotypic (G) and Phenotypic (P) correlation for important traits of brinjal

Characters		PB	CL	DFF	DFM	FD	FL	FW	FPP	Yield
PH	G	0.36**	-0.01	-0.02	0.04	-0.17	0.29*	-0.23*	0.02	-0.13
	P	0.33**	-0.01	-0.02	0.04	-0.16	0.26*	-0.22*	0.02	-0.13
PB	G		0.35**	0.26*	-0.37**	0.42**	0.00	0.36**	0.21	0.51**
	P		0.33**	0.25*	-0.36**	0.42**	0.00	0.33**	0.21	0.48**
CL	G			0.33**	-0.38**	0.61**	-0.06	0.46**	-0.20	0.17
	P			0.31**	-0.34**	0.60**	-0.05	0.44**	-0.20	0.17
DFF	G				-0.07	0.16	-0.02	0.06	0.27*	0.29**
	P				-0.05	0.15	-0.02	0.05	0.26*	0.26**
DFM	G					-0.76**	0.57**	-0.57**	0.31**	-0.25*
	P					-0.74**	0.54**	-0.56**	0.28**	-0.24*
FD	G						-0.35**	0.91**	-0.31**	0.41**
	P						-0.34**	0.90**	-0.29**	0.40**
FL	G							-0.11	0.05	-0.07
	P							-0.11	0.04	-0.07
FW	G								-0.27*	0.48**
	P								-0.25*	0.46**
FPP	G									0.68**
	P									0.64**

Residual effect= 0.1367 ; * and ** Significant at 5% level and 1% level respectively
N.B: PH- plant height (cm); PB- Number of primary branch; CL- calyx length (cm); DFF- days to first flower; DFM- days to fruit maturity; FD- fruit diameter (cm), FL- fruit length (cm), FW- fruit weight (g), FPP- fruit per plant, Yield- yield in tonnes per hectare of land

finding was in conformity with the earlier investigation of Praneetha *et al.* (2011), Praneetha (2018) and Mohanty *et al*. (2020). Fruit weight and fruit numbers per plant which were positively correlated with yield, but was negatively related with each other suggested limitation in their potentiality to manifest simultaneously and were contrasting traits contributed cumulatively towards the yield. It was clearly evident that yield was highly positively correlated with number of primary branches, first flowering, fruit diameter, fruit length and number of fruit plant. Hence, these yield attributing traits were significantly positively related with each other which suggested that simultaneous selective breeding strategy for improvement of yield considering these characters could be rewarding.

Path coefficient analysis

The effects of different independent traits, both individually and in combination with other characters, on the expression of different characters on marketable fruit yield per plant were shown using path coefficient analysis in table 3. Plant height, calyx length, days to first flower, fruit diameter and fruit length showed negligible direct and indirect effect on total yield per hectare through other traits which was inconformity with the investigation outcome of Madhavi *et al*. (2015), Arti *et al.* (2019) and Nikitha *et al*. (2020). Number of primary branches exhibited low positive direct effect (0.113) but negligibleindirect effect through other traits on total yield per hectare which wasin conformity with the finding of Nikitha *et al*. (2020). Days to fruit maturity showed moderate negative direct effect (-0.203) and negligible negative direct effect on total yield per hectare through other traits. Similar finding was earlier also reported by Arti *et al*. (2019). However, fruit weight exhibited high positive direct effect (0.565) on total yield per hectare but moderate negative indirect effect through fruits per plant (-0.206). This finding was in accordance with the observation of Muniappan *et al*. (2010) and Shekhar *et al*. (2014). Whereas, fruits per plant were also showed high and positive direct effect (0.801) on total yield per hectarewith low negative indirect effect through fruit weight (-0.145). Similar kinds of results were found by Muniappan *et al.* (2010) and Sujin *et al.* (2017). From above discussion it was clearly evident that direct contribution of the traits under experiment

Table 3: Phenotypic path coefficient analysis for brinjal considering yield as dependent variable

Character	PH	PB	CL	DFF	DFM	FD	FL	FW	FPP	Yield/ha (Pr)
PH	**-0.078**	0.039	0.000	0.000	-0.009	0.012	0.017	-0.126	0.014	-0.13
PB	-0.027	**0.113**	0.004	0.002	0.074	-0.031	0.000	0.191	0.171	0.51**
CL	0.001	0.038	**0.013**	0.003	0.069	-0.044	-0.004	0.253	-0.157	0.17
DFF	0.001	0.029	0.004	**0.008**	0.012	-0.011	-0.001	0.033	0.208	0.29**
DFM	-0.003	-0.041	-0.005	0.000	**-0.203**	0.055	0.034	-0.319	0.236	-0.25*
FD	0.013	0.048	0.008	0.001	0.152	**-0.073**	-0.022	0.510	-0.234	0.41**
FL	-0.021	0.000	-0.001	0.000	-0.111	0.025	**0.063**	-0.064	0.039	-0.07
FW	0.017	0.038	0.006	0.000	0.114	-0.066	-0.007	**0.565**	-0.206	0.48**
FPP	-0.001	0.024	-0.003	0.002	-0.060	0.021	0.003	-0.145	**0.801**	0.68**

Residual effect= 0.1367 ; * and ** Significant at 5% level and 1% level respectively

N.B: PH- plant height (cm); PB- Number of primary branch; CL- calyx length (cm); DFF- days to first flower; DFM- days to fruit maturity; FD- fruit diameter (cm), FL- fruit length (cm), FW- fruit weight (g), FPP- fruit per plant, Yield- yield in tonnes per hectare of land

on the yield as dependable variable was highest through fruit per plant followed by fruit weight, number of primary branches, fruit length, days to first flowers. Among these, fruit length exhibited negative correlation with yield due to indirect contribution of multiple traits at negative direction and days to first fruiting showed negligible direct effect with the yield. This phenomenon suggested the importance of substantiate the decision for considering the traits in breeding strategy for yield enhancement based on character association, rather trait *via* end product association should be portioned into direct and indirect relation for better understanding the relationship. Residual effect was 0.1367 at genotypic level which suggested that contribution of the traits under study was approximately 86.5% on yield, argued for appropriate selection of traits for success of present experimental study.

Conclusion

From the present investigation it was observed that there was minimal influence of environmental factors in the manifestation of the traits under study. Traits such as, plant height, number of primary branches per plant, calyx length, average fruit diameter, fruit length, fruit weight, numbers of fruit per plant and fruit yield exhibited high components of variation, heritability and genetic gain as percentage of mean was the indication for presence sufficient variation among the genotype for those traits as well as improvement could be done by pure line or bulk selection. Whereas, low estimates for different genetic components suggested there might be dominance of non-additive genetic factor for the trait that could possibility be improved at desired direction by heterosis or transgressive breeding strategy. From character associationship and path analysis, it was clearly evident that number of fruit per plant, individual fruit weight, number of primary branches per plant emerged as the major attributes with their significant contribution towards the total yield of brinjal and can be considered as important selection criteria for the improvement of the yield due to their probable conditioning by additive gene action.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Arti, D., Sharma, A. & Khar, S. (2019). Studies on correlation and path analysis in brinjal (*Solanum melongena* L.) genotypes. *The Bio-scan*, *14*(1), 031-034.

Bajaj, K. L., Kaur, G. & Chadha, M. L. (1979). Glycoalkaloid content and other chemical constituents of the fruits of some eggplant (*Solanum melongena* L.) varieties. *Journal of Plant Foods,3*(3), 163-168.

Banerjee, S., Verma, A., Bisht, Y. S., Maurya, P. K., Jamir, I., Mondal, S. & Chattopadhyay, A. (2018). Genetic variability, correlation coefficient and path coefficient nalysis in brinjal germplasm. *International Journal of Chemical Studies*, *6*, 3069-3073.

Dakone, D. & Guadie, A. (2016). A review on ethnomedicinal use, nutritional value, phytochemistry and pharmacological characteristics of *Solanum incanum* L. an important medicinal plant. *International Journal of Scientific and Technology Research, 5*(6), 350-354.

Dharwad, N. A., Salimath, P. M. & Patil, S. A. (2009). Association and path co-efficient analysis in elite germplasm lines of brinjal (*Solanum melongena* L.). *Karnataka Journal of Agricultural Sciences, 22*(5), 965-966.

Gonthier, M. P., Verny, M. A., Besson, C., Rémésy, C. & Scalbert, A. (2003). Chlorogenic acid bioavailability largely depends on its metabolism by the gut microflora in rats. *The Journal of nutrition, 133*(6), 1853-1859.

Gupta, S. P. & Singh, S. P. (2017). Bio–efficacy of some newer insecticides against brinjal shoot and fruit borer *Leucinodes orbonalis* (Guen.). *Journal of Pharmacognosy and PhytochemistrySP1*, 552-555.

Kumar, D., Kumar, R., Kumar, S., Bhardwaj, M. L., Thakur, M. C., Kumar, R. & Kumar, P. (2013). Genetic variability, correlation and path coefficient analysis in tomato. *International Journal of Vegetable Science, 19*(4), 313-323.

Kumar, S. R., Arumugam, T. & Premalakshmi, V. (2012). Evaluation and variability studies in local types of brinjal for yield and quality (*Solanum melongena* L.). *Electronic Journal of Plant Breeding, 3*(4), 977-982.

Kumar, S. R., Arumugam, T. & Ulaganathan, V. (2016). Genetic diversity in eggplant germplasm by principal component analysis. *SABRAO Journal of Breeding and Genetics, 48*(2), 162-171.

Lokesh, B., Reddy, P. S., Reddy, R. V. S. K., & Sivaraj, N. (2013). Variability, heritability and genetic advance studies in Brinjal (*Solanum melongena* L.). *Electronic Journal of Plant Breeding, 4*(1), 1097-1100.

Lush, J. (2010). Heritability of quantitive characters in farm animals. *Hereditas*, *35*, 356 - 375.

Madhavi, N., Mishra, A. C., Prasad, J. O. & Bahuguna, N. (2015). Studies on variability, heritability and genetic advance in brinjal (*Solanum melongena* L.). *Plant archives, 15*(1), 277-281.

Mohanty, B. K. (2003). Genetic variability, correlation and path coefficient studies in tomato. *Indian Journal of Agricultural Research, 37*(1), 68-71.

Mohanty, A., Panda, R. K., Rout, G. R., Muduli, K. C., & Tripathy, P. (2020). Impact of short term water logging on flowering, fruit setting, yield and yield attributes in tomato (Solanum lycopersicum L. Mill). *Journal of Pharmacognosy and Phytochemistry, 9*(4), 760-763.

Muniappan, S., Saravanan, K. & Ramya, B. (2010). Studies on genetic divergence and variability for certain economic characters in eggplant (*Solanum melongena* L.). *Electronic journal of plant breeding, 1*(4), 462-465.

Nadarajan, N. & Gunasekaran, M. (2008). *Quantitative genetics and biometrical techniques in plant breeding. Kalyani Publishers, India*.

Nikitha, M., Prabhakar, B. N., Padma, M., Bhat, B. N. & Sivaraj, N. (2020). Correlation and path coefficient analysis of yield and yield attributed characters in Brinjal (*Solanum melongen*a L.). *Journal of Pharmacognosy and Phytochemistry, 9*(5), 1997-2002.

Patel, K. K., Sarnaik, D. A., Asati, B. S. & Tirkey, T. (2004). Studies on variability, heritability and genetic advance in brinjal (*Solanum melongena* L.). *Agricultural Science Digest, 24*(4), 256-259.

Praneetha, K. J. D. S. (2018). Evaluation of brinjal (*Solanum melongena* L.) local types for yield and its quality characters. *International Journal of Chemical Studies, 6*(3), 292-297.

Praneetha, S., Rajashree, V. & Pugalendhi, L. (2011). Association of characters on yield and shoot and fruit borer resistance in brinjal (*Solanum melongena* L.). *Electronic Journal of Plant Breeding, 2*(4), 574-577.

Rauf, S., Khan, T. M., Sadaqat, H. A. & Khan, A. I. (2004). Correlation and Path Coefficient Analysis of Yield Components in Cotton (*Gossypium hirsutum* L.). *International Journal of Agriculture & Biology*, *6*(4), 686-688.

Saini, P., Chauhan, S., Shabnam, A., Chand, L., & Negi, N. (2018). Genetic Variability and Trait Association Analysis for Agro-Morphological Markers in Mulberry Genetic Resources from Kashmir, India. *International Journal of Current Microbiology and Applied Sciences*, *7*, 1799-1812.

Santhosha, H. M., Indiresh, K. M. & Lingaiah, H. B. (2017). Diallel analysis in brinjal (*Solanum melongena* L.) for fruit yield, its attributes and bacterial wilt resistance. *Journal of pharmacognosy and phytochemistry, 6*(6): 860-872.

Shekar, K., Ashok, P. & Sasikala, K. (2012). Studies on Heritability and Multivariate Analyses in Brinjal (*Solanum melongena* L.). *Vegetable Crops Research Bulletin 76*, 79.

Shilpa, B. M., Dheware, R. M. and Kolekar, R. B. (2018). Variability Studies in Brinjal (*Solanum melongena* L.). *International Journal of Bio-resource and Stress Management, 9*(5), 576-579.

Sujin, G. S., Karuppaiah, P. & Saravanan, K. (2017). Genetic variability and correlation studies in brinjal (*Solanum melongena* L.). *Indian Journal of Agricultural Research, 51*(2), 112-119.

Ullah, S., Ijaz, U., Shah, T. I., Najeebullah, M. & Niaz, S. (2014). Association and genetic assessment in brinjal. *European Journal of Biotechnology and Bioscience,2*(5), 41-45.

Yadav, S., Singh, V. B., Maurya, R., Thapliyal, V., & Singh, K. A. P. (2016). Genetic variability, heritability and genetic advance for yield and its contributing traits in brinjal (*Solanum melongena* L.). *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 3189-3193.

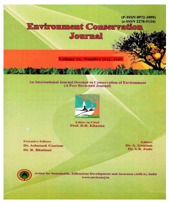
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 174-185, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Biomass partitioning, yield and economic performance of green gram (*Vigna radiate* L.) genotypes as influenced by different irrigation levels

Anil Kumar Dhaka
Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, India
Satish Kumar
Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana India
Prakriti Dhaka
Department of Botany and Plant Physiology, C.C.S. Haryana Agricultural University, Hisar, Haryana India
Ram Dhan Jat ✉
Department of Agronomy, ChaudharyCharan Singh Haryana Agricultural University, Hisar, Haryana, India
Bhagat Singh
Department of Agronomy, ChaudharyCharan Singh Haryana Agricultural University, Hisar, Haryana, India

ARTICLE INFO

Received : 05 October 2022
Revised : 19 March 2023
Accepted : 01 April 2023

Available online: 25 June 2023

Key Words:
Crop yield
Economic benefits
Growth parameters
Yield parameters

ABSTRACT

A field experiment was conducted during the *Kharif* season of2020 with four main plot treatments consisting of irrigation levels (No post sowing irrigation, one irrigation at the flower initiation stage, one irrigation at the pod filling stage and two irrigations each at flower initiation and pod filling stage) and five subplot treatments as genotypes viz., MH 1142, MH 1468, MH 1703, MH 1762 and MH 1871 following split plot design by replicating thrice. Irrigating green gram, irrespective of the growth stage, increased the seed yield significantly. Two irrigations each at the flower initiation and podding stage bring about greater seed economic yield of green gram than 1 irrigation either at each stage. Among single irrigations, flower initiation stage provided significantly superior (8.6 %) seed yield compared to the pod filling stage. During the flower initiation stage, no rain and irrigation at this stage led to more development of crop plants, as is evident from a higher number of branches per plant and, ultimately, a higher number of pods. Two irrigations, *i.e.,* each at flower initiation and podding phase, lead to considerably greater seed output than single irrigation at either growth stage, which may be attributed to the sufficient supply of water, which indirectly provided a smooth supply of nutrients to crop plants. The increase was 18.4 and 28.6 per cent over-irrigation at flowering and podding stage, respectively. Seed yield varied among green gram genotypes, which might be because of variations in the genetic potential of the genotypes. Genotype MH 1871 produced significantly higher seed yield among different genotypes. The cumulative effect of yield traits *viz.* pods per plant, branches per plant, seed index and seeds per pod attributed to the higher seed yield in MH 1871. This genotype was more efficient in utilizing radiations, as evident from the higher chlorophyll content recorded in this genotype. Genotype MH 1142 was the lowest yielder and MH 1762 although produced. To obtain a higher yield of green gram, genotype MH 1871 be taken with two irrigations each at flower initiation and pod filling stage.

Introduction

Pulses are a significant commodity category of crops that provide the country's primarily extensive vegetarian population with high-quality proteins complementing cereal protein (Satya and Sanjay-Swami, 2021; Kumar *et al.,* 2022, 2022a, 2023a). in India, pulses acreage was 29.9 M ha during 2017-18 with a total production of 25.2 Mt and an average yield of 8.41 q/ha. Green gram [(*Vigna radiata* (L.)] is one of the most crucial indigenous pulse crops of South and Southeast Asia. Green

Corresponding author E-mail: *sunda.hau04@gmail.com*
Doi: **https://doi.org/10.36953/ECJ.15222512**

gram, which is high in vegetarian protein (24%) and gives much-needed variety to the poor people's cereal-based diets. Per 100 g of dry seed, green gram provides 94 mg of vitamin A, 7.3 mg of iron, 124 mg of calcium, 3 mg of zinc, and 549 mg of folate (Kumar *et al.,* 2023). It is one of the most important conventional pulses in India for edible seed is ground, boiled, fermented, roasted, or sprouted. The rice-wheat system becomes the major production system after green revolution in the Indo-Gangetic Plains and the Peninsular Region. At the national level, the ideal NPK ratio of 4:2:1 was broadened to 8.5:3.1:1. The western Indo-Gangetic Plains exhibit the highest alteration (37.1:8.9:1), with wheat and rice being cultivated in succession on 82% of entire cropped areas. This is causing soil organic matter content to rapidly drop, especially in Punjab and Haryana (0.2% carbon concentration) (Ali and Kumar, 2004). Green gram helps to maintain soil fertility and texture while fixing nitrogen in the soil, yielding a good yield while demanding less irrigation than many field crops (Meena *et al.,* 2021, 2022; Roy *et al.,* 2022). The addition of green gram to the cereal cropping system can boost farm profitability, enhance soil productivity and human health, conserve irrigation water, and advance agriculture's long-term sustainability (Kumar *et al.*, 2017, 2022b; Meena and Kumar, 2022).In a similar manner, irrigation is one of the key elements in agricultural production techniques (Bakhsh *et al.,* 1999). It acts as a vehicle for nutrient absorption, therefore its availability at different phases of crop growth has a significant impact on the yield. For irrigated lands to produce more crops, the right amount of water must be applied. Lack of water in green gram disrupts normal turgor pressure, and a lack of turgidity in the cells may prevent cell elongation, which inhibits plant growth. It thickens and improves the cell walls' root-shoot ratio (Srivalli *et al.,* 2003). Stomatal conductance of leaves, membrane permeability and water deficit saturation are all negatively impacted by hydric deficit (Khadraji and Ghoulam, 2017). Water shortage at vegetative stage limits root growth, leaf area and plant size which lowers seed yield (Nielson and Nelson, 1998). Green gram's flowering, leaf area, and seed germination are all impacted by water stress. Additionally, it increases flowering and fruiting dates and slows photosynthesis, resulting in reduced crop output (Jordan and Ritichie, 2002).

Water stress throughout the green gram plant's blooming and pod-filling growth stages drastically decreased pod growth rates, pod initiation, reduced height, shortened the period of maturity, and decreased yield and yield traits (Masomi *et al.,* 2006). The farmer schedules irrigation by deciding when to irrigate, how much water to provide to the crop, and how to respond to yield. It is important to understand the crop water needs and yield responses to water, as well as the limitations of each irrigation method and equipment, the water supply system, and the financial and economic effects of the irrigation practice. Grain yield may be more pretentious by moisture stress during some growth stages than by equivalent stress during other growth stages. Water stress on these crops reduced the seeds, pods, test weight, and eventually the seed output. In regions of super-optimal temperature during reproductive growth, additional irrigation, especially at the stage of pod filling to advance water status of plant, results in an economically higher increase in yields. The stages of late flowering and pod formation are most vulnerable to the stress of soil moisture. When irrigation treatments were applied during flowering, whether or not pre-flowering irrigation was also used, green gram production was reduced. In irrigated farms, sufficient water must be applied at the proper time to increase crop yield.In order to maximize crop yield in a constrained space, it is crucial to understand how much water plants use and when they are vulnerable to water, in addition to the irrigation intervals. Depending on the plant species and growth stages, different plants require different amounts of water from planting seeds through harvest. Therefore, the present field research experiment was planned and conducted with the title "Biomass partitioning, yield and economic performance of green gram genotypes as influenced by different irrigation levels" during the *Kharif* season of 2020.

Material and Methods

Features of study site: The present field experiment was performed in the drought micro plots (6 x 1 x 2 m) at the Agronomy Farm of CCS HAU, Hisar, Haryana, India ($29^0 10^0$N latitude,

$75^{0}46^{0}$E longitude and elevation of 215.2 m. The experimental is characterized by a sub-tropical and semi-arid climate with very dry and hot summers, cold winters and a humid, warm rainy season.

Details about the experiment: Green gram was used as a test crop. The investigation was conducted by following the principles of split plot design with four main plot treatments consisting of irrigation levels (No irrigation, one irrigation at the flower initiation stage, one irrigation at pod filling stage and two irrigations each at flower initiation and pod filling stage) and five subplot treatments as genotypes *viz*. MH 1142, MH 1468, MH 1703, MH 1762 and MH 1871, replicating thrice (Plate 1). Following the CCS HAU package and practices, uniform nutrient and weed management was done. 20 kg N + 40 kg P_2O_5/ha basis were given as basal dose using D.A.P. Irrigations were given as per treatments.

Plate1: Layout plan of experiment

Sampling and analysis: The crop was sown in drought micro plots (6 x 1 x 2 m), which were filled with dunal sand, which was low in organic carbon (0.08 %), available N (65 kg/ha) and P_2O_5 (19.5 kg/ha) and medium in K_2O (192.0 kg/ha) with slightly alkaline in reaction (pH= 7.9). The climate data were recorded at the meteorological observatory of CCS HAU, Hisar (Table 1). The mean maximum/minimum temperature, morning/ evening relative humidity, wind speed, bright sunshine hours, Pan evaporation, total rainfall and total rainy days during crop duration from sowing up to harvesting during the study year (2020) was 35.7/26.6 °C, 87.2/63.5 %, 6.6 km/hr, 7.1, 5.3 mm, 274.4 mm and 16, respectively. The overall weather during the crop study remained favorable for the green gram crop. Three plants from each treatment (three replicates) were undertaken to determine the dry matter, yield attributes and yield for dry matter accumulation and partitioning at each sampling stage. After separating the shoot and root, the fresh weights (F.W.) of each were calculated. The shoot and roots were dried for 48 hours at 65 °C in a hot air oven before being weighed to determine their dry weight (D.W.). The canopy temperature depression and chlorophyll content were recorded on a third fully expanded leaf from the top between 1000-1200 hours at the 50% flowering stage. Transpiration cooling, *i.e.,* canopy temperature depression (CTD (-°C), was measured using an infra-red thermometer (ModelAG-42 Tele-temp Corp, California, U.S.A.). Chlorophyll content in plant leaves was also determined by using SPAD meter by assessing light absorbance of plant leaves, *viz*., blue (400-500 nm) and red (600-700nm) light. Following the last harvest at physiological maturity, the number of pods, seeds per pod, and test weight were recorded. To determine the total biomass and seed output, the harvested plants were exposed to the sun for five days. The economics (Cost and return) of different treatments was calculated by using economic input and out balance as well as the prevailing market rate of different chemicals used as per treatments in the study. Net profit was attained after subtracting the cost of cultivation from gross returns.

Statistical Analysis: The field experiment was replicated three times, adopting a Split Plot Design (S.P.D.). Data for different parameters under investigation were analyzed using Statistical Analysis Package (OPSTAT, CCS HAU, Hisar, India) and tested for their statistical significance with a critical difference (CD) at a 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Dry weight: A schematic flow chart of effect of different irrigation levels on mung bean crop is given in Figure 1. Irrespective of irrigation levels and genotypes, total dry weight and dry weight accumulated by differenHamidt plant parts, viz. root, shoot, leaf and pod, showed an increasing trend up to the harvest stage.

Table 1: Weekly meteorological data during crop season of study

Year	Period of crop duration	Temperature (°C)		Relative humidity (%)		Average Wind Speed (KM/H)	Bright Sun Shine Hours	P.A.N. Evaporation	Rainfall (mm)	Rainy Days
		Max	Min	Morning	Evening					
Kharif 2020	0-15 DAS	37.6	27.4	83	58	7.9	8.4	7.3	47.1	4
	15-30 DAS	34.6	26.4	89	68	6.9	6.1	5.0	125.8	5
	30-45 DAS	35.9	27.3	87	65	6.3	7.1	4.8	32.8	1
	45 D.A.S.- harvest	34.9	25.4	90	63	5.3	6.8	4.4	68.7	6
	Total (30th June-21st. Sep, 2020	35.7	26.6	87.2	63.5	6.6	7.1	5.3	274.4	16

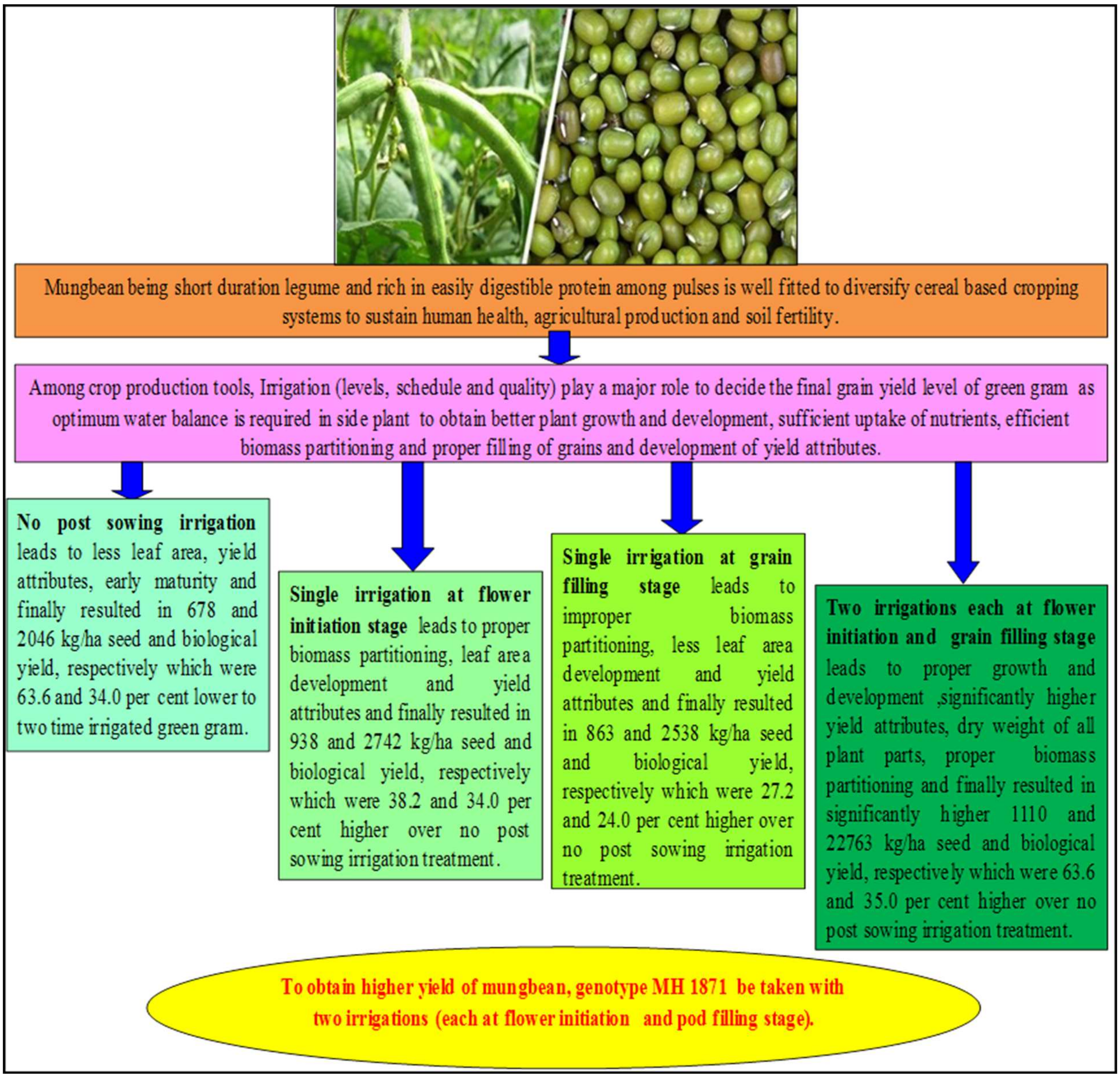


Figure 1. Growth and yield dynamics of green gram as influenced by different irrigation levels and their schedules

But the maximum increase in dry weight was recorded between 45 D.A.S. and the harvest stage (Table 2). Due to the non-imposition of irrigation treatments during the initial 30 days of crop growth, non-significant variation among irrigation schedules for dry weight of different plant parts and the total weight was recorded. At 45 D.A.S. and harvest stage, dry weight accumulated by plant parts and total weight were significantly affected by irrigation schedules. At 45 D.A.S. and harvest stage among irrigation schedules, two irrigations (each at flower initiation and pod filling stage) and no post-sowing irrigation recorded significantly higher and lower root, stem, leaf and total dry weight than other irrigation schedules, respectively. Two irrigations (each at flower initiation and pod filling stage) compared to no post-sowing irrigation recorded 62.2 and 82.9, 123.1 and 62.8, 52.5 and 69.1, 21.4 and 90.9 per cent higher root, shoot, leaf and total dry weight at 45 D.A.S. and harvest stage, respectively. Significantly higher and lower pod weight at 45 DAS stage was recorded with no post-sowing irrigation and two irrigations (at grand growth and flowering) treatments, respectively. But a reverse trend was obtained at the harvest stage regarding pod dry weight. Significantly higher dry weight with two irrigations (at grand growth and flowering) compared to no post-sowing irrigation might be attributed to better vegetative growth and proper biomass partitioning due to favorable water balance in these treatments vice-versa (Plate 2). Higher dry weight with crops irrigated during vegetative growth compared to stress was also reported by Summy *et al*. (2015), Ibrahim *et al.* (2017), Sadeghipour (2009), Mondal *et al.* (2018). Hamid *et al.* (2012) observed that water stress reduced the dry matter of plant parts in green gram. The results follow Khan (2001), who noted that irrigation significantly increased dry matter production. Similarly, Sangakara (1994) reported that the presence of adequate soil moisture increased the growth and yields of green gram. The overall dry weight and dry weight of various plant components varied significantly between genotypes at all growth stages till harvest. Among genotypes, MH 1871 and MH 1142 recorded significantly higher and lower dry weights of all plant parts and total dry weight, respectively, at all stages of observation (Plate 3).

Plate 2: Biomass petitioning

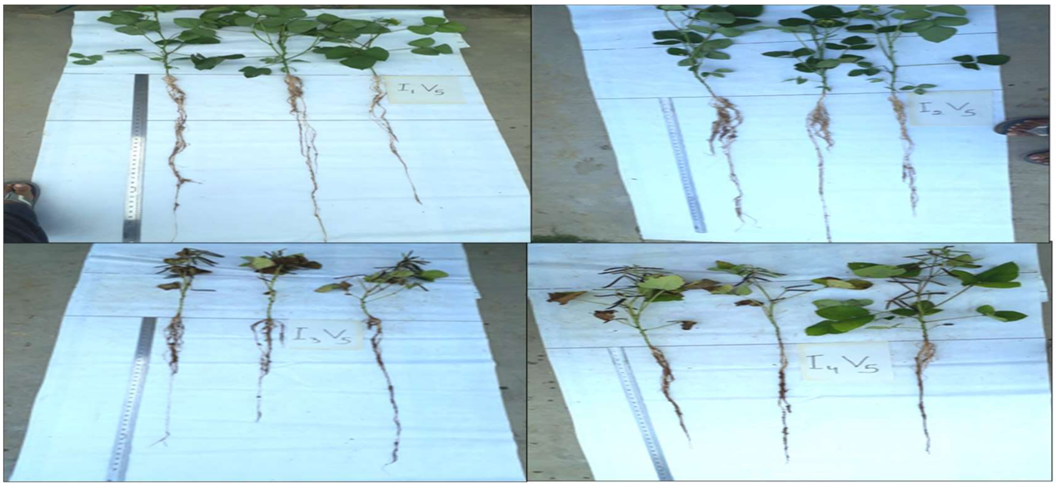


Plate 3: Effect of irrigation levels on green gram genotype MH 1871

Despite the non-imposition of irrigation schedules during the initial 30 days of plant growth, significant variation among genotypes for dry weight might be attributed to their relative ability to utilize resources and differences in biomass partitioning and genetic variability. At the 45 DAS stage, MH 1871, followed by MH 1762 over MH 1142, recorded 106.6, 147.6, 102.5, 161.1 and 110.8 per cent higher dry weight of root, shoot, leaf, pod and total, respectively. While at the harvest stage, MH 1871 recorded a significant increase of 95.0, 127.7, 149.1, 116.9 and 119.8 per cent, respectively, for root, shoot, leaf, pod and total over MH 1142. Significantly higher dry weight with MH 1871 might be a credit to its higher shoot length, more leaves, and higher number of fruiting parts compared to other genotypes. Similar variations in dry weight among genotypes were also supported by the findings of Summy *et al*. (2015), Siddique *et al*. (2006), Malik *et al*. (2008) and Rahim *et al*. (2010).

Yield and harvest index: Crop yield and harvest index of crops were significantly affected by irrigation schedules. Among Irrigation schedules, two irrigations (at grand growth and flowering) recorded 18.4/0.8, 28.6/8.9 and 63.6/35.0 per cent, significantly higher seed/biological yield compared to one irrigation at flowering, one irrigation at grain filling and no post sowing irrigation, respectively (Table 3). One irrigation at flowering and one at the grain filling stage resulted in 38.2/33.9 and 27.2/24.0 per cent higher seed/biological yield over no post-sowing irrigation. One irrigation at flowering obtained 8.6/8.0 per cent higher seed/biological yield than one at grain filling. A similar trend of observations was also obtained in the harvest index. Two irrigations (at grand growth and flowering) and no post-sowing irrigation recorded significantly higher and lower harvest indexes over other irrigation schedules, respectively. One irrigation at grand growth and one at flowering differed non-significantly regarding harvest index. The higher yield obtained by two irrigations (at grand growth and flowering) might be credited to higher water status, resulting in proper biomass partitioning, higher yield attributes, better grain filling and comparatively better growth and development compared to other irrigation schedules. These results are in line with the findings of Summy *et al*. (2015), Ibrahim *et al.* (2017), Sadeghipour (2009), and Mondal *et al.* (2018). According to Assaduzaman *et al.* (2008), T2 in the current study's more outstanding dry matter production eventually partitioned to pods per plant, seeds per pod, and 1000-seed weight, producing the highest possible seed output. The results are supported by Assaduzaman *et al.* (2008). They observed that irrigation boosted pod initiation and growth rates during the flowering and pod-filling phases, raising the harvest index as a result. Genotypes had a big impact on harvest index, biological yield, and seed production. Among genotypes, MH 1871 and MH 1142 recorded substantially higher (1125 and 3097 kg/ha) and lower (663 and 1809 kg/ha) yields (seed and biological), respectively. MH 1871 produced 15.7/1.82, 27.9/20.8, 32.6/44.7 and 69.7/71.1 per cent higher seed/biological yield than MH 1762, MH 1703, MH 1468 and MH 1142, respectively. The significantly higher seed and biological yield obtained with MH 1871 followed by MH 1762 might be due to substantially higher yield attributes (branches and pods per plant, seeds per pod and 100 seed weight) and better growth compared to other genotypes. Among genotypes, significantly higher and lower harvest indexes were recorded by MH 1468 and MH 1762, respectively. Similarly, Summy *et al.* (2015), Siddique *et al*. (2006), Malik *et al*. (2008), and Rahim *et al*. (2010) also observed variation in yield among various cultivars due to genetic divergence. The ICC 4958 showed greater promise thanks to its higher seed output, improved plant water status, reduced membrane injury, and cooler canopy temperature (Summy *et al.,* 2015).

Yield attributes: All yield attributes *viz*. branch production, seeds per pod, pods, and test weight showed significant variations among irrigation schedules (Table 3). Among irrigation schedules, two irrigations (at grand growth and flowering) and no irrigation post sowing recorded significantly higher and lower yield attributes, respectively. All yield attributes except pods per plant showed non-significant variation between one irrigation at grand growth and one irrigation at grain filling. However, numerically higher yield attributes were recorded with one irrigation at grand growth compared to one irrigation at the flowering stage. Two irrigations (at grand growth and flowering) recorded 91.5, 77.8, 15.6, 20.9 and 19.0 per cent higher branches per plant, pods per plant, seeds per

Table 2: Effect of Irrigation levels on dry weight (g/plant) of different plant parts of green gram genotypes

Treatments	Dry weight at 30 D.A.S.				Dry weight at 45 D.A.S.					Dry weight at harvest				
	Root	Stem	Leaf	Total	Root	Stem	Leaf	Pod	Total	Root	Stem	Leaf	Pod	Total
A) Irrigation														
No post sowing irrigation	0.14	0.15	0.29	0.58	0.45	0.82	1.37	0.42	3.40	0.41	0.70	0.81	3.79	5.72
One irrigation at flowering stage	0.13	0.15	0.29	0.58	0.78	1.36	1.92	0.21	4.70	0.54	0.85	1.07	7.14	9.59
One irrigation at pod filling stage	0.13	0.15	0.29	0.58	0.71	1.05	1.83	0.31	3.94	0.58	0.90	1.15	5.06	7.71
One irrigation each at flowering and pod filling stage	0.14	0.15	0.29	0.58	0.73	1.83	2.09	0.21	4.13	0.75	1.14	1.37	7.64	10.92
SEm±	0.003	0.004	0.004	0.005	0.01	0.01	0.01	0.03	0.12	0.006	0.01	0.03	0.09	0.50
CD (P=0.05)	NS	NS	NS	NS	0.03	0.05	0.05	0.11	0.43	0.02	0.04	0.10	0.33	1.79
B) Genotypes														
MH 1142	0.07	0.07	0.13	0.28	0.45	0.67	1.16	0.18	2.48	0.40	0.54	0.61	3.42	4.98
MH 1468	0.15	0.08	0.15	0.38	0.49	0.98	1.54	0.24	4.18	0.42	0.68	0.97	4.61	8.88
MH 1703	0.16	0.12	0.27	0.55	0.73	1.45	1.88	0.20	3.56	0.61	0.92	1.07	6.82	7.21
MH 1762	0.15	0.21	0.36	0.74	0.74	1.58	2.07	0.35	4.75	0.65	1.12	1.34	7.27	10.39
MH 1871	0.15	0.26	0.54	0.96	0.93	1.66	2.35	0.47	5.23	0.78	1.23	1.52	7.42	10.95
SEm±	0.008	0.008	0.008	0,01	0.01	0.02	0.02	0.02	0.12	0.008	0.01	0.03	0.14	0.86
CD (P=0.05)	0.02	0.02	0.02	0.04	0.04	0.08	0.07	0.08	0.37	0.02	0.05	0.09	0.43	2.51

Table 3: Effect of Irrigation on yield and yield attributes of green gram genotypes

Treatments	Yield (kg/ha)		H.I. (%)	Branches/plant	Pods/plant	Seeds/pod	Pod length (cm)	100 seed weight (g)
	Seed	Biological						
A) Irrigation								
No post sowing irrigation	678.8	2046.9	33.6	3.20	22.1	10.2	7.08	3.46
One irrigation at flowering stage	938.2	2742.3	35.8	4.60	32.1	10.7	8.26	3.89
One irrigation at pod filling stage	863.8	2538.2	35.4	4.40	27.4	10.7	8.26	3.66
One irrigation each at flowering and pod filling stage	1110.8	2763.7	40.9	6.13	39.3	11.8	8.56	4.12
SEm±	16.2	30.6	0.47	0.19	0.57	0.27	0.03	0.07
CD (P=0.05)	57.2	108.0	1.68	0.66	2.04	0.97	0.13	0.27
B) Genotypes								
MH 1142	663.2	1809.6	36.6	3.16	22.4	10.1	7.11	3.80
MH 1468	848.7	2101.8	40.3	4.91	28.1	10.8	7.95	3.84
MH 1703	879.5	2562.7	34.3	4.41	29.7	11.2	8.00	3.71
MH 1762	972.2	3042.1	32.2	5.16	33.9	11.1	8.41	3.65
MH 1871	1125.7	3097.7	36.8	5.25	37.1	11.2	8.74	3.91
SEm±	7.6	33.3	0.51	0.21	0.42	0.25	0.11	0.03
CD (P=0.05)	22.0	96.5	1.48	0.63	1.23	0.74	0.33	0.11

Table 4: Effect of Irrigation on Chlorophyll content and Canopy Temperature Depression (CTD) in green gram genotypes

Treatments	**Chlorophyll content**	**Canopy Temperature (° C)**	**CTD (-° C)**	**Ambiant Temperature (° C)**
A) Irrigation				
No post sowing irrigation	30.1	35.1	0.66	35.7
One irrigation at flowering stage	32.8	34.8	1.74	36.5
One irrigation at pod filling stage	32.7	33.6	2.40	35.9
One irrigation each at flowering and pod filling stage	33.8	33.5	3.52	37.1
SEm±	0.57	0.21	0.05	0.15
CD (P=0.05)	2.0	0.7	0.18	0.54
B) Genotypes				
MH 1142	29.8	35.0	1.40	36.41
MH 1468	30.0	34.5	2.12	36.83
MH 1703	31.0	34.4	2.22	36.33
MH 1762	35.1	33.8	2.30	36.08
MH 1871	35.7	33.5	2.36	35.91
SEm±	0.41	0.28	0.05	0.23
CD (P=0.05)	1.1	0.8	0.15	NS

Table 5: Effect of Irrigation on economics of green gram genotypes

Treatments	**Total cost (Rs. /ha)**	**Variable cost (Rs. /ha)**	**Total Returns (Rs./ha)**	**Net Returns (Rs./ha)**	**B:C**
A) Irrigation					
No post sowing irrigation	38635	20513	52271.3	13635.6	1.35
One irrigation at flowering stage	39639	21516	70364.4	30725.4	1.77
One irrigation at pod filling stage	39639	21516	65175.0	25536.0	1.64
One irrigation each at flowering and pod filling stage	40642	22519	82403.3	41761.1	2.02
SEm±			1132.8	1132.6	0.02
CD (P=0.05)	-	-	3996.4	3995.5	0.10
B) Genotypes					
MH 1142	39639	21516	51186.6	11547.7	1.28
MH 1468	39639	21516	64125.3	24486.3	1.61
MH 1703	39639	21516	66270.1	26631.1	1.66
MH 1762	39639	21516	72739.4	33100.4	1.83
MH 1871	39639	21516	83446.0	43807.0	2.09
SEm±			532.1	532.1	0.01
CD (P=0.05)	-	-	1539.9	1539.8	0.03

pod, pod length and 100 seed weight, respectively over no irrigation post sowing. While compared to one irrigation at grand growth / one irrigation at flowering the percentage increase of branches per plant, pods per plant, seeds per pod, pod length and 100 seed weight with two irrigations (at grand growth and flowering) was 33.2/39.3, 22.4/43.1, 10.2/10.2, 4.7/4.7 and 5.9/12.5, respectively. Significantly higher yield attributes recorded with two irrigations (at grand growth and flowering) compared to other irrigation schedules might be attributed to better vegetative and reproductive growth, proper biomass partitioning among plant parts and higher grain filling under favorable water status. Sangakara (1994) studied the effects of soil water content on crop yield and the quality of mung beans. He reported that the yield from irrigated plots had a better weight owing to heavier cotyledons. Khan (2001) also reported that irrigation levels significantly affected 1000-seed weight. A similar increase in yield attributes under irrigated conditions over no irrigation was also drawn by Ibrahim *et al.* (2017), Sadeghipour (2009), and Mondal *et al.* (2018).

All yield attributes showed significant variation among genotypes. Among genotypes, MH 1871 was statistically at par with MH 1762 and MH 1468 recorded significantly higher branches per plant and seeds per pod over MH 1142 and MH 1703. Significantly higher and lower yield attributes except 100 seed weight were reported with MH 1871 and MH 1142, respectively. MH 1762 recorded 66.1, 65.6, 10.8, 22.9 and 2.8 per cent higher branches per plant, pods per plant, seeds per pod, pod length and 100 seed weight, respectively over MH 1142. Relatively higher yield attributes in MH 1871 might be credited to its genetic constitution and better biomass partitioning over other genotypes. These qualities' high heritability and genetic progress are signs that they can be passed down readily to following generations and will hold steady under a variety of environmental conditions. The genotypes as a whole demonstrated a lot of genetic diversity that may be used in a breeding effort (Sheoran *et al.,* 2021, 2022, 2022a, 2022b). The considerable relationship between days to flowering and days to maturity, test weight and grain yield will lead to a direct or indirect improvement in earliness and grain output. Such variations of yield attributes among green gram genotypes were also reported by Siddique *et al*. (2006), Malik *et al*. (2008) and Rahim *et al*. (2010).

Chlorophyll content and Canopy Temperature Depression (CTD): Chlorophyll content and CTD showed significant variation among irrigation schedules (Table 4). Among irrigation schedules, two irrigations (at grand growth and flowering) statistically at par with one irrigation at grand growth/ flowering recorded 12.2 per cent significant higher chlorophyll content over no post-sowing irrigation. Water stress resulted in an increment in the production of reactive oxygen radicals in plants leading to a decreased amount of chlorophyll contents, pointing out the degree of oxidative damage. This reduction may be also caused by chlorophyll biosynthesis route prevention. Chlorophyll content was impacted by water stress, which eventually has an impact on seed output. Mung beans were also found to have such a reduction in total chlorophyll concentration as a result of drought stress, reported by Ibrahim *et al.* (2017), Rambhu *et al.* (2016) and Lalinia *et al*. (2012). Two irrigations (at grand growth and flowering) recorded 46.6, 102.2 and 433.3 per cent significantly higher CTD compared to one irrigation at grain filling, one irrigation at flowering and no post-sowing irrigation, respectively. A reverse trend of canopy temperature was observed among irrigation schedules. One irrigation at flowering recorded a 37.9 per cent cooler canopy compared to one irrigation at grand growth. While compared to no post-sowing irrigation treatment, one irrigation at grand growth or flowering stage recorded 163.6 or 263.6 per cent higher cool canopy, respectively. Significantly higher cool canopy and chlorophyll content recorded with irrigated over non-irrigated environments might be attributed to higher internal water balance which resulted in proper physiological processes and cool microclimatic conditions. Similar variations in CTD were also reported by Summy *et al*. (2015) and Ghassemi-Golezani *et al*. (2014). Decreased stomatal conductance and transpiration may be linked to an increase in leaf temperature brought on by water stress (Siddiaue *et al.,* 2000).

Chlorophyll content and CTD were significantly affected by genotypes. Among genotypes, MH 1871 was statistically at par with MH 1762 recorded with 19.7 and 68.5 per cent significantly higher chlorophyll content and CTD compared to

MH 1142, respectively. Such type chlorophyll content variations among crop plants were also supported by findings of Savaliya *et al.* (2019). While canopy temperature recorded with MH 1871 was 4.2 per cent lower than MH 1142. Significant variations among genotypes for chlorophyll content and CTD might be credited to differences in their genetic ability to utilize resources and to maintain internal water status and balance between different physiological processes viz. photosynthesis, respiration and transpiration. A similar finding among different genotypes of chickpea was observed by Summy *et al*. (2015).

Economics: Total/ Variable cost incurred on no post-sowing irrigation was 2.5/4.8 and 5.1/9.7 per cent lower than one irrigation at grand growth or flowering and two irrigations (at grand growth and flowering), respectively (Table 5). Among irrigation schedules, two irrigations (at grand growth and flowering) recorded 17.1, 26.4 and 57.6 per cent higher total returns while 35.9, 63.5 and 206.2 per cent higher net returns compared to one irrigation at grand growth, one irrigation flowering and no post sowing irrigation, respectively. One irrigation at grand growth was recorded with 7.9, 20.3 and 7.9 per cent higher total return, net return and B: C over one irrigation at flowering, respectively. While one irrigation at grand growth recorded 34.6, 125.3 and 31.1 per cent higher total return, net return and B: C over no post sowing irrigation, respectively. Significantly higher B: C (2.02) with a percentage increase of 14.1, 23.1 and 49.6 per cent over one irrigation at grand growth, one irrigation flowering and no post-sowing irrigation, respectively was recorded with two irrigations (at grand growth and flowering). Significantly higher economics recorded with irrigated plots might be attributed to relatively higher yield levels in irrigated treatments over the non-irrigated condition. These findings are in collaboration with the finding of Chaudhary *et al.* (2014) and Sihag *et al.* (2015).

Total returns, net returns and B: C varied significantly among genotypes. Among genotypes, MH 1871 and MH 1142 resulted in significantly higher and lower returns (total and net) and B: C, respectively. MH 1871 followed by MH 1762 recorded 63.0, 279.3 and 63.2 per cent higher total returns, net returns and B: C, respectively over MH 1142.

Conclusion

Based on the findings of the above investigation, the green gram growers may be recommended to obtain a higher yield of green gram; genotype MH 1871 be taken with two irrigations (each at flower initiation and pod filling stage). This cultivar proved to be higher productive, improved yield parameters with efficient utilization of available resources including water, nutrient, solar radiation etc. Further, with application of two irrigations at reproductive stages proved to be economically beneficial for the producers in the semi-arid regions of northern India.

Acknowledgement

The drought plot research area facility provided by the Botany and plant Physiology and Agronomy department of C.C.S. Haryana Agricultural University, Hisar, Haryana, India for experimenting is duly acknowledged.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ali, M. & Kumar, S. (2004). Prospects of green gram in rice-wheat cropping systems in Indo-Gangetic Plains of India. In: Proceedings of the Final Workshop and Planning Meeting. Improving Income and Nutrition by Incorporating Green gram in Cereal Fallows in the Indo- Gangetic Plains of South Asia, S. Shanmugasundaram (ed.). D.F.I.D. Green gram Project for 2002–2004, 27–31 May 2004, Ludhiana, Punjab, India, pp. 246-254

Assaduzaman, M., M.F. Karim, M.J. Ullah & M. Hasanuzzaman. (2008). Response of green gram to

Bakhsh, I., I.U. Awan and M.S. & Baloch. (1999). Effect of various irrigation frequencies on yield and yield components of sunflower. *Pakistan Journal of Biological Science, 2*, 194-195.

Chaudhary, A.N., Vihol, K.J. & Mor, V.B. (2014). Water use efficiency, yield, available nutrient and economics of greengram (*Vigna radiate* (L.) Wilczek) as influenced by plant density and irrigation management. *Trends in Bio Science, 7*(22), 3761-3764.

Ghassemi-Golezani, K., Abriz, S.F., Hassannejad, S. & Hassanpour-Bourkheili, S. (2014). Some physiological responses of mung-bean at different plant densities to water deficit. *International Journal of Bio Science, 4*(12), 19-26.

Gomez, K.A. & A.A. Gomez (1984). Statistical Procedures for Agricultural Research. A Wiley Inte. Sci. Publication, John Wiley and Sons, New York.

Hamid, A., F. Kubota, W. Agata & M. Morokuma. (2012). Photosynthesis, transpiration, dry matter accumulation and yield performance of green gram plant in response to water stress, J. Fac. Agric. Kyushu Univ., 35, 81-92 (1990) Lalinia, A.A., Hoseini, N.M., Galostian, M., Bahabadi, S.E. and Khameneh, M.M.: Echophysiological impact of water stress on growth and development of green gram. *International Journal of Agronomy and Plant Production, 3*(12), 599-607.

Ibrahim, S.A., Desoky, E. & Elrys, A.S. (2017). Influencing of water stress and micronutrients on physio-chemical attributes, yield and anatomical features of Common Bean plants (*Phaseolus vulgaris* L.). *Egyptian Journal of Agronomy, 39*(3), 251-265.

Jain, R.C., Nema, D.P., Khandwe, R. &Thakur, R. (1990). Effect of phosphorus and potassium on yield, nutrient uptake and oil contents of groundnut (*Arachis hypogaea* L.). *Indian Journal of Agricultural Sciences, 60*, 559- 566.

Jordan W.R. & Ritichie J.T. (2002). Influence of soil water stress on evaporation, root absorption and internal water status of cotton. *Plant Physiology, 48*, 783-788.

Khadraji A. & Ghoulam C. (2017). Effect of drought on growth, physiological and biochemical processes of chickpea- rhizobia symbiosis. *Legume Research- An International Journal,* 40 (1), 94-99.

Khan, I.A. (2001). The growth and yield responses of mungbean to variable seeding densities and irrigation levels. *Crop Husbandry, 16*, 115-120

Kumar, S., Bamboriya, S.D., Rani, K., Meena, R.S., Sheoran, S., Loyal, A., Kumawat, A. & Jhariya, M.K., 2022. Grain legumes: A diversified diet for sustainable livelihood, food, and nutritional security. In Advances in Legumes for Sustainable Intensification (pp. 157-178). Academic Press.

Kumar, S., Gopinath, K.A., Sheoran, S., Meena, R.S., Srinivasarao, Ch., Bedwal, S., Jangir, C.K., Mrunalini, K., Jat, R.D. & Praharaj, C.S., 2023. Pulse-based Cropping Systems for Soil Health Restoration, Resources Conservation, Nutritional and Environmental Security in Rainfed Agroecosystems. *Front. Microbiol.*, Doi: 10.3389/fmicb.2022.1041124.

Kumar, S., Meena, R.S., Sheoran, S., Jangir, C.K., Jhariya, M.K., Banerjee, A. & Raj, A., 2022a. Remote sensing for agriculture and resource management. In Natural Resources Conservation and Advances for Sustainability (pp. 91-135). Elsevier.

Kumar, S., Sharma, S.K., Dhaka, A.K., Bedwal, S., Sheoran, S., Meena, R.S., Jangir, C.K., Kumar, D., Kumar, R., Jat, R.D., Meena, A.K., Gaber, A., & Hossain, A., 2023a. Efficient nutrient management for enhancing crop productivity, quality and nutrient dynamics in *Lens culinaris* Medik. in the semi-arid region of northern India. *PLOS One*. https://doi.org/10.1371/journal.pone.0280636

Kumar, S., Sharma, S.K., Thakral, S.K., Bhardwaj, K.K., Jhariya, M.K., Meena, R.S., Jangir, C.K., Bedwal, S., Jat, R.D., Gaber, A. & Atta, A.A., 2022b. Integrated Nutrient Management Improves the Productivity and Nutrient Use Efficiency of *Lens culinaris* Medik. *Sustainability, 14*(3), p.1284.

Kumar, S., Singh, M.K., Meena, R.S. & Hingonia, K., 2017. Influence of crop geometry and cultivars on growth, yield and production efficiency of dry direct-seeded rice (*Oryza sativa* L.). *Journal of Applied and Natural Science, 9*(4), pp.2469-2476.

Malik, M.F.A., Awan, S.I. & Niaz, S. (2008). Comparative study of quantitative traits and association of yield and its components in black gram (*Vigna mungo*) genotypes. *Asian Journal of Plant Science, 7*(1), 26-29.

Masomi A, Kafi M, Nezami A. and Hoseini H. (2006). Effects drought stress on morphological characteristics of Cheek pea genotypes in greenhouse conditions. *Iranian Journal of Agricultural Research, 3* (2), 277-289.

Meena, R.S. & Kumar, S., 2022. Legume-based agroecosystem for sustainable intensification: An overview. *Advances in Legumes for Sustainable Intensification*, pp.3-8.

Meena, R.S., Kumar, S., Sheoran, S., Jhariya, M.K., Bhatt, R., Yadav, G.S., Gopinath, K.A., Rao, C.S. & Lal, R., 2021. Soil Organic Carbon Restoration in India: Programs, Policies, and Thrust Areas. In Soil Organic Matter and Feeding the Future (pp. 305-338). C.R.C. Press.

Meena, R.S., Yadav, A., Kumar, S., Jhariya, M.K. & Jatav, S.S., (2022). Agriculture ecosystem models for CO_2 sequestration, improving soil physicochemical properties, and restoring degraded land. *Ecological Engineering, 176,* p.106546.

Mondal, R., Ali, J., Biswas, S., Das, S., Dutta, D. & Sarkar, T. (2018). Effect of different levels of irrigation and nutrient on growth and yield of Summer Green gram cv. Bireswar in New Alluvial Zone of West Bengal. *International Journal of Crop Science, 6*(1), 386-390.

Nielson D.C. and Nelson N.O. (1998). Black Bean Sensitivity to Water Stress at Various Growth Stages. *Crop Science, 38*, 422-427.

nitrogen and irrigation management American- green gram varieties. *American-Eurasian Journal of Scientific Research, 3,* 40-43.

Rahim, M.A., Mia, A.A., Mahmud, F., Zeba, N. & Afrin, K.S. (2010). Genetic variability, character association and genetic divergence in Green gram (*'Vigna radiata'*L. Wilczek). *Plant Omics*, *3*(1),1-6.

Rambabu, B., Padma, V., Thatikunta, R. & Sunil, N. (2016). Effect of drought stress on chlorophyll content and anti-oxidant enzymes of green gram genotypes (*Vigna Radiata* L.). *Nature Environment Pollution Technology, 15*(4), 1205.

Roy, O., Meena, R.S., Kumar, S., Jhariya, M.K. & Pradhan, G., 2022. Assessment of land use systems for CO_2 sequestration, carbon credit potential, and income security in Vindhyan region, India. *Land Degradation & Development, 33*(4), pp.670-682.

Sadeghipour, O. (2009). The Influence of Water Stress on Biomass and Harvest Index in Three Mung Bean (Vigna radiata (L.) R. Wilczek) Cultivars. Asian Journal of Plant Science, 8(3), 245.

Sangakkara, U.R. (1994). Yield and seed quality of mungbean as affected by irrigation in a dry season. Journal of *Agronomy and Crop Science, 172*(5), 327-332.

Satya, Charan, M.S.S. and Sanjay-Swami. (2021). Performance of black gram (*Vigna mungo* L. Hepper) under phosphorus and boron fertilisation in acid inceptisol of Meghalaya. *Journal of Environmental Biology, 42*, 534-543.

Savaliya, H.B., Narwade, A.V., Zinzala, V.N. & Faldu, T.A. (2019). Effect of water stress on biochemical characteristics of summer Green gram (*Vigna radiata* (L.) Wilczek). *International Journal of Crop Science*, *7*(1), 862-868

Sheoran, S., Gupta, M., Kumari, S., Kumar, S. & Rakshit, S., 2022. Meta-QTL analysis and candidate genes identification for various abiotic stresses in maise (*Zea mays* L.) and their implications in breeding programs. *Molecular Breeding, 42*(5), pp.1-26.

Sheoran, S., Kumar, S., Kumar, P., Meena, R.S. & Rakshit, S., 2021. Nitrogen fixation in maise: breeding opportunities. *Theoretical and Applied Genetics, 134*(5), pp.1263-1280.

Sheoran, S., Kumar, S., Ramtekey, V., Kar, P., Meena, R.S. & Jangir, C.K., 2022a. Current Status and Potential of Biofortification to Enhance Crop Nutritional Quality: An Overview. *Sustainability, 14*(6), p.3301.

Sheoran, S., Thribhuvan, R., Saini, M., Ramtekey, V., Kumar, S., Meena, R.S., Banerjee, A. & Jangir, C.K., 2022b. Conventional, genomics, and post-genomics era of pulses breeding: Current status and future prospects. *Advances in Legumes for Sustainable Intensification*, pp.553-574.

Siddique, M., Malik, M.F.A. & Awan, S.I. (2006). Genetic divergence, association and performance evaluation of different genotypes of green gram (*Vigna radiata*). *International Journal of Agricultural Biology, 8*(6), 793-795.

Siddique, M.R.B., Hamid, A.I.M.S. & Islam, M.S. (2000). Drought stress effects on water relations of wheat. *Botanical Bulletin- Academia Sinica Taipei, 41*(1), 35-39.

Sihag, S.K., Singh, M.K., Meena, R.S., Naga, S., Bahadur, S.R. & Gaurav, Y.R., 2015. Influences of spacing on growth and yield potential of dry direct seeded rice (*Oryza sativa* L.) cultivars. *Ecoscan*, *9*(1-2), pp.517-519.

Srivalli B., Sharma G. &Khanna-Chopra R. (2003). Antioxidative defence system in an upland rice cultivar subjected to increasing intensity of water stress followed by recovery. *Plant Physiol. 119*, 503– 512.

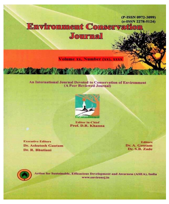
Summy, S.K., Boora, K.S. & Kumar, N. (2015). Plant water status, canopy temperature and chlorophyll fluorescence in relation to yield improvement in chickpea (*Cicer arietinum* L.) under soil moisture stress environments. *Journal of Agrometerology*, *17*(1), 11-16.

Environment Conservation Journal 24 (3): 186-198, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Evaluation of ginger genotypes for commercial cultivation in Mizoram and future prospects

Jeetendra Kumar Soni ✉
ICAR RC NEH Region, Mizoram Centre, Kolasib, India
B Lalramhlimi
ICAR RC NEH Region, Mizoram Centre, Kolasib, India
Vishambhar Dayal
ICAR RC NEH Region, Mizoram Centre, Kolasib, India
Sunil Kumar Sunani
ICAR RC NEH Region, Mizoram Centre, Kolasib, India
Lalhruaitluangi Sailo
ICAR RC NEH Region, Mizoram Centre, Kolasib, India
Amarjeet Nibhoria
CCS Haryana Agricultural University, Hisar, Haryana
I Shakuntala
ICAR RC NEH Region, Mizoram Centre, Kolasib, India
S Doley
ICAR RC NEH Region, Mizoram Centre, Kolasib, India

ARTICLE INFO

Received : 23 November 2022
Revised : 19 March 2023
Accepted : 01 April 2023

Available online: 25 June 2023

Key Words:
Economics
High yielders
Performance
Quality
Ginger

ABSTRACT

A study was carried out for three years (2019, 2020 & 2021) in the experimental field at ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram to check the performances of seven ginger genotypes *viz*., Gurubathani, Bold Nadia, Bhaise, John's ginger, PGS 121, PGS 95 and PGS 102 against Local ginger *cv* Thingria and their economic feasibility for commercialization in Mizoram, India. Out of seven genotypes when compared with Local ginger *cv* Thingria, five genotypes have out yielded Local cultivar in the range of 21.25 to 45.45% with Bhaise having 45.45% higher rhizome yield than Local ginger. On the other hand, Bold Nadia possesses a combination of good quality traits. The highest B:C ratio was obtained in Bhaise (2.08) followed by PGS 102 (1.99), Gorubathani (1.95) and Bold Nadia (1.87). The highest cost of cultivation was contributed by labour cost which was 53.40% of total cost of cultivation. The four genotypes *viz*., Bold Nadia, Bhaise, PGS 102 and Gorubathani can be selected as potential genotypes possessing optimum combination of all traits. Based on economic analysis, these genotypes can be considered for commercial purposes under Mizoram condition. Different production systems such as intercropping, pro-tray technology, and bulb extraction method may increase the overall income of farmers. Farmers need to venture the possibilities of value addition in ginger on commercial basis. Government intervention is required for creating marketing infrastructures, initiating youth-centered schemes, occasional skill training and developing farmer-friendly policies to protect them from market risks and exploitation. Ginger has been an important horticultural crop and widely marketed spice crop of Mizoram, a potential enterprise contributing to state economy.

Introduction

Ginger was more frequently described as a medicinal plant than a spice crop in ancient India, but it has since evolved into one of the most valuable spices in India today. It is an important commercial spice across the country and also holds an important position in international trade. The production of ginger in India is 2224.8 thousand tonnes from an area of 204.8 thousand hectares with productivity of 10.86 t/ha (Anonymous, 2021a). India is one of the largest producers of

Corresponding author E-mail: *jeetendra.soni@icar.gov.in*
Doi:https://doi.org/10.36953/ECJ.16332516

ginger accounting for approximately 35-40% of world production. Ginger has been grown practically in all regions of India since time immemorial. Major ginger growing states like Karnataka, Madhya Pradesh, Assam, West Bengal, Maharashtra, Odisha, Gujarat, Sikkim, Manipur, Meghalaya and Mizoram together contributed 89.10% of total production of ginger in India (Anonymous, 2021a). The contribution from the Northeast region has amounted to 23.63% of total ginger production in India from 33.14% ginger growing area which offers great scope for increasing the production of quality ginger (Anonymous, 2021b). As a result, many researchers from different institutions have focused on tapping the potential of ginger cultivation in the Northeast region. The farmers have attributed quality ginger production in the region possibly to the favourable climatic condition that prevails throughout the year. Mizoram stood 11th position in the overall production of ginger in India with 60.13 thousand tonnes from an area of 8.55 thousand hectares with productivity of 7.03 t/ha (Anonymous, 2021a) which is still low as compared to the national average (10.86 t/ha). Ginger is a major spice of Mizoram and is an important cash crop which plays a vital role in the economic stability of the farmers. It is a moderate shade loving crop, intercropping with shade giving crops like climbing vegetables, plantation crops, fruit orchards, *etc.*, can provide both optimum condition and additional income to farmers. Most of the ginger produced in Mizoram are consumed and sold in fresh form and a small quantity of the produce is converted into different processed products. Mizo gingers are prized for their excellent quality. The majority of the ginger commercially cultivated in Mizoram are local genotypes, low in yield and cultivated without proper agronomic practices. As farmers are not aware of high-yielding varieties, the potentials and economic aspect of these varieties are not well understood. As a result, local genotypes of unknown characteristics are grown in masses and the hard work of farmers is not rewarded sufficiently. As the quality of a variety has direct impact on the production and productivity of ginger (Utpala *et al.*, 2006), careful selection of suitable varieties with good quality will have a direct impact on ginger production (Soni *et al.*, 2022a) and marketability. Ginger is predominantly eaten in fresh form or used as a spice in cooking different dishes in Mizoram, although it has certain uses as food products, spice blends, and beverage industries. It possesses numerous medical benefits; thus, it also has a substantial impact on the pharmaceutical industry. Medicinal uses include the treatment of nausea, nervous diseases, migraines, rheumatic disorders, muscular pain, digestive ailments *etc*. It is reported to possess antiseptic, antioxidant, anti-inflammatory, and carminative properties (Afzal *et al.*, 2001). Various bioactive components in ginger have been identified by numerous researchers based on their properties and potential health benefits. Among these, the phenolic compounds are found to have high antioxidant capacity and are associated with many biological activities (WHO, 1999) which prevents the cells from oxidative damage induced by free radicals. Many researchers have identified antioxidant activities of ginger (Smith *et al.,* 2004; Willetts *et al.*, 2003). Most ginger varieties with large rhizomes are not suitable for dry ginger due to their high moisture content which results in poor quality, difficulty in drying with often low-quality oleoresin. Also, there exists significant variation in the pungency of ginger based on regions and varieties. Evaluation of ginger genotypes based on their biochemical properties and careful selection of ginger for commercial purpose with regards to their end use is also very important. Hence, it is important to evaluate and tap the potentials of high yielding varieties under specific region as little information is available with regards to commercial aspect and economic feasibility in Mizoram, India.

Material and Methods

Planting materials

The eight ginger genotypes which includes local ginger *cv* Thingria as check were evaluated for three years (2019, 2020 & 2021) in the experimental field at ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram (92^{0}40’52’E longitude and 24^{0}12’77’N latitude with a MSL 650-700 m) to evaluate their performances and economic feasibility for commercialization in Mizoram. These genotypes were collected from different sources and are given in Table 1.

Table 1: Sources of different genotypes used in the experiment

SN	Genotypes	Sources of collection
1	Gurubathani	Pundibari, West Bengal
2	Bold Nadia	Nagaland
3	Bhaise	Sikkim
4	John's ginger	Kerala
5	PGS 121	Pottangi, Odisha
6	PGS 95	Pottangi, Odisha
7	PGS 102	Pottangi, Odisha
8	Local ginger *cv* Thingria	Mizoram

Experimental design

The ginger genotypes were grown as a sole crop on a raised bed of size 3 × 1 × 0.15 m, at 30 × 25 cm spacing and 40 plants per plot were accommodated with three replications in randomized block design. The temperature ranges from 19.82 to 28.19℃ in the experimental field. The change in weather data was given in Figure 1. The soil was clayey loam with soil pH (5.0-5.5) and 1.2-1.4% organic carbon content.

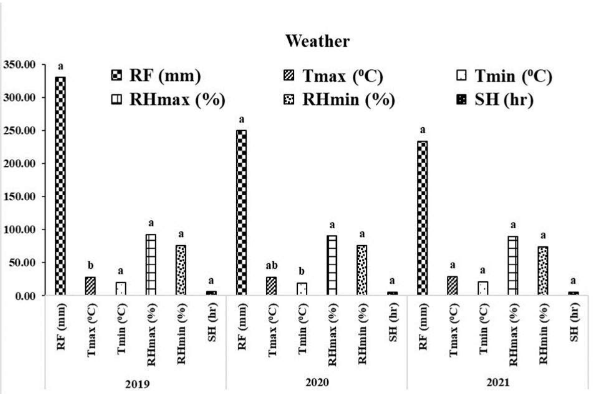


Figure 1: Weather condition for three years during the experiment from April to December. The different parameters having same letter indicated non-significant at 5% level of significance by Tukey's test

General procedures

The seed rhizomes (35-50 g) having 2-4 active buds per rhizome were used as planting material. Carbendazim 12% + mancozeb 63% WP @ 2 g/L was used for seed rhizome treatment in which rhizomes are dipped for 30 minutes and shade-dried for 24 hours before sowing. Sowing of rhizomes is done in second week of May. Small pits were dug to which carbofuran 3G and farm yard manure were applied at the rate of 5 and 100 g per pit, respectively. The recommended dose of fertilizer (80N:100P:80K kg/ha) was applied in three splits where half doses of N (40 kg), full dose of P (100 kg) and K (80 kg) per hectare were incorporated at land preparation and the remaining 40 kg of nitrogen was applied at 40 and 60 days after planting at 20 kg each application. For nitrogen source, urea was used, single super phosphate for phosphorus source and muriate of potash as source of potassium.

Data recording and analysis

Observations were taken at 180 DAS for plant height, leaf area index (LAI), number of leaves/hill, and number of tillers/plant while fresh weight of clump, number of rhizomes/plant and dry recovery were recorded at 210 DAS (maturity). Five representative plants were selected from each plot for recording the observations. The yield of rhizome was recorded in quintals per hectare. Quality parameters such as total chlorophyll and total carotenoid were recorded at 180 DAS; total phenol content (mg GAE/100g), 6-gingerol (%) and oleoresin (%) were recorded at maturity. For LAI, the fresh leaves were detached from five plants from each plot and placed in leaf area meter (LICORLI-3100C area meter) to record leaf area (cm^2) and LAI was calculated by formula as (Yoshida, 1976):

$$\text{LAI} = \frac{\textbf{\textit{Leaf area per plant}}\ (\boldsymbol{cm^2})}{\textbf{\textit{Spacing}}\ (\boldsymbol{cm^2})}$$

For the estimation of leaf pigments, 50 g of freshly harvested leaf tissue was placed in a test tube, 5 ml of Dimethyl Sulphoxide (DMSO) was poured directly to the sample at room temperature and kept overnight till tissue becomes colourless. The sample extracts were subjected to UV/VIS Spectrophotometer at wavelength of 420, 663 and 645 nm while DMSO solution was used as blank. The different pigments were calculated from the formula given below (Hiscox and Israelstam, 1979):

Chlorophyll a **(mg/g F.W) = (12.7** A_{663} **– 2.69** A_{645}**) × Dilution factor**

Chlorophyll b **(mg/g F.W) = (22.9** A_{645} **– 4.68** A_{663}**) × Dilution factor**

Total Chlorophyll **(mg/g F.W) = (20.2 A_{645} + 8.02 A_{663}) × Dilution factor**

Total carotenoids **(mg/g F.W) = [1000 A_{470} – (3.27 *Chl 'a'*+ 104 *Chl 'b'*)] × Dilution factor**

$$\text{Dilution factor} = \frac{V}{W \times 1000}$$

Where, *V* stands for volume of extract (ml), *W* stands for fresh weight of sample (g), F.W stand for fresh weight.

The oleoresin was extracted from ginger powder where ginger rhizomes were cleaned by thoroughly washing with water, oven-dried at 60°C for 48 hours and grounded into fine powder and screened through a sieve of 30 US Mesh to obtain a particle size of 0.6 mm. The oleoresin was extracted through Soxhlet apparatus using solvent ethanol. 10 mg of ginger powder was packed in a filter paper and put inside the extraction chamber. 150 ml of ethanol (80%) was used as extraction solvent which was poured from the inlet using a funnel. The extractor was refluxed at 78°C for 7 hours until the solvent in extraction chamber was transparent. The extract was evaporated at room temperature which was then filtered. The residue in filter paper was air-dried and weighed. The oleoresin (%) was calculated as (AOAC, 1975):

$$\textit{Oleoresin}\ (\%) = \frac{W_2 - W_1}{\textit{Weight of sample}\ (g)} \times 100$$

Where,
W_1= Weight of empty beaker (g)
W_2= Weight of beaker with air dried oleoresin (g)

The total phenol content was determined by Folin-Ciocalteau colorimetric method (Singleton *et al.*, 1999) with a little modification. For preparing standard gallic solution, gallic acid (10 mg) was dissolved in 10 ml of methanolto get concentration 1000 µg/ml. Various concentrations of gallic acid solutions (2, 4, 6, 8, 10 µg/ml) were prepared from the standard solution. A 5 ml solution of 10% Folin–Ciocalteau reagent (FCR) was added to 1 ml each concentration and blank solution (1 ml of methanol). After 8 minutes, 7% Na_2CO_3 (4 ml) was added to make a final volume of 10 ml. The solution was shaken well and kept in 40°C water bath for 30 minutes to remove precipitation in solution. The absorbance reading was measured at 760 nm against blank solution. The means absorbance values of different concentrations of gallic acid were used to plot the calibration curve (Figure 2). The samples were prepared the same way as standard where 10 mg of ginger extract obtained from Soxhlet extraction was dissolved in 10 ml of methanol. 0.5 ml of sample solution was diluted to 10 ml methanol. 1 ml sample solution was taken and 5 ml of 10% FCR was added. Similarly, 4 ml of 7% Na_2CO_3 was added after 8 minutes to make a final volume of 10 ml. The solution was shaken well and kept in 40°C water bath for 30 minutes and absorbance reading was measured at 760 nm using UV/VIS Spectrophotometer. All the observations were carried out in triplicates. The total phenol content in mg GAE/g was calculated by the formula (Oluyemi *et al.*, 2007),

$$C = c\frac{V}{m}$$

where C= total phenolic content mg GAE/g dry extract, *c* = concentration of gallic acid obtained from calibration curve in mg/ml, *V* = volume of extract in ml, and *m* = mass of extract in g.

All the quality analyses were carried out in three replications.

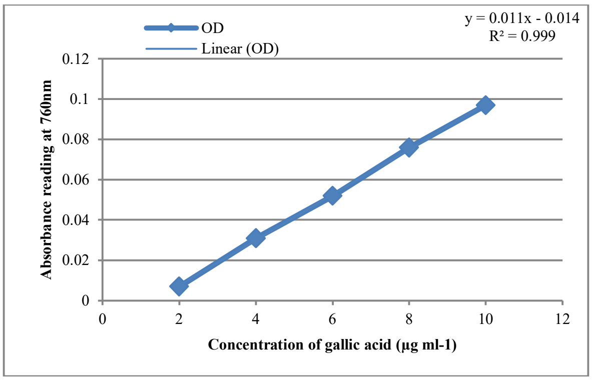


Figure 2: Standard graph for total phenol content

The pungency of ginger, 6-gingerol was determined from ginger extract obtained from solvent extraction using Soxhlet apparatus. 10 mg of ginger extract obtained from Soxhlet extraction was dissolved in methanol (100 ml) to get concentration 100 µg/ml. 5 ml was taken and volume was raised to 25 ml with methanol and the reading was taken at 282 nm wavelength using UV/VIS Spectrophotometer against methanol as blank. Percentage gingerol present in ginger extract was calculated from reference UV Spectra of Standard Gingerol (Shukla *et al.*, 2012). The mean data were statistically analysed using IBM SPSS Software, Version 26.

Economic analysis of ginger

In the Mizoram market, ginger is majorly sold in the form of fresh ginger for local consumption.

Cost of production: It was calculated by the summation of all the expenditures of variable cost items. These variable costs include cost of rhizomes, labour (land preparation, manure application, planting, intercultural operations, harvesting and other post-harvest activities), farm yard manure (FYM), fertilizer, herbicide, irrigation, insect-pest management, and disease management.

Benefit-cost analysis: The benefit-cost analysis was calculated using the total variable cost and gross returns from ginger production. The benefit-cost analysis was carried out by using the formula:

$$B:C\ Ratio = \frac{Gross\ return}{Total\ cost\ of\ production}$$

Where,
Gross return (in Rs) = Total quantity of ginger marketed (q) × price (per quintal) of ginger in Mizoram.
Total cost of production = Total variable cost *i.e.,* the total expenditure of all variables involved in production.

Results and Discussion

High yielding varieties are gaining importance to fill production gap as a result of growing population. The choice of low yielding landraces for mass cultivation has been attributed to the cause of unsatisfactory economic condition of ginger growers, despite ginger being an important cash crop of Mizoram (Soni *et al.*, 2022b). Even high yielding varieties may not reach their full potential across different locations. So, it has become important to evaluate the high yielding ginger genotypes under Mizoram condition to understand their performance capacity. The performance of eight ginger genotypes for growth, yield and quality parameters were observed and mean values for twelve important parameters were presented in Table 2. Plant height is an important determinant for rhizome yield in ginger. It is found to have significant positive correlated response to rhizome yield by Singh (2001) and Anargha *et al.* (2020). From our study, there is no significant variation in plant height among the genotypes at 80 DAS. The plant height exhibited an average value of 52 cm, ranging between 48.23 cm (PGS 95) to 57.30 cm (Gorubathani). Similar values in the range of 46.74 cm to 67.45 cm was reported by Abua *et al.* (2021). A more or less similar trend in plant height was also reported previously by Shadap *et al.*, (2013) and Islam *et al.* (2008). While slightly higher values in plant height was reported by Babu *et al.* (2019) under shade net condition. This may be the result of the genetic makeup of the genotypes, genotypic potential and availability of nutrients in the soil, which were influenced by low light intensity and high relative humidity condition under shade net situation (Amin *et al.*, 2010). Gorubathani exhibited 10.14% increase in plant height over Local ginger. LAI is an important parameter associated with yield of ginger. It helps in understanding photosynthesis, light interception, nutrient and water utilization, growth of crop and potential of yield (Smart, 1974; Williams, 1987). There was a significant difference among genotypes for LAI. Bold Nadia has significantly highest LAI (4.51) and 38.76% increment over Local ginger which was followed by PGS 121 (3.85) and Bhaise (3.74) while the lowest LAI (2.21) was recorded in PGS 95. More or less similar findings were also reported by Supriya *et al.* (2020), Babu *et al.* (2019) and Mahender *et al.* (2015) in different genotypes. Shadap *et al.* (2013) has reported higher LAI (12.64) in ginger planted in the month of June recorded which was closely followed by May planting (12.45) and the lowest LAI was recorded in March planted crops (3.50). The variation in LAI among the genotypes may be due to genotypic differences in terms of number of tillers and number of leaves per plant, interaction between genotypes and conducive environmental conditions. The number of leaves is an important determinant when selecting genotype for rhizome yield. The genotypes that have higher number of leaves per plant and produced more tillers gave the best rhizome yields (Chukwudi *et al.*, 2020). The genotype, Bold Nadia exhibited significant variation in number of leaves/hill (64.11) and 22.99% increment over Local ginger followed by PGS 102 (62.46) and PGS 121 (61.71). While lowest was recorded in PGS 95 for number of leaves/hill (44.96). A more or less similar results were reported by different researchers (Chukwudi *et al*., 2020; Lepcha *et al*., 2019). A high number of leaves/plant was recorded in the range of 166.56 to 245.16 (Babu *et al*., 2019) which may be due to relatively low temperatures combined with low light intensity that contributed to development of more chlorophyll in ginger plants grown in shade leading to higher number of leaves (Vastrad *et al*., 2006).The variation in number of leaves/hill among the genotypes may be due to differences in genetic constitution and genotypic potential of genotypes and interaction of genotypes with conducive environmental conditions. Bold Nadia exhibited highest significant number of tillers/plant (6.33) which has 5.56% increase over Local ginger followed by Bhaise (6.08). While lowest was recorded in PGS 95 for number of tillers/plant (4.08). The number of tillers is also an important yield contributing character in ginger, it influences the yield and mother rhizome as reported in ginger (Singh *et al*., 2009) and turmeric (Balakrishnamurty *et al.*, 2009; Singh, 2013). A more or less similar number of tillers/plant were also reported by Ridwansyah *et al.* (2020), Anargha *et al.* (2020) and Abua *et al.* (2021). The variation in number of tillers/plant may be due to genetic constitution of genotypes and interaction between genotypes and conducive environmental conditions.

