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Comprehensive assessment of heavy metals contamination in soil and water in peri-urban areas of National Capital Territory, Delhi

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ABSTRACT

Contamination of soil and irrigation water by heavy metals (HMs) is a genuine concern due to the possible effect on human well-being via food chain. Thus, an assessment was carried out to find HMs concentration level in water and soil samples of peri-urban areas of National Capital Territory (NCT) Delhi. Analytical results revealed that significant amount of HMs concentration were found in irrigation water, out of which concentrations of Cu (2590 µg/L), Fe (5549 µg/L), Cr (1910 µg/L), Mn (2570 µg/L), Zn (2155 µg/L) and Cd (405 µg/L) in drain water were exceeded the permissible limit of FAO. Cu (108.94 µg/g) and Pb (163 µg/g) concentration in surface soils of majority of sites were recorded beyond the permissible limit of FAO. The overall mean HMs concentration in soil found in the sequence Zn>Cu>Fe>Mn>Cr>Ni>Pb>Cd. It reveals that increasing trend of HMs concentration in water used for irrigation results in metal accumulation in soil, and their consequent accrual in the crops lead to adverse impact on human well-being.

Introduction

Peri-urban areas have dominance in a wide range of allied activities along with arable farming and are often used for production of horticulture, floriculture, poultry and dairy development due heavy demands and profitability. But majority of peri-urban lands are polluted with toxic metals by various sources such as industrial effluents, dumping sites, sewerage, vehicular emission, human induced pollution and indiscriminate use of chemicals fertilizers (Bhattacharya *et al.,* 2015; Bhardwaj *et al.,* 2020). Irrigation water is contaminated with toxic metals due to various sources (Khan *et al.,* 2015; Singh *et al.,* 2021). Thus, agriculture products grown in these areas are liked to be contaminated by heavy metals (HMs). HMs contamination of cultivated soils may create great ecological and environmental issues. Besides, their movement from soil-to-crop is the main pathway of human exposure to these metals. Continuous population growth leads to increased food requirement, large consumption of pesticides, manures, fertilizers and so on is also on the rise besides use of wastewater for agricultural irrigation. Such practices not only led to deterioration of food quality but also have serious impact on food security. Since, the physicochemical characteristics of soil and nature of plant species is important factor for HMs accumulation (Khan *et al.,* 2015; Chabukdhara *et al.,* 2016; Singh *et al.,* 2021).Globally more than 70% water is consumed by the agriculture sector (Mancosu *et al.,* 2015). However, the availability of fresh groundwater for agriculture is decreasing largely due to increasing demand of water from energy and municipal

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industries in urban as well as peri-urban regions. Irrigation with metal contaminated water *i.e.* drain, river, groundwater can lead to increase in metals concentration in cultivated soil (Gola *et al.,* 2020). Normally, wastewater contains noteworthy quantity of beneficial nutrients and toxic HMs. Increased use of agro-chemicals also causes polluted crop land by HMs (Balkhair and Ashraf, 2016).

River Yamuna is the imperative water source for northern India, and covered about 48 km of the national capital territory (NCT), Delhi, and contributing about 94%, 4% and 2% for irrigation, household and industrial and other applications, respectively (CPCB 2006). Due to metropolitan city and capital of India, industrialization and urbanization are major factor for water and soil pollution. NCT of Delhi has an impenetrable population of around 160 lakhs (Census 2011). It has the larger load of small to medium size industries deals in electroplating steel processing, battery, dyeing, electrical appliances manufacturing and printing etc. The effluents produced from these various industries are discharged into open drains or into sewerage lines which are finally disposed into river Yamuna (Bhattacharya *et al.,* 2015). Moreover, the river is also connected by around 23 drains carrying huge quantity of sewage /wastewater that released into the river without proper treatment and hence contributed sources of pollution. Considering the above problem the study was conducted to assess the HMs concentration in irrigation water as well as soil at different places belongs to NCT of Delhi.

Material and Methods

Sampling: In Per-urban and urban area of Delhi NCT, total 10 sampling sites were identified for soil and water samples collection. A Location map of sampling site is given in Figure 1. Water samples were collected from various sources such (i) drains from Najafgarh (S1), Wazirabad (S2) and Nizamuddin (S3), (ii) Yamuna River from Yamuna Vihar (S4) and Sonia Vihar (S5) and (iii) Tube wells water from Ranhaula (S6), SaritaVihar (S7), Dinchaon Kalan (S8), Madanpur Khadar (S9) and Jagatpur (S10) during post-monsoon in 2019 and 2020. Besides, soil samples from surface (0-30cm) and subsurface (30-60cm) layers were also collected from cultivated fields, which have different contamination sources due to industrialization and urbanization of Delhi NCT.

Sample preparation and heavy metal analysis: 15ml of Di-acid mixture (HNO_3 and $HClO_4$ in 9:4 ratio) was added in 100 ml of water samples and heated at 80ºC till a clear solution was attained. After cooling, this sample was filtered by filter paper (Whatman # 42) and make up the volume of the filtrate to 100 ml with double distil water. Further, One gram of soil sample was digested subsequently adding 15 ml of tri-acid mixture (nitric, sulfuric and perchloric acids in ratio 5:1:1) at 80ºC until a clear solution was achieved. Sample was cooled and filtered by Whatman No. 42 filter paper and make up the volume of the filtrate to 25 mL with double distilled water (Singh *et al.,* 2021). Copper (Cu), Iron (Fe), manganese (Mn) nickel (Ni), lead (Pb), zinc (Zn),Cadmium (Cd) and chromium (Cr), in prepared water and soil samples were examined through an atomic absorption spectrophotometer (AAS4141, ECIL, India). The instrument was calibrated by a manually prepared standard solution of each metals and drift blanks. Standard stock solutions of 1000ppm used for all metals.

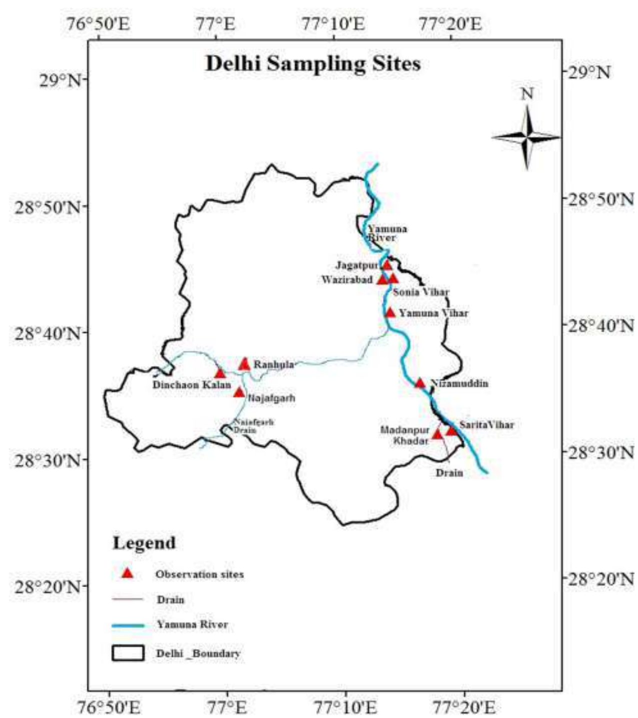

Figure 1: Location map of sampling site in Delhi NCT.

Results and Discussion

Irrigation water: A comprehensive range of eight HMs concentrations (μg/L) present in Yamuna River, associated drains and tube well water of Delhi NCT is compared with the previous studies (Table 1). Figure 2 a, b, and c representing the each metal concentrations at different sampling sites from S1 to S3 for drain, from S4 and 5 for river and S6 to S10 for tube well water. The overall mean with standard deviation (SD) of Cu, Fe, Mn, Ni, Pb, Cd, Cr, and Zn were found 795.4±1153.2, 1784.4±2353.8, 893.1±1045.4, 218.4±260.4, 5137±618,133±163.8, 472.2±693.5 and 776.1±915.7μg/L, respectively. Results reveal that, the HMs i.e. Cd, Cr, Ni and Pb in tube-well water were reported below detection limit (BDL) whereas, all the metals concentration in tube-well water were recorded as under permissible limit as suggested by FAO for irrigation. The AAS-4141 detection limit for Cu, Fe, Mn, Ni, Pb, Cd, Cr, and Zn was 40, 50, 30, 200, 200, 10, 60 and 10 μg/L, respectively. Highest concentration of Cd (405 μg/L) and Cr (1910 μg/L), Fe (5549 μg/L), Mn (2570 μg/L), Ni (612 μg/L), Pb (1490 μg/L), and Zn (2155 μg/L) were recorded at Najafgarh site followed by Nizamuddin. It may be due to contamination by industrial effluents dyes as Najafgarh site has major drain which carries lots of industrials and municipal wastewaters/ effluents. Farmers in peri-urban areas along these drains are frequently uses this water as irrigational purposes. Hence, it is serious concern to monitor the quality of soil and agricultural produce. However, higher Cu concentration (2590 μg/L) was recorded at Nizamuddin site followed by Najafgarh site. Nizamuddin sites also having industrials belt including Okhla area and carries wastewaters. More or less similar concentration of HMs were reported by Bhattacharya *et al.* (2015) for Zn (130–2220 μg/L), Bhardwaj *et al.* (2017) for Fe (878.5–53940 μg/L), Cr (2.6–1983 μg/L), and Cd (1.7–433 μg/L) (Table 1). Najafgarh drain is highly polluted, mainly due to the effluent release of the nearby industrial enclaves (alloy, pickling, printing, steel, battery, plastic, chemical, electroplating, dyeing, galvanization and leather). Nizamuddin drain is the confluence point of several drains, hence carry significant amount of pollutants from small scale industrial effluents, sewage and sludge. Yamuna River is ultimately discharge point of all drains of Delhi NCT. The concentrations of Cu, Fe, Mn, Cr, Cd, and Zn in drain water found beyond the permissible limit of FAO, except Fe and Zn concentration at Wazirabad. Pb concentration was within safe limit of FAO at all sampling sites water. Moreover, Cu, Fe, Pb and Zn concentration in river water was within limit of FAO. However, Cd, Cr, Mn and Ni concentration was beyond the permissible limit of FAO.

Heavy metals concentration in soil of peri-urban areas: HMs concentration (μg/g) in cultivated soils of different peri-urban areas and Yamuna sites of Delhi NCT is given in Table 2. The overall mean with SD of Cd, Cu, Mn, Fe, Ni, Pb, Cr, and Zn in farming soil were found 1.72±0.42, 59.53±23.99, 47.9±14.7, 54.91±11.55, 35.06±7.61, 33.56±9.81, 43.13±12.2, and 92.02±26.45 μg/g, respectively. The overall mean metal concentration reported in decrease order Zn>Cu>Fe>Mn>Cr>Ni>Pb>Cd. Concentration of all these eight metals at each sampling sites were reported in Figure3. Maximum concentrations of Cd (2.76 μg/g), Cr (66.44 μg/g), Cu (108.94 μg/g), Ni (51.92μg/g) and Zn (162.99 μg/g) were recorded at Najafgarh site followed by Nizamuddin. However, maximum Fe (79.89 μg/g), Mn (70.73 μg/g) and Ni (53.14 μg/g) concentration were recorded at Nizamuddin followed by Najafgarh. This is probably due to frequent use of Najafgarh and Nizamuddin drains water for irrigation. Moreover, this drain discharges across the industrial sites inflicted with huge effluents, vehicular emission, sewage and sludge, diesel generators and pesticides application in farming. This HMs load is often led to deterioration of soil health as well as contamination of agricultural produce.HMs concentration in soil is mainly depends on soil geogenic property, irrigation water qualities, indiscriminate use of chemical fertilizers and pesticides (Singh *et al.,* 2021). Slightly similar HMs concentration in per-urban soil was observed by Bhatia *et al.* (2015) for Cd (2.28–2.51 μg/g), Pb (21.25- 59.38 μg/g) and Zn (73.25–174.5 μg/g) (Table 2). Moreover, Patel *et al.* (2019) was reported Cr concentration 10.1– 73.6 μg/g, which is almost close to present finding.

Lower heavy metal concentration was recorded in sub-surface soil in comparison to surface soil. Minimum HMs concentrations were recorded in

Table 1: Range of heavy metal concentration (µg/L) in water of Yamuna River and associated drains in Delhi NCT

Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Water category	Reference
20–40	–	80–310	–	–	–	0.0–800	0.0–240	Drain and tube well	Singh and Kumar (2006)
0.02-0.07	–	0.18–0.28	–	–	–	0.30–0.43	0.04–0.06	Tube well	Bhatia *et al.,*(2015)
0.0–70	0.0–420	20–640	–	–	10–130	30–270	130–2220	Yamuna River and linked drains	Bhattacharya *et al.,*(2015)
1.7–433	2.6–1983	18.4–17642	878.5–53940	–	1.4–2748	6.8–1112	15.4–28520	Yamuna River and linked drains	Bhardwaj *et al.,*(2017)
1–8	60–940	50–520	–	–	–	450–680	–	Yamuna River and linked drains	Rahman and Singh (2018)
–	20–270	40–380	–	–	40–230	490–970	80–760	Yamuna River	Patel *et al.,*(2019)
0–75	0–2436	0–2617	–	–	0–596	0–1579	0–12400	Drains	Gola *et al.,*(2020)
–	35–52	50–120	40-190	–	88–253	2–40	840–1800	Yamuna River	Asim and Rao (2021)
BDL-405	BDL-1910	47-2590	58-5549	51-2570	BDL-612	BDL-1490	28-2155	Yamuna River, linked drains and tube well	Present study
10	100	200	5000	200	200	5000	2000	Irrigation water	FAO Safe limit[a]

Source: [a]Mandal *et al.,* (2019).

Table 2: Range of heavy metal concentration (µg/g) in soil in different per-urban and Yamuna sites of Delhi NCT

Cadmium	Chromium	Copper	Iron	Manganese	Nickel	Lead	Zinc	Place	References
0.6-1.30	43-95	6.39-39		142-651	11.8-48	9.90-32	31-108	Delhi	Mehra *et al.,*(2000)
2.1–2.5	–	28.8–129.6	–	–	–	32.1–59.6	83.1–196.3	Delhi	Singh and Kumar (2006)
2.28–2.51	–	23.75– 76.75			–	21.25- 59.38	73.25–174.5	Delhi	Bhatia *et al.,*(2015)
–	10.1– 73.6	7.1–42.1	–	–	6.4–19.3	9.1 -25.8	13.5–55.6	Along Yamuna River	Patel *et al.,*(2019)
1.22–2.76	21.84–66.44	29.67–108.94	37.39–79.89	28.02–70.73	25.11–51.92	20.59–53.14	56.43–162.99	Delhi	Present study
3	75	100	5000	2000	100	50	300	-	FAO/WHO standards [a, b]
3–6	NA	135–270	-	-	75–150	250–500	300–600	-	Indian standards [c]

Sources: [a]Gitet *et al.,*(2016), [b]Nartey *et al.,*(2012), [c]Bhatia *et al.,*(2015)

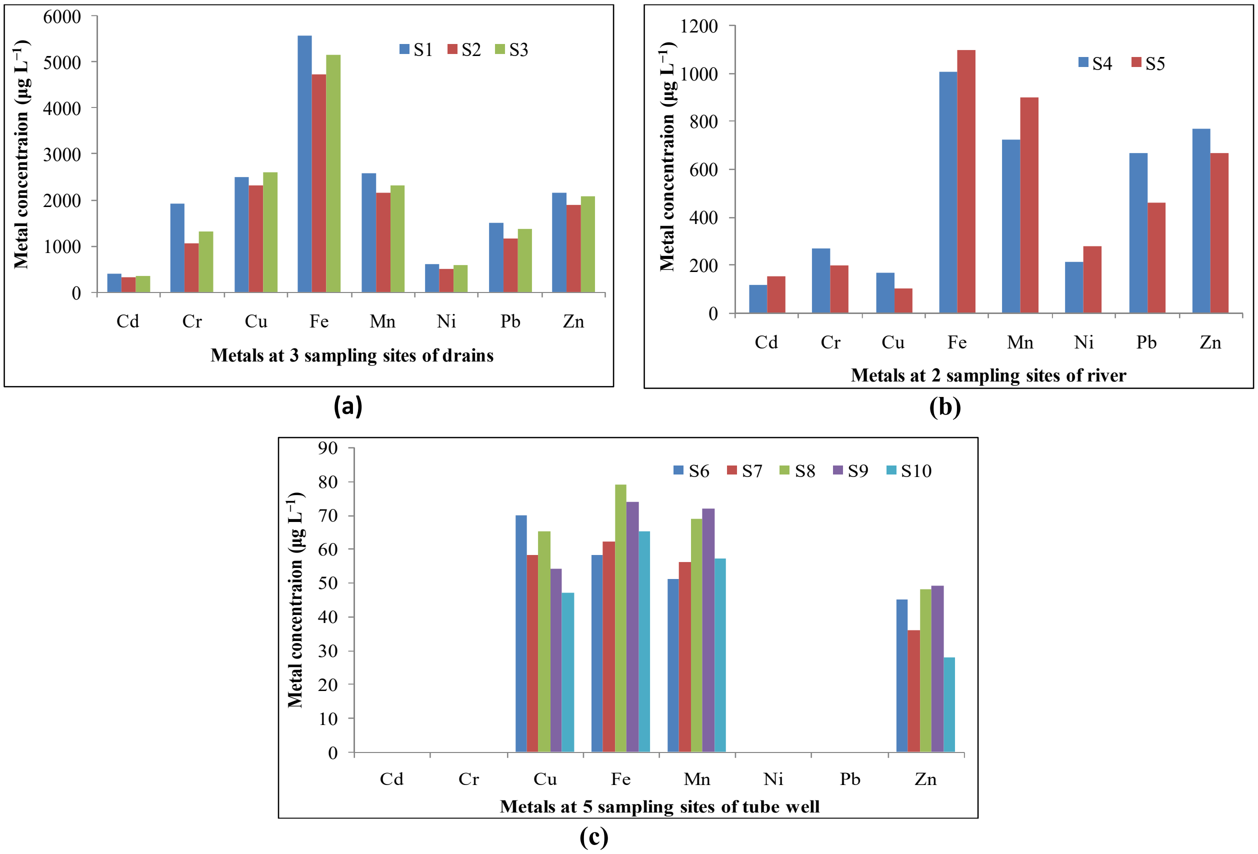

Figure 2: Heavy metals concentrations at different sampling sites in (a) drain, (b) River and (c) tube well water.

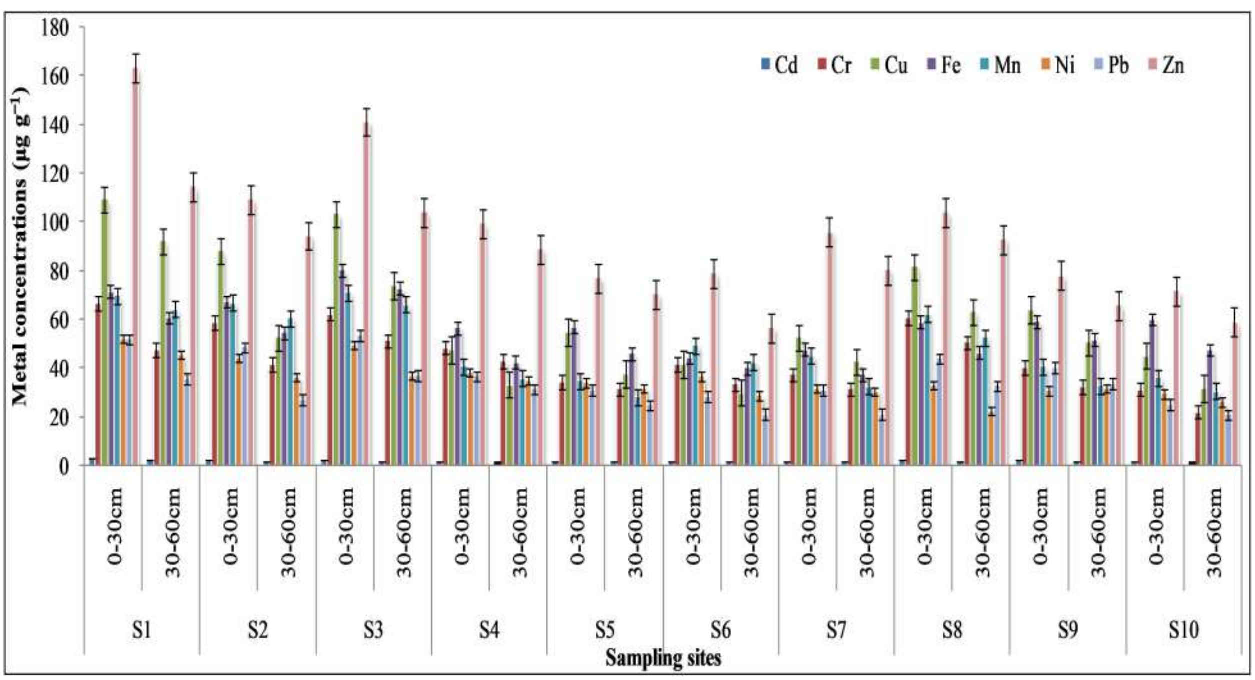

Figure 3: Eight heavy metal concentrations in 10 sampling sites of Delhi NCT.

reported occasional use of drain water for irrigation purpose in some of the agricultural fields. A significant amount of HMs concentration was found in soil along Yamuna River sites (S5–S6). Cu and Pb concentration in surface soil of Najafgarh and Nizamuddin were beyond the permissible limit of FAO *i.e.* 100 and 50 μg/g, respectively. Other metals concentration in soil falls within the permissible limits as per FAO and Indian standards. The availability of HMs and differences in heavy metal level in soils may be due to quality of irrigation water, physico-chemical properties as well as different sources of contaminations such as quality of sludge and sewage, use of agro-chemicals/ fertilizers, pesticides, kind of industrialization close to the sampling locations, industrial emission and industrial waste, nearness of cultivated field from road/ highways and urban areas.

Conclusion

Majority of soils and irrigation water of peri-urban areas are found to be contaminated with HMs by various sources such as industrial effluents, dumping sites, sewage and sludge, vehicular emission, human induced pollution and indiscriminate use of chemicals fertilizers. HMs concentration in collected samples from different sources of irrigation water along with soils from Delhi NCT reveals that most of metal concentrations in drain water found beyond the permissible limit of FAO. Continuous use of contaminated water for irrigation observed HMs accumulation in soil, agricultural produce and finally in comes into food chain. Arable contaminated soils may create soil health deterioration and long-term ecological issues. Thus, periodic monitoring of soil and water quality could ensure appropriate and safe usage of irrigation water. Irrigation with drainage water should be restricted in cultivated areas of peri-urban.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Assessing the indoor air pollution level as per energy ladder and its effect on respiratory health

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ABSTRACT

In rural areas of developing countries, where about 40 % of all people live, the household stove accounts for more of all national fuel combustion occur under cooking pots. The present study was undertaken in Hisar district of Haryana state to assess the indoor air pollution level as per the energy ladder and its effect on respiratory health. The study was conducted in the rural villages of Hisar district and rural women who were using traditional chullah were selected as the sample of the study. Results revealed that most of the women were using chullah for cooking their own food and hara for animal feed with fuel placed on the lower rung of energy ladder i.e. crop waste and dung cakes, wood, kerosene, and LPG. Major health problems faced by women were 'headache' and 'irritation in eyes' while using the traditional chullah and hara. The majority of them were also having respiratory problems like 'phlegm' (mean score-2.7) 'shortness of breath' (mean score-2.6), 'cough' (mean score-2.5), and 'wheezing' (attacks) with mean score of 2.0, respectively. Mean PEFR values for the traditional chullah and hara exposed women were significantly lower as compared with MDV chullah and improved hara. Therefore, it is recommended that the use of cheap improved chullah and hara are the best alternative, which is the permanent solution of smoke and also consumes less fuel than traditional chullah and hara.

Introduction

In India over 70 % of the population live in rural areas and less than 1 % of rural households has accessed to electricity and biomass such as firewood, coal, charcoal, kerosene, and agricultural residues. For cooking purposes, the household sector relies heavily on traditional chullah and hara. Pitt *et al.* (2005) observed that the households at lower levels of income and development tend to be at the bottom of the energy ladder, using solid fuel that is cheap and locally available but not clean and nor efficient to use. Over three billion people worldwide are at these lower rungs, depending on biomass fuels-crop waste, dung, wood, leaves etc., and coal to meet their energy needs. A disproportionate number of these individuals reside in Asia and Africa: 95 % of the population in Afghanistan uses these fuels, 95 % in Chad, 87 % in Ghana, 82 % in India, 80 % in China, and so forth (Duflo *et al.,* 2008). According to International Energy Agency (2015) an estimated 2.7 billion people cook meals over brick, stone or clay stoves fuelled by wood, leaves, dung etc. The World Health Organization (2015) reported that the traditional use of solid biomass for cooking, including the release of harmful indoor air pollutants are the major causes of premature death. Mohapatra *et al.* (2018) around three billion people use solid fuels (biomass and coal) for cooking and heating, and this number is expected to grow until at least 2030. Many women and children are

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exposed to high levels of indoor air pollution chullah. There is a serious impact of air pollutants on human health as they are taken by blood and circulated in the body. These chullah and hara are thermally as well as environmentally inefficient and are prone to damage because these are made from mud and baked mud which is quite a good insulator but at the same, it needs to be very thick as mud can crack allowing heat to escape that way and hence creating drudgery and heat problems and indoor pollution. Recently, the concentration of indoor pollution in households that burn traditional fuels is at an alarming point. Burning such fuels produce a large amount of smoke and other air pollutants in the confined space of the home. Policies to reduce indoor air pollution focus on either inducing a healthier fuel choice or on making biomass use cleaner and safer, for example through improved stoves or better ventilation in the cooking areas. As incomes rise, we would expect that households would substitute for higher quality fuel choices. Keeping the above facts in mind a study was planned to assess the indoor air quality and health hazards faced by families who were using the chullah for cooking.

Material and Methods

The present study was undertaken in Hisar district of Haryana state to assess the indoor air pollution level as per the energy ladder and its effect on respiratory health. Two villages (Ludas and Gangwa) from Hisar district were selected randomly. From the selected villages, 50 women (from each village) making a total sample of 100 women were selected randomly to find out the health problems faced by them due to the use of traditional chullah. From the selected women, ten women who were physically fit and willing to cooperate and had not MDV chullah and hara in their households were selected purposively to impart the knowledge regarding construction and benefits of improved chullah and hara. A self-structured schedule was prepared to collect the data regarding problems faced by women during the use of traditional chullah with the different fuels. An observation sheet was prepared to observe the temperature, humidity, and air pollutants in the households. A thermometer, hygrometer, and air quality monitor were used to measure the indoor air emitted from biomass fuel used in quality parameters respectively. For the lung capacity of the women, peak flow meter was used. percentage, mean score, rank, and t-test were computed to assess the different parameters in the study.

Results and Discussion

Fuel switching behaviour of respondents for cooking as per energy ladder: It is evident from perusal of data presented in Figure 1 that in totality, all of the respondents were using crop waste and dung cakes for cooking, followed by 81.00 % respondents who were using wood for cooking purposes, 17.00 % respondents were using LPG gas and an equal number of respondents (3.00% each) were using kerosene and electricity for cooking in both the villages i.e. Gangwa and Ludas. Banerjee (2019) supported this and mentioned that 63% of the rural households were using firewood as the primary cooking fuel while another 23% were using crop residues/dung cakes as fuels for cooking. Only 11 % of rural households were using LPG as primary cooking fuel.

Health-related problems while using chullah and hara: The data presented in Table 1 show that respondents reported health problems when they were using the chullah and hara. The various health constraints' reported by the respondents were; 'headache' got the first rank with a mean score of 2.8, 'irritation in eyes' got the second rank with a mean score of 2.7, 'skin problem' and 'respiratory problem' got 3rd rank with mean score of 2.6, 'backache' and 'bronchial' got 4th rank with mean score of 2.5, 'low visibility, 'decreased working efficiency' and 'cough' got 5th and 6th rank with mean score of 2.4 and 2.2 respectively. Mohapatra *et al.* (2018) also found similar results and concluded that dry cough was the most common reported symptom (15.03%), followed by eye and nose irritation present in nearly 12 % each by the respondents. Headache, dry cough, and hypertension (HT) were found to be associated with the number of cooking years and were also found to be statistically significant (P = 0.03, 0.02, and 0.0065, respectively).

Health-related problems in respondents by use of different fuels Respondents were found to face everal problems while using wood, crop waste, and dung cakes in

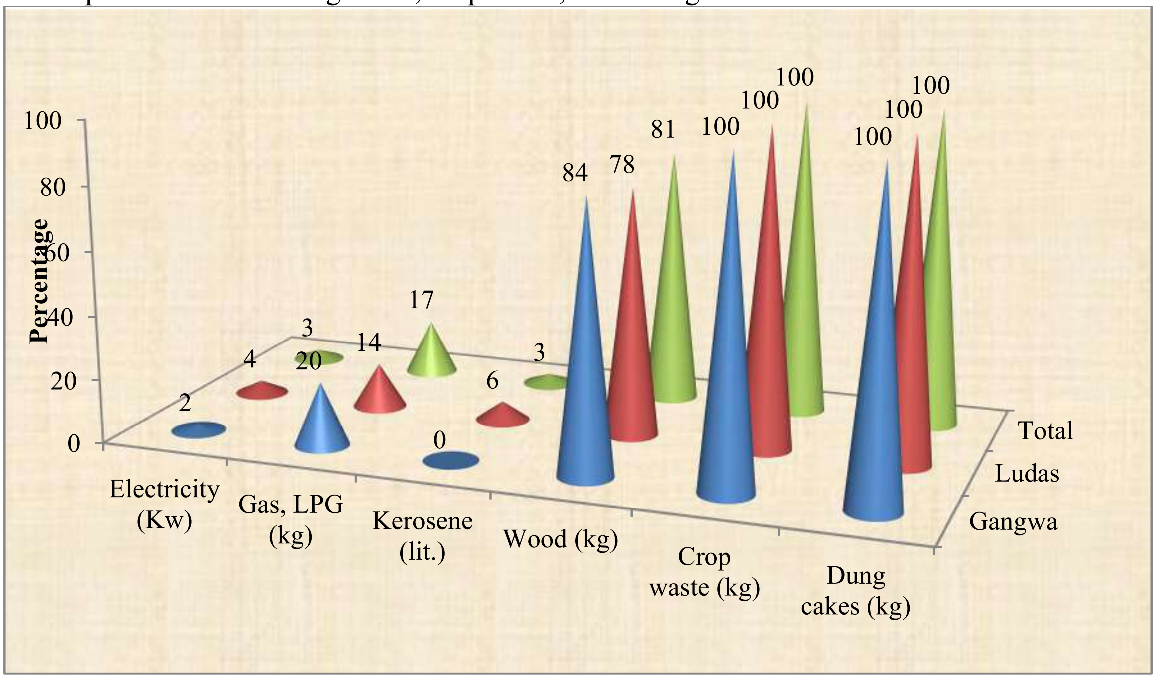

Figure 1: Fuel switching behaivour of respondents for cooking as per energy ladder

traditional chullah and hara. The various health constraints' reported by the respondents were; 'headache' and 'trouble breathing' got the first rank with mean score of 1.4, 'cough' and 'respiratory problem, got 2nd rank with mean score of 1.3, 'irritation in eyes' and 'low visibility' got the third rank with mean score of 1.2 respectively (Table 2). Jaiswal and Meshram (2019) found that most of the selected women in the households achieved a sort of comfort level with the smoke produced from the burning of biomass in chullah while cooking. In the studied populace, (96.7%) were awared about the effects of smoke produced by chullah on women's health like irritation to eyes (95.3%), cough (87.3%), and chest illness (23.8%).

Respiratory health status of respondents: The major respiratory health problems faced by them were cough, phlegm (sputum), shortness of breath and wheezing (attacks) which have been presented in Table 3. The respiratory health problems reported by the respondents were; 'phlegm' (sputum) got the first rank with mean score of 2.7, 'shortness of breath' got 2nd rank with mean score of 2.6, 'cough' got the third rank with mean score of 2.5 and 'wheezing' (attacks) got 4th rank with mean score of 2.0, respectively. According to Dass and Panda (2017), about 400 million people in India were exposed to respiratory, pulmonary, and vision problems allied with indoor air pollution from the use of biomass.

Frequency of respiratory diseases in respondents during the last year: The perusal of data given in Table 4 depicts the frequency of occurrence of respiratory diseases viz. 3 or more, 1 or 2, and not at all by the respondents during the last one year. Respiratory diseases faced by the majority of the respondents were in 'not severe' (2.6) followed by 'moderate' (1.5) and 'severe' (1.4) categories respectively. James *et al.* (2020) also concluded the self-reported health conditions among women were grouped as follows—ophthalmic conditions included diminished vision, cataract, irritation, and watering of eyes, while respiratory conditions included throat irritation, ear pain, asthma, nasal stuffiness/ running nose, cough with/ without phlegm by the exposure of biomass fuel used in chullah.

Environmental parameters in the household as per energy ladder with use of chullah: To measure the difference in environmental parameters while using different fuels as per energy ladder, only crop waste and dung cake were used as a fuel for chullah and it was observed that SPM was (456 μg/m^3) in the traditional chullah before cooking and

Table 1 : Health related problems while using chullah and hara (n=100)

SN	Health problems	Severe (3)	Moderate (2)	Not severe (1)	Mean score	Rank
1.	Cough	40	40	20	2.2	VI
2.	Backache	60	30	10	2.5	IV
3.	Headache	80	20	-	2.8	I
4.	Low visibility	50	40	10	2.4	V
5.	Irritation in eyes	70	30	-	2.7	II
6.	Decreased working efficiency	40	40	20	2.2	VI
7.	Respiratory problems	60	40	-	2.6	III
8.	Skin problem	60	40	-	2.6	III

Table 2: Health related problems in respondnets by using of different fuels (n=100)

SN	Health problems	Fuels		Mean score	Rank
		Wood (2)	Crop waste and dung cakes (1)		
1.	Cough	30	70	1.3	II
2.	Headache	40	60	1.4	I
3.	Low visibility	20	80	1.2	III
4.	Irritation in eyes	20	80	1.2	III
5.	Respiratory problems	30	70	1.3	II
6.	Trouble breathing	40	60	1.4	I

Table 3: Respiratory health status of respondents (n=10)

SN	Respiratory problem	Most days a week (4)	Several days a week (3)	Only with chest infections (2)	Not at all (1)	Mean score	Rank
1.	Cough	2	2	5	1	2.5	III
2.	Phlegm (sputum)	2	4	3	1	2.7	I
3.	Shortness of breath	2	4	2	2	2.6	II
4.	Wheezing (Attacks)	1	1	5	3	2.0	IV

*St. George respiratory health status

Table 4: Frequency of respiratory diseases in respondents during the last year (n=10)

SN	Types of diseases	3 or more (3)	1 or 2 (2)	None (1)	Mean score	Rank
1.	Severe	1	2	7	1.4	III
2.	Moderate	2	1	7	1.5	II
3.	Not severe	7	2	1	2.6	I

Table 5: Environmental parameters in household as per energy ladder with use of chullah (n=10)

Parameters	Permissible limit	Crop waste used for cooking				Dung cakes used for cooking			
		Traditional chullah		MDVchullah		Traditional chullah		Improved chullah	
		Before	After	Before	After	Before	After	Before	After
SPM($\mu g/m^3$)	500	456	670	456	490	498	980	498	596
Temp. (^0C)	25-30	34.5	37.3	34.5	36.4	34.4	38.1	34.4	36.7
R.H. (%)	40-60	50.6	47.2	50.6	48.1	50.1	46.2	50.1	48.5
CO_2(ppm)	400-600	524	782	524	672	694	825	694	745

Table 6: Environmental parameters in households as per energy ladder with use of hara(n=10)

Parameters	Permissible limit	Dung cakes used for cooking			
		Traditional hara		Improved hara	
		Before	After	Before	After
SPM(µg/m³)	500	657	710	657	545
Temp. (^{0}C)	25-30	35.1	38.4	35.1	36.9
R.H. (%)	40-60	52.0	48.4	52.0	49.3
CO_2(ppm)	400-600	668	914	668	823

Table 7: Comparative analysis of PEFR (Peak expiratory flow rate) in village Gangwa and Ludas (n=10)

SN	PEFR	Permissible Limit (L/min.)	Traditional chullah and hara	MDV Chullah and Improvedhara	Difference	t-value
Gangwa						
1.	Before	300-400	250±14.14	346±11.40	96.3**	18.83
2.	After		238±8.37	324±11.19	86.2**	12.50
Ludas						
1.	Before	300-400	262±19.23	360±15.81	98.3**	16.81
2.	After		220±18.71	332±13.04	112.5**	9.33

after cooking was 670 µg/m³ whereas, in the MDV chullah, it was observed that SPM before cooking (456 µg/m³) and after cooking (490 µg/m³) while using the crop waste. Whereas, in use of dung cakes, before cooking activity, it was 498 µg/m³ and after cooking 980 µg/m³ on traditional chullah whereas, in MDV chullah before cooking 498 µg/m³ and after cooking 596 µg/m³. The permissive value was 500 µg/m³. Data in table 5 show that the mean temperature near the cooking unit was 37.3^{o}C where cooking on traditional chullah whereas, mean temperature of the household where cooking was carried out on MDV chullah was 36.4^{o}C as use of crop waste for cooking. Whereas, the use of dung cakes for cooking, in traditional chullah the average mean temperature was 38.1^{o}C, and MDV chullah was 36.7^{o}C.

Average relative humidity was least in the household where cooking was carried out on MDV chullah i.e. 47.2% whereas 48.1% in the household environment where cooking was carried out on traditional chullah as crop waste used for cooking. The recommended level was 40 to 60 %. As dung cakes used for cooking, the average relative humidity on traditional chullah was 48.5 % whereas, 46.2 % on MDV chullah. Data in the table also show that the average CO_2 in the environment of traditional chullah before cooking was 524 ppm and after cooking was 782 ppm. Whereas, in MDV chullah it was 524 ppm before cooking and 672 ppm after cooking, respectively as used for crop waste. As dung cakes used for cooking, the average CO_2 on traditional chullah was 825 ppm whereas, 745 ppm in MDV chullah. Kasom (2019) & Baqir *et al.* (2019) reported that the majority of the rural people were using U-shaped traditional chulha. That is thermally inefficient and emitted emissions directly into the indoor areas of households and raised health and environmental issues.

Environmental parameters in the household as per energy ladder with use of dung cakes in hara: In the process of cooking in hara with dung cakes, it was observed that in the smoke of traditional hara and improved hara, the SPM present was with the difference of 710 and 545 µg/m³ respectively (Table 6) but the permissive value was 500 µg/m³. Suspended particulate matter of smoke released from both the hara was not in the permissible limit, but in improved hara it was on the lower side. After cooking, the average mean temperature of traditional hara was 38.4 ^{o}C and improved hara was 36.9^{o}C. Whereas the relative humidity of traditional hara was 48.4% and improved hara was 49.3%. Data in the table also show that the average CO_2 in the environment of traditional hara after cooking was 914 ppm and in improved hara it was 823 ppm. Faizan and Thakur (2019) also stated that the use of solid fuels in household cooking contributes to indoor air pollution and is the cause of more than 4 million deaths around the world annually. High dependence on solid fuels (80.5%) and a higher risk of respiratory diseases were observed in rural areas as compared to urban areas.

Comparative analysis of PEFR (Peak expiratory flow rate)

Before the cooking activity: Data in Table 7 elucidate that the average PEFR of the respondents of Gangwa village before cooking on traditional chullah and hara was 250±14.14 (L/min), on MDV chullah and improved hara it was 346±11.40 (L/min) and in Ludas village respondents before cooking on traditional chullah and hara was 262±19.23 (L/min), on MDV chullah and improved hara was 360±15.81 (L/min). Results were also in consonance with Ibhazehiebo *et al.* (2006) who studied the ventilatory function peak expiratory flow rate (PEFR) of 350 rural women engaged in cooking. The mean PEFR value for the wood exposed women (289 ± 19.6 L/mm) was significantly lower ($P<0.05$) compared with control (non-wood smoke exposure) (364 ± 17.2 L/mm). The PEFR decreases with increase in years of exposure to wood smoke and the fall was neither accounted for by age nor height. The respiratory symptom was also markedly elevated in these women compared to control.

After cooking activity: Data in Table 7 shows that the average PEFR of the respondents after minutes of cooking on traditional chullah and hara was 238±8.37 (L/min), followed by MDV chullah and improved hara with PEFR of 324±11.19 (L/min) in Gangwa village and 220±18.71 and 332±13.04 (L/min.). The 't' test proved that mean PEFR values for the traditional chullah and hara exposed women were significantly lower compared with MDV chullah and improved hara exposure at 5% level of significance. Hence, it can be concluded that with the use of MDV chullah and improved hara which clearly shows that quantity of smoke generated decreased in MDV chullah and improved hara. Johnson *et al.* (2011) found that PEFR was significantly decreased (319.3 l/min) in biomass users as compared to users of clean fuel (371.7 l/min). Dudi *et al.* (2017) reported that Peak Expiratory Flow Rate (PEFR) in the biomass user group was 2.34 ± 0.38 while in LPG user group FVC is 2.51 ± 0.31 which is significantly lower as compared to LPG user group.

Conclusion

It was concluded that cent percent of respondents were using chullah for own food and hara for animal feed with fuel placed on the lower rung of the energy ladder i.e. crop waste and dung cakes. While using chullah and hara, respondents faced major health problems of 'headache (mean score-2.8)', 'irritation in eyes (mean score-2.7)', respiratory and skin problems (mean score-2.6 respectively). In respiratory problems, the majority of them were having like 'phlegm' (2.7) 'shortness of breath' (2.6), 'cough' (2.5), and 'wheezing' (attacks) with mean score of 2.0, respectively. By using of dung cakes SPM and CO_2 values were high in traditional hara in comparison to improved hara. There was a significant difference in PEFR value in traditional and MDV chullah and improved hara. SPM and CO_2 were found to be in permissible limits i.e. 500 $\mu g/m^3$ and 400-600 ppm respectively with the use of improved hara and MDV chullah and hence, found to be reducing pollution burden to some extent. It is recommended that motivational programmes need to be conducted with help of anganwadi/volunteers/extension workers to promote improved cookstoves for a healthy indoor environment and to reduce respiratory problems of women.

Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of *Ailanthus* species and seasons on yarn parameters of eri silk

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ABSTRACT

Present research entails an in-depth analysis on the effect of two secondary host plants of eri silkworm *viz.,* borpat (*Ailanthus grandis* Prain) and borkesseru (*Ailanthus excels* Roxb.) and seasons on yarn parameters of eri silk as quality of silk depends on food quality and rearing season. Seasons had significant effect on all the yarn parameters *viz*., yarn size, breaking load, tenacity and elongation except twist per inch. Significantly the highest yarn size (10.26^{s}) was observed in autumn season which was *at par* with the spring season. But the maximum breaking load (0.67 kg) and tenacity (1.40 g/denier) were recorded in spring season and elongation (26.54%) in early summer season. Regardless of the seasons, significantly the higher breaking load (0.64 kg) and tenacity (1.51 g/denier) were recorded on the borkesseru leaves. The interaction effect of seasons and two host plants on eri silk yarn was found to be non-significant. Diversiform effect of both the seasons and the host plants pertaining to yarn characters were witnessed. It can be ensured that all the seasons and host plants are relevant with slight alteration in the yarn quality.

Introduction

The finished product of sericulture industry is the silk, the 'Queen of Textiles'. In India, North-Eastern region is considered as hotspot of seri-biodiversity contingent upon *vanya* silk area. The eri silkworm (*Samia ricini* Boisduval), a *vanya* silkworm, is reared indoor mostly as a part time job by the females of the tribal communities of North-East region. The North-Eastern region of India shares major portion of eri silk production in the country and Assam being the highest producer. Eri silk is also known as 'poor man's silk'. It is also referred as 'Ahimsa silk' or 'Non violent silk' as processing of cocoon does not require killing of the pupa. The unique properties of this fiber in terms of its fineness, density, cross sectional shape and surface properties play an important role in determining its end use and have immense potential for commercial exploitation by making finest quality blankets, sweaters and suiting materials (Tamta and Mahajan, 2021).

Silkworm nutrition is an important component in silk production, and this constituent determines the silk quality and silk trade all over the world (Ruth *et al.,* 2019). Qualities and production of eri silk cocoon and eri silk yarn depends on the different food plants (Gahlaut and Arjun, 2016). Silk yarn quality is also affected by the rearing activities. The execution of fibres during processing and the properties of the finished product are determined by the physical properties of spun yarn. In respect of physical properties of spun yarn, the seasonal variation plays an important role (Renuka and Shamitha, 2014; Bhuyan *et al.,* 2017). Lower (1988) disclosed that with respect to the seasons, the physical properties of the silk *viz.,* strength and elongation differs. In terms of single fibre denier and tenacity of eri silk, noticeable differences were observed when the silkworms were reared on different seasons (Chattopadhyay *et al*., 2018). Variation in the yarn quality is greatly influenced

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by the environmental condition also (Nath *et al.,* 2013). Despite the fact that various studies have been conducted, there is insufficient of literature on the impact of season and secondary host plants on yarn parameters of eri silk. The current study will have the potential to aid in the development of a feasible usage of the secondary host plant in appropriate seasons for eri silkworm without jeopardizing the quality and quantity of silk produce per crop.

Material and Methods

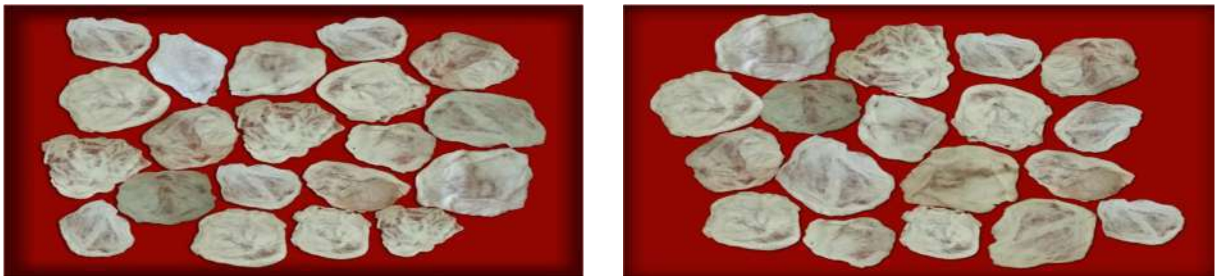
The eri spun yarn from feeding two *Ailanthus* species *viz*., borkesseru and borpat under family simaroubaceae were tested during four different seasons *viz.,* spring (March-April), early summer (May-June), late summer (August-September), autumn (October-November) in the year 2019. The sericin of harvested cocoons was eliminated by the degumming process as suggested and optimized by Somashekar (2003). The eri cakes (Figure1: A & B) were prepared from degummed cocoons by squeezing and the cakes were dried for further spinning process. The spinning of the degummed cocoons for producing single spun yarn filament out of discontinuous filament of the cocoons was performed in the Choudhury spinning machine. The testing of eri spun yarn (Figure 2: A & B) samples for yarn size (count's'), breaking load (kg), tenacity (g/denier) and elongation (%) were conducted in Indian Jute Industries' Research Association (IJIRA), Guwahati, Assam. The breaking load, tenacity and elongation test of the spun yarn were performed according to I.S procedure (1960-1991) by using computerized Instron tensile tester (Model no. 4444) with CRT (Constant Rate Traverse) principle. The twist per inch of the eri silk yarn was recorded by using manual yarn twist tester. The data were laid out in two factorial completely randomized designs for statistical analysis. Each treatment consisted of three replications. The data were subjected to ANOVA table in order to separate out all possible errors. The experimental errors of the various effects were determined by calculating their respective F-values following (Panse and Sukhatme, 1989).

Results and Discussion

The effect of seasons and host plants on yarn size (Table 1) of eri silk was found to be significantly different. Markedly the highest yarn size was observed in the autumn season (10.26^s) whereas the undermost in the early summer (9.09^s) which was found *at par* with the spring season (9.41^s). Host plants have non-significant effect on yarn size. However, the higher yarn size was recorded on borpat leaves (9.77^s) compared to borkesseru leaves (9.42^s). The interaction effect due to season and host plant was found to be non-significant.

The analysis (Table 2) for the effect of host plants on breaking load of eri silk yarn revealed significant effect during various seasons. The highest significant breaking load values were recorded in spring season (0.67 kg) and the lowest was observed in the autumn season (0.49 kg) among various seasons. Apart from the season's, highest significant breaking load was found in borkesseru leaves (0.64 kg) while the lowest in borpat leaves (0.54 kg). Interrelationship between the seasons and host plants were also found to be non-significant for the trait studied. However, the breaking load was recorded highest on borkesseru leaves in spring season (0.71 kg) and the least on borpat leaves during autumn season (0.44 kg) respectively. Seasons and host plants had significant effect on the tenacity (Table 3) of eri silk yarn. Notably tenacity of the eri silk yarn was revealed highest in the spring season (1.40 g/denier) and lowest in the late summer (1.22 g/denier). Irrespective of the seasons, comparatively tenacity of the eri silk yarn was recorded significantly higher on the borkesseru leaves (1.51 g/denier) than borpat leaves (1.11 g/denier). Interrelation impact on tenacity due to season and host plant was found to be non-significant.

A perusal of data (Table 4) revealed that the season had significant effect on the elongation percentage of eri silk yarn. The elongation percentage was found to be significantly maximum in early summer (26.54%) and minimum in autumn season (23.67%). Despite of showing non-significant effect by the host plants on elongation percentage, borkesseru leaves (25.26%) exhibited the maximum elongation percentage.The interaction effect was found to be non-significant due to seasons and host plants. However, borkesseru leaves in early summer (27.31%) showed the maximum elongation percentage and the borpat during autumn season (23.06%) exhibited minimum values.



A. Degummed eri cakes (borpat) B. Degummed eri cakes (borkesseru)

Figure 1: Degumming of eri cocoons and preparation of eri cakes

Table 1: Effect of season and *Ailanthus* species on eri silk yarn size (count 's')

Seasons	Host plants		Mean
	Borpat	Borkesseru	
Spring (Mar-April)	9.62	9.20	9.41
Early summer (May-June)	9.23	8.96	9.09
Late summer (Aug-Sept)	9.89	9.33	9.61
Autumn (Oct-Nov)	10.33	10.19	10.26
Mean	9.77	9.42	
	SED (±)	CD (5%)	
Seasons	0.24	0.51	
Host plants	0.17	NS	
Seasons × Host plants	0.34	NS	

Data are mean of 3 replications, NS = Non-Significant, SED = Standard error of difference

Table 2: Effect of season and *Ailanthus* species on breaking load (kg) of eri silk yarn.

Seasons	Host plants		Mean
	Borpat	Borkesseru	
Spring (Mar-April)	0.63	0.71	0.67
Early summer (May-June)	0.58	0.68	0.63
Late summer (Aug-Sept)	0.52	0.63	0.58
Autumn (Oct-Nov)	0.44	0.54	0.49
Mean	0.54	0.64	
	SED (±)	CD (5%)	
Seasons	0.02	0.04	
Host plants	0.01	0.03	
Seasons × Host plants	0.03	NS	

Data are mean of 3 replications, NS = Non-Significant, SED = Standard error of difference

Table 3: Effect of season and *Ailanthus* species on tenacity (g/denier) of eri silk yarn

Seasons	Host plants		Mean
	Borpat	Borkesseru	
Spring (Mar-April)	1.18	1.62	1.40
Early summer (May-June)	1.12	1.54	1.33
Late summer (Aug-Sept)	1.03	1.40	1.22
Autumn (Oct-Nov)	1.10	1.46	1.28
Mean	1.11	1.51	
	SED (±)	CD (5%)	
Seasons	0.04	0.08	
Host plants	0.03	0.06	
Seasons × Host plants	0.06	NS	

Data are mean of 3 replications, NS = Non-Significant, SED = Standard error of difference

Spring **Early summer** **Late summer** **Autumn**

A. Eri spun yarn produced from eri silkworm reared on borpat leaves in different seasons

Spring **Early summer** **Late summer** **Autumn**

B. Eri spun yarn produced from eri silkworm reared on borkesseru leaves in different seasons

Figure 2: Eri spun yarn in different seasons.

The impact of seasons and host plants *viz*., borpat and borkesseru (Table 5) was found to be non-significant for twist per inch of eri silk yarn. It was found significantly the highest in the late summer (10.10 TPI) and the lowest values were observed in the spring season (9.27 TPI). Regardless of the seasons, the notable higher value in respect to twist per inch was observed in the borkesseru leaves (10.31 TPI) in contrast to borpat leaves (9.22 TPI). The interaction effect on twist per inch due to season and host plant was also found to be non-significant. The physical properties of eri spun yarn are technically important which contribute to the behaviour of the yarn in processing and to the quality of the final product. The yarn count is the numerical expression which shows fineness or roughness of a yarn. The breaking load of a yarn indicates the maximum amount of stress that can be developed in a yarn due to the applied loads prior to breakdown of the yarn. The combine property of strength and elongation of silk yarn is a measure of toughness of material which is related to weaving property.

Table 4: Effect of season and *Ailanthus* species on elongation (%) of eri silk yarn

Seasons	Host plants		Mean
	Borpat	Borkesseru	
Spring (Mar-April)	24.07	24.98	24.53
Early summer (May-June)	25.76	27.31	26.54
Late summer (Aug-Sept)	23.77	24.48	24.13
Autumn (Oct-Nov)	23.06	24.28	23.67
Mean	24.17	25.26	
	SED (±)	CD (5%)	
Seasons	0.81	1.74	
Host plants	0.58	NS	
Seasons × Host plants	1.15	NS	

Data are mean of 3 replications, NS = Non-Significant, SED = Standard error of difference

Table 5: Effect of season and *Ailanthus* species on twist per inch (TPI) of eri silk yarn

Seasons	Host plants		Mean
	Borpat	Borkesseru	
Spring (Mar-April)	8.73	9.80	9.27
Early summer (May-June)	9.23	10.33	9.78
Late summer (Aug-Sept)	9.57	10.62	10.10
Autumn (Oct-Nov)	9.36	10.49	9.93
Mean	9.22	10.31	
	SED (±)	CD (5%)	
Seasons	1.38	NS	
Host plants	0.97	NS	
Seasons × Host plants	1.95	NS	

Data are mean of 3 replications, NS = Non-Significant, SED = Standard error of difference

Baruah *et al*. (1990) revealed that tensile strength of cocoon filaments of eri, muga and *pat* (mulberry) were 4.96 g/d, 5.54 g/d and 3.18 g/d respectively and their elongation (%) was 34.5%, 35.80% and 18.72% respectively which show the dependency of elongation of filaments on tenacity. The strength of the yarn is generally increased by the twist however detrimental impact would occur beyond the optimum point and ultimately the yarn will degrade (Sonwalkar, 2001). In case of mill spinning, the elongation (%) of the spun yarn decreases with the rise in the count (Kariyappa *et al.,* 2006). Saikia (2008) observed that tenacity and elongation percentage in barkesseru (5.83 g/tex and 23.58% respectively) was comparatively higher than in borpat (5.18 g/tex and 23.10% respectively) while on contrary, lower values in comparison to both were observed in castor. The present study revealed highest twist per inch during early summer and in borkesseru leaves though the results are not significant. In respect to twist per inch slightly lower values were observed in the present investigation as compared to the findings of Chutia (2011) who revealed highest twist per inch (16.8 TPI) in kesseru followed by tapioca (16.2 TPI) and castor (16.0 TPI) during autumn season. Goswami *et al.* (2014) found comparatively higher tensile strength and elongation (%) of green leaf fed cocoons than the red petiole castor leaf fed cocoons in case of eri silk yarn might be due to the result of higher content of the moisture percentage in the green variety castor leaf and the season observed best was spring. Brahma (2015) recorded the highest values in terms of yarn count's', breaking load, tenacity and elongation percentage in castor followed by borpat (13.95 's', 0.61 kg, 1.20 g/d and 18.90% respectively) whereas mixture of borpat with castor and kesseru exhibited slightly lower values. For garments appropriate twist is needed for the support of the dimensional stability of fabric (Sreenivasa *et al.,* 2016). Sharma and Kalita (2017) noticed variation in the quality of the yarn by the six strains of eri silkworm where, the higher maximum load and breaking tenacity (7.90 ± 0.86g and 3.419 ± 0.31 g/d) was exhibited by Greenish Blue Spotted and lowest by Yellow Plain (5.64 ± 1.29g and 2.25 ± 0.515 g/d). In contrast to the present findings, Bhuyan *et al.* (2017) revealed that elongation showed no significant difference in the cocoons from Kesseru fed worms in different seasons. However, Chattopadhyay *et al.* (2018) while studying on the structural and fibre quality characteristics of eri silk cocoons in different seasons and places observed significant influence in case of breaking elongation for all the three factors *viz.,* places, seasons and cocoon layers.

Conclusion

Eri silk is gaining popularity in the national and international market due to its 'ahimsa' way of cocoon processing, unique property and low cost compared to other natural silks. In order to capture the global competitive market and generating sustainable livelihood among the farmers by earning more income from this activity quality of the silk should be maintained. Quality of yarn is affected by various factors. In terms of physical properties of eri spun yarn food, rearing activities and seasonal variation play vital role. Due to the physical structure and chemical composition of the cocoon shells variation in the properties or characteristics of silk yarn occurs. The silk from the same species might differ due to the change in environmental conditions at the time of rearing, spinning of cocoon, mounting and processing of silk. Present study clearly revealed that spring season and borkesseru leaves exhibited better results in terms of physical property of the eri silk yarn.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Strategies and methods for improving phosphorus acquisition and its use efficiency: A review

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ABSTRACT

Phosphorus (P) is considered an essential nutrient for all and is also essential from global food security point of view but it is a limited, non-renewable nutrient resource, making its use vitally important. Nowadays, lower productivity in phosphorus availability is major concern. The decreasing ores and suboptimal levels of plant available phosphorus (P) can lead to lower yield. Its interaction with several other plant nutrients makes it very hard for plant availability. Several approaches have been tried and tested and many of them have been found effective, sustainable and cost efficient. However, the need for novel approaches for better phosphorus acquisition like physiological manipulation, better root structure and genetic alteration will help for resource conservation and is environmentally sustainable. But to diagnose environmental impact on excess use of phosphate fertilizers more improvement is required in order so that limited phosphorus stocks can be managed. Thus, there is a need for integrative approach to solve the lower P in soil system.

Introduction

The mere possibility of phosphorus (P) ores becoming scarcer in future has posed a danger to global agricultural systems (Cordell *et al.,* 2011). While, in terms of crop availability, phosphorus is a tricky element. But it will be difficult for policymakers in a country like India, where the government spends billions of rupees on fertiliser subsidies despite rising fertiliser production costs. One of the key variables limiting fertility and agricultural productivity is soil P. The plants need it for root germination, energy currency for meristem growth, nitrogen fixation, flowering, and maturation, and meristematic growth strengthens straw and reduces the likelihood of lodging. However, the regulation of metabolic pathways and for the control of important enzyme processes inorganic phosphorus
is also required. In plant growth, phosphorus is the second most often limiting macronutrient. It can cause stunted growth, low seed quality, and delayed maturity. The majority of the samples examined for available P in soil were found insufficient, and just a few were optimal, while total P was in a good amount, comparable to available P. India imports a large amount of phosphatic fertiliser from other countries, putting a strain on the Indian government. About 1-2 tonnes/ha are lost due to sheet erosion, pH imbalances cause fixation on either side of the pH scale, and leaching into streams causes eutrophication, disrupting natures delicate balance. Further, the runoff from

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agricultural lands is deposited in rivers and other bodies of water, making them non-source points of pollution that are difficult to remediate. In water critical limit of phosphorus is 0.03 mg L^{-1} dissolved phosphorus and over which eutrophication is likely to occur in 0.2 mg L^{-1} total phosphorus (Brady and Weil, 2014). The build-up of P in soil, with no long-term consequences, resulted in enhanced crop yield and quality, thus Indian farmers are using P fertilizers in excess amounts.

Due to low efficiency of phosphorus fertilisers, scientists had to think of alternate ways to manage soil phosphorus rather than adding more inputs. Soil P management has become an important aspect for optimal crop growth without any visible or invisible side effects due to vertical leaching of soil P, which is main reasons of decline and also is a source of groundwater contamination. In 2017-18, the actual NPK (Nitrogen, Phosphorus, and Potassium) consumption ratio was 6.10:2.46:1, as compared to the desired ratio of 4:2:1. Although this is a slight improvement above the consumption ratio of 7.23:2.9:1 in 2015-16, it is still a significant improvement (The Hindu 9th Oct 2019). In this heavily farmed area, 35% of the people tested surpassed the phosphate limit set by drinking water standards, according to a study of groundwater quality from wells in the Palar and Cheyyar River basins in Tamil Nadu, India (Rajmohan and Elango, 2005). So, to reduce the chemical usage of phosphorus in soil, various agronomic and chemical management strategies are necessary. However, the low phosphorus levels are due to soluble phosphate's high reactivity with other elements. In acidic soils, for example, phosphorus is combined with Al and Fe compounds (Norrish and Rosser, 1983) whereas calcium phosphate is the most prevalent inorganic phosphate (Lindsay *et al.,* 1989).

Factors for improving availability of phosphorus/PUE:-

1. Liming effect on soil P

Plants absorb phosphorus mostly as $H_2PO_4^{-1}$ and HPO_4^{-2} to a lesser extent. Soil pH determines the availability of these ions. Phosphate ions are absorbed by aluminium and iron cations at acidic pH. Higher organic matter and alkalinity were able to keep soluble P at a higher pH range, according to an aquaponics study. Plant available P remains poor in pH. Liming can increase soil phosphorus availability in a variety of ways, but it can also decrease availability by forming insoluble calcium complexes such as MCP, DCP, and apatite over time. Liming reduced the total organic phosphorus content of incubated surface samples of seven acid soils from eastern Canada by 3.6 percent in a laboratory experiment. Liming is suggested to minimise the toxicity of aluminium in the rhizosphere. Liming is also reported to enhance the intake of micronutrients like iron, boron, zinc, copper, and magnesium by balancing the pH.

2. Root Architecture

To live and finish its lifespan, phosphorus deprivation causes adaptive metabolic and structural modifications. Plants respond to low P levels in the soil by changing their root architecture, either by increasing root hairs or increasing root density. In some lowland rice genotypes, P deficiency increased the rate of organic acid exudation by 81 per cent (Hoffland *et al.,* 2006).

For solubilizing P, citric and oxalic acids are the most effective of the acids released (Hinsinger, 2001). Rhizosphere acidification reduces the pH of the bulk soil by 2-3 units. As a result of the acidification, various organic acids such as citrate and oxalate are secreted, causing the dissolution of various compounds and organic phosphorus through chelation and ligand exchange. Due to enhanced stimulation of root growth at the expense of shoot growth, an increase in root-to-shoot dry weight ratio is a common response to P deficit (Mollier and Pellerin, 1999). According to Roger and Benfey (2015) the presence of root hairs and the morphology of root tips aids in root penetration and anchoring inside the soil. Plant roots also release specialised metabolites such as phyto-siderophores in addition to organic acids. Siderophores are low-molecular-mass compounds that chelate iron in the rhizosphere while also releasing P from Fe-bound-P (Guan *et al.,* 2000).

3. P Solubilizing Microbes

The search for the efficacy and promise of P solubilizing microorganisms began in the 1960s and has continued since then. *Bacillius megaterium* and *Pseudomonas striata* are the most common bacteria engaged in P solubilization, while *Aspergillus awamori* and *Penicillium* have been observed in fungal species. It may be a realistic solution in terms of P management, but it is not particularly popular among farmers. The reason for this can be rationalised by the fact that low organic carbon content is a requirement for these bacteria in Indian subcontinent circumstances. Another reason is that this PSM only works in a very low temperature and humidity range. There are not a lot of convincing reviews on how effective they are. In their study, for the P-deficient calcareous Aridisol, Gunes *et al.* (2009) discovered that increased P availability resulted in significant P-fertilizer savings. Both microorganisms enhanced strawberry yield and mineral concentrations above what could be attained merely by fertilising with P.

4. Effect of tillage

Tillage has a variety of effects on soil parameters such as bulk density, erosion control, infiltration rate, water holding capacity, and soil compaction. So that conservation tillage, zero tillage, minimum tillage and no-tillage have a beneficial effect because these types of tillage practises disturb the soil minimally and thus loss is negligible as compared to deep tillage or conventional tillage practises. Tillage is also thought to have an impact on biochemical changes in the soil, which modify the liable fraction of soil nutrients. Gradual increase in soil MBC (microbial biomass carbon) and N were resulted in the minimum tillage residue retained (MT+R) treatment, while the lowest levels were obtained in the conventional tillage residue removed (control) treatment. Continuous no-tillage approaches can successfully enhance the amount of nutrients accessible in the soil. No-tillage methods can not only improve the amount of accessible P in the soil, but they can also efficiently maintain a constant soil P supply throughout the maize growing season (Xomphoutheb *et al.,* 2020). It is critical to establish adequate tillage and fertilisation methods in order to reduce fertiliser loss in agricultural production in order to maintain sustainable agricultural development and safeguard the environment. The availability of phosphorus is depending on the production system used (Carvalho *et al.,* 2014).

5. Effect of mulching

In 2009 and 2010, according to Vijay Kumar (2011), farmyard manure mulch had the highest soil OC (organic carbon) (6.65 and 6.85 g/kg), soil available N (239.00 and 240 kg/ha), soil available P (20.21 and 22.01 kg/ha) and soil available K (170.02 and 174.27 kg/ha). Mulching facilitates nutrient redistribution in the soil, reduces gaseous nutrient loss, and adds nutrients through decomposition of crop and mulch residues, all of which help to keep nutrients in the soil longer and boost plant uptake capacity (Amin *et al.,* 2014; Liu *et al.,* 2015; Rychel *et al.,* 2020; Wang *et al.,* 2020).

6. Agronomic practices

Good agronomic methods increase the build-up of nutrients in the soil and hence improve their bio-availability which could improve nutrient utilisation efficiency and nutrition uptake. Agronomic methods can reduce phosphorus fixation and increase phosphorus availability in soils (Horst *et al.,* 2011). Several agronomic strategies have been proven to increase the efficiency of P fertiliser use on agricultural fields (Simpson *et al.,* 2011 and McLaughlin *et al.,* 2011). However, there are numerous opportunities to reduce external P inputs by effectively manipulating soil crop and environment.

a. For Band Placement of Fertilizers

The way fertiliser is applied has an impact on the speciation of the P fertiliser reaction product (Khatiwada *et al.,* 2012). To maintain phosphorus available for plants, banding phosphorus fertilisers is a preferable agronomic method. When phosphatic fertilisers are broadcast or mixed with soil, they interact with more soil components and are swiftly transformed into insoluble complexes with calcareous soils calcium proportion (Malhi *et al.,* 2002). In-band placements of P fertilisers are more successful at reducing P-fixation and hence improving fertiliser efficiency in P-fixing soils. The amount of interaction between the soil and fertiliser is significantly reduced as a result of band placement, lowering P fixation. P fertiliser is kept in an accessible state for a longer period of time because to band placement, which improves P-uptake. When compared to the broadcast form of P administration, increased crop output and P accumulation in plant tissues have been documented in canola (Rehim *et al.,* 2012) and wheat (Karamanos, 2017). The distribution of P fertiliser in the soil at a site where P can contact active roots of the crop plant has been associated with increased fertiliser band placement efficiency. The banding enhances the likelihood that the root surface will be in close proximity to the fertiliser, which is more essential than increased P availability (Sleight *et al.,* 1983). Deep–banding methods, which apply fertilisers deep below the soil surface, are indicated for cereal crops grown on alkaline calcareous soils. Banding below the seed permits budding radicle and seminal roots to come into direct touch with the fertiliser, as per Gokmen *et al.* (1999). Thus, there are two management methods which are for promoting P nutrition in the agricultural system are banding P fertiliser in or near the seed-row and maintaining soil P levels by long-term fertiliser oversight (Rehim *et al.,* 2012; Grant *et al.,* 2001).

b. Increasing the root surface/soil contact area

This can be accomplished by altering the morphology of the roots. The roots having a longer specific root length (i.e., roots with a smaller diameter) can cover a larger area while maintaining the same level of root biomass. Increased hair root development is another method for accomplishing the same goal. P uptake efficiency in wheat is influenced by root fineness or branching (Jones *et al.,* 1989). As long as there is evidence of high genetic variability for this trait in wheat, this route appears promising. However, the current time-consuming and labour-intensive methodologies limit its use in breeding programmes that require the screening of large numbers of genotypes. Improving plant root systems ability to forage for this very immobile nutrient is one of the most important strategies for increasing P efficiency in agricultural systems (Richardson *et al.,* 2011). A variety of root morphological and architectural changes could be used to improve P absorption. Plants improve overall soil exploration through lengthening roots, branching roots, lengthening particular roots, and changing branching angles (Lynch and Brown, 2001; Gahoonia and Nielsen, 2004a; Lynch, 2007).

c. Increasing the effective root area

Root symbiosis with arbuscular mycorrhizal fungi (AMF) has been demonstrated to increase the effective root area, hence enhancing P absorption (Haymann and Mosse, 1971). P influx (P uptake per unit root length) is improved by AMF infection. On the other hand, a lack of consistency is seen in the information available about the genetic diversity present among wheat cultivars when it comes to vesicular-arbuscular mycorrhiza (VAM). Alternatively, wheat cultivars were thoroughly examined for the mycorrhizal association that only show minor changes among genotypes, which were not highly connected to increased P absorption, it was revealed during CIMMYT's (Manske *et al.,* 2000b). VAM is known to boost Cu and Zn uptake while decreasing Mn availability, in addition to P uptake.

d. Increasing nutrient availability

Nutrient availability and uptake, ranging from protons to complex chemical compounds can be affected from the root's exudates. To convert poorly available organic P, phosphatases are considered good which makes up 45-55 percent of a plants total P supply into inorganic forms that are more readily available to the plant (Randall, 1995). Root phosphatase secreted or bound at the basis surface differs according to genotype (McLachlan, 1980). An andisol study in wheat and triticale cultivars found a link between acid phosphatases and P absorption (Portilla Cruz *et al.,* 1998)

e. Crop species/variety

Plant breeding programmes can improve P use efficiency by identifying and selecting genotypes/species that are more effective in absorbing P from soils. Genotypes with efficient and wide root systems, as well as those with effective linkages with mycorrhizal fungi to access a larger soil volume are linked to this (Lynch, 2007).

f. Cover Crops and Conservation Tillage Practices

For minimizing tillage and keeping a minimum 30% crop residue on farm conservation tillage is recommended. The use of cover crops can also help to minimize P (Geohring *et al.,* 2011; Reid *et al.,* 2011). Conservation tillage is a process that involves integrating crop wastes into the soil (Gynor and Findley, 1995). This practice has been shown to reduce overall P losses and minimize particle bound P export (Ulen *et al.,* 2010). While it can improve nutrient efficiency, and cover crops can also reduce erosion and leaching. It produces rhizo-deposits that allow for the uptake of soil P (Nuruzzaman *et al.,* 2005). Some plant species, such as the Lupinus albus, can effectively solubilize soluble soil P (Braum and Helmke, 1995). This allows them to use soil as a cover crop or rotation (Njeru *et al.,* 2014).

g. Organic amendments

I tis known that the addition of organic manures in the soil can overcome the problem of soil P limitation. However, this method requires the proper quantity and quality of this practice (Kwabiah *et al.,* 2003). An organic residue can help to improve the soil's conditions by increasing the plant's available P. After breakdown, the organic manures can convert soil P into chemical form from native places (Smith *et al.,* 1998). The release of CO_2 occurs when soil's pH is lowered to a level that allows the uptake of H_2CO_3 (Mujeeb *et al.,* 2008). The organic acids released by the microbial decomposition process help in the breakdown of the soil's P.

Organic compounds that are generated during decomposition may boost the availability of P by covering or anionizing P adsorption sites or by releasing organic P into the soil (Nelson and Janke 2007). It is also important to note that organic compounds, which include phytin, are responsible for around 20% of total soil Phosphorus. Also, farmyard manure increases the microbial load on soils (Araujo *et al.,* 2009). To create a variety of organic acids and organic waste matter operation of soil microbe's breakdown was occurred (Liu *et al.,* 2017). Microbes help in the decomposition of organic debris, which helps in the release of nutrients slowly to the crop (Habai *et al.,* 2016). Increase in soil physical properties aid in P uptake by aiding root spread and enhancing mycorrhizal development (Cavigelli *et al.,* 2003; Medina and Azcon, 2010). Combination of inorganic fertilizers in conjunction with organic amendments resulted in increased crop yields and reduce liability on others inputs. Inorganic P fertilisers that are used in conjunction with FYM have been shown to improve their efficacy by lowering P fixation in the soil, boosting bioavailability, and extending the time they are available in the soil (Reddy *et al.,* 1996). Rock phosphate has a poor solubility in neutral and alkaline soils, but a higher solubility in acidic soils (Hongqing *et al.,* 2001). More solubilization was done when co-composting rock phosphate in combination with organic manures was applied (Akande *et al.,* 2005) (Tian and Kolawole, 2004). The release of organic acids during the decomposition of organic components can explain the increase in available P in rock phosphate (Kolawole and Tian, 2007).

h. Composting

Organic waste materials (composted) are recognized to reinforce manufacturing via means of improving soil physical, chemical, and biological properties as compared to raw organic waste materials (Ahmad *et al.,* 2006; Ogbonna *et al.,* 2014). During compost production, raw organic matter undergoes physical, chemical, and organic alterations, ensuing in large degrees of stabilised organic matter. As these stabilised organic components degrade, nitrogen and phosphorus are released into the soil (Sullivan *et al.,* 2003; Franklin *et al.,* 2015). This method is one of the efficient methods to boom bioavailable P and, as a result, enhance P availability from many organic materials. After composting, P conversion (Natural rate) into inorganic compounds (insoluble) is decreased. The organic component of the soil rises during the composting process, allowing for greater microbial activity and diversity. Humic material which are fresh drastically increase the addition of tens of thousands and thousands of native bacterial groups to the soil. The exothermic nature of composting contributes in the formation of various bacterial habitat.

All of these microbial communities degrade organic waste by feeding on it. During the breakdown process, organic acids are released. Some organic acids aid in the formation of a symbiotic interaction with root-invading fungus. Symbiotic partnerships with root colonisation fungi aid in increasing nutrient uptake from the soil. The composting process also aids in the convert nearby insoluble P sources so that they can converted into available form. In this process, insoluble P minerals are dissolved which react with CO_2 with the soil solution to form carbonic acid. The compost's physical, chemical, and biological activity all work together to provide long-term P nutrition to the growing plant (Kucey *et al.,* 1989).

i. Arbuscular Mycorrhizal Fungi

Root systems of most of the plants interact with symbiotic interactions that is widespread soil habitant in AMF. Over 400 million years, plants had a long relationship with AMF and this relationship resulted in a slew of positive outcomes. Multiple studies have shown that increased AMF colonisation of the host plant roots increases nutrient absorption (Smith and Smith 2011).

AMF plays a role in modifying P and increasing its In cereals plants like Rice, the more relevant pathway for absorption of P is AMF. Fine hyphae of AMF were extended when more P was absorbed by Plants and also surface area was also exposed to the soil. When total P uptake by the plant roots was increased it will gradually increase symbiosis benefits among the plants. Lower soil pH was resulted in AMF- assisted soil, which benefits the mineralization of phytate as a result, host plant transmission and P bioavailability for AMF absorption was increased (Wang *et al.,* 2013). Acid phosphatase enzyme activity is increased with AMF effect on plant P uptake (Feng *et al.,* 2003). In the vacuoles, AMF hyphae store polyphosphate enzymes. These enzymes have a strong selectivity for cleaving P bound to organic phosphates and converting them to an inorganic form. In the host plants, AMF arbuscules and inorganic P is transported. During Starvation AMF has a great role in P nutrition, when P is applied alone only 49 per cent absorption was done as compare to AMF, 78 per cent absorption was done (Thingstrup *et al.,* 2000).

bioavailability in soils (Fitter *et al.,* 1991).

Conclusion

This paper highlights how to overcome P deficiencies and their management. It is seen that today agriculture system is more dependent on intensive agriculture farming, relying too much on cereals may also cause fewer improvements in phosphorus availability. In the future, farm outputs may be affected which also increase the cost of cultivation and decrease farm income. With the scarcity of P, food security and stability are going to be affected. Soil and plant with soil interactions need to be understood to understand more about P availability. Also, more research is needed in numerous components of agricultural systems, and better strategies need to be developed to meet out the issue of boosting plant P availability, while increasing the crop yield in a sustainable manner.

Conflict of interest

The authors declare that they have no conflict of interest.

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Standardization of asexual propagation techniques in rambutan (*Nephelium lappaceum* L.) for humid tropical region of India

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ABSTRACT

Rambutan (*Nephilium lappaceum* L.) is a potential exotic crop, fetching high value demand in the tropical markets of the world. In India the states like Kerala and Karnataka are pioneer in cultivation of Rambutan. It is a natural inhabitant of warm and humid climate of South East Asia gradually finding its spread and cultivation across continents of both the spheres, but in order to sustain the demand of this crop, there is an urgent need to find out the best method of propagation. In order to assess and determine a suitable vegetative propagation protocol for true to type plant multiplication in Coorg region of Karnataka, different types of budding and grafting techniques were evaluated in Rambutan. Three different methods of budding (*i.e.* patch budding, forkert budding and chip budding) were employed, among these three methods patch budding was proven to the best with a significantly higher rate of budding success (70.00 %), minimum days taken for sprouting (36.86 days) and with a lower rate of mortality (6.28 %). In a separate concurrent experiment, approach grafting method showed superior results among three different graftinf methods (*viz.* approach grafting, cleft grafting and veneer grafting) studied. It showed maximum rate of graft success (72.86 %), higher number of sprouted bud (4.29) and minimum days taken for sprouting (46.29 days) and also had a very low mortality rate (5.87 %).

Introduction

The aspect of fruit cultivation is constantly growing, promoted through the investment made by producers or by the consumers, to meet the demand of a healthy diet cart. Along with the popular fruits, obscure yet nutritious fruits are taking up their slots in supermarket shelves. This has greatly contributed to the expansion of underutilized and exotic fruits.