Fresh weight of clump is an important trait as it has significant positive correlated response with the yield of rhizome. The fresh weight of clump has a mean value of 0.145 kg ranging from 0.097 to 0.178 kg. Bold Nadia has exhibited significantly highest fresh weight of clump (0.178 kg) followed by Gorubathani (0.168 kg) and PGS 102 (0.167 kg), which are having more weight to the range of 28.69, 21.83 and 21.14%, respectively over Local ginger. The fresh weight of rhizome/hill can reach upto 0.362 kg under partial shade condition in different genotypes (Bhuiyan *et al.*, 2012). The fresh weight of clump also has significant interaction with spacing and fertilizer treatment (Martini and Paramita, 2021). The variation among genotypes for traits may be the result of genetic constitution of genotypes, influence of environment on genotypes expression, insect pest and disease infections.Nowadays, the growing popularity of ginger as well as market demand is related to quality. Ginger has a wide range of uses in pharmaceutical and food industries due to its aroma, pungent taste and bioactive compounds. Many scientific researches have now focused not only on yield improvement of ginger but more on quality. Quality traits such as dry recovery, total chlorophyll content, total carotenoid content, total phenol content, 6-gingerol and oleoresin (Table 2) has mean values of 200.54 g/kg, 0.83 mg/g F.W, 0.16 mg/g F.W, 602.43 mg GAE/100 g, 1.85% and 4.84%, respectively. The dry recovery (g/kg) was significantly highest in Bold Nadia (242.86 g/kg) followed by PGS 102 (236.26 g/kg). Bold Nadia exhibited 26.36% more dry recovery than Local ginger. Dry recovery is an important parameter to identify genotypes with high biomass after drying. The genotypes suitable for processing into dry ginger should possess high dry recovery percentage. The total chlorophyll and total carotenoid contents varied from 0.66 mg/g F.W (John's ginger) to 1.07 mg/g F.W (Bold Naida, PGS 95) and 0.13 mg/g F.W (John's ginger) to 0.19 mg/gF.W (PGS 95), respectively. Bold Nadia and PGS 95 have 50.70% more total chlorophyll over Local ginger whereas Bold Nadia has 31.69% total carotenoid over Local ginger. Bold Nadia exhibited highest total phenol content (743.73 mg GAE/100g) which is 21.41% more than Local ginger and is at par with John's ginger while lowest was recorded in Gorubathani (430.12 mg GAE/100g) with an average of 602.43 mg GAE/100g among the genotypes. A more or less similar range of total phenol content in ginger extract was reported by Ezez and Tefera (2021). They have concluded higher phenolic content in ginger extract using methanol as solvent and least phenolic content using acetone extract. Hence, the choice of solvent extract used for determining the total phenolic content in ginger play an important role. The 6-gingerol content was 1.85% among the eight genotypes and ranging from 1.24 to 2.08%. Gorubathani exhibited significantly highest 6-gingerol content followed by PGS 102 (2.03%) and Bhaise (2.01%) while oleoresin content was significantly highest in Bold Nadia (9.06%) and minimum in Gorubathani (2.60%). The mean content of 6-gingerol obtained from the studied genotypes were found to be on par with results by

Table 2: Mean values for growth, rhizome yield and quality traits of genotypes of ginger

Genotypes	PH	LAI	NOL	NOT	FWC	DR	TC	TCA	TPC	6-GIN	OLR	YLD
Gurubathani	57.30[a]	3.19[bc]	58.85[ab]	5.29[ab]	0.17[ab]	195.63[ab]	0.75[cd]	0.15[abc]	430.12[d]	2.08[a]	2.60[g]	95.68[a]
Bold Nadia	50.24[a]	4.51[a]	64.11[a]	6.33[a]	0.18[a]	242.86[a]	1.07[a]	0.18[ab]	743.73[a]	1.87[cd]	9.06[a]	91.64[ab]
Bhaise	48.77[a]	3.74[ab]	57.51[ab]	6.08[a]	0.14[bc]	165.01[b]	0.71[de]	0.15[abc]	649.76[b]	2.01[ab]	6.81[b]	101.99[a]
John's ginger	54.03[a]	2.27[c]	44.97[b]	4.42[b]	0.12[cd]	174.46[c]	0.66[e]	0.13[c]	729.70[a]	1.75[d]	4.99[c]	67.42[c]
PGS 121	55.61[a]	3.85[ab]	61.71[ab]	5.92[a]	0.15[bc]	196.87[ab]	0.89[b]	0.14[bc]	598.00[c]	1.91[bc]	3.27[f]	85.02[abc]
PGS 95	48.23[a]	2.21[c]	44.96[b]	4.08[b]	0.10[d]	201.04[ab]	1.07[a]	0.19[a]	448.49[d]	1.94[bc]	3.46[f]	67.00[c]
PGS 102	49.78[a]	3.30[abc]	62.46[ab]	4.67[b]	0.17[ab]	236.26[bc]	0.81[bc]	0.14[bc]	607.06[bc]	2.03[ab]	4.03[e]	97.46[a]
Local ginger *cv* Thingria	52.03[a]	3.25[abc]	52.13[ab]	6.00[a]	0.14[c]	192.20[ab]	0.71[de]	0.14[abc]	612.57[bc]	1.24[e]	4.51[d]	70.12[bc]
Mean	52.00	3.29	55.84	5.35	0.145	200.54	0.83	0.16	602.43	1.85	4.84	84.54
Range	48.23-57.30	2.21-4.51	44.96-64.11	4.08-6.33	0.097-0.178	165.01-242.86	0.66-1.07	0.13-0.19	430.12-743.73	1.24-2.08	2.60-9.06	67.42-101.99

***Means with the same letter in each column are not significantly different at $p \leq 0.05$, Tukey's post hoc test.**
PH: Plant height @ 180 DAS (cm); LAI: Leaf area index @ 180 DAS; NOL: Number of leaves/hill@ 180 DAS; NOT: Number of tillers/plant @ 180 DAS; FWC: Fresh weight of clump at maturity (kg); DR: Dry recovery (g/kg); TC: Total chlorophyll content (mg/g F.W); TCA: Total carotenoid content (mg/g F.W); TPC: Total phenol content (mg GAE/100g); 6-GIN: 6-gingerol content (%); OLR: Oleoresin content (%); YLD: Yield of rhizome (q/ha)

Zhang *et al.* 1994. Crop duration is very important to get higher yield of oleoresin. Increased accumulation of oleoresin was reported with increased crop duration in ginger (Aggarwal *et al.*, 2002; Shadap *et al.*, 2013). Gorubathani exhibited 66.89% more 6-gingerol than Local ginger while Bold Nadia exhibited 101.11% more oleoresin than Local ginger. This variability may be the result of differences in genetic constitution among the genotypes from different regions, environmental effects such as climate, soil properties, and may also be the result of analytical methods and extraction processes. The yield of rhizomes varies from 67.00 q/ha(PGS 95) to 101.99 q/ha (Bhaise) which is 4.45% lower and 45.45% higher than Local ginger (70.12 q/ha). Yield variation may be due to genotypes, associated with congenial environment and soil properties. Also, incidence of rhizome rot has been a major concern in heavy rainfall region like Mizoram. Yield variation may also be the result of diseases especially rhizome rot caused by *Pythium aphanidermatum* that attacked during crop growth (Soni *et al.*, 2022a). Based on average values of different morphological, yield and quality traits, the four genotypes of ginger *viz.*, Bold Nadia, Bhaise, PGS 102 and Gorubathani can be selected as suitable genotypes for cultivation under Mizoram condition. For farmers to start commercial farming in order to support their livelihood, making a livable profit is crucial. Profitability can be significantly influenced both by internal factors like cultivation area, variety of crop, crop quality, quantity and external factors like cost of cultivation, price, market condition and public support price policy. The feasibility of these genotypes for commercial cultivation under Mizoram condition is important to understand. The economics of ginger cultivation under Mizoram condition was estimated for an area of one hectare and based on prevailing costs of crop and labour hiring in the region. In this study, the cost of cultivation of ginger per hectare area was estimated to be Rs. 1,77,207 (Table 3). This cost of cultivation includes rhizome cost, labour cost, FYM cost, fertilizer cost, herbicide cost, irrigation cost, insect and pest management cost and disease management cost. Among these variables, highest cost was incurred for labour (Rs. 94,620), which was found to be 53.40% of total cost of cultivation. In regions like Mizoram, machine power is rarely used due to the undulating topography which do not allow use of machinery for different field operations. So, the main resort is man power to handle all field operations, which is one of the major reasons to why human force contributed to major cost of cultivation. Also, the use of machines increases work efficiency resulting in greater output. Other cost variables include rhizome cost (25.39%), FYM cost (11.29%), fertilizer cost (3.77%), disease management cost (2.45%), insect and pest management cost (2.26%), irrigation cost (0.65%) and herbicide cost (0.81%). Seed cost had contributed upto 25% (Ewuziem and Onyenobi, 2012), 30.38% (GOK, 2011), 46% (USAID, 2011) and 65.10% (Poudel *et al.*, 2017) in several studies by researchers while percentage of cost share observed on human labour and organic manure was 15.3% and 10.5% respectively (Poudel *et al.*, 2017).

Table 3: Economics of ginger cultivation

Cost of production		
Variable costs	**Amount**	**% Share in total cost of production**
Rhizome cost	45,000	25.39
Labour cost	94,620	53.40
FYM cost	20,000	11.29
Fertilizer cost	6,681	3.77
Herbicide cost	1,431	0.81
Irrigation cost	1,130	0.64
Insect pest management cost	4,000	2.26
Disease management cost	4,345	2.45
Total cost of production/ha	1,77,207	100
Genotypes	**Gross return (in Rs.)**	**B:C Ratio**
Gurubathani (Pundibari)	3,46,445	1.95
Bold Nadia (Nagaland)	3,31,841	1.87
Bhaise (Sikkim)	3,69,306	2.08
John's ginger (IISR)	2,44,128	1.38
PGS 121 (Pottangi)	3,07,870	1.74
PGS 95 (Pottangi)	2,42,607	1.37
PGS 102 (Pottangi)	3,52,891	1.99
Local ginger *cv* Thingria (Mizoram)	2,53,905	1.43

As seed cost also contributed a major share of the cost of cultivation, pro-tray technology has been proved to be useful. The yield of ginger from pro-tray technology was on par with conventional planting system with a benefit cost ratio of 2.98 over 1.08 in conventional system of planting (Shil *et al.*, 2018). Based on wholesale price of ginger in Mizoram (*i.e.,* Rs. 3621/q; Economic Survey Mizoram, 2020), the gross return from ginger production is Rs. 3,69,306 (Bhaise), Rs. 3,52,891 (PGS 102), Rs. 3,46,445 (Gorubathani) and Rs. 3,31,841 (Bold Nadia) which gives 45.45, 38.99, 36.45 and 30.70% increment, respectively over Local ginger (Rs. 2,53,905). The benefit-cost ratio was highest for Bhaise (2.08) followed by PGS (1.99), Gorubathani (1.95) and Bold Nadia (1.87), which indicated that the cultivation of these genotypes will be profitable under Mizoram condition. Similar findings of profitability in ginger production were also reported (Poudel *et al.*, 2017; Acharya *et al.*, 2019). The lowest benefit cost ratio was obtained in PGS 95 (1.37). The higher profitability of a genotype is the result of variation in rhizome productivity with highest in Bhaise (101.99 q/ha) and lowest in PGS 95 (67.00 q/ha). This clearly showed the importance of choosing high yielding suitable genotypes of ginger for cultivation along with optimization of farm resources to get maximum revenue from ginger cultivation in Mizoram. Correlation analysis is important to understand the relationship between dependent and independent variables as selection of one trait can have correlated response in many other traits (Table 4). The correlation between yield of rhizome and all other traits (plant height, LAI, number of leaves/hill, number of tillers/plant, fresh weight of clump, dry recovery, total chlorophyll, total carotenoid, total phenol content, 6-gingerol content, oleoresin content) have shown that the yield of rhizome has highest positive significant correlation with fresh weight of clump (0.707**) followed by 6-gingerol content (0.522**). An increase in the fresh weight of clump and 6-gingerol content will increase the yield of rhizome. Fresh weight of clump also exhibited positive significant correlation with dry recovery. LAI has significant positive correlation with number of leaves/hill, number of tillers/plant, fresh weight of clump and oleoresin content. Number of leaves/hill and number of tillers/plant also has significant positive correlation with fresh weight of clump. Dry recovery with total chlorophyll content of leaf, total chlorophyll content of leaf with total carotenoid content of leaf and total phenol content with oleoresin content exhibited positive significant correlation. Hence, the two traits *viz.*, fresh weight of clump and 6-gingerol content are considered as an important selection indicator for yield improvement of rhizome in ginger. Ginger based intercropping system offers higher yield and income as a result of synergistic effects between the crops. The finding shows that ginger intercropping with papaya, taro, sweet corn, maize and other leguminous crops increase crop equivalent yield upto 30% over sole ginger yield. One finding has reported the benefit–cost ratio to be as high as 2.28

Table 4: Correlation of yield and quality attributes with yield of rhizome

Characters	PH	LAI	NOL	NOT	FWC	DR	TCHL	TCA	TPC	GIN	OLR	YLD
PH	1	0.174	0.274	0.014	0.166	-0.190	-0.267	-0.255	-0.140	-0.001	-0.362	-0.211
LAI		1	0.913**	0.552**	0.619**	0.292	0.189	0.273	0.305	0.099	0.456*	0.343
NOL			1	0.262	0.574**	0.307	0.117	0.284	0.096	0.254	0.171	0.292
NOTI				1	0.491*	0.114	-0.018	-0.052	0.353	-0.210	0.479*	0.392
FWC					1	0.432*	-0.013	-0.046	0.219	0.257	0.304	0.707**
DR						1	0.563**	0.179	0.064	0.158	0.179	0.173
TCHL							1	0.641**	-0.149	0.265	0.223	-0.065
TCA								1	-0.205	0.161	0.225	-0.080
TPC									1	-0.273	0.759**	0.026
GIN										1	-0.073	0.522**
OLR											1	0.229
YLD												1

****, Significant at the 0.01 level; *, Significant at the 0.05 level**

in banana + ginger mixture (Regeena and Kandaswamy, 1987), 3.22 in cowpea + ginger mixture (Baruah and Deka, 2019) and 2.04 in mango + ginger mixture (Rajesh *et al*., 2019). One of the major constraints the farmers are facing is marketing of ginger during glut season. Excess rhizomes during glut season can be utilized as seed rhizomes for off-season harvest while leaving the finger rhizomes as planting material for uniform harvest during the main season. This practice called bulb (mother rhizome) extraction, is a traditional practice by the farmers in Mizoram. In this practice, the seed rate can be increased by 1 tonne against the normal seed rate (1.2 - 1.5 t/ha) and planted in the month of March-April. After two months of sowing (May-June) at 3-4 crop leaf stage, the mother rhizomes (about 1 tonne) can be extracted while the sprouted finger rhizomes can be put back in soil to grow. Extraction of rhizome done at later stages *i.e*., 90 and 120 DAS resulted in 20.85 and 32.89%, respectively of mother rhizome losses due to rotting of rhizomes. So, the best time for operation of this method is two months (60 DAS) to get optimum and healthy bulbs. Vermicompost or well decomposed farm yard manure can be applied after 15 days of bulb extraction. During the off-season, farmers can earn around Rs. 40,000 per hectare (Rs. 40/kg ginger rhizome) without significantly affecting main crop yield. Market constraints is another factor that diminished the interest of ginger cultivation. Government intervention has taken place in the past several times to regulate marketing of ginger, but to no avail till today. Introduced marketing guidelines were used to a more or less fresh plan. Since that time, the role served by the government in the marketing of ginger has diminished to that of a promoter rather than a legislator. With ginger cultivating in most parts of Mizoram, public intervention has become important more than ever to protect the farmers from exploitation and market risks. Market constraints is intertwined with no storage facilities or infrastructures. In order to profit from momentary price swings, farmers are unable to seize opportunities for efficient marketing and price speculation. Farmers dispose their fresh goods at any prices and through any marketing channels since they lack storage facilities to wait for excellent selling opportunities. Farmers need to make use of the technologies that are readily available as many research institutions have developed low-cost storage technologies using locally available materials. In such cases, state departments, ICAR institutions, KVKs, NGOs, SHGs and other private agencies are always available for contact and enquiry. Farmers need to upgrade from traditional practices to problems driven solutions and new technologies to make the best use of these institutions. Farmers can also explore the possibilities of processing ginger into processed products such as dry ginger, ginger candy, ginger paste, ginger powder, ginger wine, *etc*. and high-end products like oleoresin, ginger oil, *etc*. which offers great scope that have not yet been fully tapped in this region. Processed products open new opportunities for commercialization of ginger and farmers need to be encouraged to take up this venture. Mizoram contributes only 2.7% of total ginger production in India which is still very low. The climate and land suitability for ginger cultivation is in no doubt excellent in Mizoram, and quality of produce possesses unique characteristics. Ginger have been considered an important cash crop due to its extensive cultivation across the state and marketing within and outside the state. It is crucial to identify, evaluate and analyse the weaknesses and threats associated with ginger cultivation to strengthen and grab the opportunities for production so that farmers could be aware of ginger enterprise and necessary developments can be taken on time.

Therefore, the strength, weaknesses, opportunities, and threats (SWOT) tool was used in this context. The strengths for ginger production in Mizoram include ginger as an important source of income and employment to farmers. It requires less care and rainfed crops also give bumper harvest. It is the major spice in Mizoram and 3rd in production among all horticultural crops. Mizoram also offers suitable climate and as a result, quality of produce has been improved. There is vast potential area available under horticultural crops. Moreover, the cooperatives and farmer's group are involved in the production of ginger. Ginger being less perishable than other crops is an important takeaway to the strengths of ginger production. Major factor contributing to its weakness is that farmers, mostly resource poor, practise subsistence farming and traditional production system such as Jhum cultivation over scientific cultivation methods. There is no credit system for production, so farmers do not afford high capital investment required to purchase the rhizome seeds. Lack of proper marketing channels and infrastructures also leads to disruption in production. Storage facilities and infrastructures for processing are also insufficient in the state. Post-harvest handling is rarely done, and poor packaging of ginger and its products are common. Lastly but crucially, there is little co-operation from the government. There are various opportunities of ginger production in the state such as adoption of high yielding varieties that boost the production and yield per unit area of ginger, increasing demand of Mizo ginger for their quality and wide options for value addition as a new venture. Organic cultivation of ginger in Mizoram offers a great scope for sustainable farming and presently, government initiatives support the growth of horticulture including ginger. Rhizome rot, a devastating disease is prevalent in the state and poses a great threat to producers. The incidence of diseases and pests discourage farmers to cultivate ginger on a large scale. High price fluctuation, improper marketing channels, uncertain external trade and slow growth of development in infrastructures leave ginger production in Mizoram in a vulnerable state.

Conclusion

Careful selection of high-yielding genotypes with superior quality for cultivation is of paramount importance for increased production. The four genotypes *viz*., Bold Nadia, Bhaise, PGS 102 and Gorubathani possess optimum combinations of yield and quality traits, and based on economic analysis, these genotypes can be considered for commercial purposes under Mizoram condition. Farmers should be aware of the variety of ginger they grow especially on commercial basis to improve productivity of ginger. The potential of high yielding varieties possessing good quality traits and disease resistance are needed to be realised for the benefit of the farmers. High labour cost for commercial production of ginger can be minimized by choosing right farm tools and mechanization. Ginger based intercropping system can be followed to achieve higher net return. Ginger processing to develop novel products will open new market opportunities for many farmers in Mizoram. Hence, ginger cultivation for commercial purpose is still a viable option for income generation in Mizoram and mass cultivation of high yielding genotypes will boost productivity in the state of Mizoram. Government training and extension programmes on ginger cultivation should be improved. Government intervention is really important for this crop for price regulation and marketing channels. This will attract more farmers to cultivate this important crop without fear of risk factors involved in cultivation. The development of policies and initiatives should focus on encouraging youth to pursue ginger farming is necessary. It is occasionally necessary to provide skill training for farmers, agribusiness owners, extensionists, and others to keep up with evolving technologies. Considering the quality, suitability, economics, strengths, and opportunities for ginger cultivation in Mizoram, more farmers need to take up ginger cultivation as a viable income source.

Acknowledgement

The authors extended gratefulness to Director, ICAR Research Complex for NEH Region, Umiam, Meghalaya for providing all kinds of support to conduct field experiments. Also, we express our sincere gratitude towards AICRP on Spices (OXX02244) for providing financial support and ginger genotypes.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Abua, M. N., Iwo, G. A., Ittah, M. A., Obok, E. E., & Edugbo, R. E. (2021). Growth and yield performance of mutant ginger (*Zingiber officinale* Rosc.) lines in South-Eastern Nigeria. *Journal of Applied Biology and Biotechnology*, *9*(5), 110-123.

Acharya, N., Acharya, B., Dhungana, S. M., & Bist, V. (2019). Production economics of Ginger (*Zingiber officinale* Rose.) in Salyan district of Nepal. *Archives of Agriculture and Environmental Science*, *4*(4), 424-427.

Afzal, M., Al-Hadidi, D., Menon, M., Pesek, J., & Dhami, M. S. (2001). Ginger: an ethnomedical, chemical and pharmacological review. *Drug Metabolism and Disposition*, *18*, 159–190.

Aggarwal, S., Korla, B. N., & Sharma, V. (2002). Effect of dates of planting and mulch materials on growth and yield of ginger (*Zingiber officinale* Rosc.). *Haryana Journal of Horticultural Science*, *31*(1 & 2), 108-110.

Amin, M. R., Ikbal, T. M. T., Miah, M. M. U., Hakim, M. A., & Manullah, A. S. M. A. (2010). Performance of ginger under agroforestry system. *Bangladesh Research Publication*, 4, 208-217.

Anargha, T., Sreekala, G. S., Nair, D. S., & Abraham, M. (2020). Genetic variability, correlation and path analysis in ginger (*Zingiber officinale* Rosc.) genotypes. *Journal of Tropical Agriculture*, 58(2), 168-178.

Anonymous (2021a). Selected state-wise area, production and productivity of Ginger in India. Indiastat. Retrieved on October 10, 2022 from https://www.indiastat.com/table/ginger/selected-state-wise-area-production-productivity-g/1220749#.

Anonymous (2021b). Sate-wise area, production and productivity of ginger in North East India (2022-21). Retrieved on October 10, 2022 from https://www.indiastat.com/table/north-east-region/ginger/selected-state-wise-area-production-productivity-g/1220749.

AOAC (1975). *Official methods of analysis.* Association of official Agricultural Chemists, Washington, D.C. Babu, M. S., Kumar, B. P., Swami, D. V., Krishna, K. U., & Emmanuel, N. (2019). Impact of shade net condition on growth, rhizome and yield characters of ginger. *Journal of Pharmacognosy and Phytochemistry*, *8*(3), 3481-3485.

Babu, M. S., Kumar, B. P., Swami, D. V., Krishna, K. U., & Emmanuel, N. (2019). Impact of shade net condition on growth, rhizome and yield characters of ginger. *Journal of Pharmacognosy and Phytochemistry*, 8(3), 3481- 3485.

Balakrishnamurty, G., Kamal, K. R., & Prabu, T. (2009). Standardization of organic manures and bioregulants for organic production of turmeric (*Curcuma longa* L.). In: Selvan, M. T., Cheriyan, H., Manoj, K. and Meena, B. (Eds.), *Production Technology for Organic Spices*. Directorate of Arecanut and Spices Development, Calicut, Kerala, India. pp. 123–30.

Baruah, A., & Deka, J. (2019). Effect of inter-cropping and weed management on the economics of ginger production. *International Journal of Current Microbiology and Applied Sciences, 8*(10), 2275-2281.

Bhuiyan, M. M., Roy, S., Sharma, P. C., Rashid, M. H., & Bala, P. (2012). Impact of multistoried agro-forestry systems on growth and yield of turmeric and ginger at Mymensingh, Bangladesh. *Crop Production*, *1*(1), 19-23.

Chukwudi, U. P., Agbo, C. U., Echezona, B. C., Eze, E. I., Kutu, F. R., & Mavengahama, S. (2020). Variability in morphological, yield and nutritional attributes of ginger (*Zingiber officinale*) germplasm in Nigeria. *Research on Crops*, *21*(3), 634-642.

Ewuziem, J. E., & Onyenobi, V. O. (2012). Cost and return analysis of ginger production in the Guinea Savannah of Nigeria. *The Journal of Agriculture and Food Sciences*, *10*(2), 26-36.

Ezez, D., & Tefera, M. (2021). Effects of solvents on total phenolic content and antioxidant activity of ginger extracts. *Journal of Chemistry*, *1-5*.

GOK (2011). *Report on cost of cultivation of important crops in Kerala 2010-11*. Government of Kerala. Department of Economics & Statistics. Thiruvananthapuram.

Hiscox, J. D., & Israelstam, G. F. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany*,*57*(12), 1332-4.

Islam, K. M., Islam, A. K. M. A., Rasul, M. G., Sultana, N., & Mian, M. A. K. (2008). Genetic variability and character association in ginger (*Zingiber officinale* Rosc.). *Annals of Bangladesh Agriculture,* 12(1), 21-26.

Lepcha, B., Avasthe, R., Singh, R., Singh, N. J., & Phukan, P. (2019). Effect of organic nutrient sources on productivity, profitability and quality of ginger (*Zingiber officinale*) in acid soils of Eastern Himalayas. *Indian Journal of Agricultural Science*, *89*(7), 1103-7.

Mahender, B., Reddy, P. S. S, Sivaram, G. T., Balakrishna, M., & Prathap, B. (2015). Effect of seed rhizome size and plant spacing on growth, yield and quality of ginger (*zingiber officinale* Rosc.) under coconut cropping system. *Plant Archives*, *15*(2), 769-774.

Martini, D. K. T., & Paramita, D. P. R. (2021). The effect of planting distance and Bokashi from several types of organic fertilizers on the growth and yield of elephant ginger variety (*Zingiber Officinale* var. Roscoe). *Agriculture and Food Sciences Research*, *8*(1), 10-14.

Oluyemi, K. A, Okwuonu, U. C, Baxter, D. G., & Oyesola, T. O. (2007). Toxic effects of methanolic exract of *Aspiliaafricana* leaf on the estrous cycle and uterine tissues of Wistar rats. *International Journal of Management*, *25*(3), 609–614.

Poudel, R. R., Regmi, P. P., Thapa, R. B., Gc, Y. D., & Kc, D. B. (2017). Economic analysis of ginger cultivation in selected locations of Nepal. *Bangladesh Journal of Agricultural Research*, *42*(4), 681-691.

Rajesh, K., Suleman, M., & Amit, K. (2019). Studies on intercropping of turmeric and ginger in mango orchard. *Annals of Biology*, *35*(2), 225-228.

Regeena, S., & Kandaswamy, A. (1987). Economics of ginger cultivation in Kerala. *South Indian horticulture*, *40*(1), 53–56.

Ridwansyah, Y., Yusraini, E., Rahmawati, N., & Harahap, M. S. M. (2020). Growth performance of three ginger (*Zingiber officinale* Rosc.) varieties in crate system. In: Proceedings of the International Conference of Science, Technology, Engineering, Environmental and Ramification Researches (ICOSTEERR 2018), Research in Industry 4.0, pp. 132-135.

Shadap, A., Hegde, N. K., & Pariari, A. (2013). Performance of ginger var. Humnabad as influenced by planting dates under northern dry zone of Karnataka. *The Bioscan*, *8*(1), 131-133.

Shil, S., Nath, D., & Mondal, J. (2018). Effect of propagation methods on yield attributes and economics of ginger production under agro-climatic condition of Tripura. *International Journal of Current Microbiology and Applied Sciences*, *7*(5), 3790-3793.

Shukla, S. S., Saraf, S., & Saraf, S. (2012). Development and Validation of spectrophotometric fingerprint method of 6-gingerol in herbal formulation: *Talisadi Churna*. *Research Journal of Pharmacy and Technology*,*5*(1), 138-140.

Singh, A. K. (2001). Correlation and path analysis for certain metric traits in ginger. *Annals of Agricultural Research*, 22, 285–286.

Singh, S. P. (2013). Response of different combination of organic manures for production of turmeric (*Curcuma longa* L.). *Journal of Eco-friendly Agriculture, 8*, 35–8.

Singh, S. P., Chaudhary, R., & Mishra, A. K. (2009). Effect of different combination of organic manures on growth and yield of ginger (*Zingiber officinale* Rosc). *Journal of Eco-friendly Agriculture, 4*, 22–4.

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In: *Methods in enzymology*, *299*, 152-178.

Smart, R. E. (1974). Photosynthesis by grapevine canopies. *Journal of Applied Ecology*, *11*(3), 997–1006.

Smith, C., Crowther, C., Willson, K., Hotham, N., & McMillian, V. (2004). A randomized controlled trial of ginger to treat nausea and vomiting in pregnancy. *Obstetrics & Gynecology*, *103*(4), 639-645.

Soni, J. K., Dayal, V., Sunani, S. K., Lalramhlimi, B., Lungmuana & Shakuntala, I. (2022a). Performance of ginger genotypes on growth, yield and quality traits under Mizoram condition. *Indian Journal of Hill Farming*, *35*(1), 106-114.

Soni, J. K., Lalramhlimi, B., & Shakuntala, I. (2022b). Ginger cultivation in Mizoram: status, constraints, sustainable approaches and prospects. In Book Advances in Agricultural, Animal and Fisheries Sciences. Znan Publishers, Society for Technology, Environment, Science & People Kozhikode, India. (ISBN: 978-81-956227-2-6). pp: 47-58.

Supriya, G. S., Bhoomika, H. R., Ganapathi, M., Nataraj, S. K., & Ravi, C. S. (2020). Effect of different media and nutrients on growth and yield of ginger (*Zingiber officinale* Rosc.) in soilless culture under protected structure. *Journal of Pharmacognosy and Phytochemistry*, *9*(6), 2004-2007.

USAID (2011). Value chain/market analysis of the ginger sub-sector. Nepal economic agriculture and trade activity-USAID. General development office, Kathmandu, Nepal. p. 8.

Utpala, P., Johny, A. K., Parthasarathy, V. A., Jayarajan, K. & Madan, M. S. (2006). Diversity of ginger cultivation in India-a GIS study. *Journal of Spices and Aromatic Crops*,*15*(2), 93-99.

Vastrad, N. V., Hegde, R. V., & Girtammanavar, V. A. (2006). Effect of light intensity and vermicompost and yield of ginger. *Karnataka Journal of Agricultural Sciences*, *19*, 941-945.

WHO (1999). World Health Organization. *WHO Monographs on Selected Medicinal Plants*; World Health Organization: Geneva, Switzerland, *1*, 277-287.

Willetts, K. E., Ekangaki, A., & Eden, J. A. (2003). Effect of a ginger extract on pregnancy-induced nausea: a randomised controlled trial. *The Australian and New Zealand Journal of Obstetrics and Gynaecology*,*43*, 139-144.

Williams, L. E. (1987). Growth of Thompson Seedless grapevines: I. Leaf area development and dry weight distribution. *Journal of the American Society for Horticultural Science*, *112*(2), 325–330.

Yoshida, S. (1976). Routine procedure for growing rice plants in culture solution. In: Yoshida, S., Forno, D. A. and Cock, J. H. (Eds.), *Laboratory Manual for Physiological Studies of Rice,* International Rice Research Institute, Los Baños, pp. 61-66.

Zhang, X., Iwaoka, W. T., Huang, A. S., Nakamoto, S. T., & Wong, R. (1994). Gingerol decreases after processing and storage of ginger. *Journal of Food Science*, *59*, 1338.

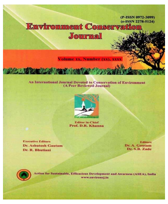
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 199-208, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Characterization of soils under different periods of eucalyptus cultivation and restoration in Malur and Hoskotetaluks of Karnataka, India

Haravina Manjunathaswamy Pruthvi Raj
Chief Minister's Natural Farming Project, Zonal Agricultural and Horticultural Research Station, Brahmavara, Karnataka, India
Belavadi Nanjappa Dhananjaya ✉
Department of Natural Resource Management (Soil Science and Agricultural Chemistry), College of Horticulture, Kolar, Karnataka, India
Bommalingaianapalya Narasahanumaiaha Maruthi Prasad
Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Bengaluru, Karnataka, India
Ramapatna Lakshmaiah Raghunatha Reddy
Regional Horticultural Research and Extension Centre, Bengaluru, Karnataka, India
Thyavanahally Hanumaiah Shankarappa
Department of Natural Resource Management (Agricultural Microbiology), College of Horticulture, Bengaluru, Karnataka, India

ARTICLE INFO

Received : 27 November 2022
Revised : 26 February 2023
Accepted : 06 March 2023

Available online: 27 June 2023

Key Words:
Croplands
Eucalyptus plantation
Fertility status
Restored lands
mg/m^3 = mega gram per cubic meter

ABSTRACT

Considerable area under eucalyptus plantation in the form of farm forestry exists in Malur and Hoskotetaluks of Karnataka, India. But in the recent years, Government of Karnataka has checked the spread of eucalyptus and farmers are gradually converting their eucalyptus plantations into agricultural lands. This study was aimed to evaluate soils of eucalyptus during growing and after restoration and its adjacent croplands having no history of eucalyptus cultivation in Taluks of Malur and Hosakote, Karnataka for physico-chemical properties and evaluated during the year 2019-2020 at College of Horticulture, Kolar. The results revealed that soils under 12, 24 and 48 years of eucalyptus cultivation when compared to soils after two, six and ten years of restoration and adjacent soils, showed significantly high bulk density (1.28 to 1.51 Mg/m^3) and low water holding capacity (30.30 to 45.61%). These soils were more acidic in reaction (pH: 6.21 to 6.65) and contained significantly lower amounts of total soluble salts (EC: 0.04 to 0.07 dS/m), organic carbon (OC: 0.24 to 0.59%), available N, P_2O_5 and K_2O (163.07 to 235.42, 26.03 to 47.23 and 112.89 to 168.55 Kg/ha, respectively), exchangeable Ca and Mg (1.70 to 2.75 and 0.80 to 1.32 cmol (p$^+$)/Kg, respectively) and available S (5.60 to 7.09 ppm) but contained significantly high amounts of available Fe, Mn, Zn and Cu (13.52 to 29.74, 14.06 to 20.14, 1.44 to 2.06 and 1.16 to 1.74 ppm, respectively). Further, bulk density, acidity and available micronutrient cations of soils tends to increase with prolonging the cultivation period of eucalyptus while, reverse trend was observed with respect to water holding capacity, organic carbon and available macronutrients contents. On the other hand, restored plots showed significantly decreased acidity, bulk density and available micronutrient cations and increased water holding capacity and macronutrients contents with increasing the restoration period.

Introduction

Eucalyptus trees are the most dominated species of the natural forests growing in a range of diverse climates and in all types of soils. Eucalyptus is indigenous to Australia with genus covering more than 700 species belonging to the family Myrtaceae and subfamily Myrotideae and its life span is about more than 250 years. Eucalyptus is commonly known by different names such as 'nilgiri tree', 'iron bark', 'string bark', 'mountain ash' and 'gum tree'. In Karnataka, it is commonly called as 'Mysore gum' because it exudes copious sap from any cut in the bark (Coppen and Hone,

Corresponding author E-mail: *bndssac@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16382421

1992).Eucalyptus was introduced in many countries owing to its fast growth and raises its demand for paper and plywood (Cossalter and Pye-Smith, 2003). It was introduced to India as an ornamental tree in the late 18th century by the ruler of Mysore 'Tippu Sultan' in Karnataka. He planted about sixteen species of eucalyptus on Nandi hills of Karnataka during the period 1782-1802 (Shyam Sunder, 1979). Subsequent to the planting at Nandi hills, the next significant introduction of eucalyptus was in the Nilgiri hills, Tamil Nadu, in 1843 and large-scale plantation of eucalyptus in Mysore district was raised from seeds collected from plants grown in the Chikkaballapur range near the Nandi hills. Eucalyptus was promoted as a profitable, no maintenance and low investment crop in cultivated land. Karajagi *et al.* (2009) have documented an area of 2.1 lakh hectares of eucalyptus in Karnataka. But in the recent years, Government of Karnataka has checked the spread of eucalyptus and its latest notification in January 2011, its cultivation was banned in Western Ghats of the state due to reported loss of soil fertility.Eucalyptus tree has special characters like fast growth, inability to fix atmospheric nitrogen in soil, resistance mechanism to severe periodic moisture stress and low soil fertility due to xeromorphic leaves (structural modifications that enable the reduction of water loss) and have specialized nutrient supplying symbiotic fungi, ectomychorrhizae that can greatly increases the rate of nutrient uptake. Being fast growing, eucalyptus also use more amounts of nutrients and water from the soil in comparison to slow-growing species. Some studies have reported that monoculture of eucalyptus plantation may affect soil fertility but ultimate impacts of eucalyptus plantation on agriculture land remains fiercely debated. Therefore, physicochemical properties of soils under different coppiced eucalyptus plantations and converted agricultural lands were evaluated. This would give a clear status of eucalyptus with respect to fertility and sustenance of soils for its continuous cultivation, diversification or possible restoration requirements.

Material and Methods

Site description

Malur taluk was situated between 13.28^0 N latitude and 77.60^0 E longitudes with an altitude of 900 m above mean sea level (MSL). The average rainfall of this region is 751 mm and the mean maximum and minimum temperatures recorded were 34 and 15ºC, respectively. While, Hoskote taluk was situated between 13.17^0 N latitude and 78.20^0 E longitudes with an altitude of 849 m above mean sea level. The average rainfall of this region is 724 mm with a large spatial and temporal variability and the mean maximum and minimum temperatures recorded were 31.6 and 19.9ºC, respectively.

Collection of surface soil samples

Considerable area under eucalyptus plantation in the form of farm forestry exists in Malur and Hoskote taluks of Karnataka. Twelve eucalyptus plantations were selected on the basis of number of coppiced or age from each taluk apportioned four each into two (12 years), four (24 years) and eight (48 years) coppiced plantations. Besides, twelve agricultural lands converted from eucalyptus plantation from each taluk were selected apportioned four each into two, six and ten years of restoration. In addition to this, four adjacent croplands from each taluk having no history of eucalyptus cultivation were selected. Thus, a total of 28 surface soil samples (0-15 cm) from each taluk were collected and processed for analysis as described by Jackson (1973).

Analysis

The collected soil samples were analyzed for various physical properties *viz.*, soil texture, bulk density and maximum water holding capacity and chemical properties *viz.*, pH, EC, organic carbon and available primary, secondary and micronutrient cations status. The soil textural class was identified using USDA equilateral textural triangle after per cent sand, silt and clay particles were determined by Bouyoucos hydrometer method as described by Bouyoucos (1962). The bulk density (BD) and maximum water holding capacity (MWHC) of soil were determined by using Keen's cup as outlined by Piper (2019). Soil pH was estimated in 1 : 2.5 soil - water suspension using calibrated pH meter, while the electrical conductivity (EC) of the supernatant was measured by using conductivity meter (Jackson, 1973). Organic carbon was determined by following wet-oxidation method (Walkley and Black, 1934). Available nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus content of soil was extracted with either

Bray's extractant-I or Olsen's extractant depending on pH of the soil and determined by spectrophotometric method (Jackson, 1973). Available potassium was determined flame photometrically using neutral normal ammonium acetate extractant as described by Jackson (1973). Exchangeable calcium and magnesium contents of soil were extracted with neutral normal ammonium acetate extractant and estimated by complexometric titration method as outlined by Hesse (1971). Available sulphur was extracted with 0.15 per cent $CaCl_2$ solution and estimated by turbidometric method as explained by Jackson (1973). The available micronutrient cations *viz.,* iron, manganese, zinc and copper were simultaneously extracted with DTPA extractant as explained by Lindsay and Norvell (1978) and were estimated using Atomic Absorption Spectrophotometer (AAS) with suitable hallow cathode lamp and measuring conditions. The data obtained during the course of study were analyzed using standard statistical procedure and independent T-test was performed for all data to assess the differences. The statistical significance was determined at $p<0.05$ (Panse and Sukhatme, 1989).

Results and Discussion

Physical properties

The soils of all sites under different cultivation periods of eucalyptus plantation and restoration were sandy clay loam in texture at Malur taluk and sandy loam at Hoskote taluk (Table 1). However, soils under cropland plots were sandy loam at Malur taluk and loamy sand at Hoskote taluk. Soil texture mainly depends on primary soil fractions present in site. The proportion of primary soil particles such as sand, silt and clay particles in a given soil (soil texture) cannot be easily altered and hence, it is considered as a basic property of a site. However, significantly lowest clay content was noticed in soils of cropland plots at both Malur and Hoskote taluks (16.84 and 12.16%, respectively). This might be due to intensive cultivation of cropland soils coupled with less quantity of organic manure application that might have resulted in destruction of soil structure followed by eluviation of clay particles from surface to lower layer of soil during heavy rain. On the other hand, clay content of soil under eucalyptus plantation and restoration was relatively high compared to cropland soils at both the taluks studied. This might be attributed to accumulation of leaf litter under eucalyptus plantation and restored lands coupled with less cultivation that might have protected the surface soil. These observations are in accordance with the observations made by Balamurugan *et al*. (2000). Alem *et al*. (2010) observed the significantly higher percentage of clay in soils collected from *Eucalyptus grandis* plantation than that of the adjacent native sub-mountain rain forest in Ethiopia.The bulk density of soil differed significantly due to prolonging the cultivation period of eucalyptus plantation and restoration (Table 1). The examination of data revealed that the soils under fourty eight years old eucalyptus plantation had significantly highest bulk density of 1.51 and 1.38 Mg/m^3 at Malur and Hoskote taluks, respectively. On the other hand, cropland plots had significantly lowest bulk density of 1.28 and 1.26 Mg/m^3 at Malur and Hoskote taluks, respectively. In general, the bulk density of soils under different cultivation periods of eucalyptus plantation ranged from 1.29 to 1.51 Mg/m^3 at Malur taluk and 1.28 to 1.38 Mg/m^3 at Hoskote taluk and was found to increase with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, bulk density of soils under different periods of restoration ranged from 1.28 to 1.37 Mg/m^3 at Malur taluk and 1.27 to 1.30 Mg/m^3 at Hoskote taluk and was found to decrease with prolonging the period of restoration at both the taluks studied. Bulk density of soil might be affected by soil texture, soil structure, soil porosity, soil compaction, soil organic matter content, soil depth, tillage operation and nature of crop grown. In general, fine textured soils usually have lower bulk density than coarse textured soils. Even though soils of eucalyptus and restored plots at both the taluks contained relatively more amount of clay particles as compared to cropland plots still showed higher bulk density values. This might be due to the fact that sparse undergrowth vegetation in eucalyptus plantation due to its allelopathic effects and very high water utilization rate by eucalyptus tree with respect to its unit biomass production that leads to drying up of water from the site of eucalyptus plantation and forms high soil compaction on top soil.

Table 1: Physical properties of surface soils under different periods of eucalyptus cultivation and restoration

Description	Age (Years)	Particle size distribution (%)			Textural class	BD (Mg/m^3)	MWHC (%)
		Sand	Silt	Clay			
Malur taluk							
Eucalyptus plots	12	76.16	3.80	20.04	Sandy clay loam	1.29	40.45
	24	62.56	7.28	30.16	Sandy clay loam	1.38	31.67
	48	71.20	4.96	23.84	Sandy clay loam	1.51	30.30
Restored plots	2	62.88	4.00	33.12	Sandy clay loam	1.37	31.06
	6	65.68	12.00	22.32	Sandy clay loam	1.35	33.04
	10	75.04	4.00	20.96	Sandy clay loam	1.28	42.89
Cropland plots	-	78.69	4.47	16.84	Sandy loam	1.28	41.75
S.Em±		**3.20**	**1.29**	**2.58**		**0.03**	**2.74**
C.D. @ 5%		**9.98**	**NS**	**8.03**		**0.09**	**8.55**
Hoskote taluk							
Eucalyptus plots	12	79.84	3.28	16.88	Sandy loam	1.28	45.61
	24	78.32	3.04	18.64	Sandy loam	1.36	35.39
	48	81.84	1.28	16.88	Sandy loam	1.38	34.59
Restored plots	2	79.28	4.56	16.16	Sandy loam	1.30	36.74
	6	78.48	4.00	17.52	Sandy loam	1.29	40.64
	10	76.84	5.00	18.16	Sandy loam	1.27	45.54
Cropland plots	-	81.84	6.00	12.16	Loamy sand	1.26	52.13
S.Em±		**1.39**	**0.92**	**1.19**		**0.01**	**2.09**
C.D. @ 5%		**4.3**	**NS**	**3.71**		**0.05**	**6.53**

The compactness of soil might have increased the soil bulk density (Aweto and Moleele, 2005). The increased bulk density of soil in eucalyptus and restored plots may also due to reduced soil infiltration, increased runoff of the surface soil and correspondingly reduced soil moisture content (FAO, 2011).Maximum water holding capacity of soil had significantly influenced by different periods of eucalyptus cultivation and restoration (Table 1). Soils after ten years of restoration showed significantly maximum water holding capacity of 42.89 per cent at Malur taluk, while soils of croplands showed maximum water holding capacity of 52.13 per cent at Hoskote taluk. However, soils of cropland and soils after twelve years of eucalyptus cultivation were on par with each other with respect to maximum water holding capacity of soil. On the other hand, soils under prolonged fourty eight years of eucalyptus cultivation showed significantly lowest water holding capacity at both Malur (30.30%) and Hoskote (34.59%) taluks. In general, maximum water holding capacity of soils under different cultivation periods of eucalyptus cultivation ranged from 30.30 to 40.45 per cent at Malur taluk and 34.59 to 45.61 per cent at Hoskote taluk and was found to decrease with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, it ranged from 31.06 to 42.89 per cent at Malur taluk and 36.74 to 45.65 per cent at Hoskote taluk under different periods of restoration and was found to increase with increasing the restoration period at both the taluks studied. The decrease in water holding capacity of soil with prolonging the cultivation period of eucalyptus plantation might be attributed to the fact that eucalyptus is a fast growing tree absorb more water according to its unit biomass production and has ability to control its stomatal opening and closing according to water availability without reducing in the biomass production (Dinesh Kumar, 1984). Gurumurthi and Rawat (2000) reported that eucalyptus tree has inherent capacity of luxury consumption of water when it is abundantly available and transpiration of water in eucalyptus tree is dependent on availability of soil moisture near the tree. Further, sparse undergrowth vegetation in eucalyptus plantation due to its allelopathic effect can leads to higher rate of soil evaporation which further contributes to reduction of soil moisture content in the eucalyptus plantation than those of cropland and restored lands.

Chemical properties

The chemical properties *viz.*, pH, EC and organic carbon content of soil were significantly influenced by different periods of eucalyptus cultivation and restoration (Table 2). Soils under fourty eight years old eucalyptus plantation had significantly lowest pH of 6.21 at Malur taluk and 6.28 at Hoskote taluk. On the other hand, soils after two years of restoration had significantly highest pH of 7.50 at Malur taluk and 7.10 at Hoskote taluk. In general, pH of soils under different cultivation periods of eucalyptus plantation ranged from 6.21 to 6.65 at Malur taluk and 6.28 to 6.46 at Hoskote taluk and was found to decrease with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, pH of soils under different restoration periods ranged from 7.21 to 7.50 at Malur taluk and 6.50 to 7.10 at Hoskote taluk and was found to decrease with prolonging the period of restoration at both the taluks studied. The soil pH values under different periods of eucalyptus cultivation at both Malur and Hoskote taluks were acidic to neutral in reaction because of the fact that eucalyptus tree immobilizes the exchangeable bases present in soil and leads to lower bases in soil that correspondingly reduces soil pH under eucalyptus plantation. Sanchez and Uehara (1980) observed the lower values of soil pH under eucalyptus plantation compared to native plantation.

With regard to total soluble salts content or electrical conductivity (EC) of surface soil, the soils under fourty eight years old eucalyptus plantation had significantly lowest EC of 0.04 dS/mat Malur and 0.05 dS/mat Hoskote taluk. On the other hand, soils after two years of restoration had significantly highest EC of 0.66 and 0.19 dS/mat Malur and Hoskote taluks, respectively. In general, the EC of soils under different cultivation periods of eucalyptus plantation ranged from 0.04 to 0.06 dS/mat Malur taluk and 0.05 to 0.07 dS/mat Hoskote taluk and was found to slightly decrease with prolonging the cultivation period of eucalyptus at both the taluks studied. On the other hand, EC of soils under different restoration periods ranged from 0.50 to 0.66 dS/mat Malur taluk and 0.14 to 0.19 dS/mat Hoskote taluk and was found to decrease with prolonging the period of restoration at both the taluks studied. However, soils under croplands and different periods of restoration were found to be on par with each other with respect to EC at both Malur and Hoskote taluks. The reduction of soil EC under eucalyptus tree plantation might be attributed to accumulation and subsequent decomposition of organic matter that releases organic acids (Gupta and Sharma, 2009; Ruhela *et al.,* 2022) and ameliorate salinity and sodicity of soil by decreasing soil EC and pH (Nasim *et al.,* 2007).

With respect to organic carbon status, soils of fourty eight years old eucalyptus plantation had significantly lowest organic carboncontent of 0.24 and 0.45 per cent at Malur and Hoskote taluks, respectively. On the other hand, soils after ten years of restoration at Malur taluk and soils of croplands at Hoskote taluk had significantly highest soil organic carbon content (0.58 and 0.70%, respectively).

In general, organic carbon content of soils under different cultivation periods of eucalyptus plantation ranged from 0.24 to 0.53 per cent at Malur taluk and 0.45 to 0.59 per cent at Hoskote taluk and was found to decrease with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, organic carbon content of soils under different restoration periods ranged from 0.32 to 0.58 per cent at Malur taluk and 0.52 to 0.62 per cent at Hoskote taluk but no definite trend was observed. The decreased organic carbon content of soil with prolonging the cultivation period of eucalyptus plantation might be attributed to less accumulation of organic matter or slower rate of organic matter decomposition due to sparse undergrowth cover in eucalyptus plantation as a result of its allelopathic effect (Aweto and Moleele, 2005).

Available primary nutrients

The available N, P_2O_5 and K_2O status of soil differed significantly due to different cultivation periods of eucalyptus plantation and restoration at both Malur and Hoskote taluks (Table 2).

Table 2: Chemical properties of surface soils under different periods of eucalyptuscultivation and restoration

Description	Age (Years)	pH (1:2.5)	EC (dS/m)	OC (%)	Avail. N	Avail. P2O5	Avail. K2O
					(Kg/ha)		
Malur taluk							
Eucalyptus plots	12	6.65	0.06	0.53	197.57	47.23	168.55
	24	6.32	0.05	0.32	169.34	32.71	137.62
	48	6.21	0.04	0.24	163.07	28.26	112.89
Restored plots	2	7.50	0.66	0.32	177.12	57.27	185.98
	6	7.29	0.56	0.43	212.80	61.73	209.98
	10	7.21	0.50	0.58	219.26	78.10	235.35
Cropland plots	-	6.86	0.60	0.55	259.24	117.02	313.01
S.Em±		**0.19**	**0.09**	**0.05**	**15.66**	**7.37**	**20.70**
C.D. @ 5%		**0.62**	**0.28**	**0.16**	**48.80**	**22.98**	**64.58**
Hoskote taluk							
Eucalyptus plots	12	6.46	0.07	0.59	235.42	31.98	142.46
	24	6.30	0.06	0.51	192.34	28.63	126.51
	48	6.28	0.05	0.45	188.16	26.03	115.18
Restored plots	2	7.10	0.19	0.62	250.88	46.52	175.12
	6	6.63	0.17	0.54	244.61	53.49	188.16
	10	6.50	0.14	0.52	238.33	62.48	199.80
Cropland plots	-	6.49	0.16	0.70	282.24	89.99	288.49
S.Em±		**0.19**	**0.02**	**0.02**	**15.38**	**6.26**	**15.11**
C.D. @ 5%		**0.62**	**0.08**	**0.08**	**47.90**	**19.52**	**47.07**

The soils of forty eight years old eucalyptus plantation had significantly lowest available N, P_2O_5 and K_2O contents of 163.07, 28.26 and 112.89 Kg/ha, respectively at Malur taluk and 188.16, 26.03 and 115.18 Kg/ha, respectivelyat Hoskote taluk. On the other hand, soils of cropland plots had significantly highest available N, P_2O_5 and K_2O contents of 259.24, 117.02 and 313.01 Kg/ha, respectivelyat Malur taluk and 282.24, 89.99 and 288.49 Kg/ha, respectivelyat Hoskote taluk while, soils under different periods of restoration were intermediate in available N, P_2O_5 and K_2O contents. In general, the available N, P_2O_5 and K_2O contents of surface soils under different cultivation periods of eucalyptus plantation ranged from 163.07 to 197.57, 28.26 to 47.23 and 112.89 to 168.55 Kg/ha, respectively at Malur taluk and 188.16 to 235.42, 26.03 to 31.98 and 115.18 to 142.46 Kg/ha, respectively at Hoskote taluk and was found to decrease with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, the available N, P_2O_5 and K_2O contents of surface soils under different periods of restoration ranged from 177.12 to 219.26, 57.27 to 78.10and 185.98 to 235.35 Kg/ha, respectively at Malur taluk and 238.33 to 250.88, 46.52 to 62.48 and 175.12 to 199.80 Kg/ha, respectively at Hoskote taluk and was found to increase with prolonging the restoration period at both the taluks studied. The relatively low available N, P_2O_5 and K_2O status of soil under eucalyptus plantation compared to restored and cropland plots might be due to rapid growth of eucalyptus that utilizes a large amount of available soil nutrients than any other crops and nutrients return of litter failed to make up for the deficiency of nutrients in time (Bauhus and Barthel, 1995; Turner and Lambert, 2008; Bhardwaj *et al.,* 2020). Further, increased harvest of eucalyptus trees decreased the available primary nutrients contents in soils due to the fact that repeated harvest of eucalyptus trees removes the primary nutrients from the soil. Zerfu Hailu (2002) reported that potential macronutrients removed from the upper layers of soil through harvesting of wood biomass from eucalyptus tree can exceeds the removal of nutrients through harvesting in agricultural crops. Tererai *et al.* (2015) observed the decreased available nitrogen content in the eucalyptus plantation area compared to the land not covered with eucalyptus plantation. Aweto and Moleele (2005) observed the lower amount of available phosphorus under 8 – 10 harvest (>50 - 60 years) of eucalyptus plantation that might be attributed to long term immobilization and P fixation in soils under eucalyptus plantation as a result of decreased soil pH. On the other hand, soils under restoration showed improved available N, P_2O_5 and K_2O contents at both Malur and Hoskote taluks that might be attributed to translocation of macronutrients from deeper horizons to the surface layer of soils (Tchienkoua and Zech, 2004) and regular application of manures and fertilizers to restored plots and croplands (Yitaferu *et al.,* 2013).

Available secondary nutrients

The exchangeable Ca and Mg as well as available S contents of soil differed significantly due to different periods of eucalyptus cultivation and restoration (Table 3). Soils under forty eight years of eucalyptus plantation had significantly lowest exchangeable Ca and Mg contents of 1.75 and 1.05cmol (p^+)/Kg, respectivelyat Malur taluk and 1.70 and 0.80cmol (p^+)/Kg, respectivelyat Hoskote taluk. On the other hand, soils of croplands had significantly highest exchangeable Ca and Mg contents of 3.85 and 1.95 cmol (p^+)/Kg, respectivelyat Malur taluk and 3.85 and 1.95 cmol (p^+)/Kg, respectivelyat Hoskote taluk while, soils under different periods of restoration were intermediate in exchangeable Ca and Mg contents. In general, the exchangeable Ca and Mg contents of soils under different cultivation periods of eucalyptus plantation ranged from 1.75 to 2.75 and 1.05 to 1.32 cmol (p^+)/Kg, respectively at Malur taluk and 1.70 to 2.65 and 0.80 to 1.25 cmol (p^+)/Kg, respectivelyat Hoskote taluk and were found to decrease with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, exchangeable Ca and Mg contents of soils under different restoration periods ranged from 2.07 to 3.50 and 1.19 to 2.00 cmol (p^+)/Kg, respectively at Malur taluk and 2.00 to 3.17 and 1.08 to 1.70 cmol (p^+)/Kgat Hoskote taluk and were found to increase with prolonging the period of restoration at both the taluks studied. With respect to available sulphur content,soils under twelve years old eucalyptus plantation had significantly lowest available sulphur content of 5.60 and 5.94 ppm at Malur and Hoskote taluks, respectively. On the other hand, soils of cropland plots had significantly highest available sulphur content of 14.79 and 12.35 ppm at Malur and Hoskote taluks, respectively while, soils under different periods of restoration were intermediate in available sulphur status. In general, the available sulphur content of soils under different cultivation periods of eucalyptus plantation ranged from 5.60 to 6.97 ppm at Malur taluk and 5.94 to 7.09 ppm at Hoskote taluk and was found to increase with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, available sulphur content of soils under different periods of restoration ranged from 7.76 to 12.08 ppm at Malur taluk and 8.92 to 10.82 ppm at Hoskote taluk and was found to increase with prolonging the period of restoration at both the taluks studied. The relatively low exchangeable Ca and Mg contents observed of surface soil under eucalyptus plantation probably due to increase in H^+ ions that lead to reduction in cation retention capacity. Aweto and Moleele (2005) reported that eucalyptus trees immobilize soil nutrients faster than that of soil nutrient recycle back to the topsoil and soil pH was significantly lower in eucalyptus tree plantations in 0 – 20 cm soil layers. Another possible reason for decreased available nutrients in soils under eucalyptus plantation might be due to greater demand of eucalyptus trees for available nutrients at the later stage of growth besides, decomposition and conversion rate of organic matter after 15 to 20 years plantation cannot meet the demand of eucalyptus trees growth (Zhu *et al.,* 2019).

Available micronutrient cations

The DTPA extractable micronutrients status of soil differed significantly due to different periods of eucalyptus cultivation and restoration (Table 3). Soils under forty eight years old eucalyptus plantation had significantly highest DTPA extractable Fe, Mn, Zn and Cu contents of 26.54, 20.14, 2.06 and 1.74 ppm, respectively at Malur taluk and 29.74, 18.28, 1.96 and 1.56 ppm, respectively at Hoskote taluk. On the other hand, cropland soils had significantly lowest DTPA

Table 3: Secondary and micronutrients content of surface soils under different periods ofeucalyptus cultivation and restoration

Description	Age (Years)	Exch. Ca	Exch. Mg	Avail. S (ppm)	DTPA extractable micronutrient cations (ppm)			
		[cmol (p+)/Kg]			Fe	Mn	Zn	Cu
Malur taluk								
Eucalyptus plots	12	2.75	1.32	5.60	15.16	16.72	1.60	1.34
	24	2.20	1.09	5.75	19.20	17.98	1.74	1.42
	48	1.75	1.05	6.97	26.54	20.14	2.06	1.74
Restored plots	2	2.07	1.19	7.76	13.32	15.54	1.20	0.88
	6	3.16	1.54	11.99	12.22	14.22	0.96	0.78
	10	3.50	2.00	12.08	9.92	12.90	0.76	0.64
Cropland plots (Control)	-	3.85	1.95	14.79	6.93	10.76	0.62	0.46
S.Em±		**0.17**	**0.11**	**0.56**	**0.29**	**0.65**	**0.18**	**0.13**
C.D. @ 5%		**0.52**	**0.35**	**1.75**	**0.90**	**2.04**	**0.58**	**0.42**
Hoskote taluk								
Eucalyptus plots	12	2.65	1.25	5.94	13.52	14.06	1.44	1.16
	24	2.01	0.97	6.25	27.34	15.90	1.63	1.32
	48	1.70	0.80	7.09	29.74	18.28	1.96	1.56
Restored plots	2	2.00	1.08	8.92	14.32	13.04	1.39	0.94
	6	2.80	1.35	9.29	12.22	12.60	1.26	0.86
	10	3.17	1.70	10.82	9.30	9.60	1.15	0.76
Cropland plots (Control)	-	3.85	1.95	12.35	4.55	6.74	0.86	0.50
S.Em±		**0.06**	**0.04**	**0.66**	**0.27**	**0.73**	**0.17**	**0.13**
C.D. @ 5%		**0.19**	**0.13**	**2.07**	**0.86**	**2.29**	**0.53**	**0.42**

extractable Fe, Mn, Zn and Cu contents of 6.93, 10.76, 0.62 and 0.46 ppm, respectively at Malur taluk and 4.55, 6.74, 0.86 and 0.50 ppm, respectively at Hoskote taluk while, soils under different periods of restoration were intermediate in available micronutrient cations status. In general, DTPA extractable Fe, Mn, Zn and Cu contents of surface soils under different cultivation periods of eucalyptus plantation ranged from 15.16 to 26.54, 16.72 to 20.14, 1.60 to 2.06 and 1.34 to 1.74 ppm, respectively at Malur taluk and 13.52 to 29.74, 14.06 to 18.28, 1.44 to 1.96 and 1.16 to 1.56 ppm, respectively at Hoskote taluk and were found to increase with prolonging the cultivation period of eucalyptus plantation at both the taluks studied. On the other hand, DTPA extractable Fe, Mn, Zn and Cu contents of soils under different restoration periods ranged from 9.92 to 13.32, 12.90 to 15.54, 0.76 to 1.20 and 0.64 to 0.88 ppm, respectively at Malur taluk and 9.30 to 14.32, 9.60 to 13.04, 1.15 1.39 and 0.76 to 0.94 ppm, respectively at Hoskote taluk and were found to decrease with prolonging the period of restoration at both the taluks studied. The increased availability of micronutrient cations in soils of eucalyptus plantation might be attributed to reduction in soil pH under eucalyptus plantation that leads to the increased availability of micronutrient cations compared to restored and cropland plots. Horneck *et al*. (2011) reported that availability of Fe, Mn, Zn and Cu increases as soil pH decreases and *vice-versa* and found higher in eucalyptus plantation.

Conclusion

The results obtained from the study, it can be inferred that eucalyptus tree affected the physical properties of soil by increasing bulk density and decreasing water holding capacity of soil and removed more macronutrients from the soil during its biomass production and enhanced the availability of micronutrient cations by reducing soil pH. On the other hand, restoration of eucalyptus plantation with agricultural crops have improved the physical properties of soil by decreasing bulk density and increasing water holding capacity of soil and enhanced the availability of macronutrients and reduced the toxicity of micronutrient cations by increasing the soil pH to near neutrality.

Acknowledgement

Senior author is grateful to Indian Tobacco Company Limited, Mysuru for its support in selection of eucalyptus plantations, restored fields and nearby croplands in Malur and Hoskotetaluks of Karnataka for the study and Dr. B.G. Prakash, Retired Dean, College of Horticulture, Kolar for providing all the facilities and guidance to conduct the laboratory analysis.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Alem, S., Woldemariam, T., & Pavlis, J. (2010). Evaluation of soil nutrients under *Eucalyptus grandis* plantation and adjacent sub-montane rain forest. *Journal of Forest Research, 21*(4), 457–460.

Aweto, A.O., & Moleele, N.M. (2005). Impact of *Eucalyptus camaldulensis* plantation on an alluvial soil in south eastern Botswana. *International Journal Environmental Studies, 62*(2), 163-170.

Bhardwaj, S., Khanna, D. R., Ruhela, M., Bhutiani, R., Bhardwaj, R., & Ahamad, F. (2020). Assessment of the soil quality of Haridwar Uttarakhand India: A comparative study. *Environment Conservation Journal*, *21*(3), 155-164.

Balamurugan, J., Kumaraswamy, K., & Rajarajan, A. (2000). Effects of *Eucalyptus citriodora* on the physical and chemical properties of soils. *Journal of the Indian Society of Soil Science,48*(3), 491-495.

Bauhus, J., & Barthel, R. (1995). Mechanisms for carbon and nutrient release and retention in beech forest gaps. *Plant and Soil*, *168*, 585 – 592.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal*, *54*, 464-465.

Coppen, J.J.W., & Hone, G.A. (1992), *Eucalyptus Oils: A Review of Production and Markets*, Natural Resources Institute Bulletin 56, http://gala.gre.ac.uk/11084.

Cossalter, C., & Pye-Smith, C. (2003). *Fast-wood Forestry: Myths and Realities.* Center for International Forestry Research, Indonesia, pp. 1-50.

Dinesh Kumar. (1984). Place of Eucalyptus in Indian Agro-forestry Systems, National Seminar on Eucalyptus, Abstracts, Jan. 30-31, Kerala Forest Research Institute, Peechi, Kerala.

FAO. (2011). Eucalyptus in East Africa: Socio-economic and environmental issues, by Gessesse Dessie and Teklu Erkossa. Planted Forests and Trees Working Paper 46/E, Forest Management Team, Forest Management Division. FAO, Rome, Italy, pp. 1-42.

Gupta, M.K., & Sharma, S.D. (2009). Effect of tree plantation on soil properties, profile morphology and productivity index-II. Poplar in Yamunanagar district of Haryana. *Annals of Forestry,17*(1), 43 – 70.

Gurumurthi, K., & Rawat, P.S. (2000). Water consumption by Eucalyptus: *In* 'Effect of growing eucalyptus' edited by Singhal, R.M., & Rawat, J.K. Pub. Forest Research Institute. New Forests, Valley Offset Printers, Dehradun, pp. 127-137.

Hesse, P.R. (1971). *A text book of soil chemical analysis*, Murray, London. pp. 120-309.

Horneck, D.A., Sullivan, D.M., Owen, J.S., & Hart, J.M. (2011). Soil test interpretation guide. Oregon State University, Extension Service, pp.1-12.

Jackson, M.L. (1973). *Soil Chemical Analysis*. First Edn., Prentice Hall (India) Pvt. Ltd., New Delhi., pp. 1-498.

Turner, J., & Lambert, M. (2008). Nutrient cycling in age sequences of two eucalyptus plantation species. *Forest Ecology and Management, 255*(5), 1701–1712.

Karajagi, R., Banakar, B., & Kunnal, L.B. (2009). Growth in area and production of eucalyptus in Karnataka. *Mysore Journal of Agricultural Sciences,43*(4), 641-645.

Lindsay, W.L., & Norvell, W.A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal, 42*, 421-428.

Nasim, M., Qureshi, R.H., Saqib, M., Aziz, T., Nawaz, S., Akhtar, J., & Anwar-ul-Haq, M. (2007). Properties of salt affected soil under *Eucalyptus camaldulensis* plantation in field conditions, *Pakistan Journal of Agricultural Sciences, 44,* 401-414.

Panse, V.G., & Sukhatme, P.V. (1989). *Statistical Methods for Agricultural Workers*, 4th Ed., ICAR, New Delhi, pp. 1-359.

Piper, C.S. (2019). *Soil and Plant Analysis: A laboratory manual of methods for examination of soils and determination of the inorganic constituents of plants.* Scientific Publishers (India), Jodhpur, Rajasthan, India, pp. 1-368.

Ruhela, M., Bhardwaj, S., Garg, V., & Ahamad, F. (2022). Assessment of soil quality at selected sites around Karwi town, Chitrakoot (Uttar Pradesh), India. *Archives of Agriculture and Environmental Science*, *7*(3), 379-385.

Sanchez, P.A., & Uehara, G. (1980). Management considerations for acid soils with high phosphorus fixation capacity. *In* 'The role of phosphorus in agriculture' (Khasawnch, F.E., Sample, E.C., & Kamprath, E.J. Eds.), pp: 471-514, *American Society of Agronomy*, Madison, WI.

Shyam Sunder, S. (1979). Eucalyptus in Karnataka. *Myforest*, *15*(3), 139.

Subbiah, B.V., & Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils, *Current Science, 25*, 259-261.

Tchienkoua, M., & Zech, W. (2004). Organic carbon and plant nutrient dynamics under three land uses in the highlands of West Cameroon. *Agriculture, Ecosystems and Environment,104*(3), 673–679.

Tererai, F., Gaertner, M., Jacobs, S.M., & Richardson, D.M. (2015). *Eucalyptus camaldulensis* invasion in Riparian zones reveals few significant effects on soil physico-chemical properties. *River Research and Applications*, *31*(5), 590-601.

Walkley, A.J., & Black, I.A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Science*, *37*, 29-38.

Yitaferu, B., Abewa, A., & Kassie, T.A. (2013). Expansion of eucalyptus woodlots in the fertile soils of the highlands of Ethiopia: Could it be a treat on future cropland use?. *Journal of Agricultural Science,5*(8), 97-107.

Zerfu Hailu. (2002). Ecological impact evaluation of *Eucalyptus* plantations in comparison with agricultural and grazing land use types in the highlands of Ethiopia. *Ph.D Dissertation* submitted to Vienna University of Agricultural Sciences, p. 271.

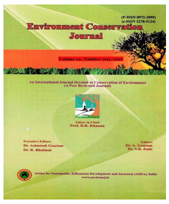
Zhu, L., Wang, X., Chen, F., Li, C., & Wu, L. (2019). Effects of the successive planting of *Eucalyptus urophylla* on soil bacterial and fungal community structure, diversity, microbial biomass and enzyme activity. *Land Degradation and Development,30*(6), 636-646.

Environment Conservation Journal 24 (3): 209-214, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Impact of different quantity and quality of irrigation water on crop yield and biomass of winter maize using FAO-Aqua crop model

Ravish Chandra ✉
Department of SWE, CAET, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, India
Vipin Chandan
Department of SWE, CAET, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, India
Manish Kumar
Department of SWE, CAET, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, India

ARTICLE INFO

Received : 02 December 2022
Revised : 13 February 2023
Accepted : 20 March 2023

Available online: 27 June 2023

Key Words:
Aqua Crop Model
Biomass
Crop Growth Model
Simulated Yield

ABSTRACT

Irrigation has a major role to play in the productivity of winter maize. Precise information about the quantity and quality of irrigation water is the key for higher productivity of winter maize. In the present study attempt has been made to assess the impact of different depth of irrigation water on crop yield and biomass of winter maize using FAO-Aquacrop Model. In the first case crop yield and biomass was simulated for irrigation water depth varied from 20 mm to 80 mm, keeping the irrigation water quality constant. Similarly, in another case the optimum irrigation depth was kept constant and irrigation water quality varied from 1 to 10 ds/m. The simulated crop yield and biomass increases up to 40 cm depth of irrigation water application for all three seasons. When a similar comparison was made for 30 cm depth of irrigation water application the simulated yield reduction was only 0.79%, 2.2% and 2.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. The analysis suggested that this yield reduction can easily be compromised for saving 10 cm of irrigation water. This study indicated that 30 cm depth of irrigation water is optimum for Winter maize in BurhiGandak river basin of North Bihar in case of deficit irrigation of 20 cm depth of irrigation water application the simulated yield reduced by 14.4 %, 25.4 % and 11.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. Assessment of response of different quality irrigation water on simulated crop yield and biomass of *winter* maize using FAO-Aquacrop model suggests that simulated yield was found maximum with 1 ds/m. The reduction in simulated yield with 10 ds/m water quality was observed maximum with a value of 41.3 %, 44.4 % and 38.4 % respectively for the year 2016-17, 2017-18 and 2018-19. FAO-Aquacrop model can be used as an important tool for efficient planning of irrigation water under diminishing water supply and deteriorating water quality.

Introduction

Irrigation water is one of the most important component in Agriculture. The scarcity of high-quality irrigation water is now widely acknowledged as a major impediment to increasing cropping intensification. In many parts of the world, a lack of irrigation water is impeding agricultural development (Barrow, 2016; Elliott *et al.,* 2014; Molden *et al.,* 2010). Water scarcity for agriculture is increasing not only because sources are dwindling, but also because water quality is deteriorating (Elliott *et al.,* 2014; Parsons *et al.,* 2010; Bhutiani *et al.,* 2016; Bhutiani and Ahamad, 2019).Maize is one of the most important crop of the world because of its excellent starch composition, it is quickly becoming a major raw material for food, textile, paper and feed industries (Kang *et al.* 2010; Tian *et al.* 2009). There are three distinct seasons for the cultivation of maize in India : Kharif , Rabi in Peninsular India and Bihar, and Spring in northern India.

Corresponding author E-mail: *ravish@rpcau.ac.in*
Doi: https://doi.org/10.36953/ECJ.16442523

Bihar is a significant maize-producing state, accounting for approximately 6.6 % of total national maize production, with nearly 0.65 million hectares of maize planted each year. Winter maize is grown on a land area of 0.46 million hectares, with a grain production of 1.86 million tonnes and a normal yield of 4.1 t/ha in 2020-21 (Source : Ministry of Agriculture & Farmers Welfar e, Govt. of India. (ON2930). Winter maize in Bihar state has a larger region with a normal productivity of 4.1 t/ha and *Autumn/kharif* maize with a normal productivity of 2.85 t/ha. Winter maize is mostly dependent on the availability of irrigation water. In Bihar, most of the maize-producing area is dependent upon groundwater. Due to the unavailability of electricity in rural areas ground water extraction is mostly done through diesel operated pumps. The cost of operation of tubewell restricts farmers to use less number of irrigation to crop leading to poor productivity of winter maize. Besides this salinity is also one of the major concerns in some of the maize growing areas. Maize is moderately salt tolerant crop. The effect of saline water on crop yield has been studied by a number of researchers. The FAO-Aquacrop model can help to assess the impact of different quantity and quality of irrigation water on crop yield and biomass in winter maize. Aquacrop models have been successfully used to simulate crop growth and yield parameters (Kumar *et al*., 2018; Chandra *et al.* 2022; Chandra and Kumari, 2021) in Eastern India. Effective rainfall in winter season in this part of the world is very deficient and assured irrigation is the key to good production of winter maize. Therefore, it is important to study the impact of different levels of irrigation along with the different level of saline water on crop yield of winter maize in Bihar. Keeping the importance of irrigation water for winter maize this study was undertaken to assess the impact of different levels of irrigation along with the different level of saline water on crop yield of winter maize in Bihar.

Material and Methods

The study was conducted during winter season for the three years 2016-17, 2017-18 and 2018-19. The crop parameters were adopted in this study from one of the studies conducted for performance evaluation of Aquacrop model for *Rabi maize* for North Bihar by Kumar and Chandra , 2018.

Study area

The study region is situated at *Pusa* block of Samastipur district of North Bihar (Fig. 1). The investigation territory is encircled by southern and western bank of the waterway Burhi Gandak at 25°59'N latitude and 85°48'E longitude. The elevation above (MSL) is 52.92 m.

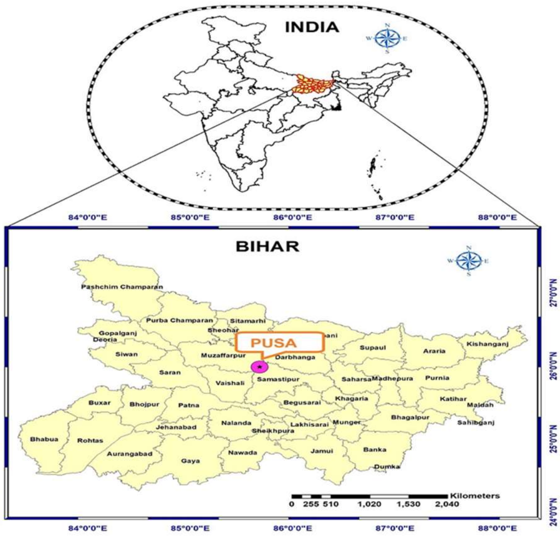


Figure 1: Map of study area

Aquacrop model

Aquacrop is a crop growth model developed by the Land and Water Division of FAO to address food security and to assess the effect of environment and management on crop production. AquaCrop simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production. When designing the model, an optimum balance between simplicity, accuracy, and robustness was pursued. To be widely applicable AquaCrop uses only a relatively small number of explicit parameters and mostly-intuitive input-variables requiring simple methods for their determination. On the other hand, the calculation procedures are grounded on basic and often complex biophysical processes to guarantee an accurate simulation of the response of the crop in the plant-soil system. The impacts of climate change are often quantified by impact models whereas impact models typically require high resolution unbiased input data, global and regional climate models are in general biased, their resolution is often lower than desired. Thus, many users of climate model data apply some form of bias correction and downscaling. Bias correction of climate model outputs for climate change impact has been assessed in Central Kashmir.

Scenario for simulation

Simulation studies using the FAO-AquaCrop model were done for the assessment of the impact of different depths of irrigation water on crop yield and biomass of winter maize for the years 2016-17,2017-18 and 2018-19. The irrigation water quality was kept constant and depth varied from 20 cm to 80 cm. The model was run separately for different depths of irrigation and details of irrigation combinations between irrigation water depth and quality have been used for simulation studies are presented in Table 1.

Table 1: Different combination of irrigation depth used for simulation studies

2016-17		2017-18		2018-19	
Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)
20	1	20	1	20	1
30	1	30	1	30	1
40	**1**	**40**	**1**	**40**	**1**
50	1	50	1	50	1
60	1	60	1	60	1
70	1	70	1	70	1
80	1	80	1	80	1

Similarly Simulation studies using the FAO-AquaCrop model were done for the assessment of the impact of different quality of irrigation water on crop yield and biomass of winter maize for the years 2016-17,2017-18 and 2018-19.The irrigation water depth was kept constant and irrigation water quality varied from 1 ds/m to10 ds/m. In this study, the simulate the effect of different quality of irrigation water on crop yield and biomass of winter maize under applied a standard irrigation depth of *winter* maize (40 cm) with varies irrigation water quality from base water quality 1 ds/mto respectively increased 2, 4, 6, 8 and 10 ds/mby using FAO-Aquacrop model. The model was run separately for different quality of irrigation displayed in Table 2.