Among these exotic fruits, one commonly found is Rambutan (*Nephelium lappaceum* L.) which belongs to the Sapindaceae family. The name of this fruit derived from its place of origin's vernacular Malayan language word "Rambut", which translates into "Hair" in English, concerning to its soft thorn like hairy outgrowth that cover the fruit surface. Rambutan fruit varies from dark red to yellowish green in colour depending on the cultivar; ovoid in its shape with gelatinous white flesh inside adhering to its seed (Li *et al.,* 2018). Rambutan has a huge potential for industrial and neutraceutical usage in future. Edible fats extracted from seeds are found to be potential for replacing cocoa butter in confectionary industries (Solis-Fuentes *et al.,* 2011). Peel flour can be constituted as an effective ingredient in biopolymer production (Nadhirah *et al.,* 2016). Rind extractants has many effective uses such as anti-viral or anti-herpes (Nawawi *et al.,* 1999), anti-oxidant, anti-bacterial (Thitilertdecha *et al.,* 2008), anti-hyperglycemic,

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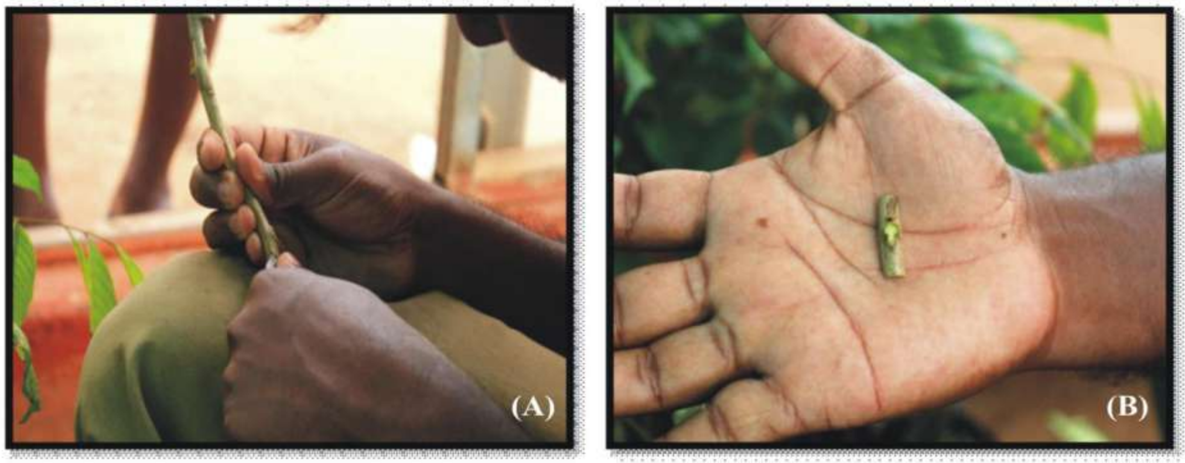
anti-inflammatory (Palanisamy *et al.,* 2011) and anti-proliferative (Kumar *et al.,* 2012). Rambutan crop has immense economic potential in market, which fetches an approximate price of ₹200/Kg of fruit for export from the states like Kerala and Karnataka. The successful commercial cultivation of this crop depends on many climatic and agronomical factors. Nevertheless a proper propagation technique is equally essential in order to supply true to type quality planting material, which eventually plays an important role in increasing the fruit yield and quality. Air layering is a common technique of propagation for Rambutan relatives such as litchi and longan. However, propagating Rambutan using air layering proved difficult (Morton, 1987). Grafting and budding success is generally determined by various factors such as grafting methods, grafting seasons, propagation environment, *etc.* (Chander *et al*., 2016). There are different grafting and budding techniques which are being practiced for commercial production of different fruit crops (Chander *et al*., 2016). As of now, there is no work done in India, for standardizing vegetative propagation methods in Rambutan. Hence, it is very much essential to arrive at a credulous method of vegetative propagation technique to maintain the genetic veracity of a variety and which can also be exploited at commercial level to increase the area of exotic crops like Rambutan. The study was undertaken to standardize suitable method for adoptable vegetative propagation technique with less rate of mortality in Rambutan under humid tropical region of Kodagu (Coorg) district Karnataka, Southern India.

Material and Methods

The experimental site of current study was located at the Central Horticultural experiment station (CHES, ICAR-IIHR), Chettalli, Kodagu, Karnataka (12°26' N latitude and 75°57' E longitude at 1050 m above mean sea level).The average annual temperature stays around 21.6 °C and the average rainfall is about 1900-1950 mm, during experimental duration average maximum temperature and average relative humidity were recorded as 29.04 °C and 97.5 % respectively. The Rambutan fruits are generally harvested during September to October month in this region. Under two separate experiments, budding and grafting operations were carried out during first week of November, 2017 and the observations were recorded upto next 120 days. One year old seedling of local variety of Rambutan, sourced from Kerala was utilized as rootstock. The seedlings of 25 to 30 cm height, thickness of a pencil grown in polybags were used for budding inside shade house. Bud woods were collected from cv. Arka Coorg Arun (CHES-27), a Rambutan selection growing in healthy manner at Rambutan orchard of CHES, Chettalli used in budding experiment. Bud woods (2.0-2.5 cm thickness) which matched with the rootstock's girth were carried to experimental site after covering in a moist sack bag to avoid desiccation. Different budding techniques were employed to find most suitable method of budding in Rambutan, Among the three different budding techniques were used the first one was patch budding (T_1), where a rectangular patch of bark (2.5 cm long and 1.0 to 1.5 cm wide) was removed from the stock and a similar patch, containing a bud was removed from the scion of Arka Coorg Arun (CHES-27). After removal, it was immediately inserted on to the stock. The patch containing bud fitted tightly at top and bottom, it was then wrapped with polythene strip (Figure 1). Under forkert budding (T_2), the root stock is prepared by giving two vertical cuts and a transverse cut above the vertical cuts to join them, along these cuts the bark was removed carefully, on which the flap of bark remains hanged down. The scion bud is prepared in same fashion as of patch budding with precise fit on root stock. The scion was then slipped into exposed portion of the stock and the flap is drawn over the inserted bud patch, followed by wrapping the region with a polythene strip and the third budding technique was chip budding (T_3), wherein a chip of bark and wood was removed from the smooth surface between the nodes of the stock. A chip of wood removed in same fashion and of similar size from the bud wood, ensuring that the bud was in middle of chip which precisely fits into stock ensuring cambium contact between chip bud and stock. It was tightly wrapped by polythene strip leaving protruding bud uncovered. After the sprout of the bud, wrapping material and above portion of stock were removed in all the treatments. In another concurrent experiment on standardization of grafting methods in rambutan, three different graftingtechniques (*viz.* G_1: Approach grafting; G_2: Cleft grafting; G_3:



A-B: Removal of patch bud from scion.

C-D: Insertion of the patch bud on rootstock.

E: Bud-stock union is wrapped with polythene

F: Sprouting of successful patch bud

Figure 1: Patch budding in Rambutan (A-F)

Side/Veneer grafting) were evaluated on same type of rootstocks used in previous budding experiment. The seedling rootstocks grown in polybags were brought in adjacent to the scion mother plant in orchard for approach grafting whereas, same types of rootstocks were placed inside shade house for cleft and side/veneer grafting. Selection of scion plant is the important factor for the propagation of fruit plants by grafting. Considering this fact, uniform bearing 10 years or older mother plant of rambutan (CHES-29) was selected as scion mother plant. The non-flowering scion shoots having dark green colored leaves, about 10-15 cm long, straight, smooth, healthy, pest and disease free were chosen from new season's growth, which were about 3-4 months old containing sufficient reserved food materials. Scion shoots were selected and marked for approach grafting on mother plant itself as it is an attached method of grafting and other selected scion shoots for detached method of grafting such as cleft and side/veneer grafting were pre-cured by defoliating them, leaving one-fourth of the petiole on the mother plants about one week before the grafting operation. After their detachment scions were carried in a poly bag to the experimental plots and kept in shady or cool place to avoid desiccation. In approach grafting technique, a thin slice of bark about 6 to 8 cm long at a height of about 20 to 25 cm above the ground level was removed from the stock. A similar reciprocate cut was made in scion with a sharp knife. Thus the cambium layer of both stock and scion were exposed. These cuts were brought together and tied tightly with the help of polythene strips (Figure 2).The rootstocks were cleft grafted after decapitating the stock 30 to 45 cm above the ground level. Beheaded stocks were split to about 5 cm depth through the centre of stem with sharp grafting knife. The scion of 15 to 20 cm size is taken from terminal shoot and wedged securely (6 to 7 cm). The cleft of the scion was slipped into the split of the stock followed by a tight wrapping of graft region with the polythene strips. In veneer grafting, the scion was inserted into the side of the rootstock, which is generally larger in diameter than the scion. First, a long sloping cut was given (2.5 to 3 cm) on the side of the rootstock at about 20 cm height. Cut was given on the scion into a wedge shape with one side slightly longer then the cut on the rootstock. Inserted the scion laid up the cambium layers. Bind the graft with wrapping material.

To evaluate the effect of treatments in these two experiments parameters like, budding success (Number of successful budding/ Total number of budding attended x 100) were recorded, successful bud showing green in colour and sprouting indicates in each treatment was counted at 20 days interval upto 60 days after budding. Similarly in grafting experiment, grafting success (%) = (Number of successful grafts/ Total number of grafted plants x 100); was recorded at 15 days interval upto 45 days after grafting. The shoot with the opened leaves from the terminal bud of scion was considered as the success of a graft. Observation regarding approach graft union was recorded by observing the greenness of the tissue. Among the other different common observations, days taken for bud sprouting, number of bud sprouts; number of leaves, number of branches, scion height, plant height, these observations were recorded on a cumulative basis 30 days interval upto 120 days after grafting. Union girth and rootstock girth were measured using vernier caliper. After 30-45 days of initial success, the grafts were observed for the next two months and in some successful budding or grafts, some scions were found to dry up due to failure of vascular connection. The number of buds or grafts mortality was recorded in percentage by using formula, Mortality (%) = (Total number of dead budded plant or grafts/ Total number of initially successful buds or grafts x 100). Design adopted for both of these experiments was randomized block design. There were three treatments with seven replications and ten numbers of grafts in each replication. The data in percentages were transformed to arc sine values for statistical analysis. The data were subjected to statistical analysis using WASP 2.0 software (ICARGOA-ICAR-Central Coastal Agricultural Research Institute). Critical difference values were tabulated at five per cent probability where "F" test was significant.

Results and Discussion

Among the different budding methods were employed to find out suitable one in Rambutan at CHES, Chettalli conditions in Karnataka, theobtained findings (Table 1) depicts that patch budding was the best among the three different

A-D: Preparing scion and rootstock for proper attachment.

E: Wrapping the graft with polythene sheet tightly.

F: Growth of rootstock and scion in successful approach graft.

G: Successfully approach grafted plants.

Figure 2: Approach grafting in Rambutan

budding treatments carried out with a significant higher rate of budding success (70.00 %), minimum days taken for sprouting (36.86 days), highest number of branches (2.86) and leaves (18.00). In addition to that, patch budding results indicating a successful bud union through significantly lowest rate of mortality (6.28 %) and maximum plant height (35.04 cm) with scion length of 17.06 cm in comparison to forkert and chip budding. Among the treatments, there was no significant variation regarding union girth (Table 1), represents the normal growth of budded plants. Normally, swelling in union region indicates lower bud growth in compared to root stock. The better performance of patch budding can be attributed to the factors like larger surface area attachment of scion bud, a precise fit on stock, less chance of injury to bud while removing the portion as patch, moreover it is easy to perform. Results from present investigation were in accordance with Morton

Table 1: Effect of different budding methods on different characters related to successful budding in Rambutan

Treatment	Budding success (%)	Days taken for bud sprouting	Number of branches	Number of leaves	Plant height (cm)	Union girth (cm)	Rootstock girth (cm)	Scion height (cm)	Mortality (%)
T_1 : Patch budding	70.00 (56.95)	36.86	2.86	18.00	35.04	0.60	0.89	17.06	6.28 (9.63)
T_2: Forkert budding	48.57 (44.16)	44.43	1.86	14.00	29.16	0.59	0.84	13.03	32.38 (34.46)
T_3 : Chip budding	24.29 (29.10)	48.86	1.57	12.71	28.86	0.69	0.80	13.53	46.43 (42.84)
Mean	47.62 (43.40)	43.38	2.10	14.90	31.02	0.62	0.84	14.54	28.36 (28.98)
S.Em±	1.95	0.75	0.23	0.71	1.10	0.04	0.04	0.43	3.35
CD (5%)	6.09	2.33	0.70	2.21	3.411	NS	NS	1.35	10.44

Note: Values in the parentheses are arc sine transformed data, NS= Non significant

Table 2: Effect of different grafting methods on different characters related to successful grafting in Rambutan

Treatment	Grafting percent success (%)	Days taken for bud sprouting	Number of bud sprouts	Number of branches	Plant height (cm)	Union girth (cm)	Rootstock girth (cm)	Scion height (cm)	Mortality (%)
G_1:Approach grafting	72.86 (58.75)	46.29	4.29	3.29	54.29	0.54	0.86	18.03	5.87 (9.30)
G_2 : Cleft grafting	32.86 (34.70)	50.57	1.57	1.86	39.20	0.49	0.83	12.93	29.48 (30.64)
G_3:Side/Veneer grafting	18.57 (25.18)	52.43	1.71	1.71	35.46	0.73	0.86	12.04	38.09 (33.52)
Mean	41.43 (39.55)	49.76	2.52	2.29	42.98	0.58	0.85	14.33	24.48 (24.49)
S.Em±	2.31	1.24	0.32	0.36	1.18	0.03	0.10	0.51	6.67
CD (5%)	7.19	3.86	1.00	1.12	3.67	0.09	NS	1.58	20.77

Note: Values in the parentheses are arc sine transformed data, NS= Non significant

(1987) and Tindall (1994) in rambutan. Obtained results were also supported by Kem and Rawat (2008) in aonla, where among the four methods of budding *i.e.*, T, Patch, Ring and Forkert budding, the maximum budding success was found in patch budding in cv. Krishna. Singh *et al*. (2003), Saroj *et al*. (2000) also observed that patch budding performed best, Prasad *et al.* (2003) also stated that patch budding gave higher success in comparison with chip budding in bael. Tripathi and Kumar (2004) and Syamal *et al*. (2013) also documented patch budding as the best budding technique. Rao *et al.* (1984) observed the maximum success under patch budding in guava than the forkert budding. Parallel reports were observed by Singh and Singh (2007) reporting that patch budding in months with high relative humidity may be adoptable for multiplication of elite tamarind genotypes. Summarized data of grafting experiments (Table 2), indicated that approach grafting was the most suitable method of grafting in rambutan under Chettalli conditions with maximum rate of graft success (72.86 %) and least day required for sprouting (46.29 days); for any successful grafting technique an early response from scion inserted is highly acceptable, It also had a higher number of sprouted bud (4.29), number of branches (3.29) and number of leaves (13.43). Approach grafting was found to be significantly, better in influencing proper scion and root stock growth. It was recorded, highest plant height (54.29 cm) and scion length of 18.03 cm along with a very low mortality rate (5.87 %). Though being considered as a cumbersome method of grafting because of essential prerequisites but in case of approach grafting, the scion used to receive continuous flow of nutrition from mother plant which act for better cambial activity led to callus development in graft union resulting into higher success rate, a higher humidity also tends to facilitate this phenomenon. Brunner (2002) also reported, approach grafting is more dependable than cleft grafting for clonal propagation of desirable varieties in rambutan in Puerto Rico. Rajamanickam *et al*. (2002) in aonla and Bhagat *et al.* (1999) in guava also advocated the benefit of approach grafting in humid tropics. In sapota, similar results were recorded by Shirol *et al.* (2005) on grafting methods (*viz.* inarching, *in-situ* and softwood grafting) of sapota cv. Kalipatti on 18 months old khirni (*Manilkara hexendra*) rootstock, where highest graft success (85 %) was in inarch grafting. Inarching was significantly superior with 98% success rate and maximum emergence of new leaves and no. of new branches in comparison to veneer grafting, stone grafting and air layering in mango plants (Sengupta, 2005).

Conclusion

The results of current study pointed out the possibilities of exploiting patch budding and approach grafting as an answer to the quest of emerging with a suitable standard vegetative propagation approach for true to type multiplication of rambutan in Kodagu (Coorg) region of Karnataka. Patch budding can be preferred over approach grafting due its feasibility in adoption.

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Abbreviations

***cv.* :** Cultivar
CHES: Central Horticultural Experiment Station
ICAR: Indian Council of Agricultural Research
IIHR: Indian Institute of Horticultural Research
WASP: Web Agri Stat Package

Conflict of interest

The authors declare that they have no conflict of interest.

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Repurposing of drugs and leading vaccines work against COVID-19

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ABSTRACT

The novel coronavirus disease 19 (COVID-19) is a highly contagious and pathogenic viral infection caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first known case was reported / identified in Wuhan, China. In March 2020, the World Health Organization (WHO) declared it a 'pandemic' due to its Worldwide spread. Researchers have been trying to find a suitable treatment from available drugs like Dexamethasone, and Remdesivir to fight the novel coronavirus outbreak. AstraZeneca-SK Bio, Moderna, Pfizer-BioNTech and Janssen vaccines were added to the WHO's list of emergency use. Our review work highlights the repurposing of drugs and leading vaccines to counter COVID-19.

Introduction

Coronaviruses are a large family of viruses that get their name from the halo of spiked proteins (S proteins) on their outer surface that looks like a crown under the microscope (Shereen *et al.,* 2020). The new coronavirus, called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) caused COVID-19 or 2019 Novel Coronavirus. On March 11, 2020, the World Health Organisation (WHO) declared this ongoing lethal disease a global pandemic (Bayat *et al.,* 2021). Even though SARS-CoV-2 has 79% similarity with SARS-CoV and 50% similarity with MARS-CoV, the infectivity and spreading rate of SARS-CoV-2 is higher than other coronaviruses (Noor, 2021). This explains the importance of developing a treatment or vaccine quickly. Reports suggested that the high spreading rate of SARS-CoV-2 maybe because of the mutation capability that makes it highly transmittable. SARS-CoV-2 has undergone 4400 amino acid substitutions and thousands of mutations since early 2020. This spike protein, which is used to enter the host cell, has demonstrated 14 mutations (Shariare *et al.,* 2021). Some scientists believed that these mutations can modify the sensitivity of the virus to neutralize antibodies. The drug development process is more challenging due to limited understanding of the molecular mechanism involved in SARS-CoV-2 infection. The host cell proteins and viral proteins are the crucial targets for drug targeting. These include furin activation site, viral spike glycoprotein, RNA polymerase and protease enzymes, host cell–ACE2 receptor, protease enzymes, etc (Shariare *et al.,* 2021). There are 2 categories for the treatments of COVID-19 – host cell proteins and targeting SARS-CoV-2 or improving the human immune system (Shariare *et al.,* 2021). Developing a new drug is a time-consuming process, thus repurposing an existing drug seems to be one of the few solutions for the pandemic. Repositioning old drugs to treat COVID-19 is an attractive strategy as the information about the side effects, safety profile and posology are known (Gautret *et al.,* 2020). As per the clinical studies, antivirals reduce the viral load by targeting the enzymes of SARS-CoV-2 hence interfering with the viral cycle (Joshi *et al.,* 2021).

Challenges

The genome-based standard technology called reverse-transcriptase polymerase chain reaction

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(RT-PCR) is the basis for several diagnostic tests for COVID-19, although none of these tests is fully standardized. The RT-PCR test can identify viral genetic material, only if there is an adequate RNA in the sample. Therefore, in early stage of infection, there is not usually enough RNA material before someone begins to feel sick (Shariare *et al.,* 2021). Hence, the RT-PCR test could deliver false-negative results and less useful information for asymptomatic patients. One of the challenges for scientists is to find an ideal animal model for testing. The SARS-CoV-2 uses the cellular surface protein angiotensin-converting enzyme 2 (ACE2) to invade host cells and the ACE2 of the mouse (*Mus musculus*) does not adequately bind with the viral spike protein (Muñoz-Fontela *et al.,* 2020). Thus, none of the animal models mimics the severe or critical patterns correlated with mortality as seen in humans with COVID-19 (Ehaideb *et al.,* 2020).

The World Health Organisation (WHO) has added some vaccines to the emergency use list. Moreover, old drugs are repurposed to fight COVID-19. Here, we discuss a few old drugs and leading vaccines that work to counter COVID-19.

Rapid Repurposing of Drugs

The following section contains a summary of some of the medications being tested as treatments for COVID-19. Few of these drugs were later not recommended for use in the treatment of COVID 19 patients by WHO, FDA and other agencies due to more harm than good and/or had limited effect due to efficacy reasons.

1. Hydroxychloroquine with Azithromycin

Hydroxychloroquine is an antimalarial drug and according to a small study by French scientists published in the International Journal of Antimicrobial Agents, hydroxychloroquine with antibiotic azithromycin might be effective against COVID-19 (Gautret *et al.,* 2020). The COVID-19 virus attaches to a small particle in the cell called a lysosome. The lysosome cell has an acidic medium for the virus to thrive. Hydroxychloroquine competes for the same site on the lysosomes and makes the cell less acidic or more alkaline. As a result, the virus is unable to replicate within the cell and dies (Singh *et al.,* 2020).

2. Dexamethasone

Dexamethasone is a steroid that reduces inflammation. According to Oxford University's RECOVERY clinical trial, a low dose of dexamethasone increases the survival rate of COVID-19 patients who need respiratory support (Ledford, 2020). In a trial, led by Oxford University, about 2,100 hospital patients were given dexamethasone and compared with more than 4,300 who were not. The risk of death for patients on ventilators was lowered from 40.7% to 29%, while the risk of death for patients using oxygen was reduced from 25% to 21.5% (Mahase, 2020).

3. Favipiravir

Favipiravir is an antiviral, used to treat influenza. Studies revealed that favipiravir inhibits the RNA-dependent RNA polymerase (RdRp) that is crucial for COVID-19 viral replication (Joshi *et al.,* 2021). An open-label multicenter trial involving 240 patients with COVID-19 from China concluded that those who got the drug tended to have a significantly high clinical recovery rate (Joshi *et al.,* 2021).

4. Remdesivir

Remdesivir is an antiviral drug used to fight Ebola. Remdesivir inhibits RNA-dependent RNA polymerase (RdRp) by imitating a part of the viral RNA and replacing it in the replicating site (Beigel *et al.,* 2020). Therefore, the virus fails to replicate further. According to the clinical trials, Remdesivir can reduce the recovery time from 15 to 11 days and the mortality rate from 11.6% to 8% in participants (National Institutes of Health, 2020).

Vaccines

While the drugs listed above may be useful to treat COVID-19, there are also vaccines in use to produce immunity. The following section contains information on the leading vaccines and vaccine candidates.

1. AstraZeneca Covid-19 vaccine

The coronavirus vaccine ChAdOx1 nCoV-19 or AZD1222 was developed and tested by the University of Oxford in collaboration with the British-Swedish company AstraZeneca (Corum and Zimmer*,* 2021). The SARS-CoV-2 virus has spiked protein that is used to enter human cells. The researchers added the gene of the spike protein into chimpanzee adenovirus, known as ChAdOx1. Adenovirus causes cold or flu-like symptoms. The adenovirus tough protein coat protects the genetic material inside (Corum and Zimmer*,* 2021). Therefore, this vaccine doesn't have to stay frozen. If refrigerated at 38–46°F (2–8°C) the vaccine can last for at least six months (Corum and Zimmer*,*

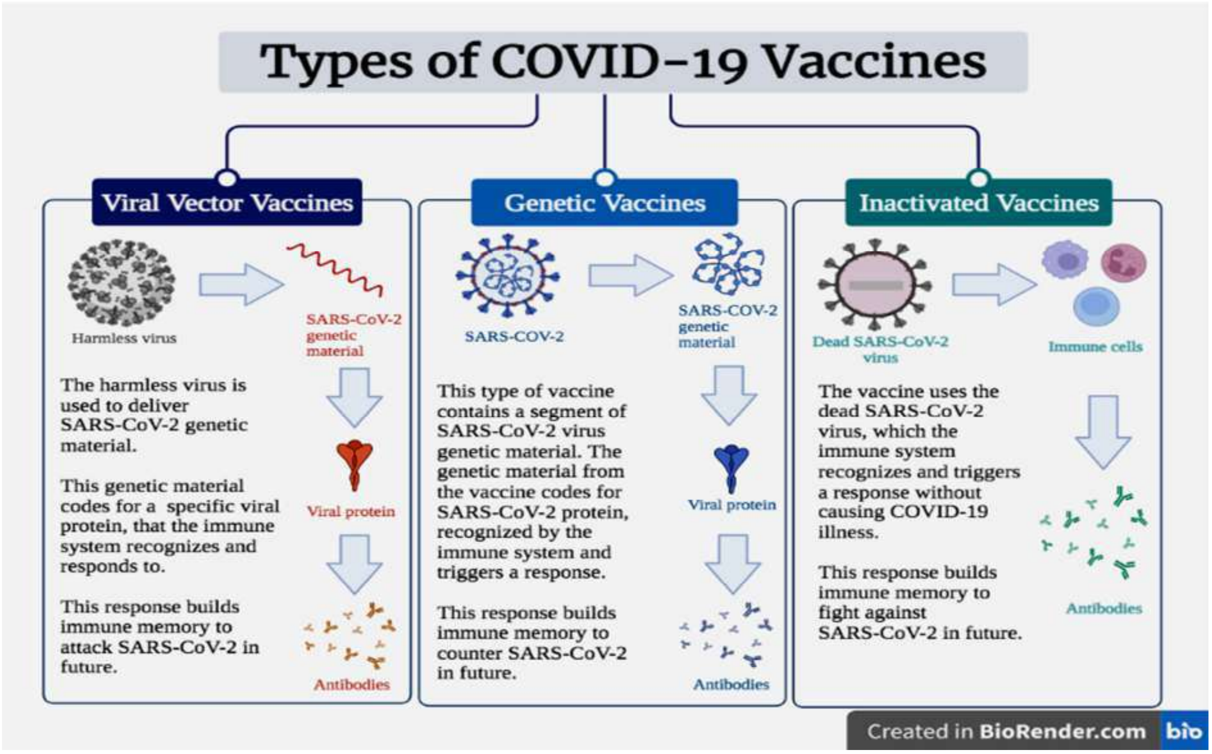

Figure 1: Summary of Types of COVID-19 Vaccines.
Created with BioRender.com

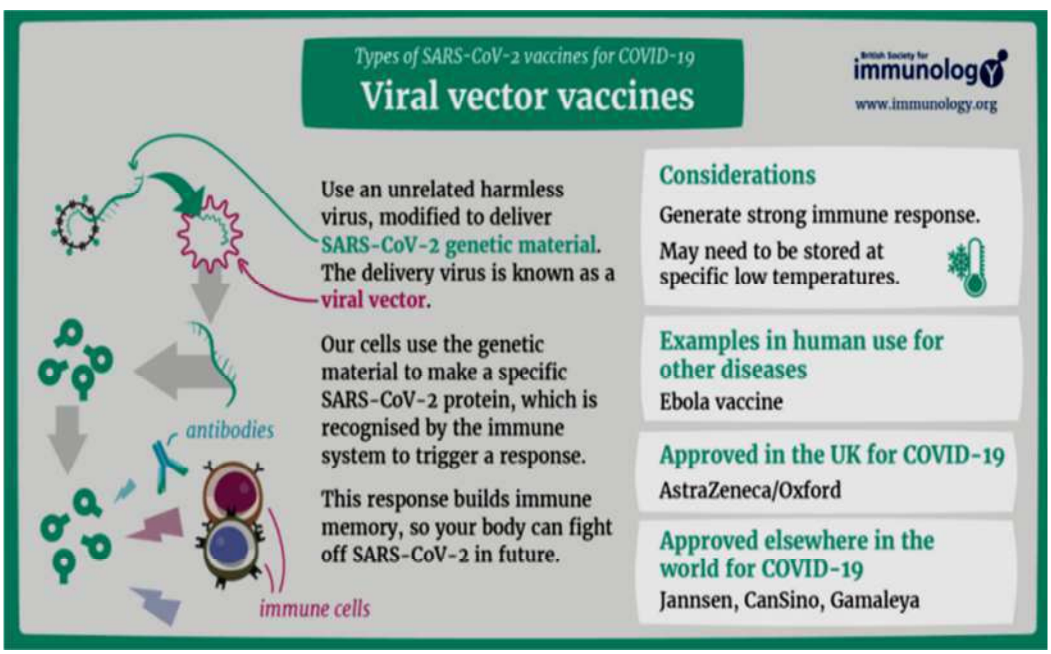

Figure 2: COVID-19 Viral Vector Vaccines.

British Society for Immunology. (2021). *Types of vaccines for COVID-19*. https://www.immunology.org/coronavirus/connect-coronavirus-public-engagement-resources/types-vaccines-for-covid-19

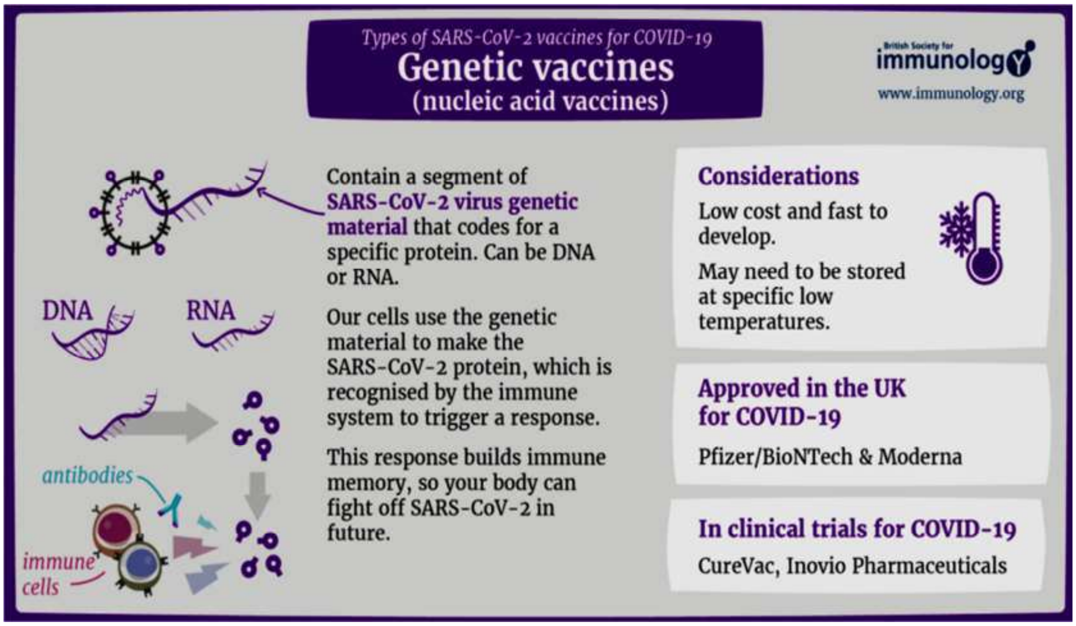

Figure 3: COVID-19 Genetic Vaccines.

British Society for Immunology. (2021). *Types of vaccines for COVID-19*. https://www.immunology.org/coronavirus/connect-coronavirus-public-engagement-resources/types-vaccines-for-covid-19

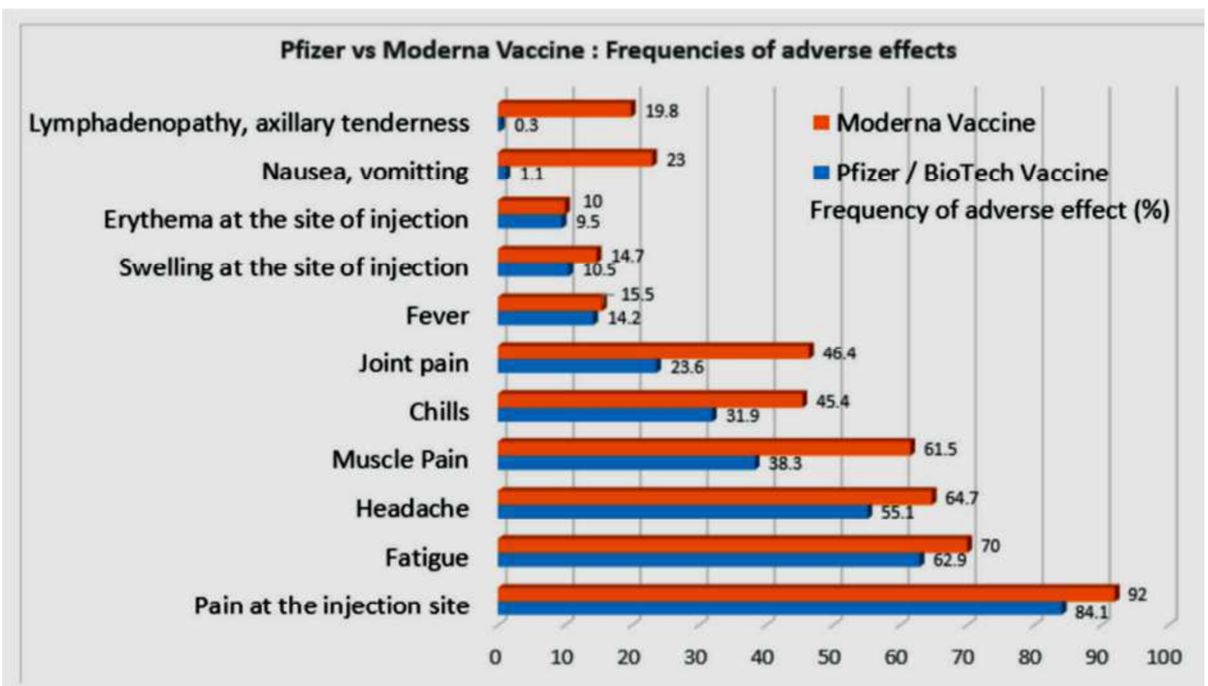

Figure 4: Comparison of frequencies of adverse effects between Pfizer-BioNTech and Moderna Vaccines.

Meo, S. A., Bukhari, I. A., Akram, J., Meo, A. S., & Klonoff, D. C. (2021). *COVID-19 vaccines: comparison of biological, pharmacological characteristics and adverse effects of Pfizer/BioNTech and Moderna Vaccines*. European Review for Medical and Pharmacological Sciences, 25, 1663–1669. https://www.europeanreview.org/wp/wp-content/uploads/1663-1669.pdf

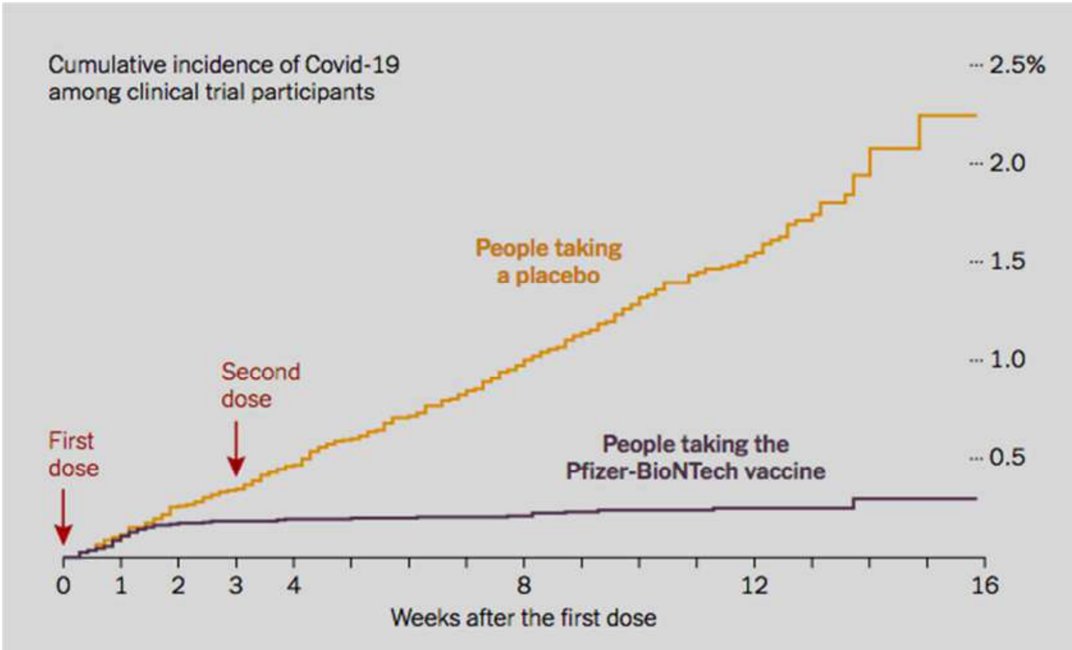

Figure 5: A preliminary study showing Pfizer-BioNTech vaccine protection compared with people taking a placebo.
Corum, J., & Zimmer, C. (2021, August 4). *How the Pfizer-BioNTech Covid-19 Vaccine Works*. The New York Times. https://www.nytimes.com/interactive/2020/health/pfizer-biontech-covid-19-vaccine.html

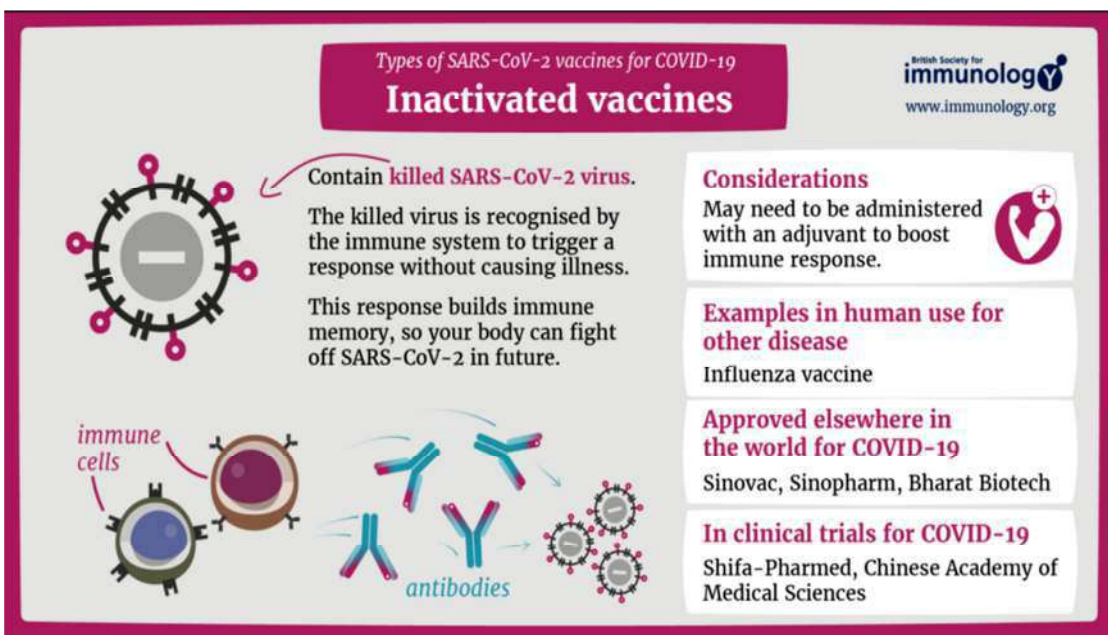

Figure 6: COVID-19 Inactivated Vaccines.
British Society for Immunology. (2021). *Types of vaccines for COVID-19*. https://www.immunology.org/coronavirus/connect-coronavirus-public-engagement-resources/types-vaccines-for-covid-19

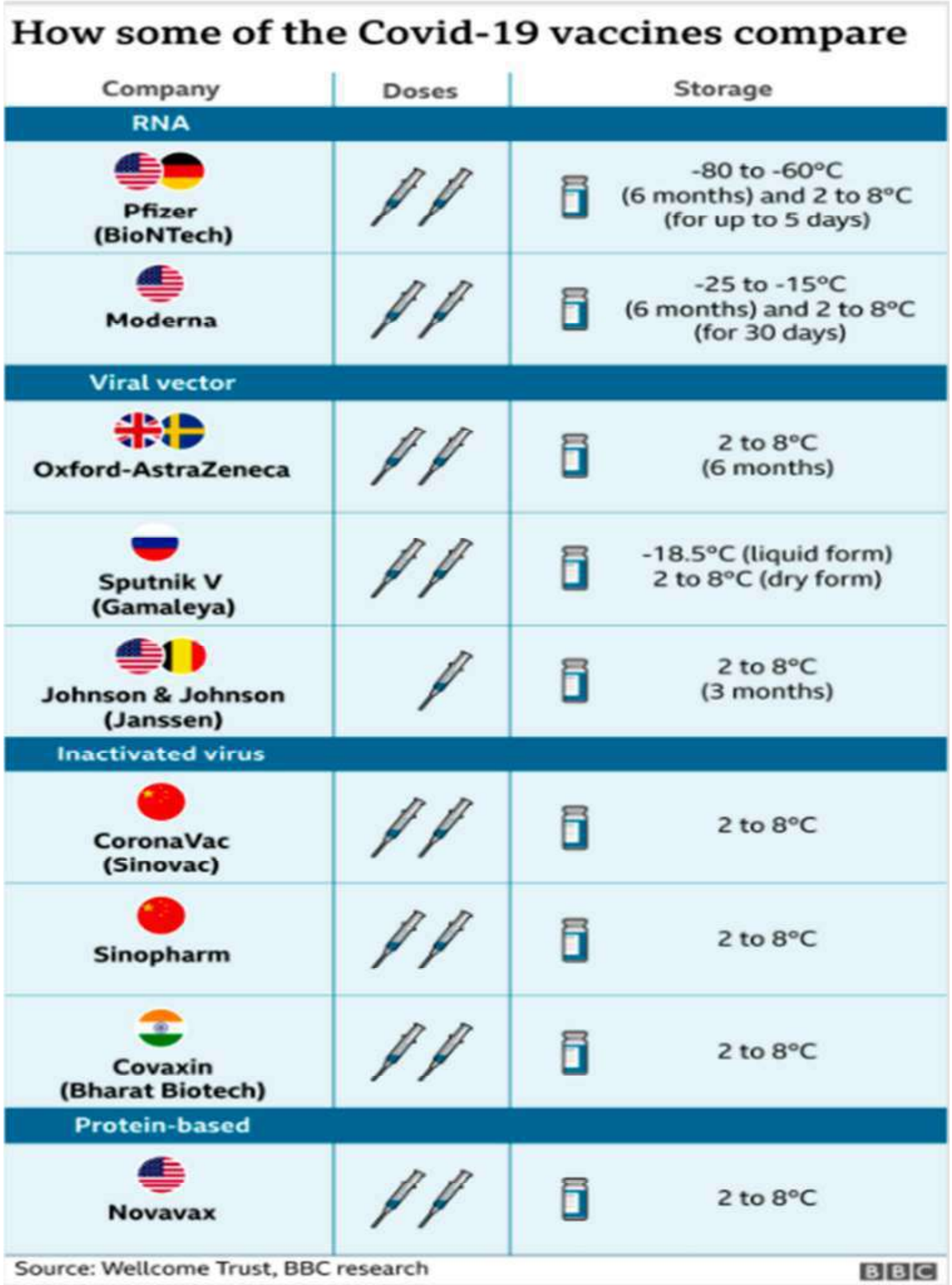

Figure 7: Comparison of COVID-19 Vaccines.
BBC News. (2021, May 7). *Sinopharm: Chinese Covid vaccine gets WHO emergency approval*. https://www.bbc.com/news/world-asia-china-56967973

2021). After entering the cell, the adenovirus engulfs the virus in a bubble and leaves the bubble to inject its DNA into the nucleus (Corum and Zimmer, 2021). Although the adenovirus cannot replicate itself, the coronavirus spike protein gene is read by the cell and transcribed into messenger RNA (mRNA). Spike proteins are formed when mRNA is translated. These spike proteins form spike and protein fragments that migrate to their surface and stick out their tips (Corum and Zimmer, 2021). The immune system recognises these protruding spikes and spikes protein fragments afterwards. Helper T cells activate B cells, causing them to produce and pour out antibodies that target the spike protein. Antibodies bind to coronavirus spikes, marking them for destruction and preventing them from connecting to other cells (Corum and Zimmer, 2021). The Oxford-AstraZeneca vaccine requires two shots four weeks apart. Depending on the dosage, the vaccination is either 62% or 90% effective (Financial Times, 2021).