Table 2: Different combination of irrigation water quality used for simulation studies

2016-17		2017-18		2018-19	
Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)
1	**40**	**1**	**40**	**1**	**40**
2	40	2	40	2	40
4	40	4	40	4	40
6	40	6	40	6	40
8	40	8	40	8	40
10	40	10	40	10	40

Results and Discussion

The response of change in amount of irrigation water applied was analyzed using FAO-AquaCrop model for three *winter* seasons of 2016-17, 2017-18 and 2018-19. The results are presented in Table 3 to Table 5. The simulated crop yield and biomass increases as depth of water application increases. The simulated crop yield and biomass increases till 40 cm depth of irrigation water application for all three seasons. This analysis will also help in understanding the impact of deficit irrigation on *winter* maize. In case of deficit irrigation of 20 cm depth of irrigation water application the simulated yield reduced by 14.4 %, 25.4 % and 11.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. The similar trend was observed for simulated biomass with biomass reduction of 12.3 %, 24.5 % and 10.6 % for the year 2016-17, 2017-18 and 2018-19 respectively for deficit irrigation depth of 20 cm. The lowest simulated yield reduction of 11.4 % was reported for the year 2018-19 is due to good amount of effective rainfall 31.0 mm during the cropping season compared to 2016-17 and 2017-18 respectively. The highest simulated yield reduction was found for the year 2017-18. When the similar comparison was made for 30 cm depth of irrigation water application the simulated yield reduction was only 0.79 %, 2.2% and 2.4% respectively for the year 2016-17, 2017-18 and 2018-19 respectively. The analysis suggests that this yield reduction can easily be compromised for saving 10 cm of irrigation water. There is no increase in simulated yield beyond 40 cm depth of irrigation water application for all the three *winter* seasons of 2016-17, 2017-18 and 2018-19. Kumar

Table 3: Response of different depth of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2016-17

Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change
20	1	8.62	-14.39	17.97	-12.34
30	1	9.99	-0.79	20.33	-0.82
40	**1**	**10.07**	**-**	**20.50**	**-**
50	1	10.10	0.29	20.54	0.19
60	1	10.07	0	20.49	-0.04
70	1	10.06	-0.09	20.47	-0.14
80	1	10.05	-0.19	20.44	-0.29

Table 4: Resp0nse of different depth of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2017-18

Applied irrigation depth (cm)	Irrigation water quality(ds/m)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change
20	1	7.03	-25.37	15.42	-24.48
30	1	9.21	-2.22	20.07	-1.71
40	**1**	**9.42**	**-**	**20.42**	**-**
50	1	9.40	-0.21	20.40	-0.09
60	1	9.39	-0.31	20.38	-0.19
70	1	9.38	-0.42	20.37	-0.24
80	1	9.35	-0.74	20.35	-0.34

Table 5: Response of different depth of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2018-19

Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change
20	1	8.87	-11.38	18.48	-10.63
30	1	9.77	-2.39	20.30	-1.83
40	**1**	**10.01**	**-**	**20.68**	**-**
50	1	9.99	-0.19	20.66	-0.09
60	1	9.96	-0.49	20.63	-0.24
70	1	9.93	-0.79	20.59	-0.43
80	1	9.90	-1.09	20.55	-0.62

et al., 2018 reported that irrigation up to 75 % of crop water requirement for rabi maize was optimum. In one of the studies by Chandra and Tyagi , 2006 , SWAP model was successfully used for assessment of impact of different depth of irrigation water on crop yield. This study indicated that 30 cm depth of irrigation water is optimum for winter maize in Burhi Gandak river basin of North Bihar.

Effect of change in the quality of irrigation water on simulated crop yield and biomass of *winter* maize

The effect of change in quality of irrigation water applied was analysed using FAO-AquaCrop model for three *winter* seasons of 2016-17, 2017-18 and 2018-19. The results are presented in Table 6 to 8 and observed that the simulated crop yield and biomass decreases as irrigation water quality deteriorates. The crop yield was found maximum with 1 ds/m. The reduction in yield with 10 ds/m water quality was observed maximum with a value of 41.3 %, 44.4 % and 38.4 % respectively for the year 2016-17, 2017-18 and 2018-19. Similarly, the reduction in simulated biomass of *winter* maize with 10 ds/m water quality was observed maximum with a value of 39.9 %, 43.8 % and 37.9 % respectively for the year 2016-17, 2017-18 and 2018-19.Minimum decrease in simulated crop yield and biomass was observed during 2018-19 growing season compared to growing seasons of 2017-18 and 2016-17. The less reduction in yield during 2018-19 may be due to probable less salt accumulation in root zone to more effective rainfall (31.0 mm) in the year 2018-19 compared to 10.0 mm of effective rainfall in the year 2017-18. The other researchers also corroborated the similar findings (Chandra *et al.,* 2009; Kang y. *et al.,* 2010; Fang and Su, 2019).

Table 6: Response of different quality of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2016-17

Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change	ET productivity (kg/m3)
1	40	10.07	-	20.50	-	4.73
2	40	9.99	-0.79	20.33	-0.82	4.73
4	40	9.59	-4.76	19.68	-4.00	4.62
6	40	8.46	-15.98	17.60	-14.14	4.32
8	40	7.27	-27.80	15.16	-26.04	3.96
10	40	5.91	-41.31	12.31	-39.95	3.56

Table 7: Response of different quality of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2017-18

Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change	ET productivity ($kg/m^{-3)}$
1	40	9.42	-	20.42	-	4.28
2	40	9.22	-2.12	20.13	-1.42	4.21
4	40	8.83	-6.26	19.36	-5.19	4.14
6	40	7.96	-15.49	17.45	-14.54	4.00
8	40	6.68	-29.08	14.64	-28.30	3.71
10	40	5.24	-44.37	11.48	-43.78	3.36

Table 8: Resp0nse of different quality of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2018-19

Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change	ET productivity (kg/m^3)
1	40	10.01	-	20.68	-	4.58
2	40	9.78	-2.29	20.32	-1.74	4.51
4	40	9.46	-5.49	19.69	-4.78	4.84
6	40	8.63	-13.78	17.98	-13.05	4.28
8	40	7.43	-25.77	15.48	-25.14	4.01
10	40	6.17	-38.36	12.85	-37.86	3.64

Crop yield and biomass of *winter* maize crop was diminished because of minimal and low-quality water in furrow watersystem framework. The inferior quality water would have influenced the plant development and soil structure legitimately and in a roundabout way. This may be attributed to high concentration of salt in low quality water, which caused soil salinity in soil profile. Salt concentration brought about high osmotic capability of soil arrangement, due to that plant utilized more vitality to ingest water. Gang *et al.,* (2009) also found decrease in both transpiration and photosynthesis due to limited carbon dioxide uptake under salt stress. ThChandrae analysis of results from Table 6 to 8 suggested that rate of evapotranspiration is decreasing with increase in salinity level and evapotranspiration productivity has reduced from 4.73 to 3.56, 4.28 to 3.36, and 4.58 to 3.64.

Conclusion

The optimum quantity and quality of irrigation water are most important for *winter* maize. This study has given insight into decision-making regarding irrigation water application for *winter* maize under different scenarios. FAO-AquaCrop model was used for this study. The simulated crop yield and biomass increases upto 40 cm depth of irrigation water application for all three seasons. When a similar comparison was made for 30 cm depth of irrigation water application the simulated yield reduction was only 0.79%, 2.2% and 2.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. The analysis suggested that this yield reduction can easily be compromised for saving 10 cm of irrigation water. This study indicates that 30 cm depth of irrigation water is optimum for winter maize in Burhi Gandak river basin of North Bihar. In case of deficit irrigation of 20 cm depth of irrigation water application, the simulated yield reduced by 14.4 %, 25.4 % and 11.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. Assessment of effect of different quality of irrigation water on simulated crop yield and biomass of *winter* maize using FAO-Aquacrop model suggests that simulated yield was found maximum with 1 ds/m. The reduction in simulated yield with 10 ds/m water quality was observed maximum with a value of 41.3 %, 44.4 % and 38.4 % for the year 2016-17, 2017-18 and 2018-19, respectively. The FAO-Aqucrop model can be used effectively to estimate the agricultural crop water requirement, crop yield and irrigation scheduling for different crops for North Bihar conditions under changing climatic scenario.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Barrow, C. J. (2016: Water Resources and Agricultural Development in the Tropics. Routledge. Tylor and Francis Group. Sci. p. 368.

Bhutiani, R., & Ahamad, F. (2019). A case study on changing pattern of agriculture and related factors at Najibabad region of Bijnor, India. *Contaminants in Agriculture and Environment: Health Risks and Remediation*, *1*, 236.

Bhutiani, R., Khanna, D. R., Shubham, K., & Ahamad, F. (2016). Physico-chemical analysis of Sewage water treatment plant at Jagjeetpur Haridwar, Uttarakhand. *Environment Conservation Journal*, *17*(3), 133-142.

Chandra, R., Tyagi, N. K., & Sakthivadivel, R. (2009). Irrigation Water Quality and Crop Yield Relationship Established for Kaithal Irrigation Circle of Bhakra System. Journal of Agricultural Engineering, 46(2), 40-44.

Chandra R. and Tyagi N. K. (2006) Field Scale Modelling Approach to Improve Productivity in Irrigated Agriculture. International Journal of Tropical Agriculture, 24(3) : 507-518

Chandra, R., Singh, P. K., & Kumar, A. (2022). Performance Evaluation of Aqua Crop Model for Broccoli Crop under Tarai Condition of Indo-Gangetic Plain. Environment and Ecology, 40(2C), 959-968.

Chandra, R., & Kumari, S. (2021). Estimation of crop water requirement for rice-wheat and rice-maize cropping system using CROPWAT model for Pusa, Samastipur district, Bihar: Estimation of crop water requirement for cropping System at Pusa Bihar. Journal of AgriSearch, 8(2), 143-148.

Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D. & Wisser, D. (2014). Constraints and potentials of future irrigation water availability on agricultural production under climate change. Proceedings of the National Academy of Sciences, *111*(9), 3239-3244.

Fang, J., & Su, Y. (2019). Effects of soils and irrigation volume on maize yield, irrigation water productivity, and nitrogen uptake. Scientific Reports, 9(1), 1-11.

Kang, Y., Chen, M., & Wan, S. (2010). Effects of drip irrigation with saline water on waxy maize (*Zea mays* L. var. ceratina Kulesh) in North China Plain. Agricultural Water Management, 97(9), 1303-1309.

Kumar, V., Chandra, R., & Jain, S. K. (2018). Performance Evaluation of AquaCrop Model for *Winter* Maize Crop in the North Bihar Condition. Journal of Pharmacognosy and Phytochemistry, 7(5), 973-979.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M. A., & Kijne, J. (2010). Improving agricultural water productivity: Between optimism and caution. Agricultural Water Management, 97(4), 528-535.

Parsons, L. R., Sheikh, B., Holden, R., & York, D. W. (2010). Reclaimed water as an alternative water source for crop irrigation. Hort Science, 45(11), 1626-1629.

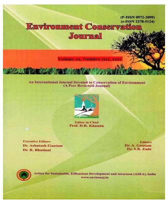
Tian, M., Tan, G., Liu, Y., Rong, T., & Huang, Y. (2009). Origin and evolution of Chinese waxy maize: evidence from the Globulin-1 gene. Genetic resources and crop evolution, *56*(2), 247-255.

Environment Conservation Journal 24 (3): 215-221, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Preliminary checklist of butterfly diversity from the Himachal Pradesh Agricultural University, Palampur, India

Praveen Kumar ✉

Department of Soil Science, CSK Himachal Pradesh Agricultural University, Palampur, (HP), India

Bharti Parmar

Department of English, School of Basic and Applied Sciences, Maharaja Agrasen University, Baddi, Solan, (HP), India

Pardeep Kumar

Department of Soil Science, CSK Himachal Pradesh Agricultural University, Palampur, (HP), India

ARTICLE INFO

Received : 06 December 2022
Revised : 13 February 2023
Accepted : 06 March 2023

Available online: 26 June 2023

Key Words:
Agricultural landscape
Conservation management
Himalayan diversity
Lepidoptera

ABSTRACT

Butterflies are the bio-indicator species for monitoring the health of the ecosystem. A preliminary checklist of the butterfly diversity was prepared by a long-term survey from 2019 to 2022 in varied habitats in the agriculture landscape of the Himachal Pradesh Agriculture University (HPAU), India. The study recorded 74 butterfly species belonging to six families Nymphalidae, Pieridae, Lycaenidae, Hesperiidae, Papilionidae and Riodinidae. In addition, there are some rare records of butterfly species such as Common Wall (*Lasiommata schakra*), Dark Blue Tiger (*Tirumala septentrionis*), Ringed Argus (*Callerebia annada*) and Pioneer (*Belenois aurota*). Some butterflies are habitat specific and few also show local migration from high-elevation areas of the surrounding Dhauladhar ranges. The preliminary checklist prepared from the present study was also compared with Central University of Himachal Pradesh (CUHP) located in the similar landscape of the study area. This will help to understand the long-term effect of habitat degradation from human-modified environment and agricultural activities to facilitate effective conservation strategies to protect Himalayan ecosystem.

Introduction

Among insects, butterflies (Insecta: Lepidoptera) are most commonly used as bio-indicator for understanding the ecosystem's health and the impact of climate change (Harsh 2014; Bhardwaj *et al.,* 2012; Kumar 2021a). The ecological studies of butterflies are always a subject of interest in the scientific community considering their distribution, short life span, rapid reproductive rates and host plant specificity. Butterfly diversity can be used as a global climate change indicator and human interventions such as urban development and habitat fragmentation. Weibull *et al.* (2000) pointed out that landscape heterogeneity has a more pronounced effect on butterfly diversity; still, the widespread use of the chemicals in modern agriculture poses an imminent threat to non-target Lepidoptera (Mule *et al.,* 2017). The agricultural landscapes of the Himalaya are also victim of the impact of anthropogenic activities such as the clearing of natural vegetation, applying chemical herbicides and insecticides and stubble burning in the agricultural fields.

Many researchers have carried out study on butterfly diversity with many checklists and new records for the hilly state of Himachal Pradesh, India (Arora *et al.,* 2009; Chandel *et al.,* 2013; Singh *et al.,* 2014; Kumar *et al.,* 2020a; Kumar *et al.,* 2020b; Kumar 2021a; Thakur *et al.,* 2021). However, the agricultural landscape is yet to be thoroughly studied for Himachal Himalaya, among these the university premises are less studied, and no records have been published by any university and related institutions. Therefore, the present study was carried out to prepare the checklist of butterfly diversity of Himachal Pradesh Agriculture University (HPAU), India. Further, the data was

Corresponding author E-mail: pk.hpkv@gmail.com
Doi: https://doi.org/10.36953/ECJ.16492525

compared with the butterfly checklist recorded for the Central University of Himachal Pradesh (CUHP), India (Kumar *et al.,* 2022). The study would generate first baseline records to know the present status of butterfly diversity and address various issues to conserve diversity in Himalayan ecosystem.

Material and Methods

The study area is located in the agro-climatic zone II of Himachal Pradesh, India (76.5489°N and 32.1029°E). The extensive survey was carried out in HPAU, Palampur, Himachal Pradesh, India, from 2019 to 2022 (Figure 1). As per Köppen and Geiger's classification, the study area comes under a monsoonal-influenced humid subtropical climate (Cwa). The area comprises various habitats such as agriculture (A), forest (F), grassland (G), tea orchards (T), wasteland (W) and wetland (Wt). The agricultural fields were covered with the experimental trials, while a large area covered scattered patches of tea orchards, grassland, wasteland and forest. Many flowering plants and wild edible fruit species, such as *Berberis aristata, B. lyceum, Terminalia chebula*, *Zizyphusm auritiana, Urtica dioica* and *Zanthoxylum armatum* (Kumar 2021b), provide shelter and food to the butterfly community.

A checklist of butterfly diversity was prepared with well-planned survey from 7:00 am to 9:00 am and 4:30 to 6:00 pm one day a week in various habitats (Figure 1). Many rare butterfly species were also recorded from opportunistic sightings while working in the experimental fields. These photographic records of the butterfly species were collected with the Nikon 3300 camera using DX NIKKOR 70-300 mm lens. Most of the butterfly species were geotagged with Nikon p900 camera that provides the option to collect geographic coordinates with GPS logging feature. The taxonomic identification of the butterflies was carried out with available literature and field guides (Mani 1986; Kehimkar 2016; Smetacek 2017; Kasambe 2018; Sondhi and Kunte 2018). Based on the relative abundance of butterflies' species, they have been categorized into three groups such as very common (VC) species (the sighting of the butterfly was >50 times in a year), common (C) (sighting of the butterfly was from 5-20 times per year) and rare (R) species, the butterfly species were recorded in unique habitat as per availability of the host plant (sighted 1-5 times in a year).

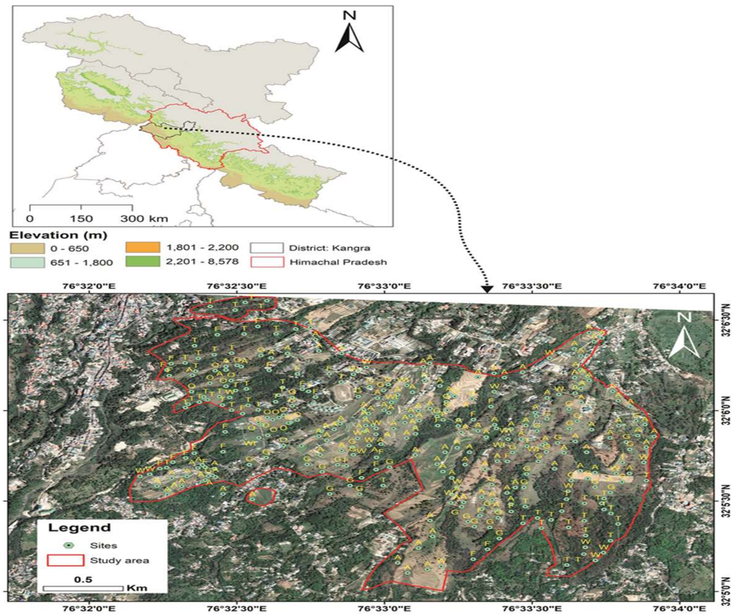


Figure 1: Sites covered to document butterfly diversity in agricultural landscape of HPAU, Palampur, north-western Himalaya, India. Abbreviation: A= agriculture; F= forest; G= grassland; O= orchard, T= tea orchard; W= wasteland vegetation; Wt= wetland habitats

Results and Discussion

The study recorded 74 butterfly species belonging to 6 families and 57 genera in HPAU (Table 1). The 53 butterfly species are common, and 23 are new in HPAU premises. The table also shows the comparison of the checklist of butterfly diversity prepared for the Temporary Academic Block (TAB), Central University of Himachal Pradesh (CUHP), India (Kumar *et al.,* 2022). The CUHP is located in the agglomeration of three academic institutions with more area under human land use and habitat diversity. The photographic records of the new butterfly species compared to the CUHP are given in Figures 2&3, while the photographic records of common species are also given for the butterfly diversity in Kangra valley, northwest Himalaya, India (Kumar 2021a). Some of the butterfly species, such as Common Copper (*Lycaena phlaeas*), Anomalous Nawab (*Charaxes agrarius*), Common Map (*Cyrestis thyodamas*), Common Wall (*Lasiommata schakra*), Dark Blue Tiger (*Tirumala septentrionis*), Ringed Argus (*Callerebia annada*), Bath White (*Pontia daplidice*) and Pioneer (*Belenois aurota*) were encountered a single time indicating their vulnerable status in the study area.

Table 1: Checklist of butterfly diversity from Himachal Pradesh Agricultural University and their comparison with Central University Himachal Pradesh, India

SN	Common Name	Scientific Name	Abundance	Wildlife (Protection) Act, 1972	CUHP (2014-2019)	HPAU (2019-2022)
Family: Hesperiidae (8)						
1	Common Spotted Flat	*Celaenorrhinus leucocera* (Kollar, 1844)	R		+	+
2	Conjoined Swift	*Pelopidas conjuncta* (Herrich-Schäffer, 1869)	R		+	+
3	Fulvous Pied Flat	*Pseudocoladenia dan* (Fabricius, 1787)	R		+	+
4	Grass Demon	*Udaspes lolus* (Cramer, 1775)	C		-	+
5	Indian Palm Bob	*Suastus gremius* (Fabricius, 1798)	R		+	+
6	Indian Skipper	*Spialia galba* (Fabricius, 1793)	VC		+	+
7	Spotted Small Flat	*Sarangesa dasahara* (Moore, 1866)	C		-	+
8	Straight Swift	*Parnara gunatus* (Bremer & Grey, 1852)	VC		+	+
Family: Lycaenidae (9)						
9	Common Copper	*Lycaena phlaeas* (Linnaeus, 1761) -	R		-	+
10	Common Flash	*Rapala nissa* (Kollar, 1844)	R		-	+
11	Common Hedge Blue	*Acytolepis puspa* (Horsfield, 1828)	VC		-	+
12	Dark Grass Blue	*Zizeeria karsandra* (Moore, 1865)	C		-	+
13	Hill Hedge Blue	*Celastrina argiolus* (Linnaeus, 1758)	VC		-	+
14	Pale Grass Blue	*Pseudozizeeria maha* (Kollar, 1844)	VC		+	+
15	Red Pierrot	*Talicada nyseus* (Guérin-Méneville, 1843)	R		-	+
16	Slate Flash	*Rapala manea* (Hewitson, 1863)	R		+	+
17	Sorrel Sapphire	*Heliophorus sena* (Kollar, 1844)	R		-	+
Family: Nymphalidae (38)						
18	Anomalous Nawab	*Charaxes agrarius* (Swinhoe, 1887)	R		-	+
19	Bamboo Treebrown	*Lethe europa* (Fabricius, 1775)	R		+	+
20	Banded Treebrown	*Lethe confusa* (Aurivillius, 1898)	VC		+	+
21	Blue Pansy	*Junonia orithya* (Linnaeus, 1758)	C		+	+
22	Broad-banded Sailer	*Neptis sankara* (Kollar, 1844)	R		+	+
23	Chocolate Pansy	*Junonia iphita* (Cramer, 1779)	VC		+	+
24	Club Beak	*Libythea myrrha* (Godart, 1819)	VC		+	+
25	Common Baron	*Euthalia aconthea* (Cramer, 1777)	C		+	+
26	Common Castor	*Ariadne merione* (Cramer, 1777)	C		+	+
27	Common Crow	*Euploea core* (Cramer, 1780)	C		+	+
28	West Himalayan Five-ring	*Ypthima nikaea* (Moore, 1875)	R		+	+
29	Common Jester	*Symbrenthia lilaea* (Hewitson, 1864)	R		+	+
30	Common Leopard	*Phalanta phalantha* (Drury, 1773)	C		+	+
31	Common Map	*Cyrestis thyodamas* (Boisduval, 1840)	R		-	+
32	Common Nawab	*Charaxes bharata* (Felder & Felder, 1867)	R		-	+
33	Common Sailer	*Neptis hylas* (Linnaeus, 1758)	C		+	+
34	Common Sergeant	*Athyma perius* (Linnaeus, 1758)	C		+	+
35	Common Threering	*Ypthima asterope* (Klug, 1832)			+	-

36	Common Treebrown	*Lethe rohria* (Fabricius, 1787)	R		+	+
37	Common Wall	*Lasiommata schakra* (Kollar, 1844)	R		-	+
38	Dark-branded Bushbrown	*Mycalesis mineus mineus* (Linnaeus, 1758)	VC		+	+
39	Dark Blue Tiger	*Tirumala septentrionis* (Butler, 1874)	R		-	+
40	Double Branded Crow	*Euploea sylvester* (Fabricius, 1793)	R		+	+
41	Glassy Tiger	*Parantica aglea* (Stoll, 1782)	R		+	+
42	Grey Pansy	*Junonia atlites* (Linnaeus, 1763)	R		+	+
43	Himalayan Chestnut Tiger	*Parantica sita sita* (Kollar, 1844)	R		+	+
44	Himalayan Tortoiseshell	*Aglais cashmirensis* (Kollar, 1844)	VC		+	+
45	Indian Fritillary	*Argyreus hyperbius* (Linnaeus, 1763)	VC		+	+
46	Indian Red Admiral	*Vanessa indica* (Herbst, 1794)	R		+	+
47	Lemon Pansy	*Junonia lemonias* (Fruhstorfer, 1758)	C		+	+
48	Orange Oakleaf	*Kallima inachus* (Doyere, 1840)	R		+	+
49	Painted Lady	*Vanessa cardui* (Linnaeus, 1758)	R		+	+
50	Peacock Pansy	*Junonia almana* (Linnaeus, 1758)	R		+	+
51	Ringed Argus	*Callerebia annada* (Moore, 1858)	R		-	+
52	Striped Blue Crow	*Euploea mulciber* (Cramer, 1777)	R	Schedule IV	+	+
53	Striped Tiger	*Danaus genutia* (Cramer, 1779)	R		+	+
54	Vagrant	*Vagrans egista* (Cramer, 1780)	R		+	+
55	Yellow Coster	*Acraea issoria anomala* (Kollar, 1819)	R		-	+
56	Yellow Pansy	*Junonia hierta* (Fabricius, 1798)	R		-	+
Family: Papilionidae (6)						
57	Common Bluebottle	*Graphium sarpedon* (Linnaeus, 1758)	R		+	+
58	Common Lime	*Papilio demoleus* (Linnaeus, 1758)	R		+	+
59	Common Mormon	*Papilio polytes* (Linnaeus, 1758)	C		+	+
60	Common Peacock	*Papilio bianor* (Cramer, 1777)	R		+	+
61	Glassy Bluebottle	*Graphium cloanthus* (Westwood, 1841)	R		+	+
62	Lesser Punch	*Dodona dipoea* (Hewitson, 1866)		Schedule II	+	-
63	Yellow Swallowtail	*Papilio machaon* (Linnaeus, 1758)	R		+	+
Family: Pieridae (11)						
64	Bath White	*Pontia daplidice* (Linnaeus, 1758)	R		-	+
65	Common Brimstone	*Gonepteryx rhamni* (Linnaeus, 1758)	R		+	+
66	Common Emigrant	*Catopsilia pomona* (Fabricius, 1775)	R		+	+
67	Common Grass Yellow	*Eurema hecabe* (Linnaeus, 1758)	C		+	+
68	Common Jezabel	*Delias eucharis* (Drury, 1773)	R		-	+
69	Dark Clouded Yellow	*Colias fieldii* (Menetries, 1855)	C		-	+
70	Hill Jezebel	*Delias belladonna* (Fabricius, 1793)	R		-	+
71	Indian Cabbage White	*Pieris canidia* (Linnaeus, 1758)	C		+	+
72	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus, 1758)	R		+	+
73	Pioneer	*Belenois aurota* (Fabricius, 1793)	R		-	+
74	Small Grass Yellow	*Eurema brigitta* (Stoll, 1780)	C		+	+
Family: Riodinidae (2)						
75	Pulm Judy	*Abisara echerius* (Stoll, 1790)	R		+	+
76	Common Punch	*Dodona durga* (Kollar, 1844)	R		-	+

Abbreviation: C= Common, VC= Very common, R= Rare

The present study revealed that Nymphalidae (38) was the dominant family, followed by Pieridae (11), Lycaenidae (9), Hesperiidae (8), Papilionidae (6) and Riodinidae (2).

The low sighting of butterfly species near the built-up area and agriculture field indicates anthropogenic disturbances and agricultural activities. Many researchers discussed the role of landscape heterogeneity as more in comparison to the farming system while comparing organic and conventional farming system (Weibull *et al.,* 2000). Furthermore, researchers also pointed out that use of agrochemicals also impact the butterfly species in the agricultural ecosystem (Pekin 2013; Pendl *et al.,* 2013; Mule *et al.,* 2017).

This also seems true for the study area where maximum rare sightings were recorded in grassland, tea orchards and forest habitat. The unavailability of the host plant in the agriculture field also seems responsible due to the clearing unwanted shrubs and other plants from the study. The impact of the surrounding landscape and habitats are responsible for the valuable supply of food and nectar for the butterfly community. More butterfly species were noticed in HPAU compared to the CUHP.

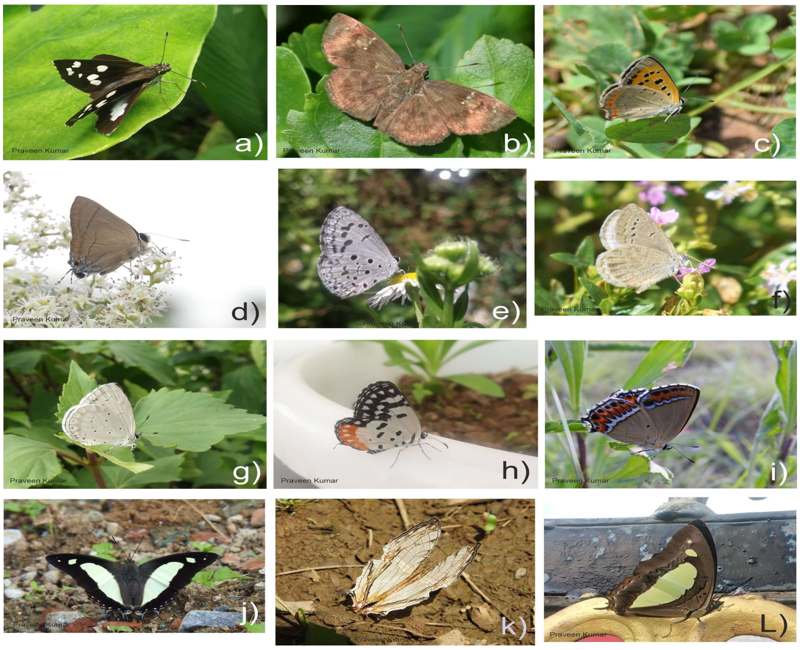


Figure 2: The representative butterfly species recorded new in HPAU in comparisons to the checklist of CUHP, India; a) *Udaspes lolus*, b) *Sarangesa dasahara*, c) *Lycaena phlaeas*, d) *Rapala nissa*, e) *Acytolepis puspa*, f) *Zizeeria karsandra*, g) *Celastrina argiolus*, h) *Talicada nyseus*, i) *Heliophorus sena*, j) *Charaxes agrarius*, k) *Cyrestis thyodamas*, l) *Charaxes bharata*

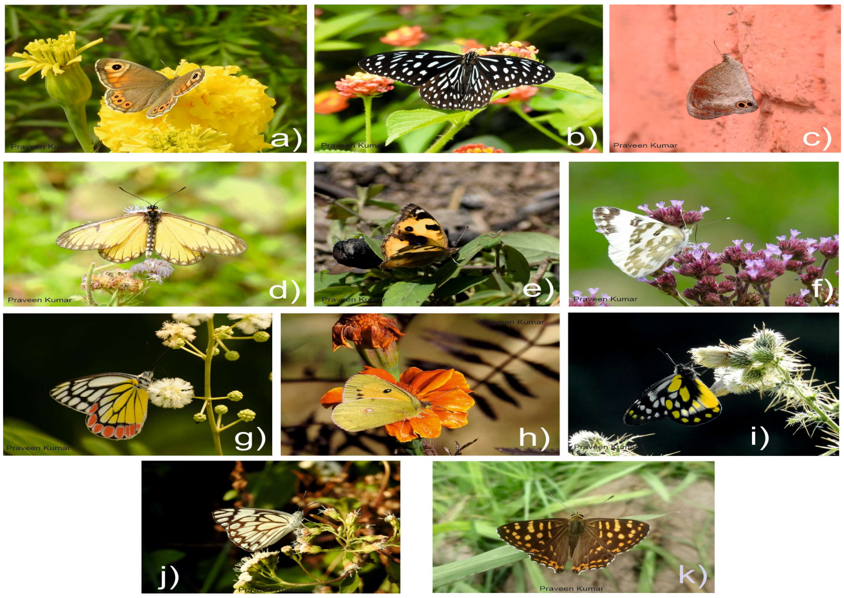


Figure 3: The representative butterfly species recorded new in HPAU in comparisons to the checklist of CUHP, India; a) *Lasiommata schakra*, b *Tirumala septentrionis*, c) *Callerebia annada*, d) *Acraea issoria*, e) *Junonia hierta*, f) *Pontia daplidice*, g) *Delias eucharis*, h) *Colias fieldii*, i) *Delias belladonna*, j) *Belenois aurota*, k) *Dodona durga*

This was due to the large study area, habitat diversity, availability of the host plant and less human interference in the areas occupied by tea plantation, mixed forest and wetlands in HPAU.

Furthermore, CUHP is working on a temporary academic block surrounded by agglomeration of three academic institutions facing more anthropogenic onslaught resulting in less butterfly diversity. However, the checklist of the butterfly' diversity of premises show some very peculiar records highlighted as rare (Table 1) are the major concern. The distribution of butterfly species are also influenced by the availability of host plants to lay eggs (Kumar *et al.,* 2022). The clearing of shrubs and natural vegetation near the built up area also confine the butterfly species in specific habitats and host plant. So, such areas under natural vegetation, abandoned tree garden, forest, wasteland and parks can be used for butterfly conservation. The sites with less anthropogenic impact, such as grassland, wasteland and forest area on the university premises can be developed to conserve butterfly's diversity. Furthermore, the non-target effects of chemicals used need to be explored for lepidopterans (butterfly and moth) families to check the lethal dosage and devise alternatives for non-target species.

Conclusion

This study provides the first checklist of butterfly fauna for the agriculture university in the hilly state of Himachal Himalaya. The checklist shows that the university premise is rich in butterfly diversity, including many rare butterfly records. The habitat preferences of some of the butterfly species are seasonal drainage, forested area, tea gardens and open grassland. Some butterfly species like to patrol around large flowering trees. The butterfly diversity decreased through various human activities, such as clearing host plants and chemical's use in agricultural fields. The impact of anthropogenic disturbances, habitat fragmentation and agricultural activities is also inferred from the high number of rare butterfly species per abundance in the checklist. The less disturbed areas are the safe home for butterfly diversity and the prominent spot for diversity conservation. The checklist can be used to understand the long-term effects of climatic change in future exploration and research.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Arora, G. S., Mehta, H. S., & Walia, V. K. (2009). *Handbook on butterflies of Himachal Pradesh*. Zoological Survey of India.

Bhardwaj, M., Uniyal, V. P., Sanyal, A. K., & Singh, A. P. (2012). Butterfly communities along an elevational gradient in the Tons valley, Western Himalayas: Implications of rapid assessment for insect conservation. *Journal of Asia-Pacific Entomology*, *15*(2), 207-217.

Chandel, S., Kumar, V., Sharma, B. P., & Patiyal, R. (2013). Butterfly species diversity of Bir-Billing area of Dhauladhar Range of Western Himalayas in Northern India. *Journal of Entomology and Zoology Studies*, *1*(5), 53-57.

Harsh, S. (2014) Butterfly diversity of Indian institute of forest management, Bhopal, Madhya Pradesh, India. *Journal of Insects2014*, 1–4.

Kasambe, R. (2018). Butterflies of Western Ghats. Second Edition. Published by author (self published) pp 372.

Kehimkar, I. (2016). BNHS Filed Guides - Butterflies of India. Bombay Natural History Society, Mumbai. pp 509.

Kumar, P., Parmar, B. & Mahajan A.K. (2022). Butterfly Diversity from the Temporary Academic Block of Central University Himachal Pradesh, India. *Journal of Himalayan Ecology and Sustainable Development,* Under review.

Kumar, P. (2021a). Butterfly diversity from the foothill region of Dhauladhar Ranges Kangra Valley, North-West Himalaya, India. *Environment and Ecology*, *39*(4A), 1257-1265.

Kumar, P. K. (2021b). Spatial distribution and ethno-botanical aspect of edible plant from foothill region of Dhauladhar Range, Kangra Valley, North-Western Himalaya, India. *J Biodiversit*, *12*(1-2), 24-31.

Kumar, P., Kumar, J. & Kumar, R. (2020b). First record of the Common Tinsel from the hilly state of Himachal Pradesh, India. *Zoo's Print, 35* (12): 38-40.

Kumar, P., Kumar, R., & Kumar, J. (2020a). *Spindasis schistacea* (Moore, 1881)—Plumbeous Silverline: A new butterfly record from Himachal Pradesh, India. *Journal on New Biological Reports*, *9*(3), 309-311.

Mani, M. S. (1986). *Butterflies of the Himalaya*. (Oxford & IBH Publishing Company, New Delhi)

Mulé, R., Sabella, G., Robba, L., & Manachini, B. (2017). Systematic review of the effects of chemical insecticides on four common butterfly families. *Frontiers in Environmental Science*, *5*, 32.

Pekin, B. K. (2013). Effect of widespread agricultural chemical use on butterfly diversity across Turkish provinces. *Conservation biology*, *27*(6), 1439-1448.

Pendl, M., Hussain, R. I., Moser, D., Frank, T., & Drapela, T. (2022). Influences of landscape structure on butterfly diversity in urban private gardens using a citizen science approach. *Urban Ecosystems*, *25*(2), 477-486.

Singh, V., & Banyal, H. S. (2014). Preliminary ecological studies on the Lepidoptera from Khajjiar lake catchment, Himachal Pradesh, India. *Biodiversity Journal*, *5*(1), 61-68.

Smetacek, P. (2017). *A naturalist's guide to the butterflies of India, Pakistan, Nepal, Bhutan, Bangladesh and Sri Lanka*. John Beaufoy Publishing Limited.

Sondhi, S., & Kunte, K. (2018). *Butterflies of Uttarakhand: a field guide*. Bishen Singh Mahendra Pal Singh. pp 310.

Thakur, S., Bahrdwaj, S., & Singh, A. P. (2021). Diversity pattern of butterfly communities (Lepidoptera) in different habitat types of Nahan, Himachal Pradesh, India. *Journal of Threatened Taxa*, *13*(8), 19137-19143.

Weibull, A. C., Bengtsson, J., & Nohlgren, E. (2000). Diversity of butterflies in the agricultural landscape: the role of farming system and landscape heterogeneity. *Ecography*, *23*(6), 743-750.

Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 222-233, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

LULC dynamics and application of nature-based solution in high erosion prone areas of Malappuram District

Thenmozhi M ✉
Department of Soil and Water Conservation Engineering, Centre for Water Resources Development and Management, Kozhikode, Kerala, India
Sreejith Prasad
CWRDM, Kunnamangalam, Kozhikode, India
Riyola George
CWRDM, Kunnamangalam, Kozhikode, India
Jayabharathi J
College of Fisheries Engineering, TNFU, Nagapattinam, India

ARTICLE INFO

Received : 13 December 2022
Revised : 13 February 2023
Accepted : 06 March 2023

Available online: 26 June 2023

Key Words:
Accuracy assessment
LULC
Nature based solutions
Soil erosion

ABSTRACT

Kerala State is highly vulnerable to natural disasters, mainly soil erosion due to changing climatic dynamics in the steep slope. In 2018 and 2019 flood, some districts in Kerala State were affected by significant floods due to extreme and prolonged rainfall, leads to large and small landslides. Malappuram is one of the districts that got affected in 2018 and 2019 flood. Disaster risks are augmented by a critical factor that has been silently rising in the State now, which is change in the land use pattern and practices. Hence, the Land Use and Land Cover Dynamics study was conducted in the selected watersheds (Kakkarathode – Pulikkal and Palathingal) of Malappuram district, and spotted major landslides in the area. The LULC dynamics were carried out in the different time periods like 2013, 2018 and 2020. LISS IV (5.8 m resolution) satellite images were used for the analysis and field visit, to identify the related changes. Accuracy of the classification was evaluated using error matrices and kappa statistics. The overall accuracies for 2013, 2018 and 2020 were 84.93%, 86.21% and 87.5% respectively and the corresponding Kappa values were 0.82, 0.84 and 0.85 which indicates the high accuracy of the classification. The flood has mainly affected Plantation, Paddy and Mixed Plantation which had been decreased during 2018-20 and has resulted in the emergence of more Barren land and Waste Land. LULC helps in identifying the changes in the erosion prone areas. Moreover, erosion hazardous area and its prioritization in applying the soil management and conservation practices can be effectively done using LULC change assessment. Nature based solutions such as planting trees and grasses (like shrubs, vetiver grass etc.), construction of ponds, creation of green walls and assemblage of vegetations can be adopted in the region of high-risk hazardous area depending on the categorized zone.

Introduction

LULC categorises the natural and human factors on the landscape throughout a specific time period. The classification is based on recognised scientific and statistical techniques for the analysis of suitable source materials. Classified areas help users in clearly recognizing the current landscape and monitor temporal dynamics in agricultural ecosystems, water bodies (surface), forest conversions, etc. on annual basis. For determining conservation priorities, LULC data sets reveal indicators of the threat by potential development. Other data sets include details on how humans have altered the landscape, results of an increase urban sprawl or other anthropogenic pressures. Many countries all over the world are experiencing rapid, broad changes in Land Use and Land Cover. The prompt rise in the world population that led to an escalate in anthropogenic actions, have ended in

Corresponding author E-mail: *thenmozhi@cwrdm.org*
Doi: https://doi.org/10.36953/ECJ. 16562529

rapid changes in LULC, forest destruction and the conversion of generative land to urban development, all of which have major ecological consequences. Understanding and mapping LULC change has become increasingly relevant in governance of natural resource management and environmental monitoring.Land use change through the conversion of forest land to other purposes is continuing to develop at a rapid rate due to the exponential growth of the human population, which enhances the need for food and land. According to a UN survey, Global forest loss was around 129 million hectares between 1990 and 2015, reflecting a 1.3 percent annual rate of loss. Urban residents account for 55 percent of the global population and are expected to rise to 68 percent by 2050. 2.5 billion more people will reside in cities by 2050 (The Global Forest Goals Report, 2021). The impact of severe LULC changes causes various issues in environment such as; climate change, increased surface erosion, depletion of soil nutrients, loss of water quality, loss of bio diversity etc. With the advanced Remote Sensing and GIS techniques, it is possible to constantly monitor LULC changes and predict the future changes. With the help of this data proper planning can be done to diminish the impact of the LULC changes.

Floods, which are one of the most dangerous natural catastrophes, are prone to any inhabited places that are generally found in tropical locations which cause damage to human lives, agriculture lands, properties and other infrastructure. Therefore, adequate knowledge of land use and land cover and the ability to accurately locate and map the flood prone areas, are required for executing proper planning and management against flood (Tiwari *et al.*, 2020). Contribution of LULC changes in August 2018 flood in Kerala was mainly due to deforestation-related changes during 1995-2005 (Ankur Dixit *et al.,* 2022). In Kerala, the built-up area significantly increased from 1988 to 2017 by 134% and from 2000 to 2017 by 265%, also increase in the average land surface temperature (LST), from 27.7 °C to 30.3 °C, was also recorded. Land cover dynamics in Kerala over different decades through MODIS data and statistical techniques, the first decade as 2001 to 2010 and second decade as 2011 to 2019, increase in the area covered by forest, urban, crop land, shrublands and natural vegetation, decreasing trend in savannas and grasslands (Vijith H *et al.,* 2022). The pre-flood Land Use and Land Cover mapping reveals that agriculture land was the major LULC (113.34 km^2), followed by water bodies (44.44 km^2), aquatic vegetation (74.83 km^2), terrestrial vegetation (40.92 km^2). With respect to post flood land use/ land cover changes, major part of agricultural land, terrestrial vegetation and others LULC classes were primarily affected and decreased (63.86 km^2, 31.21 km^2, 5.36 km^2 respectively). On the conflicting, majority of said LULC classes were covered by sand deposits (i.e. 22.76 km^2) determining the ecosystem process of lake environment (Tauseef Ahamad *et al.*, 2017). Substantial reduction in forest, agriculture and shrubs for the period of 10 years, leads to high flood risk (Sugianto *et al.,* 2022).Kerala's flood of 2018 was one of the biggest natural disasters of the century. This flood had a detrimental impact on Kerala's economy, as well as the lives and livelihoods of those who reside in the impacted areas. Over 483 people were died and thousands of homes were damaged. Malappuram district was one among the severely affected district in Kerala by 2018 flood. Therefore, a study regarding the LULC impact on flood in the selected watershed was taken.

Material and Methods

Study area

Kakkarathode-Pulikkal and Palathingal watersheds are located in Eranad Taluk of Malappuram district in Kerala which belongs to the southern part of India. Kakkarathode-Pulikkal watershed lies between latitude 11^0 03’ 23" to 11^0 05’ 47" N and longitude 76^0 08’ 42" to 76^0 10’51" E and Kakkarathode - Palathingal watershed lies between latitude 11^0 02’ 07” to 11^0 04’ 38" N and longitude 76^0 09’ 04" to 76^0 11’ 47"E. Kakarathode-Pulikkal and Palathingal watersheds are having an area of 500 ha and 730 ha and the total area of Kakkarathode watershed is 1230 ha. As per the 2011 census, the population of this area is about 4000. Physio graphically, the watershed comes under high land region with an elevation ranges from + 40 m to + 609 m from MSL. The maximum elevation of the watershed is 609m. The study area map is shown in Figure 1.

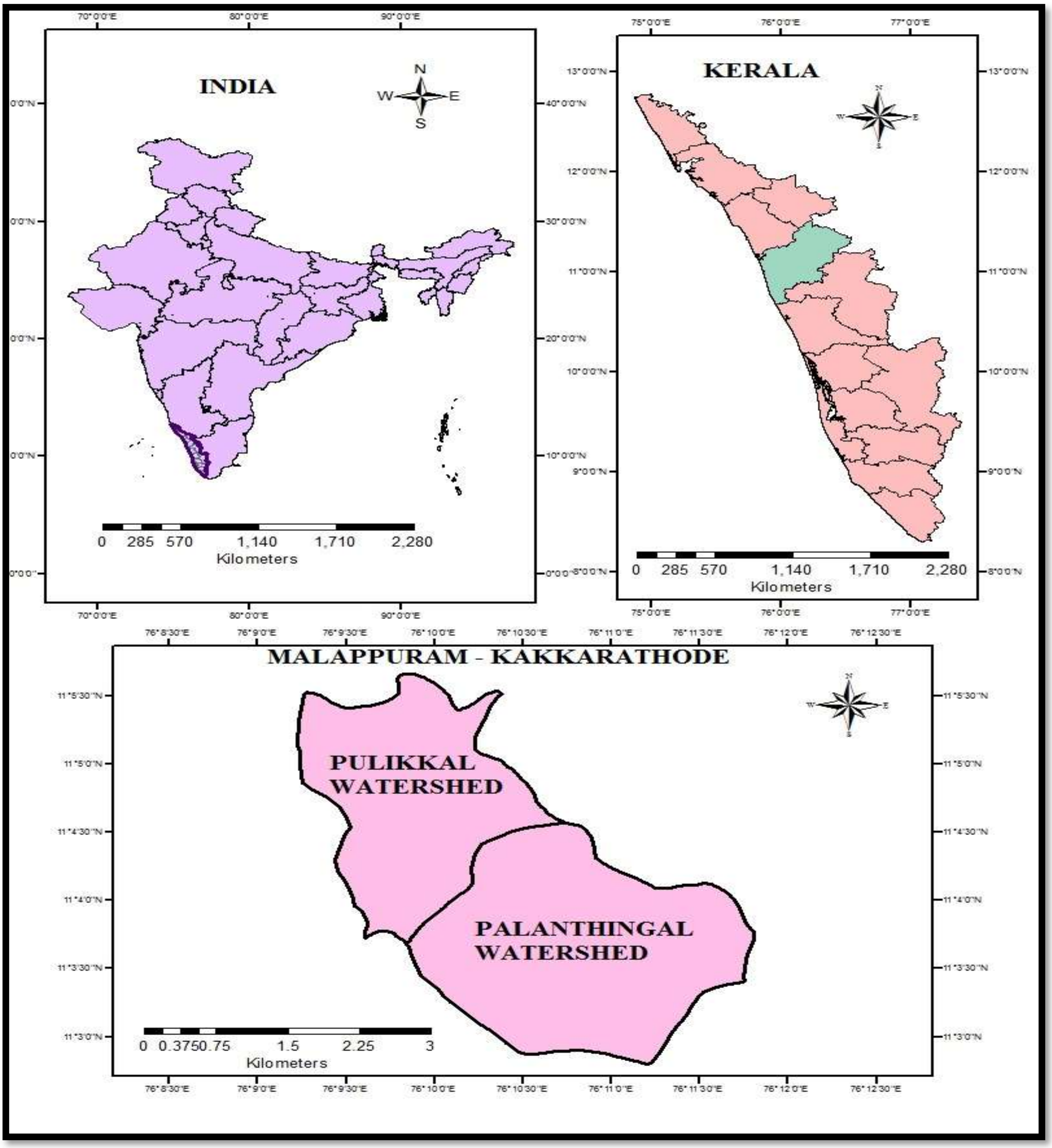


Figure 1: Study Area; Kakkarathode- Pulikkal and Palathingal watershed

Major cultivations in the watersheds include rubber plantation, coconut, banana, paddy, cashew, coffee, arecanut and vegetables. Rubber and coconut are the predominant crops in the high land. The coconut & arecanut in the area is being converted to Rubber. Plantain and vegetables are also cultivated in the low laying valley. Banana and Tapioca are the annual crop grown in this area during the monsoon season.The watershed has a humid tropical climate with an average annual rainfall of 2800 mm. The mean max. and min. temperatures are 36°C and 22°C respectively. The southwest monsoon accounts for over 70% of total rainfall, which occurs mostly in the months of June, July, and August. Pre-monsoon showers provide about 5-10 percent of total rainfall in April and May. And the remaining quantity occurs during the North East Monsoon in September and October. From December to April, there is a five-month dry period. The Kakkarathode -Palathingal watershed is a drainage area of a fourth order stream, which is a tributary of the Kadalundi river. The main drain of the watershed area is Kakkarathode which originate from Nenmini Mala area as Nenmini Church Vala thodu and flows towards western direction. Chemtheliyam para Vala thodu, Chathampara-Pattalipara thodu, Kallrutti –Mannathipara thodu, Mullarangad –Pachollaparathodu and Enchipullu thodu are the main sub drains which originates from Pandallur Mala and join to the main drain Kakkarathode. Then the main drain of Kakkarathode flows towards western direction and joins to Kadalundi puzha at Pulikkal-Pandallur. Drainage map showing their stream order is given in Figure 2.

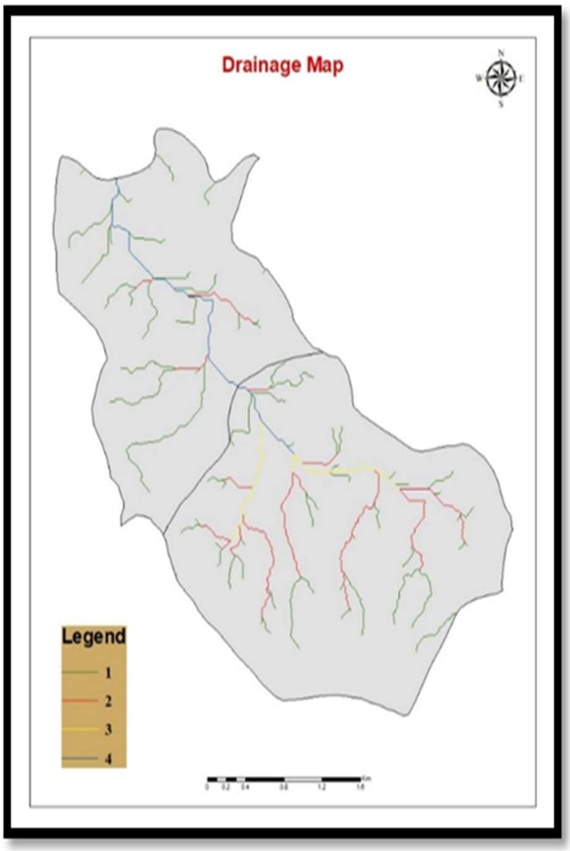


Figure 2: Drainage map of the watershed

Slope characteristics of Kakkarathode watersheds
The major landslides observed in the watersheds are about 40° slope terrains. The slope map indicates that the slope ranges from 16.17 to 1.64% rise from the general slope (Figure 3).

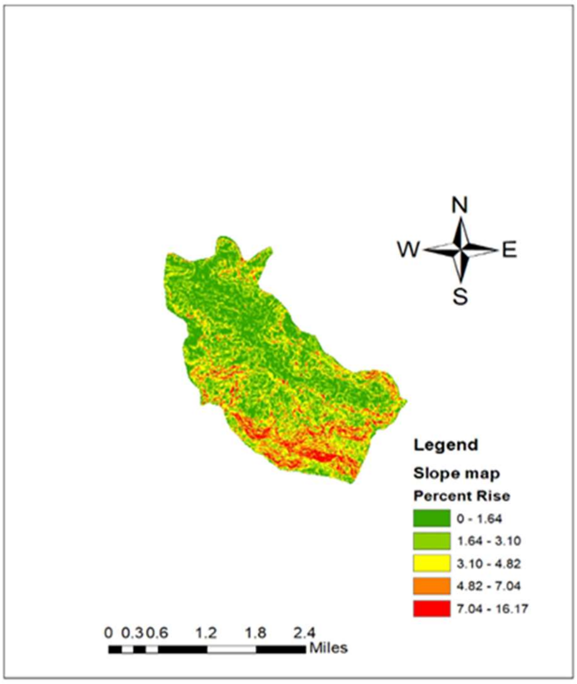


Figure 3: Slope map of the watershed

Data acquisition

LISS-IV satellite images of Kakkarathode - Pulikkal and Palathingal watersheds were acquired for the years 2013, 2018 & 2019 from National Remote Sensing Centre (NRSC), Department of Space, Govt. of India, Hyderabad, Andhra Pradesh with following specification as shown in Table 1.

Table 1: Details of Satellite Images.

Satellite	Sensor	Spatial resolution (m)	Date of Acquisition	Bands
IRS-P6	LISS-IV	5.8	02.02.2013	III
IRS-P6	LISS-IV	5.8	20.03.2018	III
IRS-P6	LISS-IV	5.8	11.02.2020	III

Software and platforms

The standard method of image processing was used, followed by ground truth collection. ERDAS Imagine version 14 and ArcGIS version 10.5 were used to create thematic maps from digital satellite data. For mapping vegetation and secondary information such as elevation (rise) and landforms, digital image processing (traditional method) was used, which included the use of image elements such as shape, position, tone, pattern, texture, association, and so on. Following the preparation of these interpretation elements, an interpretation key was prepared. Acquired data should be pre-processed to eliminate the errors. Pre- processing includes Geometric correction, Sub-setting etc. It is important to geometrically correct the data in order to perform change detection analysis. After obtaining the various data, they are likely to have varied projections, thus the next step is to project it, such that, all spatial data sets will be associated with a single coordinate system. In this study, the LISS IV imagery was geo-referenced to the UTM Zone 43N coordinate system. Universal Transverse Mercator (UTM) projection, Zone 43N, Spheroid WGS84 and WGS84 Datum was used as the primary coordinate system here.

Procedure used for LULC classification

ERDAS Imagine (Version 14), ArcGIS (Version 10.5) and Google Earth were used for classification process. After defining an area of interest (AOI), which is referred to as training classes, the supervised classification was done. The training sites were selected based on areas that were distinctly evident in each of the image sources. To reflect a specific class, more than one training sample was used. The training locations were chosen based on LISS-IV imagery and Google Earth. Following the digitization of the training site (Area of Interest), is the stage to establish statistical characterizations of each piece of data. In ERDAS Imagine 2014, these are known as Signatures editors. The SIG files are created and contain a wide range of information on the land cover classes. After specified training classes, the maximum likelihood classification (MCL) algorithm was used and finally calculated the area for the classified fields.Visual interpretation was used to solve the issue of mixed pixels. The results obtained using the supervised algorithm was substantially improved by using visual analysis reference data and local knowledge. Ground truthing is done for further improving the accuracy of the study. The accuracy of classification was determined by comparing collected reference points and classification results statistically using error matrices. The whole procedure is shown in Fig 4.

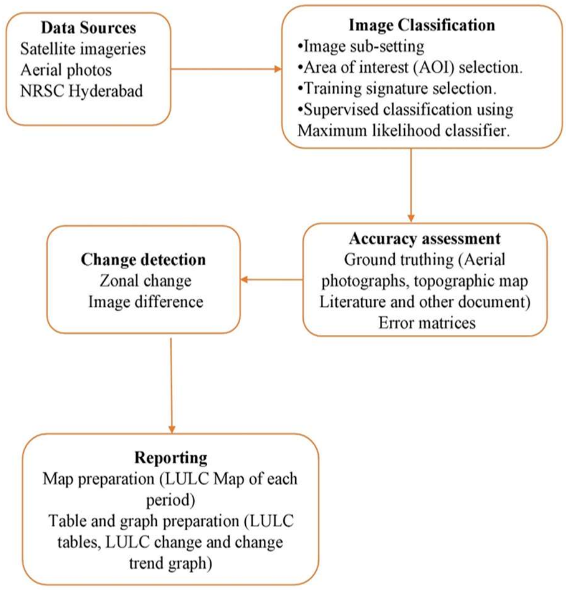


Figure 4: LULC classification chart

Accuracy assessment

In order to assess how accurately a classification represents reality, it is compared to either a high resolution image or ground truth data. The main goal of accuracy evaluation is to identify the sampling methods used to divide pixels into the appropriate land cover groups. In this study, accuracy assessment was done with ArcGIS by random sampling method. Each LULC class had at least five sample sites, and each of these points was verified in the field or using higher resolution images (Google Earth), where locations were unapproachable. If sample point taken for LULC map matches with the ground truthing data it is considered as 1 and if they miss-match, it will be counted as 0. An Error matrix is generated based on this analysis - overall accuracy, producer's accuracy, user's accuracy (FA Islami *et al.,* 2022) as well as Kappa coefficient were calculated.

1. **Overall accuracy** is the measure of ratio of the number of sample points which are correctly classified to the total number of sample point. (FA Islami *et al.*, 2022)

$$\textit{The overall accuracy} = \frac{\textbf{No. of correctly classified points}}{\textbf{Total no. of points}}$$

2. **User's accuracy** define to the ratio of number of correctly classified points in every class to the total number of samples in that particular class, ie, it's a measure of how many no. of the samples of a similar class matched correctly (FA Islami *et al.*, 2022).

$$User's\ accuracy = \frac{\text{No. of samples that are correctly classified in a given category}}{\text{Total no. of Samples in that category}}$$

3. **Producer's Accuracy** is a compute of how much of land in each LULC class was classified correctly (FA Islami *et al.,* 2022)

$$Producer\ accuracy = \frac{\text{No. of samples that are correctly classified in a particular category}}{\text{Total no. of samples that are classified to that particular category}}$$

The Kappa coefficient is the difference between true agreements or correctly categorized points (major diagonal) and chance agreements. It defines the accuracy of the entire classification. So it is crucial to do kappa statistics in order to know the extent of accuracy of any LULC study. Table. 2 shows the Kappa Statistics general way of choosing the strength of agreement. The equation used for the calculation as: (Sophia *et al.*, 2017)

$$K = \frac{N\sum_{k=1}^{r} x_{kk} - \sum_{k=1}^{r}(x_{k+} \cdot x_{+k})}{N^2 - \sum_{k=1}^{r}(x_{k+} \cdot x_{+k})}$$

Where,
r = Number of classes
N = Total number of Pixels
x_{kk}= total pixels in row "k" and column "k"
x_{k+} = total samples in a row "k,"
x_{+k} = total samples in column "k"

Table 2. Kappa Statistics

SN	Kappa statistics	Strength of agreement
1	<0.00	Poor
2	0.00 - 0.20	Slight
3	0.21 - 0.40	Fair
4	0.41 - 0.60	Moderate
5	0.61 - 0.80	Good
6	0.81 - 1.00	Very Good

Results and Discussion

The data analysis is based on the comparison of LULC classes for three different periods during 13 years period. Land Use Land Cover maps: for the years 2013, 2018 and 2020 were prepared by supervised classification of LISS IV satellite images with the help of ancillary information as well as ground truthing. A total of 8 LULC classes were identified namely; Agricultural land, paddy, mixed plantation (converted paddy), Water Body, Plantation, Built-up Land, Waste Land and Barren Land. Area distribution of various LULC classes in different study period has been summarized in Table 3.Visual analysis is the primary step in viewing an image and is the easiest way to distinguish different land covers and modify data about the specific region through a human interpreter. The visual assessment will provide a broad overview of LULC transition pattern over a 13-year cycle. The false colour (Figure 5) composite images were created using LISS IV satellite images. Natural and false colour composites are an effective method for visually extracting information from LISS IV satellite images and it can help in generating a general overview of LULC change pattern in the selected watershed for the study. Texture, size, shape and patterns of the imagery are the key factors while identifying change in LULC through visual interpretation (Padmanava Dash *et al*., 2016).

Training Areas

LULC classes have presented in the watershed and illustrative the training samples for every class, supervised classification used for generating the LULC map from a satellite image. Training samples are typically derived through first-hand experience, fieldwork, or through visual interpretation of other facilities, such as high-resolution photos from Google Earth and satellite imagery (Lu and Weng 2007).Training samples can be gathered from various sources such as in-place data, aerial photos, topographic maps etc. It is crucial and advisable that ground truth data should be taken simultaneously with data acquisition or at least before environmental situation changes, to achieve a high accuracy and to keep the results of LULC changes over time. Aerial photos, visual interpretation and in-field knowledge were used in this study to collect training samples and ground truth" data which is needed for classification as well as accuracy calculation. A minimum of 20 training pixels have been taken for each class defined, using LISS IV satellite imagery for 2013, 2018 and 2020. With its speed, precision, and affordability, collecting ground truth data from aerial photographs has a clear advantage over traditional survey processes.

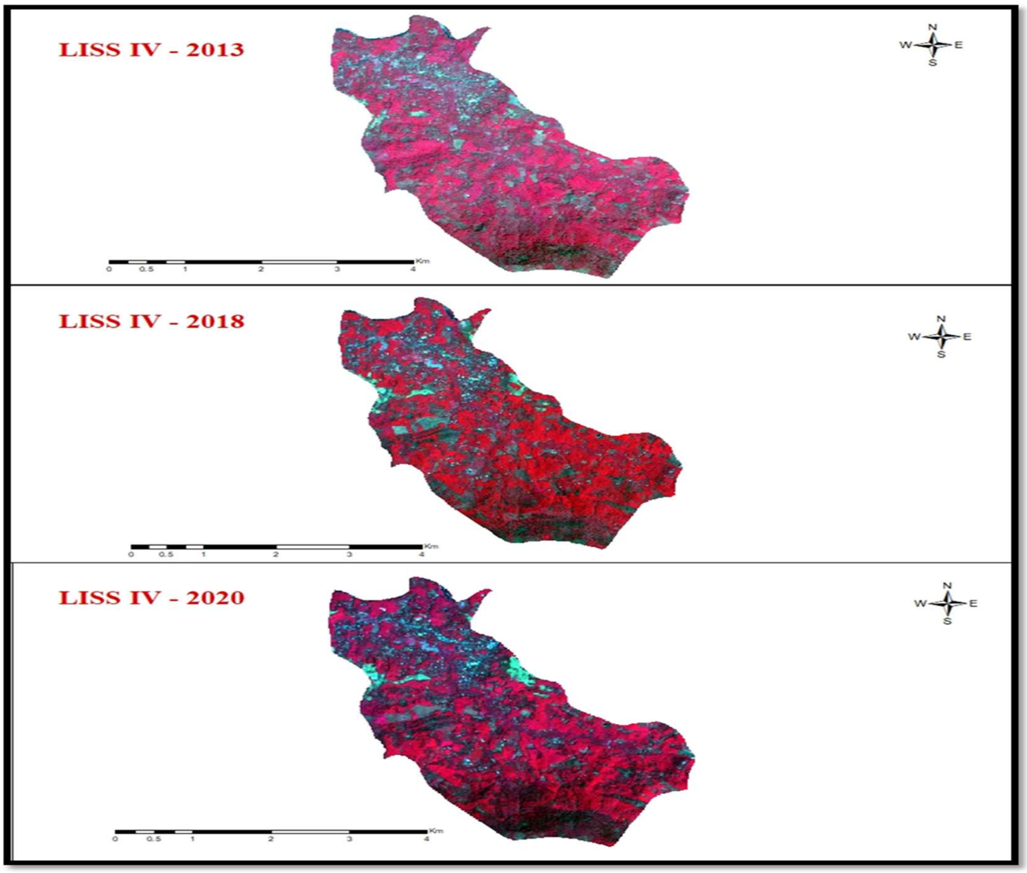


Figure 5: LISS IV False colour composite of 2013, 2018 and 2020

LULC Classification

Land Use Land Cover Analysis of 2013

LULC map of 2013 has shown that Plantation (49.75%) was the most dominant class occupied in the study area which was followed by Agricultural land (32.4%) and least area was covered by Water body (0.4%). Mixed plantation (Converted paddy) comprised an area of 95.97 ha (7.8%) where different crops such as banana, tapioca, Areca nut, various vegetables etc. Converted paddy - It was once used to cultivate paddy, which was then converted into various other plantations mainly due to lack of profit. Built-up area (1.05%), Waste Land (1.9%) and Barren land (6.27%) were the other LULC classes occupied.

Land Use Land Cover Analysis of 2018

Analysis of 2018 LULC image has revealed that Plantation and agricultural land constitutes around 80% of the total area. Here also Plantation was the most dominant class covering 55.5% of the total study area. Agricultural land was at the second position with 24.36% followed by mixed plantation (7.4%), barren land (7.28%), waste land (2.24%), built-up area (2.5%), and paddy (0.38%). Water body comprised only 0.35% which was the least in 2018.

Land Use Land Cover Analysis of 2020

As in 2013 & 2018, Similarly Plantation is major dominant and occupied 49.46% in 2020 and agricultural land retained its second position, occupied 22.12% of the study area. Barren land showed a remarkable hike in its area when compared to the previous study periods which was due to the flood occurred in 2018. Barren land was covered by 15% and finally 6.79%, 3.04%, 2.81%, 0.42% and 0.36% of the study area were covered by mixed plantation, waste land, Built-up area, water body and paddy respectively. LULC details are shown in Fig 6 & 7.

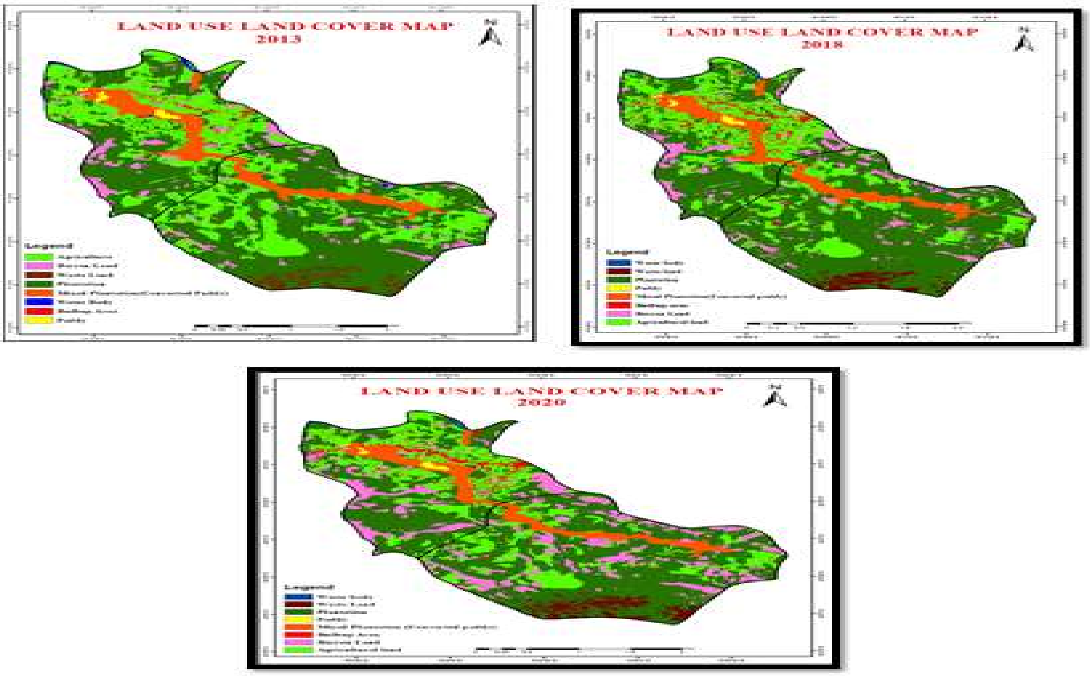


Fig 6. Kakkarathode – Pulikkal and Palathingal watersheds LULC map of 2013, 2018 and 2020

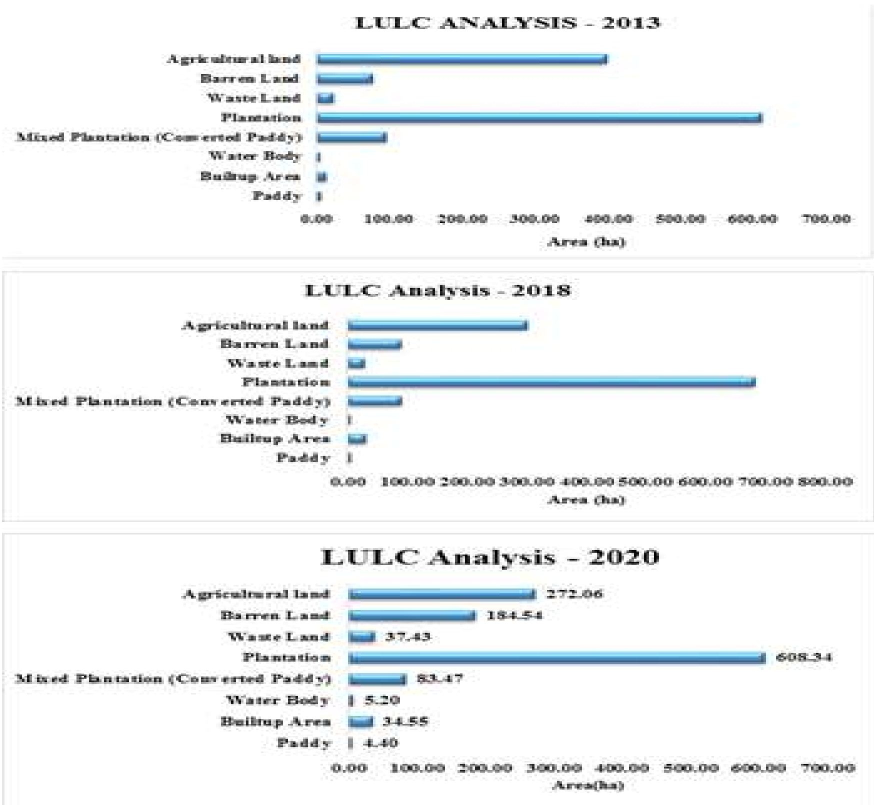


Figure 7: Area covered by different LULC classes during 2013, 2018 and 2020

Accuracy assessment

Accuracy assessment was performed using random sampling for all the 3 study periods. The overall classification accuracy and Kappa value were greater than 81% and 0.81 respectively which implies strong agreement. The overall accuracies for 2013, 2018 and 2020 were 84.93%, 86.21% and 87.5% respectively. Kappa values were 0.82, 0.84 and 0.85. According to (Vuillez *et al.,* 2018), an accuracy value of at least 85% is considered as effective classification. Thus, this classification satisfies the maximum accuracy. Mixed plantation and paddy were found to have 100% producer and user accuracy, which showed the best accuracy among all LULC classes. It could be because these classes might have better spectral discrimination.

Table 3: Area covered by each LULC groups in different study periods

LULC Class	2013		2018		2020	
	Area(ha)	% of Area	Area(ha)	% of Area	Area(ha)	% of Area
Paddy	5.16	0.42	4.69	0.38	4.40	0.36
Built up Area	12.93	1.05	30.72	2.50	34.55	2.81
Water Body	4.93	0.40	4.34	0.35	5.20	0.42
Mixed Plantation (Converted Paddy)	95.97	7.80	90.97	7.40	83.47	6.79
Plantation	611.88	49.75	682.64	55.50	608.34	49.46
Waste Land	23.43	1.90	27.54	2.24	37.43	3.04
Barren Land	77.12	6.27	89.49	7.28	184.54	15.00
Agricultural land	398.57	32.40	299.60	24.36	272.06	22.12
Total	**1230.00**	**100.00**	**1230.00**	**100.00**	**1230.00**	**100.00**

Table 4: Accuracy assessment of LULC classification

LULC Classes	2013		2018		2020	
	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy	User Accuracy	Producer Accuracy
Paddy	100	100	100	100	100	100
Built-up Area	72.72	88.89	62.5	83.33	75	90
Water Body	71.43	100	85.71	100	100	100
Mixed Plantation (Converted Paddy)	100	100	100	100	100	100
Plantation	92.31	63.16	88.89	72.72	76.92	76.92
Waste land	66.67	100	83.33	100	80	100
Barren Land	87.5	100	87.5	87.5	81.82	81.82
Agriculture	84.61	78.57	88.89	72.72	93.33	73.68
Year	**2013**		**2018**		**2020**	
Overall Classification Accuracy	**84.93**		**86.21**		**87.5**	
Overall Kappa Statistics	**0.82**		**0.84**		**0.85**	

Built-up area has shown the lowest user accuracy of 62.5% in 2018 while lowest producer accuracy has been exhibited by plantation in 2013 (63.16%). Hence this classification is within a very good range, based on the classification scale proposed by (Moriasi *et al.,* 2007).(Dires Tewabe and Temesgen Fentahun, 2020) carried out a study on LULC changes in Lake Tana Basin, Northwest Ethiopia using remote sensing and GIS for the years 1986, 2002 and 2018. This study has got an overall accuracy of 84.21%, 83.32%, and 89.66% for 1986, 2002 and 2018 respectively and the kappa values were 0.79, 0.83 and 0.89.

Land Use/Land Cover Changes in the steep slope area of the watersheds

The Land Use/Land Cover changes in the very steep slope to steep slope area of the Kakkarathode-Palathingal watershed were analysed. During field visits, we have observed the landslides in that area, which was occurred during 2018 and 2019 floods. The LULC changes is very much important to know about the changes detection, especially in the steep slopes for the proper management. The results showed that the build-up land increased by 1.92 ha in the year 2020, when compare to 2013. Similarly, Waste land and barren land increased by 4.41 ha and 1.35 ha in the year 2020. Plantation and Agriculture reduced by 4.35 ha and 2.3 ha in the year 2020. The classified area shown in the Fig. 8. The major changes in the LULC classes in the steep slope, is one of the reasons for landslide occurrence in the study area. LULC changes induced by human activities such as unendurable rural road development (Karsli *et al.,* 2009, McAdoo *et al.,* 2018), deforestation, monoculture cultivation, irrigation, mining, cut slopes for buildings and other engineering works lead to slope instability (Sheela *et al.,* 2017). LULC involves cut and fill also alter the morphology, hydrologic process and soil characteristics (Garfi *et al.,* 2007, Vuillez *et al.,* 2018). LULC may escalate when population increases in a slope region, leading to increased demand of built up areas, agriculture land and road (Prompter *et al.,* 2014), leads to more mass movements in the mountainous areas (Lorente *et al.,* 2002). The application of coir geo-textile with suitable agronomic practices can be followed in the waste land and barren land for the slope stability.

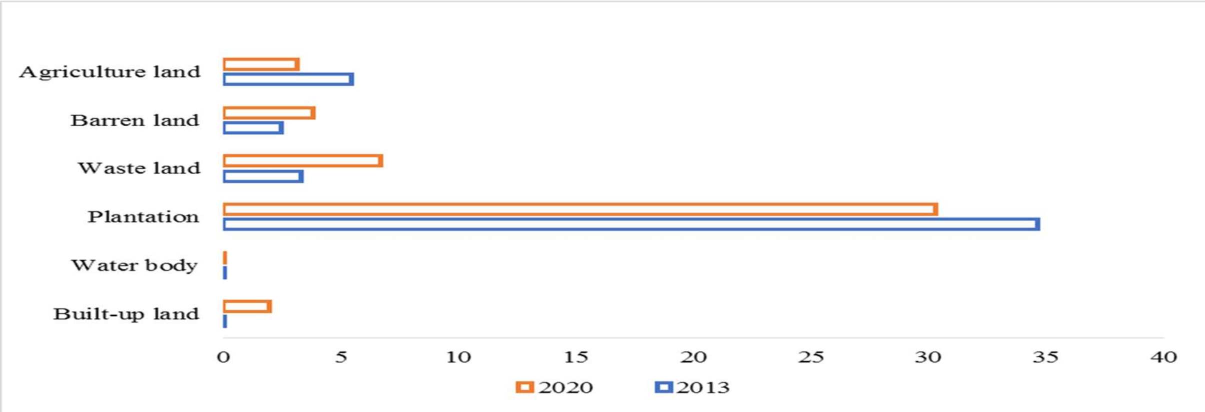


Figure 8: Area represented in steep slope of the watersheds

Nature Based Solutions in the Watersheds

During the year 2013 to 2020, the agricultural land of 10 per cent of total area was converted into barren land due to flood or human interventions. The possible way of changing the barren land into cultivable land with the proper adoption of naturally based solutions like coir geo-textile and other solutions.Coir-geo textile can control the soil erosion by acting as ground cover mulch. The mulch define to any bio-mulch materials would be decomposed fully or partially over a period of time and serving as nutrient to the crops. It reduces the flow velocity of runoff water and keep the soil intact. The coir geo-textile act as mulch, create favorable environment to germinate seeds by regulation of soil temperature, humidity, manure and controlling weeds.Application of coir geotextile for soil erosion and slope stabilization, soil was tested with varying slope and moisture content. The results indicate that the geotextile performed better for slope protection and soil erosion, hence it is biodegradable and eco-friendly (Subramani T. 2012). The effectiveness of coir geotextile in various treatments in terms of biomass production, erosion protection, and soil moisture content. The findings showed that using grass and geotextile as a treatment is an efficient eco-hydrological strategy for preventing erosion and maintaining a stable slope (Vishnudas S *et al.*, 2006).

Procedure for installing coir-geotextile

Site assessment: Considerations for the first step include slope analysis, rainfall patterns, soil type and consistency, level of damage, etc. select the appropriate coir geotextile and gather a sample of the vegetation cover.

Site preparation: The slope area is demarcated and levelled. The ground should be free of stones, earth masses.

Slope application: Slope assessment, blanket selection, vegetation selection, soil type, procedure for stabilizing the slope.

Channel application: assessment of channel, linear and vegetative selection, stabilization.

Vetiver Grass Application

The application of vetiver grass is a natural solution to reduce environmental risk in numerous ways. Vetiveria zizanioides L Nash, an Indian perennial grass currently known as Chrysopogon zizanioides L Roberty, was first established by the World Bank for soil and water conservation. It is a very useful, simple, affordable, low-maintenance method of reducing the impact of natural disasters. When combined with ecosystem management, vetiver grass can be employed as an extremely effective and efficient eco-DRR solution to address the problem of catastrophe in both the long and short term (Joice K Joseph *et al*., 2017). Vetiver buffer, planted at 5 m intervals on a 45° slope, considerably decreased runoff, soil losses, and enhanced crop yields. It also has promise for reducing GHG emissions, assisting with climate change adaptation and mitigation, and improving water usage efficiency (Effiom Oku *et al*., 2015).

Conclusion

The impact study of flood in various Land Use / Land Cover classes of Kakkarathode- Pulikkal and Palathingal watershed for the years 2013, 2018 and 2020 were studied using Remote sensing and GIS. The analysis of LULC maps identified that almost half of the area was occupied by Plantation (49.75% in 2013, 55.5% in 2018 and 49.46% in 2020) followed by Agricultural land. Agricultural Land, Paddy and Mixed plantation were continuously decreasing from 2013-2020, while Barren Land, Waste land and Built up area were constantly expanding. Plantation and Water body have exhibited undulations in their area during the period of study. Agricultural Land and Built up area were mainly distributed in the northern part and Plantation was mainly concentrated on the southern part of the Watershed. A small town along with more settlements was seemed to be gradually developing over time, resulting in the expansion of built up areas in the classification. Paddy is converted into other more profitable cultivations like banana, rubber, Areca nut, Vegetables etc. over a period of 30 years. This area is considered as mixed plantation (converted paddy) in this study. People lose interest in paddy cultivation and turn it into other plantations and cultivations mainly because paddy cultivation has more risk factors and has high maintenance costs. This study possesses a high degree of accuracy with overall accuracy greater that 85% and kappa values greater than 0.81 in all three classifications. The study resulted in a LU/LC analysis for the study region, which would aid land use planners & watershed stakeholders in formulating and implementing effective management of water resources and agricultural practices with nature based solutions.The natural based solutions like open weave geotextile erosion control meshes for the steep slope of barren land and waste land can be used for slope stability and erosion control. In a wide range of environmental situations with different rainfall intensity and soil types, woven jute products performed alternative solutions for controlling natural and man-made erosion. Sediment from bare ground can be protected using jute geotextile. On decomposition, JGT does not draw upon valuable nitrogenous reserves - rather its residue is beneficial & acts as mulch for vegetation growth. Natural fibre geosynthetics must be employed where natural vegetation is the long-term answer to control erosion. Judicious selection of geosynthetic product should be done keeping in consideration of environmental issues and positive attributes (even sometimes better) of natural products. Naturally based solutions like Vettiver grass and other erosion control grass can be grown in the disaster-prone areas of the watersheds mainly in barren and waste land.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ankur Dixit, Sandeep Sahany, Balaji Rajagopalan & Sweta Choubey. (2022). Role of changing land use and land cover on the 2018 mega floods over Kerala, India, Climate Research. Vol. 89: 1–14, 2022.

Dires Tewabe & Temesgen Fentahun. (2020). Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia, *Cogent Environmental Science*, 6:1, 1778-1798.