2. Moderna Candidate Vaccine: mRNA-1273

US biotechnology company Moderna partnered with the National Institutes of Health to develop a coronavirus vaccine known as mRNA-1273 (Corum and Zimmer, 2021). According to clinical trials, the vaccine has an efficacy rate of more than 90% in preventing COVID-19 (Mishra, 2020). Moderna's vaccine uses mRNA that is read to make proteins (Noor, 2021). The mRNA is wrapped in oily bubbles made of lipid nanoparticles to protect it from being degraded by the body (S.A. Meo *et al.,* 2021). Moderna's vaccine should be stable for up to six months if stored at –4°F (–20°C) (Corum and Zimmer, 2021). After injection, the vaccine releases its mRNA into cells and builds spike proteins. The immune system recognises these spike proteins and builds antibodies against them (Meo *et al.,* 2021). If an individual ever encounters the coronavirus, these antibodies can neutralize the virus. Moderna's vaccine requires two shots 28 days apart. Additionally, the US Food and Drug Administration (FDA) authorized the Moderna vaccine for emergency use (Tanne, 2020).

3. Pfizer-BioNTech

BioNTech partnered with Pfizer to develop a coronavirus vaccine called BNT162b2 (Bernal *et al.,* 2021). According to clinical trials, the vaccine has an efficacy rate of over 90% in preventing COVID-19 (Corum and Zimmer, 2021). The Pfizer-BioNTech vaccine is based on the coronavirus's genetic instructions for making spike protein, just like the Moderna vaccine. The vaccine storage temperature is between –80°C and -60°C to remain viable (Meo *et al.,* 2021). The vaccine introduces mRNA into the cells to develop the spike proteins. The body recognizes this protein and creates antibodies that can fight off future SARS-CoV-2 infections (Corum and Zimmer, 2021). The Pfizer-BioNTech vaccine requires 2 injections 21 days apart. A preliminary study indicates that the Pfizer vaccine offers strong protection about 10 days after the initial dose as compared with people taking a placebo (Bernal *et al.,* 2021). The Pfizer vaccine is safe and immunogenic for adolescents aged 12 to 15 years old, according to a recent study published in the New England Journal of Medicine with an efficacy of 100% against COVID-19 from 7 days after dose 2 (Frenck *et al.,* 2021).

4. Sputnik V

The Sputnik V or Gam-Covid-Vac coronavirus vaccine was created by the Gamaleya National Research Institute of Epidemiology and Microbiology in Moscow (Jones and Roy, 2021). A study published by Gamaleya showed that two doses of the vaccine had an efficacy rate of 91.6% (Corum and Zimmer, 2021). Sputnik V is based on the coronavirus's genetic instructions for building the spike protein. Unlike the Moderna and Pfizer-BioNTech vaccines, Sputnik V uses double-stranded DNA. It is a vector vaccine based on adenovirus DNA, a cold virus (Jones and Roy, 2021). The researchers added the gene for the coronavirus spike protein to Ad26 and Ad5, two types of adenoviruses to invade cells but not replicate (Corum and Zimmer, 2021). After Sputnik V is injected, the adenoviruses enter the cell and engulf the virus in a bubble. After leaving the bubble, the adenovirus injects DNA into the nucleus. The gene for the coronavirus spike protein is copied into messenger RNA or mRNA. After translating mRNA, spike proteins are produced by the cell (Corum and Zimmer, 2021). The immune system recognises these protruding spikes and begins to generate antibodies in response. This prepares the immune system to fight coronavirus when it encounters it for real. Sputnik V requires two doses 21 days apart (Jones and Roy, 2021). This vaccine uses two different versions for the first and second doses. The researchers used one type of adenovirus, Ad26, for the first dose, and another, Ad5, for the second dose (Corum and Zimmer, 2021). The theory is that by combining two separate formulae, the immune system will be boosted even more and will provide longer-lasting protection. In addition, a version of the vaccine known as Sputnik Light uses only the first dose and skips the second dose (Corum and Zimmer, 2021).

5. Covaxin

An inactivated coronavirus vaccine called Covaxin is manufactured by the Indian company Bharat Biotech partnered with the Indian Council of Medical Research and the National Institute of Virology (Kumar *et al.,* 2021). Researchers doused a large stock of the coronavirus with beta-propiolactone that inactivated coronaviruses by bonding to their genes, but their proteins, including spike, remained intact (Corum and Zimmer*,* 2021). The inactivated viruses were then drawn off and mixed with adjuvant, an aluminium-based chemical that stimulates the immune system to boost its reaction to a vaccine (Kumar *et al.,* 2021). When injected into the body, B cells produce antibodies that target the spike protein (Corum and Zimmer*,* 2021). Covaxin requires two doses 4-12 weeks apart. According to the preliminary data from its phase 3 trial, Covaxin's efficacy rate is 80.7% (Kumar *et al.,* 2021).

6. Sinopharm Vaccine

Another inactivated coronavirus vaccine called BBIBP-CorV was developed by the Beijing Institute of Biological Products (Corum and Zimmer*,* 2021). According to clinical trials run by Sinopharm, the vaccine has an efficacy rate of 79%. The WHO also announced a similar efficacy estimate of 78.1% (Corum and Zimmer*,* 2021). The Beijing Institute researchers collected three coronavirus variants from Chinese hospitals to create BBIBP-CorV (Corum and Zimmer*,* 2021). One of the variants was chosen because it could rapidly expand in monkey kidney cells cultivated in bioreactor tanks. After mass-production of coronaviruses, the researchers drenched them in a chemical called beta-propiolactone, which rendered the coronaviruses inactive. After that, researchers mixed them with a tiny amount of an adjuvant to boost immune system response to a vaccine (Corum and Zimmer*,* 2021). Once vaccinated with BBIBP-CorV, B cells produce antibodies that target the spike protein to prevent the virus from invading cells. The Sinopharm vaccine is to be given in two doses three to four weeks apart (Corum and Zimmer*,* 2021).

7. Covishield

Covishield is being developed by Oxford University in collaboration with AstraZeneca and their manufacturing and trial partner is Serum Institute of India (Inbaraj *et al.,* 2021). Covishield or AZD-1222 uses a viral vector made from a weakened version of a common cold virus (called an adenovirus) from chimpanzees (Pramod *et al.,* 2021). When the vaccine is injected, the immune system recognizes the spike protein and builds antibodies against it. There are two doses of Covishield given 12-16 weeks apart. According to the phase 3 clinical trials, the vaccine showed an efficacy of 67% (95% confidence interval [CI]: 57%-74%) against symptomatic SARS-CoV-2 infection (Pramod *et al.,* 2021). Covishield was added to the Emergency Use List (EUL) by the World Health Organisation (WHO).

8. Johnson & Johnson Vaccine

Johnson & Johnson developed a coronavirus vaccine called JNJ-78436735 or Ad26.COV2.S (Sadoff *et al.,* 2021). It is a single dose vaccine with an efficacy rate of 85% against COVID-19. The vaccine is based on the coronavirus's genetic instructions for building the spike protein. It uses double-stranded DNA. The researchers used Adenovirus 26 (common cold virus) and added the gene for the coronavirus spike protein to it (Corum and Zimmer*,* 2021). The Johnson & Johnson team used a modified adenovirus so that it would not cause any illness inside the cells. The vaccine can be refrigerated at 36–46°F (2–8°C) for up to three months (Corum and Zimmer*,* 2021). Once the disabled adenovirus is inside, the cell engulfs the virus in a bubble. The adenovirus breaks free from the bubble and pushes its DNA into the nucleus. The gene for the coronavirus spike protein is copied into mRNA. The cell's molecules read the mRNA sequence and begin assembling spike proteins. These spike proteins migrate to the cell surface and are recognized by the immune system (Corum and Zimmer*,* 2021). The immune system begins producing antibodies and activates other immune cells that target the spike protein. If ever encountered the virus that causes COVID-19 the immune system has antibodies to fight it.

Vaccine Coming Soon:

Corbevax

Corbevax is a "recombinant protein sub-unit" vaccine, which suggests that the corbevax is made from the spike protein of SARS-CoV-2 (Raghavan*,* 2021). When injected into the body, an immune response is developed against the injected spike protein. Hence, the body will already have an immune response ready when the real virus attempts to infect the body. In India, Corbevax has been approved for Phase III clinical trials (Raghavan, 2021). The manufacturer of Corbevax is Biological E, a Hyderabad-based company. For the first time, India has placed an advance order of 300 million doses for a vaccine that has not received emergency use authorisation (Sharma, 2021). Corbevax is administered in two doses. This vaccine is also predicted to be among the most affordable vaccinations available in the country.

Conclusion The COVID-19 pandemic has endangered global health security. Certain vaccines have been approved by the World Health Organization (WHO), giving hope for controlling the pandemic. Moreover, repurposing drugs or medications can help COVID-19 patients to recover. Our review work highlights some key aspects related to the recent development of drugs and vaccines to counter COVID-19.

Conflict of interest

The authors declare that they have no conflict of interest.

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Biomethanated distillery spentwash application and its impact on soil health, growth and yield of Elephant foot yam

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ABSTRACT

Agrobased industries are contributing socio-economic development of the country, distillery industries are using sugarcane molasses as a raw material for alcohol production. Every litre of alcohol production ten to fifteen litres of waste water generated named as spentwash. The disposal of spentwash is a seroious issue and looking for recycling option to enhance soil health.r Distillery Spentwashis important organic liquid manure contain high amount of nutrients like nitrogen, phosphorus, potassium, calcium and sulfur and also it contains high amount of micronutrients such as iron, zinc, copper, manganese, boron and molybdenum. Field experiment was conducted to study the efficiency of Biomethanated distillery spentwash, on improving the yield and quality of Yam at Research and Development farm of Bannari Amman Sugars Ltd., Modur, Sathyamangalamtaluk, Erode district. Distillery Spentwashwas applied in a field with the treatments from 10 to 60 KL/ha and soil samples are collected at initial, vegetative and harvesting stage of Elephant foot yam. The application of spent wash as manure was improved soil health and resulted in increasedroot and shoot length quality and yield of Elephant foot Yam. There was enhanced available N andK status of soil with the application of spent wash, particularly for K.The increase in yield and quality parameters was observed at harvest stage of Elephant foot Yam.Application of Biomethanated Distillery Spentwashat 50 KL/ha recorded higher yield of 38.20 t /ha. Elephant foot yam quality parameters like Carbohydrate, Vitamin C, Beta carotene were significantly increased when compared to control field.

Introduction

Elephant foot yam (*Amorphophallus paeonii folius* Dennst. Nicolson) is a tropical tuber crop associated with the family Arecaceae and widely consumed as vegetable (Rahman, 2020). A famine food crop in the pacific Islands which has acquiring popularity as a cash crop among the farming community of our country. It has high production potential, increased biological efficiency, good culinory properties, and medicinal utility and therapeutic values. It is grown commercially as annual crop, generally with one to few broad heavily dissected leaves with long petiole and rhizomatous stem called corm Theyare used as staple food and wealthy in starch content. After boiling, baking, and frying, the corm is eaten like a vegetable In some states like northern and eastern states use cultivars like wild and local mainly in pickle making. Elephant foot yam has high dry matter production capacity per unit area comparing with most of the othe rvegetables. The yam offers a range of health benefits and is sought after by Ayurvedic doctors. It treats abdominal pain, dysentery and spleen enlargement. Perhaps due to its numerous benefits, it has a rich cultural association in India. The assortment for business development in our nation is "Gajendra", which is a

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neighborhood determination from Kovvur, West Godavari region of Andhra Pradesh. It has high yielding potential with enthusiastic developing propensity. The corms are smooth, hemispherical and discouraged in the middle, 20-25 cm distance across and generally dull-yellowish earthy colored tone at collect. The corms are likewise liberated from corrosiveness, produce less or no cormels and have better nature of tissue.

In cultivation of different crops, spent wash have been utilized (where applied) as manure provides successful results. Continued increase was also observed in case of nutrientstatus availability of soil, uptakeof nutrientby crops and germination. It has also improved nutrient availability and uptake without having any negative post-harvest effects on soil texture, chemistry, or biology. The positive effect of spent wash on crop production is well recorded (Rajagopal *et al.,* 2014; Pugazh *et al.,* 2016) reported that total chlorophyll content, crop growth rate (CGR), total dry matter, and nutrient uptake all rose when distillery effluent was added (N, P and K). It was discovered that a one-time controlled application of diluted spentwash improved soil fertility and agricultural yields (Chandraju *et al.,* 2013; Chopra *et al.,* 2013; Bhardwaj *et al.,* 2019; Ruhela *et al.,* 2020). The availability of nutrients in distillery effluents, as well as the prospect of substituting them for inorganic fertiliser in agriculture, holds a lot of promise (Joshi and Singh, 2010).

Material and Methods

Study Location

This study was investigated to monitor the effect of distillery spentwash on soil health, growth, yield of Elephant foot Yam atBannari Amman Sugars unit, Modhur near Sathyamangalam in Erode district of Tamil Nadu. The experimental setup was conducted in Randomised Block Design (RBD) with three replications. Treatment details areT_1: Control (Recommended dose of NPK), T_2: Biomethanateddistillery spent wash @ 60 KL/ha, T_3: Biomethanateddistillery spent wash @ 50 KL/ha, T_4: Biomethanateddistillery spent wash @ 40 KL/ha, T_5: Biomethanateddistillery spent wash @ 30 KL/ha. T_6: Biomethanateddistillery spent wash @ 20 KL/ha and T_7: Biomethanateddistillery spent wash @ 10 KL/ha

Sample collection:

The soil was loamy in texture and soil samples were periodically collected (initial stage, vegetative stage and harvesting stage) and analysed for physic-chemical properties as per the standard procedure (American Public Health Association, 2012). Biometric observations and ield data's were recorded at harvest stage.

Results and Discussion

Effect of BDS application on pH

The pH of the soil (Figure1) shows slightly increased with increasing dose of BDS application except control but this shows no significant change in the pH of soil (Fig 1). The highest pH recorded are 8.05 at Initial stage of crop, 8.09 at vegetative stage and 7.45 at harvesting stage in T_2 (Biomethanateddistillery spent wash @ 60 KL/ha). There was increase in soil pH due to the application of spentwash. The spentwash reacts with the soil minerals during decomposition and dissolving large amounts of Ca, Al and Fe, Soil pH incresed subsequently due to precipitation of Ca and Mg. The new compounds formed during precipitation resulted in increase of soil pH. Addition of base materials like calcium from spentwash also has increased the pH (Baskaran *et al.,* 2010).

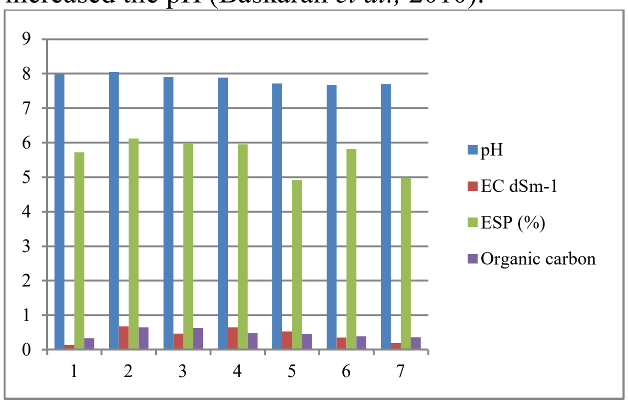

Figure 1: Effect of BDS application on physicochemical charecteristics of soil.
(Note: T1=1, T2=2, T3=3, T4=4, T5=5,T6=6 and T7=7)

Effect of BDS application on EC

The EC of the soil was significantly higher than the control at all stages of observation. The highest EC of the soil was recorded 0.68 dS m^{-1} at Initial stage of crop, 0.60dS m^{-1} at vegetative stage of crop and 0.53 dS m^{-1} at harvesting stage of cropin T_2. In the control group, the lowest EC was 0.14 dS m^{-1}. (Figure 1). PBSW contains higher amounts of soluble salts (34.90- 38.06 dS m-1). Increase in EC of soil due to increase in PBSW. Kamble and Deshpande, 2014 reported that the EC of soil increased markedly due to accumulation of salts from spentwash

Effect of BDS application on Exchangeable Sodium Percentage (ESP) of soil

There was no much variation observed for ESP which indicated that through the content of exchangeable cations like Ca, K and Mg were also present at higher level in the BDS, thereby the ESP was not appreciably increased by the application of spentwash. The ESP of the soils under study showed that it was within the critical limit of less than 15%. Soils having ESP > 15% will lead to alkali soil which is a problem soil wherein crop growth will be affected by the unfavourable physical properties of soil. Similarly when the sil possess high EC (>4 dSm^{-1}) leads to saline soil ultimately affects crop growth by diosmosis and other unfavourable effects. Kamble and Deshpande (2014) reported the increase in ESP due to repeated application of distillery effluent and it was maintained below 15. The ESP of soil was gradually increased at the end of experiment as compare to initial values. The greater ESP of soil was observed in wheat harvest 2010-11 *i.e.* at the end of experiment as compare to soybean harvest 2009-10. This was due to continuous application of spentwash.

Effect of BDS application on Organic Carbon

With the exception of the control (T1), the carbon (organic) content of the soil increased significantly as the dose of BDS was increased. When compared to the control group, the organic carbon level was considerably greater (0.65%) (0.33 %).The organic carbon content increased over different stages of crop in all the treatments (Fig 1).The spentwash treatment greatly enhanced the soil organic carbon con The spentwash used in the study was rich in organic carbon which might have enriched the Organic Carbon. The improvement in Organic Carbon due to the application of spentwash was reported by Kalaiselvi and Mahimairaja (2011). Kumar and Chopra (2012), reported increase in soil organic carbon with increase in spentwash application. Addition of organic matter through effluent and better crop growth with concomitant increase in root biomass could be the probable reasons for the improvement in organic carbon content in spentwash applied soil. .

Effect of BDS application on Available Nitrogen and Potassium content of soil

T2 had the highest N and K concentrations at the starting stage of the crop, with 135 kg per hectare and 169 kg per ha, respectively. The highest concentration of N and K (158 kg/ ha and 209 kg/ ha) were observed at vegetative stage in T_2 and 117 kg per ha and 139 kg per ha were observed in harvest stages in T_2 (Figure 2).There was enhanced available N andK status of soil with the application of spent wash, particularly for K. The increased N and K availability in soil could be due to the additional N and K support provided by the spent wash, and the other reason for the significant increase in the available N and K status of the soil could be due to increased microbial activity caused by the addition of organic matter via BDS, which in turn could have increased sufficient release of native sources of these nutrients. Because the spent wash includes adequate N and K, it is considered a nutrient source and is used to raise crops in proportion to the fertilizer's amount of these nutrients. BDS contained just a little amount of nitrogen and its application greatly improved the soil's available nitrogen status as the spentwash contains plant based proteinaceous substances the ammonification of organic N followed by nitrification of NH_4 might have occurred and increased the mineral N content of soil (Chandraju *et al.,* 2010). A remarkable increase in the availability of N, P and K content of both in the treated and raw spentwash was also reported by Moazzam *et al*. (2012).

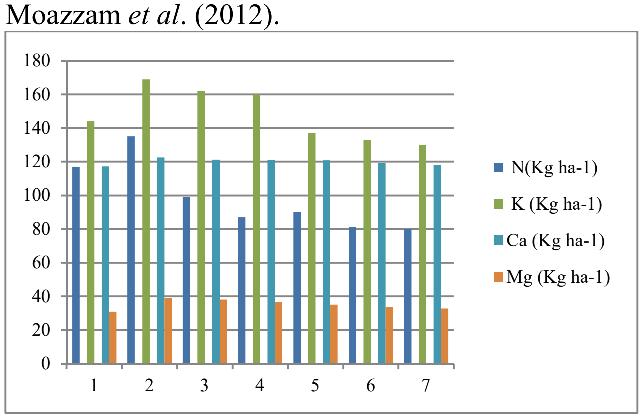

Figure 2: Effect of BDS application on physicochemical charecteristics of soil
(Note: T1=1, T2=2, T3=3, T4=4, T5=5, T6=6 and T7=7)

Figure 3. Field view and Yield of Elephant foot Yam

Table 1. Effect of Biomethanated distillery spentwash application on growth parameters of Elephant foot yam

Treatments	Plant height (cm)	Petiole length (cm)	Culm girth (cm)	No.of leaflets (no's)
T1	43.20	43.50	12.10	253.20
T2	62.53	52.70	15.20	311.10
T3	63.30	53.90	15.60	343.20
T4	59.17	49.20	14.60	288.90
T5	57.80	47.30	14.30	283.50
T6	55.30	46.20	13.40	275.20
T7	50.10	45.30	13.20	235.30

Effect of BDS application on exchangable calcium and magnesium

Distillery spentwash significantly improved the amount of exchangeable Ca and Mg in the sample. The highest Exchangeable Ca and mg concentration at initial stage of crop were 122.47kg/ ha and 38.97 kg /ha recorded in T_2.The highest concentration of Ca and Mg (122.70 kg/ ha and 37.95kg/ ha) were observed at vegetative stagein T_2 and 119.87 kg $ha^{-1}$and 35.79 kg/ha were observed in harvest stages in T_2(Figure 2). At all stages, the lowest concentration was recorded in control soil (T_1) that received no spentwash. The Exchangeable Ca content grew dramatically as the rate of spentwash application increased. also noticed increased Ca and Mg content in the soil, which might be attributed to Ca and Mg addition through effluent addition or both.

(due to the application of biomethanated distillery spentwash. Therefore, spentwash must be applied judiciously according to crop requirements. The application of spentwash increased the CEC, K, Ca, and Mg content of the soil, which might be due to addition of K, Ca and Mg either through the effluent addition or the solubilising effect of distillery effluent on the unavailable native forms. The addition of Ca, Mg and S through effluents in soil increased the availability of Ca, Mg and S in soil ultimately reflected the uptake of these nutrients. The results are similar to the findings of Chandraju *et al.* (2010).

Effect of BDS application on growth, yield and quality parametres

It is obvious from Table 1 that plant height, cum girth, length of petiole and number of leaflets showed maximum in T3 treatment when compare to other treatments. The treatments T3 and T2 showed slight variation in culmgirth and petiol length. The maximum growth period, which included synchronised height physiological activity with maximum nutrient intake, may have benefited in increasing plant height 150 days after planting. Increased culmgirth as a result of increased photosynthatis being diverted from the source (leaves) to the sink (corm), which is a common occurrence in practically all root and tuber crops

Application of BDS @ 50 KL/ ha recorded higher yield of 36.23 t per ha,BDS@ 10 t per ha(35.81 t/ha) and BDS @ 60 KL /ha recorded the yield of

35.03 t/ha (Table 2, Figure 3) BDS application at 50 KL/ha gave significant difference on yield and other yield characters such as corm diameter and yield. The increasing in yield may be due to increase in nutrient uptake. Analysis of drymatter, beta carotene, starch, calcium oxalate showed maximum in T3 treatment when compared to other treatments. The quality parameters like Carbohydrate, Vitamin C and Beta carotene were analysed and BDS @ 50 KL/ ha recorded maximum of 453 µg/100g of Beta Carotene, Carbohydrate 10.7% and 1.35 mg /100g of Vitamin (Table 2). Elephant foot yam quality parameters like Carbohydrate, Vitamin C, Beta carotene were significantly increased when compared to control field.Based on the findings of this study, it can be concluded that the effect of Biomethanated Distilley Spent wash had a significant impact on Elephant foot Yam growth and yield.

Table 2. Effect of Biomethanated distillery spentwash application on yield and quality parameters of Elephant foot yam

Treatments	Corm Diameter	Corm Yield (ha)	Dry matter (%)	Starch (%)	Calcium Oxalate (%)	Vitamin (IU)	B- Carotene (µg/100g)
T1	11.50	24.40	26.90	15.20	0.0209	138.30	381.20
T2	14.20	32.60	31.40	16.25	0.0208	146.40	422.90
T3	14.80	38.20	32.60	17.60	0.0312	148.70	453.70
T4	13.20	33.20	29.70	16.50	0.0216	142.30	371.80
T5	12.30	33.00	27.40	16.20	0.0217	140.50	403.90
T6	12.10	29.70	27.20	15.80	0.0213	140.10	399,40
T7	12.00	27.60	27.00	15.60	0.0200	140.20	377.50

Conclusion

Application of BDS @50KL /ha has recorded higher yield and also brought tremendous changes in quality parameters like carbohydrate and vitamin C and beta carotene.Hence BDS can be used as a nutrient source for the cultivation of Elephant foot Yam.f

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Conflict of interest

The authors declare that they have no conflict of interest.

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Estimation of seasonal surplus labour in agriculture in different agro-climatic regions of Rajasthan

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ABSTRACT

The present investigation was undertaken with a view to estimate the total surplus labour in agriculture to get an idea of how far agriculture provides employment to those who are fully engaged in it. The author then estimates the extent of surplus labour which is removable and the extent of seasonal surplus labour in different agro-climatic regions of Rajasthan as well as state as a whole. For this study, the primary data were collected from 200 households of 10 villages during 2018- 2019 and secondary data were used from census 2011. The results showed that there exists the total surplus labour ranging from 49.45 % in arid western and northern plain region to 80.13 % in semi-arid and flood prone region with the state level estimate of 68.33 % of labour availability. It was estimated that at the state level seasonal surplus labour is 10.51 % of the labour availability. Across the regions, the seasonal surplus labour ranges from 5.93 % in sub-humid and humid southern plain region to 19.61 % in arid western and northern plain region. This cause the unemployment, lower productivity of labour and migration of labour. To overcome such type of problems initiative to integrate MGNREGA with agriculture, create additional income opportunities for agricultural labourers, entrepreneurship training, small scale industries, and establishment of agri-business units.

Introduction

The term labour absorption means the total labour that is used or utilized in the process of production. The terms absorption and utilization, which are interchangeably used, refer to the labour employed rather than the labour required in agriculture. The actual labour employed may be more or less than the labour required. Labour required is the amount of labour to be put in the production process to get the optimum production. Due to seasonality factor in agriculture, it is very difficult to use the necessary amount of labour required. Farmers may employ less than the required number of workers in the peak season due to shortage of labour at higher wage rates and more in the lean season due to social obligations that would force the farmers to accept extra hands every day (Chand and Srivastava, 2014). Inelastic supply of labour in peak season leading to mechanization and lack of demand for labour in lean season is the major problem in agriculture sector. Peak season being of very short duration the stress is always on the demand side of labour market. According to population census 2011, the total population of Rajasthan state is 6.85 crore of which male and female are 3.55 crore and 3.29 crore, respectively. Out of the total population in Rajasthan, the total

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workers comprise 43.60 % (i.e. 2.99 crore). Out of these total workers, cultivators and agricultural labourers are 1.36 crore (45.6%) and 0.50 crore (16.5%), respectively. Agricultural workers constitute the most neglected class in Rajasthan's rural economic structure. Their income is low and employment is irregular. Since, they possess no skill or training, they have no alternative employment opportunities. Fragmentation of land holdings is major reason for increase in agricultural labour over the years.

Despite a large labour force in India, the labour shortages at peak period of agricultural activities are acute in agriculture. This problem has been compounded by the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). It seems that MGNREGA has made a perceptible difference to the 'choice of work' of the casual labour in rural and semi urban areas. It has not only increased the base wage rates but has also affected the timely operations in agriculture and thereby productivity levels. The farm-wages have shot up in many states indicating switching over towards improved techniques. According to ISEC, Bangalore, India's flagship rural wage employment scheme is causing a labour shortage for agriculture, besides increasing farm production costs by about 20 percent. The study also said that the National Rural Employment Guarantee Scheme launched in 2006 "has weaned away agricultural labour during the *kharif* sowing season that lasts from July to August during the southwest monsoon period". Ever since the scheme came into being, daily wages in the farm sector have shot up by a whopping 50 percent (Kumar and Maruthi, 2011).

Surplus labour is not really surplus unless it is such as could be mobilized for development need. For instance, it is not proper to compute surplus labour by assuming 365 days available per worker, because in reality a worker is not available for farm work for all the day in a year. Similarly, one has taken into account the labour days spent in different activities in agriculture. Farm workforce does not confine itself to crop production, & so any attempt to compute surplus by considering labour spent in crop production only would to an upward bias of surplus. One more important activity to be consider i.e., tending of cattle; considerable amount of labour is utilized for this purpose. Likewise, an estimate of surplus labour of the farm family workers engaged in self cultivation should also considering days spent in crop production and related activities. Any attempt to estimate surplus without considering the seasonality of employment would again give an incorrect picture of the real situation. The surplus estimated, thus, would not be free from the seasonality factor and any idea of removing the surplus from any farm work would affect the peak period labour requirement.

The surplus or redundant labour in agriculture, which is a typical feature of developing countries, is believed to be one of the consequence of or causes of economic backwardness. Most of the developing countries undergo from excess population growth, and the quantum of labour surplus varies from region to region depending on the structural characteristic of the region. In this context the present study investigated the region wise labour absorption in principal crops & livestock activities, labour availability and seasonal surplus labour in each agro-climatic region as well as state level in Rajasthan.

Material and Methods

In Rajasthan there are five agro-climatic regions which is subdivided into 10 agro-climatic zones. In the first stage, one district from each agro-climatic zones were selected on the basis of highest gross cropped area. From 10 agro-climatic zones, total 10 districts were selected for the study. The selected districts were Hanumangarh, Bikaner, Nagaur, Jodhpur, Jaipur, Alwar, Bhilwara, Udaipur, Baran and Jhalawar. In the second stage, one tehsil from each selected district was selected randomly. Thus, 10 tehsils were selected randomly from 10 districts for the study. The name of 10 selected tehsils were Hanumangarh, Nokha, Nawa, Luni, Bassi, Bansur, Shahpura, Vallabhnagar, Krishnganj and Jhalrapatan. In the third stage one village from each selected tehsil was selected randomly. And in the final stage twenty farmers from each village were selected according to five standard size classes i.e. marginal (<1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-6 ha) and large (>6 ha) making random selection within each category size. Thus, 200 farmers were selected from the chosen 10 districts of five agro-climatic regions, respectively. The systematic flow chart of sampling procedure is given in Figure 1. The principal crops those covering more than 75 % of the gross cropped area

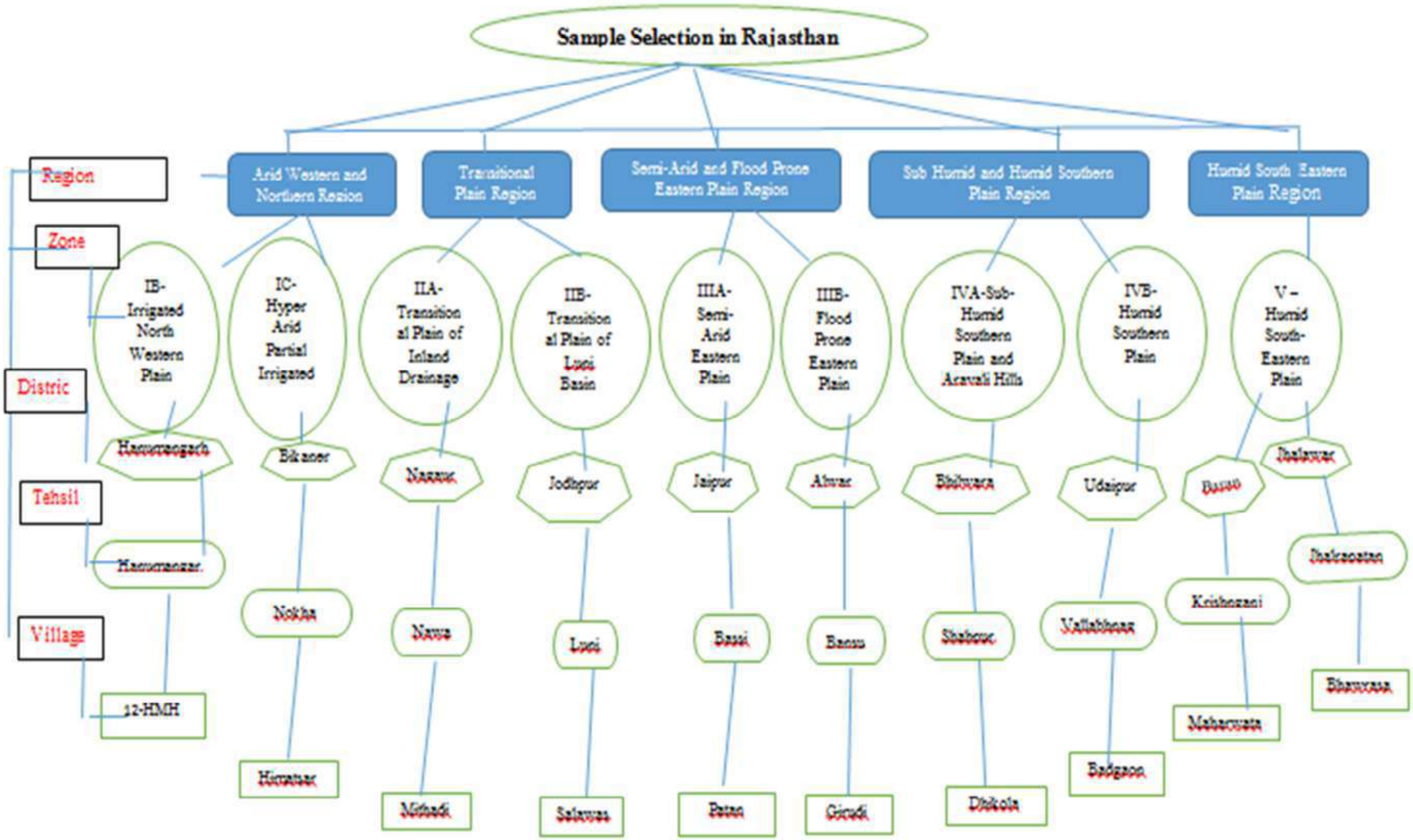

Figure 1: Five Agro-climatic Region of Rajasthan State

(GCA) in each district were selected purposively to estimate the labour absorption in crop production. The study was based on both primary and secondary data for the analysis. The primary data from the farm household was collected by personal interview based on specially designed comprehensive schedule. Secondary data were collected from the various administrative reports, government publications, surveys, records, articles, and official documents from 1981 (three decades) onwards and primary data for the year 2018-2019 was used for the present study.

Estimation of surplus labour in agriculture

The method of estimation of surplus labour in various studies can be categorized as "Indirect" and "Direct" methods. The indirect method has been used in its three variants;

(i) The number labour hours required to produce a given output is subtracted from the number of labour hours available from the active agrarian population.