Effiom Oku, Emilolorun Ambrose Aiyelari & Kwabena O. Asubonteng. (2015). Using Vetiver Technology to Control

Erosion and Improve Productivity in Slope Farming. *Publisher: United Nations University Institute for Natural Resources in Africa (UNU-INRA) m Accra, Ghana.* ISBN: 978-9988-633-05-9

FA Islami, SD Tarigan, ED Wahjunie & BD Dasanto. (2022). Accuracy assessment of Land Use Change Analysis using Google Earth in Sadar Watershed Mojokerto Regency. *IOP Conf. Ser.: Earth Environ. Sci.* 950 012091.

Garfi, G., Bruno, D.E., Calcaterra, D & Parise, M. (2007). Morphodynamics and slope instability in the Mucone River basin (Sila Massif, southern Italy): Significance of weathering and role of land use changes. *Catena 69*, 181–196.

Joice k joseph, Amrutha Haridasan, Karunakaran Akhil Dev & Pradeepkumar A.P. (2017). Application of Vetiver Grass (Chrysopogon zizanioides) in Eco System Based Disaster Risk reduction – Studies from Kerala State of India. *Journal of Geography and Natural disasters* 07(1). DOI: [10.4172/2167-0587.1000192](10.4172/2167-0587.1000192)

Karsli, F., Atasoy, M., Yalcin, A., Reis, S., Demir, O & Gokceoglu, C. (2009). Effects of landuse changes on landslides in a landslide-prone area (Ardesen, Rize, NE Turkey). *Environ. Monit. Assess.* 156, 241–255.

Lorente, A., García-Ruiz, J.M., Beguería, S & Arn´ aez, J. (2002). Factors Explaining the Spatial Distribution of Hillslope Debris Flows. *Mt. Res. Dev.* 22, 32–39.

Lu, D. & Weng, Q. (2007). A survey of image classification methods and techniques for imp roving classification performance. *International Journal of Remote Sensing,* 28 (5), 823–870.

McAdoo, B.G., Quak, M., Gnyawali, K., Adhikari, B., Devkota, S., Rajbhandari, P & Sudmeier, K. (2018). Brief communication: Roads and landslides in Nepal: How development affects risk. *Nat. Hazards Earth Syst. Sci. Discuss.* 1–6.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE,* 50(3), 885–900.

Padmanava Dash, Arveti Nagaraju & Balaji Etikala. (2016). Land Use/Land Cover Analysis Based on Various Comprehensive Geospatial Data Sets: A Case Study from Tirupati Area, South India. *Advances in Remote Sensing*. 5(2):73-82.

Prompter, C., Puissant, A., Malet, J.P & Glade, T. (2014). Analysis of land cover changes in the past and the future as contribution to landslide risk scenarios. *Appl. Geogr.* 53, 11–19. https://doi.org/10.1016/j.apgeog.2014.05.020.

Sheela, A.M., Ghermandi, A., Vineetha, P., Sheeja, R.V., Justus, J & Ajayakrishna, K. (2017). Assessment of relation of land use characteristics with vector-borne diseases in tropical areas. *Land Use Policy*. 63, 369–380.

Skariah, M., Suriyakala, C.D. (2022). Land use/land cover changes (1988–2017) in Central Kerala and the effect of urban built-up on Kerala floods 2018. Arab J Geosci 15, 999. https://doi.org/10.1007/s12517-022-10296-y

Sophia S. Rwanga & JM. Ndambuki. (2017). Accuracy assessment of Land Use and Land Cover Classification using Remote Sensing and GIS. *International Journal of Geoscience*. Vol.8, No.4. DOI:

Subramani. T (2012). Application of Eco-friendly Geotextiles for Landslide Mitigation in a Part of Ooty Hills, Tamil Nadu. *International Journal of Modern Engineering Research (IJMER)*. pp 579-585.

Sugianto, S. Deli, A. Miswar, E. Rusdi, M. & Irham, M. The Effect of Land Use and Land Cover Changes on Flood Occurrence in Teunom Watershed, Aceh Jaya. Land 2022, 11, 1271. https://doi.org/ 10.3390/land11081271

Tiwari V, Kumar V, Matin MA, Thapa A, Ellenburg WL & Gupta N. (2020). Flood inundation mapping - Kerala 2018; Harnessing the power of SAR, automatic threshold detection method and Google Earth Engine. *PLoS ONE*. 15(8):e0237324.

Tauseef Ahmad, Pandey A.C & Amit Kumar. (2017). Impact of 2014 Kashmir flood on land use/land cover transformation in Dal lake and its surroundings, Kashmir valley. SN Appl. Sci. 2, 681.

United Nations Department of Economic and Social Affairs, United Nations Forum on Forests Secretariat (2021). The Global Forest Goals Report 2021.

Vijith H. & Ninu Krishnan MV. & Alhassan Sulemana. (2022). Regional scale analysis of land cover dynamics in Kerala over last two decades through MODIS data and statistical techniques, Journal of Environmental Studies and Sciences, Springer; Association of Environmental Studies and Sciences, vol. 12(3), pp 577-593.

Vishnudas.S, H.H.G. Savenije, P. Van der Zaag, K.R. Anil & K. Balan (2006). The protective and attractive covering of a vegetated embankment using coir geotextile. *Hydrol. Earth Syst. Sci. Discuss,* 10, pp 565–574.

Vuillez, C., Tonini, M., Sudmeier-Rieux, K., Devkota, S., Derron, M.H & Jaboyedoff, M. (2018). Land use changes, landslides and roads in the Phewa Watershed, Western Nepal from 1979 to 2016. *Appl. Geogr.* 94, 30–40.

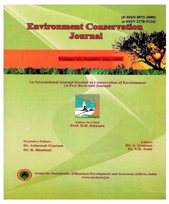
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 234-239, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Evaluation of genetic variability parameters for yield, yield attributes and fibre quality traits in the F_2 population of *Gossypium hirsutum* L.

Keerthivarman Krishnan ✉
Department of Genetics and Plant Breeding, Tamil Nadu Agricultural University, Coimbatore, India
Subhashini Selvaraj
Sugarcane Breeding Institute, Coimbatore, India
Banoth Madhu
Department of cotton, Tamil Nadu Agricultural University, Coimbatore, India
Aravind Krishnamoorthi
Central Institute for Cotton Research, Regional Station, Coimbatore, India
Akilan Manoharan
Department of Genetics and Plant Breeding, Tamil Nadu Agricultural University, Coimbatore, India

ARTICLE INFO

Received : 26 December 2022
Revised : 03 February 2023
Accepted : 13 February 2023

Available online: 25 June 2023

Key Words:
Genetic Advance
Heritability
GAM
Co-efficient of variation

ABSTRACT

The F_2 populations of the crossings CO 14 × NDLH 1938 and CO17 × NDLH 1755 were used to investigate variability and heritability studies in order to better understand the gene action involved in each characteristic studied. Morphological data *viz.,* days to first flowering, plant height (cm), number of sympodials, number of bolls per plant, boll weight (g), ginning outturn (%), upper half mean length (mm), elongation percentage (%) and micronaire value (µg/inch) were all recorded in each plant of both the populations. Studies of heritability and genetic advance as a percent of mean help us determine if a gene is additive or epistatic in nature, and so undergo appropriate breeding programmes for population enhancement. The value of PCV (Phenotypic Coefficient of variation) was always greater than GCV (Genotypic coefficient of variation) indicating the environment also plays a major role in contributing to the variations. The seed cotton yield per plant alone was shown to exhibit additive gene action with high heritability and strong genetic advance as percent of mean, suggesting that it might be used in direct selection since it is the most important attribute for population development.

Introduction

Cotton is a valuable fibre crop with a high commercial and export value, accounting for 70% of fibre use in the textile industry. It is known as the "King of Fibre Crops" and contributes significantly to the Indian economy (Boopathi *et al.,* 2011). In India's textile sector, cotton is the most common fibre. The area, production and productivity of cotton in India are, 123.50 lakh hectares, 340.62 lakh bales (1 bale = 170 kg of lint) and 469 kg per hectare respectively. India occupies the largest area under cotton cultivation of about 37% compared to world level (32.29 million hectares) between 12 million hectares and 13.5 million hectares. The cotton exports from India have increased from 47.04 lakh bales to 77.59 lakh bales during the year 2020-21 compared to previous crop year. (Committee on Cotton Production and Consumption (COCPC) in its meeting held on 22.03.2022). The genetic variability among parents is crucial for the generation of high heterotic hybrids with high yield potential. Cotton selection improvement will thus be heavily reliant on the finding and production of genetic variation. Superior genotypes produced by recombination of superior alleles at distinct loci are then carefully chosen at various breeding stages. Selection is frequently made exclusively on the basis of phenotypic expression, which might be deceiving

Corresponding author E-mail: *varmankrishnankeerthi@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16812531

due to environmental factors (Budak *et al.,* 2004). As a result, data on genotypic, phenotypic, and environmental heterogeneity is critical for efficient selection. Their coefficient of variation is used to quantify them. The genotypic coefficient of variation, on the other hand, does not provide a precise estimate of the total heritable variation. According to Magadum *et al.* (2012) heritability may be used to determine the proportional amount of heritable variation. Heritability will have to be calculated to account for the fraction of phenotypic diversity that may be attributed to genetic variance. This is crucial because it lays the groundwork for effective choosing genotypes Kale *et al.* (2007) and Eswari *et al.* (2017). Magadum *et al.* (2012) also said that the genetic variability of a character as well as its heritability, will suggest the ability and amount of phenotypic improvement. The breeding value may not be predictable based just on its heritability (Mishra *et al.,* 2015). As a result, combining genetic advance over means with prediction of the ensuing effect of selection is more effective and dependable (Patil *et al.,* 1996). When there is a lot of genetic variety, knowing about heritability and genetic progress can assist the breeder rapidly reach the goal by exercising selection on the desired features. As a result, in order to increase a desired attribute in any crop, complete knowledge of variability, heritability, and genetic advance is required (Burton, 1952; Swarup and Chaugle, 1962). Given the relevance of these factors, research was done to determine the genotypes' true potential usefulness.

Material and Methods

The experiment was conducted in the research field of the Department of Cotton at the Tamil Nadu Agricultural University, Coimbatore, in the summer of 2022. The experiment employed two F_2 populations of *G. hirsutum* segregants (CO 14 × NDLH 1938 and CO17 × NDLH 1755). The two F_2 populations were grown using a Randomized Block Design with two replications. For each population, twenty rows of 90 cm × 45 cm spacing were sown. The plant population was maintained upto 200 plants in each F_2 cross. Standard field care practices, as well as basic agronomic approaches including irrigation, fertilizer maintenance, weed control and pest management, were followed. Morphological data *viz.,* days to first flowering, plant height (cm), number of symposia's, number of bolls per plant, boll weight (g), ginning outturn (%), upper half mean length (mm), elongation percentage (%) and micronaire value (µg/inch) were all recorded in each entry. Using the High Volume Instrument 900 classic, the resulting lint was examined for fibre quality characteristics. The variances were calculated using Singh and Choudhary's (1977) technique, and the genetic components of variation were assessed using the same formula.

Phenotypic variance

The phenotypic variance was calculated using individual observations made for each characteristic on the F_2 population.

$$\text{Phenotypic variance } (\sigma^2p) = \text{Var } F_2$$

Where,
Var F_2 = variance of F_2 population

Environmental variance

The environmental variation was estimated using the average variance of the parents.

$$\text{Environmental variance } (\sigma^2e) = \frac{(\sigma^2p_1) + (\sigma^2p_2)}{2}$$

Where,
σ^2p_1 = Variance of parent P1
σ^2p_2 = Variance of parent P2

Genotypic variance

$$\text{Genotypic variance } (\sigma^2g) = \sigma^2p - \sigma^2e$$

Where,
σ^2p = Phenotypic variance
σ^2e = Environmental variance

Genetic advance (GA):

According to Johnson *et al.* (1955) genetic advance was divided into three categories: low, moderate and high.

$$GA = h^2K\,\sigma p$$

Where,
H^2 = Heritability in broad sense
K = Selection intensity which is equal to 2.06 at 5 per cent intensity of selection
σp = Phenotypic standard deviation.

Genetic advance as per cent of mean (GAM)

$$GAM = \frac{GA}{X} \times 100$$

Where,
GA = Genetic advance
X = General mean of the character

Coefficient of Variability (CV)

The approach proposed by Burton and Devane (1953) was used to calculate genotypic and phenotypic coefficients of variation. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were characterized as low (less than 10%), moderate (10-20%), and high (more than 20%) by Sivasubramanian and Menon (1973).

$$GCV (\%) = \sqrt{V_g}/mean \times 100$$
$$PCV (\%) = \sqrt{V_p}/mean \times 100$$

Heritability (h^2) (Broad Sense):

Robinson *et al*. (1949) defined heritability percentages as low (0-30 percent), moderate (30–60 percent), and high (> 60 percent).

$$\text{Heritability } (h^2) = V_g / V_p \times 100$$

Results and Discussion

The mean of F_2 populations of two crosses were given in table 1 for eleven biometrical traits taken under study. The results of the phenotypic, genotypic variances along with their coefficient of variation, heritability and genetic advance as percent of mean were given in the table 2, for the crosses CO 14 × NDLH 1938 and CO 17× NDLH 1755. Both the crosses had low PCV (7.62%, 7.14%), low GCV (6.19%, 6.31%), high heritability (65.98%, 78.21%) and low GAM (8.85%, 9.82%) for the trait days to first flowering. The trait plant height exhibited moderate PCV (13.17%, 10.67%), high heritability (79.40%, 77.75%) and low GAM (18.41%,14.60%)for both the crosses. Lokesh kumar *et al.* (2018) also found a high heritability for the trait plant height. The cross CO 14 × NDLH 1938 was observed to have moderate GCV (11.74%) and the cross CO 17 × NDLH 1755 was observed to have low GCV (9.41%) for plant height. The trait number of symposia's exhibited low PCV (16.19%), low GCV (11.76%), low heritability (52.81%) and low GAM (15.05%) in the cross CO 14 × NDLH 1938. High PCV (23.58%), moderate GCV (19.61%), high heritability (69.14%) and high GAM (28.69%) were noted in the cross CO 17 × NDLH 1755 for the trait number of sympodial branches. Similar results of high PCV, high GAM for the trait number of sympodial branches per plant was reported by Nandhini *et al.* (2018). Similar results of high GAM and high heritability for the same trait was reported by Gitte *et al.* (2007). Same trait with high GAM was reported by Lokeshkumar *et al.* (2018). Number of bolls per plant had moderate GCV (12.60%, 17.05%) and high heritability (67.52%, 66.70%) for both the crosses CO 14 × NDLH 1938 and CO 17 × NDLH 1755. The former cross had low PCV (15.34%), low GAM (18.23%) while the latter had high PCV (20.87%) and high GAM (24.50%) for the trait number of bolls per plant. Same trait with high GAM was reported by Lokesh kumar *et al.* (2018).

Table 1: The mean of F_2 populations of two crosses for eleven biometrical traits.

Traits	Crosses	Mean (m)
Days to first flowering	CO 14 × NDLH 1938	54.32
	CO 17 × NDLH 1755	56.35
Plant Height (cm)	CO 14 × NDLH 1938	101.69
	CO 17 × NDLH 1755	106.52
Number of sympodial branches	CO 14 × NDLH 1938	27.70
	CO 17 × NDLH 1755	19.91
Number of bolls per plant	CO 14 × NDLH 1938	32.69
	CO 17 × NDLH 1755	23.37
Boll Weight (g)	CO 14 × NDLH 1938	4.01
	CO 17 × NDLH 1755	4.03
Lint index (g)	CO 14 × NDLH 1938	6.26
	CO 17 × NDLH 1755	5.67
Ginning outturn (%)	CO 14 × NDLH 1938	37.61
	CO 17 × NDLH 1755	36.75
Seed cotton yield per plant (G)	CO 14 × NDLH 1938	130.84
	CO 17 × NDLH 1755	94.35
Upper Half Mean Length (mm)	CO 14 × NDLH 1938	27.01
	CO 17 × NDLH 1755	26.92
Elongation percent (%)	CO 14 × NDLH 1938	5.34
	CO 17 × NDLH 1755	5.49
Micronaire Value (µg/inch)	CO 14 × NDLH 1938	3.73
	CO 17 × NDLH 1755	4.03

Both the crosses had moderate PCV (12.09%, 13.43%), low GCV (6.96%, 3.95%) and low GAM (7.04%, 2.05%) for the boll weight character. The cross CO 14 × NDLH 1938 (33.10%) had moderate heritability while the cross CO 17 × NDLH 1755 (8.66%) had low heritability for the trait boll

Table 2: Variances and coefficient of variation for phenotype and genotype followed by heritability and genetic advance as percent of mean

Traits	Crosses	Variance		PCV	GCV	h^2 (bs)	GAM
		σ^2_p	σ^2_g				
Days to first flowering	CO 14 × NDLH 1938	17.12	11.30	7.62	6.19	65.98	8.85
	CO 17 × NDLH 1755	16.17	12.65	7.14	6.31	78.21	9.82
Plant height (cm)	CO 14 × NDLH 1938	179.35	142.41	13.17	11.74	79.40	18.41
	CO 17 × NDLH 1755	129.10	100.38	10.67	9.41	77.75	14.60
Number of sympodial branches	CO 14 × NDLH 1938	20.11	10.62	16.19	11.76	52.81	15.05
	CO 17 × NDLH 1755	22.04	15.24	23.58	19.61	69.14	28.69
Number of bolls per plant	CO 14 × NDLH 1938	25.14	16.98	15.34	12.60	67.52	18.23
	CO 17 × NDLH 1755	23.78	15.86	20.87	17.05	66.70	24.50
Boll weight (g)	CO 14 × NDLH 1938	0.23	0.08	12.09	6.96	33.10	7.04
	CO 17 × NDLH 1755	0.29	0.03	13.43	3.95	8.66	2.05
Lint index (g)	CO 14 × NDLH 1938	0.83	0.28	14.56	8.46	33.74	8.65
	CO 17 × NDLH 1755	0.39	0.16	10.97	6.99	40.59	7.84
Ginning outturn (%)	CO 14 × NDLH 1938	4.42	0.89	5.59	2.50	20.02	1.97
	CO 17 × NDLH 1755	5.18	2.03	6.20	3.87	39.07	4.26
Seed cotton yield per plant (g)	CO 14 × NDLH 1938	616.25	592.55	18.97	18.60	96.15	32.11
	CO 17 × NDLH 1755	588.62	568.45	25.71	25.27	96.57	43.71
Upper half mean length (mm)	CO 14 × NDLH 1938	6.18	2.42	9.21	5.76	39.18	6.35
	CO 17 × NDLH 1755	3.74	1.70	7.19	4.84	45.38	5.74
Elongation percent (%)	CO 14 × NDLH 1938	0.02	0.01	2.68	1.38	26.68	1.26
	CO 17 × NDLH 1755	0.06	0.02	4.34	2.83	42.61	3.26
Micronaire value (µg/inch)	CO 14 × NDLH 1938	0.27	0.06	13.88	6.39	21.18	5.18
	CO 17 × NDLH 1755	0.31	0.16	13.76	10.04	53.24	12.90

weight. Similar result of moderate heritability for the trait boll weight was reported by Nandhini *et al.* (2018). Both the crosses had moderate PCV (14.56%, 10.97%), low GCV (8.46%, 6.99%), low GAM (8.65%, 7.84%) and moderate heritability (8.65%, 7.84%) for the lint index trait. The cross CO 14 × NDLH 1938 had moderate PCV (18.97%), moderate GCV (18.60%) and the cross CO 17 × NDLH 1755 had high PCV (25.71%), high GCV (25.27%) for the trait seed cotton yield per plant. Both the crosses had high heritability (96.15%, 96.57%) and high GAM (32.11%, 43.71%) for the same trait. Similar results of high GCV, high PCV and high heritability for the trait seed cotton yield per plant was reported by Lokeshkumar *et al.* (2018), Jarwar *et al.* (2018) and Hampannavar *et al.* (2020). Both the crosses had low PCV (5.59%, 6.20%), low GCV (2.50%, 3.87%) and low GAM (1.97%, 4.26%) for the ginning outturn trait. The cross CO 14 × NDLH 1938 had low heritability (20.02%) and the cross CO 17 × NDLH 1755 showed moderate heritability (39.07%) for the ginning outturn character. Similar results of low GAM for the same trait was reported by Gitte *et al.* (2007). Both the crosses had low PCV (9.21%, 7.19%), low GCV (5.76%, 4.84%), moderate heritability (39.18%, 45.38%) and low GAM (6.35%, 5.74%) for the qualitative trait upper half mean length. The crosses CO 14 × NDLH 1938 and CO 17 × NDLH 1755 recorded low PCV (2.68%, 4.34%), low GCV (1.38%, 2.83%) and low GAM (1.26%, 3.26%) for elongation percent. Low heritability (26.68%) and high heritability (42.61%) was observed for the trait elongation percent for the crosses CO 14 × NDLH 1938 and CO 17 × NDLH 1755 respectively. Similar results of low GCV, low PCV and high heritability for the qualitative traits namely, upper half mean length and elongation percent were reported by Lokeshkumar *et al.* (2018). Similar results for the same trait with low GCV and low PCV were reported by Srinivas *et al.* (2014), Kumar *et al.* (2017). Both the crosses had moderate PCV (13.88%, 13.76%) for the trait micronaire value. The same trait had low values for GCV (6.39%), low heritability (21.18%) and low GAM (5.18%) for the cross CO 14 × NDLH 1938 and the cross CO 17 × NDLH 1755 reported moderate GCV (10.04%), moderate heritability (53.24%) and moderate GAM (12.90%) for the same trait. Regardless of the fact that the magnitude of the phenotypic coefficient of variation was greater than that of the genotypic coefficient of variation in the current study, the PCV and GCV values for all of the traits tested showed a narrow variance as reported by Gitte *et al.* (2007). Certain findings suggested that the environment had less impact on the expression of these traits but then that further breeding may be used to improve them as suggested by Johnson *et al.* (1955). Important selection characteristics include heritability and genetic advance. Heritability estimates combined with genetic advance are usually more useful than heritability estimates alone in estimating the gain under selection as reported by Lokesh Kumar *et al.* (2018). Among all the traits studied, seed cotton yield per plant is determined to have additive gene action, high heritability, and high genetic advance as a percent of mean in both the crosses. Hence, this trait may be chosen as the key attribute for population development. Other traits included non-additive or epistatic gene action, with either high heritability with medium or low genetic advance as a percent of mean, which Pujer *et al*. (2014) proposed could be improved by heterosis breeding programmes.

Conclusion

For majority of the characteristics, PCV and GCV had a high level of agreement, indicating that the observed variance might be mostly genetic. Among all the characters taken under study, the seed cotton yield per plant alone was found to have additive gene action with high heritability and high genetic advance as percent of mean, hence could be involved in direct selection as it is the major trait for improvement of the population of that trait. Other traits had non-additive or epistatic gene action with either high heritability with medium or low genetic advance as percent of mean which could be improved through heterosis breeding programmes.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Boopathi, N. M., Thiyagu, K., Urbi, B., Santhoshkumar, M., Gopikrishnan, A., Aravind, S. & Ravikesavan, R. (2011). Marker-assisted breeding as next-generation strategy for genetic improvement of productivity and quality: can it be realized in cotton. *International Journal of Plant Genomics*, 4 (8), 56-67.

Budak, H., Bolek, Y., Dokuyucu, T., & Akkaya, A. (2004). Potential uses of molecular markers in crop improvement. *KSU Journal of science and Engineering*, *7*(1), 75-79.

Burton, G. W. (1952). Qualitative inheritance in grasses. Vol. 1. In *Proceedings of the 6th International Grassland Congress, Pennsylvania State College* 3 (9), 17-23.

Burton, G. W., & Devane, D. E. (1953). *Estimating* heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy journal*, *45*(10), 478-481.

Eswari, K.B., Sudheer Kumar, S., Gopinath and Rao, M.V.B. (2017). Genetic variability heritability and genetic advance studies in cotton. *International Journal of Development Research*. 07: 10902-10904.

Gitte, V. K., Misal, M. B., Kalpande, H. V., & Deshmukh, J. D. (2007). Genetic variability studies in F_2 populations of upland cotton (*Gossypium hirsutum* L.). *Journal of Cotton Research and Development*, *21*(1), 27-28.

Hampannavar, M. R., Patil, B. R., Katageri, I. S., Kumar, B. A., & Janagoudar, B. S. (2020). Genetic variability and correlation analysis for agronomic and fibre quality traits in intra-specific cotton (*G. hirsutum* × *G. hirsutum*) recombinant inbred lines (RILs). *International Journal Current Microbiological Applied Sciences*, *9*(1), 493-503.

Jarwar, A. H., Wang, X., Wang, L., Ma, Q., & Fan, S. (2018). Genetic advancement, variability and heritability in upland cotton (*Gossypium hirsutum* L.). *Journal of Environmental and Agricultural Sciences*, *6*, 24-31.

Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans 1. *Agronomy journal*, *47*(7), 314-318.

Kale, U. V., Kalpande, H. V., Gunjkar, A. S., & Gite, V. K. (2006). Variability, heritability and genetic advance studies in cotton. *Journal-Maharashtra Agricultural Universities*, *31*(3), 389.

Kumar, N. M., & Katageri, I. S. (2017). Genetic variability and heritability study in F_2 population of *Gossypium barbadense* L. cotton for yield and its components. *International Journal of Current Microbiological Applied Sci*, *6*(6), 975-983.

Lokeshkumar, B. M., & Patil, B. R. (2018). Estimation of genetic variability parameters in F_2 population of *Gossypium hirsutum* L. for yield, yield attributes and fiber quality traits. *Electronic Journal of Plant Breeding*, 4(3), 756-763.

Magadum, S., Banerjee, U., Ravikesavan, R., Gangapur, D., & Boopathi, N. M. (2012). Variability and heritability analysis of yield and quality traits in interspecific population of cotton (*Gossypium Spp*.). *Bioinfolet* 9 (4A): 484 – 485.

Mishra, P. K., Ram, R. B., & Kumar, N. (2015). Genetic variability, heritability, and genetic advance in strawberry (*Fragaria* × *ananassa* Duch.). *Turkish Journal of Agriculture and Forestry*, *39*(3), 451-458.

Nandhini, K., Balu, P. A., & Isong, A. (2018). Genetic analysis and inheritance studies in F_2 population of upland cotton (*G. hirsutum* L.). *International. Journal. of Pure and Applied Biosciences*, 6(2), 1499-1505.

Patil, Y.B., Madalageri B.B, Biradar, B.D, and Hoshmani, R.M. (1996). Variability studies in okra (*Abelmoschus esculentus* L. *Moench*.). *Karnataka Journal of Agricultural Sciences*. 9: 289–293.

Pujer, S., Siwach, S. S., Deshmukh, J., Sangwan, R. S., & Sangwan, O. (2014). Genetic variability, correlation and path analysis in upland cotton (*Gossypium hirsutum* L.). *Electronic Journal of Plant Breeding*, *5*(2), 284-289.

Robinson, H. F., Comstock, R. E., & Harvey, P. H. (1949). Estimates of heritability and the degree of dominance in corn. 41, 353-359.

Singh, R. K., & Chaudhary, B. D. (1977). Biometrical methods in quantitative genetic analysis. *Biometrical methods in quantitative genetic analysis.* Kalyani Publishers, New Delhi, 57-58.

Sivasubramanian, S., & Menon, M. (1973). Heterosis and inbreeding depression in rice. *Madras Agricultural Journal*, 60(7), 1139-1140.

Srinivas, B., Bhadru, D., Rao, M. V., & Gopinath, M. (2014). Genetic studies in yield and fibre quality traits in American cotton (*Gossypium hirsutum* L.). *Agricultural Science Digest-A Research Journal*, 34(4), 285-288.

Swarup, V., & Chaugle, B. S. (1962). Studies on genetic variability in sorghum. Phenotypic variation and heritable component in some quantitative characters contributing towards yield. *Indian Journal of Genetics and Plant Breeding*, *22*(1),31-36.

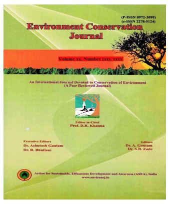
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 240-248, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Influence of weed management practices on direct-seeded rice grown under rainfed and irrigated agroecosystems

Badal Verma ✉

Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP), India

Manish Bhan

Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP), India

A.K. Jha

Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP), India

Muskan Porwal

Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP), India

ARTICLE INFO

Received : 15 December 2022
Revised : 27 February 2023
Accepted : 20 March 2023

Available online: 27 June 2023

Key Words:
Bispyribac sodium
Herbicides
Rice field
Weeds
Yield indices

ABSTRACT

Rice seedlings and weeds emerge concurrently in direct-seeded rice (DSR) production systems, while there is no flooding water to inhibit weed germination, emergence and development at crop emergence. Because of this, weeds are considered the biggest living barrier in DSR and significantly reduce yield. The purpose of the research was to devise an approach for management of weeds in the direct-seeded rice crop cultivated under various agroecosystems, while optimizing growth and production utilizing herbicides or herbicidal combinations. The impacts of several weed management techniques were assessed to determine the most efficient and cost-effective approach of managing weeds in DSR at the CoA, JNKVV, Jabalpur (MP) during 2019 rainy season under spilt plot design with 2 main plot treatments viz., rainfed agroecosystem, irrigated agroecosystem and 8 sub-plot treatments, i.e. different herbicide treatments with hand weeding and weedy check. Further growth parameters as well as yield attributes were documented. Conventional statistical techniques were used to evaluate the data. Bispyribac sodium at the dose of 25 g/ha efficiently controlled both narrow and broad leaved weeds under agroecosystems. Highest growth as well as yield parameters were recorded for irrigated agroecosystems compared to rainfed agroecosystems. The treatment with bispyribac sodium at the dose of 25 g/ha produced the greatest values for growth and yield indices as well as the maximum yield (3.68 t/ha), with the exception of manual weeding.

Introduction

Rice, an important food crop is grown on 161 million hectares in more than 100 nations (FAOSTAT, 2020). Asia itself produces and uses up 90 per cent of the total world's rice, which provides up to 75% of the calories needed for 520 million people (Priya *et al.,* 2019). The ever-increasing demands of the growing population can only be met by increasing the worldwide rice output by 26% and 50% by 2035 and 2050, respectively (IRRI, 2020). China accounts for 28% while India account for 22% out of the total global output of rice. The area shared by the rice-growing ecosystems is approximately 44 million ha, of which upland contributes 7 million ha and lowland contributes 17 million ha, respectively. India's overall production is 104.3 million tonnes (MT), and national productivity is 2.40 t/ha (GoI, 2018). Transplanted rice has several difficulties which included high demand of water (1000-2000 mm) for flooding as well as for puddling operations (Materu *et al*., 2018) and many farmers, especially marginal and small farmers, find it to be unaffordable due to its high energy consumption of 5630 to 8448 MJ/ha (Neog *et al*., 2015), as well as its nearly 15-20% higher labour inputs (Bhatt *et al*., 2016; Saharawat *et al*., 2010).

Corresponding author E-mail: *badalv82282@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16622536

A new method of growing upland rice called direct-seeded rice requires less irrigation water, labour, and energy compared to transplanted rice. Rice crops are established by simply spreading seeds in non-puddled, non-saturated soil (Liu *et al*., 2014). Direct-seeded rice does not include operations such as seeding, nursery, seedling care, removing, bundling, transferring, and transplanting (Nagargade *et al*., 2018). Direct-seeded rice can increase yield, decrease fertilizer and land preparation costs, increase household income, and improve soil productivity (Devkota *et al*., 2020). Additional advantages of DSR include quicker and more effective planting, better soil quality, high water shortage tolerance, decreased methane emissions, and even higher income in places with a secure water system (Singh *et al*., 2016). It has various advantages, including the need for less water (35–57%) and less labour (67%), respectively, compared to rice transplantation. This system saves labour from nursery preparation and allows the entire cost to be decreased by 11.2 per cent. In terms of working hours, this approach reduces labour requirements by more than 25% (Asghar *et al*., 2018). DSR has several advantages and may be a viable alternative to traditional transplantation; however, the main drawbacks are low germination, uneven crop standing, and significant weed infestation (Raj *et al.,* 2017).

A significant obstacle to the effectiveness of the direct seeded rice technology is weed infestation (Zia-Ul-Haq *et al.*, 2019). Crop establishment methods, such as transplanting versus direct sowing, resulted in significant changes in weed flora composition. In comparison to flooded transplanted rice, weeds flourish fast in DSR (Rathika *et al.,* 2020). Yield losses under DSR are anticipated to reach up to 75%, which represents more than 30% of the overall expenditures associated with rice cultivation (Rao *et al.,* 2007). In DSR, weed competition peaked between 14 to 41 days after seeding.Herbicides, manual weeding techniques, or a combination of the two can be very effectively used for managing or controlling complex weed flora in rice ecosystem. However, labour scarcity, rising costs, and laborious nature of hand weeding, chemicals have replaced it. Herbicides are becoming more common due to their quick results and reduced price in direct-seeded rice (Patel *et al*., 2018). Herbicides provide more accessible, timelier, cost-effective, and convenient weed control in rice, compared to the higher expense, drudgery, and lesser efficacy of other weed control solutions (Sen *et al*., 2020). DSR is now feasible, thanks to the new more efficiency and low dose herbicides, especially with short duration high yielding varieties (Mortimer *et al.,* 2008). A group of weed species can be effectively controlled by applying certain selective herbicides. As a result, alternative herbicides or herbicide mixtures must be evaluated for managing different types of weeds in DSR. Therefore, current research aimed to assess the efficacy of different herbicides and their combinations against various weed flora under rainfed and irrigated agroecosystems, as well as how these factors affected growth and production.

Material and Methods

During the 2019 rainy season, a research trial was carried out at College of Agriculture, JNKVV, Jabalpur (MP). The 16 different treatment combinations were included in the experimental trial with two main treatments, i.e., agroecosystems viz., rainfed and irrigated and eight sub-treatments, i.e., different weed management practices viz., bispyribac sodium 25 g/ha, fenoxaprop-p-ethyl 60 g/ha, fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha, cyhalofop + penoxsulam 135 + 26.7 g/ha, bispyribac sodium + metsulfuron methyl + chlorimuron ethyl 25+4 g/ha, triafamone + ethoxysulfuron 40+20 g/ha, weedy check and hand weeding (two) at 20 and 40 DAS. These treatment combinations were necessary to evaluate the most effective herbicide combination for the control of complex weeds under the rainfed and irrigated agro-ecosystems and to carry out a comparative analysis with hand weeding and weedy check treatments. Three replications were used and the design was split-plot. Post-emergence application of herbicides was made. At the meterorological observatory, JNKVV, Jabalpur, climatic observation was recorded. Figure 1 displays the climatic scenario of the experimental site.

In a weedy plot, weeds were permitted to grow all through the crop's growth cycle alongside the crop. A quadrate (0.25 square meters) was used to measure dry weight and number of weeds as suggested by Mishra and Misra (1997). To normalise the distribution of weed number and dry weight, the square root type of transformation was used. WCE was calculated using an equation Kumar *et al*. (2016) proposed.

$$WCE(\%) = \frac{DWC - DWT}{DWC} x100$$

All other agronomic procedures were carried out in accordance with recommendations (Pathak *et al.*, 2011). Economic analysis was carried out based upon current market value of inputs used and the output from each treatment (CIMMYT, 1998). The effect of agro-ecosystems and weed management practices was analysed in split-plot design. Treatment effects were presented by making tables of means for different parameters with appropriate standard error (SEm+) and least significant difference (0.05) (Steel and Torrie, 1980). Correlation analysis was done for estimating the extent of relationship between independent variables and dependent variable.

Results and Discussion

Soil properties

The soil of the site had a sandy clay-loam texture, a pH of 6.40, and had a medium amount of organic C (0.72%), available N (293.65 kg/ha), available P (17.50 kg/ha), as well as available P (257.47 kg/ha).

Weed species

Broad-leaved, narrow-leaved weeds and sedges were abundant in research field. Under rainfed agroecosystems, the relative density of weeds was *Echinochloa colona* L. (30%), *Alternanthera sessilis* L. (26%), *Cyperus iria* L. (18.9%) and *Cynodon dactylon* L. (18.4%). Whereas, in irrigated agroecosystems, the relative density of weeds was *Echinochloa colona* L. (28.6%), *Alternanthera sessilis* L. (25%), *Cyperus iria* L. (18%) and *Cynodon dactylon* L. (17.9%).

Weed density and dry weight

In rainfed and irrigated agroecosystems at 90 DAS, weed density was significantly reduced by weed management methods particularly in comparison to weedy check plot (Table 1). The agroecosystems did not have a significant impact on weed density and weed dry weight. However, the maximum density of weeds was noticed there in rainfed agroecosystems compared to irrigated agroecosystems due to aerobic conditions presented in rainfed agroecosystems that are beneficial for weed growth. Among herbicides, bispyribac sodium 25 g/ha controlled all the types of weeds successfully and recorded a lower weed population and was found statistically at par with fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha and Cyhalofop + penoxsulam 135+26.7 g/ha. At the same time, weedy check recorded significantly higher weed population. In the specific case of the interaction effect, bispyribac sodium 25 g/ha applied to irrigated agroecosystems resulted in a minimum weed population of all dominated weeds. The reduction in weed population in this treatment was primarily attributable to successful weed management without causing poisoning symptoms in rice plants. Herbicide efficiency differences can be linked to variations in weed flora composition and emergence patterns throughout crop development (Adigun *et al.,* 2005). Moreover, Mahajan *et al.* (2009) observed that bispyribac sodium was efficient in direct seeded rice cultures. Sekhar *et al*. (2020); Verma *et al*. (2022) also found that byspyribac sodium 25 g/ha considerably decreased weed density when compared to other herbicidal treatments and effectively controlled broad-leaved weeds, narrow-leaved weeds and sedges also. Similarly, treatments also significantly affected weed dry weight at 90 DAS (Table 2). Among agroecosystems, irrigated rice recorded a minimum weed dry weight than rainfed rice. The amount of weed biomass was found lowest in hand-weeded plots and highest in weedy check plots. The herbicidal treatment of bispyribac sodium 25 g/ha was successful in decreasing the biomass of all weeds and was determined to be efficacious for all weeds. The lowest dry biomass of grassy, sedge, and broad-leaved weeds were recorded when bispyribac sodium was utilized at a dose of 25 g/ha in irrigated agroecosystems. (Singh *et al*., 2014; Menon, 2019).

Weed control efficiency

Under treatments, there was a strong inverse association between weed control efficiency and weed dry weight. Hand weeding treatment registered maximum efficiency in rainfed (97%) and irrigated agroecosystems (97.4%) than all other treatments at 90 DAS (Figure 2) due to the production of less dry matter of the weeds over the weedy check. All herbicidal treatments reduced weed growth, but bispyribac sodium 25 g/ha had

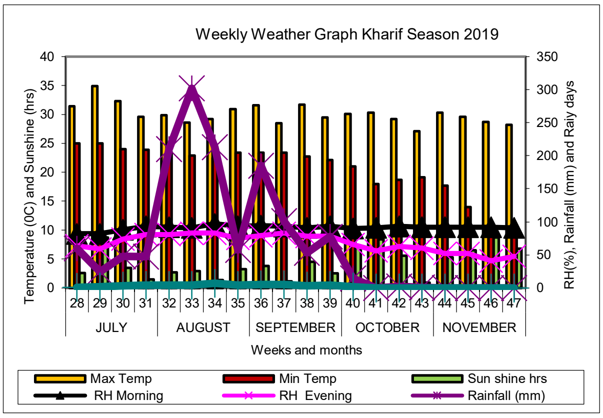


Figure 1: Graphical representation of weekly meteorological data from July 2019 to November 2019

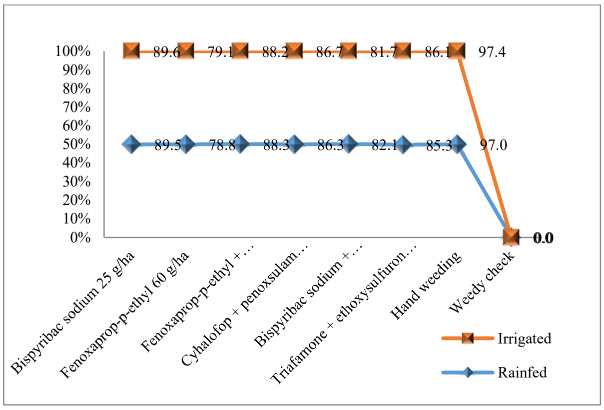


Figure 2: Weed control efficiency under rainfed and irrigated agroecosystems

Table 1: Influence of weed control practices on density of weeds under rainfed and irrigated agro ecosystems at 90 DAS

Treatments	Weed density (no./m^2)			
	Echinochloa colona	***Alternanthera sessilis***	***Cyperus iria***	***Cynodon dactylon***
Agroecosystems				
Rainfed	2.82 (10.0)	2.71 (9.0)	2.61 (7.9)	2.38 (6.7)
Irrigated	2.67 (8.8)	2.57 (8.0)	2.49 (7.0)	2.27 (6.1)
CD (P=0.05)	NS	NS	NS	NS
Weed control practices				
Bispyribac sodium 25 g/ha	1.99 (3.6)	1.79 (2.9)	1.88 (3.2)	1.57 (2.1)
Fenoxaprop-p-ethyl 60 g/ha	2.84 (7.7)	2.81 (7.5)	2.67 (6.8)	2.27 (4.9)
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	2.06 (3.9)	2.11 (4.1)	2.12 (4.1)	1.98 (3.6)
Cyhalofop + penoxsulam 135+26.7 g/ha	2.41 (5.5)	2.24 (4.8)	2.30 (5.0)	2.03 (3.9)
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	2.73 (7.1)	2.58 (6.3)	2.57 (6.3)	2.16 (4.4)
Triafamone + ethoxysulfuron 40+20 g/ha	2.44 (5.7)	2.38 (5.4)	2.34 (5.2)	2.07 (4.2)
Hand weeding	1.04 (0.6)	1.20 (1.0)	1.23 (1.1)	1.33 (1.3)
Weedy check	6.43 (41.0)	6.03 (36.0)	5.32 (27.9)	5.20 (26.7)
CD (P=0.05)	0.46	0.47	0.50	0.57

Table 2:Influence of weed control practices on dry weight of weeds under rainfed and irrigated agro ecosystems at 90 DAS.

Treatments	Weed dry weight (g/m^2)			
	Echinochloa colona	***Alternanthera sessilis***	***Cyperus iria***	***Cynodon dactylon***
Agroecosystems				
Rainfed	3.01 (11.2)	2.93 (10.5)	2.83 (9.6)	2.62 (7.9)
Irrigated	2.92 (10.6)	2.84 (9.9)	2.73 (9.0)	2.51 (7.3)
CD (P=0.05)	NS	NS	NS	NS
Weed control practices				
Bispyribac sodium 25 g/ha	2.32 (5.0)	2.25 (4.7)	2.16 (4.3)	1.87 (3.2)
Fenoxaprop-p-ethyl 60 g/ha	3.10 (9.3)	3.05 (8.9)	2.93 (8.3)	2.65 (6.8)
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	2.34 (5.2)	2.30 (5.0)	2.20 (4.6)	2.13 (4.3)
Cyhalofop + penoxsulam 135+26.7 g/ha	2.52 (6.0)	2.43 (5.7)	2.40 (5.4)	2.25 (4.8)
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	2.87 (8.0)	2.80 (7.7)	2.75 (7.3)	2.46 (5.9)
Triafamone + ethoxysulfuron 40+20 g/ha	2.57 (6.2)	2.53 (6.0)	2.41 (5.5)	2.32 (5.0)
Hand weeding	1.13 (0.8)	1.16 (0.9)	1.25 (1.1)	1.40 (1.5)
Weedy check	6.85 (46.5)	6.58 (43.1)	6.18 (37.8)	5.43 (29.1)
CD (P=0.05)	0.47	0.48	0.51	0.55

greatest amount of suppression of weeds, *fb* fenoxaprop-p-ethyl + penoxsulam 60 g/ha *fb* cyhalofop + penoxsulam 135 g/ha. It might result from wide spectrum weed control. Fenoxaprop-p-ethyl 60 g/ha is primarily effectual against grassy weeds only and thus, had lowest weed control efficiency. Interaction among the irrigated agroecosystem and herbicidal treatment bispyribac sodium 25 g/ha achieved higher (89.5%) weed control efficacy (Kaur *et al*., 2015). The results are in corroboration with the findings of Narolia *et al.* (2014).

Crop growth parameters

The rate of growth parameters has a genuinely significant impact on the ultimate yield of the plant, which is influenced by biotic and abiotic factors. The growth characteristics of DSR were greatly impacted by treatments. The information on plant growth characteristics at 90 DAS, including plant height, plant population, plant dry weight, and the number of tillers, as impacted by various weed management measures is shown in Table 3. In the case of the growth characteristics, the rainfed rice exhibited a minimum number of growth parameters than irrigated rice. This may be because of moisture stress under the rainfed agroecosystem, as it suffered abiotic stress during the reproductive stage, which affected growth parameters.

The findings showed that hand weeding produced the highest plant populations, plant heights, plant biomass, and number of tillers among the various weed management methods. In contrast, minimum values of these parameters were observed in weedy check plots. However, bispyribac sodium 25 g/ha recorded maximum values of all the growth parameters among all the herbicidal treatments, which were at par with fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha. It is primarily because bispyribac sodium has a broad-spectrum ability to suppress grasses, sedges, and broad-leaved weeds, fostering favourable conditions for crop growth (Patel *et al.,* 2018; Singh *et al.,* 2016).

Table 3: Influence of weed control practices on growth characteristics of direct seeded rice under rainfed and irrigated agro ecosystems at 90 DAS

Treatments	Plant Population/m^2		Plant height (cm)		Plant biomass (g/m^2)		Number of tillers/m^2	
	RF	IR	RF	IR	RF	IR	RF	IR
Bispyribac sodium 25 g/ha	153	153	81.3	85.0	1118	1282	359	376
Fenoxaprop-p-ethyl 60 g/ha	138	138	75.6	79.3	811	933	310	327
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	150	151	80.0	84.3	1000	1207	350	370
Cyhalofop + penoxsulam 135+26.7 g/ha	143	145	78.8	82.5	968	1122	343	361
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	139	140	76.0	80.3	836	959	322	335
Triafamone + ethoxysulfuron 40+20 g/ha	141	142	77.1	81.0	920	1051	335	350
Hand weeding	156	157	83.0	87.3	1195	1513	369	392
Weedy check	129	130	74.0	78.0	580	723	302	307
CD (P=0.05)	2.28		2.64		2.52		2.30	

RF= Rainfed, IR= Irrigated

Under irrigated agroecosystems, growth parameters viz., plant population (153), plant height (85.0 cm), plant biomass (1282 g) and the number of tillers (376) exhibited higher values with bispyribac sodium 25 g/ha application. The observed increases in these growth characteristics relative to weedy control point to the efficacy of various weed control measures in reducing weed growth, which subsequently reduced weed crop competition for any of the growth variables. Similar findings were also reported by Anwar *et al*. (2011) and Khaliq *et al.* (2012).

Yield attributing characters and yield

The information about no. of grains presented in each panicle, weight per 1000 seeds and grain yield varied significantly amongst the weed-management techniques (Table 4). Irrigated rice exhibited higher yields attributing values and grain yield than rainfed rice among agro-ecosystems, and it was due to water stress which affected the expansion and

Table 4: Influence of weed control practices on yield attributes, grain yield and economics of direct seeded rice under rainfed and irrigated agro ecosystems

Treatments	Grains/panicle		1000-seed weight (g)		Grain yield(t/ha)		NMR (x10^3 Rs/ha)	
	RF	IR	RF	IR	RF	IR	RF	IR
Bispyribac sodium 25 g/ha	71.0	84.0	22.8	24.0	1.85	3.68	16.8	52.1
Fenoxaprop-p-ethyl 60 g/ha	66.0	79.0	21.7	23.1	1.39	2.59	7.96	30.7
Fenoxaprop-p-ethyl + penoxsulam 60+26.7 g/ha	70.0	83.0	22.7	23.8	1.74	3.26	12.9	41.9
Cyhalofop + penoxsulam 135+26.7 g/ha	69.3	82.3	22.5	23.7	1.64	2.96	10.8	35.7
Bispyribac sodium + metsulfuon methyl + chlorimuron ethyl 25+4 g/ha	68.0	81.0	22.0	23.3	1.42	2.76	7.30	32.7
Triafamone + ethoxysulfuron 40+20 g/ha	69.0	82.0	22.2	23.4	1.49	2.87	7.67	33.5
Hand weeding	73.0	86.0	23.0	24.2	2.08	4.11	11.2	49.8
Weedy check	64.0	77.0	20.8	22.0	1.04	1.79	1.50	14.9
CD (P=0.05)	2.60		0.75		0.11		-	

RF= Rainfed, IR= Irrigated

maturation of the crop under rainfed rice. Irrigated rice had water application, and sufficient moisture in this way had maximum levels of yield attributing traits and grain yield. Among treatments, minimum yield attributing characteristics and grain production were observed in weedy check plot due to intense weed competition creating a limited supply of growth resources, while the maximum was recorded in hand weeding treatment because of less weed density and dry weight; there was no competition with the base crop and resulting in better growth and development of yield. Bispyribac sodium 25 g/ha, on the other hand, was found substantially superior over the remaining herbicides, with a higher no. of grains present per panicle (84.0), weight per 1000 seeds (24.0 g), and grain production (3.68 t), followed by fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha (Kaur *et al*., 2016; Vivek *et al*., 2018).

Correlation analysis

A correlation analysis was conducted to examine the relationship between various factors in rainfed and irrigated rice, including plant height, plant biomass, test weight and grain yield. This analysis was further illustrated in fugures 3 to 6, providing visual representation of the results.

Economics

The net monetary return (NMR) was higher in irrigated agroecosystems than in rainfed agroecosystems (Table 4). In the case of weed control treatments, NMR was observed to be lowest and improved with usage of bispyribac sodium 25

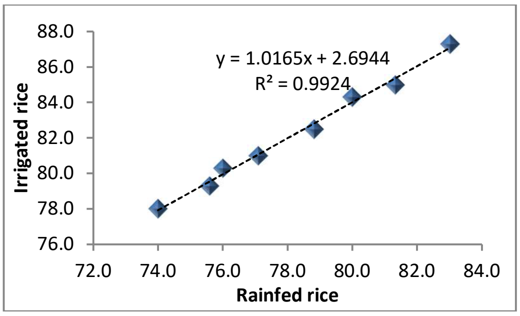


Figure 3. Relationship between plant height of rainfed and irrigated rice

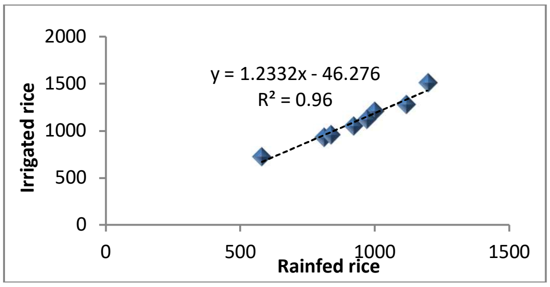


Figure 4. Relationship between plant biomass of rainfed and irrigated rice

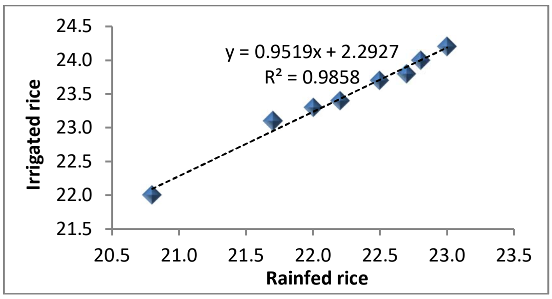


Figure 5. Relationship between 1000-seed weight of rainfed and irrigated rice

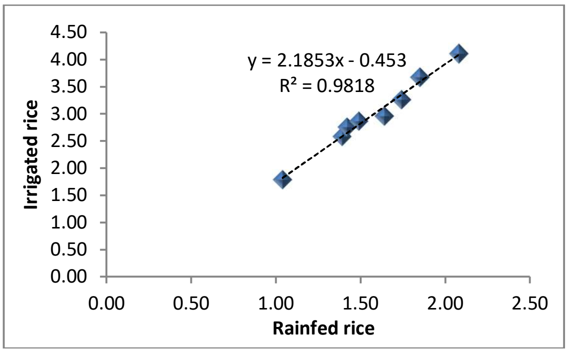


Figure 6. Relationship between grain yield of rainfed and irrigated rice

g/ha treatment (Rs.52123/ha) accompanied by fenoxaprop-p-ethyl + penoxsulam 60 + 26.7 g/ha. According to Prashanth *et al*. (2016) the treatment that generated the highest net return, was the treatment of 25 g/ha of bispyribac sodium. The lowest net monetary returns, however, were produced by unweeded checks

Conclusion

Weeds are the leading problem creators in direct seeded rice production. The control of weeds, therefore, becomes necessary through an appropriate combination of herbicides. The application of bispyribac sodium 25g/ha significantly reduced weed density and dry weight due to its broad-spectrum control of weed flora during the critical period. A higher yield was observed under the treatment of bispyribac sodium 25g/ha. The lesser weed competition resulted in better vegetative and reproductive growth, contributing to a greater number of tillers and, ultimately, a higher yield. Thus, the farmers can adopt the post-emergence application of bispyribac sodium 25g/ha as a wise option to control weeds in direct seeded rice under rainfed and irrigated agroecosystems.

Acknowledgement

I want to sincerely thank chairman and advisory committee members for providing the most appropriate counsel throughout my research work. I am also grateful to Department of Agronomy, JNKVV, Jabalpur (MP), for providing the resources required to complete this work.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Adigun, J. A., Lagoke, T. S. O., & Adekpe, I. D. (2005). Efficacy of selected herbicides for weed control in rain-fed upland rice in the Nigerian Northern Guidea Savanna. *Agricultura Tropica et Subtropica*, *38*(3-4), 99-106.

Anwar, P., Juraimi, A. S., Puteh, A., Selamat, A., Man, A., & Hakim, A. (2011). Seeding method and rate influence on weed suppression in aerobic rice. *African Journal of Biotechnology*, *10*, 15259–15270.

Asghar, W., Latif, A., Ali, I., Ahmad, A., Ali, J., Mahmood, M. T. & Ahmad, M. (2018). Screening of coarse varieties for direct seeded rice. *Res. & Rev.: J. Agric. Allied Sci*, *7*(1), 53-57.

Bhatt, R., Kukal, S. S., Busari, M. A., Arora, S., & Yadav, M. (2016). Sustainability issues on rice–wheat cropping system. *International Soil and Water Conservation Research*, *4*(1), 64-74.

CIMMYT Economics Program, International Maize, & Wheat Improvement Center. (1988). From agronomic data to farmer recommendations: an economics training manual (No. 27).

Devkota, K. P., Khanda, C. M., Beebout, S. J., Mohapatra, B. K., Singleton, G. R., & Puskur, R. (2020). Assessing alternative crop establishment methods with a sustainability lens in rice production systems of Eastern India. *Journal of cleaner production*, *244*, 118835.

Food and Agriculture Organization Corporate Statistical Database (FAOSTAT); Food and Agriculture Organization of the United Nations Database; Food and Agriculture Organization (FAO), Rome. Available online: http://www.fao.org (accessed on 12 May 2020).

GoI, 2018–19. Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi.

International Rice Research Institute (IRRI). International Rice Research Institute. 2020. Available online: http://www.irri.org (accessed on 17 May 2020).

Kaur, S., & Singh, S. (2015). Bio-efficacy of different herbicides for weed control in direct-seeded rice. *Indian Journal of Weed Science*, *47*(2), 106-109.

Kaur, S., Bhullar, M. S., & Kaur, T. (2016). Management of mixed weed flora in transplanted rice using herbicide combinations. *Agricultural Research Journal*, *53*(4), 483-487.

Khaliq, A., Matloob, A., Mahmood, S., Rana, N. A., & Khan, M. B. (2012). Seeding density and herbicide tank mixtures furnish better weed control and improve growth, yield and quality of direct seeded fine rice. *International Journal of Agriculture and Biology*, *14*(4), 499-508.

Kumar, N., Hazra, K. K., & Nadarajan, N. (2016). Efficacy of post-emergence application of imazethapyr in summer mungbean (*Vigna radiata* L.). *Legume Research-An International Journal*, *39*(1), 96-100.

Kumar, N., Singh, M. K., Kumar, M., & Verma, R. K. (2018). Effect of different chemical weed management practices on grain yield and harvest index under direct seeded rice. *Journal of Pharmacognosy and Phytochemistry*, *7*(2), 1895-1898.

Liu, H., Hussain, S., Zheng, M., Peng, S., Huang, J., Cui, K., & Nie, L. (2015). Dry direct-seeded rice as an alternative to transplanted-flooded rice in Central China. *Agronomy for Sustainable Development*, *35*(1), 285-294.

Mahajan, G., Chauhan, B. S., & Johnson, D. E. (2009). Weed management in aerobic rice in Northwestern Indo-Gangetic Plains. *Journal of Crop Improvement*, *23*(4), 366-382.

Mani, V. S., Malla, M. L., & Gautam, K. C. (1973). Weed-killing chemicals in potato cultivation. *Indian farming*.

Materu, S. T., Shukla, S., Sishodia, R. P., Tarimo, A., & Tumbo, S. D. (2018). Water use and rice productivity for irrigation management alternatives in Tanzania. *Water*, *10*(8), 1018.

Menon, M. V. (2019). Herbicide mixtures for weed management in wet-seeded rice. *Indian Journal of Weed Science*, *51*(3), 295-297.

Mishra, M., & Misra, A. (1997). Estimation of integrated pest management index in jute–A new approach. *Indian Journal of Weed Science, 29*(1&2), 39-42.

Mortimer, A. M., Riches, C. R., Mazid, M., Pandey, S., & Johnson, D. E. (2008). Issues related to direct seeding of rice in rainfed cropping systems in northwest Bangladesh. *Direct Seeding of Rice and Weed Management in the Irrigated Rice-Wheat Cropping System of the Indo-Gangetic Plains*, 272.

Nagargade, M., Singh, M. K., & Tyagi, V. (2018). Ecologically sustainable integrated weed management in dry and irrigated direct-seeded rice. *Adv. Plants Agric. Res*, *8*, 319-331.

Narolia, R. S., Singh, P., Prakash, C., & Meena, H. (2014). Effect of irrigation schedule and weed-management practices on productivity and profitability of direct-seeded rice (*Oryza sativa*) in South-eastern Rajasthan. *Indian Journal of Agronomy*, *59*(3), 398-403.

Neog, P., Dihingia, P. C., Sarma, P. K., Sankar, G. R., Sarmah, D., Sarmah, M. K., ... & Mishra, P. K. (2015). Different levels of energy use and corresponding output energy in paddy cultivation in north bank plain zone of Assam, India. *Indian Journal of Dryland Agricultural Research and Development*, *30*(2), 84-92.

Patel, T. U., Lodaya, D. H., Italiya, A. P., Patel, D. D., & Patel, H. H. (2018). Bio-efficacy of herbicides in direct-seeded rice. *Indian Journal of Weed Science*, *50*(2), 120-123.

Patel, T. U., Vihol, K. J., Thanki, J. D., Gudaghe, N. N., & Desai, L. J. (2018). Weed and nitrogen management in direct-seeded rice. *Indian Journal of Weed Science*, *50*(4), 320-323.

Pathak, H., Tewari, A. N., Sankhyan, S., Dubey, D. S., Mina, U., Singh, V. K., & Jain, N. (2011). Direct-seeded rice: potential, performance and problems-A review. *Current Advances in Agricultural Sciences*, *3*(2), 77-88.

Prashanth, R., Kalyana, K.N., Murthy, Madhu Kumar, V., Murali M., & Sunil C.M. (2016). Bispyribac-sodium influence on nutrient uptake by weeds and transplanted rice. *Indian Journal of Weed Science, 48*(2), 217–219.

Priya ,Rathna, T. S., Eliazer Nelson, A. R. L., Ravichandran, K., & Antony, U. (2019). Nutritional and functional properties of coloured rice varieties of South India: a review. *Journal of Ethnic Foods*, *6*(1), 1-11.

Raj, S. K., & Syriac, E. K. (2017). Weed management in direct seeded rice: a review. *Agricultural Reviews*, *38*(1).

Rao, A. N., Johnson, D. E., Sivaprasad, B., Ladha, J. K., & Mortimer, A. M. (2007). Weed management in direct-seeded rice. *Advances in agronomy*, *93*, 153-255.

Rathika, S., Ramesh, T., & Shanmugapriya, P. (2020). Weed management in direct seeded rice: a review. *IJCS*, *8*(4), 925-933.

Saharawat, Y. S., Singh, B., Malik, R. K., Ladha, J. K., Gathala, M., Jat, M. L., & Kumar, V. (2010). Evaluation of alternative tillage and crop establishment methods in a rice–wheat rotation in North Western IGP. *Field Crops Research*, *116*(3), 260-267.

Sekhar, L., Ameena, M., & Jose, L.N. (2020). Herbicide combinations for enhancing the weed control efficiency in wet direct-seeded rice. *Journal of Crop and Weed, 16*(3), 221-227.

Sen, S., Ghosh, A., Mondal, D., Sadhukhan, R., Roy, D., & Paul, K. Herbicide options for cost-effective weed control and sustainable rice production in direct-seeded rice. Food and Scientific Reports, 1(9): 19-25.

Singh, Rohitashav, Pal, Ram, Singh, Tejpratap, Singh A.P., Yadaw, Subash, & Singh, Jodhpal. (2014). Management of weeds in direct-seeded rice by bispyribac-sodium. *Indian Journal of Weed Science, 46*(2), 126–128.

Singh, V., Jat, M. L., Ganie, Z. A., Chauhan, B. S., & Gupta, R. K. (2016). Herbicide options for effective weed management in dry direct-seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains. *Crop Protection*, *81*, 168-176.

Steel, R. G. D., & Torrie, J. H. (1980). Principles and procedures of statistics, a biometrical approach (No. Ed. 2). McGraw-Hill Kogakusha, Ltd.

Verma, Badal, Bhan, Manish, Jha, A.K., Singh, Vikash, Patel, Rajendra, Sahu, M.P., & Kumar, Vijay. (2022). Weed management in direct-seeded rice through herbicidal mixtures under diverse agroecosystems. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*, *53*(4), 7299-7306.

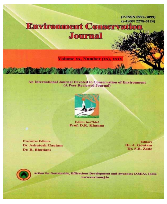
Zia-Ul-Haq, M., Khaliq, A., Qiang, S., Matloob, A., Hussain, S., Fatima, S., & Aslam, Z. (2019). Weed growth, herbicide efficacy, and rice productivity in dry seeded paddy field under different wheat stubble management methods. *Journal of Integrative Agriculture*, *18*(4), 907-926.

Environment Conservation Journal 24 (3): 249-259, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Water and soil studies in Shrimp aquaculture systems

Praveen Joshi H S ✉

Department of Aquatic Environment Management, Karnataka Veterinary, Animal and Fisheries Sciences University, College of Fisheries, Mangaluru, Karnataka, India

Ramachadra Naik A T

Department of Aquatic Environment Management, Karnataka Veterinary, Animal and Fisheries Sciences University, College of Fisheries, Mangaluru, Karnataka, India.

ARTICLE INFO

Received : 19 November 2022
Revised : 26 February 2023
Accepted : 01 April 2023

Available online: 16 August 2023

Key Words:
Biological oxygen demand
Carbon/Nitrogen ratio
Dakshina kannada
Litopeneaus vannamei
Mangaluru

ABSTRACT

Litopeneaus vannamei **is the most preferable species for culture by shrimp producers due to short time crop, hardy species and high market value. Present investigation was carried out to comprehend the significance of the carbon and nitrogen ratio in shrimp farming systems at Ankola, Uttara Kannada (District) and Haleyangadi, Mangaluru (Taluk) and Dakshina kannada (District). The pond water characteristics namely temperature, pH, alkalinity, salinity, Dissolved oxygen, biological oxygen demand, total suspended solids, total dissolved solids, Ammonia, NO_2, NO_3, PO_4, SiO_3 were found to vary from 28 to 35°C, 6.9 to 9.4, 25 to 125 mg/l, 0 to 36 ppt, 0 to 4.20mg/l, 0.020 to 0.259mg/l, 1.63 to 81.24mg/l, 0.12 to 36.45µg at./l as micro-mole per litre, 0.09 to 11.12 µg at./l, 0.26 to 32.15µg at./1, 0.15 to 26.18µg at./l, 2.40 to 90.18µg at./l respectively. The pond soil characteristics comprising of pH, organic carbon were ranged from 6.5 to 8.6, 0.235 to 1.994%, respectively while texture comprising of sand content varied from 48.41 to 96.26%, clay 0.3 to 2.45% and silt 3.14 to 51.24%. C/N ratio is varied 1.084-11.450 during the research phase. The outcomes of the water quality parameters shown quite higher nutrient all selected ponds and Organic carbon showed high in all ponds along with day of culture that's impact data on water quality and influence on pond biomass and the C/N ratio. A culture system's ability to produce more can be greatly increased by maintaining the quality of the soil and water by removing toxicity though nitrification and continuous monitoring.**

Introduction

Shrimp aquaculture has increased recently in Southeast Asia has after decade fast expansion and also due to COVID-19 aqua farmers faced plenty of problems *viz* Seed and Feed purchase, marketing, labours etc. Particularly in aquaculture continues monitoring is very essential during the culture period. The primary principle of carbon and nitrogen is to reduce water exchange and promote heterotrophic organisms by utilising waste nitrogen that is assimilated within the pond or tank. Carbon and Nitrogen (C/N) ratio regularly fallowed in biofloc aquaculture system by addition of organic carbon as a source to the animal tank which is utilize by the inorganic nitrogen to aggregate the microorganisms. To maximise the growth of heterotrophic bacteria, the feed must have an ideal carbon to nitrogen ratio. A method of regulating the nitrogen content in water is the carbon to nitrogen ratio (CN Ratio). The most common CN ratios are 10:1 and 15:1, which indicates that for a CN Ratio of 10:1, 10 Carbon Sources are required to neutralise 1 Nitrogen. In aquaculture, total ammonia nitrogen and the protein percentage of feed are used to compute the CN Ratio. If the ratio of carbon to nitrogen in the solution is optimal, bacterial biomass will also be produced from organic nitrogenous waste and ammonium (Schneider *et al.,* 2005). Waste produced during culture, primarily faeces and leftover feed, causes harmful metabolites like ammonium and nitrite to build up and ruin the shrimp's habitat in intense aquaculture systems (Avnimelech and Ritvo, 2003;

Corresponding author E-mail: *hspraveenjoshi123@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16132511

Piedrahita, 2003). In aquaculture ponds with increased stocking rates, water quality management is of utmost importance. Growth and survival are hampered by poor water quality. According to standard definitions, good quality water is appropriate or suitable for shrimp survival and growth. According to Avnimelech (1999) the pond's heterotrophic bacterial growth is boosted by the addition of carbohydrates, and nitrogen uptake occurs as a result of the creation of microbial proteins. Muthusamy (2016) reported reduced total nitrogen-ammonia ratio while preserving high water quality for shrimp farming in biofloc systems. In ponds with or without a carbohydrate-based diet for the shrimp, meticulous control was used to monitor the water purity and productivity (Hari *et al.* 2006). pH, salinity, carbonates, bicarbonates, total alkalinity, calcium, magnesium, total hardness, total ammonia, and nitrite are just a few of the factors that were examined, reported by Jaganmohan and Kumar (2017) to be kept at ideal levels that are suitable for *L. vannamei* farming. Islam *et al*. (2004) found that the salinity varied from 2.5 to 20.0 ppt in the southeast compared to 3.0 to 15.0 ppt in the southwest, and that the total ammonia-nitrogen was higher than the threshold recommended for shrimp cultivation in Bangladesh.

Material and Methods

Area of study: The current study was completed at Fisheries Research and Information Centre (Marine), which is situated in 14°65'96.5"N 74°28'22.1"E Ankola in Uttara kannada district (Earthen ponds) and Haleangadi or Haleyangady which is situated in 13°03'48.8"N 74°47'22.3"E Dakshina Kannada district of Karnataka's Mangalore taluk (Plastic lined and Biofloc ponds).

Altogether, three experiments were conducted triplicate. The first experiment was conducted in earthen ponds located Ankola, Uttara Kannada–dist. A total of three ponds were selected for the study *viz,* first and second ponds were from private farmers (ponds locations: 14°64'096.1"N 74°29'633.3"E) while the third pond selected was located at Fisheries Research and Information Centre (Marine), Bela, Ankola (pond location: 14°65'96.5"N 74°28'22.1"E). The second and third experiments were initiated at Haleyangady near Mangaluru taluk of Dakshina Kannada dist. (ponds locations: 13°03'48.8"N74°47'22.3"E).

Experiment 1: In the first experiment, three earthen shrimp aquaculture ponds were selected. All these were named as earthen pond 1 and designated as EP1, earthen pond 2 as EP2 and earthen pond 3 as EP3. In addition to these ponds, a water inlet channel was also selected and named as earthen pond channel and designated as EPC.

Experiment 2: In the second experiment, three plastic lined shrimp aquaculture ponds were selected. All these were named as plastic lined pond 1 and designated as PP1, plastic lined pond 2 as PP2 and plastic lined pond 3 as PP3. Addition to these ponds, a water inlet channel was also selected and named as plastic-lined pond channel and designated as PLC.

Experiment 3: In the third experiment, three biofloc shrimp aquaculture ponds were selected. All these were named as biofloc pond 1 and designated as BP1, biofloc pond 2 as BP2 and biofloc pond 3 as BP3. Addition to these ponds, a water inlet channel was also selected and named as biofloc pond channel and designated as BFC.

The geographical locations and map of the selected ponds for sampling are shown in Plate 1 and 2.

Carbon and Nitrogen ratio (C/N Ratio): Method was carried according to the procedure described by Nasrin islaam *et al.* (2016). Walkley and Black (1934) method was employed to ascertain soil organic carbon. Various physico-chemical characteristics of soil and water will be determined as per the standard procedure (APHA, 2005).

Results and Discussion

Present investigation, Water's physicochemical characteristics, soil and carbon and nitrogen ratio (C/N ratio) were recorded from different shrimp culture ponds. The detailed results on various parameters are outlined in table 1 to 7 and graphically predicted in figure 1 to 3.

Physico-chemical characteristics of selected shrimp pond water

In shrimp ponds, temperature is the most critical component that determines water quality and aquatic organism metabolic activity. The water temperature of the selected ponds was recorded ranged between 28 ºC and 35 ºC maximum water temperature recorded in the month of April 60th day of culture in earthen ponds. The high temperature will cause the high organic load formation and

Plate 1: Google map showing earthen ponds, Ankola, Uttara Kannada

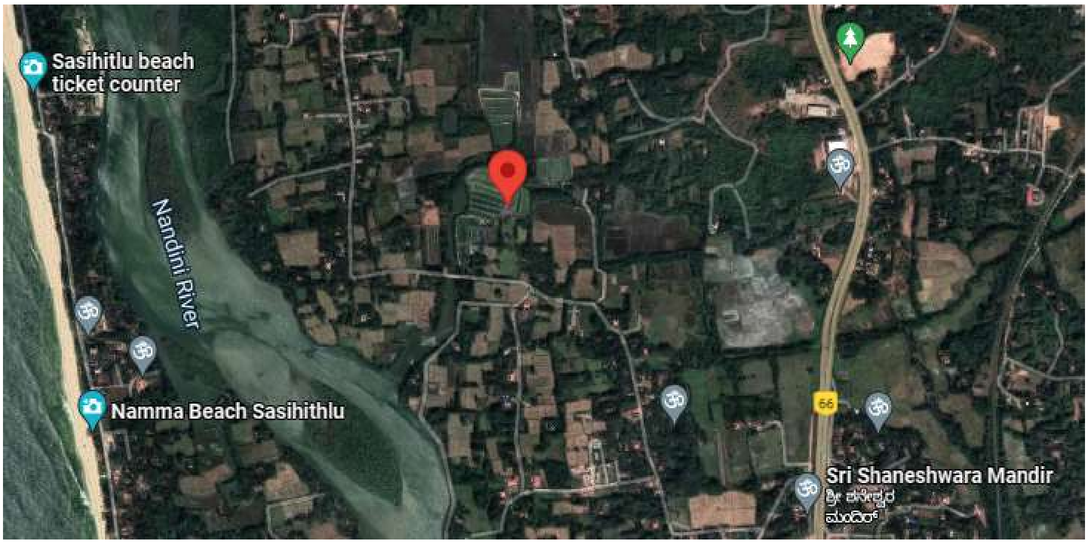


Plate 2: Google map showing plastic lined and biofloc ponds, Haleyangadi, Mnagaluru, Dakshina Kannada

Plate 3: Photographs showing collection of samples from cultured ponds

increase the bacterial loads in the culture ponds; Air temperature had the direct influence on the variation of water temperature. Alakinity plays very important role in aquatic environment because of its significance in the moulting process of shrimp, , alkalinity is very important in shrimp culture ponds. Low alkalinity causes wide pH changes in shrimp, resulting in stunted growth and even death. Due to excessive salt loss, high alkalinity levels may halt the moulting process in shrimp. In the present study minimum alkalinity recorded 25ppm in the month of June on 105th day of sampling in earthen ponds and maximum 125ppm recorded in the month of January on 60th day of sampling in biofloc ponds. Salinity recorded was ranged between 0-35ppt the salinities observed in the current investigation were suitable for *L. Vannamei*. However, it appears that the salinities exceeding 2 ppt were used for the majority of effective shrimp production (Roy *et al.,* 2010). Araneda *et al*. (2008) stated *L. vannamei*, a species used in cultivation, can withstand salinities of 0.5 to 45 ppt.

Table 1: Physico-chemical characteristics of water in earthen and plastic-lined shrimp ponds during the study period

Aquaculture systems	Earthen ponds				Plastic-lined ponds			
Ponds / Parameter	EP1	EP2	EP3	EPC	PP1	PP2	PP3	PLC
Temperature (°C)	31.0-33.0	30.5-32.5	28.5-35.0	29.0-35.0	28.5-33.0	28.5-32.5	29.0-33.0	28.0-30.5
pH	8.5-9.4	8.5-9.0	7.8-8.3	7.1-8.5	7.1-8.2	7.2-8.2	7.1-8.2	7.5-7.7
Alkalinity (mg/l)	85-118	82-123	76-116	25-118	84-112	82-105	80-109	77-121
Salinity (ppt)	23-26	22-28	15-36	0-35	16-28	15-27	18-26	12-25
DO (mg/l)	7.0-9.1	7.3-9.2	6.1-9.3	7.8-8.1	6.5-8.2	6.9-8.2	7.1-8.2	6.1-7.5
BOD (mg/l)	0-1.6	0-1.4	0.4-2.2	0-3.2	0.5-3.2	0.6-3.1	0.4-3.2	0.2-2.1
TSS (mg/l)	0.04-0.18	0.03-0.12	0.03-0.2	0.02-0.18	0.04-0.07	0.04-0.08	0.04-0.08	0.04-0.09
TDS (mg/l)	34.7-56.2	35.4-51.4	19.8-67.2	1.63-62.7	20.1-59.6	21.3-58.3	21.9-59.6	25.1-61.4
NH_3 (μg at./l)	3.2-27.40	4.2-27.50	0.12-5.74	0.50-4.98	5.3-12.41	5.1-13.41	4.9-13.11	1.1-5.64
NO_2 (μg at./l)	0.31-10.7	0.21-11.5	0.11-1.87	0.16-1.52	0.5-8.2	0.31-5.3	0.41-6.8	0.32-1.8
NO_3 (μg at./l)	1.59-24.8	2.13-22.8	0.53-3.71	0.26-4.24	0.9-22.13	0.57-23.5	0.91-24.1	0.47-8.51
PO_4 (μg at./l)	0.78-19.8	0.67-20.0	0.15-7.30	0.15-11.3	1.2-22.1	1.3-23.54	3.1-22.41	0.54-6.91
SiO_3 (μg at./l)	7.23-87.7	6.98-88.2	6.41-76.23	2.4-56.27	5.6-72.51	5.84-74.6	6.41-74.2	3.12-68.6

Table 2: Physico-chemical characteristics of water in biofloc shrimp ponds during the study period

Aquaculture system	Biofloc ponds			
Ponds / Parameter	BP1	BP2	BP3	BFC
Temperature (°C)	28.0-32.0	28.0-32.5	28.0-33.0	28.0-31.5
pH	6.9-8.3	7.1-8.3	7.2-8.4	7.1-7.7
Alkalinity (mg/l)	81-124	80-123	84-125	79-110
Salinity (ppt)	18-28	19-27	18-26	12-25
DO (mg/l)	7.1-9.4	7.8-9.5	7.6-9.2	7.2-7.9
BOD (mg/l)	0.5-4.2	0.4-3.9	0.9-3.6	0.4-1.8
TSS (mg/l)	0.04-0.24	0.04-0.21	0.04-0.25	0.04-0.10
TDS (mg/l)	26.4-81.2	27.8-77.4	23.9-80.0	22.3-55.1
NH_3 (μg at./l)	6.21-30.5	6.51-32.5	7.1-36.45	4.10-6.20
NO_2 (μg at./l)	0.51-11.1	0.54-9.44	0.61-8.12	0.47-2.56
NO_3 (μg at./l)	0.91-32.1	0.84-30.0	0.65-31.2	0.51-7.12
PO_4 (μg at./l)	0.94-24.1	0.94-25.9	1.11-26.1	0.54-26.0
SiO_3 (μg at./l)	8.22-90.1	8.11-88.2	9.65-90.3	3.21-92.7

μg at./l = Micro-mole per liter, mg/l = Milligram per litre, ppt = Parts per thousand

Table 3: Soil characteristics in earthen and plastic-lined shrimp ponds

Aquaculture systems	Earthen ponds				Plastic-lined ponds			
Ponds / Parameter	EP1	EP2	EP3	EPC	PP1	PP2	PP3	PLC
Soil pH	7.1-8.3	7.2-8.1	8.0-8.5	7.7-8.3	7.2-8.3	6.9-8.5	6.5-8.1	6.6-7.8
Organic carbon (%)	0.41-1.23	0.32-1.39	0.11-0.63	0.18-0.71	0.30-1.20	0.25-1.29	0.23-1.22	0.28-0.65
Avl. Nitrogen (mg/100gm)	2.05-3.15	2.10-3.25	2.01-3.02	2.0-2.62	1.17-3.25	2.21-3.90	2.20-3.51	1.05-2.19
Avl. Phosphorous (mg/100gm)	0.33-1.05	0.29-0.58	0.28-1.02	0.22-0.42	0.54-1.27	0.45-1.14	0.37-1.05	0.27-0.36

In the present study the dissolved oxygen values recorded ranged from 4.80 to 9.50 mg/l. The minimum concentration was recorded in the month of March in EPC on 30^{th} and in EP3 in the month of April on 60^{th} day of sampling while maximum was reported in the month of January at BP2 on 60^{th} day of sampling. Duru *et al.* (2018) stated that the increase in temperature decreases the solubility of oxygen, while at lower temperature dissolved oxygen increases. The optimal range of dissolved oxygen for shrimp was found in prior research to be >4 ppm, which is remarkably comparable to the results of the current study (Lazur, 2007). The BOD concentration ranged from 0 to 4.2 mg/l. The minimum concentration was recorded in the month of March and April in EP1 and EP2 on 30^{th}, 45^{th} and 60^{th} day of sampling while maximum was reported in the month of of April in EP3 on 60^{th} and in the month of January in BP1 on 60^{th} day of sampling. Maximum value of BOD level could be due to accumulation of uneaten feed settlement in pond bottom and increased excretion rate. Priyadarsani and Abraham (2016) recorded 6.45 mg/L in brackish water shrimp pond. The Ammonia level was ranged from 0.12 to 36.45 µg at/l. The minimum concentration was reported in the month of March in EP3 on 30^{th} day while maximum was reported in the month of January BP3 during 60^{th} day of sampling. Ammonia was recorded lowest value of that could be due to less organic load during the initial days of culture; maximum NH_3 was recorded might be due to increased metabolic rate in shrimp results in increased excretion. Krishnani *et al.* (2011) reported about Kerala's huge shrimp growing system has substantially higher levels of ammonia-N (0.27–0.35 ppm) occurred. According to Bhatnagar and Pooja (2019) ammonia levels greater than 0.1 mg/l, are likely to result in gill damage, the destruction of mucous-producing membranes, "sub-lethal" effects such as stunted growth, poor feed conversion, and decreased disease resistance at levels below lethal concentrations, as well as osmoregulatory imbalance and kidney failure. Ammonia poisoning usually makes fish or shrimp appear sluggish or frequently surface gasping for air. Nitrite-nitrogen content was ranged between 0.11 and 11.56 µg at./l as micro-mole per liter. The minimum concentration value was observed in the month of March in EP3 on 0^{th} day of sampling while maximum was observed in the month of April in EP2 on 60^{th} day of sampling. Nitrite is a by-product of the autotrophic Nitrosomonas bacteria's aerobic nitrification bacterial activity, which occurs when oxygen and ammonia are mixed. In shrimp (*Litopenaeus vannamei*) culture ponds at Narsapurapupeta, Kajuluru, and Kaikavolu villages of East Godavari district, Andhra Pradesh, Chakravarty *et al*. (2016) detected 0.01 to 0.80 mg/l. According to Maia *et al*. (2011), the top limits for marine shrimp culture systems should be below 0.2 mg/l and 0.3 mg/l, respectively. The Nitrate-nitrogen content was ranged between 0.26 and 32.15 µg at./l as micro-mole per liter. The minimum concentration value was observed in the month of March in EPC on 0^{th} day while maximum was observed in the month of February in BP1 on 90^{th} day of sampling. The autotrophic Nitrobacter bacteria combines oxygen and nitrite to generate nitrate, which is innocuous to fish where ammonia and nitrite were poisonous. According to Bhatnagar and Pooja (2019) Nitrate concentrations typically stabilise between 50 and 100 ppm. Meck (1996) said that its concentrations between 0 and 200 ppm are tolerable in a fish pond and that it is generally low harmful for some species, while particularly marine species are sensitive to its presence. In fish or shrimp culture water, Santhosh and Singh (2007) described the ideal range as being between 0.1 mg/l to 4.0 mg/l.