(ii) The density of population deemed adequate for a given type of cultivation is subtracted from the actual density of the population, and

(iii) The number of hectares required under a given type of cultivation to provide one person with a standard income is contrasted with the number of hectares and the agrarian population available.

However, Roden (1957) described that out of these two methods, direct method is the only satisfactory method based on empirical investigations with questionnaires distinguishing different cultivation practices, size and forms of property and composition of labour force. Indirect method does not give any clear idea about the extent of surplus labour. At the most, these methods can be used to test whether there exists surplus labour or not. Therefore, the present study chose direct method of estimation procedure was chosen for the study as used by Roden (1957), Rudra (1973), Reddy (1988) and Parthasarthy (1990) with some modifications in their assumptions.

The present study estimated the available labour time of agricultural work force and total labour time actually utilized in crop production and other allied activities with the current level of technique and organization. The difference between the two would provide the extent to which available labour time is actually unemployed and hence the study estimated the resultant surplus labour. Three sets of surplus labour estimates were made separately, namely, total, removable and seasonal (non-removable) surplus for each of the agro-climatic region and for the state as a whole.

Estimation of available labour time in agriculture: Cultivators and agricultural labourers are the two main constituents of agricultural work force. Though, there is some seasonal migration of agricultural labourer to agriculturally developed regions from agriculturally backward regions. Due to absence of any such reliable data region wise, it was not included in the present study. Gender wise population of cultivators and agricultural workers in each district were obtained from population census report of 2011. This census data was then extrapolated by the annual rate of growth of population to get the figure for 2018-19. Total number of labour available in agriculture sector were then converted into man-days considering availability for employment 300 days for male workers and 270 days for female workers. A lower level of female labour availability was considered because in traditional Indian household, irrespective of being employed or not, females manage most of the household responsibilities including bringing up the children and maternity related demands. Besides, female labour demand is by and large, seasonal/operation specific (Parthasarthy, 1990). It is pertinent to mention here that estimates of available labour time in the present study were made by accounting main and marginal workers. Main workers are the workers who work for more than six months in a year, while marginal workers are those who work for less than six months in a year.

Estimation of surplus labour: The difference between total available labour time as estimated in Table 1 and total labour time actually utilized for carrying out crop production and livestock activities as estimated in Table 2 was taken as an estimate of surplus labour. These region wise estimates show the extent to which agriculture provides employment to agricultural work force. This is known as disguised unemployment as this surplus is not altogether removable. This surplus includes both seasonal (non-removable) as well as removable surplus. Therefore, three sets of surplus labour estimated consisting of total, removable and seasonal (non-removable) surplus were separately worked out for five agro-climatic regions as well as state level as a whole.by summing up estimates of all the regions, estimates at the state level was arrived.

To arrive at region wise peak operational labour requirement in the crop production, the per hectare coefficient of peak operation labour use was worked out for each crop and multiplied by the respective area under different crops in each region. In order to compute peak operation labour use coefficient, the study considered labour use per hectare in peak operation of each crop multiplied by its crop duration. The estimates of peak operational labour requirement were deducted from the total available labour time to arrive at an estimate of removable surplus in the given region. The procedure can be expressed mathematically as follows.

$$L_{pi} = \sum_{c=1}^{J} A_{ic} . l_{pic}$$

Where,

L_{pi}= Total peak operational labour requirement in i^{th} region (man-days)

A_{ic}= Area under c^{th} crop in i^{th} region (hectares)

l_{pic} = Peak operational labour use per hectare throughout c^{th} crop duration in i^{th}region (man-days)

C= Number of crops grown in the region (1, 2, ------------j)

Removable surplus estimates in crop production were obtained in the following manner

$$L_{Ri} = L_{Ti} – L_{pi}$$

Where,

L_{Ri} = Removable surplus labour in i^{th} region (man-days)

L_{Ti} = Labour time availability in i^{th} region (man-days)

L_{pi} = Peak operational labour requirement in crop operation in i^{th} region (man-days)

Seasonal surplus labour in crop production is the extent of labour which is either not engaged or partially engaged during the lean season but is fully engaged during the peak seasons. Hence, this seasonal surplus is non-removable. In order to arrive at the seasonal surplus estimates, the difference between the peak operational labour requirement and the average labour use in crop production was estimate. Algebraically, the method can be expressed a s follows;

$$L_{Si} = L_{Pi} - L_{Ti}$$

Where,

L_{Si}= Seasonal surplus labour in the i^{th} district/zone/region in man-days.

L_{Pi}= Peak operational labour requirement in the i^{th} district/zone/region in man-days.

L_{Ti} = Average labour use throughout the year in i^{th}district/zone/region in man-days.

Results and Discussion

Estimates of Surplus Labour in Agriculture in Different Agro-Climatic Regions

The study follows the direct estimation procedure for surplus labour estimation as used by Reddy (1988) and Parthasarthy (1990). Focusing on the time dimension aspect of underemployment, the present study attempted to empirically estimate the magnitude of surplus labour engaged in agriculture in terms of utilized man-days across different agro-climatic regions of the state of Rajasthan. The estimates of surplus labour were worked out by comparing the total labour availability and total labour utilization in agriculture. First, total surplus labour was calculated considering labour use in crop production activities only (Table 1). In the crop production activities from land preparation, input procurement, sowing, inter-culture, fertilizer/manuring application, plant protection measures, irrigation, harvesting/picking, threshing upto marketing of farm produce were considered. Secondly, total surplus labour was estimated considering both labour use in crop production as well as livestock activities. In the third set peak operational labour usage in crop production was taken for the estimation of surplus labour. Seasonal surplus labour was also estimated as the gap between peak operational labour use and average labour use in crop production. This estimate shows the amount of seasonal unemployment in agriculture sector. For calculating total labour availability the number of cultivators and landless agricultural laborers were aggregated (including both main workers as well as marginal workers) from the census 2011 extrapolated by the annual rate of growth of population to get the figure for 2018-19 for Rajasthan.

Total available labour man-days in agriculture sector were 2416.30 million man-days in Rajasthan. Thus, 2416.30 million man-days of labour were

Table 1: Region wise Estimates of Surplus Labour in Rajasthan, 2018-2019 (million man-days)

SN.	Particulars	Regions					
		Arid Western and Northern	Transitional Plain	Semi-Arid and Flood Prone	Sub Humid and Humid Southern	Humid Southern Eastern Plain	State
1	Labour available	367.23	595.01	665.85	479.29	308.92	2416.30
2	Labour usage in crop production	131.15	163.19	92.91	62.55	50.62	500.42
3	Total surplus labour considering crop production only (1-2)	236.08	431.82	572.94	416.74	258.29	1915.88
4	Row 3 as % of row 1	64.29	72.57	86.05	86.95	83.61	79.29
5	Labour use in livestock activity	54.48	63.27	39.36	49.48	58.18	264.77
6	Total surplus labour considering crop production and livestock activity (3-5)	181.60	368.55	533.58	367.26	200.11	1651.11
7	Row 6 as % of row 1	49.45	61.94	80.13	76.63	64.78	68.33
8	Peak operational labour usage in crop production	203.15	244.82	135.20	90.95	80.33	754.44
9	Removable surplus considering crop production only (1-8)	164.08	350.19	530.65	388.34	228.59	1661.86
10	Row 9 as % of row 1	44.68	58.86	79.70	81.02	74.00	68.78
11	Removable surplus labour considering crop production and livestock (9-5)	109.60	286.92	491.29	338.86	170.41	1397.09
12	Row 11 as % of row 1	29.85	48.22	73.78	70.70	55.16	57.82
13	Seasonal surplus labour (8-2)	72.00	81.63	42.29	28.40	29.70	254.01
14	Row 13 as % of row 1	19.61	13.72	6.35	5.93	9.61	10.51

Table 2: Region wise Comparison of Total Human Labour Utilization between Crop Activity and Livestock Activity in the State of Rajasthan

SN	Particulars	Arid Western and Northern Region		Transitional Plain Region		Semi-arid and Flood Prone Eastern plain Region		Sub humid and Humid Southern Plain Region		Humid Southern Eastern Plain Region		State	
	Total human labour absorption	LACA	LALA	LACA	LALA	LACA	LALA	LACA	LALA	LACA	LALA	LACA	LALA
1	Male	12.84 (32.48)	12.60 (23.13)	17.50 (36.89)	17.28 (27.31)	15.70 (32.22)	8.76 (22.26)	20.51 (33.84)	9.53 (19.26)	11.16 (19.26)	40.05 (28.79)	14.67 (32.58)	13.70 (33.18)
2	Female	26.69 (67.52)	41.88 (76.87)	29.95 (63.11)	45.99 (72.69)	33.02 (67.78)	30.60 (77.74)	40.10 (66.16)	39.95 (80.74)	27.60 (80.74)	18.13 (71.21)	30.36 (67.42)	27.58 (66.82)
3	Total Labour Absorption	39.53 (100.00)	54.48 (100.00)	47.45 (100.00)	63.27 (100.00)	48.72 (100.00)	39.36 (100.00)	60.61 (100.00)	49.48 (100.00)	38.76 (100.00)	58.18 (100.00)	45.03 (100.00)	41.29 (100.00)
4	Share of Total Labour Absorption	42.05	57.95	42.86	57.14	55.31	44.69	55.05	44.95	39.98	60.02	52.17	47.83

LACA=Labour absorption in crop activities (man-days/hectare); LALA= Labour absorption in livestock activities (man-days/animal/year)
Figures in parentheses denote percentage of total labour absorption

available in Rajasthan in agriculture sector in 2018-19. Out of five regions of the state the highest labour availability was in semi-arid and flood prone (665.85 million man-days) followed by transitional plain (595.01 million man-days), sub-humid and humid southern plain (479.29 million man-days), arid western and northern plain (367.23 million man-days) and the lowest in humid southern and eastern plain (308.92 million man-days) (Table 1).

Labour utilization in crop production (row 2) is estimated to be 500.42 million man-days at the state level. Of this, transitional plain region accounts for the highest share (32.61 %) followed by arid western and northern plain (26.21 %), semi-arid and flood prone (18.57 %, sub-humid and humid southern plain (12.50 %) and humid southern and eastern plain (10.12 %).

The variations in labour availability across the regions is essentially because of agricultural work force availability differentials, while labour usage in crop production is the result of per hectare labour use, cropping pattern and gross cropped area of the respective regions (Reddy, (1989). Considering surplus labour estimates based on the crop production only (row 4), the results showed that there exists surplus labour ranging from 64.29 % in arid western and northern plain region to 86.95 % in sub-humid and humid southern plain region with the state level estimate of 79.29 % of labour availability respectively. A relatively lower level of surplus labour found in arid western and northern plain region is mainly on account of the fact that this region has availability of irrigation from Indra Gandhi Nahar Pariyojana (IGNP). Thus, relatively higher level of irrigation, fertilizer use, cropping intensity and cultivation of high labour intensive crops as compared to other regions. These results imply that cropping pattern in favour of the labour intensive crops and higher level of farming technology tends to enhance labour use.

Apart from crop production, 'livestock activity' constitute the other important engagements, especially carried out by agricultural workers. Thus, any attempt to estimate surplus labour by considering labour time spent only crop production alone would lead to an upward bias. Therefore, at the state level (row 7) total surplus labour taking into account crop production and livestock activity, turns out to be 68.33 % of the available labour. Across the regions, the total surplus labour ranges from 49.45 % in arid western and northern plain region to 80.13 % in semi-arid and flood prone region. Out of five regions of the state, two regions namely, semi-arid and flood prone region and sub-humid and humid southern plain region have surplus labour higher than that at the state level (row 7). The labour utilization on livestock based activities in relation to other farm activities in different size groups of different regions under study indicated that labour utilization per farm family for livestock based activities is remarkably very high. This confirms the fact that livestock is an integral component of economic activities for income and employment generation in all the regions of the state. It provided an important economic base of farm families in rural areas as evidenced by the large share of employment by this activity. The estimates of total surplus labour seem to be high because it includes both removable as well as seasonal (non-removable) surplus labour. Removable surplus labour is the extent of surplus labour that can be removed from agriculture without affecting the output. In other words, this surplus labour is estimated by deducting peak operational labour usage from the labour availability. The estimates of removable surplus (row 12) turns out to be relatively higher in semi-arid and flood prone region (73.78 %) and sub-humid and humid southern plain region (70.70 %) compared to arid western and northern region (29.85 %) with the state level estimate of 57.82 %. Out of five regions of the state, two regions namely, semi-arid and flood prone region and sub-humid and humid southern plain region have higher percentage of removable surplus labour than that of state average.

The results broadly point out that the region with lower proportion of removable surplus labour (arid western and northern region) mainly comprise of developed region either agriculturally (by using new tools and techniques) and/or industrially. In contrast to this, higher proportion of removable surplus labour in semi-arid and flood prone region (73.78 %) and sub-humid and humid southern plain region (70.70 %) may perhaps be due to low level of agricultural development (use of new technology) which was due to water scarcity problem and fact that these regions from the hinterlands which explain the relatively large proportion of worker's dependent on agriculture (Pal *et al.* (2018) and Kwan *et al.* (2018).

Seasonal surplus labour reflects that the labour are partly and wholly unemployed during the lean season but employed during the peak season. Therefore, removal of seasonal surplus labour would affect the peak season labour operations. Therefore, it is estimated as the difference between the peak period labour requirement and the average labour requirement throughout the year. The results (row 14) showed that at the state level seasonal surplus labour is 10.51 % of the labour availability. Across the regions, the estimates ranges from 5.93 % in sub humid and humid southern region to 19.61 % in arid western and northern region. The results indicated that in relatively developed region, i.e. arid western and northern region the seasonal surplus labour turn out to be higher due to larger peak operational labour requirement. In sub-humid and humid southern plain region and humid southern eastern plain region, the incidence of seasonal surplus labour is found to be relatively less. Out of five regions of the state, two regions namely, arid western and northern region and transitional plain region have higher percentage of seasonal surplus labour than that of state average.

The demand for labour in agriculture is characterized with high seasonality followed by inelastic supply of labour at peak season and lack of demand for labour in lean season. Inelastic supply of labour at peak season leading to mechanization and similarly lack of demand for labour in lean season is one of the major causes of poverty. Thus, result revealed the existence of surplus labour in the all regions of the state. However, nature and magnitude of surplus labour seem to be associated with development and socio-economic character of each region. In relatively developed region (arid western and northern region), there is higher seasonal surplus labour (i.e. more non-removable surplus) along with lower removable surplus labour. As against this, in relatively backward region sub-humid and humid southern region, the incidence of removable surplus labour is found to be relatively high along with relatively low level of seasonal surplus labour (non-removable). The high level of removable surplus in this region perhaps explains the generally observed phenomena of migration of agricultural labour to other developed regions of the state and the country. These results were in conformity with Venu *et al.* (2016), Gunabhagya *et al.* (2017), Pal *et al.* (2018) and Kwan *et al.* (2018).

Conclusion

1. The study showed existence of seasonal surplus labour to the tune of 10.51 % of labour availability. This labour can be utilized through initiative to integrate MGNREGA with agriculture. This will improve the productivity of labour and also may check the seasonal migration of labourers.
2. The study emphasised the role and importance of livestock sector as the major employment generation sector of state economy. The potential of livestock sector for employment generation can be utilized by framing policies for creation of milk processing facilities, developing supply chains, cold chains and improvement of breeds.
3. Total available labour in agriculture sector was 2416.30 million man-days in Rajasthan in agriculture sector in 2018-19. Due to mechanization, labour absorption is being reduced and surplus labour is enormous in the state. Therefore, absorb this surplus labour by created through developing agricultural services, small scale industries, establishment of agri-business units to make them atmanirbhar.
4. The results showed that there exists surplus labour. This unemployment of agricultural labourers has negative impact on their income, consumption expenditure and savings. So there is need to create additional income opportunities for agricultural labourers.
5. In relatively developed region (arid western and northern region), there is higher seasonal surplus labour (i.e. more non-removable surplus) along with lower removable surplus labour. As against this, in relatively backward region sub-humid and humid southern region, the incidence of removable surplus labour is found to be relatively high along with relatively low level of seasonal surplus labour (non-removable).

Conflict of interest

The authors declare that they have no conflict of interest.

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Detection of antibiotic resistance in *Escherichia coli* isolates from Egyptian vultures from arid regions of India

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ABSTRACT

Egyptian vultures (*Neophron percnopterus*) wintering in north-western India remains for several months (October to March) and with due course they have become an inhabitant of a synanthropic site in Jorbeer, a livestock and other animal carcasses dumping and disposing site in the outskirts of Bikaner city of Rajasthan. The main purpose of this study was to isolate and identify *E. coli* from critically endangered Egyptian vultures through conventional and molecular methods along with determining their antibiotic resistance profile. Bacteriological analyses were conducted on 38 freshly voided fecal samples, leading to the isolation of *E. coli* in 30 samples which were identified by biochemical tests and 16S rRNA sequencing. In the antibiogram study, out of 12 antibiotics two antibiotics namely norfloxacin and co-trimoxazole were highly effective against most (93.33%) of the isolates. Highest resistance was against cephotaxime (56.65%) followed by amoxyclav (43.33%). Antibiogram showed a moderate spread of *E. coli* strains showing antibiotic resistance among Egyptian vultures at Jorbeer, Bikaner.

Introduction

Egyptian vultures wintering in north-western India remain for several months (October to March), with some of them assembling at a synanthropic site in Jorbeer, located in the outskirts of Bikaner city and used to dump livestock and other animal carcasses. The key source of food for these vultures in shared dumps is farm animal carcasses and stray animal carcasses, which contain high levels of antimicrobial resistance (Kang *et al.,* 2004). This species has been listed as critically endangered by IUCN and in India, there has been a rapid decline in the population with a 35% decrease each year since 1999 which has been attributed mainly to the use of NSAIDs (diclofenac sodium in particular) (Cuthbert *et al.,* 2006). All bacteria including *E. coli* isolated from vultures, internally or externally, can potentially be the cause of diseases both in wildlife, domestic animals and humans (Hubalek, 2004).

Escherichia coli (*E. coli*) is a common colonizer of the gastrointestinal tract which belongs to the family *Enterobacteriaceae* and is a short gram negative, non-spore forming, peritrichous and fimbriate bacillus which may have a capsule or a microcapsule. *Escherichia coli* has been extensively studied in various taxonomic classes of mammals and bird species. The majority of acquired virulence factors that differentiate

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pathogenic *E. coli* from harmless *E. coli* are encoded on mobile genetic elements capable of horizontal gene transfer or on elements that were once mobile but now have become a stable part of the genome with time (Kaper *et al.,* 2004). The selective pressure exerted by antibiotic exposure has been proposed as a key factor in the development and spread of antimicrobial resistance in commensal *E. coli* which is a reliable indicator of antimicrobial selection pressure (Fluckey *et al.,* 2007). The fact that antibiotic use increased by 30% globally between 2000 and 2010 demonstrates the rise in antibiotic use. A survey conducted in India between 2005 and 2009 revealed a 40% rise in the use of antibiotics (Ganguly *et al.,* 2011). Due to its natural history and habits, Egyptian vultures are suitable for testing both virulence and antibiotic resistance trends, but very little microbial studies and antibiotic sensitivity profiling using this host species have been conducted to date in this region (India). Hence the present study was conducted to detect the antibiotic resistance pattern of *Escherichia coli* isolates from Egyptian vultures from Bikaner, Rajasthan, India.

Material and Methods

Sampling

A total of 38 freshly voided faecal samples were collected from Egyptian vultures from Jorbeer conservation area, Bikaner (Raj.). The faecal droppings were collected aseptically with the help of sterile spatula in sterile collection bottles. For further processing, the samples were transported to the laboratory as soon as possible and incubated overnight in nutrient broth for 24 hours.

Isolation and Identification of *E. coli*

Escherichia coli strains from faecal samples were isolated and identified as described by Edward and Ewing (1986) and Quinn *et al.* (2000). Identification of the *E. coli* isolates was based on culture and biochemical characteristics. For genotypic confirmation, amplification of the 16S rRNA genes was performed. Bacterial DNA was extracted using method of Chen and Kuo (1993) and 5'-GCTTGACACTGAACATTGAG-3' was used as the forward primer and 3'-GCACTTATCTCTTCCGCATT-5' as the reverse primer in a polymerase chain reaction (PCR) as per Khaled *et al.* (2010).

Antimicrobial susceptibility testing

The antibiotic susceptibility of 30 *E. coli* isolates was determined by the disc diffusion method on Mueller–Hinton agar (Hi Media) by Bauer *et al.* (1966). A set of 12 antibiotics representative of the main classes used in human and veterinary medicine were used in the antibiogram study. The surface of Mueller–Hinton agar plates was inoculated by swabbing overnight broth cultures of *E. coli* with turbidity adjusted to 0.5 McFarland standards. Seven antibiotic discs were carefully placed on the surface of one MHA plate with enough space around each disc to allow diffusion of the antibiotic and incubated at 37 °C for 16 to 18 h. The inhibition zone around each disc was measured in millimetres and results were interpreted according to CLSI guidelines (CLSI, 2013). Multiple antibiotic resistance (MAR) index was determined according to the method described by Krumperman (1983).

Results and Discussion

In the present study, out of 38 faecal samples collected from Egyptian vultures from Jorbeer conservation area, Bikaner (Raj.), 30 (78.94%) *E. coli* isolates were identified using conventional and molecular tests (Figure1, 2). The antibiotic sensitivity test using 12 antibiotics was determined for 30 isolates and the results of the antibiograms are presented in Table 1. Two antibiotics namely norfloxacin and co-trimoxazole were highly effective against most (93.33%) of the isolates followed by tetracycline (86.67%), ciprofloxacin (83.33%), gentamicin (76.66%) and chloramphenicol (73.33%) (Figure 3,4). The highest resistance was found against cephotaxime (56.65%) followed by amoxyclav (43.33%) and streptomycin (33.33%). *Escherichia coli* may have a multi-resistant phenotype because of distant use of antibiotics, which lead to evolution of a multi-resistant organism which has spread to various ecological niches. The sensitivity of *E. coli* isolates to ciprofloxacin was recorded as 83.34% in present study which is similar to observation made by Sharada *et al.* (2008) who reported 83% *E. coli* isolates from poultry in Bangalore sensitive to ciprofloxacin. In the present study, no *E. coli* was resistant to ciprofloxacin which is similar to the observations made by Shrestha *et al.* (2011), Borges *et al.* (2012) and Saidi *et al.* (2012). This

Table 1: Antibiogram of *E. coli* isolated from Egyptian Vultures

SN	Antibiotic disc	Antibiogram pattern (%)		
		Sensitive	Intermediate	Resistant
1.	Norfloxacin(NX)	93.33	6.67	-
2.	Co-Trimoxazole(COT)	93.33	-	6.67
3.	Tetracycline(TE)	86.67	13.33	-
4.	Ciprofloxacin (CIP)	83.33	16.67	-
5.	Gentamicin(HLG)	76.66	16.67	6.67
6.	Chloramphenicol (C)	73.33	20	6.67
7.	Ampicillin(AMP)	23.33	56.67	20
8.	Streptomycin(S)	23.33	43.33	33.34
9.	Nalidixic acid(NA)	20	66.67	13.33
10.	Kanamycin(K)	16.66	76.67	6.67
11.	Amoxyclav (AMC)	6.67	50	43.33
12.	Cephotaxime (CTX)	-	43.35	56.65

may be due to less use of ciprofloxacin and other fluoroquinolones at farms or hospitals in the study area since ciprofloxacin resistance in gram negative bacilli is coincident with increased use of fluorquinolones. In contrary, high level of resistance was reported from China against ciprofloxacin by Gyles (2008). Kibret and Abera (2011) in a study on *E. coli* from clinical sources in Ethopia found high degree of sensitivity to norfloxacin (90.6%) and gentamicin (79.6%) which is almost similar to our results. Similarly Akond *et al.* (2009) found 80% *E. coli* strains from poultry and poultry environment in Bangladesh susceptible to gentamicin and none of the isolates showed resistance to norfloxacin. Similar to present study Miles *et al.* (2006) reported 2.9% isolates from avian samples resistant to chloramphenicol.

In the present study, 13.33% of *E. coli* isolates were found resistant to nalidixic acid which is similar to the observations made by Costa *et al.* (2008) and Umar *et al.* (2018) who recorded 14% and 18.03%. *E. coli* isolates obtained from wild animals and Indonesian zoo birds respectively, resistant to nalidixic acid. Contrary to present observation Salehi and Bonab (2006) found 100% *E. coli* isolates from broiler chickens with colisepticemia resistant to nalidixic acid. Blanco *et al.* (2016) detected the residues of fluoroquinolones in the plasma of 92% nestling vultures feeding on domestic livestock carcasses. In the present study, 20% *E. coli* isolates were resistant to ampicillin which is similar to results obtained by Miles *et al.* (2006) who reported 20.6% *E. coli* isolates from broiler chickens and humans and Aksoy *et al.* (2007) reporting 13.1% *E. coli* isolates from cattle and sheep resistant to ampicillin. Contrarily, 100% resistance was observed by Matin *et al.* (2017) from faecal, liver and spleen samples of chicken and by Sarker *et al.* (2019) in *E. coli* from broilers. About 50% of *E. coli* isolates from cloacal samples of Canarian Egyptian vultures were resistant to ampicillin and tetracycline which is in contrast to present study. Whereas susceptibility to ampicillin (23.33%) among *E. coli* isolates was almost similar to that observed by Gyles (2008) (38%) from avian population from Canada.

In present study, 56.62% of *E. coli* isolates were found resistant to cephotaxime which is contrary to observation made by Kar *et al.* (2015) who observed 100% *E. coli* isolates from poultry faecal and cattle milk samples resistant to cephotaxime. Resistance to cephotaxime and ampicillin is also suggestive of relatively high proportion of extended spectrum β-lactamases (ESBL) producing *E. coli* strains in Egyptian vultures in the present study which could contribute to the spreading of such ESBL producing strains as observed by Alcalá *et al.* (2016). No resistance was found in *E. coli* isolates for tetracycline in given study which is similar to observation made by Allen *et al.* (2011) from samples of landfills and natural habitats. On contrary high percentage of resistance against

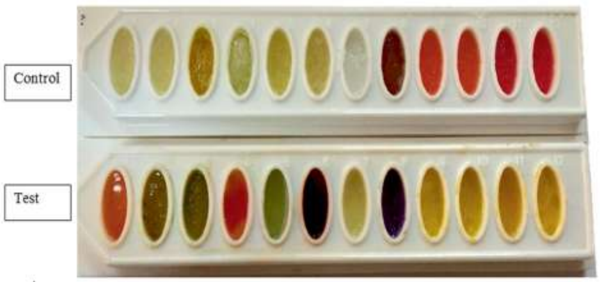

Figure 1: Metabolic and biochemical reactions by Hi *E. coli*TM Identification Kit.

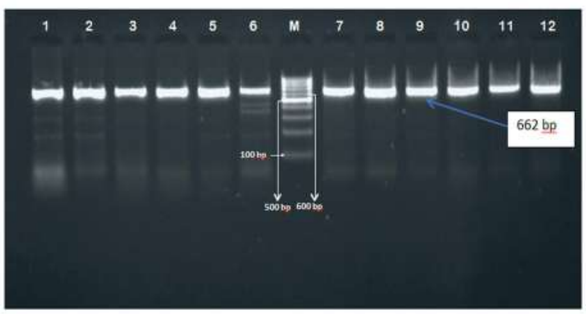

Figure 2: 16S rRNA ribotyping of *Escherichia coli* isolates from Egyptian vultures

Figure 3: Sensitivity pattern of *E. coli* isolates against various tested antibiotics

tetracycline was observed by other scientists *viz.* 100% by Sarker *et al.* (2019) in *E. coli* from broilers. A high level of resistance to tetracycline (83.08%) and co-trimoxazole (76.92%) reported by Sharada *et al.* (2008) and resistance to co-trimoxazole (88%), ciprofloxacin (83%), norfloxacin (78%) and tetracycline (77%) noted by Kar *et al.* (2015) in *E. coli* isolates from poultry faecal and cattle milk samples is in contrast to present study. The *E. coli* isolates from poultry are resistant to these drugs because of regular usage in poultry industry for control of pathogenic avian colibacillosis which is not commonly done in wild birds like vultures.

Ammar *et al.* (2015) observed *E. coli* isolates from avian samples in Egypt to be 100% resistant to amoxyclav which is way higher than our observation (43.33%). The resistance observed in our study is much higher than the observation made by Costa *et al.* (2008) in which resistance of *E. coli* isolates from wild animal was in range of 4.5-7%.

Except for gentamicin an overall high resistance (intermediate + resistant) was recorded for other aminoglycosides *i.e.* streptomycin (76.68%) and kanamycin (83.34%), in the present study. A higher resistance of 60.4% in *E. coli* isolates from turkey to streptomycin was seen by Cunha *et al.* (2014) which is similar to present study. Salehi *et al.* (2007) found out susceptibility to kanamycin for *E. coli* isolates to be 11% which is almost similar to our observation (16.67%). Horn *et al.* (2015) determined that *E. coli* strains isolated from necropsy samples and cloacal swabs of canaries were resistant to gentamicin (4%) and 40% to streptomycin. De Pontes *et al.* (2018) observed a high resistance to aminoglycosides (74%), and streptomycin (67%) in *E. coli* isolates from cockatiels kept in captivity. Aminoglycosides, such as amikacin or gentamicin, are clinically important therapeutic agents for treatment of infections particularly severe infections by Gram-negative bacteria in human and veterinary medicine, but they are less preferred in birds because of the toxicity disadvantage (Flammer, 2006). However, carcasses and other remains, frequently from diseased animals treated with aminoglycosides, can be consumed by vultures leading to the ingestion of antimicrobial residues or resistant bacteria such as *E. coli*. The difference in the prevalence of antimicrobial resistance in wildlife living in natural habitats in different geographic sites may reflect different levels of general pollution in the local environment. All the multidrug resistant *E. coli* isolates were subjected to determination of MAR (Multiple Antibiotic Resistance) index. Five antibiotic resistant patterns with MAR index ranging from 0.08-0.41 were obtained. In addition, the results obtained showed the presence of eight multidrug-resistant strains (MDR), which were

Table 2: Multiple antibiotic resistance (MAR) index of *E. coli* isolates

SN	MAR index value type	Isolate I.D.	No. of isolates	No. of antibiotics to which isolates were resistant	MAR Index value	Significance
1	MAR1	$E_1, E_3, E_4, E_6, E_7, E_8, E_9, E_{10}, E_{11}, E_{12}, E_{14}, E_{15}$	12	1	0.08	22 (73.3%) isolates had less than 0.2 MAR index value with less risk source of MDR strains
2	MAR2	$E_{16}, E_{17}, E_{19}, E_{20}, E_{21}, E_{23}, E_{24}, E_{27}, E_{29}, E_{30}$	10	2	0.16	
3	MAR3	$E_{22}, E_{25}, E_{26}, E_{28}, E_{18}$	5	3	0.25	08 (26.7%) Isolates had 0.2 or more than 0.2 MAR index value with high risk potential source of spread of MDR strains
4	MAR4	E_5, E_{13}	2	4	0.33	
5	MAR5	E_2	1	5	0.41	

resistant to three or more antibiotics having MAR index more than 0.2. The majority of the *E. coli* (12 isolates) were resistant to only one antibiotic (MAR index of 0.08). The majority of isolates (73.3%) had a MAR index of less than 0.2 while 26.7% isolates had MAR index value more than 0.2 and were considered as multiple drug resistant (Table 2) suggesting exposure of the vultures to bacteria from significantly contaminated sites. These results are almost identical to the findings of Kelsey *et al.* (2003), who found that 97% of *E. coli* isolates from surface water were resistant to one or two antibiotics, with only one isolate resistant to more than two antibiotics. Multidrug resistance (MDR) was detected in 18.8% of *E. coli* isolates from healthy wildlife and livestock by Kabali *et al.* (2021) which corroborates present study. On the contrary, Adzitey, 2015 had only four isolates with MAR index less than 0.2 out of 45 isolates of *E. coli*. All *E. coli* isolates from fecal matter samples of migratory birds in Bangladesh were found to be multidrug resistant (MDR) by Islam *et al.* (2021) which is in contrast to present study. Szmolka and Nagy, 2013 described the role of antimicrobial therapy in animals in the selection of multidrug resistant populations of commensal *E. coli* that could transfer those resistance genes in vivo to pathogenic strains of *E. coli* or to *Salmonella.*

Conclusion

In conclusion, considerable number of MDR *E. coli* strains from Egyptian vultures in arid regions of Rajasthan was observed that raises concern regarding the use of antimicrobials in human and veterinary medicine. Hence to protect the populations of this threatened species it is necessary to prevent the vultures from feeding largely on the carcasses of farm animals or from different clinical settings which contain high rates of antimicrobial resistance as they can serve as a source of antimicrobial-resistant bacteria and can spread them to other species and into the environment, and consequently may pose a risk to human and animal health. The proper disposal of diseased and subsequently medicated livestock carcasses through burial or incineration can prevent the spillover of veterinary antimicrobials in the scavenging vultures.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Assesment of divergence among soybean [*Glycine max* (L.) Merrill] genotypes based on phenological and physiological traits.

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ABSTRACT

A study was conducted to understand genetic divergence in Randomized complete block design accommodating 30 soybean [*Glycine max* (L.) Merrill] genotypes randomly in three replications. These genotypes were evaluated for twenty-seven traits: five phenological, nine agro-morphological, eight physiological traits (from field-trial) and five physiological traits (from laboratory experiment) recorded and subjected to PCA (Principal Component Analysis) and cluster analysis. Among all the studied cultivars, significant diversity, as well as analysis of dispersion, was recorded for different agro-morphological characters. D^2-statistic (Tocher method) framed (generalized distance-based) nine clusters: largest with eight and five were oligo-genotypic. Harvest index>seed yield per plant>germination relative index>seedling dry weight contributed maximum towards total divergence. From the most divergent clusters, 21 crosses involving cluster v genotypes (PS-1347, RKS-18, PS-1092, NRC-142, VLS-94, NRC-136, and Shalimar Soybean-1) with monogenotypic cluster VII (AMS-2014), VIII (RSC-11-15) and III (RSC-10-71) suggested for future hybridization. Out of eighteen, only eight principal components revealed more than 1.00 eigen value and exhibited about 85.03% variability among the traits studied. The highest variability (25.41%) by PC1 followed by PC2 (15.60%), PC3 (12.35%), PC4 (10.13%), PC5 (7.20%), PC6 (5.43%), PC7 (4.80%) and PC8 (4.11%) for characters under study.

Introduction

Soybean is the globally oldest cultured plant. Historical shreds of evidence indicate its use for over 5000 yrs by human. It dates back to 1000 AD when soybean was introduced from China to India. Soybean development programme of India was initiated in the 1960s and the expansion was exceptionally rapid between 1972 and 1984. Now, it has centers all across the country. This crop has a fairly wide range of adaptation involving a wide array of climatic, soil and growth conditions and is known for its highly valued protein and oil owing to its use in food, feed and industrial applications (Kumar *et al.,* 2015). At present, soybean has acquired global importance, first ranked oilseed contributing 25% and 40% share in global and national level, respectively in oilseed production. Brazil, U.S.A and Argentina contribute 80% of the world's soybean production. India is the fourth largest country in the world following the United States of America, Brazil and Argentina regarding area but fifth regarding total production after China. In India, major soybean-producing states are

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Madhya Pradesh, Maharashtra and Rajasthan whereas, Bihar is an emerging state for soybean cultivation. It recorded 15-20% annual growth in India. Since the early eighty's it has emerged very fast and in agriculture, edible oil economy, foreign exchange and upliftment of the social status of farmers, soybean played a vital role. According to the first advance estimate in 2019-20, India has an 11.398 million-hectare area, 13.505 million tonnes production and 1.190 tonnes per ha average yield at the national level. D^2-Statistic using tocher method was extensively used by several breeders in many crops but more critically, Principal Component Analysis method for factor extraction using statistical analysis system (SAS,2011) using scree plot and rotated component matrix can help to identify and classify maximum variability into total variability and genotype grouping considering between their several trait and relationship. Genetic variability, as this provides a wider scope for selection, is the basic need for every crop improvement(Chandra *et al.,* 2018). To incorporate useful diversity in breeding programme breeders required a better understanding of evolutionary relationships among accessions, to sample germplasm in a more systematic fashion and to develop strategies to incorporate useful diversity in their breeding programs (Yadav and Pandey, 2018).

Material and Methods

The experiment was carried out during *Kharif*, 2019 at the farm of Tirhut College of Agriculture, Dholi (25.5^{0}N, 35.4^{0}S and 52.2m MSL) in Muzaffarpur District (North Bihar) located in the eco-geographical region I Sub-region IV of Bihar. Thirty entries (including 3 checks) were sown in Randomized Complete Block Design. Each plot consisted of three rows of 3-meter length. The row to row and plant to plant distance was 45 cm and 5 cm, respectively. Trial laid out for 27 (22 field and 5 laboratory screening) morpho-physiological traits *viz*., germination relative index seedling length (cm), seedling dry weight (g), vigour index I, vigour index II, formation of flower tubercles (days), flower budding (days), first flowering (days), cessation of flower (days), physiological maturity (days), plant height (cm), main shoot length (cm), primary branches plant^{-1}, secondary branches plant^{-1}, no of clusters plant^{-1}, no of pods cluster^{-1}, no of pods plant^{-1}, pod length (cm), no of seeds pod^{-1}, growing degree days (°c), specific leaf weight (g/cm^2), leaf area index, 100-seed weight (g), harvest-index (%), dry matter efficiency, effective rainfall use efficiency, seed yield plant^{-1} (g). Data for individual characters were observed replication-wise and mean data was used for statistical analyses.

Two methods of genetic divergence with D^2 statistic following tocher clustering and PCA were performed to assess the diversity. SAS software 2011 utilised to perform multivariate analysis for PCA.

Results and Discussion

Based on D^2 (Tocher) values (Table 1), the 30 genotypes were grouped into 9 clusters. Cluster I was polygenotypic with 8 genotypes followed by cluster II with 7 genotypes, cluster V with 7 genotypes, cluster IV with 3 genotypes, cluster III with 1 genotype, cluster VI with 1 genotype, cluster VII with 1 genotype, cluster VIII with 1 genotype and clusters IX with 1 genotype. In conformity to the present investigation, Tyagi and Sethi (2011) 6 clusters by evaluating 40 genotypes, Patil *et al.* (2011) 6 clusters by evaluating 36 genotypes, Pawar *et al*. (2013) 7 clusters by evaluating 42 genotypes and Adsul and Monpara (2014) 15 clusters by evaluating 100 genotypes of soybean, Mehbub *et al*. (2016) 5 clusters by evaluating 28 genotypes, Milli *et al*. (2017) 5 clusters by evaluating 27 genotypes.