Table 4: Soil characteristics in biofloc shrimp ponds during the study period

Aquaculture system	Biofloc ponds			
Ponds / Parameter	BP1	BP2	BP3	BFC
Soil pH	6.5-8.3	6.6-8.2	6.7-8.4	7.1-8.0
Organic carbon (%)	0.465-1.325	0.411-1.994	0.505-1.314	0.325-0.504
Avl. Nitrogen (mg/100gm)	1.54-4.12	1.98-4.05	1.25-3.75	1.01-2.10
Avl. Phosphorous (mg/100gm)	0.41-1.35	0.48-1.46	0.43-1.21	0.21-0.41

Table 5: Variation of carbon and nitrogen ratio in different earthen ponds during the study period

Sampling day / Pond	Month								
	March 2021		April 2021		May 2021		June 2021		
	0	15	30	45	60	75	90	105	120
EP1	2.050	4.506	5.696	3.925	4.090	5.854	5.096	-	-
EP2	3.291	3.178	4.269	3.843	6.886	6.983	7.866	-	-
EP3	1.138	1.084	1.607	3.033	4.371	4.421	5.545	2.187	3.733
EPC	3.308	3.233	3.745	2.862	2.569	3.744	1.744	1.606	1.336

Table 6: Variation of carbon and nitrogen ratio in different plastic lined ponds during the study period

Sampling day / Pond	Month						
	November 2021		December 2021		January 2022		February 2022
	0	15	30	45	60	75	90
PP1	2.014	3.625	5.479	4.897	4.117	5.845	6.264
PP2	2.015	3.167	4.156	4.289	5.986	7.097	7.447
PP3	2.138	2.654	2.611	3.014	3.587	3.901	4.524
PLC	1.314	2.417	3.001	2.964	2.667	2.805	3.214

Table 7: Variation of carbon and nitrogen ratio at different biofloc ponds during the study period

Sampling day / Pond	Month						
	November 2021		December 2021		January 2022		February 2022
	0	15	30	45	60	75	90
BP1	5.535	7.271	10.428	9.518	11.450	10.192	10.550
BP2	5.074	5.924	10.721	10.107	10.925	7.617	9.495
BP3	5.260	7.358	12.752	10.950	11.020	9.850	10.755
BFC	3.316	3.484	4.181	3.868	4.463	5.538	3.436

The Phosphate-phosphorous content was ranged between 0.15 and 26.18 µg at./l as micro-mole per liter. The minimum concentration value was observed in the month of March in EP3 and EPC on 0^{th} day of sampling while maximum was observed in the month of January in BP3 on 60^{th} day of sampling. A macro-mineral called phosphorus is a crucial component for shrimp. Phosphorus, along with calcium, is a key element in the exoskeleton. It performs useful functions in numerous metabolic processes. As a crucial part of phospholipids (such as lecithin and cephalin), nucleic acids, phosphor proteins, high-energy substances (such as adenosine triphosphate), several metabolic intermediates, and co-enzymes. To keep the pH of intracellular and extracellular fluids at a normal level, inorganic phosphates are also crucial buffers. Therefore, it is doubtful that considerable amounts of phosphorus will be absorbed via water, making a nutritional supply crucial for the majority of aquatic organisms (Akiyama *et al*, 1992). For fish culture, a phosphate content of 0.06 mg/l is preferred, according to Stone and Thomforde (2004). Bhatnagar *et al*. (2004), 0.05-0.07 ppm is ideal and productive, while 1.0 ppm is beneficial for plankton and shrimp production. The Silicate content was ranged between 2.4 and 90.18 µg at./l. The minimum silicate value was observed in the month of March in EPC on 0^{th} day of sampling while maximum was observed in the month of January in BP1 on 60^{th} day of sampling. Ryther and Officer (1981) proposed that silica depletion and the eradication of diatoms from phytoplankton populations could result from the eutrophication of coastal waters by residential wastes that are relatively low in silica. Marine diatoms frequently develop faster and can out compete other algae species when silica levels are sufficient. In the experimental shrimp ponds, Natarajan and Deivasigamani (2017) found that the silicate concentration ranged from 0.0058 to 0.0131 ppm. Boyd (2003) recommended silicate concentrations greater than 1 mg/l. A high concentration of silicate is harmful to adjacent receiving environments, as it causes changes to the phytoplankton community.

Soil characteristics of selected shrimp farms

In the current study, earthen ponds soil pH content was ranged between 7.1 and 8.5, Plastic-lined ponds with 6.6 and 8.5 and biofloc ponds with 6.5 and 8.4. Chakravarty *et al*. (2016) reported the soil pH of 6.5 to 7.5 in Shrimp culture ponds in the Andhra Pradesh villages of East Godavari, Kogodu, and Atchutapuratrayam. Rahman *et al*. (2017) observed 7.7 to 7.8 in semi-intensive culture system of shrimp farms of Bangladesh. Boyd (2000) reported soil pH in shrimp ponds in the range from 6.5 to 7.5 and stated that in waterlogged soils, pH typically decreases as the redox potential increases result, the microbial activity in the absence of molecular oxygen. In the present experiment the earthen ponds soil organic carbon content was recorded between 0.112 and 1.391%, plastic-lined ponds with 0.235 and 1.291% and biofloc ponds with 0.325 and 1.994%. Vinothkumar *et al*. (2018) reported organic carbon content of 0.41 to 0.74%. Kunlapapuk *et al*. (2021) reported 1.87 to 3.06% of organic carbon, they believed that the carbon burial rate of sediment in the ponds was correlated with pond age, sediment depth, dry bulk density of sediment, and the amount of organic carbon in the Pacific white shrimp (*L. vannamei*) ponds in the Phetchaburi Province of the upper Gulf of Thailand. Nitrite concentrations in shrimp ponds are rarely high enough to kill the shrimp, although concentrations above 4 or 5 mg/l may have a negative impact on growth (Boyd and Fast, 1992). Earthen ponds soil available nitrogen content in the present study was recorded between 2.0 and 3.25 mg/100g, plastic-lined ponds with 1.05 and 3.90 mg/100g and biofloc ponds with 1.01 and 4.12 mg/100g. High range of available nitrogen content in soil was 18.2 to 20.00 mg/100g in shrimp ponds compared to the present study was observed. Vinothkumar *et al*. (2018) stated that In order to produce aquatic biomass, nitrogen must be present at an optimal level, which is highly desirable. In the present research, earthen pond soil available phosphorus content was recorded between 0.22 and 1.05 mg/100g, plastic-lined ponds with 0.27 and 1.27 mg/100g and biofloc pond with 0.21 and 1.46 mg/100g. According to Muhammad (2014), brackishwater ponds in Takalar Regency coastal areas had phosphorus contents that were relatively high. For shrimp farming, phosphorus levels should be between 30 and 60 mg/l. Phosphorus availability in brackishwater ponds is advised to be more than 60 mg/l and is regarded as modest or suitable and limiting factors when it meets these conditions. Rahman (2017) reported 13.41 to 17.28 µg/l in shrimp ponds, Bangladesh. Vasin (2011) observed 41.1 mg/kg available phosphorous in commercial shrimp farms, Chantaburi Province, Thailand. Even with strong phosphate fertilization, it can be challenging to start plankton blooms in semi-intensive shrimp ponds with heavy clay soils because high clay content in soil is related with a high phosphorus fixation capacity (Boyd and Munsiri, 1996). *Penaeid* shrimp have been reported to thrive and survive better on sandy surfaces (Bray and Lawrence 1993).

Carbon and Nitrogen ratio

Since many years ago, conventional agriculture has evaluated soil organic matter state and the value of livestock manure and other organic matter sources as soil amendments and fertilisers using the carbon to nitrogen (C/N) ratio. Indicators of pond bottom soil fertility and the quality of organic fertilisers used in aquaculture include the C/N ratio. The C/N ratio has served as a foundation for better biofloc production in aquaculture systems. To maximise the growth of heterotrophic bacteria, the feed must have an ideal carbon to nitrogen ratio. Controlling the amount of nitrogen in water is done by adjusting the C/N ratio. The most common C/N ratios are 10:1 and/or 15:1, which implies that 10 carbon sources must kill 1 nitrogen in order for a C/N ratio of 10:1 to exist. The C/N ratio in aquaculture is computed using the total ammonia nitrogen content of the feed and the feed's protein content. The carbon and nitrogen content was recorded in different shrimp ponds during the study period is given in Table 5, 6 and 7. Graphically depicted in Figure 1, 2 and 3.

The control of inorganic nitrogen accumulation in a biofloc system is dependent on carbon metabolism and nitrogen-immobilizing microbial activities (Avnimelech, 1999). While bacteria use inorganic nitrogen as nourishment to produce new cells

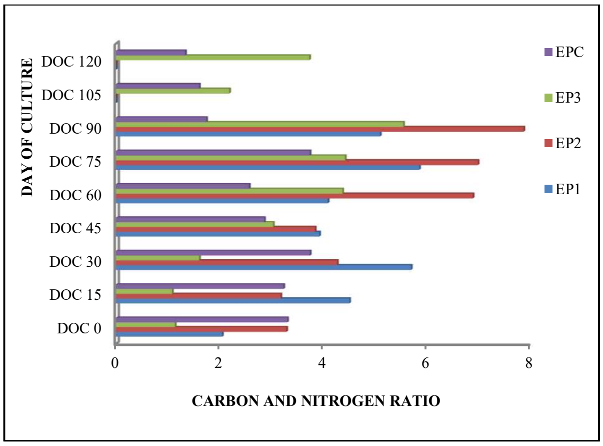


Figure 1: Variation of C/N Ratio in different earthen ponds during the study period

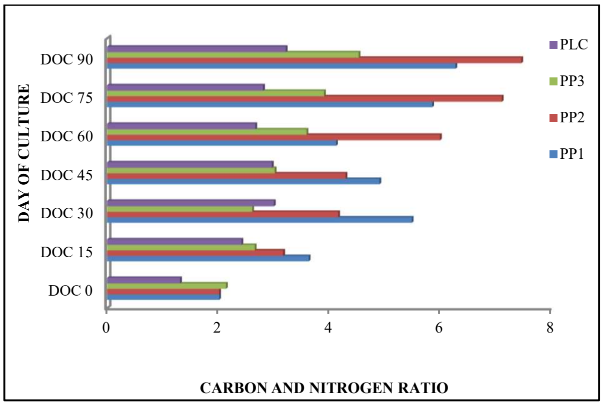


Figure 2: Variation of C/N Ratio in different plastic-lined ponds during the study period

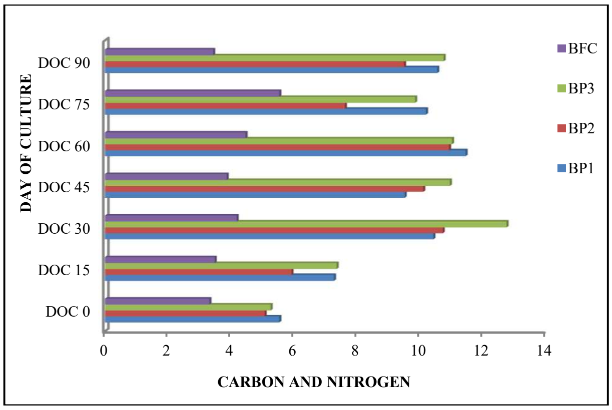


Figure 3: Variation of C/N Ratio in different biofloc ponds during the study period

throughout this process, carbon is required (Deng *et al.,* 2018; Hargreaves, 2006). The C/N ratio was recorded in earthen pond between 1.084 and 7.866 during the study. The least value was recorded in the month of March in EPC on 15th day of sampling while maximum was observed in the month of May in EP2 on 90th day of sampling. The C/N ratio was recorded in plastic-lined pond between 1.314 and 7.447 during the study dated. The minimum C/N ratio was recorded in the month of November in PLC on 1st day of sampling while maximum C/N ratio was observed in the month of February in PP2 on 90th day of sampling. The carbon and nitrogen ratio were recorded in biofloc culture ponds between 3.316 and 11.450. The minimum values were recorded in the month of November in BFC on 1st day of sampling while maximum was observed in the month of January in BP1 on 60th day of sampling. In the present investigation, earthen ponds reported C/N ratio between 1.084

and 7.866 while plastic-lined ponds had 1.314 and 7.447 and biofloc ponds with 3.316 and 11.450. Chakrapani *et al*. (2020) studied on three different carbon and nitrogen ratios for Pacific white shrimp. The overall results showed that raising *P. vannamei* shrimp in the biofloc system, particularly at a level of C/N ratio of 10 and 15, might result in enhanced water quality, greater productivity, and improved growth performance. Along these lines, in the present study too, showed good growth and survival rate of shrimps reared in biofloc culture system. Maximum C/N ratio 11:1 was observed in the month of January on 60^{th} day of sampling. Similarly, Mustafa *et al*. (2021) reported 2.65 to 11.19 in brackishwater pond soil at East Java Province, Indonesia. According to Banarjea (1967) the ideal C/N ratio in soil for pond culture ranged from 8:1 to 12:1.

Conclusion

Current growth rate of population explosion and the rate of anthropocentric encroachment of land, scientists have put forward a concern of challenges in production of food to meet the global demand. About 20% of human population consume fish, is being supplied majorly by aquaculture sector. The popular shrimp (*Litopeneaus vannamei*) is the most preferable species for culture by shrimp producers due to its short time crop, hardy species and high market value. However, a number of issues, including disease outbreaks, deteriorating water quality, and germplasm degradation, have been faced by the *L. vananmei* aquaculture business. Keeping the aspects in mind, present investigation was focussed to understand the productivity and C/N ratio in shrimp (*L. vannamei*) aquaculture systems at Ankola in Uttara Kannada district and Haleyangady in Dakshina Kannada district. The water and soil quality parameters and C/N ratio results shown higher deviation in biofloc ponds compared to earthen and plastic-lined ponds.

Acknowledgement

The authors are thankful to Prof. Dr. A.T. Ramachandra Naik, Department of Aquatic Environment Management. Karnataka Veterinary, Animal and Fisheries Sciences University. College of Fisheries, Manguluru, Karnataka. Dr. Chandrakant Lingadhal, Associate professor & Head (I/c) Fisheries Research Information Centre (M), Ankola for their constant encouragement and support during the study period.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Akiyam, D. M. (1992). Future consideration for shrimp nutrition and the aquaculture feed industry. In: J. W yban (Ed.), Proceedings of the Special Session on Shrimp Fanning. *World Aquaculture Society,* 198-205.

APHA, 2005. Standard methods for examination of water and waste water. *Standard Methods* (19th ed.) 874.

Araneda, M., Perez, E. P & Gasca, E. (2008). White shrimp *Penaeus vannamei* culture fresh water densities; condition state based on length and weight. *Aqua*culture, 283(1-4):13-18.

Asaduzzaman, M., Rahman, M. M., Azim, M. E, Islam, M, A., Wahab, M. A., Verdegem, M. C. J., & Verreth, J. A. J. (2010). Effect of C/N ratio and substrate addition on natural food communities in freshwater prawn monoculture ponds. *Aquaculture and Fisheries*, 306:127-136.

Avnimelech, Y. (1999). Carbon/nitrogen ratio as a control element in aquaculture systems. *Aquaculture,* 176:227–235.

Avnimelech, Y., & Ritvo, G. (2003). Shrimp and Fish Pond Soils: Processes and Management. *Aquaculture,* 220:549-567.

Banerjea, S.M. (1967). Water quality and soil condition of fish ponds in some states of India in relation to fish production. *Indian J. Fish*, 14: 113-144.

Bhatnagar, A., & Pooja, D. (2019). Water quality guidelines for the management of pond fish culture, *International Journal of Environmental Science,* 5-2.

Bhatnagar. A., Jana, S. N., Garg, S. K., Patra, B. C., Singh, G. & Barman, U. K. (2004). Water quality management in aquaculture, In: Course Manual of summer school on development of sustainable aquaculture technology in fresh and saline waters. *Haryana Agricultural, Hisar* (India), 203- 210.

Boyd, C. E. (2003). Fertilizantes químicos na aqüicultura de viveiros. Revista da Associacao Brasileira.*de Criadores de Ca.marao*, 5(3):79-81.

Boyd, C.E. & FAST, A.W. (1992). Pond monitoring and management and Marine shrimp culture principles and practices. *Elsevier the Netherlands*, 862: 497-513.

Boyd, C.E. & Munsiri, P., 1996. Phosphorus adsorption capacity and availability of added phosphorus in soils from aquaculture areas in Thailand. *J. World Aquacul. Socie*, 27: 160-167.

Boyd, C.E., (2000). Pond bottom soil analyses. Global aquaculture advocate September. US., 92 pp.

Bray, W.A. & Lawrence, A.L, (1993). The effect of four substrates on growth and survival of *Penaeus vannamei* at two salinities. *Ciencias Marinas*, 19: 229-244.

Chakrapani, S., Akshaya, P., Jayashree, S., Mullaivanam, R., Sivakumar R.P. & Vinodh, K., (2020). Three different C: N ratios for Pacific white shrimp, *Penaeus vannamei* under practical conditions: Evaluation of growth performance, immune and metabolic pathways. *Aquaculture Research*, 1-12.

Chakravarty, M. S., Ganesh, P. R. C., Amarnath, D., Shanthi, S. B., & Srinu, B. T. (2016). Spatial variation of water quality parameters of shrimp (*Litopenaeus vannamei*) culture ponds at Narsapurapupeta, Kajuluru and Kaikavolu villages of East Godavari district, Andhra Pradesh, *International Journal of Fisheries Aquatic Studies*, 4(4): 390-395.

Deng, M., Chen, J., Hou, J., Li, D. & He, X. (2018). The effect of different carbon sources on water quality, microbial community and structure of biofloc systems. *Aquaculture*, 482: 103-110.

Duru, C. C., Daniel, U. I. & Ogbulie, J. N. (2018). Impacts of organic wastes on water quality of Woji Creek in Port Harcourt, Nigeria. *Journal of Applied Science Environmental Management*, 22(5): 625-630.

Hargreaves, J. A. (2006). Photosynthetic suspended-growth systems in aquaculture. *Aquacult. Eng*, 34: 344-363.

Hari, B,, Madhusoodana, B. M., Johny, T., Varghese, J. W., Schrama. & Verdegem, M. C. J. (2006). The effect of carbohydrates addition on water quality and the nitrogen budget in extensive shrimp culture systems. *Aquaculture*, 252:248-263.

Islam, M. S, Mustafa, K. A. H., Wahab, M. A. & Dewan, S. (2004). Water quality parameters of coastal shrimp farms from southwest and southeast regions of Bangladesh. *Fisheries Resources*, 8(1): 53-60.

Jaganmohan, P. & Leela, K. C. H. (2018). Assessment of water quality in shrimp (*L. vannamei*) grow out ponds in selected villages of S.P.S.R Nellore district of Andhra Pradesh. *International Journal of Fisheries and Aquatic Studies*, 6:2394-0506.

Krishnani, K. K., Gupta, B. P, Muralidhar, M., Saraswathy, R., Pillai, S. M., Ponnusamy, K. & Nagavel A. 2011. Soil and water characteristics of traditional paddy and shrimp fields of Kerala. *Indian Journal of Fisheries*, 58: 71-77.

Kumar, S., Anand, P. S., De, D., Deo, A. D., Ghoshal, T. K, Sundaray, J. K. & Lalitha, N. (2017). Effects of biofloc under different carbon sources and protein levels on water quality, growth performance and immune responses in black tiger shrimp *Penaeus monodon* (Fabricius, 1978). *Aquaculture Research*, 48(3): 1168-1182.

Kunlapapuk, S., Saipattana, P., Limhang, K. and Kulabtong, S. (2021). Sediment accumulation rate and carbon burial rate in the pacific white shrimp (*Litopenaeus vannamei*) ponds, Phetchaburi Province, upper Gulf of Thailand. *Int. J. Agri. Tech*, 17(3): 929-940.

Lazur, A. (2007). Good Aquacultural Practices Program: Grow out Pond and Water Quality Management. Joint institute for food safety and applied nutrition, University of Maryland. 17 pp

Maia, E. P, Alfredo, O. G. & Silva, L. O. B. (2011). Brazilian shrimp farms for *Litopenaeus vannamei* with partial and total recirculation systems. *International Journal of Aquatic Science*, 2(1): 16-27.

Meck, N. (1996). Pond water chemistry, San Diego, Koi Club, Http://users.vcnet.com/rrenshaw/h2oquality.html Revised on July 31, 1996.

Muhammad, K. (2014). Soil Quality analysis of brackishwater shrimp farming in coastal areas of Takalar Regency - Indonesia. *J. Env. Eco*, 5(2): 22-30.

Mustafa, A., Kamariah & Ratnawati, E. (2021). Soil quality and its implication for brackishwater pond soil management option in East Java Province, Indonesia. *Marine Sci. Fish*, 860: 20-37.

Muthusamy., Pramod, K. P., Radhakrishnapillai, A., Alagarsamy, V., Vivekanand, B. & Chandra, S. P. (2016). Effect of different biofloc system on water quality, biofloccomposition and growth performance in *Litopenaeus vannamei* (Boone,1931). *Aquaculture Research*, 47:3432–3444.

Nasrin, I., Shahadat, H. & Abdul, B. (2016). Soil Carbon and Nitrogen dynamics Agricultural Soils of Mymensingh, Bangladesh. *International Journal of Agriculture Bioscience Engineering*, 1(1): 1-8.

Natarajan, S. & Deivasigamani, B. (2017). Studies on Biosecured Shrimp Culture of *Penaeus monodon* (Fabricius, 1798). *Aquaculture Research*, 4(1):1031.

Piedrahita, R. H. (2003). Reducing the Potential Environmental Impact of Tank Aquaculture Effluents through Intensification and Recirculation. *Aquaculture,* 226:35-44.

Priyadarsani, L. & Abraham, T. J. (2016). Water and sediment quality characteristics of medium saline traditional shrimp culture system (Bheri). *Journal of Fisheries,* 4(1): 309-318.

Rahman, M., Ariful, I., Amirul, I., Syed, A. H. & Uddin, A. (2017). Investigation of semi-intensive culture system of shrimp with special reference to soil-water characteristics of Bangladesh. *International Journal of Fisheries and Aquatic Studies*, 5(2): 42-49

Roy, L. A., Davis, D. A., Saoud, I. P., Boyd, C. A., Pine, H. I. & Boyd, C. E. (2010). Shrimp culture in inland low salinity waters. *Reviews in Aquaculture* 2:191-208.

Ryther, J. H. & Officer, C. B. (1981). Impact of nutrient enrichment on water uses. In: Estuaries and nutrients (ed. By B.j. Neilson and L.E. Cronin).

Santhosh, B. & Singh, N. P. (2007), Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center, 29.

Schneider, O., Sereti, V. E. H. & Verreth, J. A. J. (2005). Analysis of nutrient flows in integrated intensive aquaculture systems. *Aquaculture Engineering*, 32:379-401.

Vinothkumar, R., Aurag, S. &. Srinivasan, M., (2018). Analysis of bottom soil quality parameters of shrimp pond culture in modified extensive method. *J. Emerging Tech. Innovative Res.*, 5:7-12.

Wu, J. X., Timothy, C. M. & Tzachi, M. S. (2016). Effects of C/N ratio on biofloc development, water quality and performance of *Litopenaeus vannamei* juveniles in a biofloc-based, high-density, zero-exchange, outdoor tank system. *Aquaculture*, 453:169-175.

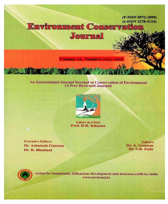
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 260-267, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Nutritional effect of zinc and boron on growth, yield and oil content of hybrid sunflower (*Helianthus annuus* L.)

Champak Kumar Kundu
Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, WB, India
Naorem Meena Devi ✉
Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, WB, India
Lalatendu Nayak
Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, WB, India
Hirak Banerjee
Regional Research Station (CSZ), BCKV, Akshaynagar, Kakdwip, South 24 Parganas, West Bengal, India
Soumyajyoti Das
Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, WB, India
Tripti Nandi
Apiculture unit, BCKV, Mohanpur, Nadia (WB), India.
Shantanu Jha
Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, WB, India

ARTICLE INFO

Received : 07 January 2023
Revised : 19 March 2023
Accepted : 01 April 2023

Available online: 18 August 2023

Key Words:
Hybrid variety
KBSH 78
Micronutrients
Oil yield

ABSTRACT

The experiment was conducted to assess the impactofZn and B application on sunflower growth, yield and oil content in sub-tropical condition. The experiment was laid out in randomized complete block design (RCBD) with twelve treatmentsand replicated thrice. The treatments comprised *viz*; T_1: Without fertilizers (absolute control), T_2: RDF ($N_{80}P_{40}K_{40}$), T_3: $N_{80}P_{40}K_{40}Zn_{0.5\%}$, T_4: $N_{80}P_{40}K_{40}Zn_4$, T_5: $N_{80}P_{40}K_{40}B_{0.2\%}$, T_6: $N_{80}P_{40}K_{40}B_2$, T_7:$N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$,$T_8$: $N_{80}P_{40}K_{40}Zn_4B_2$, T_9:$N_{80}P_{40}K_{40}Zn_4Zn_{0.5\%}$, T_{10}: $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$, T_{11}: $N_{80}P_{40}K_{40}B_2B_{0.2\%}$, T_{12}: $N_{80}P_{40}K_{40}B_2Zn_{0.5\%}$.From the experimental results recorded it can be concluded that the growth and yield components of the tested crop were significantly influenced by the application of micronutrients as compared to the control (without fertilizer) and recommended dose of fertilizer alone. Among the treatmentsapplication of $N_{80}P_{40}K_{40}Zn_4B_2$foundhigher diameter of capitulum (17.72 cm), number of seeds per capitulum (763), seed weight per capitulum(48.98 g), seed yield (2563 kg/ha) and oil yield (1097 kg/ha) of hybrid sunflower (variety KBSH 78) accounting 35.49%,43.25%, 26.66%, 46.50% and 51.32% more than control.

Introduction

Sunflower (*Helianthus annuus* L.) is the fourth most important (after groundnut, mustard and soybean) non-conventional oilseed crop cultivated in India. Recently, sunflower became very popular because of its short duration, high oil quality, photo-insensitivity, drought tolerance, and wider adaptability to a diversity of cropping patterns.Its oil is abundant in polyunsaturated fatty acids (60 %), linoleic and oleic acid of 72.5% and 16.0 % respectively. Seed has greater oil content (35-48 %), which helps to manage blood cholesterol in human (Patra *et al.*, 2013). As the protein content of oil cake is rich in quality protein (40-44%), it can be used as cattle and poultry feed.Sunflower is currently grown in0.26 million hectares in India, with a production of and average productivity of 0.22 million tonnes and 826 kg/ ha respectively. It is grown in 0.01 million hectares in West Bengal, with a production of 0.01 million tonnes and productivity of 952 kg/ ha (Agricultural Statistics at a Glance, DES, GOI, 2020). India is significantly reliant on imports to meet its edible oil demand,

Corresponding author E-mail: *meenanaorem26@gmail.com*
Doi: https://doi.org/10.36953/ECJ.17352542

and the country is the world's leading importer of vegetable oils followed by China and the United States (Annual Report, DF& PD 2020-21). Imports of edible oil have doubled the domestic production (all primary and secondary sources), placing the country under severe economic pressure. Under such conditions, increasing oilseed crop production and productivity is essential in order to close the gap between current demand and supply via advancing production technology. Sunflower, a premium crop, is still in its early phases of development, but it appears to be the most essential oilseed crop for combating the oil issue in the future.

Micronutrient deficiency in Indian soil is progressively emerging and becoming a severe constraint to sustainable agriculture. Deficiency of micronutrient in Indian soil has been recorded with respect to Zn (36.50 %), Fe (12.8 %), Cu (4.20 %), Mn (7.10 %), and B (23.4 %), while West Bengal soil has a deficiency of Zn (14.42 %), Fe (0.03 %), Cu (1.76 %), Mn (0.98 %), and B (37.05 %) (Shukla *et al.*, 2018).This is aggravated by agriculture intensification, followed by the use of high-analysis fertilizer. Furthermore, cultivation is mostly restricted to small and marginal farmers with low socio-economic condition. Nevertheless in the current exploitive agriculture, large-scale production improvements have also been observed with the application of micronutrients in combination with NPK (Rego *et al.*, 2007).

Boron plays a vital role in hormonal development, cell division, fruit and seed setting, sugar translocation of crops (Ahmad *et al.*, 2021). Deficiency of B in sunflower cause pollen tube deformation resulting in increased empty seeds in sunflower on the other hand, zinc is essential for a variety of physiological and metabolic activities in plants. Zinc deficiency diminishes net photosynthesis, induces chlorosis and necrotic patches on the leaves, and significantly reduce yield of the crop (Alloway, 2008). Hence the sustainable solution is application of sufficient and balanced nutrient for proper plant growth and biomass production in sunflower (Banerjee *et al.*, 2014). Application of micronutrients like zincand boron and iron through broadcasting and foliar application is known to enhancethe yield, yield components of oilseeds crop (Alloway, 2008). The combinedapplication of Zn and B was found to be beneficial in increasing chlorophyll content, nutrient uptake, yield and oil content in sunflower(Gitte *et al.*, 2005; Rex Immanuel *et al.*, 2020). Foliar application is better than soil application as rapid translocation of nutrients to leaf and seed take place, but foliar spray does not completely replace soil-applied fertilizer; however, it can only improve nutrientuptake. So it is the efficiency of soil-applied nutrients that ultimately brings increased crop production (Kannan, 2010). With this perspective, the experiment was mainly focused on micronutrient (Zn and B) management in sunflower, either soil applied, foliar spray or in combination during *rabi* season in irrigated conditions.

Material and Methods

The field experiment was laid out at farmer's field located in Panchkahania, Barajaguli, Nadia under sub humid and sub-tropical climatic conditions of West Bengalduring *rabi* season of 2020-21. Maximum and minimum temperature of the experimental area was fluctuated between 33.2^{0}C and 24.8^{0}C and 20.8^{0}C and 11.5^{0}Crespectively. Relative humidity prevailed between 96.5% and 41.27% during the period of experimentation.The soil of the experimental site was sandy loam in texture having pH 7.2, EC 0.46dS/m, medium organic carbon, 219.0 kg N/ha, 31.24kg P_2O_5/ha and 218.23kg K_2O/ha respectively.

The experiment was laid outin randomized complete block design (RCBD), with twelve treatment combinations andreplicated thrice. The treatments comprised *viz*; T_1: Without fertilizers (absolute control), T_2: RDF (80-40-40)NPK kg/ha ($N_{80}P_{40}K_{40}$), T_3 : RDF + Foliar Application(FA) of Zn @0.5% at 25 DAS ($N_{80}P_{40}K_{40}Zn_{0.5\%}$), T_4: RDF + Soil application (SA) of Zn @ 4 kg/ha ($N_{80}P_{40}K_{40}Zn_4$), T_5: RDF + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}B_{0.2\%}$), T_6: RDF + SA of B @ 2 kg/ha as basal($N_{80}P_{40}K_{40}B_2$), T_7: RDF +FA of Zn @ 0.5% at 25 DAS + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$), T_8: RDF + SA of Zn @ 4 kg/ha + B @ 2 kg/ha($N_{80}P_{40}K_{40}Zn_4B_2$), T_9 : RDF + SA of Zn @ 4 kg/ha + FA of Zn @0.5% at 25 DAS($N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$), T_{10} : RDF + SA of Zn @ 4 kg/ha + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$), T_{11} : RDF + SA of B @

2 kg/ha + FA of B @ 0.2% at 50 DAS($N_{80}P_{40}K_{40}B_2B_{0.2\%}$), T_{12} : RDF + SA of B @ 2 kg/ha + FA of Zn @0.5% at 25 DAS($N_{80}P_{40}K_{40}B_2Zn_{0.5\%}$). All phosphorus and potassium fertilizers were added to the soil at the time of sowing in each plot according to the recommended dose. However, nitrogen fertilizer was applied in two splits i.e, 50% each at the time of sowing and at 30 days after sowing (DAS). The hybrid seed 'KBSH 78' was sown on 21st November, 2020, by maintaining a spacing of 60cm × 30cm. After harvesting, seeds were manually separated from capitulum and air-dried. Weight of seeds was recorded by discarding the border plantsand then converted into kg/ha. And seed index represented the weight of 100 sunflower seeds. The plants (without capitulum) were sun-dried and weighed to get stem and husk yield and finally presented in kg/ha.

Oil content determination was done by following the standard procedure (AOAC, 2005). Oil yield could be determined by multiplying their concentrations (%) with the seed yield (kg/ha) divided by 100.

The final recorded data were subjected to analysis of variance (ANOVA) as randomized complete block design(Gomez and Gomez, 1984). The significant difference for sources of variance was tested by error mean square by Fisher Snedecor's 'F' test at probability level of 0.05. For comparison of 'F' values and computation of critical difference (CD) at 5% level of significance, Fisher and Yates' tables were used.

Results and Discussion

Growth attributes

The experimental results postulated that the application of primary nutrients and micronutrients in various combination showed pronounced effect on growth of hybrid sunflower (Table 1). Significantly different plant height was observed at all the stages of growth except at early growth stage i.e. 30 DAS. Application of $N_{80}P_{40}K_{40}Zn_4B_2$ recorded maximum plant height at harvest (170.4 cm). However, accounting 12.33 % more than RDF treatment and remained at par with $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$ (168.7 cm)and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$(165.1 cm) and significantly different from control. The least plant height was recorded with absolute control (141.0cm).This could be attributed to increase photosynthetic and metabolic activity, which is responsible for cell division and cell elongation thatresulted in increases plant height.Baloch *et al.* (2015) and Elayaraja *et al.* (2019) also found a positive response between soils applied micronutrients and plant height.Longer stems (higher plant height) had more nodes, which resulted in more number of leaves as the plant grows taller(Ramulu *et al.,* 2011). In the present study significantly higher LAI was obtained at 60 DAS and declined gradually, as the crop progressed towards physiological maturity. The maximum value of LAI was obtained with the application of $N_{80}P_{40}K_{40}Zn_4B_2$ at 60DAS (4.85) which remain at par with $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$ (4.73)and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$ (4.59) and the minimum was observed in absolute control plot (3.52). Dry matter accumulation (DMA) increased progressively with the advancement in growth and continued until maturity in all the treatments. The DMA was found to be higher with $N_{80}P_{40}K_{40}Zn_4B_2$all throughout the crop growth stage and finally reached at 1458.1 g/m^2 during harvest which was not significantly different from $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$ (1432.2 g/m^2) and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$ (1395.6 g/m^2) accounting 35.06% more than RDF.More leaf area and LAI of sunflower plants realized with this treatment might have allowed more solar energy to be captured over longer periods of time, resulting in more photosynthesis and higher total dry matter (Ravikumar *et al.,* 2021). The availability of micronutrients due to the treatment from planting to maturity stage would have improved the source-sink relationship, resulted in a larger quantity of total DMA of sunflower(Alipatra *et al*., 2019).

The different micronutrient treatmentsalso influenced crop growth rate. The highest CGR value of 14.99 and 25.66 g/m^2/day was recorded in $N_{80}P_{40}K_{40}Zn_4B_2$ between 30-60DAS and 60DAS-harvest, respectively and it was closely followed by the treatments with $N_{80}P_{40}K_{40}Zn_4Zn_{0.5\%}$ and $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$. Micronutrients, zinc and boron in particular, are known to have profound influence on the plant growth by indirect ways than direct participation in physiological activities (Rex Immanuel *et al*., 2020). Hence, their availability might have induced the ability of sunflower crop to utilize the soil available nutrients to the maximum extent during vegetative stage. Furthermore, Banerjee *et al.* (2014) opined that the degree of

Table 1:Growth attributes of hybrid sunflower as influenced by the application of zinc and boron during *rabi 2020-21*

Treatments	Plant height (cm)			LAI			DMA (g/m^2)			CGR (g/m^2/day)	
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30-60 DAS	60-108 DAS
Absolute Control	11.6	48.4	141.0	1.39	3.52	1.57	13.0	365.3	1064.5	11.74	17.51
$N_{80}P_{40}K_{40}$ (RDF)	11.1	55.4	151.7	1.52	3.68	1.96	13.4	374.1	1079.6	12.02	17.64
$N_{80}P_{40}K_{40}Zn_{0.5\%}$	11.0	55.7	155.0	1.55	3.72	1.70	13.4	377.7	1113.5	12.14	18.80
$N_{80}P_{40}K_{40}Zn_{4}$	10.9	50.9	158.7	1.51	3.80	1.95	14.5	404.6	1173.3	13.00	19.38
$N_{80}P_{40}K_{40}B_{0.2\%}$	10.7	51.3	156.6	1.62	3.78	1.84	13.7	381.3	1122.9	12.26	19.25
$N_{80}P_{40}K_{40}B_{2}$	10.6	51.9	160.8	1.68	3.86	2.18	14.7	411.2	1273.2	13.22	21.97
$N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$	11.3	55.5	161.7	1.72	3.97	2.34	16.3	416.4	1312.1	13.68	22.87
$N_{80}P_{40}K_{40}Zn_{4}B_{2}$	12.0	62.7	170.4	1.92	4.85	2.90	19.0	475.8	1458.1	14.99	25.66
$N_{80}P_{40}K_{40}$ $Zn_{4}Zn_{0.5\%}$	11.5	58.8	165.1	1.83	4.59	2.68	18.1	446.6	1395.6	14.28	24.58
$N_{80}P_{40}K_{40}Zn_{4}B_{0.2\%}$	11.5	62.2	168.7	1.87	4.73	2.84	18.6	467.7	1432.2	14.77	25.11
$N_{80}P_{40}K_{40}B_{2}B_{0.2\%}$	11.1	55.7	162.0	1.71	3.78	2.23	16.0	414.9	1279.0	13.56	22.60
$N_{80}P_{40}K_{40}B_{2}Zn_{0.5\%}$	11.2	56.5	160.4	1.77	4.36	2.43	17.9	442.9	1374.7	13.99	24.29
SEm ±	0.3	2.0	2.55	0.04	0.12	0.08	0.9	10.27	26.74	0.38	1.05
CD (P=0.05)	NS	6.1	7.86	0.13	0.37	0.26	2.9	31.66	82.39	1.16	3.23

RDF- Recommended dose of fertilizer; Subscript digits signify respective dose of N, P, K, Zn and B in Kg /ha
***NS- Non-significant; LAI- Leaf Area Index; DMA- Dry Matter Accumulation; CGR- Crop Growth Rate; DAS – Days After Sowing**

Table 2: Yield components, seed yield, oil content and oil yield of hybrid sunflower as influenced by the application of zinc and boron during *rabi* 2020-21

Treatments	Capitulum diameter (cm)	Number of seeds/capitulum	Seed weight/capitulum(g)	Seed index(g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
Absolute Control	11.43	433	34.45	4.95	1371	38.96	534
$N_{80}P_{40}K_{40}$ (RDF)	14.06	518	38.47	5.14	1806	40.14	725
$N_{80}P_{40}K_{40}Zn_{0.5\%}$	14.87	536	40.40	5.26	1951	41.53	810
$N_{80}P_{40}K_{40}Zn_{4}$	15.10	582	41.98	5.37	2118	41.29	874
$N_{80}P_{40}K_{40}B_{0.2\%}$	14.94	533	40.76	5.30	2068	41.45	856
$N_{80}P_{40}K_{40}B_{2}$	15.42	613	42.86	5.36	2194	41.18	904
$N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$	16.17	626	46.19	5.45	2297	41.95	964
$N_{80}P_{40}K_{40}Zn_{4}B_{2}$	17.72	763	48.98	6.16	2563	42.78	1097
$N_{80}P_{40}K_{40}$ $Zn_{4}Zn_{0.5\%}$	16.33	665	46.38	5.78	2374	42.42	1008
$N_{80}P_{40}K_{40}Zn_{4}B_{0.2\%}$	16.88	739	47.90	6.08	2427	42.57	1034
$N_{80}P_{40}K_{40}B_{2}B_{0.2\%}$	15.77	622	46.10	5.40	2251	42.20	950
$N_{80}P_{40}K_{40}B_{2}Zn_{0.5\%}$	16.25	657	46.27	5.71	2321	42.12	977
SEm ±	0.46	35.5	0.85	0.13	67.09	0.31	42
CD(P=0.05)	1.42	100.18	2.62	0.39	206.72	0.97	128

Table 3: Pearson's correlation co-efficient showing pair-wise association of different traits assessed for hybrid sunflower grown during *rabi* 2020-21

Parameters	PH 30 DAS	PH 60 DAS	PH 108 DAS	LAI 30 DAS	LAI 60 DAS	LAI 108 DAS	DMA 30 DAS	DMA 60 DAS	DMA 108 DAS	CGR 30-60 DAS	CGR 60-108 DAS	CD	NSC	SWC	SI	SY	OC	OY
PH 30 DAS	1.000																	
PH 60 DAS	0.600*																	
PH108DAS	0.242^{NS}	0.798**																
LAI DAS	0.428^{NS}	0.860**	0.929**															
LAI DAS	0.622*	0.872**	0.823**	0.912**														
LAI 108 DAS	0.545^{NS}	0.870**	0.896**	0.957**	0.943**													
DMA 30DAS	0.596*	0.837**	0.850**	0.939**	0.946**	0.967**												
DMA 60DAS	0.543^{NS}	0.829**	0.894**	0.938**	0.955**	0.972**	0.981**											
DMA108 DAS	0.498^{NS}	0.796**	0.889**	0.957**	0.916**	0.966**	0.980**	0.981**										
CGR30-60 DAS	0.518^{NS}	0.813**	0.913**	0.945**	0.921**	0.974**	0.979**	0.991**	0.990**									
CGR60-108 DAS	0.469^{NS}	0.786**	0.886**	0.965**	0.896**	0.951**	0.972**	0.965**	0.995**	0.978**								
CD	0.225^{NS}	0.808**	0.980**	0.923**	0.807**	0.869**	0.841**	0.868**	0.870**	0.886**	0.872**							
NSC	0.427^{NS}	0.857**	0.962**	0.956**	0.913**	0.962**	0.941**	0.975**	0.960**	0.977**	0.948**	0.945**						
SWC	0.332^{NS}	0.799**	0.961**	0.947**	0.823**	0.913**	0.917**	0.919**	0.941**	0.950**	0.948**	0.964**	0.961**					
SI	0.547^{NS}	0.884**	0.900**	0.935**	0.978**	0.949**	0.947**	0.974**	0.931**	0.950**	0.914**	0.883**	0.965**	0.891**				
SY	0.194^{NS}	0.752**	0.985**	0.926**	0.800**	0.874**	0.853**	0.880**	0.891**	0.904**	0.896**	0.990**	0.945**	0.974**	0.874**			
OC	0.206^{NS}	0.774**	0.949**	0.897**	0.766**	0.806**	0.820**	0.826**	0.838**	0.851**	0.856**	0.965**	0.894**	0.953**	0.847**	0.963**		
OY	0.222^{NS}	0.768**	0.985**	0.934**	0.812**	0.880**	0.865**	0.888**	0.899**	0.912**	0.904**	0.991**	0.950**	0.980**	0.885**	0.999**	0.972**	

Notes: DAS= Days After Sowing; PH = Plant height in cm, LAI = Leaf area index, DMA = Total dry matter accumulation in g/m^2, CGR= Crop growth rate in g/m^2/day, CD = Capitulum diameter at harvest in cm, NSC = Number of seeds/capitulum, SWC= Seed weight/ capitulum in g, SI = Seed index in g, SY = Seed yield in kg/ha, OC= Oil content in (%) and OY= Oil yield in kg/ha, NS= non-significant
***and ** represents significance at 5% and 1% levels respectively**

internode elongation is influenced by physiological parameters, favourable environmental conditions, and the time of fertiliser application, which exerts positive impacts on plant height, LAI, DMA and CGR of sunflower.

Yield components

Yield components of tested hybrid sunflower variety wererecorded and significantly higher capitulum diameter (17.72 cm), number of seeds/capitulum (763), seed weight/capitulum (48.98 g) and seed index (6.16 g) were found with the application of $N_{80}P_{40}K_{40}Zn_4B_2$ and it was statistically at par with $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$ and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$, accounting 35.5, 43.2, 29.7 and 19.6 % more than control respectively. This might be due to addition of micronutrients (zinc and boron) along with macronutrients (NPK) under micronutrient deficit condition that adds to seedling hardiness in the early stages. Thus, application of sufficient micronutrients in the initial stages might haveresulted in balanced soil macro and micronutrient status which improved nutrient availability in the rhizosphere soil (Rex Immanuel *et al.,* 2019). Besides, Zn and B plays a key function in boosting crop photosynthetic ability and participating in a number of enzymatic and other biochemical reactions, metabolism of carbohydrates, protein synthesis, chlorophyll synthesis (Patil *et al*., 2006) anther and pollen grain development (Krudnak *et al*., 2013).In present study also, partitioning of photosynthates from source to sink was better due to a balanced supply of these nutrients which ultimately resulted in higher yield attributing traits of hybrid sunflower. These results were corroborated with the findings of Shekhawat and Shivay (2008) and Sheoran *et al.,* (2018).Further Zn induced pollination by influencing pollen tube formation, that decided the number of seeds/capitulum and capitulum diameter which directly influence the seed yield (Alipatra *et al*., 2019). According to Ramulu *et al*. (2011), an increase ofcapitulum diameter by one centimetre would increase the number of seeds in sunflower by 75 to 100. Furthermore, there exists a direct relationship between seed yield and seed index, as the size of seed increased with increase in seed weight. The contribution of total number of seeds/capitulum to seed yield increases as the number of filled seeds/capitulum increases (Rex Immanuel *et al.,* 2020). A significant increase in seeds/capitulum with B application was observed due to induce flowering, pollen germination, and water balance between photosynthesis and respiration of the crop plant (Alipatra *et al.,* 2019). They further opined that B application increases the pollen- producing capacity, pollen viability, and seed setting, ultimately increases the seed index.

Seed yield, oil yield and oil content

Application of $N_{80}P_{40}K_{40}Zn_4B_2$ resulted in significantly higher seed yield (2563 kg/ha), oil content (42.78%) and oil yield (1097 kg/ha) accounting 46.5, 8.9 and 51.3% higher than control respectively. However, there was no significant difference in the yield components of tested variety with the applications of $N_{80}P_{40}K_{40}Zn_4B_2$, $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$ and $N_{80}P_{40}K_{40}$ $Zn_4Zn_{0.5\%}$ (Table 2 and Fig 1). An increase in seed yield is accounted for increase in yield components especially number of filled seed/capitulum, seed weight/capitulum and seed index, as observed in the present study also. Such response might be due to balanced supply of these nutrients that causes increased rate of photosynthesis and translocation of photosynthates to the site of storage organ ultimately resulted higher yield of sunflower (Ravikumar *et al.,* 2021). The seed oil content is an important parameter of sunflower. Oil content decided the oil yield and oil yields mirrored the response of seed yields being significantly increased due to the Zn and B fertilization (Sheoran *et al.,* 2018). The higher oil content and oil yield might be due to enzymatic activity in the formation of glucosides, glucosinolates and additionally sulphydril-linkage in biochemical reaction within the plant which helps in bio-synthesis of oil. These results are also in accordance with the earliest finding of Suryavanshi *et al.* (2015) and Sheoran *et al.* (2016). Furthermore, soil application of zinc and boron increases the fertilizer (NPK) use efficiency (Patil *et al*., 2006) thereby produces higher yield of quality sunflower seeds. Gitte *et al.* (2005) was in the view that combined application of Zn and B is more effective than Zn alone or B alone.

Correlation studies

In order to show how the growth and yield parameters were interacted with one another and with the yield of the hybrid sunflower, Pearsoncorrelation coefficients were determined

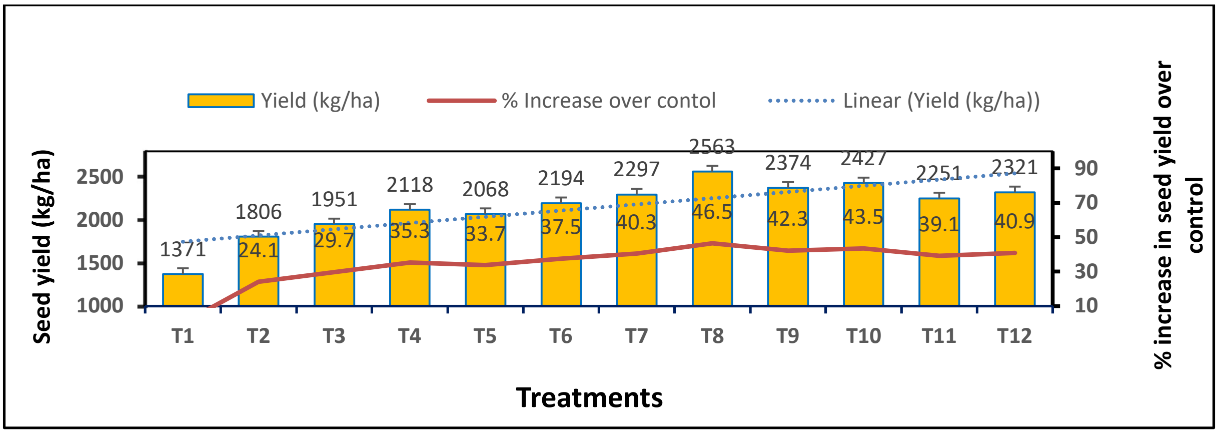


Figure1: Effect of Zn and B application on seed yield and percent increase in seed yield of hybrid sunflower over control

T_1 : (Without fertilizers) absolute control, T_2: $N_{80}P_{40}K_{40}$, T_3 : $N_{80}P_{40}K_{40}Zn_{0.5\%}$, T_4: $N_{80}P_{40}K_{40}Zn_4$, T_5: $N_{80}P_{40}K_{40}B_{0.2\%}$, T_6: $N_{80}P_{40}K_{40}B_2$, T_7: $N_{80}P_{40}K_{40}Zn_{0.5\%}B_{0.2\%}$, T_8: $N_{80}P_{40}K_{40}Zn_4B_2$, T_9 : $N_{80}P_{40}K_{40}Zn_4Zn_{0.5\%}$, T_{10} : $N_{80}P_{40}K_{40}Zn_4B_{0.2\%}$, T_{11} : $N_{80}P_{40}K_{40}B_2B_{0.2\%}$, T_{12} : $N_{80}P_{40}K_{40}B_2Zn_{0.5\%}$

(Table 3). The highly significant and favourable correlation between seed yield and LAI, DMA, capitulum diameter, seed weight per capitulum, number of seed per capitulum, and seed index (100-seed weight) was found in the current study concluded that adequate accumulation of photosynthates during vegetative phase and its efficient translocation to the storage organ site during reproductive phase, and ultimately supporting the crop for producing higher seed yield. The positive and highly significant relationship was found to exist between seed yield and oil content and oil yield which suggested that oil productivity is directly dependent on seed yield and oil content.

Conclusion

Micronutrients play different specific roles in the plant growth and development processes. The current experiment also clearly showed the favourable role of micronutrients especially Zn and B in augmenting sunflower production. Maximum plant height, leaf area index, dry matter accumulation, crop growth rate, yield components like capitulum diameter, number of seed/ capitulum, seed yield, oil yield etc. were found to be highest with the soil application of zinc and boron @ 4kg/ha and 2 kg/ha respectively. Hence their application in combination with RDF i.e. $N_{80}P_{40}K_{40}Zn_4B_2$kg/ha was identified as best treatment combination for higher productivity and profitability of sunflower production in alluvial soil of West Bengal.

Conflict of interest

The authors declare that they have no conflict of interest.

References

A.O.A.C.(Association of Official Analytical Chemists) (2005). Official Methods of Analysis of the Association of Analytical Chemists International, 18th edition. *Gathersburg, U.S.A.*

Agricultural Statistics at a Glance, DES GOI (2020). Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare, GOI. New Delhi.

Ahmad, S. H. E. R. , Sattar, A. , Muhammad, I. J. A. Z. , Nawaz, A. , Yasir, T. A. , Hussain, M., & Yaseen, M. (2021). Combined foliage application of zinc and boron improves achene yield, oil quality and net returns in sunflower hybrids under an arid climate. *Turkish Journal of Field Crops,*26(1), 18-24.

Alipatra, A., Banerjee, H. , Bhattacharyya, K., Bandopadhyay, P. , Mazumdar, D. & Sarkar, S. (2019). Productivity, nutrient uptake and profitability of hybrid sunflower (*Helianthus annuus*) as influenced by irrigation and fertilizer-management practices under sub-tropical climate of West Bengal. *Indian Journal of Agronomy,* 64(1),107-114.

Alloway, B. J.(2008). Zinc in soils and crop nutrition. published by IZA and IFA.*Brussels, Belgium and Paris, France*, 135.

Annual Report, DF & PD. (2020-21). Department of Food and Public Distribution, Ministry of Consumer Affairs, Food and Public Distribution. Ministry of Agriculture, Government of India, New Delhi

Baloch, R. A., Baloch, S. U., Baloch, S. K ., Baloch, A. B., Baloch, H. N., Bashir, W. , Kashani, S. , Saeed, Z., Baloch, M., Akram, W., Badini, S. A., Ahmed, M.& Ruk, A. S.(2015). Effect of zinc and boron in combination with NPK on sunflower (*Helianthus annuus* L.) growth and yield. *Journal of Biology, Agriculture and Healthcare,* 5(19), 101-107.

Banerjee, H., Dutta, S. K. , Pramanik, S. J. , Ray, K. , Phonglosa , A.& Bhattacharyya, K.(2014). Productivity and profitability of spring planted sunflower hybrid with nitrogen, phosphorus and potassium fertilizer. *Annals of Plant and Soil Research,*16(3), 250-256.

Elayaraja, D., Anandan, P.& Kamalakannan, P.(2019). Influence of secondary and micronutrients along with organics on the nutrients availability and yield of sunflower (*Helianthus annuus* L.) in coastal saline. *Plant Archives,*19(2), 2708-2712.

Gitte, A. N., Patil, S. R. & Tike, M. A.(2005). Influence of zinc and boron on biochemical and yield characteristics of sunflower. *Indian Journal of Plant Physiology,* 10, 400-403.

Gomez, K. A. & Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, 2ndedn. A Willey Inter-science Publication (John Willey and Sons), New York, USA

Kannan, S.(2010). Foliar fertilization for sustainable crop production. In *Genetic engineering, biofertilisation, soil quality and organic farming* (pp. 371-402). Springer, Dordrecht.

Krudnak, A., Wonprasaid, S.& Machikowa, T.(2013). Boron affects pollen viability and seed set in sunflowers. *AfricanJournal of Agricultural Research,* 8(2), 162–166.

Patil, S. B., Vyakaranahal, B. S., Deshpande, V. K.& Shekhargouda, M.(2006). Effect of boron and zinc application on seed yield and quality of sunflower restorer line, RHA-857. *Karnataka Journal of Agricultural sciences,* 19, 708-710.

Patra, P., Pati, B. K., Ghosh, G. K. , Mura, S. S.& Saha, A.(2013). Effect of biofertilizers and sulphur on growth, yield, and oil content of hybrid sunflower (*Helianthus annuus* L.) in a typical lateritic soil. *Open Access Scientific Reports,* 2, 603.

Ramulu, N., Murthy, K., Jayadeva, H. M., Venkatesha, M . M. & Ravi Kumar , H. S. (2011). Seed yield and nutrients uptake of sunflower (*Helianthus annuus* L.) as influenced by different levels of nutrients under irrigated condition of eastern dry zone of Karnataka, India. *Plant Archives,* 11(2), 1061-1066.

Ravikumar, C., Karthikeyan, A., Senthilvalavan, P.& Manivannan, R.(2021). Effect of sulphur, zinc and boron on the growth and yield enhancement of sunflower (*Helianthus annuus* L.). *Journal of Applied and Natural Science,* 13(1), 295-300.

Rego, T. J., Sahrawat, K. L., Wani, S. P.& Pardhasarthi, G.(2007). Widespread deficienceies of sulfur, boron, and zinc in Indian semi-arid tropical soils: on-farm crop responses. *Journal of Plant Nutrition,* 30, 1569-1583.

Rex Immanuel, R. D., Saravanan, D. R. G. S., Thiruppathi, M.& Saravanaperumal, M.(2019). Zinc and boron micronutrient fertilization on the growth and physiological attributes of sunflower in rice-sunflower cropping sequence. *Plant Archives,* 19(2), 3015-3020.

Rex Immanuel, R., Saravanan, D. R. G. S.& Thiruppathi, M.(2020). Zinc and boron micronutrients on yield and economics of sunflower grown on coastal regions of northern Tamil Nadu, India. *Plant Archives,* 20 (2), 2070-2075.

Shekhawat, K.& Shivay, Y. S. (2008). Effect of nitrogen source, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (*Helianthus annuus* L.). *Indian Journal of Agronomy,* 53, 129-134.

Sheoran, P., Sardana, V., Singh,S., Kumar, A., Mann, A.& Sharma, P. (2016). Agronomic and physiological assessment of nitrogen use, uptake and acquisition in sunflower. *International Journal of Plant Production,* 10, 109-122.

Sheoran, P., Sardana, V., Chander, S., Kumar, A., Meena, M. D. M., Bali, A.& Sharma, P.(2018). Sulphur, boron and zinc nutrition to improve productivity, profitability and oil quality in sunflower (*Helianthus annuus*). *Indian Journal of Agricultural Sciences,* 88(11), 1746–54.

Shukla, A. K., Behera, S. K., Pakhre, A.& Chaudhari, S. K. (2018). Micronutrients in soils, plants, animals and humans. *Indian Journal of Fertilisers,* 14(3), 30-54.

Suryavanshi, V. P., Sudhakara, B. S. N. & Suryawanshi, S. B.(2015). Seed yield, economics, sustainability and soil fertility as influenced by long-term nutrient management in soybean (*Glycine max*)–sunflower (*Helianthus annuus*) cropping system in Vertisols. *Indian Journal of Agronomy,* 60, 212-216.

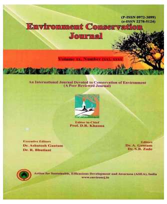
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 268-273, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Antimycotic activity of green tea phytocompounds against *Candida glabrata*

Priyanka Sirari
Department of Biotechnology, Graphic Era Deemed to be University, Dehradun, Uttarakhand, India

Jigisha Anand
Department of Biotechnology, Graphic Era Deemed to be University, Dehradun, Uttarakhand, India

Manjusha Tyagi
Department of Microbiology, SGRR University, Dehradun, Uttarakhand, India

Rakesh Kumar Bachheti
Department of Industrial Chemistry, College of Applied Science, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia

Ashish Thapliyal
Department of Microbiology, Graphic Era Deemed to be University, Dehradun, Uttarakhand, India

Nishant Rai ✉
Department of Biotechnology, Graphic Era Deemed to be University, Dehradun, Uttarakhand, India

ARTICLE INFO

Received : 06 February 2023
Revised : 05 May 2023
Accepted : 18 May 2023

Available online: 18 August 2023

Key Words:
Antimycotic Activity
Candida glabrata
Green tea
Phytocompounds
viability

ABSTRACT

One of the medically important opportunistic fungal pathogen for humans is *Candida glabrata* that causes various types of candidiasis. Its environmental adaptations and antimicrobial resistance is now a great concern for public health. In the present study, the green tea phytocompounds; EGCg, Chlorogenic acid, Coumaroyl quinic acid and Rutin trihydrate along with a known antimycotic Fluconazole were studied for their antimycotic activity against *Candida glabrata.* The MIC$_{90}$ for *C. glabrata* was observed at 125µg/ml for EGC g, 250 µg/mlf or Chlorogenic acid, 500µg/ml for Coumaroyl quinic acid and Rutin trihydrate while 12.5µg/ml for Fluconazole in macro dilution assay while the MFC values were 1000 µg/ml for EGC g, 500 µg/ml for Chlorogenic acid, Coumaroyl quinic acid, Rutin trihydrate and 50 µg/ml for Fluconazole. In microdilution assay, the MIC$_{90}$ for *C. glabrata* was observed 125µg/ml for EGC g and chlorogenic acid, 500µg/ml for Coumaroyl quinic acid, Rutin trihydrate and 12.5µg/ml for Fluconazole while the MFC values were 31.25 µg/ml for Fluconazole, 250 µg/ml for chlorogenic acid and 500 µg/ml for EGC g, Coumaroyl quinic acid and Rutin trihydrate. EGCg and Chlorogenic acid was found to be more effective against *C. glabrata* and therefore these two were used for synergistic study along with Fluconazole. The viability of HeLa cells (in per cent) was observed ≥100% green tea phyto compounds. The viability of treated cells (in per cent) with a combination of Green tea, phytocompounds and fluconazole was observed between ≥98± 0.79 to ≥ 98± 0.87. Green tea phytocompounds mainly EGC g and chlorogenic acid can be used as synergistic molecules having antimycotic activity against *C. glabrata*.

Introduction

Candida albicans causes a high mortality rate of 10%-49% while Non-albicans Candida species including *C. glabrata, C. tropicalis*, *C. krusie* and *C. auris*is increasing in India. *C. albicans* is responsible for over 90% of infections, followed by *C. glabrata*, *C. tropicalis*, *C. parapsilosis* and *C. krusei* (Pfaller *et al*., 2007). According to reports, India has one of the highest incidences of blood stream Candida infections worldwide (Gaffi - Global Action For Fungal Infections). About 35 to 40% of *C. tropicalis* species have been reported from clinical specimens like blood, urine, sputum, pus, lung aspirate, catheter tips, nail, throat swab, tested in patients in north India (Singh *et al*., 2011;

Corresponding author E-mail: *nishantrai1@gmail.com*
Doi:https://doi.org/10.36953/ECJ.26042341

Patel *et al.*, 2012; Yapar, 2014). *Candida glabrata* (also now known as *Nakaseomyces glabrata*) has emerged as a very common bloodstream pathogen and recently it is reported as a widely prevalent pathogen in Asia (Gómez *et al.*, 2023, Sarah *et al.*, 2023). *C. glabrata* produces systemic fungal infection and its emergence has caused alarm because of its drug resistance and variations/mutations occurring in its genome. *C. glabrata is* continuously emerging as more serious pathogen for humans because of high-stress resistance and high adhesion characteristics. It has progressed a vigorous tolerance to cationic, oxidative, osmotic and nitrosative stresses. It has a large collection of adhesins, which enable its ability to colonize humans (Chew *et al.*, 2019; Kumar *et al.*, 2019; Pais *et al.*, 2019., Lionakis *et al.*, 2023). In addition, it has very high adaptability and can be found on catheters and inanimate hospital equipment. Particularly in ICU-recommended patients, such as elderly patients with underlying illnesses, candidemia has a significant fatality risk. (Ayhanım, 2020) and also detected in Hospitalized Patients with COVID-19 (Cattaneo *et al.*, 2023). As a result, natural chemotherapeutic agents, such as plant extracts, represent a potential source for the creation of strong antifungal drugs and disease management strategies. To lessen side effects and toxicity, combining recognised beneficial medications with phytoconstituents is a great idea (Aboody and Mickymaray, 2020).

The present study has evaluated the anticandidal activity of green tea phytocomponds viz. EGCg, Chlorogenic acid, Coumaroylquinic acid and Rutin trihydrate along with a known antimycotic Fluconazole against *Candida glabrata.*

Material and Methods

Green tea phytocompounds

A purified form of (−)Epigallocatechin gallate (EGCg), Chlorogenic Acid, Coumaroylquinic Acid, Rutin trihydrate were procured from Sigma Aldrich and SRL.

Yeast strains

Candida glabrata (MTCC 3019) was procured from MTCC, IMTech, Chandigarh and employed for assessing the potential of Green Tea for anticandidal activity. It was grown and preserved in Yeast Peptone Dextrose (YPD) agar and broth.

Broth Macrodilution Assay

Two-fold dilution of EGCG, chlorogenic acid, Coumaroylquinic acid, and rutin trihydrate was prepared from 1000 µg/ml to 31.25 µg/ml and Fluconazole from 100 µg/ml to 3.125 µg/ml in YPD broth.*C. glabrata* culture was cultured in YPD broth at 37^0C for 18 h.Each diluted samples were inoculated with $1x10^3$ CFU of *C. glabrata*. The controls taken were YPD broth only, YPD broth with *C. glabrata*, 10% DMSO as a negative control. These were incubated at 37^0C for 18h after which two-fold dilutions of each sample were made and poured on YPD agar plates, incubated at 37^0C, colonies were counted and CFU/ml was calculated. Minimum inhibitory concentration (MIC) was calculated as the concentration which inhibited 90% growth of *C. glabrata*. Minimal fungicidal activity (MFC) was calculated as the lowest concentration which resulted in 99.9% death of cultures. For this 100µl of the test sample with culture was poured on YPD agar plates, incubated at 37^0C and CFU/ml was calculated (Kaya and Ozbilge, 2012).

Broth microdilution assay

The MIC of EGCg, Chlorogenic acid, Coumaroylquinic acid, Rutin trihydrate and Fluconazole were assessed following the micro dilution method (CLSI, 2002). The *C. glabrata* culture was pre-incubated in broth at 37°C for 18hr at 150rpm. Two-fold dilutions of EGCg, Chlorogenic acid, Coumaroylquinic acid, Rutin trihydrate was prepared as described above and 100µl of each sample was added into wells microtitre plate (Axygen, USA) followed by inoculation with 5µl of *C. glabrata* ($1x10^3$CFU) with gentle plate shaking.The 10% DMSO was taken as negative control and YPD broth in wells as blank. The microtitre plate was incubated at 37°C for 18hr and MIC was calculated by recording the absorbance at 600nm (Radji *et al.*, 2013).

Assay of synergistic activity

The inhibitory effects of each GT phytocompounds with fluconazole combinations were evaluatedusing micro dilution checker board technique (CLSI, 2002). Fluconazole and GT phytocompounds were produced and employed in several combinations at 2-fold serial dilutions that were equivalent to, below, and above their MICs for *C. glabrata*.

The effective MIC was considered for the combination that completely inhibited the growth of *C. glabrata* (Jin *et al*., 2010). The growth was quantified using spectrophotometer and then analysed for fractional inhibitory concentration index (FICI). The drugs combination that inhibited the growth completely was considered as an effective MIC for the combination. Fractional inhibitory concentration index (FICI) was evaluated using standard formula; FICI = FIC A + FIC B, where, FIC A = MIC of the combination A and B /MIC of drug A alone; FIC B = MIC of the combination A and B / MIC of drug B alone. The effects of the combinations were classified as synergistic if the FIC index was equal to 1, indifferent if it was between 1 and 4, and antagonistic if it was greater than 4.

In vitro cytotoxicity

The HeLa cell line procured from NCCS, Pune was cultured in 25cm^2 culture flasks having DMEM media with 10% FBS, Gentamycin (5µg/ml) in an incubator with 5% CO_2tension at 37˚C until confluent and was used in cytotoxicity study by MTT assay.The HeLa monolayer was trypsinized with TVS before cells were planted into each well of the microtitre plate at a density of 1x 10^5 cells/ml. Two-fold dilutions of GT phytocompounds and fluconazole as described above were prepared in DMEM. 100µl of various test concentrations were added into the partial monolayer in 96-well plates and incubated at 37^{0}C (5% CO_2) for 24 hr. The cells are examined under microscope at 0 and 24hrs. Wells with no media added are used as controls, along with untreated cells. As a positive control, H_2O_2 was employed, and as a negative control, 10% DMSO. After 24 hr, the solutionswere discarded. 20µl of MTT (5mg/ml) was incorporated to wells and kept for 4hr at 37^{o}C in a 5% CO_2 atmosphere. 100µl of 0.04N HCl was added to solubilise the formazan. The absorbance was recorded at 540 nm**.** The percentage viability was calculated as: Percentage viability (%) = [(At-Ab) / (Ac-Ab)] X 100; where, At is Absorbance of treated wells, Ab is Absorbance of blank, Ac is Absorbance of control wells.Lethal Concentration 50 percent was defined as the lowest concentration of the GT phytocompounds that caused a 50% reduction of cell development (LC50) (Fadeyi *et al*., 2013).

Results and Discussion

Antimycotic effect of green tea using broth macrodilution assay

The MIC$_{90}$ for *C. glabrata* was observed at 125µg/ml for EGCg, 250 µg/mlfor Chlorogenic acid, 500µg/ml for Coumaroylquinic acid and Rutin trihydrate while 12.5µg/ml for Fluconazole (Table 1). The MFC values were 1000 µg/ml for EGCg, 500 µg/ml for Chlorogenic acid, Coumaroylquinic acid, Rutin trihydrate and 50 µg/ml for Fluconazole.

Table 1: MIC$_{90}$ and MFC of GT Phytocompounds against *C. glabrata* using broth macrodilution

GT Phytocompounds	MIC$_{90}$ (µg/ml)	MFC (µg/ml)
EGCg	125	1000
Chlorogenic acid	250	500
Coumaroylquinic acid	500	500
Rutin trihydrate	500	500
Fluconazole	12.5	50

Antimycotic effect of green tea using broth microdilution assay

The MIC$_{90}$ for *C. glabrata* was observed 125µg/ml for EGCg and chlorogenic acid, 500µg/ml for Coumaroylquinic acid, Rutin trihydrate and 12.5µg/ml for Fluconazole. The MFC values were 31.25 µg/ml for Fluconazole, 250 µg/ml for chlorogenic acid and 500 µg/ml for EGCg, Coumaroylquinic acid and Rutin trihydrate (Table 2).

Table 2: MIC$_{90}$ and MFC ofGT phytocompounds against *C. glabrata*using broth microdilution assay

GT Phytocompounds	MIC$_{90}$ (µg/ml)	MFC (µg/ml)
EGCg	125	500
Chlorogenic acid	125	250
Coumaroylquinic acid	500	500
Rutin trihydrate	500	500
Fluconazole	12.5	31.25

Synergistic activity by Checkerboard susceptibility assay

In macrodilution and microdilution assays, it was found that EGCg and Chlorogenic acid gave better results and found more effective and therefore these two were used for synergistic study along with Fluconazole. The results obtained are shown in

Table 3. On HeLa cell lines, the cytotoxicity experiment for various mixtures of GT phytocompounds and fluconazole was carried out. When HeLa cells were exposed to GT Phytocompounds alone at concentrations ranging from 15.625 g/ml to 500 g/ml, they displayed growth viability in a dose-dependent manner. HeLa cells' vitality was observed to be 100 percent.
(table 4). At 0 hours and 24 hours of incubation, the cells were seen to be stable and in good condition. When cells were treated with a mixture of GT phytocompounds and antimycotics, the % viability was assessed, and results ranged from 98 to 98.87.
(Table 4). Additionally, the cytotoxicity of pure catechins on HeLa cells was assessed; the results revealed an increase in cell viability after 24 hours of incubation (Fig.1 to 4).The percentage vitality of HeLa cells treated with GT Phytocompounds and fuconazole was evaluated at 0 hours and 24 hours following treatment.HeLa cell viability was measured as a percentage and ranged from 98.7 to 99.8.

Table 3: Synergistic activity of green tea phytocompounds and fluconazole by checkerboard antimycotic susceptibility assay for *C. glabrata*

GT Phytocompounds (µg/ml)	MIC_{90}	FICI
EGCg +Chlorogenic acid (62.5 each)	62.5	1.5(I)
EGCg + Fluconazole (15.625/12.5)	15.625	0.5 (S)
Chlorogenic acid + Fluconazole (15.625/12.5)	15.625	0.5 (S)

Table 4: Assay of the viability of HeLa cells treated with the combination of GT Phytocompounds with antimycotics after 24 hr of incubation

GT phytocompounds (µg/ml)	% Viability
EGCg +Chlorogenic acid (62.5/62.5)	≥98±0.79
EGCg + Fluconazole (15.625/12.5)	≥98±0.87
Chlorogenic acid + Fluconazole	≥99.8±0.19
Healthy HeLa cells	≥ 100

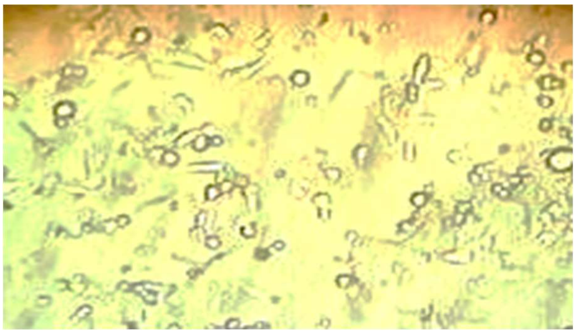


Figure 1: Untreated healthy HeLa cells at 24 hr

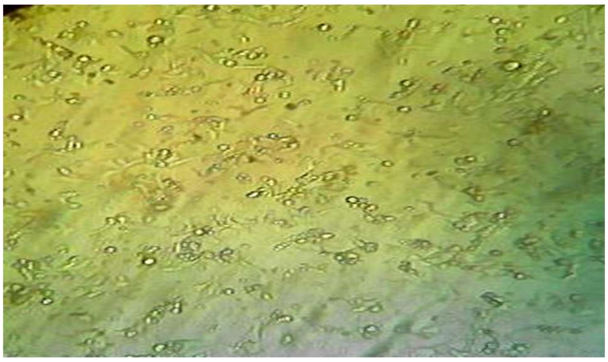


Figure 2: HeLa cells treated with EGCg and Chlorogenic acid at 24hr

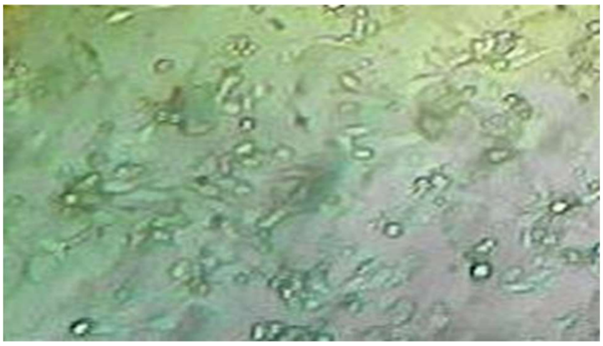


Figure 3: HeLa cells treated with EGCg and Fuconazole at 24 hr

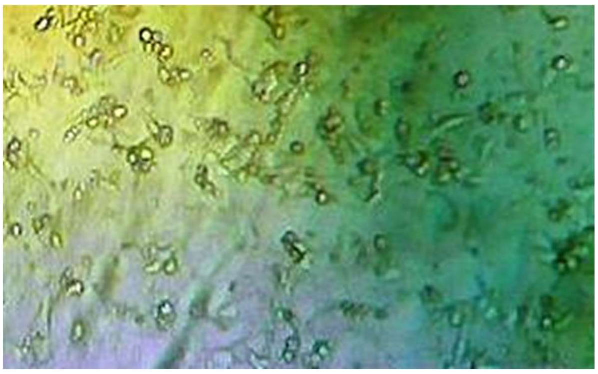


Figure 4: HeLa cells treated with Chlorogenic and Fluconazole at 24 hr

The green tea is known for its active phytocompounds with multiple benefits including antimicrobial properties (Anand, 2012, Sirari *et al.*, 2021). In the present investigation effective anticandidal synergistic activity of green tea compounds in combinations is evaluated (Hirasawa et al., 2004, Behbehani *et al.*, 2019, Kane *et al.*, 2022). In macrodilution assay, the MIC_{90} for *C. glabrata* was observed at 125µg/ml for EGCg, 250 µg/mlfor Chlorogenic acid, 500µg/ml for Coumaroylquinic acid and Rutin trihydrate while 12.5µg/ml for Fluconazole. The MFC values were 1000 µg/ml for EGCg, 500 µg/ml for Chlorogenic acid, Coumaroylquinic acid, Rutin trihydrate and 50 µg/ml for Fluconazole. Using microdilution,the MIC_{90} for *C. glabrata* was observed 125µg/ml for EGCg and chlorogenic acid, 500µg/ml for Coumaroylquinic acid, Rutin trihydrate and 12.5µg/ml for Fluconazole. The MFC values were 31.25µg/ml for Fluconazole, 250 µg/ml for chlorogenic acid and 500 µg/ml for EGCg, Coumaroylquinic acid and Rutin trihydrate. In macrodilution and microdilution assays, it was found that EGCg and Chlorogenic acid gave encouraging results and therefore these two were used for synergistic study along with Fluconazole. The interaction between an antibiotic and GT depends on a number of variables, including the type of bacteria involved (Haghjoo *et al*., 2013). In the present study, percentage viability of HeLa cells was observed between ≥98± 0.79 to ≥ 99.8± 0.19 alone at concentrations ranging from 31.25µg/ml to 500µg/ml. The percentage viability of HeLa cells was reported to be >100%.

HeLa cells were used to test the cytotoxicity of GT phytocompounds; the results revealed an increase in cell viability after 24 hours of treatment. The synergistic inhibition of a combination of fluconazole and cylcosporine was studied against *Candida albicans* based on checkerboard assay and no significant change in MIC of fluconazole was seen (Marchetti *et al*., 2000). However, in the present study the MIC of fluconazole decreased to half when combined with GT Phytocompounds. However, it is clear from the current results that EGCg induced higher percentage inhibition of *Candida glabrata* (99.8 0.19) when fluconazole was present. The present findings support that effective synergistic GT based combinations are potential candidate against many human pathogens (Anand and Rai, 2017, Mengjiao et al., 2017, Haji et al., 2022, Kováč et al., 2023).

Conclusion

The green tea phytocomponds EGCg, Chlorogenic acid, Coumaroylquinic acid and Rutin trihydrate along with a known antimycotic Fluconazole were studied for their antimycotic activity against *C.glabrata.* It was found that these showed antimycotic activity against *C. glabrata*. EGCg and chlorogenic acid showed enhanced activity against *C. glabrata*. Their combination with fluconazole also showed enhanced activity. Therefore, it is evident that green tea phytocompounds mainly EGCg and chlorogenic acid can be used as synergistic molecules having antimycotic activity against *C. glabrata*.

Acknowledgement

We are thankful to the Department of Biotechnology, Graphic Era Deemed to be University and TGTRI, Dehradun for providing technical support for this study.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Aboody, M. S. A., & Mickymaray, S. (2020). Anti-Fungal Efficacy and Mechanisms of Flavonoids. *Antibiotics (Basel, Switzerland)*, *9*(2), 45.

Anand J, Rai N, Kumar N, Gautam P. (2012). Green tea: a magical herb with miraculous outcomes. Int. Res. J. Pharm. *3*(5): 139-148.