Divergence analysis exhibited (Table 2, Fig 1) the maximum inter-cluster distance between clusters V and VII, followed by clusters V and VIII. Larger distance showing clusters are desirable for the breeders. The highest intra-cluster divergence was recorded for cluster V followed by IV. Similar findings have been reported by Tyagi and Sethi (2011) among total 6 clusters highest genetic divergence was observed between cluster II and IV, followed by clusters III and IV. Adsul and Monpara (2014) inter-cluster distance was highest between clusters XIII and XIV followed by clusters X and XII, XIII and XIV, III and XIV and XII and XIV, Pawar *et al*. (2013) among total 7 clusters, intra cluster distance is highest in cluster VI and lowest in cluster V whereas highest inter cluster distance was noticed between cluster III and VII and the

Cluster	No. of genotypes	Genotypes included
I	8	SL1074, JS9752(NC), JS9305, MACS1493, Pusa9712, SL688, SL955, JS-20-116
II	7	RSC1052, NRC132, NRC12, NRC137, RSC1103, NRC128, PS1572
III	1	RSC1071
IV	3	SL1028, JS335(NC), RSC11-7
V	7	PS1347, RKS18(NC), PS1092, NRC142, VLS94, NRC136, Shalimar soy1
VI	1	RSC-11-17
VII	1	AMS-2014
VIII	1	RSC-11-15
IX	1	NRCSL-1

lowest was between cluster I and II. Mehbub *et al*. (2016) highest intra cluster distance was found in

Table 1: Distribution in different cluster based on D^2 statistic (Tocher method)

Table 2: Mean intra and inter-cluster distances (Toucher) for soybean [*Glycine max* (L.) Merrill]

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	12.63	20.25	25.48	17.19	20.59	27.36	28.51	27.1	27.14
II		15.55	19.39	23.51	22.38	18.56	22.38	20.45	18.46
III			0	22.36	32.13	15.29	10.87	12.18	20.6
IV				15.63	28.2	26.57	24.53	23.45	28.51
V					16.65	29.92	35.33	33.75	29.06
VI						0	14.72	17.05	22.84
VII							0	13.58	26.14
VIII								0	19.49
IX									0

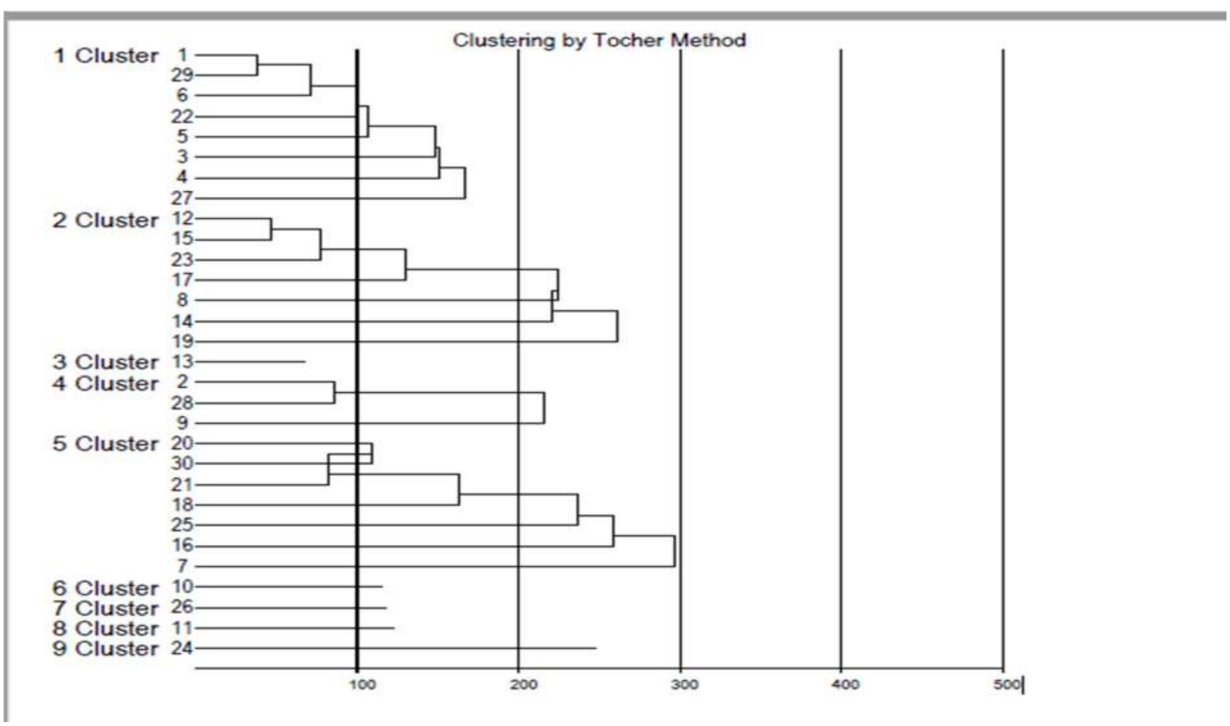

Figure 1: Clustering Pattern of 30 Genotypes of Soybean([*Glycine max* (L.) Merrill]) by Toucher method.

cluster V and the lowest in cluster IV whereas highest inter cluster distance was noticed between cluster II and IV followed by II and V, III and IV and the lowest between II and III, and Milli *et al*. (2017) among total 5 clusters highest inter cluster distance was found between cluster I and IV followed by I and V. The independent character contribution percentage (Table 3) was found maximum in 100-seed weight (g), followed by grain yield per plant (g), germination relative index, seedling dry weight, vigour index I, days to cessation, seedling length, harvest- index (%), specific leaf weight, effective rainfall use efficiency, days to physiological maturity, vigour index II, days to flower budding, pod length (cm), and seed per pod. The above results revealed that the highest percentage contribution towards genetic divergence was recorded by yield and yield attributing traits. In conformity to the present investigation Dhapke *et al*. (2011) for no. of branches per plant, Shadakshari *et al* (2011) for seed per pod and seed yield per plant, Adsul and Monpara (2014) for pods per plant revealed highest percentage contribution.

The cluster mean values (Table 4) of all the twenty-seven characters were studied in the present investigation and found high for most of the yield and yield attributing traits in cluster I, cluster V, cluster VI, and cluster III. The overall conclusion of D^2 analysis revealed that the genotypic distribution into various clusters was at random and sufficient D^2 values among different clusters suggests that the genetic constitution of the promising entries in one cluster is in close proximity with the promising line in other clusters of the pair. A sufficient intra-cluster distance was also observed among the genotypes of different polygenotypic clusters. The genotypes of cluster V (PS1347, RKS18 (NC), PS1092, NRC142, VLS94, NRC136, Shalimar soy1) showing higher inter-cluster distance with cluster VII (AMS-2014) may be crossed to broaden the genetic base of soybean. Intra cluster distance has been found the highest of cluster V hence, the hybridization among the genotypes of cluster V may also result in transgressive recombinants.

PCA analyses provide superiority over D^2 statistics following the Tocher method as it offers an opportunity to compute the voluminous data and interpretation thereof. Loading of many traits on particular PCs reflects their comparative superiority and value thus provide criteria to a researcher for selecting genotype for genetic divergence through such measure axis of differentiation. In this investigation, out of eighteen, only 8 principal components (PCs) revealed more than 1.00 eigen value and exhibited about 85.03% variability among the traits studied (Table 5, Figure 2). A similar result was reported by Li *et al*. (2020) in which 3 principal componants with cumulative contribution of 84.4-87.6 % was found.

Rotated component matrix had shown that the first principal component (PC1) which accounted for the highest variation (25.41%) was mostly related to traits such as effective rainfall use efficiency, grain yield per plant, seedling length and vigour index I.

In PC2 (15.60%) the traits *viz*., days to tubercles formation, days to flower budding, days to first flowering and days to the cessation of flowering, PC3 (12.35%) was consisting of mainly three traits *viz*., no of pod per cluster, harvest index and dry matter efficiency, PC4 (10.13%) was related with seedling dry weight (g) and vigour index II, PC5 (7.20%) was related with no of primary branches and leaf area index, PC6 (5.43%) with specific leaf weight, while PC7 (4.80%) with no of pod per plant. Whereas, principal component 8 (4.11%) was more related with days to physiological maturity, no of secondary branches, no of cluster per plant and leaf area index (Table 5). Based on PCA, most of the important yield and yield attributing traits were present in PC1, PC2 and PC8. The top principal component scores (PC score) for all the traits and in 30 soybean genotypes, were estimated in these eight components and shown in table 6. To propose precise selection indices, these scores can be utilized whose intensity can be decided by variability explained by each principal component. For a particular genotype, a high PC score in a particular component indicates high values for the variables in that particular genotype. NRC-136 had the highest PC score followed by SL 955, MACS 1493, NRC 137, and NRC-128 in PC1 indicated that these genotypes possess high values of traits *viz*., effective rainfall use efficiency, grain yield per plant, seedling length and vigour index I. The highest PC score of AMS 2014 followed by NRC 128, RSC 11-17, RSC 11-15, RSC 1071, and NRC 132 in PC2 was mainly related to days to tubercles formation, days to flower budding, days to first

Table 3: Cluster mean for 27 morpho-physiological characters in soybean [*Glycine max* (L.) Merrill

	Character	Mean of cluster									Total mean
		I	II	III	IV	V	VI	VII	VIII	IX	
1	DT	29.00	31.19	31.00	28.89	28.86	35.00	30.67	33.00	33.33	31.22
2	DFB	38.17	39.19	41.67	36.56	35.29	40.67	41.33	39.00	37.67	38.84
3	DFF	42.58	44.71	46.33	43.11	41.57	43.67	46.33	46.67	41.67	44.07
4	DC	54.00	56.43	59.00	53.78	52.67	61.67	66.33	57.67	55.00	57.39
5	DPM	112.21	107.48	113.33	107.00	102.33	98.00	108.67	112.33	112.33	108.19
6	PH	66.83	68.05	81.00	59.56	59.05	49.33	74.33	69.00	78.33	67.28
7	MSL	50.42	63.81	81.00	46.44	47.29	57.00	63.33	69.00	50.33	58.74
8	PB	8.61	7.20	6.83	7.71	6.80	7.92	6.97	7.77	4.83	7.18
9	SB	3.87	3.35	3.44	3.37	3.19	3.84	2.74	2.49	3.42	3.30
10	C/P	29.20	25.90	24.72	24.76	24.29	21.15	31.33	28.77	21.69	25.76
11	P/C	3.01	2.90	3.13	3.13	3.42	3.40	3.07	3.13	3.13	3.15
12	P/P	83.09	74.32	82.69	74.95	80.86	62.76	91.15	81.13	69.12	77.79
13	PL	3.25	3.28	3.50	3.08	3.65	2.67	2.40	3.10	4.40	3.26
14	S/P	3.00	2.55	3.44	2.55	2.98	1.77	1.89	2.66	3.77	2.73
15	GDD	18.06	18.25	18.03	18.29	18.45	18.65	18.20	18.07	18.07	18.23
16	SLW	0.01	0.01	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.02
17	LAI	8.98	6.32	4.97	6.82	5.76	5.30	5.15	6.82	5.50	6.18
18	SW	8.64	6.01	5.97	9.63	6.29	4.86	5.99	7.85	6.64	6.88
19	HI	39.57	36.33	47.93	36.77	43.47	48.67	35.72	48.60	29.27	40.70
20	DME	1.29	1.29	1.36	1.31	1.42	1.52	1.28	1.38	1.18	1.34
21	ERUE	2.15	1.92	1.64	1.53	1.89	1.24	1.90	2.15	1.46	1.76
22	GYPP	13.53	11.39	9.82	9.71	11.74	6.54	11.34	11.43	7.77	10.36
23	GER	91.71	87.10	89.33	84.67	86.19	87.67	81.33	81.33	62.67	83.56
24	SL	29.06	28.59	27.67	30.30	26.94	22.13	25.03	29.83	30.73	27.81
25	SDW	0.61	0.43	0.87	0.59	0.55	0.82	0.89	0.70	0.09	0.62
26	V1	2667.71	2497.47	2474.13	2609.03	2348.29	1955.93	2036.47	2425.40	1919.40	2325.98
27	V2	56.36	37.42	77.68	49.39	47.48	71.75	72.66	56.66	6.06	52.83

Table 4: Independent character contribution towards total divergence of soybean [Glycine max]

SN	Character	Times ranked first	Contribution
1	DT	0	0.00%
2	DFB	3	0.69%
3	DFF	0	0.00%
4	DC	11	2.53%
5	DPM	5	1.15%
6	PH	0	0.00%
7	MSL	0	0.00%
8	PB	0	0.00%
9	SB	0	0.00%
10	C/P	0	0.00%
11	P/C	0	0.00%
12	P/P	0	0.00%
13	PL	2	0.46%
14	S/P	2	0.46%
15	GDD	0	0.00%
16	SLW	6	1.38%
17	LAI	0	0.00%
18	SW	129	29.66%
19	HI	8	1.84%
20	DME	0	0.00%
21	ERUE	6	1.38%
22	GYPP	99	22.76%
23	GER	63	14.48%
24	SL	9	2.07%
25	SDW	53	12.18%
26	V1	35	8.05%
27	V2	4	0.92%

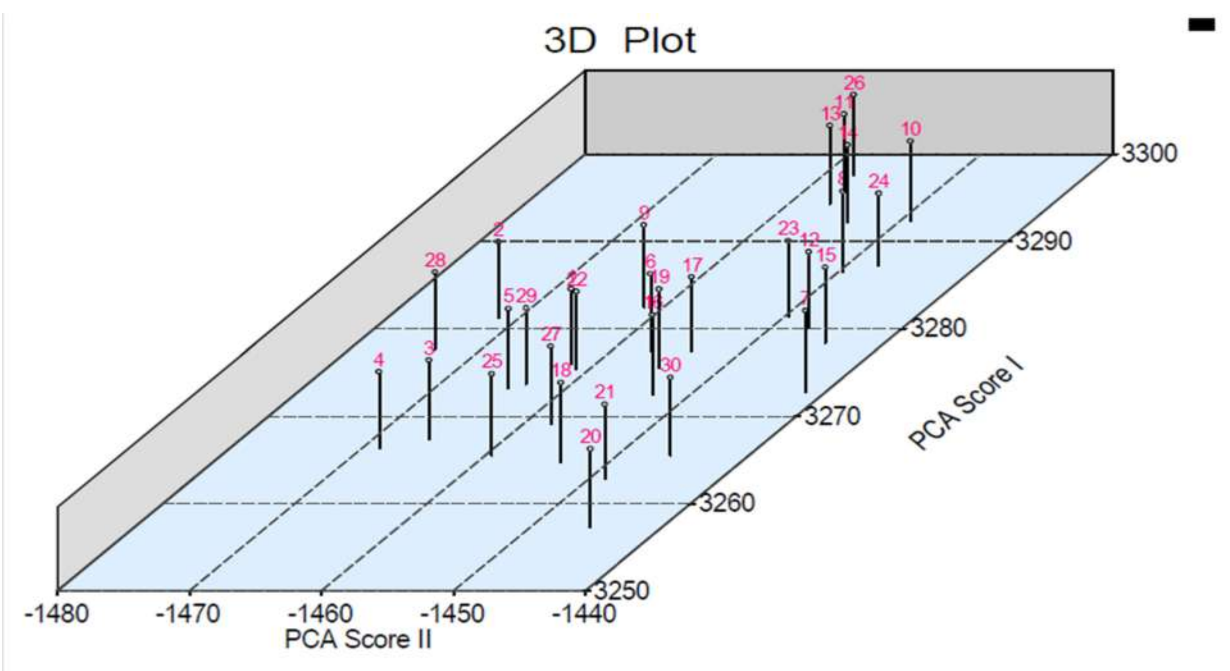

Figure 2: 3D Diagram of 30 Genotype of Soybean [*Glycine max* (L.) Merrill]

Table 5: Principal components (PCs) for twenty- seven traits of soybean

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Eigen value	6.86	4.21	3.33	2.74	1.94	1.47	1.29	1.11
Variability (%)	25.41	15.60	12.35	10.13	7.20	5.43	4.80	4.11
Cumulative %	25.41	41.01	53.36	63.49	70.69	76.12	80.91	85.02
Traits	**Eigen vectors**							
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**
Days to tubercle formation	-0.2661	**0.6378**	0.2316	-0.3423	-0.2589	-0.1266	-0.3271	0.0905
Days to flower budding	0.0446	**0.8842**	-0.0541	-0.0046	-0.1481	-0.1038	0.1356	0.2524
Days to first flowering	0.1129	**0.8962**	-0.0959	-0.0148	-0.0879	0.1722	0.0498	-0.0106
Days to cessation	-0.0053	**0.8783**	0.0906	-0.0133	0.0473	0.1660	-0.0099	-0.1123
Days to physiological maturity	0.2436	0.1062	-0.1451	-0.0577	-0.0115	0.0671	-0.0672	**0.9075**
Plant height (cm)	0.3529	0.1329	-0.3680	0.2705	-0.6443	0.0723	0.1901	0.3522
Main shoot length (cm)	0.2138	0.4967	-0.1777	0.2097	-0.7060	-0.0122	-0.0192	0.0621
No. of Primary branches	0.3221	0.0992	0.1938	0.2205	**0.6326**	-0.0930	0.0889	0.4501
No. of Secondary branches	0.1096	-0.0383	0.1690	-0.0500	0.1265	-0.4173	0.1042	**0.6741**
No of Cluster per plant	0.4755	0.3682	-0.0176	-0.1320	0.2244	-0.1687	0.2415	**0.5237**
No of Pod per cluster	0.0220	-0.1781	**0.6186**	0.0586	0.2071	-0.1515	0.4090	-0.1096
No of Pod per plant	0.4839	0.0955	0.1724	0.0227	0.2176	-0.1321	**0.5481**	0.2692
Pod length (cm)	-0.0970	-0.5031	0.1026	-0.4294	-0.5061	0.2319	0.1372	-0.1260
No of Seed per pod	0.0664	-0.4523	0.0643	-0.4017	0.0089	0.4023	0.0269	0.4976
Growing degree days(^{0}c)	-0.2647	-0.0981	0.1613	0.0581	0.0240	-0.0628	0.0664	-0.8983
Specific leaf weight(g/cm^2)	-0.0982	0.1227	0.0232	0.1000	-0.0563	**0.9214**	0.0234	0.0194
Leaf area index	0.2198	-0.1580	-0.1158	0.1071	**0.5587**	-0.1470	0.0559	**0.5746**
100-Seed weight(g)	0.2684	-0.3080	-0.1540	0.1322	0.4944	0.2739	-0.0030	0.4847
Harvest index	0.0828	0.0478	**0.9526**	0.0813	0.0563	0.0569	-0.0567	0.0209
Dry matter efficiency	-0.1142	-0.0370	**0.7815**	0.1133	0.0600	-0.0100	0.0015	-0.5594
Effective rainfall use efficiency(kg/ha)	**0.8629**	0.0836	0.2453	0.0795	0.0119	-0.0999	0.0914	0.2140
Grain yield per plant(g)	**0.8916**	-0.0073	0.1834	0.0957	0.0699	-0.0820	0.1083	0.1881
Germination relative index	0.3527	-0.0987	0.0902	0.2406	0.2242	-0.1166	-0.7138	0.1414
Seedling length(cm)	**0.8494**	0.0262	-0.2768	0.0061	-0.1197	0.0655	-0.0722	0.1746
Seedling dry weight(g)	0.0550	-0.0121	0.0828	**0.9715**	-0.0202	0.0594	0.0204	-0.0825
Vigour index I	**0.8671**	-0.0239	-0.2042	0.1153	-0.0081	0.0045	-0.3109	0.1801
Vigour index II	0.1096	-0.0532	0.0810	**0.9629**	-0.0151	0.0409	-0.1047	-0.0270

flowering and days to cessation which are mainly yield attributing traits. The highest PC score was obtained by NRC-136 followed by PS-1092, Shalimar soy 1, RSC 11-17 and RSC 1028 in PC3 for characters namely no of pod per cluster, harvest index and dry matter efficiency. PC scores in PC4 were recorded the highest value for characters *viz*., seedling dry weight and vigour index II by the genotypes NRC 142, JS 20-116, AMS 2014, RSC 1071, SL 688, NRC 137 and JS 97-52. PC scores in PC5 were recorded the highest value for characters *viz*., no of primary branches and leaf area index by the genotypes Pusa 9712, SL 955, SL 1028, SL 688 and RSC 1103.

PC scores in PC6 were recorded the highest value for characters *viz*., specific leaf weight by the genotypes RSC 1071, PS 1572, Pusa 9712, NRCSL 1, VLS-94, NRC-128 and RSC 11-15. PC scores in PC7 were recorded the highest value for characters viz., no of pods per plant by the genotypes VLS-94, Shalimar Soy 1, NRC 12, NRC-136, AMS-2014, NRCSL 1 and SL-688. However, SL 1074, SL 688, Pusa 9712, RSC 1071, and PS 1092 had the highest PC scores in PC8 for Days to physiological maturity, no of secondary branches, cluster per plant and leaf area index. Genotypes were categorized in table 6, based on top PC scores.

Table 6: Scoring of soybean genotypes in eight principal components

Genotypes	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
SL 1074	-1.0165	-0.1880	0.2491	0.2720	0.6430	-0.4156	-0.2631	**1.6818**
SL 1028	-0.2779	-0.0701	-1.3125	0.2121	**1.5167**	0.0003	-0.0241	0.6918
SL 955	**2.0295**	-0.0299	0.1256	-0.6855	**1.5761**	-0.1709	-0.0383	0.9771
SL 688	-0.5252	-1.2065	-0.0477	**1.1265**	**1.1750**	-0.6176	**1.0367**	**1.6628**
Pusa 9712	-0.2577	-0.2231	0.0382	-1.1184	**1.7326**	**1.3082**	0.1873	**1.1986**
JS 9305	-0.4307	0.4301	0.3569	0.7799	0.5665	-0.9888	0.1384	0.9597
Shalimar soy-1	-0.5386	-0.1519	**1.6398**	-1.6697	0.3798	-0.6765	**1.7271**	-0.9756
RSC 1103	-1.4011	0.6380	0.4291	-0.6933	**1.0267**	0.0879	-1.5027	-1.6552
RSC 11-7	-0.6358	-0.1413	0.2214	0.3978	0.4754	0.9444	0.5336	-1.8975
RSC 11-17	-1.5785	**1.5325**	**1.6131**	0.9997	0.2313	-1.2243	-1.3299	-0.7703
RSC 11-15	0.1194	**1.2644**	0.8263	0.3095	-0.3156	**1.0033**	-0.0106	0.3813
RSC 1052	-0.5068	0.6820	-0.6745	-1.2075	-0.4069	-1.0325	0.3223	0.6122
RSC 1071	-0.4851	**1.0761**	**1.2838**	**1.2152**	-1.7708	**2.5826**	-0.0302	**1.1952**
NRC-128	**1.0813**	**1.5515**	-0.1055	-0.3493	-0.3447	**1.0380**	-0.3003	0.0851
NRC-132	0.1173	**1.0335**	-0.9533	-1.1904	0.5436	-1.6171	-0.8503	0.1501
NRC-136	**2.5750**	0.0436	**1.9839**	0.2282	0.4257	-0.7772	**1.2502**	-1.1396
NRC-137	**1.6481**	0.1016	-0.1948	**1.0500**	-1.5055	-1.2734	0.2157	0.4126
NRC-142	-0.3064	-1.8892	-0.7151	**1.8299**	-0.5170	-0.3892	0.3614	-1.2501
PS-1572	0.6484	-0.2509	-0.7272	-0.4363	0.0364	**1.5873**	-1.8968	-0.9442
PS-1347	0.3567	-1.1244	0.5780	-0.3904	-0.9138	0.1688	-0.9157	-0.8856
PS-1092	0.0080	-1.5387	**1.8551**	-0.9565	-1.5747	-0.9565	-1.0929	**1.1913**
MACS-1493	**1.9521**	0.5562	-0.8199	-0.7095	-0.5305	0.3415	0.6221	-0.4560
NRC-12	-1.1920	0.6645	-1.3545	-0.1695	-1.7678	-1.2718	**1.5325**	-0.1963
NRCSL-1	-1.0192	-0.6597	-0.8483	-2.0932	-1.7998	**1.1725**	**1.1339**	0.7641
VLS-94	-0.7346	-1.7164	0.4631	0.4497	0.8773	**1.1575**	**1.8447**	-1.0094
AMS-2014	-0.2942	**2.3342**	-0.7455	**1.2486**	0.3710	0.1373	**1.2284**	-0.4065
JS-20-116	0.5063	-0.6136	-1.8889	**1.6107**	-0.5537	-0.2157	-0.7287	-0.4148
JS-335(NC)	0.4171	-0.6028	-1.1446	0.0494	0.8951	0.8210	-0.5476	0.3826
JS-97-52(NC)	0.0372	-0.9071	0.6979	**1.0054**	-0.2030	-0.0910	-1.4804	0.8840
RKS-18(NC)	-0.2963	-0.5946	-0.8289	-1.1151	-0.2686	-0.6325	-1.1229	-1.2291

Table 7: Genotypes based on overall superiority in divergence and *per se* performance for yield and morpho-physiological traits in soybean [*Glycine max* (L.) Merrill].

SN	Genotype & Pedigree	Desirable *per se** for Traits	PCA			Tocher		GYPP *per se (g)*
			PC	% Variability	Traits	Cluster (O/P)	Traits	
1	NRC-136 (JS 97-52 X NRC-36)	GYPP, DPM, P/C, P/P, HI, DME, ERUE	PC1, PC3, PC7	25.41 12.35 4.80	ERUE, GYPP, SL, V1, **P/C,** HI, DME P/P	V (P)	Early DT, DFB(E), DFF(E), DC(E); **more P/C,**	**21.00****
2	SL-955 (SL599 X PK1283)	GYPP, PB, SB, C/P, LAI, ERUE, SL, V1	PC1, PC5	25.41 7.20	ERUE, GYPP, SL, V1 PB, LAI	I (P)	More PB, SB, LAI, ERUE, GYPP, GER, V1	**20.17****
3	NRC-128 (JS 97-52 X PBM-1-1-9-2-6-1)	PH, MSL	PC1, PC2, PC6	25.41 15.60 5.43	ERUE, GYPP, SL, V1 DT, DFB, DFF, DC SLW	II (P)	High GER Medium DPM	**15.46 (at par)**
4	RSC-10-71 (BRAGG X JS 335)	PH, MSL, S/P, SLW	**PC2, PC3, PC4, PC6, PC8**	15.60 12.35 10.13 5.43 4.11	DT, DFB, DFF, DC P/C, HI, DME SDW, V2 SLW DPM, SB, C/P, LAI	III (O)	PH & MLS (tall) more SLW, high V2	9.82
5	SL-688 (PK 416 X SL 317	P/C, P/P, LAI, SL, V1	PC4, PC5, PC7, PC8	10.13 7.20 4.80 4.11	SDW, V2 PB, LAI P/P DPM, SB, C/P, LAI	I (P)	More PB, SB, LAI, ERUE, GYPP, GER, V1	11.70 (at par)
6	Shalimar Soybean-1 (Selection from local landrace genotype AGR/538)	DPM(E), C/P, P/P, PL, GDD, DME	PC3, PC7	12.35 4.80	P/C, HI, DME P/P	V (P)	Early DT, DFB(E), DFF(E), DC(E); more P/C	7.19
7	RSC-11-17 (JS 97-52 X JS 93-05)	DPM(E), P/C, GDD, DME	PC2, PC3	15.60 12.35	DT, DFB, DFF, DC P/C, HI, DME	VI (O)	PH (dwarf), SW (low), high HI, & DME	6.54
8	RSC-11-15 (JS 335 X PS 1024)	MSL	PC2, PC6	15.60 5.43	DT, DFB, DFF, DC SLW	VIII (O)	Late DFF, High HI	11.43 (at par)
9	AMS-2014 (AMS 99-33 X H6P5)	DPM(E), PH, MSL, C/P	PC2, PC7	15.60 4.80	DT, DFB, DFF, DC P/P	VII (O)	More C/P & P/P, high SD W	11.34 (at par)
10	Pusa -9712 (Mutant Of DS-74)	C/P, S/P, LAI	PC6, PC8	5.43 4.11	SLW DPM, SB, C/P, LAI	I (P)	More PB, SB, LAI, ERUE, GYPP, GER, V1	10.32 (at par)
NC	**JS-97-52 (NC) (PK327XL129)**	**GYPP, SDW, V2, PB, LAI, ERUE, GER(High)**	**PC4**	**10.13**	**SDW, V2**	**I (P)**	**More PB, SB, LAI, ERUE, GYPP, GER, V1**	**13.90 ± 3.68 CD (5%)**

Tochers method resulted in nine clusters; Maximum intra-cluster distance (7genotypes in cluster V) depicting diversity within cluster, which might be attributed to their pedigree. Maximum inter-cluster distance between V-VII followed by V-VIII and V-III; suggested that seven above mentioned genotypes of cluster V were distant and diverse to oligo-genotypic clusters VII, VIII and III with unique genotypes. Genetic divergence and geographical distribution were incomparable mainly due to the free sharing of breeding lines. It was very clear that genotypes from one and different geographic regions are grouped together.
Harvest- index (%) > grain yield per plant (g) > germination relative index > seedling dry weight explaining 71 % of the total divergence were most important contributor traits. Genotypes RS-11-17, SL-1074, JS-97-52, JS 93-05, MACS-1493, Pusa-97-12, SL-688, SL-955 and JS-20-116 and AMS-2014 were found desirable for above mentioned traits. Eight Principal Components explaining 85.02 per cent cumulative (Spatial distance-based) variability was obtained in Principal component analysis (PCA). Yield (GYPP) related best genotype was NRC-136 (In PC1, PC3 and PC7) followed by SL-955 (PC1 and PC5); NRC-128 (PC1, PC2 and PC6). For phenol-agro-morpho-physiological traits best source was RSC-10-71(PC2, PC3, PC4, PC6 and PC8) along with SL-688 (PC4, PC5, PC7 and PC8); Shalimar Soybean-1 (PC3, PC7); RSC-11-17 (PC2 and PC3); RSC-11-15 (PC2 and PC6), and AMS-2014 (PC2, PC7).
NRC-136, Shalimar Soybean-1(common in PCA and Cluster V: Tocher) RSC-10-71(common in PCA and Cluster III: Tocher), RSC-11-15(common in PCA and Cluster VIII: Tocher) and AMS-2014 (common in PCA and Cluster VII: Tocher) along with SL-955 (PC1 and PC5), NRC-128 (PC1, PC2 and PC6), Pusa -9712 (PC5, PC6 and PC8) may prove their merit as diverse parents for pheno-agro-morpho-physiological traits (table 7). Their pedigree: NRC-136 (JS-97-52 X NRC-36) and Shalimar soybean-1 (selection from Local Landrace genotype AGR/538)]; RSC-1071(Bragg X JS-335); RSC-11-15(JS-335 X PS-1074); AMS-2014 (AMS-99-33X H6P5); SL-955(SL-599X PK-1283) ; NRC-128 (JS-97-52 X PBM-1-1-9-2-6-1) and Pusa-9712 (Mutant of DS-4) is quite diverse as they involved Local Landrace genotype (AGR/538) / EC: Bragg /Strain: H6P5/ Line: PBM-1-1-9-2-6-1 as parent as well as mutant derivative (table 7).

Conclusion

Crosses may be attempted in future between such diverse parents could through useful transgressive segregants for yield and component traits related to earliness in flowering and maturity, seedling growth and vigour, effective rainfall use efficiency, germination, branching, pod, leaf parameters toward redesigning, for various purposes (for yield, earliness, effective rainfall use efficiency, germination, growth and vigour) the soybean plant types.

Conflict of interest

The authors declare that they have no conflict of interest.

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Evaluating anti-microbial and anti-oxidative potential of red biopigment from *Monascus purpureus*

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ABSTRACT

In the present study, *Monascus* red biopigment produced by solid-state fermentation was evaluated for its anti-microbial and antioxidative potential. The antibacterial activity through Scanning Electron Microscopy against *Bacillus cereus*, *Escherichia coli*, and *Staphylococcus aureus* was found to show morphological damage in some cells, as evidenced by the outflow of cell contents, deep craters, burst cells, and cell death at concentration of 200 µg/ml of biopigment. Moreover, antibacterial activity through agar well diffusion method against *Bacillus cereus, Staphylococcus aureus, Klebsiella pneumonia* and *Pseudomonas aeruginosa* was in range of 2-6 mm by varying concentration of biopigment from 1 to 20 mg/ml.Next, the antifungal activity of the extracted biopigment was in the range of 2-9 mm for *Aspergillus flavus, Fusarium oxysporum* and *Alternaria alternata.* In addition, antioxidant efficacy of red biopigment through DPPH, ABTS and FRAP assay results was found to show 59.69 %, 91.1 %, and 15.22 % free radical scavenging activity. The results of this study revealed that red biopigment has potential to modulate the antimicrobial and antioxidative activity.

Introduction

The food colorants, based on "natural" biopigments, are highly preferable over present day used "synthetic" chemical colors, which are generally "toxic" in nature and may cause various allergic and intolerance reactions (Weiss, 2012; Tkaczyk *et al.,* 2020). On contrary, "natural" biopigments serve additional health benefits with a number of anti-cancers, anti-microbial and therapeutic properties (Park and Kim 2011; Lin *et al.,* 2019). The biopigments are derived from plants and microorganisms such as *Monascus purpureus* (*M. purpureus*) and *Rhodotorula* etc. (Marova *et al.,* 2012; Vendruscolo *et al.,* 2016), among which, *M. purpureus*, a filamentous fungus, is highly versatile and produces several bioactive secondary metabolites of polyketide origin, such as mixture of three (orange, yellow and red) biopigments, monacolins K (Lovastatin) etc. (Chen *et al.,* 2015; Chen *et al.,* 2017). The biopigment is commonly produced by fermentation method with both solid-state and submerged cultivation, among which, solid state fermentation (SSF) offers high yield of biopigment due to the use of solid substrate, generally agricultural products, for release of biopigment (Thomas *et al.,* 2013). On contrary, the biopigments in submerged cultivation are mainly retained intracellularly, which impedes further development and evolution of biopigment (Velmurugan *et al.,* 2011). Among two, the red biopigment is of high demand in food industry due

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to its extensive use in meat products to replace synthetic nitrites colorants (Yu *et al.,* 2015).
Monascus spp naturally produces other secondary metabolites, chemical constituents (monascin, monascopyridines, monapurpyridines A, monacolin) and phytochemical such as flavonoids, polyphenols, terpenoids in significant quantities (Wild *et al.,* 2002; Hsu *et al.,* 2012; Cheng *et al.,* 2013; Ji *et al.,* 2018). Additionally, polyphenolic components of higher fungi like *M. purpureus,* etc. protected alongside oxidative loss through preventing or reducing free radicals as well as reactive oxygen species *in vitro*. Molecules like flavonoids, phenolics, phenylpropanoids in addition strongly polymerized molecules (i.e. tannins) and acetate accumulate naturally end products through shikimate pathways, signifying the extensively antioxidant activity in a generally distributed sub-group and can be applied in the food, health, and cosmetics industries (Smith *et al.,* 2015; Tan *et al.,* 2018). These pigments and chemical components are secondary metabolites with a common skeleton of azaphilone might be having antimicrobial and antioxidative activity (Chen *et al.,* 2017; Patakova *et al.,* 2017; Wu *et al*., 2019).
Keeping in view of the importance of *Monascus* pigments and their associated biochemical activities, the current study was aimed to reveal the antimicrobial (antibacterial and antifungal) potential including anti-oxidative activity of biopigment. In this manuscript the effect of red *Monascus* biopigment was evaluated on bacterial pathogens through scanning electron microscopy and agar well assay including fungal pathogens through agar well asasay. Next, the antioxidative effect of *Monascus* red biopigment was evaluated through DPPH, ABTS and FRAP assay. The current study specifies the antimicrobial and antioxidative effect of *Monascus* red biopigment.

Material and Methods

The red biopigment was produced at a pilot-scale using tray-type fermenter from *M. purpureus* (MTCC-369) using broken rice as substrate through solid-state fermentation. Subsequently, red biopigment was extracted from *Monascus* fermented biomass through static extraction method (Roy, 1967) with 60% ethanol at 60°C for 80 min at 10,000 rpm. The extracted red biopigment was collected and stored in refrigerated conditions (-20°C) till further analysis.

Antibacterial activities: Antibacterial activity of red biopigment against various bacterial pathogens such as *Bacillus cereus* MTCC 1272, *Staphylococcus aureus* MTCC 96, *Streptococcus mutans* MTCC 890*, Listeria monocytogenes* MTCC 1143*, Klebsiella pneumoniae* MTCC 109*, Proteus mirabilis* MTCC 425*, Pseudomonas aeruginosa* MTCC 741*, Salmonella typhi* MTCC 733*, Shigella flexneri* MTCC 1457 and *Escherichia coli* MTCC 723 was determined using agar well diffusion assay and scanning electron microscopy. The bacterial cultures were revived on Brain Heart Infusion broth incubated at 37°C for 24 hrs. The stock cultures were preserved at 4°C in a refrigerator and sub-cultured every three weeks.

Scanning Electron Microscopy (SEM): The overnight grown bacterial cultures of *B. cereus, E. coli, and S. aureus* was used to perform the SEM for antibacterial evaluation as described previously (Chen *et al.,* 2018). The reaction mixture of red biopigment was prepared by mixing 1 mg/ml with DMSO. For the antibacterial assay, 2 ml microcentrifuge tubes were taken and the reaction mixture was prepared by adding 200 µg of 1 mg/ml red biopigment mixed each tube along with 100 µl of the bacterial culture. After mixing the reaction mixture make the final volume was 1.5 ml with BHI broth. BHI broth as such served as a negative control whereas BHI broth with culture instead worked as a positive control. The mixture was vortexed and incubated at 37ºC for 96 hrs. After incubation bacterial cells were harvested at 8000 rpm for 10 min. Cell pellets were washed 3 times with phosphate buffer saline (10 mM PBS), after washing cells were re-suspended in normal saline and made smear on a glass coverslip. Briefly, cells were fixed with 3 % glutaraldehyde buffered with 0.1 M phosphate buffer (pH 7.2) at 4°C for 24 hrs. After fixation, cells were washed for 3x10 min in 0.1 M phosphate buffer and Post-fixation, with 2 % osmium tetroxide (in 0.1 M phosphate buffer pH = 7.2) for 4 hrs at room temp in a light-tight container. The samples were then washed in 0.1 M phosphate buffer (3 × 10 min.) and dehydration was done with a graded ethanol solutions in water – 30 %, 50 %, 70 %, 80 %, 90 %, 96 %, 100 % for 5-15 min each; 2 x 100 % ethanol for 15-30 min each. The treated samples were dried in a desiccator and metal coated by an ion spray instrument (MSP-2S, IXRF, USA) followed by analysis using S-3400 scanning electron microscopy carried out at Electron Microscopy Centre of Dairy Microbiology Division, ICAR-NDRI Karnal, Haryana.

Agar well diffusion assay: The overnight grown bacterial cultures of *B. cereus*, *S. aureus*, *S. mutans, L. monocytogenes, K. pneumoniae, P. mirabilis, P. aeruginosa, S.Typhi, S. flexneri* and *E. coli* was used to evaluate the antibacterial activity of biopigment (Vendruscolo *et al.* 2014). The reaction mixture of red biopigment was prepared by mixing 1 mg/ml, 5 mg/ml, and 20 mg/ml with Dimethylsulfoxide (DMSO) and DMSO as such without biopigment served as control. For the antibacterial assay, Brain Heart Infusion agar plates were prepared and 100 µl of 24 hrs grown test bacterial culture was seeded on the surface of Petri plates. Wells of approximately 10 mm was bored using a cork borer and sealed with soft agar. Then 100 µl samples of various concentration i.e. 1 mg/ml, 5 mg/ml, and 20 mg/ml of biopigment were introduced in each well. Petri plates were incubated at 37^{o}C for 48 hrs. Growth of bacterial culture was observed at 6, 12, 24, 48 hrs and diameters of zones of inhibition were recorded after 48 hrs. The antibacterial activity was assayed by measuring the diameter of the inhibition zone formed around the well.