Anand, J., & Rai, N. (2017). Anticandidal synergistic activity of green tea catechins, antimycotics and copper sulphate as a mean of combinational drug therapy against candidiasis. *Journal de mycologie medicale*, *27*(1), 33–45.

Behbehani, J. M., Irshad, M., Shreaz, S., & Karched, M. (2019). Synergistic effects of tea polyphenol epigallocatechin 3-O-gallate and azole drugs against oral Candida isolates. *Journal de mycologie medicale*, *29*(2), 158–167.

Cattaneo, L., Buonomo, A. R., Iacovazzo, C., Giaccone, A., Scotto, R., Viceconte, G., Mercinelli, S., Vargas, M., Roscetto, E., Cacciatore, F., Salvatore, P., Catania, M. R., Villari, R., Cittadini, A., Gentile, I., & Covid Federico Ii Team (2023). Invasive Fungal Infections in Hospitalized Patients with COVID-19: A Non-Intensive Care Single-Centre Experience during the First Pandemic Waves. *Journal of fungi (Basel, Switzerland)*, *9*(1), 86.

Chew, S. Y., Ho, K. L., Cheah, Y. K., Sandai, D., Brown, A. J. P., & Than, L. T. L. (2019). Physiologically Relevant Alternative Carbon Sources Modulate Biofilm Formation, Cell Wall Architecture, and the Stress and Antifungal

Resistance of *Candida glabrata*. *International journal of molecular sciences*, *20*(13), 3172.

CLSI. (2002). M27-A2, Reference method for broth dilution antifungal susceptibility testing of yeasts; approved standard-2nd Ed., vol.22, no.15.

Fadeyi, S. A., Fadeyi, O. O., Adejumo, A. A., Okoro, C., & Myles, E. L. (2013). In vitro anticancer screening of 24 locally used Nigerian medicinal plants. *BMC complementary and alternative medicine*, *13*, 79.

Gómez-Gaviria, M., Ramírez-Sotelo, U., & Mora-Montes, H. M. (2022). Non-*albicans Candida* Species: Immune Response, Evasion Mechanisms, and New Plant-Derived Alternative Therapies. *Journal of fungi (Basel, Switzerland)*, *9*(1), 11. https://doi.org/10.3390/jof9010011

Haghjoo, B., Lee, L.H., Habiba, U., Tahir, H., Olabi, M.M., & Chu, T. (2013). The synergistic effects of green tea polyphenols and antibiotics against potential pathogens. *Advances in Bioscience and Biotechnology, 4*, 959-967.

Haji, M.H., Mohamed, A.B., Albashir, A.A., & Mirghani, M.E. (2022). A Review of Antifungal Activity of Combined Plant Extracts or Plant Exudates from Medicinal Plants either together or with Known Antifungal Agents. *European Journal of Medicinal Plants*.

Hirasawa, M., & Takada, K. (2004). Multiple effects of green tea catechin on the antifungal activity of antimycotics against Candida albicans. *The Journal of antimicrobial chemotherapy*, *53*(2), 225–229.

Jin, J., Guo, N., Zhang, J., Ding, Y., Tang, X., Liang, J., Li, L., Deng, X., & Yu, L. (2010). The synergy of honokiol and fluconazole against clinical isolates of azole-resistant Candida albicans. *Letters in applied microbiology*, *51*(3), 351–357.https://doi.org/10.1111/j.1472-765X.2010.02900.x

Kane, A., & Carter, D. A. (2022). Augmenting Azoles with Drug Synergy to Expand the Antifungal Toolbox. *Pharmaceuticals (Basel, Switzerland)*, *15*(4), 482.

Kaya, E.G., & Ozbilge, H. (2012). Determination of the effect of fluconazole against Candida albicans and Candida glabrata by using microbroth kinetic assay*. *Turkish Journal of Medical Sciences*.

Kováč, J., Slobodníková, L., Trajčíková, E., Rendeková, K., Mučaji, P., Sychrová, A., & Bittner Fialová, S. (2022). Therapeutic Potential of Flavonoids and Tannins in Management of Oral Infectious Diseases-A Review. *Molecules (Basel, Switzerland)*, *28*(1), 158.

Kumar, K., Askari, F., Sahu, M. S., & Kaur, R. (2019). *Candida glabrata*: A Lot More Than Meets the Eye. *Microorganisms*, *7*(2), 39.

Lionakis, M. S., Drummond, R. A., & Hohl, T. M. (2023). Immune responses to human fungal pathogens and therapeutic prospects. *Nature reviews. Immunology*, *23*(7), 433–452. https://doi.org/10.1038/s41577-022-00826-w

Lu, M., Li, T., Wan, J., Li, X., Yuan, L., & Sun, S. (2017). Antifungal effects of phytocompounds on Candida species alone and in combination with fluconazole. *International journal of antimicrobial agents, 49 2*, 125-136.

Marchetti, O., Moreillon, P., Glauser, M.P., Billé, J., & Sanglard, D. (2000). Potent Synergism of the Combination of Fluconazole and Cyclosporine in Candida albicans. *Antimicrobial Agents and Chemotherapy, 44*, 2373 - 2381.

Pais, P., Galocha, M., Viana, R., Cavalheiro, M., Pereira, D., & Teixeira, M.C. (2019). Microevolution of the pathogenic yeasts Candida albicans and Candida glabrata during antifungal therapy and host infection. *Microbial Cell, 6*, 142 - 159.

Patel, LR., JD, Pethani., P, Bhatia., SD, Rathod., P.D, Shah. (2012). Prevalence of Candida infection and its antifungal susceptibility pattern in tertiary care hospital, Ahmedabad. *Nat J Med Res*. *2*: 439-441.

Pfaller, M. A., Diekema, D. J., Procop, G. W., & Rinaldi, M. G. (2007). Multicenter comparison of the VITEK 2 antifungal susceptibility test with the CLSI broth microdilution reference method for testing amphotericin B, flucytosine, and voriconazole against Candida spp. *Journal of clinical microbiology*, *45*(11), 3522–3528.

Radji, M., Agustama, R. A., Elya, B., & Tjampakasari, C. R. (2013). Antimicrobial activity of green tea extract against isolates of methicillin-resistant Staphylococcus aureus and multi-drug resistant Pseudomonas aeruginosa. *Asian Pacific journal of tropical biomedicine*, *3*(8), 663–666. https://doi.org/10.1016/S2221-1691(13)60133-1

Singh, RI., I, Xess., P, Mathur., B, Behera., B, Gupta., M C, Misra. (2011). Epidemiology of candidaemia in critically ill trauma patients: experiences of a level I trauma centre in North India. *J Med Microbiol*. *60*: 342-348.

Sirari, P., Anand, J., Devvret, Thapliyal, A & Rai, N. (2021). Green tea phytocompounds targets Lansterol 14-α demethylase against ergosterol biosynthesis in Candida glabrata. International Journal of Research in Pharmaceutical Sciences, 12(3), 1793–1797. Retrieved from https://ijrps.com/home/article/view/304

Yapar, N. (2014). Epidemiology and risk factors for invasive candidiasis. *Therapeutics and clinical risk management*, *10*, 95–105.

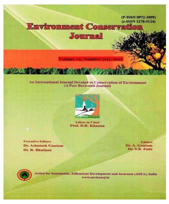
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3): 274-282, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Azo dye degrading bacteria and their mechanism: A review

Manasi Upadhyay
Department of Microbiology, Bijoy Krishna Girls' College, Howrah, India
Ahana Mondal
Department of Microbiology, Bijoy Krishna Girls' College, Howrah, India
Biswajit Saha ✉
Department of Microbiology, Bijoy Krishna Girls' College, Howrah, India

ARTICLE INFO

Received : 28 October 2022
Revised : 27 February 2023
Accepted : 20 March 2023

Available online: 28 June 2023

Key Words:
Synthetic dyes
Idols
Azo dye
Toxicity
Laccase, GMO

ABSTRACT

Major part of the aesthetics and beauty of idols, textiles, paper, paintings industries, etc. finds its roots in the use of colours (azo compound). These synthetic dyes can not degrade easily by physical and chemical means and are toxic for the environment and animals including humans. Even if they get degraded, it becomes difficult to get rid of the secondary toxic products. Microbes especially bacteria can be used which results cheap, eco friendly and complete degradation of azo dye products without production of any secondary toxic products (or secondary products with way lesser toxicity). Also, it requires no new chemical to be added (in an attempt to degrade azo dye) in an already polluted environment, as the bacterial enzymes would do the job without requiring any other added chemicals. This review article discusses the use of bacteria for azo dye degradation, the bacterial enzymes such as laccase etc. that degrade azo dye and how they work to decolourise the dyes, the common genetic elements found in the different bacteria that can degrade azo dye. This article also includes information on future prospects and some *genetically modified organism* (GMO) that are being/ (can be) brought to use for dye degradation and pollution reduction.

Introduction

The use of dye for the aesthetic enhancement of objects is an ancient practice. With the discovery of new pigments and dyes the dyeing technology has been evolved. Nowadays uses of azo dye are ever present & they are widely used in the textile, paper and food, painting industries. Releasing this untreated waste into the environment without prior treatment can pose significant environmental risks as azo dyes and their metabolites are *toxic*, *carcinogenic*, *mutagenic* and *highly recalcitrant*.
The synthetic design of these dyes is described by the presence of azo bonds (-N = N-), associated with naphthalene or benzene rings . These aromatic rings can have different substituents, for example, sulfonic corrosive (SO_3H), chloro (- Cl), hydroxyl (- Gracious), methyl (- CH_3), carboxyl (- COOH) , nitro (- NO_2) and amino (NH_2) groups. These substituents make azo dyes *water-soluble* and degradation resistant under environmental conditions and they cause serious harm to the marine environment. This is not only a threat to the marine animals but consumption of such water may cause *cancer* in humans.So, this is important to treat the dye containing effluent before discharging them in to water bodies (Ruhela *et al.,* 2021; Bhutiani *et al.,* 2021; Bhutiani *et al.,* 2022). The chemical, physical methods to treat this effluent but they are expensive and produces amine residue containing sludge. So, utilization of microorganisms for remediation design is consequently a potential answer for ecological contamination since it incorporates reasonable remediation innovations. Under certain conditions several microorganisms helps to decolorize and mineralize the azo dye. Bacteria have become the main tool for the degradation of the azo-dye containing waste water as they produce various intracellular redox enzymes, can easily be cultured and reproduce at a rapid rate (Garg, 2012). Also they can survive in high salt concentration and high

Corresponding author E-mail: *biswajit.saha1402@gmail.com*
Doi:https://doi.org/10.36953/ECJ.15672490

temperature environment and they have high degradation and decolorization ratios.Studies have shown that most azo-dye degrading bacteria are commonly *mesophilic* (20-40 ^{0} C) (Sudha *et al.,* 2018) in nature. Although most azo-dye waste water produces in the dyeing bath and rinsing process with discharge temperatures reaching as high as 50 – 70^{0}C (Boonyakamol, 2009). So, this type of waste water can be treat effectively using thermophilic bacteria. Thermophilic bacteria are also have some advantages including fast metabolic ratios, high processing efficiencies and the capacity to effectively kill pathogens when azo dye were degraded at high temperatures and enzymes secreted by the thermophilic bacteria are stable and resistance to chemical degradation. In recent days, from the azo-dye containing waste water researchers isolate and screen some azodye degrading bacteria *Bacillus sp., Micrococcus sp., Lysinibacillus sphaericus sp., Aeromonas hydrophila sp. Anoxybacillus sp.*

What are azo dyes?

Before we discuss this specific category of dye, the azo dye, we should know what is a dye. Dyes are synthetic, aromatic compounds used as colouring agents. They're used to colour various substances, giving them a new look, a new colour. One other substance used for colouring are pigments. Dyes are different from pigments in the way that pigments are mostly insoluble in substrate and their application is mostly in dispersed powder or crystal form.Dyes, on the other hand, get dissolved in the substrate at the molecular level. They're better colouring agents and find use in all the various industries— the textile industry, leather industry, cosmetic industry, paper industry, idol making industry etc.Dyes, in turn, are of many types of which, the azo dyes form the most widely used category. Their omnipresence can be credited to their characteristic strong colouration. They are synthetically made – organic chemical compounds with high stability and chemical versatility. The azo dyes consist of one or more (–N=N–) bonds which are referred to as azo. They also feature amino, chloro, nitro, hydroxyl and methyl substituent groups (Bell *et al.,* 2000).Though these dyes are used in almost all industries that deal with colouring, they cause a major environmental concern. The azo dyes that get dispersed into the nature, mostly into water bodies, as a part of industrial effluents or via idol dispersing etc. don't get degraded easily. They do break down via mineralization and form aryl-amine which are highly suspected carcinogens. As we already discussed, azo dyes are mostly water soluble and thus they can be absorbed directly via skin and inhalation, causing risks of cancer and allergic reactions. Toxic compounds of azo dyes can get absorbed into the aquatic organisms in form of water-dye mixture(He *et al.,* 2004; Asad *et al.,* 2007). When humans consume this water or the aquatic organisms from a dye polluted water body, the toxic substances reach man and cause various diseases like, *renal damage, acute tubular necrosis, sporadic fever, splenic sarcomas, hepatocarcinoma, oedema of the larynx, urinary bladder cance*r etc. Nuclear anomalies and chromosomal aberration in laboratory animals and mammalian cells dye to azo dyes has also been observed (Bayoumi *et al.,* 2010; Puvaneswari *et al.,* 2006; Mani and Bhargava 2016 a,b; Houk *et al.,* 1991; Haley, 1975). Dye effluents may also contain suspended solids particulate or heavy metal B which again are environmental and life hazard. Dyes are also known to absorb sunlight due to the presence of chromophoric group. This absorption of sunlight by the dye present in water hampers and has a detrimental effect on the photosynthetic process of water flora, like the phytoplankton, algae and water plants (Kagalkar *et al.,* 2010).

Such a group of compounds, which are toxic and detrimental to both flora and fauna including humans, should be gotten rid of. But it is not possible as we do need them for the aesthetic and colouring in various fields. Such is the condition that we can neither fully get rid of these dyes nor can we leave it as is. So, the best we can do is make sure that these dyes are degraded and don't persist in the environment in their own toxic form or even as toxic secondary products. The best way to achieve this is by biodegradation of the azo dyes rather than by chemical degradation. Use of chemical or physical means for the breakdown of the dyes comes forward as an expensive method and on top of that, considerable amount of chemical sludge waste is produced whose disposal, once again, is no less problematic. Thus biodegradation or microbial decolourisation and degradation forms a cost effective method of pollutant-dye removal from the environment. Of the microbes, many fungal, algal, and bacterial species have been found with the capability of degrading azo dyes. This study focuses on the use of bacteria and their enzymes for biodegradation and decolourisation of azo dyes.

Azo dye degradation by bacteria:

As we have already mentioned earlier, bacteria form a very good mean of biodegrading the azo dyes. Bacterial enzymes and bioadsorption by bacteria form the two major biodegrading pathway for dyes.These microorganisms can completely degrade the azo dyes. They have developed enzyme systems and produce enzymes like azo reductase, laccase, hydrogenase, peroxidase and exo-enzymes which reduce the azo dyes. The reduced forms are then converted to simpler compounds and/or used as energy source by the bacteria (Stolz, 2001).The complete degradation of azo dyes by bacteria mostly occur as a two step process and is carried out by bacterial enzymes acting on the dues. The reactions involved in these two steps are partially aerobic and partially anaerobic. Thus, a coupled aerobic-anaerobic process brings about the full degradation of azo dyes. The 1st step is the reductive cleavage of azo bonds (–N=N–) which leads to production of aromatic amines, the toxic carcinogens. In the 2nd step, these aromatic amines (aryl-amines) are degraded and thus, the environment is fully cleared of any toxic dye product.One other process by which bacteria clear the environment of azo dyes is by biosorption. Biosorption by bacteria depends on the composition of heteropolysaccharides and lipids in the bacterial cell wall. The attraction between the various charged groups of the cell wall and the azo dyes forms the basis of biosorption. Though biosorption is helpful to some extent, it is not a complete solution for the problem as the dye does not gets destroyed but is only embedded inside the biomass matrix. So, bacterial enzymatic processes for dye degradation are the most preferred method for removal of azo dye compounds from the environment. Some bacterial species that have been isolated and screened for their dye degrading ability are *Bacillus sp, Pseudomonas sp, Rhabdobacter sp, Enterococcus sp, Staphylococcus sp, Xenophilus sp, Cornebacterium sp, Clostridium sp., Micrococcus sp, Dermacoccus sp, Acinetobacter sp, Geobacillus sp, Lactobacillus sp, Rhizobium sp, Proteus sp, Morganella sp, Aeromonas sp, Alcaligenes sp, and Klebsiella sp.(*Stolz, 2001; Olukanni *et al.,* 2006; Vijaykumar *et al.,* 2007; Chen *et al.,* 2008; Lin and Leu, 2008*)*.

Enzymatic degradation of azo dyes:

Enzymes form a very effective bioremediation tool. Decolouration of dyes by bacteria depends fully on their capability to produce the various dye degrading enzymes. Azo reductases are known for their anaerobic dye degrading ability yet, some specific azo reductase enzymes have the potential to degrade azo dyes under aerobic conditions (Stolz, 2001; Naik and Singh , 2012). Laccases are known for dye degradation by free radical mechanism. Peroxidase enzymes in addition to laccases show an extra 25% decolourisation rate (Hadibarata *et al.,* 2012). These three enzymes, azo reductase, laccase and peroxidase form the most studied groups of dye degrading enzymes.

Azo reductase:

Azo reductases form the largest group of dye degrading enzymes. They specifically cleave the azo bonds producing aryl-amines. They use reducing agents like FADH, NADH and NADPH as an electron donor for the degradation reactions (Tian *et al.,* 2014; Jadhav *et al.,* 2008). These enzymes are mostly oxygen sensitive. As aerobic respiration also uses the same reducing agents as that of the azo reductase catalysed reaction, presence of oxygen impedes the azo bond degradation steps by competing for the reducing agents. So, Azo reductases are more related to anaerobic degradation of dye. Despite of this, there have been certain examples of aerobic azo reductases found in *Pseudomonas sp.*(Zimmermann *et al.,* 1982,1984).

Laccase:

Laccases are copper containing oxidases. One of their main advantage over other dye degrading enzymes is that they function through a free radical mechanism and form phenolic compounds rather than the toxic aromatic amines (Chivukula and Renganathan, 1995). The reduction mechanism of laccase entails the removal of a hydrogen ion (H^+)

from the amino and hydroxyl group of the substituted ortho and para position of phenolic compounds and aromatic amines.Laccases are non-specific enzymes and work on a wide variety of azo dyes. On top of that, laccases don't require cofactors for their activation. Redox mediators help expand the range of azo dyes that a laccase enzyme can degrade. Bacterial laccases also have properties like wide pH range of function and high thermal stability. All these qualities make them an enzyme of great industrial interest and they play important roles in textile industry, cosmetic industry, bioremediation and biodegradation etc. (Tian *et al.,*2014).

Peroxidases:
Peroxidases are exo enzymes mostly present in fungi but they do occur in some bacteria as well (Kandelbauer and Guebitz, 2005). They are hemoprotein and need hydrogen peroxide (H_2O_2) to catalyse reactions. Reduction mechanism of peroxidases is very similar to that of azo reductases. Only difference is in the electron donor used.Of the peroxidases, lignin peroxidase and manganese peroxidase are directly involved in biodegradation and decolouration of azo dyes (Paszczynski *et al.,* 1991; Pasti *et al.,* 1992).Some examples of dye degrading bacteria and enzymes is given in Table 1.

Table 1: Some examples of dye degrading bacteria and enzymes

Bacterial strains	Dye	Enzyme	References
Lysinibacillus fusiformis	Methyl red	Enzymatic-Laccase, Azoreductase and Lignin Peroxidase	Sariand Simarani, 2019
Pseudomonas extremorientalis	Congo red	Laccase	Neifar *et al.,* 2016
Bacillus subtilis	Acid blue 113		GuruLakshmi *et al.,* 2008
Comamonas sp.	Direct Red 5B	Enzymatic-Laccase and Lignin Peroxidase	Jadhav *et al.,* 2008
EnterococcusFaecalis YZ 66	Reactive Orange II		Sahasrabudhe and patthade, 2011
Proteus mirabilis	Reactive Blue 13	Enzymatic- Laccase, azoreductase and veratryl alcohol oxidase	Olukanni *et al.,*2010
Aeromonashydrophila, Lysinibacillussphaericus	Reactive Red 195	Enzymatic-Laccase and Azoreductase	Srinivasan and Sadasivam, 2018
Aeromonas sp.	Methyl orange	laccase, NADH-DCIP reductase, and azoreductase	Du *et al.,* 2015

Isolation and screening of azo-dye degrading bacteria:
A large number of azo dye degrading bacteria have already been isolated from soil and water from industrial area, and effluents from water bodies by researchers. Literatures present many examples of such various strains that can degrade and decolourize the azo dyes. For example, one process used for isolating and screening dye degrading bacteria was carried out by Khan and Joshi (2020) from Rajasthan, India. The authors isolated azo dye degrading bacterial strain from water and soil from textile industries in Jodhpur province. *Bacillus pumilis* and *Paenibacillus thiaminolyticus* were the two bacterial strains which were screened and identified by theirbiochemical characteristics. Serial dilution and streaking method was used to obtain several colonies which were, separately inoculated into nutrient broth media. A 10% (v/v) inoculum was transferred into 100 mL of mineral salt medium (MSM) and incubated at 37^0C at 125 rpm for 24-48 hrs. 10% (v/v) of the sample was sub-cultured into 10 mg/L MSM of the respective dyes and further incubated after 24 hrs. Strains which were able to utilize the fresh dyes as their source of nutrient were plated on Nutrient agar plate and incubated at 37^0C. After that pure bacterial cultures were transferred into the Nutrient broth subsequently (Khadijah *et al.,*2009).
Alternatively we can take some carbon free media like Bushnell Haas agar media and enrich it with respective dyes at different concentrations. After the inoculation, we need to check whether the growth has appeared or not. If growth appears, we can surely say that organism is capable of degrading the dyes. This is because Bushnell Haas media lacks carbon and here we are using the dye in the place of carbon, so if the bacteria are able to

utilize the dyes only then they will show growth. Many other processes have also been developed by other researchers that have been used to isolate and screen various other dye degrading bacterial species.

Laccase activity assay :

Laccase plays an important role in the bioremediation of several aromatic compounds. Especially they help in dye degradation and waste water detoxification. The basic reaction mechanism of laccase involves the formation of two water molecules upon the accompanying electron loss of a single oxygen molecule. This abstracting electron leads to the oxidation of several benzene ring-containing compounds (Solomon *et al.,* 1996; Chandra and Chowdhary 2015). With the cation generation catalytic activity of the laccase plays an important role in the degradation of aromatic compounds. As these cations are less stable, in the presence of laccase they converted to the stable product (quinine → phenol). Due to the presence of four copper atoms that forms the central part of this reaction, the redox mechanism takes place. The mechanism is given in Figure number 1. They are classified into three types – type 1 copper (T1Cu), type 2 copper (T2Cu) and type 3 copper (T3Cu). Near the T1- copper center (shallower than the oxygen binding center) substrate molecules are bound. One-electron abstraction occurs from the substrate to T1 copper by an outer-sphere process. That's why, substrate molecules are converted to free radicals which can undergo further oxidation or radical coupling reactions. This leads to the formation of polymers or oligomers. Via a cysteine–histidine pathway that is highly conserved among multi-copper oxidases the abstracted electron moves from the T1 center to the trinuclear cluster. This so-called super-exchange pathway is created by overlapping redox active molecular orbitals of the T1 coordinating cysteine, the backbone atom, and the T3 copper coordinating histidine residue (Solomon *et al.,* 2008). Type 2 and type 3 copper make up the trinuclear center. After oxygen molecules attach to the trinuclear cluster and prevent further entry of any other molecules the catalytic process begins. The T2Cu site interacts with two histidine molecules and one water molecule, whereas the T3Cu interacts with three histidines and a hydroxide molecule. In the last step, laccase converts the oxygen molecule to water in two steps. In the first step, the first electron is reduced by T2Cu and T3Cu, while the reduction of the second electron is assisted by a peroxide mediator that protects the T2Cu site and T1Cu is linked to T3Cu through a Cys-His covalent bonds. As we have already mentioned, enzymes like azoreductase, Peroxidase degrades the dyes with the production of aromatic amines which are toxic in nature (carcinogenic). But laccase reduce the azo dyes to the phenolic compounds. This property is advantageous as well as of industrial interest in dye degradation process. Therefore various scientists did laccase activity assay. For example, Fatemeh Sheikhi *et al.* (2012) Centrifuged (6000 * g) bacterial cultures at 4^0c for 20 min to obtain cellular debris precipitate and clear supernatants. After that they washed bacterial pellets with phosphate buffer(0.1 M, pH 6.5) containing 10mM of phenylmethylsulfonyl fluoride (PMSF). They used PMSF because it helps to inhibit the activity of protease before sonication. Then they obtained the cell extract by centrifugation (14000 * g) for 20 min at 4^0c , which was used as a crude intracellular enzyme. To remove the effect of H_2O_2 produced by bacteria assay solution was incubated with catalase (1,000 U/mL; Sigma-Aldrich) for 1 h at 37^0c. At 436 nm spectrophotometrically laccase activity was determined as described by Niku-Paavola et al. with 2, 2- azino - di- [3- ethylbenzo- thiazolin-sulphonate] (ABTS) as a substrate. The amount of enzyme that oxidized 1 μmol of ABTS per min at 25 °C was defined as one activity unit (U) and in terms of U/L activities were expressed. Also laccase activity was determined at 465 nm spectrophotometrically using a substrate (2 mM guaiacol) in a reaction mixture containing 50mM phosphate buffer. The amount of enzyme that increased the absorbance by 0.001 units per min at 55 °C was defined as one unit of enzyme activity (Bains*et al.,*2003). Here also activities were expressed in U/L. Sondhi *et al.* (2014) also measured the laccase activity by governing the oxidation of 2 , 6-Dimethoxyphenol, (2, 6-DMP) buffered with 100 mM phosphate buffer for 1 min at 450 nm. An absorption coefficient of 14,800 M/cm was used to calculate the enzyme activity. According to Ang *et al.* (2012)the amount of enzyme required to oxidise 1μM of 2, 6-DMP per minute is defined as the enzyme activity.

GMO for dye degradation:

Nowadays, dye degradation is becoming more and more challenging as they are being produced in such a way that they resist degradation. Dyes degradation is either achieved by a single treatment method or by an integration of physical, chemical and biological methods. Interestingly, microbiological treatment methods have found acceleration due to environmental friendliness, improved performance and low cost nature (Moharikar *et al.,* 2005). Under environmental conditions improvement of dye degradation can be achieved using GMOs. A GMO is obtain by modifying their genetic material using genetic engineering. Functional genes from several bacterial strains such as *Sphingomonas desiccabilis*, *Escherichia coli*, *Bacillus idriensis*, *Pseudomonas putida*, *Mycobacterium marinum*, *Ralstoni aeutropha* are transferred into other species to produce GMO for dye degradation (Saxena *et al.,* 2019). For example, Jin *et al.*(2008) and (2009), produced *Escherichia coli* JM109(pGEX-AZR), a GMO that was able to degree the dyes– Acid red GR and Direct blue 71. Azo reductase gene from a subspecies of *Rhodobacter sphaeroides* was isolated and inserted in the vector pGEX4T-1 and then expressed in *Escherichia coli* JM109 under the control of lac operon.In another attempt, Dixit and Garg (2019) reported Methyl orange degradation by a GMO *Escherichia coli* BL21. Azok gene from a *Klebsiella pneumoniae* strain was expressed in *Escherichia coli* DH5 to produce this GMO.Many more such GMOs have been developed which degrade a variety of dyes. These GMOs demonstrate high dye decolorization and degradation rate and are instrumental in effective bioremediation.

Future prospects:

Bioremediation using microbes has emerged as a promising approach and an eco friendly technology of degrading dyes. Enhancing this technology via further research is the need of time. Genetic engineering and molecular biology tools are already being exploited for potential benefits in the field of dye degradation and environmental purification. Still, more in-depth study of the genetic aspect of dye degradation by bacteria along with the study of mechanisms of degradation is very much required to have a more clear understanding on how to take help from the bacterial world for more efficient and complete degradation of dyes, which still stands as a challenge. Future research should focus on reducing limiting factors upon dye degrading microbial activities and improving and enhancing the efficiency of already existing bioremediation processes. In future, studies can focus on introducing non-indigenous bacteria in sites where critical dye degrading microbes are absent. Or, novel genetic engineering techniques, i.e. CRISPR/Cas9, can be used for modifying indigenous bacteria into bacteria with dye degrading ability.Use of microbial consortia instead of a single bacterial species should also be explored in the coming years. It would present higher and more complete degradation of dyes in shorter time as synergistic effects would come into play. Searching out the various bacterial strains whose enzymatic activity would positively influence and supplement each other in degrading dyes can be an open wide field for future research. These bacteria will be useful in reclaiming the polluted soils around dye-related industries and cleaning the water bodies where the effluents are dumped. Although, use of microbial consortia or a non-indigenous bacteria and GMO to assist dye degradation is a scope for future research, care should be taken as adaptation of microbial community to a new environment is not always an efficient process. Factors like stress due to different environmental condition, competition with the indigenous species etc. affect the adaptation/ acclimatization process. Apart from that, the introduced bacteria may also cause changes in the environment that might influence the survival of both the introduced bacteria as well as the indigenous microbial species either positively or negatively. This acclimatization process and it's after effects can be monitored by using diversity indexes such as Shannon diversity index (1949), which is a way to mathematically measure the species diversity in a community. Shannon index depends on both, species richness as well as species evenness and it's value for ecological studies typically varies between 1.5 to 3.5. It increases with the increase in both, the richness as well as the evenness.

It is calculated as:

$$H = -\Sigma[pi * ln(pi)$$

Where, H– Shannon diversity index; Σ– Summation; ln– Natural log; pi– proportion of entire community made up of species 'i'.

Conclusion

Dye, the important component involved in colouring and decorating the items used in our daily lives, becomes intractable and hazardous colouring pollutant, toxic for environment and human, animals and plant lives, when it is dumped untreated into water bodies as dispersed dyed items or industrial effluents. In this review article, the problem as well as the solution has been discussed and we can conclude that, degradation of dyes is a huge problem in today's world and bacterial bioremediation is a good way to get rid of it. It is a sustainable and green process but a lot still needs to be studied and researched. There are factors to consider including the maintenance and implementation cost of bioreactor, available space for using bioreactor, availability of nutrients under optimal conditions, presence of redox mediator for proper functioning of azo-dye reducing enzymes etc. Despite the limiting factors, the knowledge of the bacterial enzymes and the mechanism of dye degradation that has been acquired till date has been put to use and it has proved to the most economic and eco friendly way to overcome dye pollution. In recent times, creation of new GMOs and use of extensive genetic engineering tools, along with the efforts to produce useful microbial consortium has been another successful step and has additional benefits to improve degradation process efficiency. With the fast, new developments happening in this field, we can be hopeful of more improved processes and maybe even complete dye degradation can be accomplished in the near future.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ang, T. N., Ngoh, G. C., Chua, A. S. M., & Lee, M. G. (2012). Elucidation of the effect of ionic liquid pretreatment on rice husk via structural analyses. *Biotechnology for biofuels*, *5*(1), 1-10.

Asad, S., Amoozegar, M. A., Pourbabaee, A., Sarbolouki, M. N., &Dastgheib, S. M. M. (2007). Decolorization of textile azo dyes by newly isolated halophilic and halotolerant bacteria. *Bioresource technology*, *98*(11), 2082-2088.

Bains, J., Capalash, N., & Sharma, P. (2003). Laccase from a non-melanogenic, alkalotolerant γ-proteobacterium JB isolated from industrial wastewater drained soil. *Biotechnology Letters*, *25*, 1155-1159.

Bayoumi, R. A., Musa, S. M., Bahobil, A. S., Louboudy, S. S., & El-Sakawey, T. A. (2010). Biodecolorization and biodegradation of azo dyes by some bacterial isolates. *Journal Of Applied Environmental and Biological Science, 1*(1), 1-25.

Bhutiani, R., Ahamad, F., & Ruhela, M. (2021). Effect of composition and depth of filter-bed on the efficiency of Sand-intermittent-filter treating the Industrial wastewater at Haridwar, India. *Journal of Applied and Natural Science*, *13*(1), 88-94.

Bhutiani, R., Tiwari, R. C., Chauhan, P., Ahamad, F., Sharma, V. B., Tyagi, I., & Singh, P. (2022). Potential of *Cassia fistula* pod-based absorbent in remediating water pollutants: An analytical study. In *Sustainable Materials for Sensing and Remediation of Noxious Pollutants* (pp. 261-272). Elsevier.

Bell, J., Plumb, J. J., Buckley, C. A., & Stuckey, D. C. (2000). Treatment and decolorization of dyes in an anaerobic baffled reactor. *Journal of Environmental Engineering*, *126*(11), 1026-1032.

Boonyakamol, A., Imai, T., Chairattanamanokorn, P., Higuchi, T., Sekine, M., &Ukita, M. (2009). Reactive Blue 4 decolorization under mesophilic and thermophilic anaerobic treatments. *Applied biochemistry and biotechnology*, *152*, 405-417.

Chandra, R., &Chowdhary, P. (2015). Properties of bacterial laccases and their application in bioremediation of industrial wastes. *Environmental Science: Processes & Impacts*, *17*(2), 326-342.

Chen, C. H., Chang, C. F., Ho, C. H., Tsai, T. L., & Liu, S. M (2008). Biodegradation of crystal violet by a Shewanella sp. NTOU1. *Chemosphere*, *72*(11), 1712-1720.

Chivukula, M., &Renganathan, V. (1995). Phenolic azo dye oxidation by laccase from Pyriculariaoryzae. *Applied and Environmental Microbiology*, *61*(12), 4374-4377.

Dixit, S., & Garg, S. (2019). Development of an efficient recombinant bacterium and its application in the degradation of environmentally hazardous azo dyes. *International Journal of Environmental Science and Technology*, *16*, 7137-7146.

Du, L. N., Li, G., Zhao, Y. H., Xu, H. K., Wang, Y., Zhou, Y., & Wang, L. (2015). Efficient metabolism of the azo dye methyl orange by Aeromonas sp. strain DH-6: characteristics and partial mechanism. *International Biodeterioration& Biodegradation*, *105*, 66-72.

Garg, S. K., Tripathi, M., Singh, S. K., & Tiwari, J. K. (2012). Biodecolorization of textile dye effluent by Pseudomonas putida SKG-1 (MTCC 10510) under the conditions optimized for monoazo dye orange II color removal in simulated minimal salt medium. *International biodeterioration& biodegradation*, *74*, 24-35.

Gurulakshmi, M., Sudarmani, D. N. P., &Venba, R. (2008). Biodegradation of leather acid dye by Bacillus subtilis. *Advanced Biotech*, *7*, 12-19.

Hadibarata, T., Yusoff, A. R. M., Aris, A., Hidayat, T., &Kristanti, R. A. (2012). Decolorization of azo, triphenylmethane and anthraquinone dyes by laccase of a newly isolated Armillaria sp. F022. *Water, Air, & Soil Pollution*, *223*, 1045-1054.

Haley, T. J. (1975). Benzidine revisited: a review of the literature and problems associated with the use of benzidine and its congeners. *Clinical toxicology*, *8*(1), 13-42.

He, F., Hu, W., & Li, Y. (2004). Biodegradation mechanisms and kinetics of azo dye 4BS by a microbial consortium. *Chemosphere*, *57*(4), 293-301.

Houk, J.M., Doa, A., Dezube, M., and Rovinski, J.M. (1991). Evaluation of dyes submitted under the toxic substances control act new chemical programme. In: Color Chemistry. *Elsevier Science Publishers Ltd., London*, pp. 135 150.

Jadhav, U. U., Dawkar, V. V., Ghodake, G. S., &Govindwar, S. P. (2008). Biodegradation of Direct Red 5B, a textile dye by newly isolated Comamonas sp. UVS. *Journal of Hazardous Materials*, *158*(2-3), 507-516.

Jadhav, S. U., Kalme, S. D., &Govindwar, S. P. (2008). Biodegradation of methyl red by Galactomycesgeotrichum MTCC 1360. *International Biodeterioration& Biodegradation*, *62*(2), 135-142.

Jin, R. F., Zhou, J. T., Zhang, A. L., & Wang, J. (2008). Bioaugmentation of the decolorization rate of acid red GR by genetically engineered microorganism Escherichia coli JM109 (pGEX-AZR). *World Journal of Microbiology and Biotechnology*, *24*, 23-29.

Jin, R., Yang, H., Zhang, A., Wang, J., & Liu, G. (2009). Bioaugmentation on decolorization of CI Direct Blue 71 by using genetically engineered strain Escherichia coli JM109 (pGEX-AZR). *Journal of hazardous materials*, *163*(2-3), 1123-1128.

Kagalkar, A. N., Jagtap, U. B., Jadhav, J. P., Govindwar, S. P., &Bapat, V. A. (2010). Studies on phytoremediation potentiality of Typhoniumflagelliforme for the degradation of Brilliant Blue R. *Planta*, *232*, 271-285.

Kandelbauer, A.; Guebitz, G.M. (2005). Bioremediation for the Decolorization of Textile Dyes—A Review. In: Lichtfouse, E., Schwarzbauer, J., Robert, D. (eds), *Environmental Chemistry* (269–288). Springer: Berlin/Heidelberg, Germany. (ISBN 978-3-540-22860-8)

Khadijah, O., Lee, K. K., &MohdFaiz, F. A. (2009). Isolation, screening and development of local bacterial consortia with azo dyes decolourising capability. *Malaysian Journal of Microbiology,* 5, 25-32.

Khan, S., & Joshi, N. (2020). Molecular identification of dye degrading bacterial isolates and FT-IR analysis of degraded products. *Environmental Engineering Research*, *25*(4), 561-570.

Lin, Y. H., &Leu, J. Y. (2008). Kinetics of reactive azo-dye decolorization by Pseudomonas luteola in a biological activated carbon process. *Biochemical Engineering Journal*, *39*(3), 457-467.

Mani, S., &Bharagava, R. N. (2016,a). Exposure to crystal violet, its toxic, genotoxic and carcinogenic effects on environment and its degradation and detoxification for environmental safety. *Reviews of Environmental Contamination and Toxicology Volume 237*, 71-104.

Mani, S. and Bharagava, R.N. (2016,b). Microbial degradation and decolorization of dyes from Textile industry wastewater. In: Bharagava, R.N. and Saxena, G. (1stEd) *Bioremediation Of Industrial Pollutants.* Write & Print Publications New Delhi, 110 015. (ISBN: 978-93-84649-60-9).

Moharikar, A., Purohit, H. J., & Kumar, R. (2005). Microbial population dynamics at effluent treatment plants. *Journal of Environmental Monitoring*, *7*(6), 552-558.

Naik, C., & Singh, C. R. (2012). Isolation screening and development of Bacillus sps with decolorization and degradation capabilities towards reactive dyes and textile effluents. *Recent Research in Science and Technology,* 4, 1–5.

Neifar, M., Chouchane, H., Mahjoubi, M., Jaouani, A., &Cherif, A. (2016). Pseudomonas extremorientalis BU118: a new salt-tolerant laccase-secreting bacterium with biotechnological potential in textile azo dye decolourization. *3 Biotech*, *6*, 1-9.

Olukanni, O. D., Osuntoki, A. A., &Gbenle, G. O. (2006). Textile effluent biodegradation potentials of textile effluent-adapted and non-adapted bacteria. *African Journal of Biotechnology*, *5*(20), 1980-1984.

Olukanni, O. D., Osuntoki, A. A., Kalyani, D. C., Gbenle, G. O., &Govindwar, S. P. (2010). Decolorization and biodegradation of Reactive Blue 13 by Proteus mirabilis LAG. *Journal of Hazardous Materials*, *184*(1-3), 290-298.

Pasti-Grigsby, M. B., Paszczynski, A., Goszczynski, S., Crawford, D. L., & Crawford, R. L. (1992). Influence of aromatic substitution patterns on azo dye degradability by Streptomyces spp. and *Phanerochaete chrysosporium*. *Applied and Environmental Microbiology*, *58*(11), 3605-3613.

Paszczynski, A., Pasti, M. B., Goszczynski, S., Crawford, D. L., & Crawford, R. L. (1991). New approach to improve degradation of recalcitrant azo dyes by Streptomyces spp. and Phanerochaetechrysosporium. *Enzyme and Microbial Technology*, *13*(5), 378-384.

Puvaneswari, N., Muthukrishnan, J., &Gunasekaran, P. (2006). Toxicity assessment and microbial degradation of azo dyes. *Indian journal of experimental biology*, *44*(8), 618–626.

Ruhela, M., Jena, B. K., Bhardawaj, S., Bhutiani, R., & Ahamad, F. (2021). Efficiency of Pistia stratiotes in the treatment of municipal solid waste leachate in an upwards flow constructed wetland system. *Ecology Environment & Conservation 27 (February Suppl. Issue): 2021;* pp. (S235-S244).

Sahasrabudhe, M. M., &Pathade, G. R. (2011). Biodegradation of sulphonated azo dye CI reactive orange 16 by Enterococcus faecalis strain YZ 66. *European Journal of Experimental Biology*, *1*(1), 163-173.

Sari, I. P., &Simarani, K. (2019). Decolorization of selected azo dye by Lysinibacillus fusiformis W1B6: Biodegradation optimization, isotherm, and kinetic study biosorption mechanism. *Adsorption Science & Technology*, *37*(5-6), 492-508.

Saxena, G., Kishor, R., Saratale, G.D., Bharagava, R.N., (2019). Genetically Modified Organisms (GMOs) and their Potential in Environmental Management: Constraints prospects, and Challenges. In: Bharagava, R., Saxena, G. (Eds.). *Bioremediation of Industrial Waste for Environmental Safety* (1-19). Springer, Singapore.

Shannon, C.E. and Weaver, W. (1949). The Mathematical Theory of Communication. *Urbana, IL: The University of Illinois Press*, 1-117.

Sheikhi, F., RoayaeiArdakani, M., Enayatizamir, N., & Rodriguez-Couto, S. (2012). The determination of assay for laccase of Bacillus subtilis WPI with two classes of chemical compounds as substrates. *Indian journal of microbiology*, *52*, 701-707.

Solomon, E. I., Augustine, A. J., & Yoon, J. (2008). O 2 Reduction to H2O by the multicopper oxidases. *Dalton Transactions*, (30), 3921-3932.

Solomon, E. I., Sundaram, U. M., &Machonkin, T. E. (1996). Multicopper oxidases and oxygenases. *Chemical reviews*, *96*(7), 2563-2606.

Sondhi, S., Sharma, P., Saini, S., Puri, N., & Gupta, N. (2014). Purification and characterization of an extracellular, thermo-alkali-stable, metal tolerant laccase from Bacillus tequilensis SN4. *PloS one*, *9*(5), e96951.

Srinivasan, S., &Sadasivam, S. K. (2018). Exploring docking and aerobic-microaerophilic biodegradation of textile azo dye by bacterial systems. *Journal of water process engineering*, *22*, 180-191.

Sudha, M., Bakiyaraj, G., Saranya, A., Sivakumar, N., &Selvakumar, G. (2018). Prospective assessment of the Enterobacteraerogenes PP002 in decolorization and degradation of azo dyes DB 71 and DG 28. *Journal of environmental chemical engineering*, *6*(1), 95-109.

Stolz, A. (2001). Basic and applied aspects in the microbial degradation of azo dyes. *Applied microbiology and biotechnology*, *56*, 69-80.

Tian, Y. S., Xu, H., Peng, R. H., Yao, Q. H., & Wang, R. T. (2014). Heterologous expression and characterization of laccase 2 from Coprinopsiscinerea capable of decolourizing different recalcitrant dyes. *Biotechnology & Biotechnological Equipment*, *28*(2), 248-258.

Vijaykumar, M. H., Vaishampayan, P. A., Shouche, Y. S., &Karegoudar, T. B. (2007). Decolourization of naphthalene-containing sulfonated azo dyes by Kerstersia sp. strain VKY1. *Enzyme and Microbial Technology*, *40*(2), 204-211.

Zimmermann, T., Gasser, F., Kulla, H. G., &Leisinger, T. (1984). Comparison of two bacterial azoreductases acquired during adaptation to growth on azo dyes. *Archives of Microbiology*, *138*, 37-43.

Zimmermann, T., Kulla, H. G., &Leisinger, T. (1982). Properties of purified Orange II azoreductase, the enzyme initiating azo dye degradation by Pseudomonas KF46. *European Journal of Biochemistry*, *129*(1), 197-203

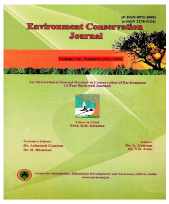
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3):283--295, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Mulching: A diversified and multipurpose input in agriculture

Soumya, T. M. ✉
Department of Agronomy, AINP (T), Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

Siddharth Hulmani
Department of Agronomy, College of Agriculture, Navile, Shivamogga, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga, Karnataka, India.

Vignesh
Department of Agronomy, College of Agriculture, Navile, Shivamogga, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga, Karnataka, India.

Manjunath Madhukar Mopagar
Department of Agronomy, College of Agriculture, Navile, Shivamogga, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga, Karnataka, India.

Akarsh, S. V.
Department of Agronomy, College of Agriculture, Navile, Shivamogga, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga, Karnataka, India.

ARTICLE INFO

Received : 11 August 2022
Revised : 17 January 2023
Accepted : 06 March 2023

Available online: 26 June 2023

Key Words:
Agriculture
Inorganic
Mulching
Organic

ABSTRACT

The ever-growing demand for food has led to the depletion of natural resources. Water scarcity, land degradation, and climate change are the main factors contributing to declining crop productivity. To address this issue, there is a need to adopt suitable agronomic strategies. Mulching is one way this practice addresses this issue. Since time immemorial, people have been using organic residues as mulching material. Nowadays, people find it cumbersome to utilise crop residues. The development of plastic mulching material overcame this issue due to its easy and plentiful availability. Plastic mulch has its own advantages and disadvantages. In today's world, the haphazard use of this material has led to the threat of micro plastics. Micro plastics are small in size and escape waste management practices. They contaminate ecosystems, clog the soil pores, enter the food chain, and take a very long time to degrade. So, balanced use of both organic and inorganic materials is the need of the day. This article reviews the benefits of mulching as an agronomic strategy to boost present-day agriculture.

Introduction

The increasing demand for natural resources like water and soil is being caused by the growing global population, climate change, and global warming (Colak *et al.,* 2015). Due to lower precipitation and higher evaporation rates, some regions of the world have experienced challenges with water scarcity (Li *et al.,* 2000). Mulch is a crucial agronomic practice that is defined as the materials that are put in opposition to the soil profile to cover the soil's surface. It is a method of water conservation that increases the soil's capacity to absorb water, slows soil erosion, and so lowers surface runoff (Chalker-Scott, 2007; Adekalu *et al.,* 2007). It raises the soil's surface temperature, makes the soil more fertile, modifies the microbial biomass, and improves soil quality, all of which promote seed germination, root growth, and plant development and raise agricultural yields in regions with minimal water input (An *et al.,* 2015; Huo *et al.,* 2017; Qiu *et al.,* 2014; Siczek *et al.,* 2015; Wang *et al.,* 2016; Zhang *et al.,* 2016; Gao *et al.,* 2019). Mulching increases soil enzyme activity, which creates favourable conditions for plant metabolism, eradicates weed infestation, and lowers weed biomass and density (Masciandaro *et al.,* 2004; Splawski *et al.,*2016).

What is mulching?Mulching is the technique of covering the soil's surface with plastics, organic

Corresponding author E-mail: *soumya.tm.agron@gmail.com*
Doi: https://doi.org/10.36953/ECJ.14352435

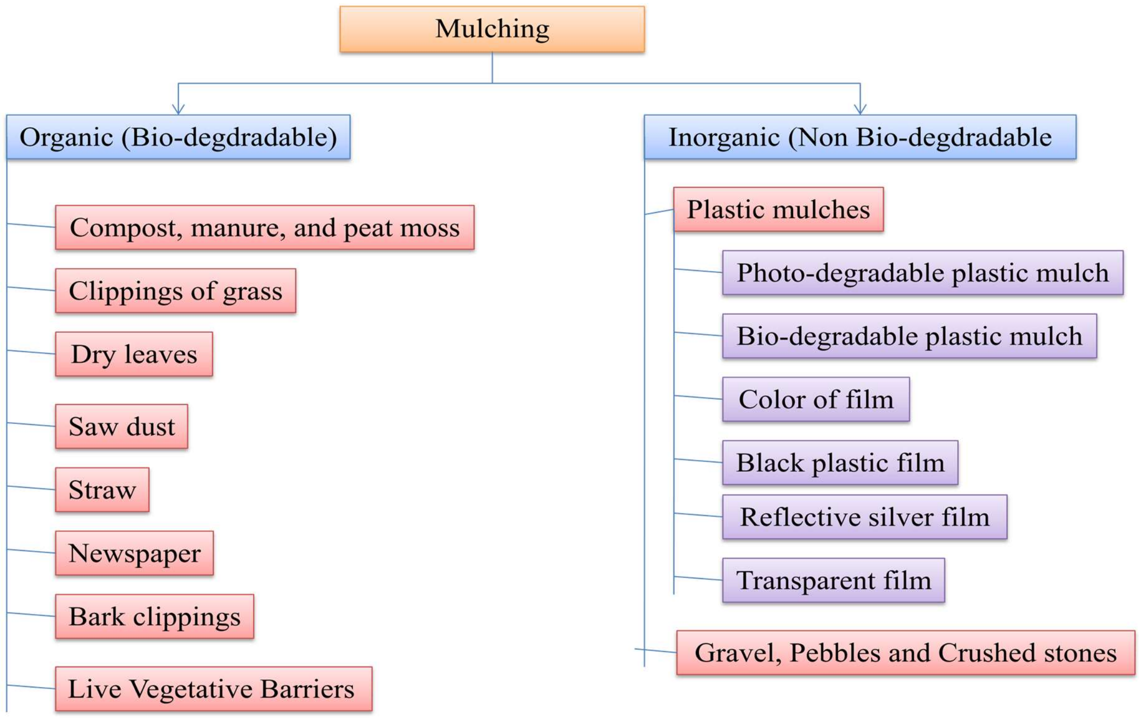


Figure 1: Classification of mulching materials based on their composition/degradability

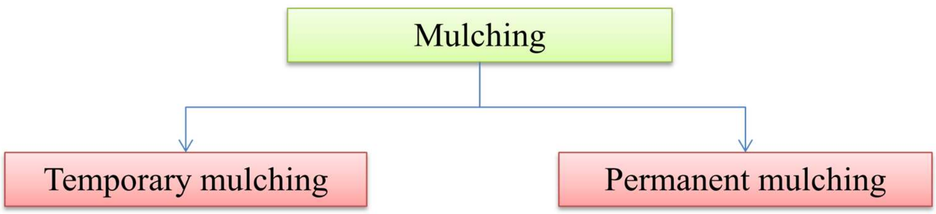


Figure 2: Classification of mulching materials based on their duration

materials, and non-organic materials in order to prevent evaporation and mitigate significant diurnal temperature changes, especially in the root zone environment. The word "mulch" is thought to be originated from the German word "molsch," which means "soft to decay," and appears to refer to the use of straw and leaves as mulch by gardeners(Jacks *et al.,* 1955).

Advantages of mulching

It has influence on crop productivity directly by improving the growth and yield of crops and indirectly by reducing weed density, water conservation (reduced evaporation, runoff and more infiltration), soil temperature regulation, nutrient cycling and improved microbial population in soil.

Different mulching material in agriculture

Mulches are divided into two types based on their composition: organic and inorganic mulches (Fig. 1).

Organic mulching has many advantages:

1. Weed germination is hindered when organic mulch is covered with soil because they do not receive the light they require for germination and growth.
2. Organic mulch is essential for reflecting solar energy. This keeps the soil colder and reduces evaporation.
3. Mulches that have been placed to the soil slow down rainwater flow and increase the quantity of water that the soil can hold. Additionally,

greater water in the soil means that the crops will receive more water.

4. Due to the fact that it is not directly in contact with wind or water, which would otherwise blow or wash it away, it also reduces soil erosion.
5. Organic mulches help to improve the soil's condition. This improves root growth, water infiltration, and soil water-holding capacity.
6. It creates a very good porous soil by maintaining a more even soil temperature.

Organic Mulching has a few drawbacks:

1. Some mulch, such as hay and straw, contain seeds that can grow into weeds.
2. Mulches can keep the soil too moist on poorly drained soils, which reduces the amount of oxygen available to roots.
3. When mulch is used in close proximity to or directly on the stem, retained moisture produces an ideal habitat for disease and pest development.

2) Inorganic mulches:

These mulches have no soil-enhancing qualities (adding fertilizers). Inorganic mulches are usually made of plastic.

a. Plastic mulches-

Plastic mulches can be highly useful as evaporation control mulches if cost is not an issue. Both dark and transparent coatings are frequently used for mulching. Plastic chemistry advancements have resulted in the fabrication of films with optical qualities that are ideal for a certain crop in a specific region (Steinmetz *et al.,* 2016).

The thickness of the plastic is determined by the duration of the crop.

Annuals (short-term crops) have a thickness of 20 to 25 microns.

Biennials (short-term) with a thickness of 40 to 50 microns.

Perennials (long-term crops) have a thickness of 50-100 microns.

Benefits of inorganic mulches:

1. Long lasting compared to organic mulches. Up to 2 to 3 season plastic mulches can be used.
2. Most effective in soil solarisation by increasing the soil temperature**.**

Limitations of inorganic mulches:

1. Many times inorganic mulches may not be available locally.
2. Laborious during setting and removing plastic mulch compared to organic mulches.
3. Non biodegradable which may pollute the soil.

Mulching can be done on a long-term or ad hoc basis. Based on this mulches can be divided into temporary mulches and permanent mulches.

Temporary mulches: - The goal of temporary mulch is to reduce erosion by applying a layer of mulch to damaged areas that will not receive permanent stabilization for a length of time or that may be disturbed at a later date.

Preparation of temporary mulch-

- In a large mixing bowl, combine the mulching materials with the compost.
- Plow the land using this mixture. They can be mulched after crops have been planted or used on fallow land.
- As the plants grow, the mulch will decompose. Potatoes, onions, and garlic, for example.

Permanent mulches: Before planting the crop, the mulches are laid down for a long time. A layer of well-rotted compost, decomposed biomass, and fresh biomass is placed in the soil and seeds or saplings are planted into it to create permanent mulch. Once or twice a year, new mulch can be added.

Permanent mulch preparation-

- Plow the land and add compost.
- Add a 3-inch layer of semi-decomposed biomass, such as straw, litter, leaves, and so on, on top of it.
- For each layer, water it.
- Add fresh, green biomass to the top of the decomposed biomass. Weeds (no seeds), pruned plant parts, and so on.
- For each layer, water it.
- It's all set to be planted. Use a stick to dig a hole for planting.

Methodology

This review article is prepared to synthesize the works conducted in mulching. Keywords like mulching, organic mulches, plastic mulches, and types of mulches were used to search research articles. Once the papers were collected, only the papers published after 2010 were used to review the results of the work. The theoretical background on mulching is described, including the benefits and different types of mulches available, as well as the

Table 1: Advantages and disadvantages of biodegradable non-biodegradable mulches

Biodegradable		Non-biodegradable	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
After use, the components are intended to be incorporated into the soil and broken down by residing microbes.	Bulky nature of the organic mulches leading to costlier handling and transportation charges.	Cheap, simple to process, incredibly strong, and adaptable (Kasirajan and Ngouajio, 2012)	Serious environmental contamination
Polymers used in biodegradable plastic mulches contain polysaccharides which are amenable to microbial hydrolysis (Brodhagen *et al.,* 2015).	Lignin rich materials degrade after several years.	Modify soil temperatures, conserve soil moisture and reduce weed pressure, ultimately improving crop productivity (Martin-Closas *et al.,* 2017)	Never entirely removed from a field, leaving behind traces that persist in the soil for decades (Briassoulis *et al.,* 2015).
Facilitates nutrient availability, supports the carbon cycle, and collects rainfall.	Chances of nutrient fixation due to imbalanced/ improper C: N ratio leading to nutrient deficiency in crops.	Inert chemically	In addition to potentially entering the food chain, plastic pieces can physically alter soil.
Increases the amount of soil moisture, prevents soil erosion, slows down moisture evaporation and moderates soil profile temperature. (Bhale and Wanjari, 2009, Ram *et al*., 2012).			Pollute soil (Wang *et al.,* 2015)

Table 2: Influence of mulches on yield of cereal crops

SN	Crop	Yield increase	Mulch material	Authors
1	Quality protein maize (QPM)	77.079	Water hyacinth	Khan and Parvej, 2010
2	Sugarcane	84.17	Black, polyethylene sheet	Ahmed *et al*., 2013
		44.09	Red polyethylene sheet	
		25.47	Green polyethylene sheet	
3	Wheat	20		Wei *et al*., 2015
	Maize	60		
4	Wheat	3.04	Maize straw	Abdul *et al*., 2019
5	Wheat	67.00 to 122.80	Plastic mulch	Zhang *et al.,* 2022
	Maize	148.4 to 237.8		
6	Wheat	3.23 and 2.35	Straw mulch	Prabhjot *et al.,* 2020
7	Maize	12.12 and 8.38	Wheat straw	De and Bandyopadhyay, 2013
8	Maize	15.9 to 16.5	Straw mulch	Rakesh, 2015
9	Maize and wheat	15.82 and 39.51		Priya and Sashidhara, 2016
10	Maize	13.88 (cob) and 12.22 (grain yield)	*Centrosema pubescens* mulch	Nkiruka *et al*., 2020
11	Sweet corn	2.96 (Fresh ear yield)	Plastic mulch	Kara and Atar, 2013

pros and cons of using mulches. For better clarity, the results of the experiments were summarized by organising the papers into categories based on crop types (cereals, pulses, oilseeds, fruits, vegetables, and quality), soil properties (physicochemical and biological properties), and other related factors (moisture content and nutrient release/availability). The results are converted to percentage changes in order to make the interpretation of the results uniform. The gaps in existing research are identified, and the areas for future research are also mentioned.

Influence of mulches on growth and yield of cereal crops-

Mulching has a significant benefit in terms of increasing total yield. Mulching techniques influence cereal yield. Table 2 shows the increase in yields of various cereals with various mulching materials. Improved soil temperature, reduced weed growth, and improved soil moisture conservation can all contribute to increased yields (Chalfant *et al.,* 1977).

Table 3: Influence of mulches on yield of pulse crops

SN	Crop	Yield increase (%)	Mulch material	Authors
1	Chickpea	18	Straw mulching	Reghar *et al*., 2010
2	Soybean	35.18	Rice straw mulch	Eid *et al*., 2013
		58.33	200 mm black Plastic mulch	
3	Pigeonpea	2.20	Soil mulch	Mathukia *et al*., 2015
		17.64	Wheat straw mulch	
		12.63	Groundnut shell mulch	
		6.10	Weed mulch	
4	Summer groundnut	31.99	Black polythene mulch	Kamble *et al.,* 2018
		46.69	Transparent polythene mulch	
		17.22	Soybean straw mulch	
5	Groundnut	27.12	Transparent 7 micron polythene	Mousumi *et al.*, 2018
6	Lentil	4.16	Rice straw mulch	Mandal *et al*., 2018
7	Soybean	43.28 to 83.64	Rice straw, rice husk and their combinations and polythene sheet	Anand *et al*., 2020
8	Pigeonpea	39.56	Wheat straw	Jadav *et al.,* 2020
		48.01	Plastic mulch of 25 micron	
9.	Soybean	7.69	*Centrosema pubescen* weed mulch	Nkiruka *et al.,* 2020

Table 4: Influence of mulches on yield of oilseed crops

SN	Crop	Yield increase (%)	Mulch material	Authors
1.	Niger	3.18	Soil dust	Mandal and Saren, 2012
		10.75	Rice straw	
		16.34	Black polythene	
2.	Groundnut	24.41	-	Zayton *et al*., 2014
3.	Mustard	48.7 to 134.00	Rice straw	Saikia *et al.,* 2014
4.	Niger	4.75	Soil dust mulching	Sudeshna *et al*., 2015
		13.00	Rice straw mulch on seeded rows	
		19.72	Rice straw mulch between rows	
5	Linseed	5.55	Water hyacinth	Sarkar and Sarkar, 2017
		11.46	Straw mulch	
		14.76	Black polythene	
6.	Sunflower	More than 3 times	Plastic mulch	Kumar *et al.*, 2018
7.	Toria mustard	13.88	Groundnut haulm mulch	Chaudhry and Bhagawati, 2019

Influence of mulches on yield of pulse crops-

Mulching practises not only boost cereal crop yields, but they also boost pulse crop yields. This could be owing to improved weed control, resource efficiency, and dry matter buildup during vegetative growth and photosynthetic mobilisation from source to sink (Anand *et al.,* 2020). Table 3 demonstrates the increase in grain yields with different mulching materials.

Influence of mulches on yield of oilseed crops

Table 4 presents the yield increase caused by various mulch types. Mulches preserved more soil moisture through greater penetration and retention while suffocating weed growth, resulting in improved crop growth and development as well as increased yield in all oilseed crops (Teame *et al.,* 2017).

Influence of mulches on yield of vegetable crops

Horticulture crops such as vegetables and fruits, like agricultural crops, respond well to mulching. Tables 5 and 6 show the level of yield augmentation of various vegetables and fruits under various mulch materials.

Influence of soil physico chemical properties

According to Kahlon *et al.* (2013), the application of wheat straw mulch at increasing rate from 0 to 16 mg/ha decreased the bulk density of soil (mg/m^3) from 1.46 to 1.31, 1.45 to 1.36 and 1.50 to 1.47 and increased steady infiltration rate (cm/h) from 3.1 to 4.6, 2.3 to 3.5 and 1.2 to 2.1, saturated hydraulic conductivity ($\times 10^{-2}$ cm/h) from 1.78 to 3.37, 1.57 to 2.95 and 1.37 to 2.28, mean weight diameter (mm) from 0.36, 0.29 and 0.25 to 1.21, 0.84 and 0.62, respectively, water stable aggregates (%) from 52.7 to 77.4, 43.7 to 66.6, and 39.5 to 59.5 and total carbon (%) from 1.26 to 1.50, 1.20 to 1.47 and 0.95 to 1.10 under no, reduced and plow till, respectively in the first 10 cm soil depth. The infiltration rate and water retention increased linearly. Pervaiz *et al.* (2009) concluded that increasing the mulching rates from 0 to 14 Mg/ha increased the soil moisture content of the soil by 21.42 per cent, decreased the bulk density and soil strength by 4.25 and 35.10 per cent, respectively. In the 0–15 and 15–30 cm soil depths, the organic matter in soil increased by 103.53 and 104.71 per cent, respectively. There was a 28.10, 22.35 and 9.47 per cent increase in the post-harvest soil NPK.

Jordán *et al.* (2010) recorded that there was an increase in soil organic matter content, total porosity, wilting point, field capacity, Saturation, available water, Saturated conductivity (mm/h) 2025, 100, 30.34, 28.47, 50.48, 25.69, 657.62 per cent and decrease in bulk density (g/cm^3), run off (mm/h), steady state run off (mm/h) and sediment concentration (g/L) by 8.96, 96.45, 95.73 and 97.70 per cent**,** respectively.

Influence of mulches on soil biological properties and nutrient release/ release pattern

Siczek and Frac (2012) observed that mulching increased the bacteria number (108 cfu/kg) by 34.54, 26.95 and 73.91 per cent, dehydrogenases (cm^3 H_2/kg/d) by 41.17, 24.59 and 38.23 per cent, protease (mg tyrosine/kg/h) by 27.58, 1.23and 56.25 per cent, alkaline phosphatases (mmol PNP/kg/h) by 46.34, 149.46 and 21.73 per cent and acid phosphatases (mmol PNP/kg/h) by 124.43, 21.16 and 66.14 per cent under no, moderate and strong compaction situations, respectively. Plastic film mulching enhanced the relative abundances of *Proteobacteria* and *Actinobacteria* over a 28-year period in Shenyang, China (Farmer *et al.,* 2017).

Ibrahim (2018) concluded that 15.0, 0.6, and 29.0 kg/ha of N, P and K was released from millet straw, respectively compared to the 32.0 kg/ha, 1.0 kg/ha, and 29.0 kg/ha of N, P and K released from the acacia cuttings treatment. Similarly, 35 and 33 per cent increase in grain yield was observed, respectively. The balance between increased root development and exudate secretion and microbial degradation and loss to CO_2 determines how plastic affects soil organic carbon (SOC) (Wien *et al*., 1993; Nan *et al*., 2016).

Influence of different mulching moisture content of soil

Mulching is a water-saving practice used in rain-fed agriculture to assist alleviates water scarcity. It's necessary for keeping soil moist, reducing evaporation, and regulating soil temperature, all of which have an impact on food production. Mulching has emerged as a critical component of agricultural output in recent years. Mulching has a number of strategic implications for the soil ecosystem, crop growth, and climate.

In order to maintain soil moisture, control soil temperature, and reduce soil evaporation, all of which have an effect on crop productivity, mulching is essential (Yang *et al*., 2015; Kader *et al.,* 2017). Mulch protects the soil by acting as insulation against the cold and heat, helping to create stunning and secure landscapes. Wheat straw mulch is less effective than plastic sheet mulch at preserving soil moisture (Li *et al*., 2013). The amount of water saved by mulching is yet unknown due to the interaction of microclimate, soil environment, and plant growths (Steinmetz *et al.,* 2016).

Mulching shortens the time it takes to harvest

Mulching produces early maturation and higher yields in warm-season plants such cucumbers, muskmelons, watermelons, eggplant, and peppers. The early maturity is most likely attributable to the preservation of favourable temperatures throughout the growing season. Apply black mulch to the planting bed prior planting to warm the soil and encourage quicker growth in the early season, for getting an earlier harvest (Tarara, 2000 and Lamont, 2005). In comparison to the control, organic mulches caused earlier blooming, lesser days to set fruits, and early harvest in the tomato crop (Ravinderkumar and Srivastava, 1998). Mulching with polyethylene films has been found to shorten the growing season and boost yield and earliness in a number of vegetable crops (Goreta *et al*., 2005; McCann *et al.,* 2007). The early harvest and improved productivity of watermelon, zucchini, tomatoes, and peppers were all positively impacted by polyethylene mulch, according to research by Romic *et al.* and Walters in 2003, Hutton and Handley (2007).

Table 5: Influence of mulches on yield of vegetable crops

SN	Crop	Yield increase (%)	Mulch material	Authors
1.	Tomato	45.52	Red plastic	Agrawal *et al.,* 2010
		40.06	Black plastic	
		35.30	White plastic	
2.	Chilli	37.07	Transparent,	Ashrafuzzaman *et al.*, 2011
		58.46	Black	
		42.27	Blue mulch	
3.	Potato	48.40 to 85.15	Plastic film mulch	Zhao *et al.,* 2012
4.	Tomato	21.7 to 29.8	Plastic mulching	Singh and Kamal, 2012
5.	Potato	30	Plastic mulch	Xie *et al.,* 2012
6.	Brinjal	27.07 to 77.44	Straw mulch	Pirboneth *et al.*, 2012
7.	Cucumber	67.68	Wheat straw	El- Shaikh and Fouda, 2015
		109.15	Black	
		124.77	Yellow	
		129.26	Transparent	
8.	Potato	3.82	FYM mulch	Dhiman, 2017
		32.41	Rice straw mulch	
		30.33	Rice stubble mulch	
9.	Chilli	16.18 and 37.48	Organic mulch @ 9 and 12 t/ha	Narayan *et al.*, 2017
		220.80	Double coated black polythene (30 micron)	
		65.37	double coated white polythene (30 micron)	
		117.80	30 micron single coated black polythene	
10.	Tomato	50.66	Black mulch,	Sunil, 2018
		44.54	Transparent mulch	
		22.14	Straw mulch	
11.	Potato	14.64	Rice straw	Bharati *et al.*, 2020
		10.04	Saw dust	
		6.69	Rice husk	
		39.33	Black plastic	

Table 6: Influence of mulches on yield of fruit crops

SN	Crop	Yield increase (%)	Mulch material	Authors
1.	Strawberry	63.94	Paddy straw	Bakshi *et al.*, 2014
		56.72	Wheat straw	
		37.13	Grass cuttings	
		38.34	Saw dust	
		91.29	Transparent polythene	
		138.09	Black polythene sheet	
2.	Sapota	7.62 to 41.00	Plastic mulch	Tiwari *et al.*, 2016
3.	Strawberry	38.05	Rice husk	Pandey *et al.*, 2016
		118.41	White polythene	
		145.13	Black polythene mulch	
4.	Watermelon	17	Plastic sheet mulching	Nodar *et al.*, 2016
5.	Watermelon	39.32	Paddy straw	Rao *et al.*, 2017
		61.39	Yellow mulch	
		67.60	Pink mulch	
		79.68	Blue mulch	
		94.90	Red mulch	
		111.88	Black mulch	
		132.33	Silver mulch	
6.	Summer squash	86.68	Black plastic sheets	Dinesh and Rishu, 2017
		60.12	Blue plastic sheets	
		12.09	Rice straw material	
		39.64	Transparent sheets	
7.	Watermelon	12.87	Wheat straw	Dadheech *et al.,* 2018
		13.75	Grasses	
		50.62	Black mulch	
		59.19	Silver mulch	
		36.03	Red mulch,	
		31.35	Blue mulch	
		17.18	Yellow mulch	
8.	Squash melon	26.6	Plastic	Birbal *et al.*, 2019
		48.60	Straw mulching	

Table 7: Influence of mulching on moisture content of soil

SN	Crop	Change in Soil moisture content (%)	Mulch material	Authors
1.	Eureka lemon	23.55 to 51.53 (0-15 cm)	Bajra straw, Maize straw Grasses, Brankad, FYM and Black polyethylene	Kumar *et al.*, 2015
		19.76 to 49.90 (15-30 cm)		
2.	Okra	-	-	Mahammed and Singh, 2015
3.	Watermelon	1.26	-	Dadheech *et al.,* 2018
4.	Maize	20.4	Plastic mulch	Wang *et al.,* 2022
		13.9	Sand mulch	
		12.2	Alternate plastic mulch	

Table 8: Economics of different moisture conservation materials

Sl. No.	Crop	B: C ratio	Mulch material	Scientist
1.	Pearlmillet	2.38	*Tephrosia* mulch	Meena and Bhaduri, 2007
		2.23	Dust	
		2.12	Mustard mulch	
		0.86	Black polythene mulch	
2.	Tomato	1.76	Red plastic mulch	Agrawal *et al.*, 2010
		1.61	Black plastic mulch	
		1.47	White plastic mulch	
		0.78	Control	
3.	Tomato	2.49	Black polyethylene mulch	Sunil, 2018
		2.05	Transparent polyethylene mulch	
4.	Potato	2.01	Black plastic	Bharati *etal.*, 2020
		1.64	Rice husk	

Mulch and quality

Mulch keeps fruits clean by preventing them from touching the ground, and in many cases, it also helps to prevent soil rot, fruit cracking, and blossom end rot. Smoother fruits with fewer scars are more common. Plastic mulch, when properly installed, prevents soil from splashing onto plants during heavy rains, reducing grading time. Tomatoes, cucumbers, muskmelons, and eggplant yields and chemical compositions were discovered to be improved. Early potatoes, cabbage, and other vegetables can benefit from straw mulch in terms of yield and quality of storage. Mulching has been shown to have a favourable effect on the production and quality characteristics of practically all fruit crops in a number of studies. Here are some relevant findings to back up the viewpoint.

Chan *et al.* (2010) looked at the effect of composted mulch on grape quality metrics. Brix increased from 24.13 to 24.16, and titrable acidity increased from 3.94 to 3.99. The greatest TSS (10.43%), reducing sugars (1.80%), total sugar (5.47%), and non-reducing sugar (3.67%) of all the mulching treatments were found in treatment in black mulch, according to Parmar *et al.* (2013). While no mulch contained the least amount of sugar found in watermelon fruit.

Future line of work:

Aside from these, there is a need to investigate alternative mulching materials such as biodegradable films and recycled mulches. The impact of mulching on carbon sequestration and its impact on microbial activity can be studied. Mitigating the effects of climate change by managing soil erosion, soil temperature, and soil moisture. Identify the optimal mulching practices for different crops, soil types, and climates. Study the biodiversity and ecological resilience and the management of soil-borne diseases in different cropping systems. Identify the most effective types and thicknesses of mulch for controlling different weed species, promoting plant growth and yield, reducing soil compaction, improving soil structure, and promoting crop quality. Mulching can affect pest populations by altering the microclimate and soil conditions, but the effects on different pest species are not well understood. Identify the optimal types and thicknesses of mulch for different soil types and slopes to achieve maximum erosion control. Mulching can impact greenhouse gas emissions from the soil by affecting soil organic matter decomposition and nutrient cycling. Further research is needed to understand how different types of mulch and mulching practices can impact greenhouse gas emissions. Identify the social and economic impacts of different mulching practices on farmers and communities. The effects of mulching in high-rainfall areas can be studied. The removal of plastic residues from plastic mulches in the ecosystem through enzymatic degradation or any other mechanism must be developed.

Conclusion
Diverse mulches play an important role in increasing grain, pulse, oilseed, fruit, and vegetable yields, according to the evidence obtained in this review study. Increased weed populations and weed management with chemical herbicides are widely known to damage crop quality. Mulching alters the soil's microclimate, reduces evaporation rates, increases soil moisture and regulates soil temperature; boosts the rhizospheric microbial population; alters the soil's physico-chemical properties; and keeps pests and weeds at bay. All of these favourable impacts promote plant growth and development. Incorporating inorganic mulch into soil comes with its own set of issues in terms of material cost and disposal. Contrarily, organic mulch is widely accessible, affordable, and decreases labour costs while also adding nutrients to the soil that are vital for plant growth and development when it decomposes. Furthermore, the use of bioplastic in agriculture has been promoted in order to address the issues associated with organic mulches as well as the environmental concerns associated with plastic mulches. Also, suitable technologies must be developed to decontaminate the ecosystem which is already polluted with microplastics. This report will provide farmers and manufacturers with a wealth of useful information, allowing them to apply suitable mulch to boost yields.

Conflict of interest
The authors declare that they have no conflict of interest.

References

Abdul, R., Muhammad, J. K., Tahir, S. & Mohammad, J. K. (2019). Influence of deficit irrigation, sowing methods and mulching on yield components and yield of wheat in semiarid environment. *Pakistan Journal of Botany*, *51*(2), 553-560.

Adekalu, K. O., Olorunfemi, I. A. & Osunbitan, J. A. (2007). Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. *Bioresource Technology*,*98*, 912-917.

Agrawal, N., Panigrahi, H. K., Sharma, D. & Agrawal, R. (2010). Effect of different colour mulches on the growth and yield of tomato under Chhattisgarh region. *Indian Journal of Horticulture*, *67*(5), 295-300.

Ahmed, M., Baiyeri, K. P. & Echezona, B. C. (2013). Effect of coloured polyethylene mulch and harvesting stage on growth and yield of industrial sugarcane in Nigeria. *African Journal of Biotechnology*, *12*(10), 1078-1083.

An, T., Schaeffer, S., Li, S., Fu, S., Pei, J., Li, H., & Wang, J. (2015). Carbon fluxes from plants to soil and dynamics of microbial immobilization under plastic film mulching and fertilizer application using 13C pulse-labeling. *Soil Biology and Biochemistry*, *80*, 53-61.

Anand, D. D., Sumarjit, S. M., Jamkhogin, L., Surbala, D. N. & Gopimohan, S. N. (2020). Effect of mulching on growth and yield of soybean (*Glycine max* (L.) Merrill). *International Journal of Current Microbiology and Applied Science*, *9*(9), 3313-3318.

Ashrafuzzaman, M., Abdul, M., Ismail, M. R., Shahidullah, S. M. & Hossain, M. A. (2011). Effect of plastic mulch on growth and yield of chilli (*Capsicum annum* L.). *Beaz Archives of Biology and Technology*, *54*, 321-330.

Bakshi, P., Deep, J. B., Wali, V. K., Akash, S. & Mudasir, I. (2014). Growth, yield and quality of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler as influenced by various mulching materials. *African Journal of Agricultural Research*,*9*(7), 701-706.

Bhale, V. M. & Wanjari, S. S. (2009). Conservation agriculture: A new paradigms to increase resource use efficiency. *Indian Journal of Agronomy*, *54*(2), 167-177.

Bharati, S., Joshi, B., Dhakal, R., Paneru, S., Dhakal, S. C., & Joshi, K. R. (2020). Effect of different mulching on yield and yield attributes of potato in Dadeldhura district, Nepal. *Malaysian Journal of Sustainable Agriculture*, *4*(2), 54-58.

Birbal, Soni, M. L., Rathore, V. S., Nathawat, N. S. & Renjith, P. S. (2019). Interactive effect of FYM and mulching on productivity and water use efficiency of squash melon (*Citrullus vulgaris* var. *fistulosus*) grown with supplemental irrigation in hot arid region of Rajasthan. *Indian Journal of Agricultural Sciences*, *89*(2), 307-313.

Briassoulis. D., Epifaneia. B. & Miltiadis. H. (2015). Analysis of long term degradation behavior of polyethylene mulching film with pro-oxidants under real cultivation and soil burial conditions. *Environmental Science and Pollution Research*, *22*, 2584-2598.

Brodhagen, M., Peyron, M., Miles, C. & Inglis, D. A. (2015). Biodegradable plastic agricultural mulches and key features of microbial degradation. *Applied Microbiology and Biotechnology*, *99*(3), 1039-1056.

Chalfant, R. B., Jaworski, C. A., Johnson, A. W. & Sumner, D. R. (1977). Reflective film mulches, millet barriers, and pesticides: Effects on watermelon mosaic virus, insects, nematodes, soil borne fungi, and yield of yellow summer squash. *Journal of American Society of Horticultural Science*, *102*, 11-15.

Chalker-Scott, L. (2007). Impact of mulches on landscape plants and the environment-a review. *Journal of Environmental Horticulture*,*25*, 239-249.

Chan, K. Y, Fahey, D. J., Newell, M & Barchia, I. (2010). Using composted mulch in vineyards effects on grape yield and quality. *International Journal of Fruit Science*, *10*,441-453.

Choudhary, V. K. & Bhagawati, R. (2019). Planting method, row arrangement and crop residue mulch influence on weed dynamics and productivity of toria mustard. *Indian Journal of Weed Science*, *51*(3), 298-301.

Colak, Y.B., Yazar, A., Çolak, I., Akça, H. & Duraktekin, G. (2015). Evaluation of crop water stress index (CWSI) for eggplant under varying irrigation regimes using surface and subsurface drip systems. *Agriculture and Agricultural Science Procedia*,*4*, 372-382.

Dadheech, S., Ramawtar, K. & Yadav, C. (2018). Impact of Mulching Material on the Growth, Yield and Quality of Watermelon (*Citrullus lonatus*). *International Journal of Current Microbiology Applied Science*, *7*(7), 2774-2782.

De, B. & Bandyopadhyay, S. (2013). Influence of soil conservation techniques on growth and yield of maize (*Zea mays* L.) in Terai region of West Bengal. *SAARC Journal of Agriculture*, *11*(1), 133-147.

Dhiman, M. (2017). Influence of mulching and graded fertility levels on microbial population, growth and productivity of potato (*Solanum tuberosum* L.). *International Journal of Current Microbiology and Applied Science*, *6*(10), 4784-4792.

Dinesh, K. & Rishu S. (2017). Effect of Mulching on Growth, Yield and Quality in Different Varieties of Summer Squash (*Cucurbita pepo* L.). *International Journal of Current Microbiology and Applied Science*, *7*(6), 2113-2119.

Eid, A. R., Bakry, A. B. & Moamen, H. T. (2013). Effect of pulse drip irrigation and mulching systems on yield, quality traits and irrigation water use efficiency of soybean under sandy soil conditions. *Agricultural Science*, *4*(5), 249-261.

El Shaikh, A. & Fouda, T. (2015). Effect of different mulching types on soil temperature and cucumber production under Libyan conditions. *MISR Journal of Agricultural Engineering*, *25*(1), 160-175.

Farmer, J., Zhang, B., Jin, X., Zhang, P. & Wang, J. (2017). Long-term effect of plastic film mulching and fertilization on bacterial communities in a brown soil revealed by high through-put sequencing. *Archives of Agronomy and Soil Science*, *63*(2), 230-241.

Gao, H., Yan, C., Liu, Q., Ding, W., Chen, B. & Li, Z. (2019). Effects of plastic mulching and plastic residue on agricultural production: a meta-analysis. *Science Total Environment*, *651*, 484-492.

Goreta, S. Perica., S. Dumicic., G. Bucan, L. & Zanic, K. (2005). Growth and yield of watermelon on polyethylene mulch with different spacing and nitrogen rates. *Horticulture Science*, *40*, 366-369.

Huo, L., Pang, H., Zhao, Y., Wang, J., Lu, C. & Li, Y. (2017). Buried straw layer plus plastic mulching improves soil organic carbon fractions in an arid saline soil from Northwest China. *Soil and Tillage Research*, *165*, 286-293.

Hutton, M. G. & Handley, D. T. (2007). Effects of silver reflective mulch, white inter-row mulch, and plant density on yields of pepper in Maine. *Horticulture Technology*, *17*, 214-219.

Ibrahim, A., Abaidoo, R.C., Iliasso, A. D. K. T. & Fatondji, D. (2018). Nutrient release dynamics from decomposing organic materials and their mulching-effect on pearl millet yields in a low-input Sahelian cropping system. *Nutrient Cycling in Agroecosystem*, *112*(1), 45-59.

Jacks, C. V., Brind, W. D. & Smith, R. (1955). Mulching technology Comm., No. 49, Common Wealth. *Bulletin of Soil Science*, *118*.

Jadav, M. L., Mishra, K. P., Anjaney, P., Mishra, U. S., Duggal, A., Gautam, S. S. & Khariya, R. K. (2020). Influence of mulch and drip irrigation on growth and yield of pigeonpea. *The Pharma Innovation Journal*, *9*(9), 374-377.

Jordán, A., Zavala, L. M. & Gil, J. (2010). Effects of mulching on soil physical properties and runoff under semi-arid conditions in southern Spain. *Catena*, *81*(1), 77-85.

Kader, M. A., Senge, M., Mojid, M. A. & Ito, K. (2017). Recent advances in mulching materials and methods for modifying soil environment. *Soil and Tillage Research*, *168*, 155-166.

Kahlon, M. S., Lal, R. & Ann-Varughese, M. (2013). Twenty two years of tillage and mulching impacts on soil physical characteristics and carbon sequestration in Central Ohio. *Soil and Tillage Research*, *126*, 151-158.

Kamble, D. R., Gokhale, D. N., Gadade, G. D. & Jadhav, P. B. (2018). Yield and economics of summer Groundnut as influenced by different irrigation level and mulches. *International Journal of Current Microbiology and Applied Science*, *6*(2), 135-139.

Kara, B. & Atar, B. (2013). Effects of mulch practices on fresh ear yield and yield components of sweet corn. *Turkish Journal of Agriculture and Forestry*, *37*(3), 281-287.

Kasirajan, S. & Ngouajio, M. (2012). Polyethylene and biodegradable mulches for agricultural applications: a review. *Agronomy for Sustainable Development*, *32*(2), 501-529.

Khan, M. A. H. & Parvej, M. R. (2010). Impact of conservation tillage under organic mulches on the reproductive efficacy and yield of quality protein maize. *Journal of Agricultural Science*, *5*(2), 52-63.

Kumar, T., Mohammad, A. H., Saiful, M. I., Fazlul, M. H. & Rajib, J. (2018). Effect of polythene mulch on growth and yield of sunflower (*Helianthus annuus*). *Archives of Crop Science*, *2*(1), 38-46.

Kumar, V., Bhat, A. K., Sharma, V., Gupta, N., Sohan, P., & Singh, V. B. (2015). Effect of different mulches on soil moisture, growth and yield of Eureka lemon (*Citrus limon burm*) under rainfed condition. *Indian J. Dryland Agricultural Research and Development*, *30*(1), 83-88.

Lamont, W. J. (2005). Plastics: Modifying the microclimate for the production of vegetable crops. *HortTechnology*, *15*(3), 477-481.

Li, R., Hou, X., Jia, Z., Han, Q., Ren, X. & Yang, B. (2013). Effects on soil temperature, moisture, and maize yield of cultivation with ridge and furrow mulching in the rainfed area of the Loess Plateau, China. *Agriculture Water Management*, *116*, 101-109.

Li, X. Y., Gong, J. D. & Wei, X. H. (2000). In-situ rainwater harvesting and gravel mulch combination for corn production in the dry semi-arid region of China. *Journal of Arid Environments*, *46*, 371-382.

Mahammed & Singh, K. (2015). Effect of mulching and nitrogen on growth, yield and economics of Okra (*Abelmoschus esculentus*). *Ecology, Environmental and Conservation, 23*(2), 2017-2026.

Mandal, K. & Saren, B. K. (2012). Productivity, water use efficiency and economics of rainfed niger (*Guizotia abyssinica*) as influenced by mulching and row spacing in red and lateritic soil of West Bengal, India. *International Journal of Bio-resource and Stress Management*, *3*(3), 295-298.

Mandal, T. K., Puste, A. M. & Sagar, M. (2018). Influence of irrigation and mulching on yield attributes, yield and quality of lentil (*Lens esculentum* L.) grown as intercrop under limited water conditions. *International Journal of Bioresource Science*,*5*(1), 61-64.

Martín-Closas, L., Costa, J., & Pelacho, A. M. (2017). Agronomic effects of biodegradable films on crop and field environment. In *Soil degradable bioplastics for a sustainable modern agriculture* (pp. 67-104). Springer, Berlin, Heidelberg.

Masciandaro, G., Ceccanti, B., Benedicto, S., Lee, H. C. & Cook, H. F. (2004). Enzyme activity and C and N pools in soil following application of mulches. *Canadian Journal of Soil Science*, *84*(1), 19-30.

Mathukia, R. K., Mathukia, P. R. & Polara, A. M. (2015). Effect of preparatory tillage and mulch on productivity of rainfed pigeonpea [*Cajanus cajan* (L.) Millsp.]. *Indian Journal of Dryland Agriculture Research and Development*, *30*(2), 58-61.

McCann, I.. Kee., E. Adkins., J. Ernest., E. & Ernest, J. (2007). Effect of irrigation rate on yield of drip-irrigated seedless watermelon in humid region. *Science Horticulture*, *113*, 155-161.

Meena, H. N. & Bhaduri, D. (2007). Improvement in productivity, water-use efficiency, and soil nutrient dynamics of summer peanut (*Arachis hypogaea* L.) through use of polythene mulch, hydrogel, and nutrient management. *Communications in Soil Science and Plant Analysis*,*48*(5), 549-564.

Mousumi, M., Sunil, K. G., Amrita, S. & Rajib, K. (2018). Productivity enhancement of *rabi* groundnut (*Arachis hypogaea* L.) under polythene mulching and *Rhizobium* inoculation under new alluvial zone of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences,7*(9), 2308-2313.

Nan, W. G., Yue, S. C., Huang, H. Z., Li, S. Q. & Shen, Y. F. (2016). Effects of plastic film mulching on soil greenhouse gases (CO_2, CH_4 and N_2O) concentration within soil profiles in maize fields on the Loess Plateau, China. *Journal of Integrative Agriculture, 15*(2), 451-464.

Narayan, S., Makhdoomi, M. I., Ajaz, M., Ambreen, N., Hussain, K. & Khan, F. A. (2017). Influence of Plastic and organic mulching on productivity, growth and weed density in chilli (*Capsicum annuum* L.). *Journal of Pharmacognosy and Phytochemistry*,*6*(6), 1733-1735.

Nkiruka, C. O., Effiom, E. O. & Emem, E. E. (2020). Performance of maize and soybean mixture as influenced by organic mulch in the southern guinea savannah zone of Nigeria. *The International Journal of Agriculture and Environmental Research*, *6*(3), 422-434.

Nodar, A. A., Elgailani, A. A., Elshiekh, A. I. & Ahmed, M. El Naim. (2016). The effect of plastic mulch on growth and yield of rain-fed cowpea and watermelon in North Kordofan state of Sudan. *World Journal of Agricultural Research*, *4*(5), 139-142.

Pandey, S., Girja, S. T., Jitendra, S., Deepak, R. & Gopal, K. (2016). Efficacy of mulches on soil modifications, growth, production and quality of strawberry (*Fragaria x ananassa* Duch.). *International Journal of Natural Sciences*, *7*(4), 823-820.

Parmar, H. N., Polara, N. D. & Viradiya, R. R. (2013). Effect of mulching material on growth, yield and quality of watermelon (*Citrullus lanatus* Thunb) Cv. Kiran. *Universal Journal of Agricultural Research*, *1*(2), 30-37.

Pervaiz, M.A., Iqbal, M., Shahzad, K. & Hassan, A.U. (2009). Effect of mulch on soil physical properties and N, P, K concentration in maize (*Zea mays* L.) shoots under two tillage systems. *International Journal of Agriculture and Biology*, 11(2), 119-124.

Pirboneth, H., Ghasemi, M., Gohari, A. A., Bahari, B. & Bazkiyaei, Z. B. (2012). Effect of irrigation and straw mulch on yield and yield components of eggplant (*Solanum Melongena* L.). *International Research Journal of Applied and Basic Sciences*, *3*(1), 46-51.

Prabhjot, K., Gurbaksh. S. C. & Amandeep, K. (2020). Effect of legume intercropping and straw mulching on growth and yield of wheat crop. *European Journal of Molecular and Clinical Medicine*, *7*(7), 2764-2770.

Priya, R. & Shashidhara, G. B. (2016). Effect of mulching on maize and wheat (*Triticum aestivum*) in maize-wheat cropping system. *Journal of Farm Sciences*, *29*(4), 449-455.

Qin, W., Hu, C., & Oenema, O. (2015). Soil mulching significantly enhances yields and water and nitrogen use efficiencies of maize and wheat: a meta-analysis. *Scientific Reports*, *5*(1), 1-13.

Qiu, Y., Wang, Y. & Xie, Z. (2014). Long-term gravel–sand mulch affects soil physicochemical properties, microbial biomass and enzyme activities in the semiarid Loess Plateau of North-western China. *Acta Agriculturae Scandinavica, Section B. Soil and Plant Science*, *64*(4), 294–303.

Rakesh Kumar. (2015). Influence of mulching, liming and farm yard manures on production potential, economics and quality of maize (*Zea mays* L.) under rainfed condition of Eastern Himalaya. *Bangladesh Journal of Botony*, 44(3), 391-398.

Ram, H., Singh, Y., Saini, K. S., Kler, D. S. & Timsina, J. (2012). Tillage and planting methods effects on yield, water use efficiency and profitability of soybean–wheat system on a loamy sand soil. Experimental *Agriculture*, *49*(4), 524-542.

Rao, K. V. R., Bajpai, S., Gangwar, L., Chourasia, S. & Soni, K. (2017). Effect of mulching of growth, yield and economics of watermelon (*Citrullus lanatus Thunb*). *Environment* and *Ecology*, *35*(3), 2437-2441.

Ravinderkumar & Srivatsava, B. K. (1998). Influence of different mulches on flowering an fruit setting of winter tomato. *Crop Research*, *12*, 174-176.

Reghar, P. L., Rao, S. S. & Joshi, N. L. (2010). In-situ rain water conservation practices on productivity of chickpea (*Cicer arietinum*) in the rainfed conditions of arid Rajasthan, India. *Indian Journal* of *Soil Conservation*, *38*(2), 111-115.

Romic, D., Borosic, J., Poljak, M. & Romic, M. (2003). Polyethylene mulches and drip irrigation increase growth and yield in watermelon (*Citrullus lanatus* L.). *European Journal of Horticultural Science*, *68*, 192-198.

Saikia, U. S., Kumar, A., Das, S., Pradhan, R., Goswami, B., Wungleng, V. C., ... & Ngachan, S. V. (2014). Effect of mulching on microclimate, growth and yield of mustard (*Brassicajuncea*) under mid-hill condition of Meghalaya. *Journal of Agrometeorology*, *16*(1), 144-145.

Sarkar, S. & Sarkar, A. (2017). Impact of irrigation schedules and mulch on productivity and moisture extraction pattern of linseed (*Linum usitatissimum*). *Journal of Oilseeds Research*, *34*(4), 207-211.

Siczek, A. & Frac, M. (2012). Soil microbial activity as influenced by compaction and straw mulching. *International Agrophysics*, *26*(1), 65-69.

Siczek, A., Horn, R., Lipiec, J., Usowicz, B. & Lukowski, M. (2015). Effects of soil deformation and surface mulching on soil physical properties and soybean response related to weather conditions. *Soil and Tillage Research*, *153*, 175-184.

Singh A. K. & Kamal, S. (2012). Effect of black plastic mulch on soil temperature and tomato yield in mid hills of Garhwal Himalayas, *Journal of Horticulture and Forestry*, *4*(4), 77-79.

Splawski, C. E., Regnier, E. E., Harrison, S. K., Bennett, M. A., & Metzger, J. D. (2016). Weed suppression in pumpkin by mulches composed of organic municipal waste materials. *HortScience*, *51*(6), 720-726.

Steinmetz, Z., Wollmann, C., Schaefer, M., Buchmann, C., David, J., Tröger, J., ... & Schaumann, G. E. (2016). Plastic mulching in agriculture. Trading short-term agronomic benefits for long-term soil degradation?. *Science of the total environment*, *550*, 690-705.

Sudeshna, K., Lina, H., Saren, B. K. & Kausik, M. (2015). Effect of mulching and boron application on growth, productivity and water use of winter niger under red-lateritic belt of West Bengal. *International Journal of Applied and Pure Science and Agriculture*, *1*(10), 1-7.

Sunil, A. N. (2018). Effect of mulching on hydrothermal regime and fruit yield of tomato (*Lycopersicon esculentum*). *International Journal of Current Microbiology and Applied Sciences, 7*(2), 1005-1013.

Tarara, J. M. (2000). Microclimate modification with plastic mulch. *HortScience*, *35*(2), 169-180.

Teame, G., Tsegay, A., & Abrha, B. (2017). Effect of organic mulching on soil moisture, yield, and yield contributing components of sesame (*Sesamum indicum* L.). *International Journal of Agronomy*. https://doi.org/10.1155/2017/4767509

Tiwari, K. N., Kumar, M., Santosh, D. T., Singh, V. K., Maji, M. K., & Karan, A. K. (2014). Influence of drip irrigation and plastic mulch on yield of sapota (achraszapota) and soil nutrients. *Irrigation and Drainage Systems Engineering*, *3*, 116.

Walters, S. A. (2003). Suppression of watermelon mosaic virus in summer squash with plastic mulches and rowcovers. *HortTechnology*, *13*(2), 352-357.

Wang, H., Zhang, X., Zhang, G., Yu, X., Hou, H., Fang, Y., & Lei, K. (2022). Mulching coordinated the seasonal soil hydrothermal relationships and promoted maize productivity in a semi-arid rainfed area on the Loess Plateau. *Agricultural Water Management*, *263*, 107448.

Wang, J., Huang, J., Zhao, X., Wu, P., Horwath, W. R., Li, H., & Chen, X. (2016). Simulated study on effects of ground managements on soil water and available nutrients in jujube orchards. *Land Degradation & Development*, *27*(1), 35-42.

Wang, J., Luo, Y., Teng, Y., Ma, W., Christie, P., & Li, Z. (2016). Soil contamination by phthalate esters in Chinese intensive vegetable production systems with different modes of use of plastic film. *Environmental Pollution*, *180*, 265-273.

Wien, H. C., Minotti, P. L., & Grubinger, V. P. (1993). Polyethylene mulch stimulates early root growth and nutrient uptake of transplanted tomatoes. *Journal of the American Society for Horticultural Science*, *118*(2), 207-211.

Xie, K., Wang, X. X., Zhang, R., Gong, X., Zhang, S., Mares, V., & Quiroz, R. (2012). Partial root-zone drying irrigation and water utilization efficiency by the potato crop in semi-arid regions in China. *Scientia Horticulturae*, *134*, 20-25.

Yang, N., Sun, Z. X., Feng, L. S., Zheng, M. Z., Chi, D. C., Meng, W. Z., ... & Li, K. Y. (2015). Plastic film mulching for water-efficient agricultural applications and degradable films materials development research. *Materials and Manufacturing Processes*, *30*(2), 143-154.

Zayton, A. H. M., Guirguis, A. E., & Allam, K. A. (2014). Effect of sprinkler irrigation management and straw mulch on yield, water consumption and crop coefficient of peanut in sandy soil. *Egyptian Journal of Agricultural Research*, *92*(2), 657-673.

Zhang, X., Hou, H., Fang, Y., Wang, H., Yu, X., Ma, Y., & Lei, K. (2022). Can organic carbon and water supplementation sustain soil moisture–carbon balance under long-term plastic mulched semiarid farmland?. *Agricultural Water Management*, *260*, 107303.

Zhang, Y., Li, H., He, J., Wang, Q., Chen, Y., Chen, W., & Ma, S. (2016). Effect of mulching with maize straw on water infiltration and soil loss at different initial soil moistures in a rainfall simulation. *Frontiers of Agricultural Science and Engineering*, *3*(2), 161-170.

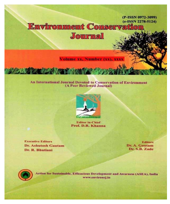
Zhao, H., Xiong, Y. C., Li, F. M., Wang, R. Y., Qiang, S. C., Yao, T. F., & Mo, F. (2012). Plastic film mulch for half growing-season maximized WUE and yield of potato via moisture-temperature improvement in a semi-arid agroecosystem. *Agricultural Water Management*, *104*, 68-78.

Environment Conservation Journal 24 (3):296--304, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Potential effects of audible sound signals including music on plants: A new trigger

Mousumi Das ✉

Department of Zoology, Sammilani Mahavidyalaya, Baghajatin, E.M. ByPass, Kolkata, West Bengal, India

ARTICLE INFO

Received : 27 October 2022

Revised : 26 February 2023

Accepted : 20 March 2023

Available online: 28 June 2023

Key Words:

Acoustic frequency technology

Frequency

Germination

Music

Plant growth

Sound wave

ABSTRACT

Plants are highly sensitive organisms and can indeed benefit from specific sound signals in multi-layered processes. Scientific evidences have shown the potential applications of sound wave treatment in plant biology. However, there are some limitations to sound wave treatment that must be overcome. We still do not understand how do plants initially perceive and recognize sound signals, which is very critical to maximize the effectiveness of the use of sound treatment from practical viewpoint. Proper setup of sound treatment equipment and detailed understanding and evaluation of the effects of selected frequencies and intensities along with sound exposure times are also very crucial during sound treatment. More experimental studies with different models need to be done in a multidisciplinary approach toward establishing suitable mechanism for sound treatment application in agriculture production. The aim of this paper is to provide an overview of findings associated with potential effects of audible sound waves including music on different biological, physiological and biochemical processes in plants.

Introduction

Sound wave is ubiquitous across the world. Frequency, intensity, amplitude and speed are some fundamental characteristics features of sound. Audible sound which is perceptible by human ears has frequency range of 20 Hz to 20,000 Hz. Musical sound is nothing but the regular or periodic vibrations of sound with a definite pitch combined with loudness, timbre and duration. Music is a mode of communication between human beings as well as between other living creatures. From the work of Bose (1902, 1926), an eminent biophysicist we came to know that like other living organisms plants also respond to sounds. Even the unicellular organisms are also responsive towards sound vibration (Shaobin *et al.,* 2010). Plants have well developed sensitivity towards sound wave of different ecologically significant frequencies. Buzz pollination is a strong example of it (De Luca *et al.,* 2010). Scientists have investigated the effects of pure tone audible sound and music on plants at various physiological processes like germination (Das and Ghosh, 2022), callus development (Yang *et al.,* 2004), growth (Weinberger and Measures, 1979), photosynthesis (Meng *et al.,* 2011), mechanisms of hormone production, (Zhu *et al.,* 2011) and transcription of certain genes (Jeong *et al.,* 2008). Recently plant acoustic frequency technology (PAFT) is being used to treat plants with an intermittent pulse of sound frequency with specific intensity. By applying PAFT treatment a significant increase in biological responses have been found in various fruits and vegetables (Meng *et al.,* 2012a; Hou *et al.,* 2009). The application of PAFT in greenhouses also had enhanced yields of vegetables with increased disease resistance capacity (Jiang and Huang, 2012). Increase drought tolerance (Jeong *et al.,* 2014), and decreased requirements for pesticides and chemical fertilizers were also noticed by scientists after PAFT treatment (Yu *et al.,* 2013).

Effects of pure tone audible sound waves on callus of medicinal plants

Actinidia chinensis (Kiwi) is one of the extensively used medicinal plant rich in sugar and vitamins. It

Corresponding author E-mail: *mousumidas21@gmail.com*

Doi: https://doi.org/10.36953/ECJ.15592489

was found that sound stimulation accelerated the root activity in *Actinidia chinensis* including increased number of roots and total length but retarded the cell membrane permeability (Yang *et al.,* 2004). It was also reported that sound stimulation of 1 kHz with 100 dB intensity has increased the ATP content, Superoxide dismutase (SOD) and soluble protein contents in *Actinidia chinensis* but these activities decreased when sound stimulation exceeds the above mentioned frequency and intensity (Yang *et al.,* 2002; Yang *et al.,* 2003). *Dendrobium candidum* Wall. ex Lindl is a precious Chinese medicinal herbal plant used to treat eye diseases, removing toxins from human body and also have other immunomodulatory effects. The aerial parts of *Dendrobium* are mainly used for medicinal purposes (Zha *et al.,* 2009). Evidence shows increased activities of antioxidative enzymes in different parts (shoots, roots and leaves) of *Dendrobium candidum* Wall. ex Lindl under exposure to sound vibration (Li *et al.,* 2008). *Chrysanthemum* is also a worldwide used medicinal herbal plant. Studies have shown that sound stimuli could influence the growth rate of *chrysanthemum* callus by affecting the cell wall calcium (Wang *et al.,* 2002). Sound frequency of 1000 Hz with 100dB intensity had enhanced root metabolism and growth in *Chrysanthemum* including increased soluble sugar contents with higher amylase and protein activities (Jia *et al.,* 2003). Playing appropriate sound by using sound stimulation generator had enhanced levels of soluble proteins and superoxide dismutase activity along with increased rate of calcium absorption by *Chrysanthemum* callus. Sound wave exceeding 0.8 kHz and intensity of 100 dB had negative impact on the above indexes. (Liu *et al.,*2002). Sound wave stimulation accelerated the synthesis of nucleic acid and protein in *Chrysanthemum* (Wang *et al.,* 2003a). Report showed enhanced growth of *Chrysanthemum* under sound treatment with increased number of cells in the S phase and decreased number of cells in the G_0/G_1 phase (Wang *et al.,* 2003b). Indole-3-acetic acid or IAA is one of the most important auxin produced in the apical portion of shoot and younger leaves of plants and helps in plant growth and development (Cutler *et al.,* 2010; Wilkinson *et al.,* 2010). Abscisic acid or ABA is a plant stress hormone accumulated under stress condition (Zhang *et al.,* 2006; Lovelli *et al.,* 2012). Reports demonstrated that exposing *Chrysanthemum* callus to a particular sound stimulation (frequency of 1.4 kHz and intensity 95 dB) significantly increased the levels of Indole-3-acetic acid and decreased the levels of Abscisic acid when compared to control. These changes subsequently help in callus development and maturation (Wang *et al.,* 2004). Sound stimulation also had positive effects on cell membrane deformability (Wang *et al.,* 2001).

Impact of pure tone audible sound wave on different phases of plant life cycle

Sound waves with different frequencies, intensities and amplitudes affect plant growth differently in different plant species. Studies have shown that sound vibration could stimulate a seed or plant. Sound treatment with different frequencies and intensities, particularly wave of 5 kHz with 92 dB enhanced tiller growth including number of roots and plant dry weight in Rideau wheat seedlings (Weinberger and Measures, 1979). Investigating the biological effect of sound stimulation on *Oryza sativa*, scientists revealed that sound frequency of 0.4 kHz with SPL of 106 dB significantly promoted the germination index, fresh weight, shoot length, cell membrane permeability and activity of root system. Sound stimulation exceeding 4 kHz and 111 dB had negative impact on growth of *Oryza sativa* (Wang *et al.,* 2003c). Young *Zea mays* root tips showed bending pattern towards continuous sound stimuli and best response was measured between 0.2 and 0.3 kHz (Gagliano *et al.,* 2012). Scientists also revealed that sound wave with 1000 Hz and 100 dB made the germination rate faster with reduced germination time in *Echinacea angustifolia* (Chuanren *et al.,* 2004). Sound frequency of 50 Hz had positive effects on seed germination in *Oryza sativa and Cucumis sativa* (Takahashi *et al.,*1991). Germination rate of *Arabidopsis thaliana* was improved by treatment with sound frequency above 70 Hz with 0.42 mm amplitude (Uchida and Yamamoto, 2002). It has been reported that audible sound with specific range of frequencies (1000-1500 Hz, 1500-2000 Hz, and 2000-2500 Hz) and intensities (80 dB, 90 dB, and 100 dB) had different effects on mung been (*Vigna radiate*) germination and growth. Significant reduction in germination time and as enhanced plant growth were noticed after treatment with frequency around 2000 Hz and intensity around 90 dB (Cai *et al.,* 2014). Research demonstrated that *Oryza sativa* exposed to sound wave of 0.125 kHz and 0.250 kHz showed significant increase in Ald (fructose 1,6-bisphosphate aldolase) mRNA expression, in contrast treatment with 0.050 kHz has showed significant decrease in Ald mRNA expression (Jeong *et al.,*2008). Researchers also have investigated sound wave induced increased expression of TCHs genes encoding calmodulin-related proteins and xyloglucan endotransglycosylase / hydrolase in *Arabidopsis* (Johnson *et al.,* 1998). Investigating the effects of sound wave on protein structure in *tobacco*, scientists pointed out that 0.4 kHz sound frequency with 90 dB SPL influenced the secondary protein structure of the plasma membrane by increasing the α-helix and decreasing the β-turn. The rate of cell growth and phase transition temperature slowed down significantly under sound treatment (Keli *et al.,* 1999; Zhao *et al.,* 2002). Sounds of varying frequencies and intensities have changed the secondary structure of cell wall proteins by altering the amide I and II bonds in tobacco (Shen *et al.,* 1999). Sound stimulation accelerated the cell division and cell metabolism by forming increased amount of sugar and soluble protein in the cytoplasm of *Dendranthema morifolium* callus when exposed to frequency of 1 kHz with100 dB intensity (Zhao *et al.,* 2003). Sound waves also accelerated the fruit size (2.4-43.3%) and yield (8.0-15.8%) in edible mushrooms (Jiang *et al.,* 2011). It was shown that sound wave of varying frequencies influenced the impatiens and bean plants. When the wavelength of pure tone sound coincides with the average of major leaf dimensions, maximum plant growth has occurred (Collins and Foreman, 2001). Reports pointed out that polyamines play a major role in normal plant developmental processes such as cell growth, cell division, organ development, flowering, fruiting, ripening and embryogenesis (Evans and Malmberg, 1989; Pal Bais and Ravishankar, 2002). Sound wave exposure has also made plants more defensive against *Pieris rapae* caterpillar. The treated plants exhibited higher amounts of anthocyanin and glucosinolate compared to untreated control (Appel and Cocroft, 2014). Studies pointed out that sound treatment upregulated a number of genes including the mechanostimulus responsive genes, redox homeostasis genes, defence related genes, biosynthesis related genes, signalling related genes and transcription factors encoding genes in *Arabidopsis thaliana*. Sound wave stimulation with 0.5 kHz and 80 dB had showed maximum impact on phytohormones. Significant changes in the production of gibberellin (GA), indole- 3-acetic acid (IAA), jasmonic acid (JA) and salicylic acid (SA) were also noted (Ghosh *et al.,* 2016). Gibberellin and indole- 3-acetic acid are growth related hormones, whereas salicylic acid and jasmonic acid are defence related hormones in plants. Report showed that sound vibration of 1000 Hz with 100 dB enhanced the maximum disease resistance capacity both in whole plants and detached leaves of *Arabidopsis thaliana* against *Botrytis cinerea* infection. Corroboratively, during the infection period an elevated level of salicylic acid (SA) and demoted level of jasmonic acid (JA) were also noted in treated plants compared to that of control (Choi *et al.,* 2017). *Arabidopsis* exposed to sound waves either of 250 Hz or 500 Hz had enhanced expression of photosynthesis related proteins (Kwon *et al.,* 2012). *Solanum lycopersicum* (Tomato plant) is one of the most consumed and antioxidant rich vegetable source. Plants exposed to1600 Hz and 90 dB showed best results in tomato fruit with increased contents of vitamin C, lycopene, total sugar, total phenol and total acid. Sound wave accelerated the accumulation of metabolites in tomato giving rise to improved fruit quality (Altuntas and Ozkurt, 2019). Sound wave stimulation with 1 kHz delayed the ripening processes in tomato and made them firm by negatively regulating the following genes - ACS2, ACS4, ACO1, E4, E8, IN, TAGL1, HB-1, NOR, and CNR. Sound treatment also affected some transcription factors facilitating the fruit ripening processes (Kim *et al.,* 2015, 2016). Audible sound also enhanced the growth and biomass production in cells of *Picochlorum oklahomensis* (Cai *et al.,* 2016). Sound stimulation influenced plant tolerance to abiotic stresses as well. For example, one hour sound exposure of 800-15000 Hz enhanced drought tolerance in rice including higher water contents and increased conductance of stomata (Jeong *et al.,* 2014). Sound of bee buzzing facilitated the pollination of flowers by inducing pollen release from anthers (De Luca and Vallejo-Marin, 2013). Therefore bee buzzing served as beneficial signals to plants.

Influence of Plant Acoustic Frequency Technology (PAFT) on field crops and vegetables

Plant Acoustic Frequency Technology or PAFT is used to treat plants with an intermittent pulse of sound frequency with specific intensity. By applying PAFT treatment a significant increase in biological responses have been found in cotton plants including seedling height, leaf width, single boll weight, boll numbers, number of boll bearing branches and yields. All these effects were very much frequency, intensity, distance and direction of sound dependent (Hou *et al.,* 2010a). The yield of paddy and wheat were increased qualitatively and quantitavely when exposed to PAFT generator. A significant increase in protein content of rice; and protein, fat and starch contents of wheat were observed. This technology also made plants more insect pest and disease resistance by strengthening the immune systems. A 50% reduction in rice sheath blight disease was also noticed. In addition, three years experimental results revealed that PAFT could reduce the use of fertilizer by an amount of about 25% when applied in rice field (Hou *et al.,* 2010b; Yu *et al.,* 2013). Investigating the effects of PAFT on vegetables, scientists revealed an improved production of endogenous hormones including ZR, GA and IAA in eggplant, muskmelon, cowpea, tomato, and cucumber (Zhu *et al.,* 2011; Meng *et al.,* 2012a; Huang and Jiang, 2011). Scientists also have investigated the effect of PAFT on cucumbers, strawberries, and tomatoes and observed increased number of flowers and fruits along with enhanced biological changes in chlorophyll content, photosynthetic activity, non-photochemical quenching and PS II photochemical efficiency in greenhouses (Fan *et al.,* 2010; Zhou *et al.,* 2010; Meng *et al.,* 2011; Meng *et al.,* 2012b). The PAFT treated strawberries were grown stronger with greener leaves. The blossoming, fruiting and rate of photosynthesis were also accelerated significantly with an enhanced insect pests resistance and disease resistance capacity (Qi *et al.,* 2009). The application of PAFT in greenhouses also enhanced the yield of cucumber, tomato and sweet pepper with increased disease resistance capacity. It was noticed that viral and late blight diseases decreased in greenhouse tomatoes along with reduced aphids, mites and gray mold attacks (Hou *et al.,* 2009; Jiang and Huang, 2012).

Agri- wave technology which is nothing but applying PAFT technology with spraying of microelement fertilizer also has been applied on plants for enhancing the yield both qualitatively and quantitavely. This technology significantly enhanced the growth of tomatoes, promoted the ripening process and also increased the yield qualitatively and quantitavely (Hou *et al.,* 1999a). Spinach and lettuce showed similar results of enhancement in growth rate and yield when treated with Agri- wave technology. An increased amount of vitamins A, B, C and sugar contents were also found in treated plant species. Further, the agri-wave technology has increased the disease resistant properties in spinach (Hou *et al.,* 1999b).

Impact of music on different plant species

Music is made up of sound waves with various frequencies and intensities and mathematically music is ordered. Researchers have investigated the effect of music on plant growth and plants treated with certain melodies have showed better growth when compared to control (Subramanian *et al.,* 1969; Coghlan, 1994). Ponniah and Singh were two of the pioneers in this kind of work. As a source of music they played violin pieces to plants for observing plant growth (Ponniah, 1955; Singh and Ponniah, 1955). Report has pointed out that musical sound significantly accelerated the germination rate in okra and zucchini seeds when compared to untreated control and noise (Creath and Schwartz, 2004). It has been investigated that long term exposure to powerful beating of heavy metals and rock music had detrimental effects on plants. In contrast, light and soft music with gentle vibrations accelerated plant growth with increased yield and also made plants stronger (Klein and Edsall, 1965). Studies have shown that music treated plants produced thicker and greener stems and sprouted faster than control (Hicks, 1963) and music exposed vegetables exhibited improved quality and yield (Xiao, 1990). It is also reported that musical sound of different kinds had positive effects on root elongation as well as on cell metabolism (Seregin and Ivanov, 2001). Report also pointed out that classical music treated plants have shown highest growth than that of the untreated control (Retallack, 1973). Rhythmic music, one classical and another with dynamically changing lyrics increased the onion root tips elongation by enhancing mitotic cell division during germination (Ekici *et al.,* 2007). In another experiment *Rosa chinensis* plants were divided into five groups, one group was used as control group and rest were exposed to four different kinds of music including Indian Classical, Vedic chants, Rock, and Western Classical music. It was found that plants exposed to Indian Classical music and Vedic chants exhibited promoted plant growth when compared to Rock music treated group, Western Classical music treated group as well as control group (Chivukula and Ramaswamy, 2014). Rhythmic soft-melodious music promoted growth and development in eight different medicinal and ornamental plants (*Tagetes erecta, Catharanthus roseus, Trachyspermum ammi, Duranta repens, Hibiscus rosa- sinensis, Epipremnum aureum, Dendranthema grandiflorm, Ocimum sanctum*) including increased height, increased number of leaves and flowers, advanced flowering time and enhanced level of various metabolites including elevated levels of starch and chlorophyll (Sharma *et al.,* 2015). Researchers have investigated the positive impact of Indian classical raga on overall protein production in paddy, wheat, soya, horse gram and spinach plants (Reddy and Raghavan, 2013). Study has shown that light Indian music and Meditation Music could increase the height of stem and length of leaves in marigold plant along with higher number of buds and flowers whereas noise treatment had negative impacts on the above attributes. Exposure to Indian light music also showed faster sprouting and enhanced growth development in chickpea (*Cicer arietinum*) compared to untreated control plants (Chowdhury and Gupta, 2015). Classical music and rhythmic rock music had positive effects and non-rhythmic traffic noise has negative effects on number of germinated seeds, height of plants and number of leaves in *Cyamopsis Tetragonoloba* (common guar or cluster bean) as compared to control (Vanol and Vaidya, 2014). Playing rhythmic violin music and non-rhythmic traffic noise to *Phaseolus vulgaris* (common bean plant) scientists have investigated that both music and noise had positive effects on plant growth as compared to control. Rhythmic violin music treated plants showed better growth than the non-rhythmic traffic noise treated plants (Chatterjee*et al.,* 2013). Investigating the biological effects of classical music and rock music on *Triticum aestivum* (wheat) plant growth, scientists observed that plants grew well with brighter green leaves when exposed to classical music than either the control or rock music exposed plants (Rachieru *et al.,* 2017). Folk music played from wind instruments flute and pipe flute had increased average weight and yield outputs in apple tree and salad plants (Popescu *et al.,* 2013). Sanskrit sholkas (Vedic Chants) exposed *Vigna radiate* plants were much healthier and showed enhanced shoot elongation. On the contrary discouraging words had negative impact on plant growth and quality (Patel *et. al*., 2016). *Ocimum sanctum* (*Tulasi*) plants subjected to Gayatri mantra, *Solanum indicum* plants exposed to Om Rsi Kesavaaya Namah mantra and *Tylopphora indica* climbers charged with Om Anantaya Namah mantra had showed increased growth along with enhanced efficacy in curing diseases (Karnick, 1983). Playing Western pop music and Buddhist *pirith* chanting to *Codariocalyx motorius*, scientists have found discernible effects of Buddhist *pirith* chanting on plant height, number of leaves, chlorophyll content, leaflet length, leaf width and leaf area; indicating improved growth performance when compared to Western pop music and control (Munasinghe *et al.,* 2018). Study also has shown that Agnihotra which is a Vedic ritual of chanting mantras with offerings of brown rice mixed with cow ghee to the fire, produced enhanced stem length and root length in *Vigna radiate* (moong) 38% and 31% respectively than the untreated control (Abhang *et al.,* 2015). Agnihotra also contributed an accelerated germnation rate in rice seeds along with increased growth rate in rice seedlings (Swamy and Nagendra, 2004). Sindhu bhairavi classical raga exposed *Oryza sativa* (paddy), *Triticum asteivum* (wheat), *Spinacia oleracea* (palak), *Glycine max* (soya) and *Macrotyloma uniflorum* (horse gram) plants exhibited better overall plant protein productions when compared to control, Kapi and Desh ragas respectively (Reddy and Ragavan, 2013).

Conclusion

Summing up all the above scientific observations, it can be concluded that audible sound with specific frequencies and intensities facilitated different stages of plant life cycle. Investigations were also noted in this domain with music. Plants were benefited with different genre of music but that dependence were species specific. The above studies indicate that there is a strong relationship between audible sound waves and plant growth and development but the detail mechanisms still remain obscure. The positive effect of audible sound stimuli including music on seed germination; plant growth; productivity; along with reduce requirements for chemicals fertilizers, pesticides; enhanced fitness and resistance against biotic as well as abiotic factors can benefit the sustainability of agricultural sector in a green way.

Conflict of interest

The author declare that they have no conflict of interest.

References

Abhang, P., Manasi, P., & Pramod, M. (2015). Beneficial effects of Agnihotra on environment and agriculture. *International Journal of Agricultural Science and Research, 5*(2),111-120

Altuntas, O., & Ozkurt, H. (2019). The assessment of tomato fruit quality parameters under different sound waves. *Journal of food science and technology*, *56*(4), 2186-2194.

Appel, H. M., & Cocroft, R. B. (2014). Plants respond to leaf vibrations caused by insect herbivore chewing. *Oecologia*, *175*(4), 1257-1266.

Bose, J. C. (1902): *Response in the Living and Non-living*. Longmans, Green, and Company, London, New York & Bombay.

Bose, J. C. (1926). *The nervous mechanism of plants*. Longmans, Green, and Company, London, New York & Bombay.

Cai, W., Dunford, N. T., Wang, N., Zhu, S., & He, H. (2016). Audible sound treatment of the microalgae Picochlorum oklahomensis for enhancing biomass productivity. *Bioresource technology*, *202*, 226-230.

Cai, W., He, H., Zhu, S., & Wang, N. (2014). Biological effect of audible sound control on mung bean (Vigna radiate) sprout. *BioMed research international*, *2014*.

Chatterjee, J., Jalan, A., & Singh, A. (2013). Effect of sound on plant growth. *Asian journal of plant science and research*, *3*(4), 28-30.

Chivukula, V., & Ramaswamy, S. (2014). Effect of different types of music on Rosa chinensis plants. *International journal of environmental science and development*, *5*(5), 431.

Choi, B., Ghosh, R., Gururani, M. A., Shanmugam, G., Jeon, J., Kim, J., & Bae, H. (2017). Positive regulatory role of sound vibration treatment in Arabidopsis thaliana against Botrytis cinerea infection. *Scientific Reports*, *7*(1), 1-14.

Chowdhury, A. R., & Gupta, A. (2015). Effect of music on plants–an overview. *International journal of integrative sciences, innovation and technology*, *4*(6), 30-34.

Chuanren, D., Bochu, W., Wanqian, L., Jing, C., Jie, L., & Huan, Z. (2004). Effect of chemical and physical factors to improve the germination rate of Echinacea angustifolia seeds. *Colloids and Surfaces B: Biointerfaces*, *37*(3-4), 101-105.

Coghlan, A. (1994). Good vibrations give plants excitations. *New Scientist*, *28*.

Collins, M. E., & Foreman, J. E. (2001). The effect of sound on the growth of plants.*Canadian Acoustics*, *29*(2), 3-10.

Creath, K., & Schwartz, G. E. (2004). Measuring effects of music, noise, and healing energy using a seed germination bioassay. *The Journal of Alternative & Complementary Medicine*, *10*(1), 113-122.

Cutler, S. R., Rodriguez, P. L., Finkelstein, R. R., & Abrams, S. R. (2010). Abscisic acid: emergence of a core signaling network. *Annual review of plant biology*, *61,*651-679

Das, M., & Ghosh, D. (2022) Quantitative effect of musical sound on seed germination kinetics in Pisum sativum. *Ecology. Environment. & Conservation, 28* (1), 357-361.

De Luca, P. A., & Vallejo-Marin, M. (2013). What's the 'buzz'about? The ecology and evolutionary significance of buzz-pollination. *Current opinion in plant biology*, *16*(4), 429-435.

Ekici, N., Dane, F., Mamedova, L., Metin, I., & Huseyinov, M. (2007). The effects of different musical elements on root growth and mitosis in onion (Allium cepa) root apical meristem (musical and biological experimental study). *Asian Journal of Plant Sciences*, *6*(2), 369-373.

Evans, P. T., & Malmberg, R. L. (1989). Do polyamines have roles in plant development?. *Annual review of plant biology*, *40*(1), 235-269.

Fan, R., Zhou, Q., & Zhao, D. (2010). Effect on changes of chlorophyll fluorescence in cucumber by application of sound frequency control technology. *Acta Agriculturae Boreali-occidentalis Sinica*, *19*(1), 194-197.

Gagliano, M., Mancuso, S., & Robert, D. (2012). Towards understanding plant bioacoustics. *Trends in plant science*, *17*(6), 323-325.

Ghosh, R., Mishra, R. C., Choi, B., Kwon, Y. S., Bae, D. W., Park, S. C., & Bae, H. (2016). Exposure to sound vibrations lead to transcriptomic, proteomic and hormonal changes in Arabidopsis. *Scientific reports*, *6*(1), 1-17.

Hicks, C. (1963). Growing corn to music. *Popular Mechanics*, *183*, 118-121.

Hou, T. Z., & Mooneyham, R. E. (1999). Applied Studies of Plant Meridian System I. The Effect of Agri-Wave Technology on Yield and Quality of Tomato. *The American journal of Chinese medicine*, *27*(01), 1-10.

Hou, T. Z., & Mooneyham, R. E. (1999). Applied Studies of the Plant Meridian System II. Agri-wave Technology Increases the Yield and Quality of Spinach and Lettuce and Enhances the Disease Resistant Properties of Spinach. *The American journal of Chinese medicine, 27*(02), 131-141.

Hou, T., Li, B., Teng, G., Qi, L., & Hou, K. (2010). Research and application progress of plant acoustic frequency technology. *Journal of China Agricultural University*, *15*(1), 106-110.

Hou, T., Li, B., Teng, G., Zhou, Q., Xiao, Y., & Qi, L. (2009). Application of acoustic frequency technology to protected vegetable production. *Transactions of the Chinese Society of Agricultural Engineering*, *25*(2), 156-160.

Hou, T., Li, B., Wang, M., Huang, W., Teng, G., Zhou, Q., & Li, Y. (2010). Influence of acoustic frequency technology on cotton production. *Transactions of the Chinese Society of Agricultural Engineering*, *26*(6), 170-174.

Huang, J., & Jiang, S. (2011). Effect of six different acoustic frequencies on growth of cowpea (Vigna unguiculata) during its seedling stage. *Agricultural Science & Technology-Hunan*, *12*(6), 847-851.

Jeong, M. J., Cho, J. I., Park, S. H., Kim, K. H., Lee, S. K., Kwon, T. R., & Siddiqui, Z. S. (2014). Sound frequencies induce drought tolerance in rice plant. *Pakistan Journal of Botany, 46*, 2015-2020.

Jeong, M. J., Shim, C. K., Lee, J. O., Kwon, H. B., Kim, Y. H., Lee, S. K., & Park, S. C. (2008). Plant gene responses to frequency-specific sound signals. *Molecular breeding*, *21*(2), 217-226.

Jia, Y., Wang, B. C., Wang, X. J., Wang, D. H., Duan, C. R., Toyama, Y., & Sakanishi, A. (2003). Effect of sound wave on the metabolism of chrysanthemum roots. *Colloids and Surfaces B:Biointerfaces*, *29*(2-3), 115-118.

Jiang, S., & Huang, J. (2012). Effects of music acoustic frequency on greenhouse vegetable. *Journal of Zhejiang University of Science and Technology*, *24*, 287-293.

Jiang, S., Huang, J., Han, X., & Zeng, X. (2011). Influence of audio frequency mixing of music and cricket voice on growth of edible mushrooms. *Transactions of the Chinese Society of Agricultural Engineering*, *27*(6), 300-305.

Johnson, K. A., Sistrunk, M. L., Polisensky, D. H., & Braam, J. (1998). Arabidopsis thaliana responses to mechanical stimulation do not require ETR1 or EIN2. *Plant Physiology*, *116*(2), 643-649.

Karnick, C. R. (1983). Effect of mantras on human beings and plants. *Ancient Science Life*, *2*(3), 141-147.

Keli, S., Baoshu, X., Guoyou, C., & Ziwei, S. (1999). The effects of alternative stress on the thermodymical properties of cultured tobacco cells. *Shengwu Wuli Xuebao*, *15*(3), 579-583.

Kim, J. Y., Ahn, H. R., Kim, S. T., Min, C. W., Lee, S. I., Kim, J. A., & Jeong, M. J. (2016). Sound wave affects the expression of ethylene biosynthesis-related genes through control of transcription factors RIN and HB-1. *Plant Biotechnology Reports*, *10*(6), 437-445.

Kim, J. Y., Lee, J. S., Kwon, T. R., Lee, S. I., Kim, J. A., Lee, G. M.,& Jeong, M. J. (2015). Sound waves delay tomato fruit ripening by negatively regulating ethylene biosynthesis and signaling genes. *Postharvest Biology and Technology*, *110*, 43-50.

Klein, R. M., & Edsall, P. C. (1965). On the reported effects of sound on the growth of plants. *Bioscience*, *15*(2), 125-126.

Kwon, Y. S., Jeong, M. J., Cha, J., Jeong, S. W., Park, S. C., Shin, S. C., & Bae, D. W. (2012). Comparative proteomic analysis of plant responses to sound waves in Arabidopsis. *Journal of Plant Biotechnology*, *39*(4), 261-272.

Li, B., Wei, J., Wei, X., Tang, K., Liang, Y., Shu, K., & Wang, B. (2008). Effect of sound wave stress on antioxidant enzyme activities and lipid peroxidation of Dendrobium candidum. *Colloids and Surfaces B: Biointerfaces*, *63*(2), 269-275.

Liu, Y. Y., Wang, B. C., Long, X. F., Duan, C. R., & Sakanishi, A. (2002). Effects of sound field on the growth of Chrysanthemum callus. *Colloids and surfaces B: Biointerfaces*, *24*(3-4), 321-326.

Lovelli, S., Scopa, A., Perniola, M., Di Tommaso, T., & Sofo, A. (2012). Abscisic acid root and leaf concentration in relation to biomass partitioning in salinized tomato plants. *Journal of plant physiology*, *169*(3), 226-233.

Meng, Q. W., Zhou, Q., Gao, Y., & Zheng, S. J. (2011). Effects of acoustic frequency treatment on photosynthetic and chlorophyll fluorescence characters of tomato. *Acta Agriculturae Jiangxi*, *23*, 57-59.

Meng, Q. W., Zhou, Q., Gao, Y., Zheng, S. J., & Gao, Y. (2012). Effects of plant acoustic frequency technology on the growth traits, chlorophyll content and endogenous hormones of Lycopersicon esculentum. *Hubei Agricultural Sciences*, *51*(8), 1591-1595.

Meng, Q., Zhou, Q., Zheng, S., & Gao, Y. (2012). Responses on photosynthesis and variable chlorophyll fluorescence of Fragaria ananassa under sound wave. *Energy Procedia*, *16*, 346-352.

Munasinghe, D. S. P., Weerakoon, S. R., & Somaratne, S. (2018). The effect of Buddhist pirith chanting and Western pop music on growth performance of "Pranajeewa", Codariocalyx motorius (Houtt.) H. Ohashi. *Ceylon Journal of Science*, *47*(4), 357-361.

Pal Bais, H., & Ravishankar, G. A. (2002). Role of polyamines in the ontogeny of plants and their biotechnological applications. *Plant cell, tissue and organ culture*, *69*(1), 1-34.

Patel, A., Shankar, S., &. Narkhede, S. (2016). Effect of Sound on the growth of plant: Plants pick up the vibrations. *Asian Journal of Plant Science and Research*, *6*(1), 6-9.

Ponniah, S. (1955). On the effect of musical sounds of stringed instruments on the growth of plants. In : *Proc. Indian Sci. Cong,42*(3),255.

Popescu, Ș., & Mocanu, R. (2013). The effect of music produced by winds instruments on cultivated plants. *Lucrări Științifice, Universitatea de Stiinte Agricole Și Medicină Veterinară" Ion Ionescu de la Brad" Iași, Seria Agronomie*, *56*(1), 127-129.

Qi, L., Teng, G., Hou, T., Zhu, B., & Liu, X. (2009, October). Influence of sound wave stimulation on the growth of strawberry in sunlight greenhouse. In : *International Conference on Computer and Computing Technologies in Agriculture* (pp. 449-454). Springer, Berlin, Heidelberg.

Rachieru, M. A., Iacob, I., Cristea, M., & Ortan, A. (2017). Studies regarding the influence of music on the wheat plants growth. *Journal of Young Scientist*, *5*, 73-76.

Reddy, K. G., & Ragavan, R. (2013). Classical ragas: A new protein supplement in plants. *Indian Journal of Life Sciences*, *3*(1), 97.

Retallack, D. L. (1973). *The sound of music and plants*. DeVorss.

Seregin, I. V., & Ivanov, V. B. (2001). Physiological aspects of cadmium and lead toxic effects on higher plants. *Russian journal of plant physiology*, *48*(4), 523-544.

Shaobin, G., Wu, Y., Li, K., Li, S., Ma, S., Wang, Q., & Wang, R. (2010). A pilot study of the effect of audible sound on the growth of Escherichia coli. *Colloids and Surfaces B: Biointerfaces*, *78*(2), 367-371.

Sharma, D., Gupta, U., Fernandes, A. J., Mankad, A., & Solanki, H. A. (2015). The effect of music on physico-chemical parameters of selected plants. *International Journal of Plant, Animal and Environmental Sciences*, *5*(1), 282-287.

Shen, Z. W., Sun, K. L., Yang, J., Cai, G., & Xi, B. (1999). The secondary structure changes of plant cell wall proteins aroused by strong sound waves using FT-IR. *Acta Photonica Sinica*, *28(7)*, 600-602.

Singh, T. C. N., & Ponniah, S. (1955). On the Response of Structure of the Leaves of Balsam and Mimosa to the Muscial Sounds of Violin. *Proceedings of the Indian Scientific Congressional Association*, *42*, 254.

Subramanian, S., Chandrasekharan, P., Madhava-Menon, P., Raman, V. S., & Ponnaiya, B. W. X. (1969). study of the effect of music on the growth and yield of paddy. *Madras Agricultural Journal,* 56, 510-516.

Swamy, N. V. C., & Nagendra, H. R. (2004). Vivekanda yoga research foundation bangalore-560019 "Effect of agnihotra on the germination of rice seed. *Indian journal of traditional knowledge*, *3*(3), 231-239.

Takahashi, H., Suge, H., & Kato, T. (1991). Growth promotion by vibration at 50 Hz in rice and cucumber seedlings. *Plant and cell physiology*, *32*(5), 729-732.

Uchida, A., & Yamamoto, K. T. (2002). Effects of mechanical vibration on seed germination of Arabidopsis thaliana (L.) Heynh. *Plant and cell physiology*, *43*(6), 647-651.

Vanol, D., & Vaidya, R. (2014). Effect of types of sound (music and noise) and varying frequency on growth of guar or cluster bean (cyamopsis tetragonoloba) seed germination and growth of plants. *Quest*, *2*(3), 9-14.

Wang, B. C., Shao, J., Li, B., Lian, J., & Duan, C. R. (2004). Soundwave stimulation triggers the content change of the endogenous hormone of the Chrysanthemum mature callus. *Colloids and surfaces B: Biointerfaces*, *37*(3-4), 107-112.

Wang, B., Zhao, H., Duan, C., & Sakanishi, A. (2002). Effects of cell wall calcium on the growth of Chyrsanthemum callus under sound stimulation. *Colloids and Surfaces B: Biointerfaces*, *25*(3), 189-195.

Wang, B.C., Chen, X., Wang, Z., Fu, Q.Z., Hao, Z., & Ran, L. (2003). Biological effect of sound field stimulation on paddy rice seeds. *Colloids and Surfaces B: Biointerfaces*, *32*(1), 29-34.

Wang, B.C., Zhao, H.C., Liu, Y.Y., Jia, Y., & Sakanishi, A. (2001). The effects of alternative stress on the cell membrane deformability of chrysanthemum callus cells. *Colloids and surfaces B: Biointerfaces*, *20*(4), 321-325.

Wang, X. J., Wang, B. C., Jia, Y., Duan, C. R., & Sakanishi, A. (2003). Effect of sound wave on the synthesis of nucleic acid and protein in chrysanthemum. *Colloids and Surfaces B: Biointerfaces*, *29*(2-3), 99-102.

Wang, X. J., Wang, B. C., Jia, Y., Huo, D., & Duan, C. R. (2003). Effect of sound stimulation on cell cycle of chrysanthemum (Gerbera jamesonii). *Colloids and surfaces. B, Biointerfaces, 29*(2-3), 103-107.

Weinberger, P., & Measures, M. (1979). Effects of the intensity of audible sound on the growth and development of Rideau winter wheat. *Canadian journal of botany*, *57*(9), 1036-1039.

Wilkinson, S., & Davies, W. J. (2010). Drought, ozone, ABA and ethylene: new insights from cell to plant to community. *Plant, cell & environment*, *33*(4), 510-525.

Xiao, H. (1990). Vegetables and music. *Pictorial science*, *6*, 36.

Yang, X. (2004). Effects of different sound intensities on root development of Actinidia chinensis plantlet. *Chinese Journal of Applied and Environmental Biology*, *10*(3), 274-276.

Yang, X. C., Wang, B. C., & Duan, C. R. (2003). Effects of sound stimulation on energy metabolism of Actinidia chinensis callus. *Colloids and Surfaces B: Biointerfaces*, *30*(1-2), 67-72.

Yang, X. C., Wang, B. C., Duan, C. R., Dai, C. Y., Jia, Y., & Wang, X. J. (2002). Brief study on physiological effects of sound field on Actinidia Chinese callus. *Journal of Chongqing University*, *25*, 79-84.

Yu, S., Jiang, S., Zhu, L., Zhang, J., & Jin, Q. (2013). Effects of acoustic frequency technology on rice growth, yield and quality. *Transactions of the Chinese Society of Agricultural Engineering*, *29*(2), 141-147.

Zha, X. Q., Luo, J. P., & Wei, P. (2009). Identification and classification of Dendrobium candidum species by fingerprint technology with capillary electrophoresis. *South African Journal of Botany*, *75*(2), 276-282.

Zhang, J., Jia, W., Yang, J., & Ismail, A. M. (2006). Role of ABA in integrating plant responses to drought and salt stresses. *Field Crops Research*, *97*(1), 111-119.

Zhao, H. C., Wu, J., Xi, B. S., & Wang, B. C. (2002). Effects of sound-wave stimulation on the secondary structure of plasma membrane protein of tobacco cells. *Colloids and Surfaces B: Biointerfaces*, *25*(1), 29-32.

Zhao, H. C., Wu, J., Zheng, L., Zhu, T., Xi, B. S., Wang, B., & Younian, W. (2003). Effect of sound stimulation on Dendranthema morifolium callus growth. *Colloids and Surfaces B: Biointerfaces*, *29*(2-3), 143-147.

Zhou, Q., Qu, Y., Li, B., Hou, T., Zhu, B., & Wang, D. (2010). Effects of sound frequency treatment on plant characters and chlorophyll fluorescence of the strawberry leaf. *Journal of China Agricultural University*, *15*(1), 111-115.

Zhu, J., Jiang, S., & Shen, L. (2011). Effects of music acoustic frequency on indoleacetic acid in plants. *Agricultural Science & Technology-Hunan*, *12*(12), 1749-1752.

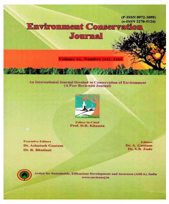
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures

Environment Conservation Journal 24 (3):305--310, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Influence of heat treatment on the properties of tin oxide nanoparticles: A potential material for environmental remediation applications

Manmeet Kaur
Department of Physics, MM Engineering College, Maharishi Markandeshwar, Mullana-Ambala, Haryana, India
Dixit Prasher
Department of Physics, MM Engineering College, Maharishi Markandeshwar, Mullana-Ambala, Haryana, India
Ranjana Sharma ✉
Department of Physics, MM Engineering College, Maharishi Markandeshwar, Mullana-Ambala, Haryana, India

ARTICLE INFO

Received : 05 December 2022
Revised : 26 February 2023
Accepted : 20 March 2023

Available online: 27 June 2023

Key Words:
Band gap
EDAX
Metal oxides
SEM
XRD

ABSTRACT

Metal oxides have gained a growing interest in the field of material science owing to their size and shape dependent physiochemical properties. Tin oxide (SnO_2) is considered as a multifaceted material with its widespread applications such as oxidation catalysis, energy harvesting, bio-imaging, gas sensing, storage devices and many more. This study reports the synthesis of SnO_2 nanoparticles derived via sol-gel route. To observe the effect of thermal treatment on the grown material, the samples were subjected to calcination at different temperature ranging from 350 °C to 550 °Cfor about 4 hrs. The structural, compositional, morphological and optical properties of Tin oxide were studied by XRD, EDAX, FESEM, and UV-Vis spectroscopic analysis respectively. The XRD pattern consists only SnO_2 peaks with preferred orientation along (110) plane. The crystallite size increases with higher calcination temperature and is found in the range of 3-15 nm. All the peaks corresponding to SnO_2 matches with the standard data indicating the growth of good quality single phase material. Compositional data reveals that that grown material manifested in required stoichiometric ratio of SnO. Scanning electron micrographs show uniform growth of SnO_2 nanoparticles with particle size ranging from 10-20 nm. The energy band gap of the SnO_2 calculated by optical studies was 3.1eV and 3.0 eV for 450 °Cand 550 °Crespectively. The calculated band gap lies in the visible region of the solar spectrum which could be beneficial for the enhanced photocatalytic performance of the SnO_2 nanoparticles.

Introduction

Metal oxides nanostructures are known for exhibiting unique and excellent physiochemical and optical properties as compared to their bulk counterparts due to their ability to show quantum confinement at nanoscale. Among various literature reported metal oxide semiconductors, particularly, Tin oxide (SnO_2) has gained considerable interest of scientific community due to its multifaceted applications in different sectors such as oxidation catalysis, energy harvesting, sensors and storage devices etc (Kaur *et al.,*2022). SnO_2, being n-type semiconducting oxide known to have wide bandgap energy of nearly 3.4-3.6 eV and also demonstrates strong thermal ability and magnificent transparency in the visible range (Lin *et al.,* 2016). The size dependent properties play a pivotal role in modifying SnO_2 nanostructures performance which provides the pathway for various applications. It is very important to control the particle size during the synthesis process (Mohana Priya *et al.,* 2016) as it directly correlates with the optical band gap which plays a crucial role in the photocatalytic performance of the metal oxides Several wet chemical synthesis route such sol-gel, hydrothermal, co-precipitation, spray pyrolysis and microwave method have been adopted by various

Corresponding author E-mail: *ranjanadixit2417@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16482524

researchers to fabricate SnO_2 nanoparticles with different size and distributions. Among all of them, we employed sol-gel approach owing to its numerous benefits such as room temperature synthesis, cost effectiveness, and it possesses better homogeneity in results. Due to its simplicity and flexible nature nanocomposites can synthesized at an affordable price (Parashar *et al.,* 2020; Pawar *et al.,* 2012). Different operating features for instance reaction time, pH value and concentration of catalysts enhance functionality of synthesized SnO_2 nanoparticles. Also, the precise control on the annealing temperature helps in modifying the structure, morphology and band gap of tin oxide nanoparticles (Habte *et al.,* 2020; Rasheed *et al.,* 2016). Diallo *et al.* (2016) reported the calcination of cassiterite SnO_2 nanoparticles at elevated temperatures from 400 to 900 °C. Nehru *et al.* (2012) reported spherical SnO_2 nanoparticles using precipitation route. They showed that size of crystallite increases with the increment in temperature. It is evidently revealed that the crystallinity, size and phase of synthesized samples can effectively tuned the nanostructures by the process of controlled thermal treatment. In this present research work, efforts have been made to synthesize the SnO_2 nanoparticles via sol-gel approach. The main approach of the work was to study the impact of calcinating temperature on the structure, morphology and optical behavior of the prepared tin oxide nano powder.

Material and Methods

Tin (II) chloride dihydrate ($SnCl_2.2H_2O$), ammonia hydroxide (NH_4OH) and ethanol (C_2H_5OH) were procured from Sigma Aldrich. In this work sol-gel methodology was adopted to synthesize tin oxide (SnO_2) nanoparticles (Patel *et al.,* 2021). Initially, a sol was prepared by taking 0.3M Stannous chloride dihydrate ($SnCl_2.2H_2O$) as a precursor and dissolved completely in ethanol (50ml) subjected to constant stirring. To the stirred solution, freshly prepared ammonia drops (3.0 M) were added to sustain the pH 10.. At room temperature, the obtained gel was allowed to age for 10 hours. The so formed gel was then centrifuged and washed 3-4 times with distilled water to wipe out excess Cl^- ions. A schematic flowchart of the experimental procedure is shown in Figure 1. The structural and morphological analysis of the synthesized material was performed using X-ray diffractometer with Cu Kα-1 radiation (1.5406Å) and scanning electron microscope with EDS respectively. The UV-VIS absorption studies of prepared SnO_2 samples were done using UV-VIS Spectra Max iD3 spectrophotometer in the range 200-800 nm.

The mechanism involved during chemical reaction between $SnCl_2.2H_2O$ and NH_4OH is given below:

$$\mathbf{SnCl_2 \cdot 2H_2O + 2NH_4OH \rightarrow Sn(OH)_2 + 2NH_4CI + 2H_2O}$$

$$\mathbf{Sn(OH)_2 \rightarrow SnO+H_2O}$$

$$\mathbf{SnO+1/2\ O_2 \rightarrow SnO_2}$$

The overall reaction is:

$$\mathbf{SnCl_2\cdot 2H_2O+ 2NH_4OH+ 1/2O_2 \rightarrow SnO_2 +2NH_4Cl+3H_2O}$$

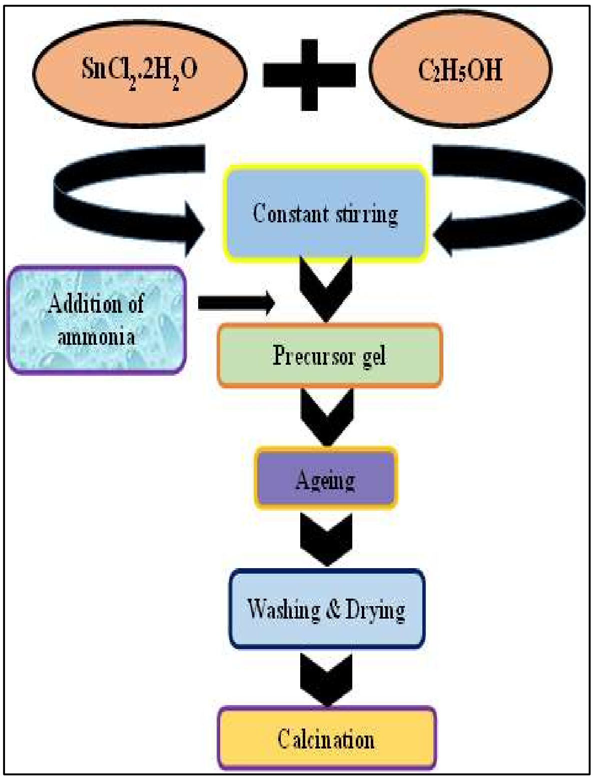


Figure 1: Flowchart of experimental procedure

Results and Discussion

Figure 2 reflects the XRD peaks of the prepared SnO_2 and the observed peaks indicating planes (110), (101), (200), (211), (220), (002), (310), (112), (301), (202), (321) are matched with the JCPDS No: 41-1445, a=4.738Å and c=3.178Å which confirms the tetragonal rutile structure of the nanoparticles and the diffracted peaks of the prepared samples agrees very well with the lattice parameters. Fig 2 clearly demonstrates a correlation between the calcinating temperature and sharpness, height and narrowness of the emerged XRD predominant peaks revealing the formation of nanocrystallites with elevated temperature. The size of crystallites of SnO_2 particles was derived by applying Debye Scherer formula (Kundu *et al.,* 2013; Gaber *et al.,* 2014):

D= 0.94 λ / β Cos θ…………………………(i)

$$D = 0.94\, \lambda / \beta \cos \theta \quad \text{(i)}$$

In equation (i), D is the crystallite size, wavelength of X-rays is 'λ' , β is full width - half maximum (in radian) and θ is the diffracting angle.

The calculated crystallite size was found in the range of 3-15 nm. The results obtained clearly show that the crystallinity of the sample increases on increasing calcination temperature because defect concentration decreases at elevated temperature. Our results corroborated the previous findings reported by the various researchers (Al-Hada, N.M. *et al.,* 2018; Khaenamkaew *et al.,* 2020).The obtained crystallite dimension of the SnO_2 nanoparticles with increasing calcination temperature is shown in the table 1.

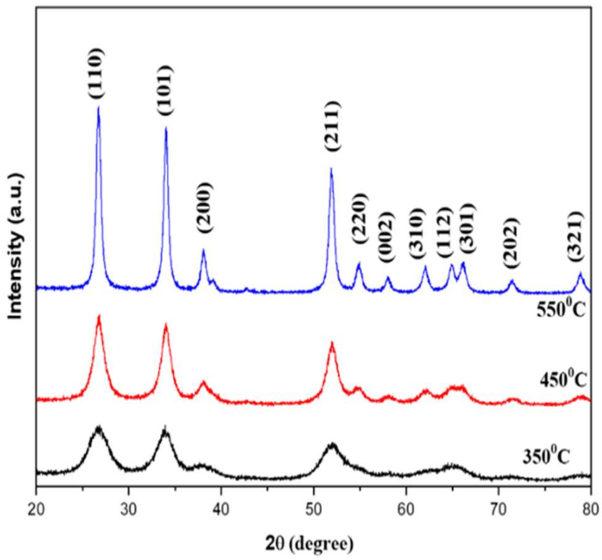


Figure 2: XRD peaks of SnO_2 nanoparticles calcined at different calcination temperatures

Table 1: Influence of calcination temperature on crystallite size

Calcination Temperature (^0C)	Crystallite size (nm)
350	2.85
450	7.1
550	13.4

The atomic composition of the required elements and morphology of the prepared material was also studied by using scanning electron microscopy with EDS attachment. The SEM pictures of the SnO_2 particles are presented in the Figure 3. Generally, the size of grains depends on the nucleation rate and growth process of the nanostructures. The FESEM images indicated that the formation of spherical tin oxide nano particles and was found to be in 10-20 nm range. It is clear from the micrographs that after thermal treatment ranging from 350 °C– 550 °C, the particle size gradually increased due to higher nucleation rate which further resulted in the lower bandgap energy. These findings are consistent with the past reported literature (Tazikeh, S *et al.,* 2014).

EDAX analysis was also conducted to analyze the composition of SnO_2 nanoparticles at different calcination temperature and the results are presented in the Figure 4, which confirm that tin and oxygen element exist in well stoichiometric ratio in the samples. Figure 4(a) shows that at temperature 350 ^0C, the Sn and O atomic percentage is around 43.06, 56.94 respectively. In this case the grown material is Sn rich which signifies its oxygen-deficient state which means that there are more O vacancies or Sn interstitial sites. Generally, increase in calcination temperature results in decreasing the Sn content, while O content increases, which means that Sn interstitial or O vacancies were reduced into matrix. This fact can be seen in figure 4(b) where Sn:O molar ratio is perfectly near to stoichiometry. Hence, at higher temperature large particle size causes decrement in surface defects (Zulfiqar *et al.,* 2017).

The optical study of the synthesized samples was conducted from 300-800 nm wavelength. The energy band gap of the samples was evaluated from Tauc's formula:

$$\alpha h\nu = A\,(h\nu - E_g)^n$$

Where, α is known as absorption coefficient, A is absorbance, hν stands for energy of incident photon and optical energy band gap is E_g (Ahmed *et al.*, 2012). The energy band gap of the SnO_2 grown at different calcinating temperatures was also determined. A Tauc plot of the samples can be plotted off $(\alpha h\nu)^2$ vs hν as shown in the Fig. 5 and the calculated band gap was 3.1eV and 3.0 eV for 450^{0}C and 550^{0}C respectively. As the calcination temperature raised, the optical band gap moved towards lower energy range (visible region). Similar behaviour was also reported by Baco*et al.* 2012). The red-shift occurred due to the increment in particle size, decrease in grain boundaries and defect densities. These results states that the grown

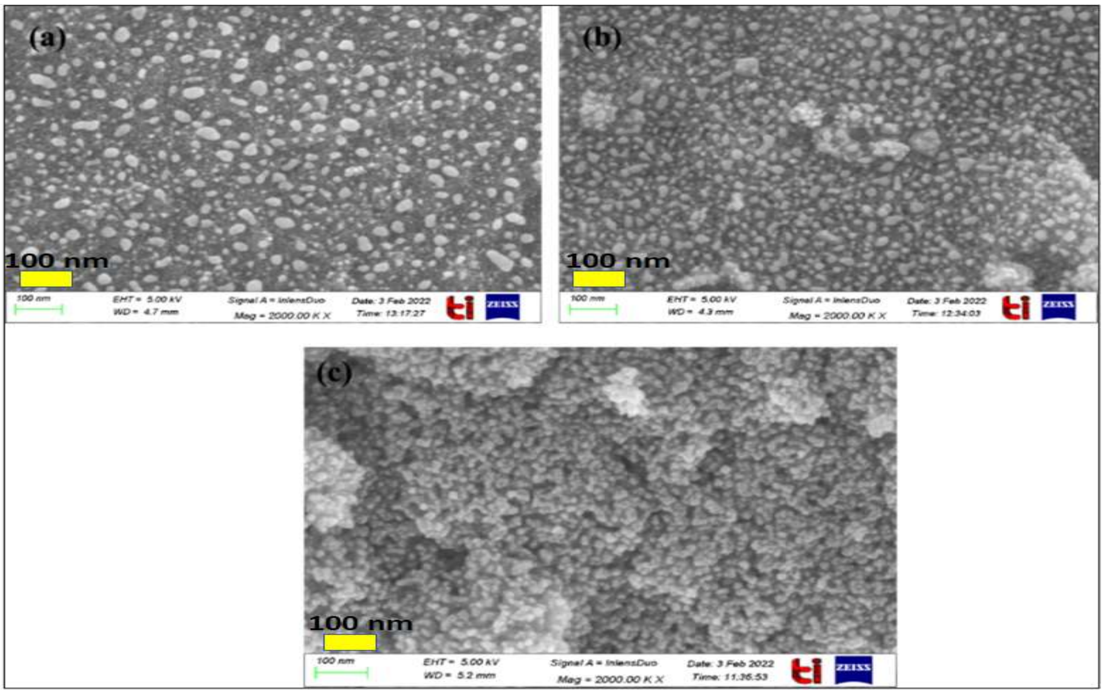


Figure 3: SEM micrographs of SnO_2 calcined at (a) 350 °C, **(b) 450** °C **and (c) 550** °C

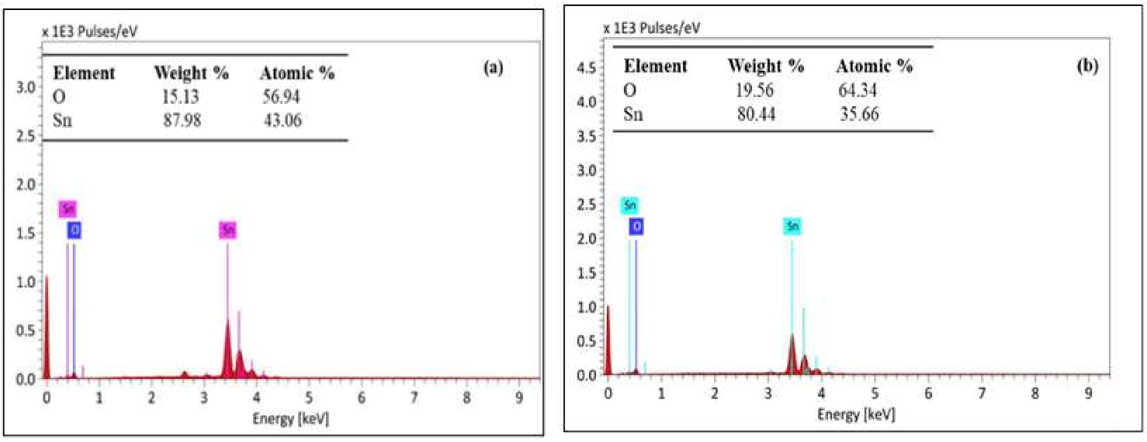


Figure 4: The composition analysis (EDAX) of SnO_2 NPs calcined at (a) 350 °C, **(b) 550**°C

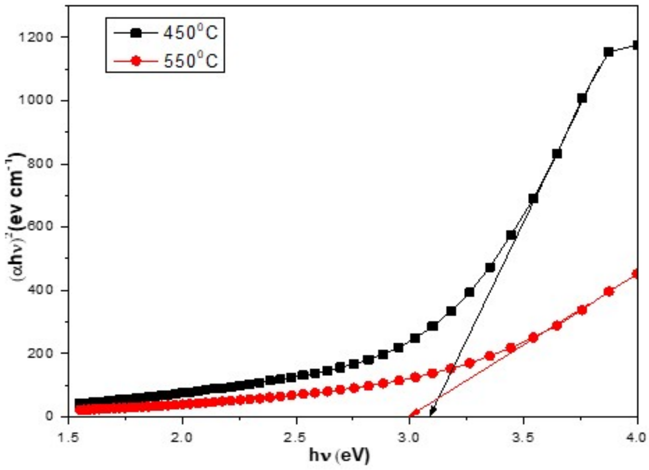


Figure 5: $(\alpha h\nu)^2$ versus hν plot shows the variation in the band gap energy at different calcinating temperature

SnO_2 nanoparticles can be used as highly promising material for solar optoelectronic devices and environment remediation applications especially for the natural sunlight driven photocatalytic dye degradation (Vidhya *et al.,* 2020)

Conclusion

In this present report, sol-gel technique was successfully employed to derive tin oxide (SnO_2) nanoparticles and the influence of calcinating temperature on its structure, morphology and band gap is investigated. The XRD results confirms the tetragonal geometry of the grown samples and shows that on increasing the temperature the crystallite size of the samples increases from 2.85 to 13.4 nm. The FESEM studies reveal the particle size of the tin oxide ranging between 10-20 nm. The band gap value of the prepared nanoparticles marginally changed from 3.1 to 3.0 eV at elevated temperature from 450°Cto 550°C.

Acknowledgement

One of the author, Ms. Manmeet Kaur acknowledges the MM (DU), Mullana for the financial assistance as a Ph.D Research fellowship. The authors are grateful to Prof. N. K. Batra, HOD Mechanical Engineering, MM (DU) for providing the calcination facility. We are also thankful to XRD lab, SAIF, PU Chandigarh, SAI Lab, TIET Patiala and Central R&D cell MM (DU) for the characterizations of the samples.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ahmed, A. S., Azam, A., Muhamed Shafeeq, M., Chaman, M., & Tabassum, S.(2012). Temperature dependent structural and optical properties of tin oxide nanoparticles. *Journal of Physics and Chemistry of Solids*, *73*(7), 943–947.

Al-Hada, N.M.; Kamari, H.M.; Baqer, A.A.; Shaari, A.H.; Saion, E. (2018) Thermal Calcination-Based Production of SnO_2 Nanopowder: An Analysis of SnO_2 Nanoparticle Characteristics and Antibacterial Activities. *Nanomaterials* , *8(4)*, 250, 18 pages.

Baco, S., Chik, A., & Md. Yassin, F. (2012). Study on Optical Properties of Tin Oxide Thin Film at Different Annealing Temperature. *Journal of Science and Technology*, 4(1) 61-71.

Diallo, A., Manikandan, E., Rajendran, V., & Maaza, M. (2016). Physical enhanced photocatalytic properties of green synthesized SnO_2 nanoparticles via Aspalathus linearis. *Journal of Alloys and Compdounds*, 681, 561–570.

Gaber, A., Abdel-Rahim, M.A., Abdel-Latief, A.Y. & Abdel-Salam M. N. (2014). Influence of Calcination Temperature on the Structure and Porosity of Nanocrystalline SnO_2 Synthesized by a Conventional Precipitation method. *International Journal of Electrochemical Science*, *9*(1), 81-95.

Habte, A. G., Hone, F. G. & Dejene, F. B. (2020). Influence of annealing temperature on the structural, morphological and optical properties of SnO_2 nanoparticles. *Physica B: Condensed Matter*, *580*, 411760.

Kaur, M., Prasher, D., & Sharma, R. (2022). Recent Developments on I and II Series Transition Elements Doped SnO_2 Nanoparticles and its Applications For Water Remediation Process: A Review. *Journal of Water and Environmental Nanotechnology*, *7*(2), 194-217.

Kundu, V. S., Dhiman, R. L., Singh, D., Maan, A. S., & Arora, S. (2013). Synthesis and characterization of tin oxide nanoparticles via sol-gel method using ethanol as solvent. *International Journal of Advanced Research in Science and Engineering*, *2*(1), 1-5.

Lin, S.S., Tsai, Y.S., & Bai, K.R. (2016):Structural and physical properties of tin oxide thin films for optoelectronic applications. *Applied Surface Science,380*, 203–209.

Mohana Priya, S., Geetha, A., & Ramamurthi, K. (2016). Structural, morphological and optical properties of tin oxide nanoparticles synthesized by sol–gel method adding hydrochloric acid. *Journal of Sol-gel Science and Technol*ogy, *78*(2), 365–372.

Nehru, L. C., Swaminathan, V., & Sanjeeviraja, C. (2012). Photoluminescence Studies on Nanocrystalline Tin Oxide Powder for Optoelectronic Devices. *American Journal of Materials Science*, *2*(2), 6–10.

Khaenamkaew, Panya , Dhonluck Manop, Chaileok Tanghengjaroen, Worasit Palakawong Na Ayuthaya, (2020). Crystal Structure, Lattice Strain, Morphology, and Electrical Properties of SnO_2 Nanoparticles Induced by Low Calcination Temperature, *Advances in Materials Science and Engineering*, 2020, Article ID 3852421, 10 pages.

Parashar, M., Shukla, V.K., & Singh, R. (2020). Metal oxides nanoparticles via sol–gel method: a review on synthesis, characterization and applications. *Journal of Materials Science: Materials in Electron*ics, *31*(5), 3729–3749.

Patel, G. H., Chaki, S. H., Kannaujiya, R. M., Parekh, Z. R., Hirpara, A. B., Khimani, A. J., & Deshpande, M. P. (2021). Sol-gel synthesis and thermal characterization of SnO_2 nanoparticles. *Physica B: Condensed Matter*, *613*, 412987.