Antifungal Activity: The Antifungal activity of red biopigment was estimated using the agar well assay method described by Ferdes *et al.* (2009) with slight modification. In brief, five fungal species *Aspergillus flavus* NCIM535*, Penicillium chryosogenum* ATCC66564*, Mucor azygosporus* ATCC15087*, Fusarium oxysporum* NCIM1008*,* and *Alternaria alternata* ATCC6663 were procured from the Institute of Microbial Technology, Chandigarh, India. The culture was revived on Potato Dextrose Agar incubated at 30°C for 7 days. The stock culture was preserved at 4°C in a refrigerator and sub-cultured every three weeks. The reaction mixture of red biopigment was prepared by mixing 1 mg/ml, 5 mg/ml, and 20 mg/ml with DMSO and DMSO alone served as control. For the antifungal assay, PDA plates were prepared and wells of approximately 10 mm were bored using a cork borer and sealed wells with soft agar. The fungal culture bit size of 8 to 10 mm was placed onto the center of the Petri plate and 100 µl of different dilutions was introduced in each well around the fungal bit. The Petri plates were then incubated at 30^{o}C for 7 days. The growth of fungal species was observed each day and diameters of zones of inhibition were recorded after 7 days. The antifungal activity was assayed by measuring the diameter of the inhibition zone formed around the well.

Anti-oxidative activity: Radical scavenging activity was determined using 2, 2 diphenyl-1-picrylhydrazyl (DPPH) assay, 2, 2‟-Azino-Bis-(3–Ethylbenzthiazoline–6-Sulfonic acid) assay (ABTS) and ferric reducing antioxidant power (FRAP) assay.

DPPH assay: The antioxidant activities of the *Monascus* red biopigments were determined by the activities of 2,2-Diphenyl-1-(2,4,6-trinitrophenyl) hydrazyl (DPPH) free radical scavenging activity assay (Tan *et al.,* 2018) with minor modifications. In brief, the reaction mixture was prepared by using various concentration 2, 10, 20, 40 60, 80, 160, 320, 640 µl/ml of 5 mg/ml red biopigment combined with 2 ml of the DPPH ethanol solution (0.05 mM in ethanol). Ethanol served as blank whereas DMSO instead of sample functioned as control. The mixture was vortexed and incubated for 60 min at room temp in the dark. Following incubation, reaction mixtures were centrifuged (8000 rpm for 10 min) and each reaction mixture (200 µl) was transmitted to a 96 well plate, and absorbance was measured at 517 nm on ELISA plate reader (Thermo Fisher, Scientific). Positive controls included BHT, Ascorbic acid, and Quercetin. The concentration of sample that resulted in free radical scavenging activity was recorded.

$$\textbf{DPPH scavenging ability}\ (\%) = \left(\mathbf{1} - \frac{(\mathbf{S}-\mathbf{B})}{\mathbf{C}}\right) \times \mathbf{100}$$

Where; A_{sample} = Absorbance of the test sample, A_{blank} = Absorbance of blank, $A_{control}$ - Absorbance of control

ABTS Assay: The freshly prepared ABTS solution was prepared by oxidation of 7.4 mmol/L ABTS with 4.90 mmol/l potassium persulfate according to Tan *et al.* (2018) with minor modification. In brief, the reaction mixture was prepared 5 mg/ml of red biopigemt at various concentration of 2, 10, 20, 40

60, 80, 160, 320, 640 µl/ml. 50µl of different dilution of red biopigment was mixed with 200 µl ABTS solution. Ethanol served as blank whereas DMSO instead of sample served as control. The mixture was vortexed and incubated for 5 min at room temp in the dark. Absorbance was measured at 734 nm on an ELISA plate reader. All the values were normalized with control. The positive controls included BHT, Ascorbic acid, and Quercetin. The scavenging ability of the ABTS was estimated by following Equation:

$$\textbf{ABTS free radical scavenging activity } (\%) = \left(1 - \frac{(S - B)}{C}\right) \times 100$$

FRAP assay: The freshly prepared FRAP (Xiao 2015) reagent consisted of 300 mM acetate buffer (pH 3.4), 100mM 2,4,6-tripydyl-s-triazine (TPTZ) solution in 40 mM HCl and 20 mM $FeCl_3.6H_2O$ in ratio of 10:1:1. In brief, the reaction mixture consist of 5 mg/ml of red biopigemt at various concentration of 2, 10, 20, 40 60, 80, 160, 320, 640 µl/ml. 50µl of each dilution was mixed with 200 µl of FRAP reagent and incubated at 37ºC temp for 30 min in the dark. An ELISA plate reader was used to measure the absorbance at 517 nm. Different concentrations of ferrous sulphate (0-1mM) were used to create the standard curve (Figure 1) by following the same procedure; just replacing the sample with the known concentration of ferrous sulphate solution (Ferrous sulphate 1mM= 1.51 mg/10ml) (Shokryazdan *et al.,* 2018). The FRAP antioxidant activity was expressed as mM ferrous sulphate equivalent using a standard curve prepared by ferrous sulphate. The values were normalized with control. BHT, Ascorbic acid, and quercetin were used as positive control.

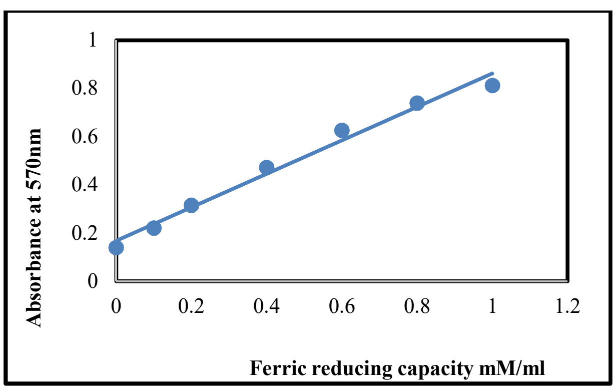


Figure 1: Standard curve of ferrous sulphate.

Statistical analysis: The collected research data in triplicate was analyzed for the mean values and standard error through Microsoft Excel. To determine the significance of the collected data one-way analysis of variance (ANOVA) tests were used in SPSS (16.0v). Differences in means of less than 0.05 % were measured statistically significant.

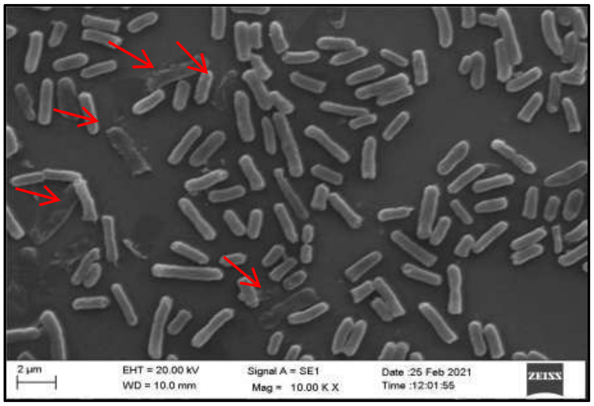
Results and Discussion

Antibacterial activity

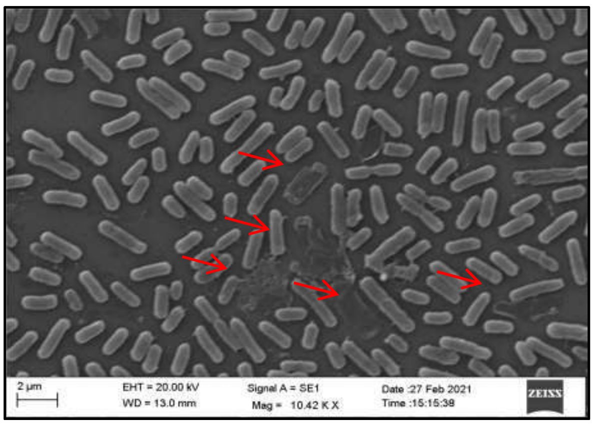
The antibacterial activity of extracted red biopigment was determined against strains of Gram-positive and Gram-negative food pathogenic bacteria by the scanning electron microscopy (SEM) and agar well diffusion method.

Scanning Electron Microscopy (SEM)

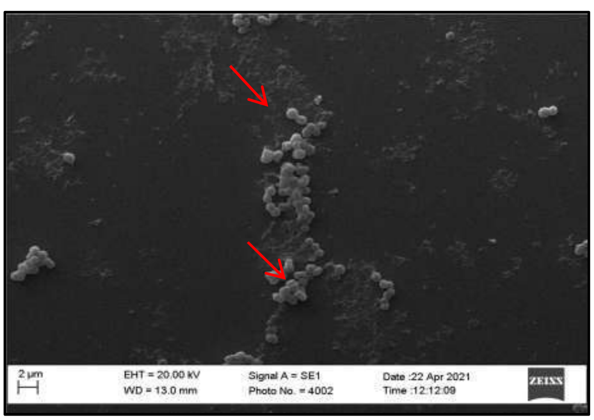
The antibacterial activity was observed in 200 µg/ml of extracted biopigment against *Bacillus cereus*, *Escherichia coli*, and *Staphylococcus aureus* after 96 hrs of incubation at 37ºC temperature. Morphological changes were analyzed and are shown in (Figure 2). Bacterial cells in the control group were healthy and smooth, with no signs of damage. In contrast, *B. cereus*, *E. coli*, and *S. aureus* cells treated with *Monascus* biopigment were found to show morphological damage in some cells, as evidenced by the outflow of cell contents, deep craters, burst cells, and cell death (Figure 2 a,b and c). Furthermore, the total numbers of cells into given suspension were reduced with treatment of biopigment in comparison to the control cells. The extracted biopigment was observed to be slightly effective based on SEM results. Zhao *et al.* (2016) also demonstrated that a 2.5 mg/ml concentration of orange pigment derived from *M. purpureus* damage *E. coli* bacterial cells, resulting in cell death. Likewise,100 µl of red biopigment from *M. purpureus* MTCC 1090 was also found to be effective against *S. aureus*, *E. coli*, *Klebsiella pneumonia*, and Providencia by Bi and Gajalakshmi (2018).Furthermore, Feng *et al.* (2019) used scanning electron microscopy and transmission electron microscopy to analyze that 10 mg/ml *Monascus* pigment has antibacterial activity against *S. aureus*. The antibacterial properties of *Monascus* pigment can be due to disruption to bacterial cell membranes, which allows some cellular components such as proteins and DNA to escape, resulting in bacterial cell death (Feng *et al.,*2019).As a result, *Monascus* biopigment could be used as a natural food preservative in the food industry.



(a): *Bacillus cereus*



(b): *Escherichia coli*

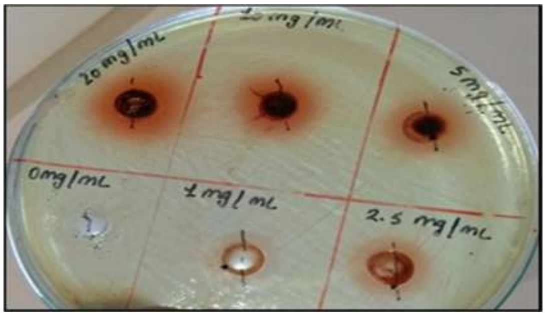


(c): *Staphylococcus aureus*

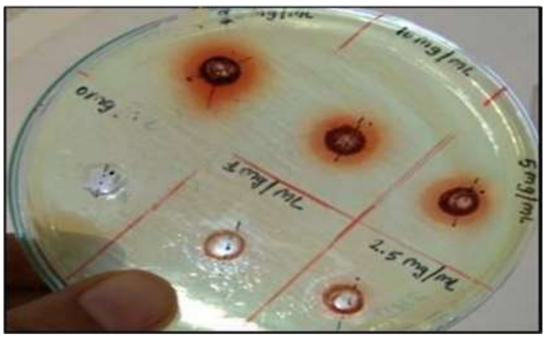
Figure 2: Morphological changes of a) *B. cereus,* b) *E. coli* andc) *S. aureus* after treatment with red biopigment for 96 hrs with 200 µg/ml of biopigment. Red arrows indicate formation deep craters and cell death.

Agar well diffusion assay: The antibacterial activity of the extracted biopigment was tested against *B. cereus*, *S. aureus, K. pneumonia* and *Pseudomonas aeruginosa* by varying the concentration from 1, 5 and 20 mg/ml (Figure 3). The zone of inhibition produced by biopigment at varying concentration was in the range of 2-6 mm for *B. cereus,* 2-5 mm for *S. aureus,* 2-4 mm for *K. pneumonia* and again 2-6 mm against *P. aeruginosa* (Figure 3 a-d). Whereas, biopigment exhibited no activity against *Sreptococcus mutans, Listeria monocytogenes, Proteus mirabilis*, *Salmonella typhi, Shigella flexneri, and E. coli* (Table 1). Based on the agar well assay, extracted biopigment was found to be slight effective against *B. cereus*, *S. aureus*, *K. pneumoniae*, *P. aeruginosa.* The results were corroborated with Mukherjee and Kumar (2011), who demonstrated that extracted pigment from *M. purpureus* NFCCI 1756 strain exhibited the antibacterial activity against *Bacillus megaterium*, *Bacillus mycoides* and *B. subtilis* ranging from 1.26 to 1.36 cmand no activity against *Salmonella typhimurium*, *S. typhi*, and *E. coli.* Similarly, Vendruscolo *et al.* (2014) reported that extracted biopigment from *M. purpureus* CCT 3802 was effective against *S. aureus* and *E. coli* while showed no antagonostic activity against *Salmonella enteritidis*. Ferdes *et al.* (2009) demonstrated that pigment extracted from *M. purpureus* M5 strain exhibited antibacterial activity against *Bacillus subtilis*, *P. aeruginosa*, *E. coli* species ranging from 8 to 12 mm. Antibacterial activity of *Monascus* pigments demonstrated the preservative properties of natural food colorants.

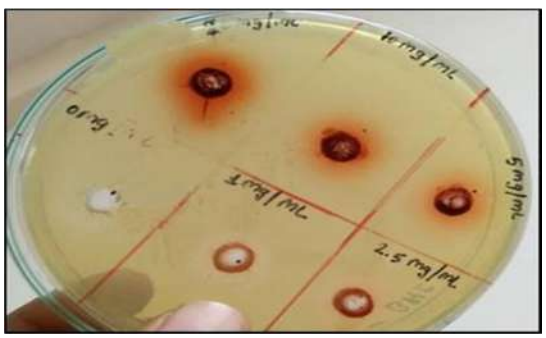
Antifungal activities: The antifungal activity of the extracted biopigment was tested against *Aspergillus flavus, Penicillium chryosogenum, Mucor azygosporus, Fusarium oxysporum,* and *Alternaria alternata* by varying the concentration from 1, 5 and 20 mg/ml (Figure 4) (Table 2). The zone of inhibition produced by biopigment at varying concentration was in the range of 2-8 mm for *A. flavus,* 3-9 mm for *F. oxysporum* and 2-6 mm for *A. alternata* (Figure 4 a, d and e). Biopigment did not show any antifungal activity against *P. chryosogenum* (Figure 4 b) and *M. azygosporus* (Figure 4 c). In addition, DMSO which was used as a solvent, thereby served as



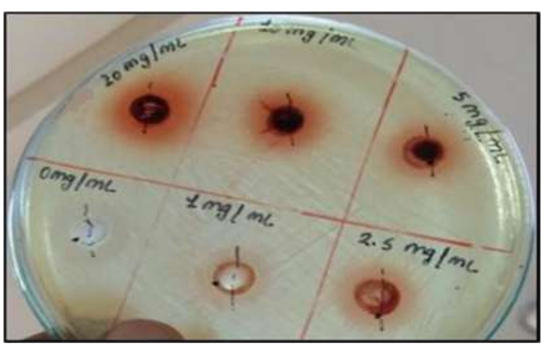
(a): ***Bacillus cereus***



(b): ***Staphylococcus aureus***



(c): ***Klebsiella pneumonia***



(d): ***Pseudomonas aeruginosa***

Figure 3: Zone of inhibition produced by different concentration of biopigment against bacterial pathogens (a) *B. cereus* MTCC 1272 (b) *S. aureus* (c) *K. pneumoniae* (d) *P. aeruginosa.*

control, exhibited no activity against the fungal pathogens. Based on the agar well assay, extracted biopigment was the most effective against *A. flavus, F. oxysporum, A. alternata*. The antifungal activity of extracted pigment from *M. purpureus* against some fungal strains might be due to monascidin A, the main compound responsible for the inhibitory activity (Ferdes *et al.,* 2009). The results were corroborated with Ferdes *et al.* (2009), who demonstrated that pigment extracted from *M. purpureus* M5 strain exhibited the antifungal activity against *Aspergillus*, *Mucor*, *Penicillium*, and *Fusarium* species. In addition, another study conducted by Cheng *et al.* (2011) showed that chemical constituents extracted from *M. purpureus* BCRC 38038 were also found to be effective against *Candida albicans* and *Saccharomyces cerevisiae* by a TLC bioautographic approach. Antifungal activity of *Monascus* pigments demonstrated the preservative properties of this natural food biopigment.

Screening for antioxidative potential of *Monascus* biopigment: The antioxidant efficacy of red biopigment were tested in this study using 2, 2 Diphenyl-1- Picrylhydrazyl (DPPH) free radical scavenging assay, 2, 2 -Azino-Bis-(3–Ethylbenzthiazoline–6-Sulfonic acid) assay (ABTS) and ferric reducing antioxidant power (FRAP) assay.

Diphenyl-1-Picrylhydrazyl (DPPH) assay: Basically, DPPH molecule is characterized as a stable free radical by virtue of the delocalization of the spare electron over the molecule that gives rise to the deep violet color. When a solution of DPPH is mixed with tested antioxidant substance, that can donate a hydrogen atom, the intensity of violet color gets reduced. Therefore, in order to evaluate the antioxidant efficacy through free radical scavenging by the test samples, the change in optical density of DPPH radicals is monitored (Alam *et al.,* 2013). The results showed that there was a significant difference between concentrations of biopigment on the antioxidant ability at 5 % (0.05 %) level of significance. The results revealed that 640 µl of 5 mg/ml of extracted biopigment and positive control BHT, ascorbic acid and quercetin had higher free radical scavenging activities as compared to other concentration (Figure 5a-b). In particular, 1 to 640 µl/ml of 5 mg/ml red biopigment significantly increased antioxidant ability ranging from 1.16 to 59.69 % (51.45 fold).

Table 1: Antibacterial activity of extracted red biopigment of *M. purpureus*

Test Bacteria	Red biopigment concentration (mg/ml)				
	1	2.5	5	10	20
	Zone of inhibition (mm)				
Bacillus cereus MTCC 1272	2	2	2	4	6
Staphylococcus aureus MTCC 96	2	2	2	3	5
Streptococcus mutans MTCC 890	-	-	-	-	-
Listeria monocytogenes MTCC 1143	-	-	-	-	-
Klebsiella pneumoniae MTCC 109	2	2	2	3	4
Proteus micrabilis MTCC 425	-	-	-	-	-
Pseudomonas aeruginosa MTCC 741	2	3	3	5	6
Salmonella typhi MTCC 733	-	-	-	-	-
Shigella flexneri MTCC 1457	-	-	-	-	-
Escherichia coli MTCC 723	-	-	-	-	-

- Nil

Table 2: Antifungal activity of extracted red biopigment of *M. purpureus*

Test Fungi	Red biopigment concentration (mg/ml)		
	1	5	20
	Zone of inhibition (mm)		
Aspergillus flavus NCIM535	2	4	8
Penicillium chryosogenum ATCC66564	-	-	-
Mucor azygosporus ATCC15087	-	-	-
Fusarium oxysporum NCIM1008	3	4	9
Alternaria alternata ATCC6663	2	4	6

- Nil

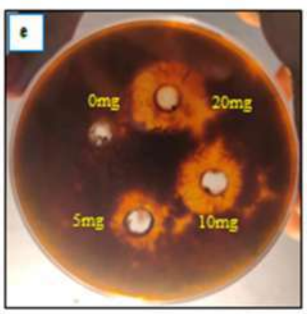
(Figure 5a). Similarly, 1 to 640 µl/ml of 5 mg/ml BHT, ascorbic acid and quercetin showed significantly increased antioxidant ability ranging from 3.77 to 45.33 % (12.02 fold), 2.40 to 38.52 % (16.05 fold) and 3.40 to 40.52 % (11.91 fold) (Fig 5 b). The antioxidant activity of red biopigment might be due to the reduction of hydroperoxide, inactivation of free radicals or complex formating with metal ions or combination there of (Lee *et al.* 2008). Moreover, this good antioxidant activity of red biopigment might be attributed to the presence of phytochemical nutrients (Wang and Wixon, 1999). The results imply that these active extracts may contain constituents with strong proton-donating abilities (Olivero *et al.,* 2010).

The results corroborated to Tan *et al.* (2018), who reported that 1 mg/ml red yeast *Monascus* pigment extracted from *Monascus ruber* CGMCC 10910 has the highest antioxidant activity of 32.84 %. In addition, red yeast rice extracted from *M. purpureus* CICC 40942 were found to show 9.739 ± 0.652 mg AEE/g of sample scavenging activity (Huang *et al.,* 2017). According to a comparable investigation, several *M. purpureus* extracts have DPPH radical scavenging activity ranging from 69.18 to 77.33 % at 100 mg/ml concentration of sample (Lin *et al.,* 2019). The good antioxidant activity of red biopigment might be attributed to the presence of many peptides and some metabolites produced by *Monascus* species during the fermentation and pigment derived from polyketides (Cheng *et al.,* 2016).

2,2'-Azino-Bis-(3–Ethylbenzthiazoline–6-Sulfonic acid) assay (ABTS): 2, 2′-azinobis (ethyl benzothiazoline 6-sulfonate) is oxidized by oxidants to its radical cation, ABTS•−, which is intensely colored, and antioxidant capacity is measured as the ability of test compounds to


(a) ***Aspergillus flavus*** ***(b) Penicillium chryosogenum***


(c)***Mucor azygosporus*** **(d)** ***Fusarium oxysporum***



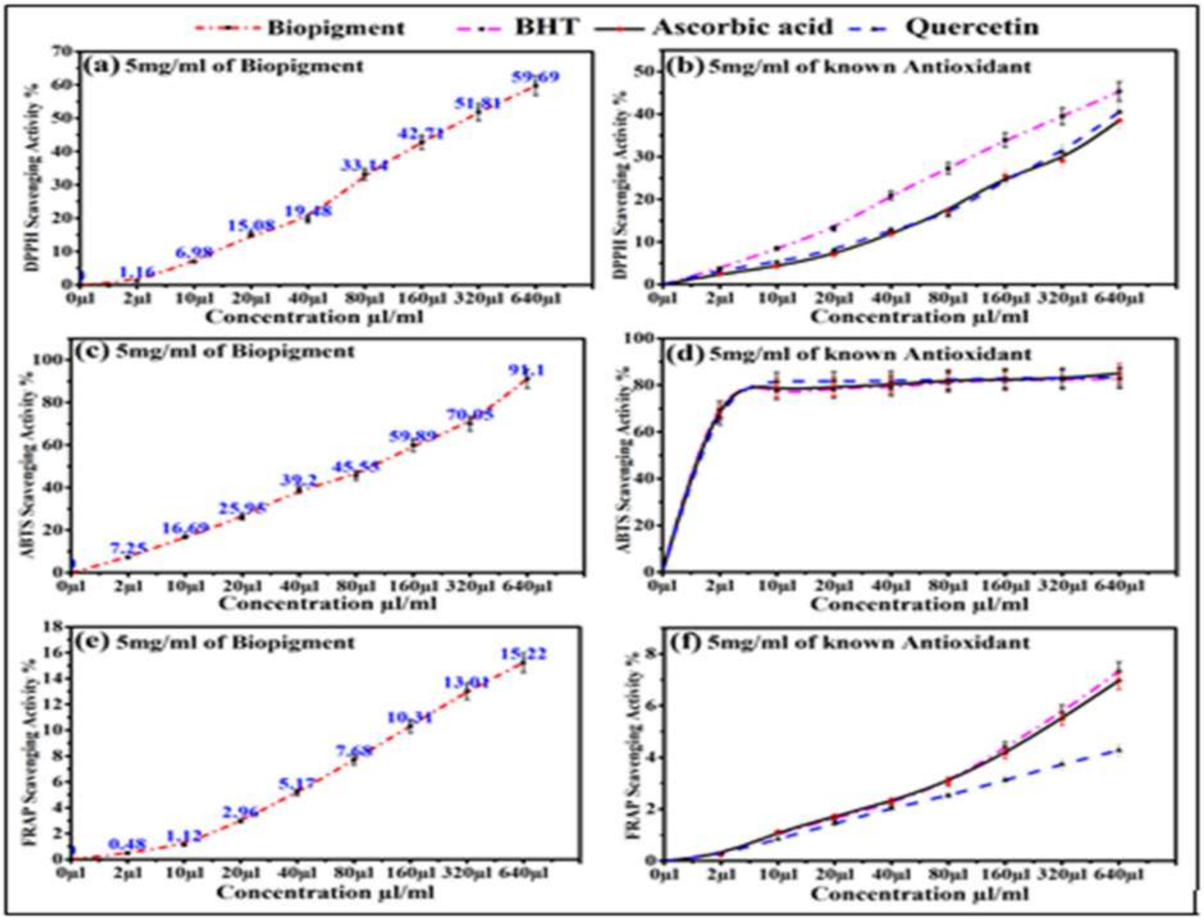
(e) Alternaria alternata

Figure 4: The inhibition zone (mm) produced by different concentration of *Monascus* biopigment against (a) *A. flavus,* (b) *P. chryosogenum,* (c) *M. azygosporus,* (d) *F. oxysporum,* and (e) *A. alternate.*

decolorize the ABTS radical directly. The results showed that 640 µl of 5mg/ml of extracted biopigment and positive control BHT, ascorbic acid and quercetin had higher free radical scavenging activities as compared to other concentration (Figure 5 c-d). There was a significant difference between concentration of biopigment and the antioxidant ability at 5 % (0.05 %) level of significance. In particular, 1 to 640 µl/ml of 5 mg/ml red biopigment significantly increased antioxidant ability ranging from 7.25 to 91.1 % (12.56 fold) (Figure 5 c). While, 1 to 640 µl/ml of 5 mg/ml BHT, ascorbic acid and quercetin showed significantly increased antioxidant ability ranging from 69.66 to 82.77 % (1.18 fold), 68.29 to 84.99 % (1.24 fold) and 66.22 to 83.19 % (1.25 fold) (Figure 5 d). The antioxidant action of red biopigment could be attributed to hydroperoxide reduction, free radical inactivation, metal ion complexing, or a combination of these factors Lee *et al.* (2008). Furthermore, the presence of phytochemical elements may be responsible for red biopigment's high antioxidant activity Wang and Wixon, (1999).

The results corroborated to earlier studies by Tan *et al.* (2018) showing that 1 mg/ml red yeast *Monascus* pigment extracted from *Monascus ruber* CGMCC 10910 has the highest antioxidant activity of 84.92 %. The antioxidant activity of *Monascus* fermented rice bran produced by *Monascus pilosus* KCCM60084 increased from 25 to 75 % at concentration of 0.25, 0.5, and 1 mg/ml of test samples (Cheng *et al.,* 2016). According to a comparable study, red yeast rice extracted from *M. purpureus* CICC 40942 were also found to show 9.739 ± 0.652 mg AEE/g of sample scavenging activity (Huang *et al.,* 2017). Due to several metabolites formed during the fermentation, the results suggest that the *Monascus* red pigment may contain components with considerable antioxidant potential (Olivero *et al.,* 2010; Cheng *et al.,* 2016).

Ferric Reducing Antioxidant Power (FRAP) assay: FRAP assay is widely-used to directly test the total antioxidant potential of several foods and plant extracts based on the reduction of complexes of 2,4,6-32 tripyridyl-s-triazine (TPTZ) with ferric chloride hexahydrate ($FeCl_3.6H_2O$), which are almost colorless. The solution eventually turns slightly brownish forming blue ferrous complexes after complete reduction. The results showed that 640 µl of 5 mg/ml of extracted biopigment and positive control BHT, ascorbic acid and quercetin had higher free radical scavenging activities as compared to other concentration. There was a significant difference between concentrations of biopigment on the antioxidant ability at a 5 % (0.05 %) level of significance. In particular, 1 to 640 µl/ml of 5 mg/ml red biopigment significantly increased antioxidant ability ranging from 0.48 to 15.22 % (31.74 fold) (Figure 5 e). Whereas, 1 to 640 µl/ml of 5 mg/ml BHT, ascorbic acid and quercetin showed significantly increased antioxidant ability ranging from 0.26 to 7.32 % (28.15 fold), 0.22 to 6.96 % (31.63 fold) and 0.24 to 4.27 % (17.79 fold) (Figure 5 f). The increased antioxidant activity could be



Error bars are the mean ± standard deviation from independent variations

Figure 5: Free radical DPPH, ABTS and FRAP scavenging activity of red biopigment with respect to positive controls.

attributable to the increased polyphenol and flavonoid contents. Furthermore, fermentation can generate a large number of small peptides and other secondary metabolites with high antioxidant potential (Wang and Wixon, 1999; Cheng *et al.,* 2016).

The results corroborated to Chang *et al.* (2016) who reported that 1 mg/ml extract from *Monascus* fermented rice bran by *Monascus ruber* CGMCC 10910 demonstrated 15 to 38 % reducing activity at concentration of 0.25, 0.5, and 1 mg/ ml of test samples. In addition, according to a comparable study, extract of red yeast rice produced from *M. purpureus* CICC 40942 were found to show 0.023 ± 0.002a mmol Fe^{2+}/g of sample reducing activity (Huang *et al.,* 2017). The results imply that extracted biopigment may contain constituents with strong proton-donating abilities (Olivero *et al.,* 2010).

Conclusion

The efficacy of *Monascus* biopigment as an agent that selectively inhibits bacterial and fungal pathogens. The antibacterial activity through Scanning Electron Microscopy and agar well assay against *B. cereus*, *E. coli*, and *S. aureus, K. pneumonia* and *P. aeruginosa* was observed show morphological damage in some cells and zone of inhibition produced. Whereas, biopigment exhibited no antibacterial activity against *S. mutans, L. monocytogenes, P. mirabilis*, *S. Typhi* and *S. flexneri*. Next, the antifungal activity of the extracted biopigment was observed zone of inhibition produced for *A. flavus, F. oxysporum* and

A. alternata. Biopigment did not show any antifungal activity against *P. chryosogenum* and *M. azygosporus*. *Monascus* biopigment demonstrated the potential antimicrobial effect through inhibition of bacterial cells and fungal pathogens. In addition, antioxidative assay DPPH, ABTS and FRAP based results showed that there was a significant difference between various concentrations of biopigment on the antioxidant ability. Considering these observations, it appears that red biopigment may be a useful supplement for antimicrobial and therapeutic related diseases.

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

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Effect of phosphorus and biofertilizers on growth and yield of Mothbean (*Vigna aconitifolia* (Jacq.) Marechal) in Prayagraj conditions

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ABSTRACT

The present study was carried out during *Kharif*, 2020 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj to determine the effect of phosphorus and biofertilizers on growth and yield of Mothbean (*Vigna aconitifolia* (Jacq.) Marechal). The experiment was set up in Randomized Block Design, consisting of 10 treatments replicated three times. The RMO 40 variety of Mothbean was sown in June, 2020.The results of the field experiment propound that application of 30 kg P/ha and seed inoculation by Rhizobia and Phosphate Solubilizing Bacteria significantly increased the growth parameters of mothbean *viz*., plant height (21.09 cm), branches per plant (6.53), nodules per plant (16.93), dry weight (5.481 g), crop growth rate (5.37 g/m^2/day). This treatment also showed its positive effect on number of pods (20.40), number of seeds (3.87), test weight (22.06 g) and seed yield (452.88 kg/ha) of the crop.

Introduction

Arid legumes form a very important source of staple food and nutrients, rich in protein for human beings. Arid legumes such as mothbean, lentil, horse gram, etc. are grown mostly in infertile and eroded soils, dry land areas with lack of irrigation facility and low in rainfall. They have spreading habit with good vegetative growth, provide effective cover to ground surface, prevent soil erosion and improves the fertility of the soil. Growing arid legumes with proper cultural practice and addition of fertilizers allows for the remedy o soil deficiencies as well as creation of proper soil physical conditions required for crop growth and productivity. Mothbean, also known as moth, mat bean, matki and dew bean is an essential component of dry land farming system in arid and semi-arid areas of India. It is one of the significant wellspring of protein, and one of the most drought tolerant crop among kharif pulses. Dry seeds offer a variety of delicious confectionary snacks (papad, mangodi, bhujia), as well as mature and immature green pods as vegetable consumption. Uttar Pradesh produces 100 tonnes from an area of 300 ha with an average productivity of 333 kg ha^{-1} (Anonymous, 2010). Moth bean is generally grown on the less managed and neglected lands, which are extremely poor in physical properties and deficient in plant nutrients. Phosphorus is required for the conversion of essential biochemical reaction in plants and as a component of several key plant structural compounds. Amongst the several factors restricting the plant growth, phosphorus shortage is a recognized key obstacle in attaining the maximum yield potential of mothbean (Patel *et al.,* 2008). It is responsible for root growth and development as well as influencing nodulation in positive way. It also has a significant impact on energy storage and transport. Phosphorus is an integral part of nucleic acids (DNA and RNA) and most of enzymes involved in energy conversion in carbohydrate

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metabolism and plant respiration. As nitrogen is fixed through symbiosis with Rhizobium bacteria, phosphorus fertilization for legumes is foremost than nitrogen. Rhizobium and Phosphate Solubilising Bacteria play a critical role in N_2-fixation and P-solubilisation in soil. Rhizobium inoculation improves root nodulation by promoting root growth and increasing nutrient availability, leading in better nutrient uptake and use (Singh *et al.,* 2007). The PSB (Phosphate Solubilising Bacteria), dissolves interlocked phosphates in soil appears to have a significant impact on Indian agriculture. Dual inoculation of Rhizobia and PSB may benefit the plant in acquiring both nitrogen and phosphorus. Seed inoculation with Rhizobia and PSB has gathered a lot of attention to increase the availability of phosphate fixed in rhizosphere and to reduce fertilizer use (Chakrabarti *et al.,* 2007).

Hence, Phosphorus application in addition with biofertilizers inoculation (Rhizobia and PSB) in pulse crop provide easy access of nitrogen and phosphorus to the cropped plant. Phosphorus application along with biofertilizers creates a favourable environment for microorganism's proliferation in the rhizosphere that leads to easy nutrient assimilation by plants during their growth and developmental period.

Material and Methods

A field trial was conducted during the *Kharif* 2020, at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The experimental field's soil is neutral and deep, constituting a part of central Gangetic alluvium. It had sandy loam texture and contained medium nitrogen (N) and low phosphorus (P). The experiment was set up using Randomized Block Design with ten treatments that were replicated three times *viz*.,T_1 – control (farmer's practice 20-40-0 kg NPK/ha), T_2 - Rhizobia+20 kg P/ha, T_3 - Rhizobia+30 kg P/ha, T_4 - Rhizobia+40 kg P/ha,T_5 - PSB+20 kg P/ha, T_6 - PSB+30 kg P/ha, T_7 -PSB+40 kg P/ha, T_8 – (Rhizobia+PSB)+20 kg P/ha, T_9 – (Rhizobia +PSB)+30 kg P/ha, T_{10} – (Rhizobia+PSB)+ 40 kg P/ha. The experimental field was thoroughly ploughed, harrowed and brought to fine tilth and 30 plots each of 3.0 m x 3.0 m size were laid out according to layout design. The inorganic fertilizers were applied as per treatment combination in the form of urea and SSP entire as basal dose. The seeds of moth bean (RMO-40) were sown in lines 30 cm apart at seed rate of 15 kg/ha. The seeds were treated with liquid rhizobia (10 ml/kg seeds) and liquid PSB (10 ml/kg seeds) as per the treatment combination and shade dried one hour before sowing. The growth parameters such as plant height (cm), number of branches (No.), number of nodules (No.), and dry weight per plant (g) were recorded at various growth stages while crop growth rate ($g/m^2/day$) was calculated by the methods described by Watson, 1947. The pods/plant, seeds/pod, test weight and seed yield were recorded at the time of harvest and averages were calculated and data was statistically analysed using ANOVA technique (Gomez and Gomez, 1984).

Figure 1: Measuring Plant height

Figure 2: Flowering and pod formation

Figure 3: Intercultural operation in field

Results and Discussion

Observation of Growth determining attributes *viz*., plant height, number of branches, number of nodules, and dry weight per plant presented in Table 1. Significantly highest plant height (21.09 cm) and number of branches (6.53) were recorded with seed inoculation by Rhizobia and PSB along with application of 30 kg P/ha over control. This could be owing to the combined effect of dual biofertilizers and phosphorus which increased nutrient availability during the crop growth. Haque and Khan (2012) and Rasool and Singh (2016) both reported similar results. At 45 DAS, maximum number of nodules per plant (16.93) has been recorded with combined inoculation of seed with Rhizobia and PSB and application of 30 kg P/ha over control. However, nodules per plant in Rhizobia+ PSB+40 kg P/ha (16.13) and in seed inoculation with PSB and basal dose of 30 kg P/ha (15.80) found on par with highest. This is due to synergistic effect of the Rhizobia and Phosphate Solubilising Bacteria for biological nitrogen fixation as opposed to their individual application. Similar results were also validated by Rudresh *et al*. (2005) and Tagore *et al*. (2013). This result might be due to the fact that when in Rhizobia and phosphate solubilizing bacteria are inoculated together, both microorganisms assist the plant in acquiring nitrogen and phosphorus. By supplying assimilates to roots in the rhizosphere, phosphorus not only aids in proliferation and growth but also promotes nodulation and nitrogen fixation, reported by Puniya, 2010. The seed inoculation with Rhizobia and PSB along with basal dose of phosphorus @ 30 kg/ha recorded significantly higher dry weight per plant (5.481 g) over control, whereas seed inoculation by Rhizobia and PSB along with basal application of 40 kg P/ha (5.274 g), found statistically on par with highest. The higher dry weight per plant in T_9 might be due to increased availability of phosphorus results in increased plant vigour, number of new cells, and root growth, which speeds up the leaf development, aids in utilizing the radiant energy and nitrogen assimilation by plant. Similar findings were reported by Puniya (2010) and Iqbal (2018). During 45-60 DAS significant and higher crop growth rate (5.37 g/m^2/day) was recorded with seed inoculation by Rhizobia and PSB and application of phosphorus @ 30 kg/ha, might be because of direct and higher translocation of nutrients during crop development stage, which enhances the physiological and metabolic activities of plant, allowing it to put up more growth by faster assimilation of the available nutrients and facilitate more photosynthesis and ultimately increase Crop Growth Rate (Kumawat *et al.,* 2017).