Pawar, B.G., Pinjari, D.V., Kolekar, S.S., Pandit, A.B., & Han, S.H. (2012). Effect of Sintering Temperatures on the Synthesis of SnO_2 Nanospheres. *International Scholarly Research Notices*, 2012.

Rasheed, R.T., & Al-Algawi, S. D. (2016). Annealing Effect of SnO_2 Nanoparticles Prepared by the Sol–Gel Method. *Journal of Advanced Physics,5*(3), 236–240.

Tazikeh, S., Akbari, A., Talebi, A. et al. (2014). Synthesis and characterization of tin oxide nanoparticles via the Co-precipitation method. *Materials Science-Poland* 32, 98–101.

Vidhya, M., Raja Pandi, P., Archana, R., Sadayandi, K., Sagadevan, Suresh., Gunasekaran, S., Podder, J., Mohammad, Faruq., Hamad A. Al-Lohedan, Won, Chun Oh. (2020). Comparison of sunlight-driven photocatalytic activity of semiconductor metal oxides of tin oxide and cadmium oxide nanoparticles, *Optik,* 217, 164878.

Zulfiqar; Khan, R., Yuan, Y., Iqbal, Z., Yang, J., Wang, W., Ye, Z., & Lu, J. (2017). Variation of structural, optical, dielectric and magnetic properties of SnO_2 nanoparticles. *Journal of Materials Science: Materials in Electron*ics, *28*(6), 4625–4636.

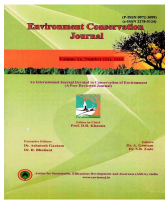
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures

Environment Conservation Journal 24 (3):311--325, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Lignocellulosic biomass feedstock: A benchmarking green resource for sustainable production of bioplastics

Shivani Narwal
Department of Environmental Science, Maharshi Dayanand University Rohtak, Haryana, India
Rajesh Dhankhar ✉
Department of Environmental Science, Maharshi Dayanand University Rohtak, Haryana, India
Savita Kalshan
Department of Environmental Science, Maharshi Dayanand University Rohtak, Haryana, India
Poonam Yadav
Department of Environmental Science, Maharshi Dayanand University Rohtak, Haryana, India
Azad Yadav
Department of Environmental Science, Maharshi Dayanand University Rohtak, Haryana, India
Tamanna Deswal
Department of Environmental Science, Maharshi Dayanand University Rohtak, Haryana, India

ARTICLE INFO

Received : 25 November 2022
Revised : 14 March 2023
Accepted : 01 April 2023

Available online: 17 August 2023

Key Words:
Biopolymer synthesis
Pre-treatment
Polyhydroxyalkanoates
Polylactic acid
Renewable feedstock

ABSTRACT

Presence of plastics in the surroundings is ubiquitous, as generation of plastics is booming globally and it gets accumulated in oceans leading to deleterious impacts on marine life, public health and the surrounding environment. Owing to its non-degradable nature, plastic particles remain in surroundings for extended periods which automatically facilitate its out spreading. Therefore, there is a need to shift to bio-based plastics, as bio-based green economy hinges on sustainable employment of bioresources for generating a broad spectrum of products, biofuels, chemicals and bioplastics. Typically bioplastics are synthesized from bio-based resources considered to contribute more to sustainable production of plastic as a part of the circular economy. Bioplastics are luring attention and growing as counterfeit material for petroleum-derived plastics owing to their biodegradability. Recently an engrossed interest has been burgeoning in producing drop-in polymers and new-fangled bioplastics by utilizing lignocellulosic feedstock. This paper reviews the enormous potential of lignocellulosic feedstock as a significant inedible substrate for bioplastic synthesis. Polyhydroxyalkanoates, polyurethanes, polylactic acid and starch-bioplastic are prevailing bio-based plastic comparably derived from lignocellulosic biomass. In forthcoming years bioplastic derived years' bioplastic derived from lignocellulose will loom as valuable material in numerous fields for an extensive range of cutting-edge applications.

Introduction

Plastics have circumvented other polymers and conquered human lives owing to their inexpensiveness, flexibility, versatility and exceptional thermal properties. Plastic is an indispensable artificial polymer that has surmounted contemporary societies. Accumulating plastic wrecks in marine areas dates back half a century, with progress piling up on the ocean's surface in the past 60 years. But even in one of the most promising scenarios of the ultimate reduction of plastic waste in forthcoming years, plastic is aggregating and building up regularly in the environment. The projected global emanation of plastics in ocean lakes and rivers ranges from 9 to 23 million tons yearly, comparably 13 to 25 million metric tons annually into the terrestrial environment as of 2016 (Rhodes, 2018). Plastic has numerous applications for multifarious utilizations and is a

Corresponding author E-mail: *rajeshdhankhar669@gmail.com*
Doi: https://doi.org/10.36953/ECJ.16352517

distinguished counterfeit for diverse materials. Proclaimed global reports show that relatively 187 million tonnes of synthetic polymers based on petroleum are profusely generated annually and consequentially result in an enormous accumulation of plastic material, which induces environmental deterioration (Li *et al.,* 2021). Plastic garbage makes up around 8% of the entire weight of municipal solid waste, which is 25% (Lau *et al.,* 2020). Degradation of conventional plastics takes about 20-100 years in nature. It creates perilous problems, for instance, water pollution, air pollution and environmental contamination, which are further infuriated by the incineration of petroleum-based plastics as it discharges noxious gases into the atmosphere. Plastic pollution is extensively perceived as a principal environmental burden, peculiarly in aquatic ecosystems due to prolonged biophysical breakdown.Additionally, the presence of plastics in oceans manifests an alarming situation for marine organisms and affects them gigantically. Plastics consist of pernicious components such as phthalates, antimony trioxide, bisphenol A (BPA), and polyfluorinated compounds; they generally leach and cause adverse impacts on health and the environment. Plastics customarily end up in landfills with municipal solid waste due to inadequate waste management practices. There are elucidations required to solve the menacing problem of plastic waste, which has triggered the need to generate environment-friendly materials such as bioplastics. Bioplastics are innovative materials of this century and would be of immense relevance to the materials world. Bioplastic generation and usage will advance more in the forthcoming years; owing to this; these materials require careful evaluation for waste management and sustainability. Bioplastics are approaching imminent substitutes for petroleum-based plastics to diminish the detrimental environmental impacts and perilous health issues (Okolie *et al.,* 2020). Several applications of bioplastics have been depicted in figure 1. Bioplastic fabrication by exploiting renewable feedstocks has been endorsed in former years for the generation of advanced bio-sourced plastics. Using renewable resources for bioplastic production has distinguished research interest in the past years as an expedient to mitigate and alleviate greenhouse gas emissions that are principally generated by fossil fuel burning, production and fabrication of petrochemical-based plastics. Because such materials might be used for the preservation of resources which automatically renders sustainability (Ahmad *et al.,* 2018) among them, lignocellulosic feedstocks are an appealing alternative. Lignocellulosic feedstocks are specified non-edible plant components primarily composed of three building blocks (i.e. lignin, cellulose and hemicellulose) (Nanda *et al.,* 2014). On average, lignin is (10-40%), cellulose (25-55%) and hemicellulose (11-50%) (Zhang *et al.,* 2020). Lignocellulosic biomass (LCB) is principally categorized into forestry biomass (e.g. wood logs, sawdust bark etc.), energy crops (e.g. poplar, switchgrass, willow, elephant grass etc.) and crop residues (e.g. wheat straw, corn stover, rice straw, oat hall etc.) (Singh *et al.,* 2020). LCB is a propitious feedstock for the feasible production of bioplastics owing to its non-seasonal opportunistic availability and socioeconomic advantages. Additionally, lignocellulosic feedstock being non-edible does not miens any competition to food crops, being contemplated as next-generation feedstocks (Nanda *et al.,* 2018). Recently, numerous inedible resources such as bagasse, kraft pulp, corn stover, and switchgrass are being employed as lignocellulosic feedstock for a significant circular economy (Sherwood, 2020). This review highlights recent bioplastic overtures and bio-based polymer synthesis from lignocellulosic feedstocks. Fig. 2 depicts sustainable bioplastic production using LCB.

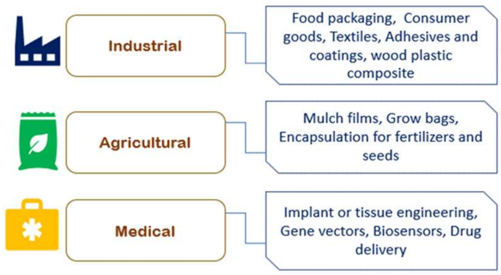


Figure 1: Plethora of applications of bioplastics

Present scenario of bioplastic production from lignocellulose

The aim of developing bio-based and eco-friendly polymers has tremendously increased in current years. LCB has enormous capability to produce bioplastics, and it is compelling because the

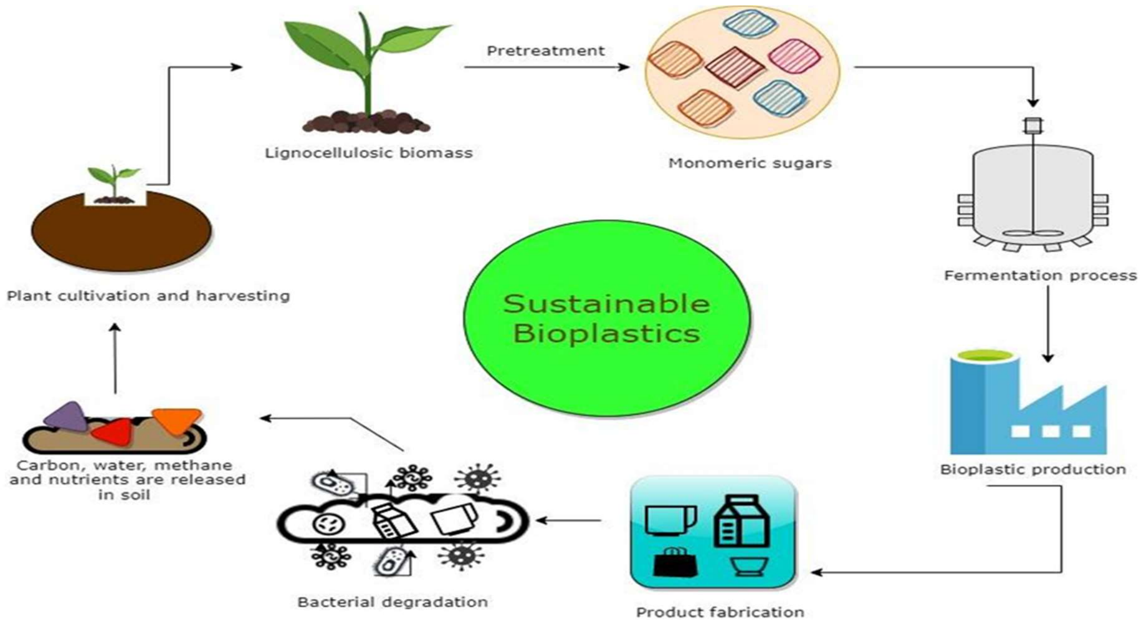


Figure 2: Sustainable production of bioplastics from LCB

generation of high-performing renewable materials is an indispensable factor for bio-based industries (Deepa *et al.,* 2015). The usage of LCB for bioplastic generation faces confrontations, such as the high cost of production routes, and it signifies the necessity for technical advances and improvement in the field. In reported studies, it has been investigated that bioplastic production from organic waste and corn stover can typically cut down expenses (Kim *et al.,* 2020). This interdisciplinary section of research is a remarkable amalgam of engineering and life science. It can offer and endeavour novel methodologies to redesign routes of biosynthesis for conversion of biomass; it will eventually lead to supreme economic and effective strategies to transform biomass into valuable commodities such as biopolymers (Galbe and Walberg, 2019). The recalcitrant nature of LCB is a primary heed in biorefinery industrial processes for bioplastic production and chemical transformation. In order to accomplish environmental and economic feasibility, it is necessary to use an adequate pre-treatment method, which typically increments cellulose digestibility through disruption of the complex lignin-carbohydrate matrix; it also helps in increasing specific surface area and in reducing particle size ultimately, resulting in an extensive recovery of sugar after the process of enzymatic hydrolysis. Pre-treated biomass could be saccharified using acid hydrolysis, by simultaneous saccharification and co-fermentation (SSCF) or by simultaneous saccharification and fermentation (SSF). Released monomeric sugars are directly fermented into biopolymers after the process of enzymatic hydrolysis. Required components are fermented by utilizing a broad range of microbes to produce several fragments that can be used for biopolymer production.

Pre-treatment of LCB for bioplastic production

LCB has a complex and heterogeneous composition, ultimately making it demanding for bioplastic production. In order to make LCB technically, environmentally, and economically feasible, there is a need to assimilate their production with different components. In the sector of bio-refineries, this includes techniques and several processes for the conversion and extraction of numerous products. Multifarious pre-treatment methods will be discussed in the next section.

Physical pre-treatment methods

Size reduction is a powerful method to escalate the receptibility of enzymes for hydrolysis. Hammer milling, chipping, cutting and grinding are the physical methods to curtail the particle size of biomass (Raj *et al.,* 2022), thereby immensely increasing pore size, surface area and decrystallizing biomass for high enzymatic digestibility. Meanwhile, the final particle size totally depends on the kind of method used; chipping gives a particle size of 10-30mm, while milling and grinding provide a particle size of 0.2-2mm (Veluchamy *et al.,* 2019). But the primary drawback of ball milling is that it consumes high energy and sometimes does not remove lignin content efficiently (Mankar *et al.,* 2021). In a study to attempt the minimum energy consumption, wet desk milling (WDM) was used for the pre-treatment of rice straw, Hideno *et al.,* (2009) found the energy requirement for 30 minutes (10 cycles of 3 min each) was 5.4 MJ/Kg. In contrast, the energy requirement during the dry ball milling method for the pre-treatment of rice straw under the same conditions was found to be 54 MJ/kg of biomass. The energy required for pre-treatment in the WDM process also depends on the kind of biomass feedstock (Da silva *et al.,* 2010).

Another promising and encouraging thermo-mechanical method is extrusion; biomass is exposed to shear and heat with continuous mixing (Duque *et al.,* 2017). High temperature and pressure during the process modify the substrate's physical (defibrillation) and chemical structure; it boosts the availability of surface area and augments enzyme accessibility for expediting hydrolysis (Kumar *et al.,* 2020). Extrusion has been established as a comparable method for accustomed methods, such as alkaline and acid treatments relating to hydrolysis efficiency. In a demonstrated study, a comparison of saccharification yields was established between extruded soybeans hulls with material pre-treated with alkali-acid and being extruded. Extrusion was found to be as competent as alkali, effectively superior to acidic pre-treatments, and improved saccharification by 132% (Yoo *et al.,* 2011).

Microwaves are nonionizing electromagnetic radiations having a wavelength range between 1mm to 1m, and these radiations selectively transfer energy to different substances (Huang *et al.,* 2016). Microwave radiation disrupts recalcitrant units by triggering an explosion within the particles in the given material (Mankar *et al.,* 2021). Microwaves have captured comprehensive attention in diligent biorefinery applications for the treatment of LCB, being a thermal process. And in the last three decades, the utilization of microwaves in the pre-treatment processes of LCB has deliberately moved from the laboratory to pilot scale studies (Li *et al.,* 2016). Heating by microwave distinguishably enhances the enzymatic saccharification process by fibre fragmentation and swelling (Diaz *et al.,* 2015) by virtue of accelerated hasty and uniform heating of LCB particles. Plant fibres remain intact, and approximately no effect can be seen in plant fibres when pre-treated with microwaves under a temperature equivalent to 100 ^{0}C (Chen *et al.,* 2017).

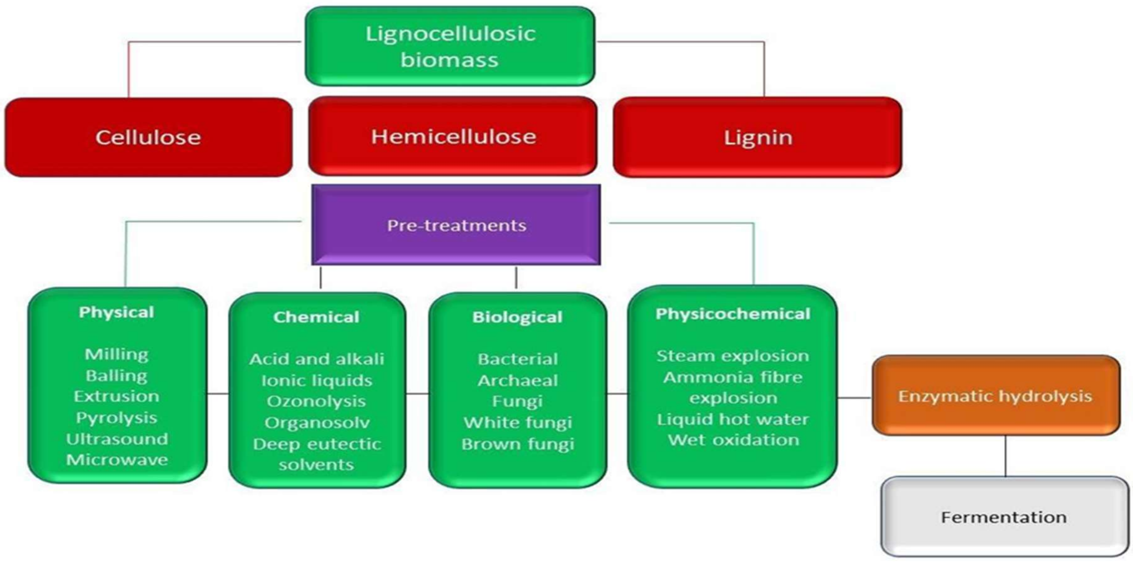


Figure 3: Different pretreatment approaches for LCB

Alternatively, LCB is grounded into minuscule particles in traditional heating pre-treatment methods to avoid a temperature gradient. Then high-pressure steam injection and heat conduction are used for heating; it might degrade the hemicellulose in humic acid or furfural and therefore afflicts the sugar recovery (Li *et al.,* 2016). Fig. 3 shows several pre-treatment approaches**.**

Chemical pre-treatment methods

An array of distinct chemical methods are used for the pre-treatment of LCB, including organosolv, kraft pulping, ionic liquid and dilute acid etc. Mentioned pre-treatment methods have compellingly proven as an adequate and effective method for a broad range of lignocellulosic feedstocks (Tu and Hallett, 2019).LCB acid treatment is primarily accustomed to eliminate hemicellulose. Acid pre-treatment results in enhanced receptivity of enzymes towards cellulose; generally, phosphoric acid, acetic acid, and sulphuric acid are used for improved pre-treatment (Rezania *et al.,* 2020). In dilute acid pre-treatment, LCB is treated through the action of hydrolysis and solubilization of hemicellulose and acid-catalyzed depolymerization of the lignin. Moreover, the type of acid used and its concentration can affect solubilized lignin's condensation (Hendricks and Zeeman, 2009). Two different ways could achieve acid pre-treatment – concentrated acid (30-70%) treatment at approximately lower temperatures and dilute acid treatment at relatively higher temperatures (Den *et al.,* 2018). Both the mentioned approaches have their own leverage and impediments, In dilute acid treatment minimum amount of acid is used, but the needful energy requirement for the process is ultimately higher. On the contrary, meagre energy is consumed in treatment with concentrated acid, but it relatively results in higher acidity, which brings about the generation of fermentation inhibitor (5-hydroxymethylfurfural). These inhibitors severely affect fermenter microorganisms by breaking down DNA and reducing RNA synthesis, which automatically hinders enzymatic activity (Woiciechowski *et al.,* 2020). On the other hand, alkali pre-treatment includes hydroxides of calcium, sodium, ammonium, and potassium, amid pre-treatment bond cleavage (ester,alkyl-aryl, aryl-ether) occurs, and uronic acid and acetyl groups are subsequently removed from hemicellulose and lignin (Kumar *et al.,* 2020), and it results in improved access of enzymes towards cellulose thus helps in efficient fermentation of sugars(Cheah *et al.,* 2020). In an investigated study, alkali-catalyzed hot water pre-treatment was performed at 170 °C, and it resulted in the alteration of present recalcitrants in bamboo biomass and produced 30.9% reducing sugars. In a reported study, pine poplar wood treated with sodium carbonate (NA_2CO_3) and NaOH(sodium hydroxide) at a temperature of 93°C, it adeptly dissolved hemicellulose and lignin content and generated 69.3% glucose (Bay *et al.,* 2020). Furthermore, ammonia or CO_2 explosions and ozonolysis are effective alternative pre-treatment methods. Biological pre-treatments are usually innocuous and require low energy, and do not generally generate inhibitors for the downstreaming processes (Tu and Hallett, 2019). Microorganisms such as bacteria and fungi are utilized in degrading LCB to macromonomers by hydrolyzing cellulose or depolymerizing lignin (Chen *et al.,* 2017)

Cellulose conversion routes for bioplastics production

Cellulose is extracted from LCB and practised for bioplastic production (Govil *et al.,* 2020). The ultimate amount of cellulose content relies on the source from which it has come. Conversion of cellulose into bioplastic composites includes lignin and hemicellulose removal, cellulose extraction and surface modifications (Reshmy *et al.,* 2021).

Hemicellulose removal and delignification

Generally, the removal of lignin includes high pressure and temperature, the occurrence of developmental processes at lower temperatures promptly removes the lignin, and simple recovery of chemicals becomes difficult (Yang *et al.,* 2019). In the delignification process, lignin is isolated from biomass, and some part of hemicellulose also gets removed. Delignification is imposed using hydrogen peroxide, sodium chlorite and oxygen. Delignification results in the degradation of lignin content, transfer of it into a liquid medium and consequentially, elimination of lignin by proper washing. Delignification does not selectively remove lignin; therefore, some quantity of cellulose and hemicellulose is eliminated altogether (Reshmy *et al.,* 2021).

Cellulose extraction and surface modification

Highly purified cellulose in different forms has been extracted by utilizing several processes relatively depending on the source and type of pre-treatments (Mondal, 2017). Various methods such as pulping ball milling, microfluidization and homogenization are practised for cellulose extraction from LCB. Extracted pulp through these techniques can be further chemically and mechanically treated for liberating cellulose. High-pressure homogenizing techniques are used for refining to get the defibrillated cellulose in the nano range (Kargarzadeh *et al.,* 2017). Combined force in high-pressure technique aids immense defibrillation and results in the generation of nanocellulose. The kraft process is a supreme chemical pulping method, in this method, lignin is dissolved using HO_3S^- and H_2SO_4 (Khalil *et al.,* 2012). Another cellulose extraction method is steam explosion; this LCB is treated with several chemicals at high-pressure steam for a precise interval of time, followed by abrupt steam discharge. Due to the abrupt release of pressure, the extracted cellulose will be having high aspect ratio and size of particles in the nano range (De Moraes *et al.,* 2013).

Cellulose has hydrophilic nature to boost its solubility and processibility; some surface modifications are needed, and various methods are being used for this purpose (Yoo and youngblood, 2016). Surface modification methods include surfactants and graft copolymerization (Rahman and Putra, 2019) and surface derivatization (Kargarzadeh *et al.,* 2017). A graft polymer primarily consists of branches of a particular polymer being attached to the backbone of other polymers; typically, graft polymerization is of specific interest because of its adaptability in creating an extensive range of functional groups on the surface since it allows the combination of required properties of two or more polymers into an individual unit Acetylation was found to improve transparency, and thermal degradation contrastingly decreases the hygroscopicity of biocomposites of cellulose without even intruding the microfibrillar morphology (Ahmad *et al.,* 2015). Owing to its defined structure, modifications can be made in cellulose in numerous ways; presence of hydroxyl groups in the chain offers many potential capabilities and the way in which cellulose will be affected ultimately depends on the conditions and chemicals applied (Rol *et al.,* 2019). Carboxymethlation of cellulose generates extensively pure water-soluble cellulose derivatives being applicable primarily as ophthalmic solutions. Various novel enzymes have been substantially tested, such as laccases, hemicellulases and lytic polysaccharide monooxygenases (LPMO); these enzymes promote and improve fibrillation by improving access to cellulose to cellulase (Rodríguez-Zúñiga *et al.,* 2015). In a study, an epoxy modification was done by surface modification of fibrils of cellulose through the process of oxidation using cerium (IV) consequential follow-up by grafting with glycidyl methacrylate (Oliveira *et al.,* 2017). Bioplastics incorporated with cellulose have exceptional mechanical strength. They can be produced from the suspension of nanocellulose by practising several film-forming methods such as extrusion or blow molding.

LCB bioconversion to biodegradable and recyclable biopolymers

Polyhydroxyalkanoates (PHAs)

PHAs are polyesters and both biocompatible and biodegradable in nature, consisting of hydroxyalkanoic acids. Numerous bacterial species extensively synthesize them as a reserve material for carbon and energy. Synthesis of PHAs in bacterial cells occurs in unfavourable conditions like surplus carbon with environmental stress of essential growth nutrients such as phosphate, nitrogen or oxygen limitations (Annamalai and Sivakumar, 2016). PHAs have loomed and emerged as an excellent polymer for the corrective solution to the problem of plastic waste. PHAs are biodegradable in the marine environment and soil, forming methane, carbon dioxide, biomass and water as by-products after efficient decomposition (Chalermthai *et al.,* 2021; Jadaun *et al.,* 2022).

Additionally, PHAs classically represent those value-added products which are generated from renewable feedstocks such as LCB by utilizing microorganisms and pose comparable properties to petroleum-based polymers (Mannina *et al.,* 2019). Numerous strategies to produce PHAs from LCB have been developed and demonstrated based on the bacteria used or which LCB should be used (hemicellulose-rich or cellulose-rich) (Moorkoth and Nampoothiri, 2016). Various *Bacillus* sp. has the potential to produce poly(3-hydroxybutyrate) [P(3HB)], a class of PHAs, from LCB without pre-treatment, i.e. mango peels (Gowda and Shivkumar, 2014) and oil palm trunk sap (Lokesh *et al.,* 2012) were utilized as a primary carbon source to produce [P(3HB)] in *B. thuringienis* and *B. megaterium* with a concentration of 4.03 g/L and 3.28 g/L respectively. However, detoxification and pre-treatment are required in most cases. Over time, several methods have been advanced and developed for the pre-treatment of LCB s and to depose the inhibiting compounds for the efficient and adequate usage of lignocellulosic feedstock. Sugarcane bagasse, a cellulose-rich biomass, was effectively detoxified and pre-treated with acid to form sugarcane bagasse hydrolysate, it was utilized as a substrate to produce P(3HB) with an achieved concentration of 4.4 g/L and 2.73 g/L in *Burkholderia cepacia* and *Burkholderia sacchari* strains. (Silva *et al.,* 2007). Another reported study demonstrated and established an integrated pre-treatment process, AFEX (Ammonia fibre expansion), followed by enzymatic hydrolysis of hemicellulose and cellulose fractions to prepare wheat straw hydrolysate, *B.sacchari* potentially produced P(3HB) with a final titer of 105g/L by utilizing a feedstock that primarily consisted xylose, arabinose and glucose in fed-batch fermentation (Ces´ario *et al.,* 2014).PHA copolymers production, counting natural and non-natural PHAs, in addition to P(3HB), is another compelling research area. At first, numerous LCBs, such as sugarcane bagasse, rubber wood, cassava stalk and sorghum stalk, were investigated and tested for mixed microbial fermentation as a feedstock for the production of PHA after being given pressurized hot water treatment. Physical treatments given to feedstocks efficiently increase saccharification with the distinguished recovery of sugar yields of 178.0 mg/g of xylose and 438.7 mg/g of glucose in rubber wood. Microbial fermentation, principally including Alphaproteobacteria and Bacteroidia classes, culminated in the production of poly(3-hydroxybutyrate-co-3-hydroxyvalerate) [P(3HB-co-3HV)] (Yan *et al.,* 2021). Using the same microbial classes to produce P(3HB-co-3HV.), rubber wood hydrolysates were also investigated. Primary PHA accumulating strains belonging to the Bacteroidia and Alphaproteobacteria classes were successfully screened by adding xylose to rubber wood hydrolysate as a co-substrate with final PHA content of 43.6% of dried cell weight (Li *et al.,* 2022). Table 1 is displaying production of PHA copolymers using LCB

Table 1: PHA copolymer production from LCB (Govil et al., 2020)

Lignocellulosic feedstock	PHA Conc. (g/L)	% PHA accumulation (w/w)	Microbe used	PHA copolymer	References
Barley biomass hydrolysate	1.8	54	*Ralstonia eutropha* 5119	PHBV	Bhatia *et al.*, 2018
Grass biomass hydrolysates	0.3	33	*Pseudomonas strains*	MCL-PHA	Davis *et al.*, 2013
Liquefied wood hydrolysates	60.5	NA	*Cupriavidus necator*	PHBV	Koller *et al.*, 2015
Sawdust hydrolysates	0.3	78	*Brevundimonas vesicularis* and *Sphingopyxis macrogoltabida*	MCL-PHA	Silva *et al.*, 2007
Miscanthus biomass hydrolysate	2.0	44	*Ralstonia eutropha* 5119	PHBV	Bhatia *et al.*, 2018
Pine biomass hydrolysate	1.7	63	*Ralstonia eutropha* 5119	PHBV	Bhatia *et al.*, 2018
Rice bran and corn starch hydrolysates	77.8	55.6	*Haloferax mediterranei*	PHBV	Matsumoto *et al.*, 2011

PHBV - Poly (3-hydroxybutyric acid-co-3-hydroxyvaleric acid).
MCL-PHA - Medium chain length PHA.
NA - Not available.

Polylactic acid (PLA)

Lactic acid (LA) is a polymerized chemical that could be utilized to produce biodegradable LA polymers using biotechnology on waste and agricultural residues (Djukić-Vuković *et al.,*2019). It has extensive usage in food, pharmaceutical and cosmetic industries as a preservative as it retards the growth of pathogens (Komesu *et al.,* 2017). Still, the crucial application of LA is its usage in the processing and synthesis of polylactic acid (PLA), a significant biocompatible plastic currently in use. Biotechnological practices predominantly prevailed production and synthesis of LA to possibly obtain optically pure LA enantiomers by selecting a suitable strain which can be efficiently grown on renewable feedstocks, resulting in high productivity and purity (Lunelli *et al.,* 2010). Commercially available PLA is generated by ring-opening polymerization and polycondensation (Garlotta *et al.,* 2001), PLAs chirality is controlled by tuning the optical activity and dissemination of LA units in the polymer backbone; it enhances final polymer performance. Currently, sugar beet, sugarcane and corn starch are used as raw materials for the production of LA on a global scale. Profound research is going on PLA resin production on a lab scale using second-generation feedstock such as wheat straw bagasse, wood chips and corn stovers, striving to accomplish comparable qualities, challenges and solutions relevant to increase sustainability and competitiveness of LA production on agricultural residues and wastes. The fermentation of monomeric sugar generates bio-based lactic acid, and hydrolysis of LCB is a luring way to the production of lactic acid. PLA being thermoplastic, can be easily transformed into different end products using numerous industrial techniques such as blow molding, fibre extrusion, film extrusion and injection molding; PLA's processing temperature is low in contrast to conventional thermoplastics. Numerous strains, such as *Bacillus coagulans,* can metabolize hexose and pentose to LA in an effective way. In a study, LA was synthesized from Beachwood and pine being organosolv pretreated, cellulose-rich solids were subsequently fractionated and simultaneously employed saccharification and fermentation using *Lactobacillus delbrueckii* subsp. in batch mode, and the final yield reported was 62g/L^{-1} (Karnaouri *et al.,* 2020).The polymerization of LA could be carried out through either ring-opening polymerization or direct condensation polymerization (Lopes *et al.,* 2014). Reactions in direct condensation require probably high temperature, an extended reaction time and low pressure for producing PLA of high molecular weight. On the contrary, ring-opening polymerization could be carried out at relatively low temperatures and requires a meagre reaction time. PLA being made from direct condensation generally has low molecular weight with indigent mechanical properties, while ring-opening-produced PLA has high molecular weight through heating in the presence of the catalyst, stannous octoate under Vaccum (Singla *et al.,* 2012). In recent times several PLA-based technologies are imminently emerging expeditiously for the advances in developing green material procured by making blends with polymers and reinforced fibres like starch and cellulose with enhanced mechanical, chemical, and biological properties in accordance with the required application. List of various lignocellulosic feedstocks is given in Table 2 that could be used for producing bioplastics.

Bio-ethylene

Polyethylene (PE) is an aliphatic polyolefin generated by the polymerization of ethylene and conjointly impersonates more than 30% of the plastic market on a global scale (Hutley and Ouederni, 2016). And presently produced from natural gas or crude petroleum by employing steam cracking using numerous metal catalysts at a temperature of 750–850 ◦C. In spite of that, bio-based-polyehtylene can be produced from second-generation ethanol generated in cellulosic biorefineries (Raj *et al.,* 2022). Bioethylene is a chemically indistinguishable substitute for ethylene we get from petrochemicals. Bioethanol is produced from well-developed routes such as fermentation and hydrolysis of sugarcane and corn feedstocks. The ultimate production cost of bio-ethylene depends on bioethanol production, which shows the importance of the origin of bioethanol in the process. The technology used to convert ethanol to ethylene is well-established and commercially available; bio-polyethylene(bio PE) is a newly developed bioplastic being prepared and produced from ethanol extracted through solid-state fermentation of LCB (Reshmy *et al.,* 2021).

Table 2: Production of PHA and PLA using LCB (Kawaguchi *et al.*, 2022)

Bioplastic	Lignocellulosic feedstock	Specified condition	Microorganism used	Titer (g/l)	Reference
PHAs	Rice husk	Alkali pre-treatment given; Batch fermentation with supplementary urea	*Burkholderia cepacia* USM	2.35	Heng *et al.,* 2017
	Corn stover	Combined acid and alkali pre-treatment; fed-batch fermentation using lignin	*Pseudomonas putida* KT2440	1.0	Sindhu *et al.,* 2013
	Lignin	Fed-batch using lignin-abundant black liquor; obtained from alkaline pretreated sugarcane bagasse	*Pseudomonas monteilii*	0.24	Unrean *et al.,* 2021
PLA	Sugarcane bagasse	Acid pre-treatment; furfural-supplemented pre-culture	*Bacillus coagulans*	75.9	Van der Pol *et al.,* 2016
	Pulp residues	Fed batch SSF; pH neutralized with $CaCO_3$	*Bacillus coagulans*	110	Zhou *et al.,* 2016
	Sugarcane bagasse	Acid and steam explosion treatment; pH adjustment using NaOH	*Lactobacillus pentosus*	72.8	Unrean, 2018

Numerous commercial stakeholders, like SABIC (Netherlands), Braskem (Brazil) and Ineos (bio-naphtha from UPM Biofuels) are currently producing bio HDPE, bio-PE and bio-LDPE from bioethanol, being derived from sugarcane (Raj *et al.,* 2022). Moreover, advances in bioethanol-producing technologies are highly alluring, as they are a drop-in equivalent to petroleum-based polyethylene, bio-PE also displayed effective applications as being used ad epoxy resins as a substitute to petroleum-based processes (Delgado-aguliar *et al.,* 2017). In a study bio-PE from sugarcane ethanol was synthesized for the purpose of biocomposite reinforcement application; it improved tensile and mechanical strength (Castro *et al.,* 2017). Consequentially unified synthesis of C2 molecules from relatively bountiful renewable feedstock has acquired a massive interest in substituting synthetic plastics in biorefineries.

Polyglycolic acid (PGA)

It is an integral biopolymer owing to its biodegradable nature and mechanical properties which offers numerous applications of this biopolymer in the medical and renewable industries (Budak *et al.,* 2020). Glycolic acid (monomer of PGA) is relatively small alpha-hydroxy acid which consists of alcohol and carboxyl groups. PGA is produced petrochemically from formaldehyde and CO by utilizing several acid catalysts; it is an aliphatic ester of glycolic acid. Although it can also be obtained from renewable resources (sugarcane, sugar beets etc.), the worldwide market of glycolic acid will exceed from $160 million in 2015 to an estimated $415 million by 2030 (Jem and Tan, 2020). Generally, PGA could be synthesized via two methods, first one is Poly-Condensation of glycolic acid and the one is Ring-Opening Polymerization of glycolide. Precursors of glycolic acid can be generated from renewable resources (grapes, cantaloupe, sugar beets and sugar cane) via biotechnological approaches by using genetically modified strains like E. coli and Corynebacterium glutamicum (Salusajarvi *et al.,* 2019). Gokturk *et al.,* (2015) optimized copolymerization conditions for the conversion of C1 feedstocks into formaldehyde and CO into PGA through cationic alternating copolymerization and ultimate results gave 92% yield of PGA with extensive crystallinity and high melting point (192°C), triflic acid was being used as catalyst. The presented method constituted a simple, effective and economical approach for the purpose of synthesizing PGA directly from C1 feedstocks, which are derived potentially from biomass. VTT research centre demonstrated the formation of glycolic acid using natural feedstocks i.e., sugar hydrolysate by the fermentation of sugars using constructed engineered yeast strains (Gadda *et al.,* 2014). A number of blends can be prepared using PGA, PLA, PHAs and cellulose, in a study PGA-PLA polymer blend was prepared for particular uses in drug delivery and tissue scaffolds applications (Salusajarvi *et al.,* 2019).

Polyurethanes (PUs)

PUs are generated from condensation polymerizations between polyols and isocyanates, which are one of the most versatile and flexible polymer families. Presently, isocyanates and polyols together are extensively petroleum-derived; in recent years, comprehensive research interest has developed in generating polyols and PUs from renewable bioresources (Tenorio-alfonso *et al.,* 2020). Being the most plentiful biomass in the world, LCB has enormous potential to be used as feedstock for the production of polyols and PUs as it contains hydroxyl groups (Malani, 2021). LCB acts as an economical substitute for the development of PUs. Conversion of LCB into liquid polyols for PU applications includes acid- or base-catalyzed atmospheric liquefaction processes using polyhydric alcohols as liquefaction solvents, and derived polyols could be further used to prepare several PU products like film, foams and adhesives. And eventual properties of these biomass-derived polyols extensively depend on the characteristics of the biomass being used and liquefaction conditions. Various diverse LCBs, including crop residues, wood and biorefinery by-products examined for PUs and polyols production. LCB has solid nature; hence its chemical modification is essential to change LCB into liquid polyols for the generation of PUs. For optimized mechanical properties of PUs, it is necessary to incorporate versatile aliphatic polyols with tough and rigid lignin polyols (Kuranska *et al.,* 2013). The ultimate mechanical properties of PUs largely depend on the relative content of lignin and its nature. Organosolv lignin (15–25 W%) in non-modified forms generates quality PUs on the other hand, large quantities of lignin accompany brittle PUs. Lignin fragments having low molecular weight amalgamated with flexible polyols such as glycerol and polyethylene glycol via enzymatic hydrolysis with consequentially following mechanical treatments In a study conducted by Araujo and Pasa (2003), they used guaiacyl-syringyl-based lignin having residual polysaccharides obtained from Eucalyptus tar distillation, and prepared PUs using different amount of hydroxyl-terminated polybutadiene.

Challenges and future prospects

The abundant availability of LCB composed it an economical source for fabricating biobased polymers using innovative biotechnological avenues. Nonetheless, commercial feasibility is still defined by virtue of the huge cost of transportation, curtailed pre-treatment efficiency, extensive chemical input and enzyme requirement demand. (Hassan *et al.,* 2019). In the world's bioplastic market, the contribution and participation of LCB-derived bioplastic are flat due to lower prices of crude oil. The approach of circular bioeconomy should be contemplated for the valorization of a variety of by-products from a specific biorefinery process. For instance, a pilot plant in cellulose biorefinery might be used for the production of the biodegradable polymer such as PLA and PHA from monomeric sugars. In the same way, ethanol being generated in the cellulosic biorefinery may be integrated with catalytic conversion techniques for the production of biological origin Bio-PE and PET (Rosales-Calderon,and Arantes 2019). However, recyclable bioplastic has comparable attributes to petroleum-based plastics, but worldwide acquiescence of these biobased plastics is still restricted. Presently, maximum bioplastics are being derived from monomeric sugars generated from starch-based feedstocks; the apparent complexity of LCB is its recalcitrant nature and inaccessibility to combined LCB to recyclable plastic process are primary limitations in its commercial evolution. Additionally, the maximum quantity of sugar titer after enzymatic hydrolysis and the requirement of well-fermenting microbial strains to produce bioplastic monomers are the prime tailbacks in LCB-based plastic manufacturing industries. The cost of feedstock plays an important factor, which significantly depends on harvesting methods, land use, and supply chain; therefore, a careful, perceptive understanding of all the factors would enormously contribute to bioprocess economics. However, numerous parameters like hydrolysis, pre-treatment and fermentation have been well investigated and documented in the literature though cost reduction of unified units at the commercial level requires evaluation.

Out of the total overall operational cost, 25-30% only accounts for processes of sugar extraction for bioplastic generation from LCB. Therefore a cocktail of development of in-situ, economic enzymes would be significant for the bioplastic industry. And on a general basis, the government must strengthen the effective implementation of policies related to biobased resources and should promote the usage of bioplastics instead of synthetic plastic for daily routine applications. Although recycling compostable and biodegradable plastics is technically possible, however presently, <1% of bioplastics is being recycled due to non-availability of adequate labelling European standards of bioplastics. Furthermore, automation, skilled manpower, and proper collection management system should be steadfast through responsible government agencies. Significant R&D technology ramifications for anaerobic digestion, impurity eradication and waste recycling should be recommended through private and public agencies.

Conclusion

Polymeric sugars enmeshed in LCB can be obtained using the required pre-treatment method to transform them into biopolymers. Conversion of renewable chemicals generated from LCBs into biodegradable and recyclable plastic is an entrancing option to supersede conventional petroleum-based plastics. Utilization of LCB for bioplastic production renders sustainability and promotes a circular economy, although variable structure, heterogenous nature and complexity of LCB are eloquent critical sides that need to be remediated through technological advancements and development of strategies for effective substrate conversion, which would directly enhance commercial viability. Bioplastic production from LCB is at an inchoate phase, but the future outlooks are promising and luring. Significant advancements in fermentation techniques with this inexpensive LCB have to potential to completely transform the shape of the biopolymer industry, allowing production costs to permit to an extent. It will compete with conventional plastic and will offer valuable biodegradable and biocompatible properties with environmental sustainability.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ahmad, A., Waheed, S., Khan, S. M., Shafiq, M., Farooq, M., Sanaullah, K., & Jamil, T. (2015). Effect of silica on the properties of cellulose acetate/polyethylene glycol membranes for reverse osmosis. *Desalination*, *355*, 1-10.

Ahmad, E., & Pant, K. K. (2018). Lignin conversion: a key to the concept of lignocellulosic biomass-based integrated biorefinery. In *Waste biorefinery* (pp. 409-444). Elsevier.

Annamalai, N., & Sivakumar, N. (2016). Production of polyhydroxybutyrate from wheat bran hydrolysate using Ralstonia eutropha through microbial fermentation. *Journal of Biotechnology*, *237*, 13-17.

Araujo, R. C. S., & Pasa, V. M. D. (2003). Mechanical and thermal properties of polyurethane elastomers based on hydroxyl-terminated polybutadienes and biopitch. *Journal of applied polymer science*, *88*(3), 759-766.

Bay, M. S., Karimi, K., Esfahany, M. N., & Kumar, R. (2020). Structural modification of pine and poplar wood by alkali pretreatment to improve ethanol production. *Industrial crops and products*, *152*, 112506.

Bhatia, S.K., Gurav, R., Choi, T.R., Jung, H.R., Yang, S.Y., Moon, Y.M., 2018. Bioconversion of plant biomass hydrolysate into bioplastic (polyhydroxyalkanoates) using Ralstonia eutropha 5119. Bioresour. Technol. 271, 306e315. https:// doi.org/10.1016/j.biortech.2018.09.122.

Budak, K., Sogut, O., & Aydemir Sezer, U. (2020). A review on synthesis and biomedical applications of polyglycolic acid. *Journal of polymer research*, *27*(8), 1-19.

Castro, D. O., Passador, F., Ruvolo-Filho, A., & Frollini, E. (2017). Use of castor and canola oils in "biopolyethylene" curauá fiber composites. *Composites Part A: Applied Science and Manufacturing*, *95*, 22-30.

Chalermthai, B., Giwa, A., Schmidt, J. E., & Taher, H. (2021). Life cycle assessment of bioplastic production from whey protein obtained from dairy residues. *Bioresource Technology Reports*, *15*, 100695.

Cheah, W. Y., Sankaran, R., Show, P. L., Ibrahim, T. N. B. T., Chew, K. W., Culaba, A., & Jo-Shu, C. (2020). Pretreatment methods for lignocellulosic biofuels production: current advances, challenges and future prospects. *Biofuel Research Journal*, *7*(1), 1115.

Chen, H., Liu, J., Chang, X., Chen, D., Xue, Y., Liu, P., & Han, S. (2017). A review on the pretreatment of lignocellulose for high-value chemicals. *Fuel Processing Technology*, *160*, 196-206.

Chen, W., Chen, Y., Yang, H., Xia, M., Li, K., Chen, X., & Chen, H. (2017). Co-pyrolysis of lignocellulosic biomass and microalgae: Products characteristics and interaction effect. *Bioresource technology*, *245*, 860-868.

Da Silva, A. S. A., Inoue, H., Endo, T., Yano, S., & Bon, E. P. (2010). Milling pretreatment of sugarcane bagasse and straw for enzymatic hydrolysis and ethanol fermentation. *Bioresource technology*, *101*(19), 7402-7409.

Davis, R., Kataria, R., Cerrone, F., Woods, T., Kenny, S., O'Donovan, A., (2013). Conversion of grass biomass into fermentable sugars and its utilization for medium chain length polyhydroxyalkanoate (mcl-PHA) production by Pseudomonas strains. Bioresour. Technol. 150, 202e209. https://doi.org/10.1016/ j.biortech.2013.10.001

De Moraes, J. O., Scheibe, A. S., Sereno, A., & Laurindo, J. B. (2013). Scale-up of the production of cassava starch based films using tape-casting. *Journal of Food Engineering*, *119*(4), 800-808.

Deepa, B., Abraham, E., Cordeiro, N., Mozetic, M., Mathew, A. P., Oksman, K., ... & Pothan, L. A. (2015). Utilization of various lignocellulosic biomass for the production of nanocellulose: a comparative study. *Cellulose*, *22*(2), 1075-1090.

Den, W., Sharma, V. K., Lee, M., Nadadur, G., & Varma, R. S. (2018). Lignocellulosic biomass transformations via greener oxidative pretreatment processes: access to energy and value-added chemicals. *Frontiers in chemistry*, *6*, 141.

Diaz, A. B., de Souza Moretti, M. M., Bezerra-Bussoli, C., Nunes, C. D. C. C., Blandino, A., da Silva, R., & Gomes, E. (2015). Evaluation of microwave-assisted pretreatment of lignocellulosic biomass immersed in alkaline glycerol for fermentable sugars production. *Bioresource technology*, *185*, 316-323.

Djukić-Vuković, A., Mladenović, D., Ivanović, J., Pejin, J., & Mojović, L. (2019). Towards sustainability of lactic acid and poly-lactic acid polymers production. *Renewable and Sustainable Energy Reviews*, *108*, 238-252.

Duque, A., Manzanares, P., & Ballesteros, M. (2017). Extrusion as a pretreatment for lignocellulosic biomass: Fundamentals and applications. *Renewable energy*, *114*, 1427-1441.

Gadda, T. M., Pirttimaa, M. M., Koivistoinen, O., Richard, P., Penttila, M., & Harlin, A. (2014). The industrial potential of bio-based glycolic acid and polyglycolic acid. *Appita: Technology, Innovation, Manufacturing, Environment*, *67*(1), 12.

Galbe, M., & Wallberg, O. (2019). Pretreatment for biorefineries: a review of common methods for efficient utilisation of lignocellulosic materials. *Biotechnology for biofuels*, *12*(1), 1-26.

Garlotta, D. (2001). A literature review of poly (lactic acid). *Journal of Polymers and the Environment*, *9*(2), 63-84.

Govil, T., Wang, J., Samanta, D., David, A., Tripathi, A., Rauniyar, S., ... & Sani, R. K. (2020). Lignocellulosic feedstock: A review of a sustainable platform for cleaner production of nature's plastics. *Journal of cleaner production*, *270*, 122521.

Hassan, S. S., Williams, G. A., & Jaiswal, A. K. (2019). Moving towards the second generation of lignocellulosic biorefineries in the EU: Drivers, challenges, and opportunities. *Renewable and Sustainable Energy Reviews*, *101*, 590-599.

Hendriks, A. T. W. M., & Zeeman, G. (2009). Pretreatments to enhance the digestibility of lignocellulosic biomass. *Bioresource technology*, *100*(1), 10-18.

Heng, K. S., Hatti-Kaul, R., Adam, F., Fukui, T., & Sudesh, K. (2017). Conversion of rice husks to polyhydroxyalkanoates (PHA) via a three-step process: optimized alkaline pretreatment, enzymatic hydrolysis, and biosynthesis by Burkholderia cepacia USM (JCM 15050). *Journal of Chemical Technology & Biotechnology*, *92*(1), 100-108.

Hideno, A., Inoue, H., Tsukahara, K., Fujimoto, S., Minowa, T., Inoue, S., ... & Sawayama, S. (2009). Wet disk milling pretreatment without sulfuric acid for enzymatic hydrolysis of rice straw. *Bioresource Technology*, *100*(10), 2706-2711.

Huang, Y. F., Chiueh, P. T., Kuan, W. H., & Lo, S. L. (2016). Microwave pyrolysis of lignocellulosic biomass: Heating performance and reaction kinetics. *Energy*, *100*, 137-144.

Hutley, T. J., & Ouederni, M. (2016). Polyolefins—the history and economic impact. In *Polyolefin Compounds and materials* (pp. 13-50). Springer, Cham.

Jadaun, J. S., Bansal, S., Sonthalia, A., Rai, A. K., & Singh, S. P. (2022). Biodegradation of plastics for sustainable environment. *Bioresource Technology*, 126697.

Jem, K. J., & Tan, B. (2020). The development and challenges of poly (lactic acid) and poly (glycolic acid). *Advanced Industrial and Engineering Polymer Research*, *3*(2), 60-70.

Kargarzadeh, H., Ioelovich, M., Ahmad, I., Thomas, S., & Dufresne, A. (2017). Methods for extraction of nanocellulose from various sources. *Handbook of nanocellulose and cellulose nanocomposites*, *1*, 1-51.

Karnaouri, A., Asimakopoulou, G., Kalogiannis, K. G., Lappas, A., & Topakas, E. (2020). Efficient d-lactic acid production by Lactobacillus delbrueckii subsp. bulgaricus through conversion of organosolv pretreated lignocellulosic biomass. *Biomass and Bioenergy*, *140*, 105672.

Kawaguchi, H., Takada, K., Elkasaby, T., Pangestu, R., Toyoshima, M., Kahar, P., ... & Kondo, A. (2022). Recent advances in lignocellulosic biomass white biotechnology for bioplastics. *Bioresource Technology*, *344*, 126165.

Khalil, H. A., Bhat, A. H., & Yusra, A. I. (2012). Green composites from sustainable cellulose nanofibrils: A review. *Carbohydrate polymers*, *87*(2), 963-979.

Kim, H., Lee, S., Ahn, Y., Lee, J., & Won, W. (2020). Sustainable production of bioplastics from lignocellulosic biomass: technoeconomic analysis and life-cycle assessment. *ACS Sustainable Chemistry & Engineering*, *8*(33), 12419-12429.

Koller, M., Miranda de Sousa Dias, M., Rodríguez-Contreras, A., Kunaver, M., Zagar, E., Krzan, A., Braunegg, G., (2015). Liquefied wood as inexpensive precursor-feedstock for bio-mediated incorporation of (R)-3-Hydroxyvalerate into polyhydroxyalkanoates. Materials 8 (9), 6543e6557. https://doi.org/ 10.3390/ma8095321.

Komesu, A., de Oliveira, J. A. R., da Silva Martins, L. H., Maciel, M. R. W., & Maciel Filho, R. (2017). Lactic acid production to purification: a review. *BioResources*, *12*(2), 4364-4383.

Kumar, B., Bhardwaj, N., Agrawal, K., Chaturvedi, V., & Verma, P. (2020). Current perspective on pretreatment technologies using lignocellulosic biomass: An emerging biorefinery concept. *Fuel Processing Technology*, *199*, 106244.

Kurańska, M., Aleksander, P., Mikelis, K., & Ugis, C. (2013). Porous polyurethane composites based on bio-components. *Composites Science and Technology*, *75*, 70-76.

Lau, W. W., Shiran, Y., Bailey, R. M., Cook, E., Stuchtey, M. R., Koskella, J., ... & Palardy, J. E. (2020). Evaluating scenarios toward zero plastic pollution. *Science*, *369*(6510), 1455-1461.

Li, H., Qu, Y., Yang, Y., Chang, S., & Xu, J. (2016). Microwave irradiation–A green and efficient way to pretreat biomass. *Bioresource technology*, *199*, 34-41.

Li, J., Li, D., Su, Y., Yan, X., Wang, F., Yu, L., & Ma, X. (2022). Efficient and economical production of polyhydroxyalkanoate from sustainable rubber wood hydrolysate and xylose as co-substrate by mixed microbial cultures. *Bioresource Technology*, *355*, 127238.

Li, P., Wang, X., Su, M., Zou, X., Duan, L., & Zhang, H. (2021). Characteristics of plastic pollution in the environment: a review. *Bulletin of environmental contamination and toxicology*, *107*(4), 577-584.

Lokesh, B. E., Hamid, Z. A. A., Arai, T., Kosugi, A., Murata, Y., Hashim, R., ... & Sudesh, K. (2012). Potential of oil palm trunk sap as a novel inexpensive renewable carbon feedstock for polyhydroxyalkanoate biosynthesis and as a bacterial growth medium. *Clean–Soil, Air, Water*, *40*(3), 310-317.

Lopes, M. S., Jardini, A., & Maciel Filho, R. (2014). Synthesis and characterizations of poly (lactic acid) by ring-opening polymerization for biomedical applications. *Chemical engineering transactions*, *38*, 331-336.

Lunelli, B. H., Andrade, R. R., Atala, D. I., Wolf Maciel, M. R., Maugeri Filho, F., & Maciel Filho, R. (2010). Production of lactic acid from sucrose: strain selection, fermentation, and kinetic modeling. *Applied biochemistry and Biotechnology*, *161*(1), 227-237.

Malani, R. S., Malshe, V. C., & Thorat, B. N. (2021). Polyols and polyurethanes from renewable sources: past, present and future—part 1: vegetable oils and lignocellulosic biomass. *Journal of Coatings Technology and Research*, 1-22.

Mankar, A. R., Pandey, A., Modak, A., & Pant, K. K. (2021). Pretreatment of lignocellulosic biomass: A review on recent advances. *Bioresource Technology*, *334*, 125235.

Mannina, G., Presti, D., Montiel-Jarillo, G., & Suárez-Ojeda, M. E. (2019). Bioplastic recovery from wastewater: A new protocol for polyhydroxyalkanoates (PHA) extraction from mixed microbial cultures. *Bioresource technology*, *282*, 361-369.

Matsumoto, K., Kobayashi, H., Ikeda, K., Komanoya, T., Fukuoka, A., Taguchi, S., (2011). Chemo-microbial conversion of cellulose into polyhydroxybutyrate through ruthenium-catalyzed hydrolysis of cellulose into glucose. Bioresour. Technol. 102 (3), 3564e3567. https://doi.org/10.1016/j.biortech.2010.09.098.

Mondal, S. (2017). Preparation, properties and applications of nanocellulosic materials. *Carbohydrate polymers*, *163*, 301-316.

Moorkoth, D., & Nampoothiri, K. M. (2016). Production and characterization of poly (3-hydroxy butyrate-co-3 hydroxyvalerate)(PHBV) by a novel halotolerant mangrove isolate. *Bioresource technology*, *201*, 253-260.

Nanda, S., Mohammad, J., Reddy, S.N., Kozinski, J.A., Dalai, A.K.: Pathways of lignocellulosic biomass conversion to renewable fuels. Biomass Conv. Bioref. **4**, 157–191 (2014)

Nanda, S., Rana, R., Sarangi, P.K., Dalai, A.K., Kozinski, J.A.: A broad introduction to first, second and third generation biofuels. In: Sarangi, P.K., Nanda, S., Mohanty, P. (eds.) Recent Advancements in Biofuels and Bioenergy Utilization, pp. 1–25. Springer Nature, Singapore (2018)

Okolie JA, Nanda S, Dalai AK, Kozinski JA (2020) Chemistry and specialty industrial applications of lignocellulosic biomass. Waste Biomass Valoriz 20:1–25. https://doi.org/10.1007/s12649-020-01123-0

Oliveira, J. A. R. D., Silva Martins, L. H. D., Komesu, A., & Neto, J. M. (2017). Nanotechnology applications on lignocellulosic biomass pretreatment. In *Nanotechnology* *for bioenergy and biofuel production* (pp. 19-37). Springer, Cham.

Rahman, R., & Putra, S. Z. F. S. (2019). Tensile properties of natural and synthetic fiber-reinforced polymer composites. *Mechanical and physical testing of biocomposites, fibre-reinforced composites and hybrid composites*, 81-102.

Raj, T., Chandrasekhar, K., Kumar, A. N., & Kim, S. H. (2022). Lignocellulosic biomass as renewable feedstock for biodegradable and recyclable plastics production: A sustainable approach. *Renewable and Sustainable Energy Reviews*, *158*, 112130.

Reshmy, R., Thomas, D., Philip, E., Paul, S. A., Madhavan, A., Sindhu, R., ... & Binod, P. (2021). Bioplastic production from renewable lignocellulosic feedstocks: a review. *Reviews in Environmental Science and Bio/Technology*, *20*(1), 167-187.

Rezania, S., Oryani, B., Cho, J., Talaiekhozani, A., Sabbagh, F., Hashemi, B., ... & Mohammadi, A. A. (2020). Different pretreatment technologies of lignocellulosic biomass for bioethanol production: an overview. *Energy*, *199*, 117457.

Rhodes, C. J. (2018). Plastic pollution and potential solutions. *Science progress*, *101*(3), 207-260.

Rodríguez-Zúñiga, U. F., Cannella, D., de Campos Giordano, R., Giordano, R. D. L. C., Jørgensen, H., & Felby, C. (2015). Lignocellulose pretreatment technologies affect the level of enzymatic cellulose oxidation by LPMO. *Green chemistry*, *17*(5), 2896-2903.

Rol, F., Belgacem, M. N., Gandini, A., & Bras, J. (2019). Recent advances in surface-modified cellulose nanofibrils. *Progress in Polymer Science*, *88*, 241-264.

Rosales-Calderon, O., & Arantes, V. (2019). A review on commercial-scale high-value products that can be produced alongside cellulosic ethanol. *Biotechnology for biofuels*, *12*(1), 1-58.

Rosales-Calderon, O., & Arantes, V. (2019). A review on commercial-scale high-value products that can be produced

Tu, W. C., & Hallett, J. P. (2019). Recent advances in the pretreatment of lignocellulosic biomass. *Current opinion in green and sustainable chemistry*, *20*, 11-17.

Unrean, P. (2018). Optimized feeding schemes of simultaneous saccharification and fermentation process for high lactic acid titer from sugarcane bagasse. *Industrial Crops and Products*, *111*, 660-666.

Unrean, P., Napathorn, S. C., Tee, K. L., Wong, T. S., & Champreda, V. (2021). Lignin to polyhydroxyalkanoate bioprocessing by novel strain of Pseudomonas monteilii. *Biomass Conversion and Biorefinery*, 1-7.

van der Pol, E. C., Eggink, G., & Weusthuis, R. A. (2016). Production of L (+)-lactic acid from acid pretreated sugarcane bagasse using Bacillus coagulans DSM2314 in a

alongside cellulosic ethanol. *Biotechnology for biofuels*, *12*(1), 1-58.

Salusjärvi, L., Havukainen, S., Koivistoinen, O., & Toivari, M. (2019). Biotechnological production of glycolic acid and ethylene glycol: current state and perspectives. *Applied microbiology and biotechnology*, *103*(6), 2525-2535.

Sherwood, J. (2020). The significance of biomass in a circular economy. *Bioresource Technology*, *300*, 122755. https://doi.org/10.1016/j.biortech.2020.122755

Silva, J. A., Tobella, L. M., Becerra, J., Godoy, F., & Martínez, M. A. (2007). Biosynthesis of poly-β-hydroxyalkanoate by Brevundimonas vesicularis LMG P-23615 and Sphingopyxis macrogoltabida LMG 17324 using acid-hydrolyzed sawdust as carbon source. *Journal of bioscience and bioengineering*, *103*(6), 542-546.

Sindhu, R., Silviya, N., Binod, P., & Pandey, A. (2013). Pentose-rich hydrolysate from acid pretreated rice straw as a carbon source for the production of poly-3-hydroxybutyrate. *Biochemical engineering journal*, *78*, 67-72.

Singh, A., Nanda, S., Berruti, F.: A review of thermochemical and biochemical conversion of miscanthus to biofuels. In: Nanda, S., Vo, D.V.N., Sarangi, P.K. (eds.) Biorefinery of Alternative Resources: Targeting Green Fuels and Platform Chemicals, pp. 195–220. Springer Nature, Singapore (2020)

Singla, P., Kaur, P., Mehta, R., Berek, D., & Upadhyay, S. N. (2012). Ring-opening polymerization of lactide using microwave and conventional heating. *Procedia Chemistry*, *4*, 179-185.

Tenorio-Alfonso, A., Sánchez, M., & Franco, J. M. (2020). A review of the sustainable approaches in the production of bio-based polyurethanes and their applications in the adhesive field. *Journal of Polymers and the Environment*, *28*(3), 749-774.

simultaneous saccharification and fermentation strategy. *Biotechnology for biofuels*, *9*(1), 1-12.

Veluchamy, C., Kalamdhad, A. S., & Gilroyed, B. H. (2019). Advanced pretreatment strategies for bioenergy production from biomass and biowaste. *Handbook of environmental materials management*, 1507-1524.

Woiciechowski, A. L., Neto, C. J. D., de Souza Vandenberghe, L. P., de Carvalho Neto, D. P., Sydney, A. C. N., Letti, L. A. J., ... & Soccol, C. R. (2020). Lignocellulosic biomass: Acid and alkaline pretreatments and their effects on biomass recalcitrance–Conventional processing and recent advances. *Bioresource technology*, *304*, 122848.

Yan, X., Li, D., Ma, X., & Li, J. (2021). Bioconversion of renewable lignocellulosic biomass into multicomponent substrate via pressurized hot water pretreatment for bioplastic polyhydroxy alkanoate accumulation. *Bioresource Technology*, *339*, 125667.

Yang, J., Ching, Y. C., & Chuah, C. H. (2019). Applications of lignocellulosic fibers and lignin in bioplastics: A review. *Polymers*, *11*(5), 751.

Yoo, J., Alavi, S., Vadlani, P., & Amanor-Boadu, V. (2011). Thermo-mechanical extrusion pretreatment for conversion of soybean hulls to fermentable sugars. *Bioresource technology*, *102*(16), 7583-7590.

Yoo, Y., & Youngblood, J. P. (2016). Green one-pot synthesis of surface hydrophobized cellulose nanocrystals in aqueous medium. *ACS Sustainable Chemistry & Engineering*, *4*(7), 3927-3938.

Zhang, J., Cai, D., Qin, Y., Liu, D., & Zhao, X. (2020). High value-added monomer chemicals and functional bio-based materials derived from polymeric components of lignocellulose by organosolv fractionation. *Biofuels, Bioproducts and Biorefining*, *14*(2), 371-401.

Zhou, J., Ouyang, J., Xu, Q., & Zheng, Z. (2016). Cost-effective simultaneous saccharification and fermentation of l-lactic acid from bagasse sulfite pulp by Bacillus coagulans CC17. *Bioresource technology*, *222*, 431-438.

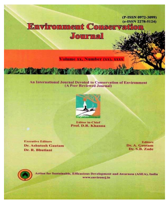
Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.

Environment Conservation Journal 24 (3):326--329, 2023

Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Role of eco-friendly dental clinic option in water saving

Hossam Mohamed Hassan Soliman ✉

Clinical Research Department Director, Health Insurance Organization, Alexandria, Egypt

ARTICLE INFO

Received : 16 November 2022

Revised : 16 January 2023

Accepted : 24 January 2023

Available online: 12 April 2023

Key Words:

Green dentistry

Dental technology

Water consumption

Water resources

ABSTRACT

Water shortage is considered as a major problem worldwide. Moreover, the adverse effects of climate change would make the issue worse. Most classical dental facilities had inappropriate water consumption practices. Green dentistry is an innovative approach to a dental procedure that is environmentally sustainable while also saving money and time by minimizing waste, conserving water and energy, and lowering pollution through the use of cutting-edge techniques and procedures. However, scarcity of studies about this topic represented the main challenge to our study which was overcome by carrying out precise data collection. Our main objective was to clarify the role of eco-friendly dental technology in water saving. Environmental case study approach was used to answer research question and formulate a hypothesis. Data was collected from several evidence based sources. The study results showed that there was a significant reduction in water consumption after the implementation of Eco dental options. The current findings shed light on the significant role of green dentistry on water saving and serves as a base of future research.

Introduction

One of the most important economic and social problems of the century on a worldwide basis will be the concern with water resources (Bhutiani *et al.*, 2021a&b; Ruhela *et al.*, 2022). Egypt is one of the nations that will experience significant issues due to its fixed portion of the Nile and its restricted access to groundwater, rainfall, and desalinated water (Abdel-Shafy and Kamel, 2016). Seventy percent of this need is met directly by the Nile River, and the bulk of the other 30% is met by the Nile indirectly through its groundwater aquifers, reuse of agricultural drainage water, and return flows from the river (Amer *et al.*, 2017). Water shortages could occur as a result of increased competition for water in the upper Nile basin (caused by the Grand Ethiopian Renaissance Dam) (Abdel-Shafy and Kamel, 2016). Additionally, the negative effects of climate change, including the potential impacts on the Nile Delta and coastal areas of sea level rise and temperature rise that increases water evaporation, would make the issue worse (Amer *et al.*, 2017). Egypt experienced a 21 Billion Cubic Meters (BCM) per year water shortage in 2019 (Elkholy, 2021). The Egyptian government has taken steps to address this issue, such as treating industrial effluent and sewage, which can provide about three billion cubic meters of water annually (Abdin and Gaafar, 2009). Water desalination is already one of the options that have been implemented to use seawater as a source of water (Fried and Serio, 2012). Furthermore, in the agricultural sector, the chosen strategies were to minimize either the crop consumption rate or the water loss rate through irrigation canal lining and maintenance, and subsequently to reduce water demands and shortages (Abdel-Shafy and Kamel, 2016; Bhutiani and Ahamad, 2019). Because wastewater treatment and desalination plants are costly, consume massive energy, and utilize a lot of chemicals, every effort should be taken to conserve water resources by lowering water usage as well as wastewater output. Therefore our current perspective focused on the water aspect of dental treatment.

Standard approaches

There are thousands of dental clinics in Egypt including the private and public sectors; one of the most important sectors continuously consumes

Corresponding author E-mail: *hiph.hossamsoliman@alexu.edu.eg*

Doi: https://doi.org/10.36953/ECJ.16092509

significant amounts of water through cleaning, sterilization, and suction procedures. In addition, dental clinics use many types of equipment for which electricity is required such as compressors, drills, overhead lights, operatory lights, and computers. The majority of dental facilities use standard technology approaches which consume and waste a huge amount of water and energy.

Modern approaches

Green dentistry is the practice of using technologies, methods, and materials that are not harmful to the environment (Fotedar, 2014). It can be done by conservation of water and energy, use of nonhazardous products, reduction of waste, and eliminating hazardous chemicals that negatively affect patients and the environment such as the chemicals used in the processing of X-rays which can be replaced by digital X-rays and promoting increased usage of green products.

Worldwide, Eco-dental clinics implement modern technology in their equipment such as dry dental vacuum pumps, fast cycle automated cleaning equipment washers/thermal disinfectors, and Eco sterilizers. Additionally, installing low-flow faucets and water-efficient toilets will be helpful. This technology significantly reduces overall water consumption, moreover, it has a positive impact on the environment by reducing the amount of wastewater. Additionally, this option will significantly minimize energy consumption which in turn minimizes the negative contribution to climate change. However, few studies have been performed on the assessment of the impact of Eco dental clinics on water saving.

Eco-friendly dental technology solutions:

Suction system in a dental clinic:

The usage of a dental vacuum is crucial at the dentist's office because it facilitates the removal of saliva, debris, and bacteria from the patient's oral cavity while dentists work (Dentalez, 2021). Dental vacuums come in both dry and moist varieties. Dry vacuums use no water, in contrast to the 350–500 gallons per day that conventional wet ring vacuum systems in the US use. We're thrilled to employ waterless pumps since they help us save over 200,000 gallons of water annually. Water conservation is a major issue at the water cooler these days. In the United States, only around 10% of dental offices have converted to dry pump technology, which uses 77% less water than the typical dental office. Beyond financial considerations, everyone in our community has a moral obligation to conserve water (Studio Z Dental, 2022). Since most dry vacuum systems are belt-driven and so use less electricity over a year, there are other ways to reduce costs and resource utilization. Although the initial expenditure is greater, it soon pays for itself frequently in 3–4 years (Dentalez, 2021).

ECO sterilizers (Steelco, 2022)

Some sterilizers are already more efficient than comparable types. To help clients conserve water, even more, ECO water and energy-saving packages have been introduced, which can lower overall water consumption by up to 90% depending on the options chosen, with a 13% reduction in energy. Steelco ECO 1 and ECO 2 options are two of these sorts as part of its environmental water-saving philosophy.

ECO 1

This standard option contributes to a 35 % reduction in water consumption by requiring less water to cool the drain before discharge.

ECO 2

This method uses cold water from a chilled water system. It is made up of a series of high-efficiency heat exchangers that allow for significant savings in vacuum pump water consumption and a reduction of over 90% in overall water usage. Drain water is also chilled, thus no extra tap water is required to lessen the temperature before discharge, as illustrated in Figure (1).

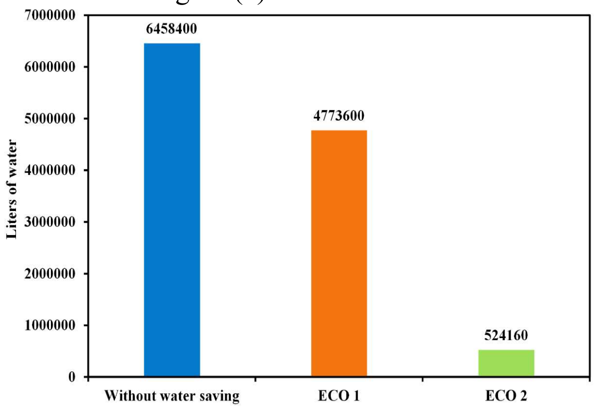


Figure 1: Annual water usage in liters of a Cental Sterilization Supply Department (CSSD) in a typical university hospital with 4 units of 18 Standard Measuring Unit (STU) sterilizers with house steam: 15 cycles per day, 6 days per week, and 52 weeks per year.

Water conservation consolidated's-water eco series sterilizers (Consolidated sterilizer Systems, 2022): To comply with local building codes and reduce the temperature of the effluent discharged to the drain, most modern autoclaves use a substantial volume of water. This water quenching may consume up to 1,600 gallons of water each day! The Consolidated Water Eco Series dramatically reduces water use, saving up to 99 percent of the water used by other market autoclaves.

Consolidated's water eco series:

Water eco : All Consolidated sterilizers include this mechanism. They not only save water but also monitors usage and cool effluent with a combination of air, previously cooled effluent, and a little amount of cold water.

Water eco-plus : This technology saves water by using a stainless steel heat exchanger that uses the facility's chilled water supply, effectively eliminating the need for once-through cooling water.

Water eco vacuum plus: This system integrates with pre-vacuum autoclaves when chilled water is readily available. The full recovery system uses chilled water to cool the vacuum water and exhaust and is the best solution to minimize water.

The benefits of water eco sterilizers: A single ecologically friendly autoclave can save a facility approximately 60.000 gallons of water per year. Based on current utility prices, over fifteen years, that translates to $100,000, assuming SSR-3A, 3 cycles each day, 30 minutes at 250 degrees Fahrenheit with 5 minutes dry (Consolidated Sterilizer Systems, 2022).

A fast cycle washer disinfector: It is worth saving about 54.000 liters of water in a year of normal use! It also conserves both time and energy (Steelco, 2022). Overall, we compared the different aspects of eco-friendly dental technology to provide an overview so we can decide which is more useful or valuable as shown in Table 1. As it is apparent from this table, I can suggest that implementation of dry dental vacuum suction, fast cycle washer disinfector, and Consolidated's Water Eco Series technologies or ECO sterilizers – ECO 2 together will be the best choices to reduce water consumption in dental facilities.

Table 1: Comparison between different eco-friendly dental technologies regarding water saving

SN	Eco-friendly dental technology	Water saving by (%) or water liters or gallons
1	Dry dental vacuum	77% - 200,000 gallons of water annually
2	ECO sterilizers – ECO 1	35 % reduction in water consumption
3	ECO sterilizers – ECO 2	90% in overall water usage
4	Consolidated's Water Eco Series - Water Eco Series Sterilizers	99% - 584,000 gallons of water annually
5	Fast cycle washer disinfector	54.000 liters of water in a year
6	Water Eco sterilizers	60.000 gallons of water per year

Outcome

Our findings suggested that there is significant reduction in water consumption, electricity, cost, and water waste after the implementation of Eco dental options (generated hypothesis). Accordingly, if Egyptian health care authorities implement these technologies in dental facilities licensing policy, we can easily test our hypothesis as there are thousands of dental clinics in Egypt including the private and public sectors.

Relevance to sustainable development goals (SDGs) under climate change challenges:

"Eco-friendly" and "green" are frequently used interchangeably and denote a variety of characteristics, including renewability, sustainability, energy efficiency, lack of toxicity, little invasiveness, and a lower carbon footprint. It encompasses sustainable and eco-friendly techniques, hospital and office design, and waste management in the healthcare sector. Sustainable dentistry combines dentists' responsibilities to society, the economy, and the environment (World Dental Federation [FDI], 2007). Eco dentistry implements sustainable practices by keeping resource consumption in line with nature's economy, safeguarding the environment through means that will assist in eliminating or reducing outgoing wastes, and reducing energy consumption, which in turn promotes the well-being of all individuals in the environment by a significant reduction of greenhouse gases generated in the breathable air, which also affect climate change (Adams, 2007). All of these impacts are compatible with the National Sustainable Development

Strategy (Egypt Vision 2030) goals, more particularly the fifth track, the theme of "Environment and Natural Resources Protection", section 2, "Stimulating and supporting the green economy" (Ministry of Higher Education and Scientific Research [MOHESR], 2019).

Conclusion

Our study findings support the perspective that implementation of eco-friendly dental technology options could save considerable amount of water consumption. In my opinion, further intervention studies in the future are required to assess the effect of dry vacuum suction system, fast cycle washer disinfector, and water eco sterilizer or ECO sterilizers – ECO 2 on water saving in dental care facilities.

Acknowledgement

First and foremost, my thanks are directed to Prof Dr. Aleya Hanafy El-Zoka and Prof Dr. Mmdouh Hanafy Abdou, Professors of Environmental Health, Department of Occupational Health and Industrial Medicine, High Institute of Public Health, Alexandria University for their unlimited help and continuous assistance.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Abdel-Shafy, H. I., & Kamel, A. H. (2016). Groundwater in Egypt issue: resources, location, amount, contamination, protection, renewal, future overview. *The Egyptian Journal of Chemistry, 59*(3), 321-362.

Abdin, A. E., & Gaafar, I. (2009). Rational water use in Egypt. In M. El Moujabber, L. Mandi, G. T. Liuzzi, I. Martin, A. Rabi & R. Rodriguez (Eds.), *Technological perspectives for rational use of water resources in the Mediterranean region* (p.p. 11-28). Centre International des Hautes Etudes Agronomiques Méditerranéennes (CIHEAM), Italy.

Adams, E. (2007). Eco-friendly dentistry: not a matter of choice. *Journal (Canadian Dental Association), 73*(7), 581-584.

Amer, M. H., Abd El Hafez, S. A., & Abd El Ghany, M. B. (2017). *Water Saving in Irrigated Agriculture in Egypt*. LAP LAMBERT Academic Publishing, Mauritius.

Bhutiani, R., Ahamad, F., & Ram, K. (2021). Quality assessment of groundwater at laksar block, haridwar in uttarakhand, India using water quality index: a case study. *Journal of Applied and Natural Science*, *13*(1), 197-203.

Bhutiani, R., Ahamad, F., & Ruhela, M. (2021). Effect of composition and depth of filter-bed on the efficiency of Sand-intermittent-filter treating the Industrial wastewater at Haridwar, India. *Journal of Applied and Natural Science*, *13*(1), 88-94.

Bhutiani, R., & Ahamad, F. (2019). A case study on changing pattern of agriculture and related factors at Najibabad region of Bijnor, India. *Contaminants in Agriculture and Environment: Health Risks and Remediation*, *1*, 236.

Consolidated Sterilizer Systems. (2022). Consolidated Sterilizers. Retrieved from https://consteril.com/products/sterilizers/.

Dentalez. (2021). The Guide to Dental Vacuum Pumps: Wet vs Dry. Retrieved from https://www.dentalez.com/the-guide-to-dental-vacuum-pumps-wet-vs-dry/.

Elkholy, M. (2021). Assessment of Water Resources in Egypt: Current Status and Future Plan. In A. Negm & A. Elkhouly (Eds.), *Groundwater in Egypt's Deserts* (p.p. 395-423). Springer, Cham.

Fotedar, S. (2014). Green dentistry: eco-friendly dentistry. *Indian Journal of Dental Advancements, 6*(4), 1703-1706.

Fried, A., & Serio, B. (2012). *Water industry segment report desalination*. A report by World Trade Center San Diego (WTCSD),

Ministry of Higher Education and Scientific Research [MOHESR]. (2019). *National Strategy for Science, Technology and Innovation 2030*. MOHESR, Egypt.

Ruhela, M., Sharma, K., Bhutiani, R., Chandniha, S. K., Kumar, V., Tyagi, K., ... & Tyagi, I. (2022). GIS-based impact assessment and spatial distribution of air and water pollutants in mining area. *Environmental Science and Pollution Research*, *29*(21), 31486-31500.

Steelco. (2022). ECO options: every drop counts!. Retrieved fromhttp://www.steelcogroup.com/en/products-catalogue/item/eco-options-med.

Studio Z Dental. (2022). Water Conservation. Retrieved from https://www.studiozdental.com/blog/water-conservation/.

World Dental Federation [FDI]. (2007). Sustainability in Dentistry. Retrieved from https://www.fdiworlddental.org/sustainability-dentistry.

Subscription/ Membership Information

Membership of Action for Sustainable Efficacious Development and Awareness (ASEA), INDIA is open for all those interested in the field of environment. There are two types of membership's available *i.e* Annual Membership and Life# Membership. All Members are entitled to get Environment Conservation Journal free and are entitled to submit their papers/ articles for publication in the journal.

MEMBERSHIP FORM/ SUBSCRIPTION FORM

Name ....

Designation ....

Qualification ....

Organization ....

Address ....

....

Electronic Address..

Telephone .... Fax Number..

Type of Membership Annual [ ] Life# [ ]

Attach Biodata along with this application

Subscription/Membership Fee

	India		Abroad	
	Annual (In Rs.)	**Life# (In Rs.)**	**Annual (In US$)**	**Life# (In US$)**
Individual	2000	15000	75	1000
Institutional	5000	25000	250	2500

All remittance should be paid by DD in the name of **Environment Conservation Journal,** Payable at Haridwar (U.K.) India, and be sent to **Prof. D.R. Khanna, 405-Vivek Vihar, Ranipur More Haridwar, 249407 (Uttarakhand), INDIA.** For and queries or enquiries you may contact us on **environcj@gmail.com**

#Note: Life membership is for 10 years

Xerox of this form may be used if required

Website: www.environcj.in