Table 1. Effect of phosphorus and biofertilizers on growth parameters of mothbean

Treatments	At Harvest			At 45 DAS	During 45-60 DAS
	Plant Height (cm)	Branches per plant(No.)	Dry weight (g plant^{-1})	Nodules per plant (No.)	CGR (g/m^2/day)
T_1: Control	18.25	5.27	4.224	12.27	4.26
T_2: Rhizobia + 20 kg P/ha	13.00	4.40	3.528	12.13	3.67
T_3: Rhizobia + 30 kg P/ha	16.36	4.60	3.884	14.27	3.85
T_4: Rhizobia + 40 kg P/ha	17.45	5.33	4.265	13.47	4.50
T_5: PSB + 20 kg P/ha	17.41	4.67	3.607	12.67	3.68
T_6: PSB + 30 kg P/ha	19.83	6.00	5.022	15.80	5.07
T_7: PSB + 40 kg P/ha	19.29	5.27	4.598	15.27	4.91
T_8: (Rhizobia + PSB) + 20 kg P/ha	18.87	5.93	4.426	13.13	4.61
T_9: (Rhizobia + PSB) + 30 kg P/ha	21.09	6.53	5.481	16.93	5.37
T_{10}: (Rhizobia. + PSB) + 40 kg P/ha	20.98	6.20	5.274	16.13	5.12
S.Em (±)	0.63	0.15	0.143	0.50	0.52
CD (5%)	1.89	0.45	0.424	1.49	1.09

Table 2: Effect of phosphorus and biofertilizers on yield attributes and yield of mothbean

Treatments	Pods/plant (No.)	Seeds/pod (No.)	Test weight (g)	Seed yield (kg/ha)
T_1: Control	17.93	3.63	18.81	232.91
T_2: Rhizobia sps. + 20 kg P/ha	13.80	3.05	17.31	129.49
T_3: Rhizobia + 30 kg P/ha	14.67	3.46	17.97	176.32
T_4: Rhizobia + 40 kg P/ha	18.07	3.69	19.04	241.40
T_5: PSB + 20 kg P/ha	16.47	3.22	17.21	145.83
T_6: PSB + 30 kg P/ha	18.73	3.79	21.07	345.73
T_7: PSB + 40 kg P/ha	18.20	3.77	20.47	288.18
T_8: (Rhizobia + PSB) + 20 kg P/ha	18.47	3.69	19.79	269.65
T_9: (Rhizobia + PSB) + 30 kg P/ha	20.40	3.87	22.06	452.88
T_{10}: (Rhizobia + PSB) + 40 kg P/ha	19.60	3.83	21.66	430.51
S.Em (±)	0.72	0.05	0.29	12.39
CD (5%)	2.15	0.16	0.86	36.82

The observation related to yield attributing parameters were shown in Table 2. The pods/plant (20.40), seeds/pod (3.87) and test weight of seeds (22.06 g) were notably higher in T_9. The observed results of yield attributing parameters were attributed to phosphorus' regulatory activities in photosynthesis and glucose metabolism in leaves, which limit plant growth, especially during the reproductive phase. The observation of seed yield at the time of crop harvest is shown in Table 2. It shows significantly highest seed yield (452.88 kg ha^{-1}) in dual seed inoculation by biofertilizers with 30 kg P/ha, whereas seed yield in T_{10} (Rhizobia+PSB+40 kg P/ha) (430.51 kg/ha), was found to be statistically on par with highest. The maximum seed yield in dual inoculation of biofertilizers and 30 kg P/ha application is due to the collateral increament in pods/plant, seeds/pod and test weight under this treatment. This could be due to surplus assimilates being stored in the leaves and then translocated into seeds during senescence, resulting in increased seed yields. These findings are in agreement with Kumawat (2006).

Conclusion

In eastern plain zones of Uttar Pradesh, under inceptisol soil order, cultivation of mothbean with the application of phosphorus at the rate of 30 kg per hectare along with seed co-inoculation by Rhizobia and Phosphate Solubilising Bacteria was found to be more desirable in terms of increasing growth parameters, yield attributing parameters, seed yield of Mothbean crop during *Kharif* season.

Conflict of interest

The authors declare that they have no conflict of interest.

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Subhash palekar natural farming - scope, efficacy and critics

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ABSTRACT

By 2050, India is expected to surpass China as the world's most populated country, with a population of almost 1.7 billion people. To feed this exponentially increasing population, the country must pursue a policy of vertical productivity growth, as the possibilities for additional horizontal expansion of cultivated land are rapidly diminishing. Furthermore, continual cropping depletes soil nutrient resources, necessitating the replenishment of soils with critical major and minor plant nutrients. The country cannot compromise with nutritional supply in order to end "Silent Hunger" and the immoral perpetuation of high concentrations of increasing number of malnourished children and anaemic moms. While the country is intending to restructure its agricultural production system, including R&D, to meet the needs of rising problems, the 2018-19 economic survey established a strong case for the widespread adoption of 'Zero Budget Natural Farming' (ZBNF) to double farmers' revenue. As a result, crop productivity will remain low, and farmers will not be able to earn enough to double their income and get out of debt with this level of output. Also at the country level, we will not be able to meet the expanding populations food and nutritional demands and hence will fail to meet the sustainable goals of "Zero Hunger and Poverty Elimination" by 2030. Thus, with zero budget natural farming practices we can feed to the India and world, our emphasis is too elaborate all aspects.

Introduction

India is the second largest country in terms of demography and feeding the population of 130 crores is a humongous task. Sustainable development and food security are the wheels on which Indian agriculture runs. However, the term food security replaced with nutritional security is more appropriate. Green revolution has certainly made us self-dependent in terms of food security but its aftermath was devastating. The input intensive agriculture lured farmers of taking non-institutional loans but the low productivity, monsoon dependence, low minimum support price, market upsets trapped farmers in infinite loop of debts. According to the National Bank for Agriculture and Rural Development's (NABARD), 2018 financial inclusion survey, 52.5 percent of all agricultural households in India were in debt. NABARD gave the country a gift on August 16 when it released the results of its All-India Rural Financial Inclusion Survey (NAFIS), which revealed that 87 percent of families were small and marginal farmers. NAFIS estimates that in the agriculture year 2015-16, according to household-level statistics, the average Indian agricultural household earned Rs. 8931 per month. Annual changes in agricultural production have been connected to weather, minimum support prices, demand-supply gaps, and natural disasters. India has certainly grown from its days of hunger to exporting food commodities of worth about 11.72 billion US dollars (DGCIS, 2019-20), but after the green revolution India has heavily depended on import of fertilizers pesticide and several other chemicals for conventional farming worth 2,098.61

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million US Dollars in year 2014-15 (Department of fertilizers, 2014-15). The injudicious use of chemicals in soil has damaged the fertility by degrading its physical, chemical and biological aspects damaging native soil flora, loss in population of honeybees and several other agriculturally beneficial insects, polluting water and atmosphere compelled the policy makers and scientists to steer their strategies towards organic farming.

The other problems include shift in cropping system, depletion in groundwater, loss of nutrients, loss of organic carbon and pesticide residual effects. The subsidies on fertilizer also cost a staggering amount of 79,996 crores during year 2019-20 according to the budget estimate (FAI). India aims to double the farmers income by 2022, but there are several roadblocks ahead in achieving this goal. There are several problems which can be mitigated through organic farming system. However, organic farming has 5-12% less production than conventional farming in low water stress areas and 7-15% less production in water stress areas. Organic farming has shown promising results in terms of sustaining soil health but lags behind yield and productivity in comparison to conventional farming. In order to feed the ever-growing population, the agrarian crisis must be resolved by combining strong government policies with funding and improved agricultural practises. The concept of natural farming originated from Japan by a naturalist and philosopher named Masanobu Fukuoka (1913–2008).

Principally it minimises the human interaction while it gives nature to do its own so it is also called do nothing farming.

According to FAO, 2017 India still has a quarter of the world's hungry population and about 190 million people who are malnourished. Poverty is currently estimated to affect approximately 30% of the population. In the period from July 2012 to June 2013, farm households earned INR 77,888 or INR 6491 per month (NSSO, 2016). Even though, being a leading producer in many agricultural commodities, India lags behind many developing countries in terms of per capita income and living standard of farmers. These huge gaps between the earning of small and large farmers can be filled by Palekar's natural farming which require low input and tailored fitted for small and marginal farming. In India, Subhas Palekar introduced the idea of zero budget natural farming which include a desi cow (*Bos indicus*) as the focal point for input. Cow urine, dung, butter milk, jaggery, pulse flour and other several homemade products serve as input. The basic principles of natural farming are of intercropping, agro-forestry, microbial inoculation and increasing the activity of native soil biota. The inputs for natural farming are homemade, low cost and has no negative ecological impact.

What is Subhash Palekar Natural Farming (SPNF)

It is naturistic way of farming given by Subhas Palekar for the farming of marginal and small farmers using desi cow's products. There are basically four wheels of natural farming named- 1) *Beejamrit* (Nectar for seeds), 2) *Jeevamrit* (Nectar of microbes), 3) *Acchadana* (mulching) and 4) *Whapasa* (Soil moisture). According to Palekar for 30 acres only one desi cow is required and in absence of cow, buffalo can be used but he suggest that native cow breed have greater microbes population compared to exotic counter parts and desi cow is more adaptable to Indian conditions, less disease susceptibility and it is easily manageable by the resource poor farmers. It is extreme form of LEISA (low external input sustainable agriculture) that use the symbiotic relationship between cow output as farm input. Cow dung is also said to attract earthworms that are currently missing from our farms. It is a grass root level movement started by Padmashri Subash Palekar (2006) in mid 1990s which spread through Karnataka, Andhra Pradesh, Punjab, Himachal Pradesh and Kerala is planning to adopt it. Central government has also talked in length and breadth about it but there was no budget allocation in the year 2019-20. India has about 82% small and marginal farmers but till date there are only few viable options for small scale farmers thus, there is huge gap in earning of large and small-scale farmer. Natural farming system should be seen as a solution to small farmers. Palekar was appointed as advisor to Karnataka state government. Andhra Pradesh has a very ambitious plan regarding adoption of SPNF/ZBNF, according to Galab *et al.,* 2019 6 million farmers are ready to adopt zero budget natural farming by 2024.

The main contribution of natural farming is making small farmer financially independent. It promotes neo-Gandhian virtues such as self-sufficiency and autonomy. (Khadse and Rosset, 2019). It involves a variety of agro-ecological principles, such as diversification, nutrient recycling and promoting positive biotic interactions, among others, to improve soil fertility (Palekar 2006).

A survey was conducted on ZBNF, and it was noted that among 97 farmers and their households who adopt ZBNF, debt was reduced up to 30 %, environmental reasons by 42 % and also decrease in cost of cultivation by 38 % and apart from all these benefits **to** their family health was increased up to 54 % as compare to farmers who adopt other farming practices (Khadse *et al.,* 2018).

From the survey it was revealed that adoption was not only for food security or for sustaining development but it was overall development of a farmer. Finance Minister Nirmala Sitharaman had mentioned in her budget speech the need to "return to basics" and "replicate this unique concept (that) will aid in doubling our farmers income". Zero budget natural farming practices major advantages are- it is fully chemical free, sustaining soil and environmental health, almost zero cost of cultivation, use of traditional seed (climate resilient, low input intensive, preservation of traditional seeds), risk reduction by crop rotation, easier to adopt, preservation and entanglements of desi cow breeds. Palekar has done workshops throughout India and spreading his innovative idea.

Beejamrit/ Beejamruth

It is a fermented cow-based product used for protecting seeds from soil and seed borne disease in their early establishment. It is not a nutrient source but microbial load and growth hormones. It is a concoction made from water (20 litre), cow dung (5 kg), cow urine (5 litre), lime and a handful of soil. The seed or seedling are dipped in *Beejamrit* and then planted. Various experiments have been conducted throughout India to find the efficiency of *Beejamrit* and *Jeevamrit* in various agro-ecological regions of India. In organic solutions, Sujana *et al.* (2019) discovered that the *Jeevamrit* treatment had considerably higher growth attributes and quality parameters of chilli fruits than the *Beejamrit* + *Jeevamrit* + *Amrutpani* treatment, with the exception of fruit length. According to Jandaik *et al.* (2015) all three fungal pathogens (*Ralstonia stolonifer, Sclerotium rolfsii* and *Fusarium oxysporum*) growth was maximum with the application of cow urine @ 15 % concentration. In ancient Indian literatures it was well documented that cow and its product have always a special place. According to Shubha *et al.* (2014), microbial population was increased when seeds was treated with *Panchgavya* and *Beejamrit*.

An experiment in Nanded (Maharashtra) showed that the *Jeevamrit,* FYM and *Beejamrit* increases the micro flora population of soil and yield suggesting thereby a positive correlation between fungal population and yield of Arhar (*Cajanus cajan)* in organic field compared to inorganic field (Shaikh and Gachande, 2015). A trial in Dharwad (Karnataka) stated that Bacteria isolated from *Beejamrit* increases N_2-fixation, inocitol acetic acid, gibberalic acid production and P-solubilization in addition to suppression of *Sclerotium*. However, not every experiment was in favour of *Beejamrutha* as other liquid organic formulations like *Panchgavya*, vermiwash were far better in terms of chemical analysis and growth and yield (Chadha *et al.,* 2012). They also discovered that Beejamrit was the most successful seed treatment, with 92 percent seed germination of pea seeds compared to 56 percent in the control treatment. It acts as a potent antibacterial and antifungal solution. Chandrakala, (2008) found out that seed weight of chilli was increased over control treatments with the application of *Beejamrut* + *Jeevamrit* + *Panchagavya*.

Jeevamrit/ Jeevamruta

Jeevamrit is a fermented microbial culture which acts as a fertilizer substitute made from water (200 litre), cow dung (10 kg), cow urine (5-10 litre), pulse flour (2 kg), jaggary (2 kg) and handful of soil from the farm. To ferment and to multiply aerobic and anaerobic bacteria 48 hours are given to mixture. It is believed that jaggery acts as a nutrient source for native soil microbes. Very high amount of microbial load was found under *jeevamrit* which helps in increasing soil bio mass even if we supply it at very lesser rate which helps in increasing soil health. *Jeevamrit* comparison with various other organics, Chongre *et al.* (2019) in Mohanpur (West Bengal) inferred that for better organic package for gram, FYM @ 12 kg N equivalent at land preparation and Panchgavya @ 8 kg N equivalent (twice at 30 DAS and 45 DAS by irrigation water) may be advised. It is often said that it promotes immense biological activity. According to Palekar, to make system self-sustaining *Jeevamrit* is given only first three years. Lahariya *et al.* (2013) recorded significantly highest yield of soybean grain (16.70 q/ha) and straw (30.27 q/ha) with application of 100% recommended dose of nitrogen through vermicompost +*Jeevamrit* which was statistically at par with that of 100% RDN through vermicompost, whereas lowest yield was obtained in control and *Jeevamrit* alone. However, the minimum bulk density was found with application of 100% RDN through vermicompost + *jeevamrut*. According to Palekar (2005) all the nutrients that are required for the growth and development of crops are already presented in the soil thus no external input is required, we have to unlocked the existing nutrients and make bioavailable via *Jeevamrit*. Later it was called *Annapurna*.

With the application of *Beejamrit*, *Jeevamrit* and *Panchagavya* increase in yield of soybean by 25 to 35 % was reported by Shwetha and Babalad (2008). In general, it is not a substitute for fertilizer but it acts as a catalytic agent that promotes microbes and biological activities. In another experiment in Ludhiana (Pb), Aulakh *et al.* (2018) reported that crop productivity was not influenced with the application of *Jeevamrit* on the other hand soil microbial population was increased. *Jeevamrit* is also said to increase earthworm count that increases the aeration and water holding capacity and thus root surface area that increases the nutrient absorption. Lahariya *et al.* (2013) recorded the minimum bulk density of soil and highest hydraulic conductivity (HC), mean weight diameter (MWD) and available water capacity (AWC) with application of 100% RDN through vermicompost + *Jeevamrit*, might be due to presence of organic material.

Acchadana (mulch)

By managing soil temperature, maintaining soil moisture and lowering soil evaporation, mulching is an effective means of manipulating the crop-growing environment to boost crop productivity and quality (Chakraborty *et al.,* 2008). Three types of mulches which was suggested according to Palekar- i) Soil mulch- It protect the top soil during cultivation. He also suggested to avoid deep tillage, ii) Straw mulch- The previously grown crops residues or biomass from nearby trees or shrubs are used as a mulching and iii) Live mulch- It is necessary to grow monocot and dicot crops in the same field to get all the essential nutrients.

One of the key benefits of mulch is that it conserves soil moisture (Mulumba and Lal, 2008). Mulching enhanced soybean seed yields, according to Sekhon *et al.* (2005) in addition they said that it also raised plant biomass and nodule mass. All of the growth parameters were also improved. Despite these benefits, farmers have not taken to mulching since crop response varies depending on the season. According to Jordan *et al.* (2010), increasing mulching rates increased soil physical qualities. Under a mulching rate of 6 Mg ha-1year-1, there was a reduction in runoff generation and soil losses to bare soil.

Plastic mulching is considered as a better option for disease control as it leaves no chemical residue. Jalota *et al.* (2007) review shows that improvement was found in yield of crops with the use of straw mulching in Punjab. This practice also saved irrigation water and fertilizer nitrogen. The benefits of mulching are more in summer/ *kharif* season and on soils having low water retentivity. Chakraborty *et al.* (2010) burning of wheat and rice straw in the Indo-Gangetic plains is also causing one of the major causes of air pollution in northern Indian states. Central and state governments are also giving incentives to the farmers for not burning stubble and straw but it doesn’t seem to be working at all. Mulching found to be effective in improving 25 % efficiency of crop water use and reduction of 3–11% water. Mulumba and Lal (2008) found that increasing mulch rates increased available water capacity up to 35%, total porosity up to 46% and soil moisture retention at low suctions up to 70%.

Legume intercropping advantages

Intercropping refers to planting two or more crops on the same field at the same time (Sangakkara *et al.,* 2003; Belel *et al.,* 2014). Baby corn equivalent yield and land use efficiency were higher in intercropping systems (47.2 percent), land use efficiency (15.3 percent) and monetary advantages, notably in 2:2 row ratios baby corn +

pea and baby corn + chickpea appeared to be the best intercropping systems in terms of yield benefits and economic returns. There are plenty of documents that praise the idea of intercropping both theoretically and practically that includes better yield, better use of environment resources, reduction of insect- pest and weed damage and improved soil fertility. Among different intercropping systems studied, According to Swain *et al.* (2012), the mango + guava + cowpea system increased soil physical and chemical properties. It may be suggested that inter-cropping breaks the chain of infection/events and it is also known that mono-cropping generally make the soil sick. It is generally said that inter-cropping increases dry mass production, reduced nitrogen application, crop diversity, better land utilization than sole cropping system according to Gitari *et al.* (2018). It is also generally seen that in intercropping there should be companion effect between major crop and inter-crop otherwise it may have negative effect on yield and other growth factors. It may not come as a surprise that largest importers of pulses in world is India and in the year 2018 it has imported pulses to a staggering amount of 1040 million US dollars (APEDA, 2018).

Plant Protection

According to Subhas Palekar, disease control and prevention in natural farming can be done by locally sourced concoctions like *Neemasatra*, *Agniastra* and various others.

Rana *et al.* (2006) reported that fermented buttermilk and cow urine mixture (1:1) was found to inhibit the pathogen at 10 % concentration. For seed treatment, seeds were also treated with organic inputs and *Beejamrit* was more successful as it resulted in 94.66 % seed germination and also reduced *Pyricularia* infection to 4% compared with control where infection was 24%. Pathania *et al.* (2006) reported that maximum mycelial inhibition of 72.9 % followed by *Panchgavya* with 62.9 % was recorded with cow urine @10 %. When *dashaparni* extract, *Azadirachta indica* leaf extract and *Azadirachta gcapsicum alliums* extract were used instead of a combination of the above bio-organic formulations, the total plant biomass was found to be higher. Sharma *et al.* (2015) found that 10 % aqueous leaf extract of *Polygonum hydropiper* followed by *Panchgavya* @ 10% in capsicum and a module containing soil treatment with *Panchgavya* @ 10% followed by sprays of neem oil at 10-day intervals, respectively, were effective against mustard aphid. *Panchgavya* and *Lantana camara* were proven to be highly effective aphidicides against cowpea and okra aphids. Lower cost of cultivation, no toxic effects, no toxic effect on environment and have no residual effect these all-good impacts are linked to organic insecticides.

Other organic pesticides and insecticides are also available in market as *Chrysanthemum* based pyrethroids and *neem*-based insecticides as *Achook* and various others.

Vocal critique of ZBNF

The government should not spend financial and human resources promoting ZBNF, which is behind in terms of production and productivity, and will result in a significant setback to the goal of food security according to Panjab Singh, president of the National Academy of Agricultural Sciences (NAAS). Indian soil is deficient in many nutrients and *Jeevamrit* is not able to supply all the nutrients in the required amount and time. Natural farming uses traditional varieties that yield lower than high yielding varieties (HYV). Many scientists calling it a half-baked concept which overthrows the whole idea of two centuries study of soil chemistry and fertility. It is basically considered as more of naturistic and philosophical way of farming rather logical and scientific way of doing it. It is fairly new concept rather an untested one that needs a scientific validation from the farmers, scientists, policymakers and NGOs across the country. The Subhas Palekar natural farming (SPNF) methods are not new discovery and products obtained from desi cows were used in pre-green revolution era and that resulted in famine, low crop productivity, hunger and several other predicaments that has been proven albatross for food security at national level and this farming system should not entrusted with farmers money, time and resources. As its adoption rate is increasing it can be seen as threat to capitalist industries of fertilizers, pesticides and several other agricultural chemicals. There is the trend that positively correlates the increases in use of NPK fertilizers has increased the yield.

ICAR/NITI Aayog view of ZBNF

In the *Business Standard* Vice- Chairman NITI Aayog wrote a two-part article on ZBNF. He described it as a "unique and proven solution for environmental degradation and farmer distress". He wanted it quickly scaled up without awaiting certification from some "respected foreign institutions". With ZBNF, he said, "Indian agriculture can emerge as an example for the rest of the world". Speaking to The Print, Trilochan Mohapatra, Secretary, Agricultural Research and Education, said: "Trials are going on in Modipuram (Uttar Pradesh), Ludhiana (Punjab), Pantnagar (Uttarakhand) and Kurukshetra (Haryana). It will take at least two to three years to get results. We will only launch the scheme then." Mohapatra added that a team has been constituted under Telangana University vice-chancellor Dr Praveen Rao and Prof. Jaishankar of the same university to oversee the trials. The plan is to expand the tests to 20 other locations. Natural farming overthrows the whole idea of father of fertilizer industry 'Justus Von Liebig' law of restitution and calls him Mr Lie Big. In my conclusion I want to say that it is a very unique and tailored fit farming system for small and marginal farmers to uplift them from poverty. In terms of soil health, it is an excellent idea as it doesn't rely on chemicals for growth and development but uses native micro-flora for nutrients and also makes soil sustainable and healthy.

Conclusion

Beejamrit was seen to result better germination percentage than any treatment and cow urine is known to have antibiotic effects. *Jeevamrit* was unable to provide all the adequate nutrients in the required time but in combination with other organics like vermicompost, FYM and *Panchgavya*, it has shown better results than other treatments. The increase in native earthworm species increased water-holding capacity and aeration that make the crops less dependent on irrigation. The low cost of preparation of *Beejamrutha* and *Jeevamrit* certainly has edge over chemical fertilizers and other seed treatments. Nature farming is one of the highways through which India can achieve all sustainable development goals and inspire a million more to adopt it. Adoption of ZBNF will remove the extra burden of fertilizers and other chemicals imports, taxes and fertilizers subsidies which will certainly save thousands of crores of government money. Maintenance of soil fertility through crop rotation was an old idea but effective one and use of agro-forestry to conserve soil and water erosion is also effective and it will also give extra income. The use of neem products and black pepper also found effective because of less incidence of pest and disease due to zero application of chemical nitrogen and more resilient traditional seeds varieties. But it was worth notable that there was no measure to counteract weeds and their ill effects as we all know that weeds cause about 33% loss in crop productivity and this coupled with low efficiency of *Jeevamrit* will jolt the crop productivity and hence, in the era of food security we cannot afford to suffer from low productivity. Economic survey has dedicated a section to natural farming dictating its ecological benefits to soil fertility and water stress. Subhas Palekar natural farming (SPNF) has a great potential among low income farmers but wide research across every ecological situation with willingness by policymaker will inspire the world to adopt chemical free farming. Conventional farming has ensured that India produce enough grain to export but the modern farming system has become unsustainable as the yield is decreasing along with ecological contamination and financial troubles for farmers make it dysfunctional. In the 21st century we have to find an alternative that doesn't compromise our battle with poverty and hunger along with sustaining nature.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Response of different methods of sowing and organic manures on growth and yield of Wheat (*Triticum aestivum* L.)

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ABSTRACT

To study the retaliation performances of various methodologies of sowing by accompanying organic manures on growth, yield, and all other yield attributes of wheat (*Triticum aestivum* L.) crop. A field experiment was executed during the *Rabi* season of 2020-21 at the crop research farm of SHUATS, Prayagraj.The experiment was laid out in the most commonly encountered Randomized Block Design (RBD) with three replications of each treatment for all traits. Given this experiment three methods of sowing, *i.e.* M1 (Broadcasting), M2 (Line sowing), M3 (System of Wheat Intensification) as well as three organic manures *i.e.* O1 (Farmyard manure 12 t/ha), O2 (Poultry manure 5 t/ha), O3 (Vermicompost 4 t/ha) and two liquid manures Panchagavya 3% and Jeevamrutha 500 l/ha. And the liquid manures were foliar sprayed at 15, 30, and 45 days after sowing (DAS). Results were revealed that the maximum number of tillers (10.53), Dry weight (18.00 g/plant), Effective tillers (10.43), Spike length (11.73 cm), and Grains per spike (58.38) were found to be significantly higher with the application of treatment SWI + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500/h FS as compared to the other treatments. Maximum values were ensured with Plant height (78.30 cm), test weight (36.73 g), Grain yield (3.16 t/ha), Straw yield (4.48 t/ha), and harvest index (41.39 %). Hence with the current experiment's outputs, this study concluded that Line sowing + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS were produced more grains and productivity as compared to other organic treatment combinations.

Introduction

Wheat (*Triticum aestivum* L.) is one of the entire world's greatest crops that excels all other cereals both in area and production, called as "king of cereals". It's a highly nutritious cereal foodstuff and its organic compound yield per acre far exceeds that of animal products. Wheat grain rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate, and 27.20% minerals (BARI, 2016). Wheat occupied a dominant position in the Indian food security system and it was consumed as one of the major staple food around a minimum of 43 countries. Global wheat is cultivated in an area of about 220 million hectares with a record production of 763.06 million tonnes of grain. In India wheat is the second most important cereal crop next to the rice and key crop of the revolution era. India stands second among wheat-producing countries in area and production. In India, the wheat cultivated area

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rose to 30.54 million hectares from 29.04 million hectares with a net gain of 5% in area APEDA (2019). The Broadcasting method produced the foremost effective spacing. While different methods of sowing methods are adopted by farmers for wheat cultivation. In which as compared to traditional drill planting, broadcast seedling would force 10-20 yet one more seed, it's simple, faster, and easier than traditional row spacing methodology. Line sowing is being practiced with proper row spacing and is an advisable sowing method because of its uniform plant population per unit area. As seeds are planted at an even depth and covered with soil, high germination and uniform stands are expected. Wheat intensification may be a new concept and goes with the systematic rice intensification (SRI) principle. Just in the case of SWI, all agronomic principles of SWI are put into practice and integrated with a package of practices of wheat crop. The technology has a high potentiality to provide a high wheat yield per drop of water as well per kg of agriculture inputs (Dhar *et al*., 2016). Adaptation of this technology can increase the productivity of wheat over two times (Uphoof *et al*., 2011). The role of foliar application or seed soaking of panchagavya in the production of many plantation crops had been well documented in India. These organic formulations contain all the trace elements and some essential plant growth hormones. Natural plant growth regulators (e.g. Auxin, Gibberellin, and cytokinin) present in these liquid organic formulations give a major boost to crop yields by accelerating the plant metabolic function. Presence of macro (N, P, K, and Ca) and micro (Zn, Fe, Cu, and Mn) nutrients besides total reducing sugar (glucose) in liquid manure (Papen *et al*., 2002; Swaminathan *et al*., 2007). Organic manures in agriculture add up a much-needed organic and mineral touch on the soil. The organic matter added is an imperative component of soil, and plays a vital role in the maintenance and improvement of soil fertility and productivity. The rise in eco-friendly production of wheat is often made possible by wider spread adaption of improved technologies of which fertilizer management, particularly that the nitrogen and organic manure can play a key role. It must be stressed that the worth of FYM, Vermicompost, Poultry manure, and manures in soil improvement is because of their nutrient content. To overcome the problem of nutrient deficiency and help nature rather than destroy it. Organic sources of nutrients are the best option to maintain the health of soil, plant, and animal and provide equal opportunity for all living existence to live and use from their beneficial activities, like nitrogen fixation, phosphorus solubilization, recycling of animal's waste, etc. Hence, the present study was undertaken. This, those two-factor sowing methods and organic manure interrelate providing important insight to the study combination effect on wheat production. Keeping these in view, an experiment was planned to study the Response of methods of sowing and organic manures on the growth and yield of wheat.

Hence, the present investigation was carried out to study the agronomic evaluation of wheat (*Triticum aestivum* L.) under a certified organic production system.

Material and Methods

A field experiment was conducted during the *Rabi* season of 2020-21 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) which is located at 25 degrees 24'41.27" N latitude, 81 degrees 50'56" E longitude, and 98 m altitude above the sea level. During this season soil (sandy loam), tested at a certified organic farm, SMOF. [SMOF was developed under the National Project on Organic Farming (NPOF) by the Department of Agronomy, the 2 hectares area has been certified by Lacon Quality Certification (P) Ltd, (Accreditation by Ministry of Commerce, Govt. of India). Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj. Having nearly neutral in soil reaction (pH 7.0), organic carbon (0.375 %), available nitrogen (168.75 kg/ha), available phosphorus (17.4 kg/ha) and available potassium (231.7 kg/ha). The climate of the region is semi-arid subtropical. In this experiment, a total of nine treatments has been developed and were tested. Treatment comprised of T_1- Broadcasting + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_2- Line sowing + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_3- SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_4- Broadcasting + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_5- Line sowing + Poultry manure (5 t/ha) +

Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_6- SWI + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_7- Broadcasting + Vermicompost (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_8- Line sowing + Vermicompost (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS, T_9- SWI + Vermicompost (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS. Nine treatments were replicated thrice in Randomized Complete Block Design. Organic Manures were applied in advance to the sowing day and whereas the liquid foliar sprays were applied in different time intervals as 15, 30, and 45 days after sowing (DAS).

Chemical analysis of soil

Composite soil samples are collected before the layout of the experiment to determine the initial soil properties. The soil samples are collected from 0-15 cm depth and were dried under shade, powdered with wooden pestle and mortar, passed through a 2 mm sieve, and were analyzed for organic carbon by rapid titration method by Nelson (1975). Soil texture by Bouyoucos Hydrometer Method (Gee and Baudev, 1986). Available nitrogen was estimated by alkaline permanganate method by Subbiah and Asija (1956), available phosphorus by (Olsen *et al.,* 1954) and available potash was determined by Flame photometric method, Jackson (1973), available potassium was determined by using the flame photometer normal ammonium acetate solution and estimating by using flame photometer (ELICO Model) as outlined.

Statistical analysis

The data recorded were different characteristics were subjected to statistical analysis by adopting Fishers the method of analysis of variance (ANOVA) as described by Gomez and Gomez (2010). Critical difference (CD) values were calculated the 'F' test was found significantly at 5% level.

Results and Discussion

Response on plant height (cm)

Observations recorded in respective to the plant height of wheat were represented in Table 1 there was an increase in crop age and plant height was progressively noticed with the advancement during the experimentation period. The analysis on plant height was significantly higher in all the different growth intervals with the different methods of sowing and organic manures. At harvest, maximum plant height (78.30 cm) was recorded with the application of Line sowing + FYM (12 t/ha) + Panchagavya 3% FS + jeevamrutha 500 l/ha FS which was significantly superior over all the treatments and statistically at par with treatment of Line sowing + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (77.80 cm) and Line sowing + Vermicompost (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (76.76 cm). This may be due to the application of poultry manure leading to the availability of nutrients necessary for the good growth of the plant. These results are consistent with what was achieved by Abbas *et al*. (2012) and Rasul *et al*. (2015). Chandrashekar *et al.* (2000) reported that application of poultry manure at 10 t/ha with recommended rates of fertilizers produced taller plants (187.5 cm) as compared to control.

Response on No. of tillers per plant of wheat

The obtained results in response to the tillers per hill were depicted in Table 1 and there were tillers progressively increased with the advancement of the crop during the crop growth period. At harvest maximum number of tillers per plant (10.53) was recorded with the application of SWI + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS which is significantly superior over all the treatments and statistically at par with treatment of SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (10.26) and SWI + Vermicompost (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (10.23). Several tillers were influenced significantly by different spacings and planting methods. SWI technique decreases the competition between the plant for light, water, space, and nutrients hence there is an increased number of tillers. There is an increase in the number of tillers in wheat crops due to the influence of different organic fertilizer combinations (Singh *et al*., 2011).

Response on Dry weight (g/plant)

Recorded observations relative to the dry weight were given in Table 1 and there was dry weight had given consecutively increased performance from 20 DAS to till harvest. At harvest, maximum dry weight (18.00 g/plant) was recorded with application of SWI+ Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS

Table 1: Response of wheat by different methods of sowing and organic manures

Treatments	Growth attributes of wheat at Harvest		
	Plant height (cm)	No. of Tillers/plant	Dry weight (g)
T_1- Broadcasting + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	72.57	5.43	16.94
T_2- Line sowing + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	77.8	7.41	17.01
T_3- SWI + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	72.9	10.26	17.59
T_4- Broadcasting + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	74.43	5.7	16.04
T_5-Line sowing + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	78.3	7.47	16.71
T_6- SWI + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	73.7	10.53	18.00
T_7- Broadcasting + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	70.26	5.58	15.14
T_8- Line sowing + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	76.76	7.23	16.02
T_9- SWI + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	71.93	10.23	17.05
SEm (±)	1.24	0.13	0.35
CD (5%)	3.68	0.41	1.05

Table 2: Yield attributes of wheat by different methods of sowing and organic manures

Treatment	No. of Effective tillers	Spike length (cm)	No of grains per spike	Test weight (g)
T_1- Broadcasting + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	5.26	10.44	47.11	29.23
T_2- Line sowing + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	7.27	10.75	48.56	35.13
T_3- SWI + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	10.16	11.35	54.76	30.43
T_4- Broadcasting + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	5.53	10.43	45.7	29
T_5-Line sowing + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	7.36	10.94	49.97	36.73
T_6- SWI + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	10.43	11.73	58.38	31.1
T_7- Broadcasting + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	5.48	10.21	41.82	27.6
T_8- Line sowing + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	7.13	10.63	47.96	31.5
T_9- SWI + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	10.13	11.00	52.28	29.93
SEm(±)	0.13	0.29	1.46	0.69
C.D (P=0.05)	0.39	0.88	4.34	2.05

which were significantly superior over all other treatments except with application of SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (17.59 g/plant), SWI + Vermicompost (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (17.05 g/plant), Line sowing + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (17.01 g/plant) were statistically on par. The cause of the rapid increase of Dry matter at crop harvest or ripening stage was possibly due to the emergence of the number of new tillers per plant and more fertile spike per plant (Alam, 2012).

The response over yield attributes of wheat

Observations regarding yield attributes are given in Table 2. Maximum number of effective tillers per plant (10.43) was recorded with application of SWI + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS which was significantly superior over all other treatments except with the application of SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (10.16) and SWI + VC (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l /ha FS (10.13) were statistically at par with SWI + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS.

Table 3: Yield of wheat by different methods of sowing and organic manures

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T_1- Broadcasting + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.28	3.55	39.05
T_2- Line sowing + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.99	4.31	40.80
T_3- SWI + FYM 12 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.75	3.95	41.03
T_4- Broadcasting + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.2	3.44	38.95
T_5-Line sowing + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	3.16	4.48	41.39
T_6- SWI + Poultry manure 5 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.66	3.92	40.45
T_7- Broadcasting + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.12	3.37	38.61
T_8- Line sowing + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.51	3.78	39.91
T_9- SWI + Vermicompost 4 t/ha + Panchagavya 3% + Jeevamrutha 500 L/ha	2.37	3.63	39.52
SEm(±)	0.05	0.05	0.42
C.D (P=0.05)	0.17	0.17	1.26

Spike length (11.73 cm) was recorded maximum with the application of SWI + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS which were significantly superior over all other treatments except with the application of SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (11.35 cm), SWI + VC (4 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (11.00 cm) and Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (10.94 cm) were statistically at par with SWI + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS. The maximum number of grains per spike (58.38) was recorded with the application of SWI + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS which was significantly superior over all other treatments except with the application of SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (54.76) was found. Maximum test weight (36.73 g) was recorded with the application of Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS which were significantly superior over all the treatments except with the application of Line sowing + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (35.13 g) was found statistically at par with Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS. The improvement in yield attributes, i.e., the number of grains per spike of wheat with the application of organic manures may be assigned to the fact that proper decomposition and mineralization of these manures supplied available plant nutrients directly to plants and also had a solubilizing effect on the fixed form of nutrients in the soil (Singh and Singh, 2005). The observation regarding yield is given in Table 3. Grain yield is an important and considerable trait all the time. Maximum grain yield (3.16 t/ha) and Straw yield (4.48 t/ha) were recorded with the application of Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS which were significantly superior overall the treatments except with the treatment of Line sowing + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS with grain yield (2.99 t/ha) and Straw yield (4.31 t/ha) which were statistically on par with Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS. This in turn might have increased the values of growth and yield contributing attributes which are reflected in the grain and straw yield of wheat. A similar finding was reported by the higher yield maybe because these organic manures supply directly available nutrients such as nitrogen to plants and these organic manures improve the portion of water holding stable aggregates of the soil (Channabasanagowda *et al.*, 2008). While maximum harvest index (41.39 %) was recorded with application of Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 /ha FS which were significantly superior over all the treatments except with the treatment of SWI + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (41.03 %), Line sowing + FYM (12 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (40.80 %) and SWI + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS (40.45 %) which were statistically at par with Line sowing + PM (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS. It might be due to enhancement of grain yield and straw yield which in turn results in a higher harvest index. Due to the yield and straw yield which is out turned into higher harvest index. Similar findings are found by the Amin and Baque (2019).

Conclusion

It is concluded that application of Line sowing + Poultry manure (5 t/ha) + Panchagavya 3% FS + Jeevamrutha 500 l/ha FS was found more productive in grain yield (3.16 t/ha).

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Conflict of interest

The authors declare that they have no conflict of interest.

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Conservation and successful utilization of landraces for rice improvement

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ABSTRACT

Germplasm is the basis of all plant improvement programmes. The collected landraces of rice possessed high probability of the useful genes for efficient application in the breeding programmes to develop high yielding varieties with quality and resistance to biotic and abiotic stresses. Those landraces needs to be conserved *ex situ* or *in situ*. In the rice repository of Uttar Banga Krishi Viswavidyalaya, Pundibari has about 200 landraces collected from West Bengal, Assam and Manipur. Every *Kharif* season, they are being cultivated and seeds are collected to conserve since 2008. High variability has been observed among those varieties. Some special characteristics also have been identified during characterization and *ex situ* conservation of those landraces, such as, long and white sterile lemma, double and triple kernelled spikelets. Important landraces were used as donor in rice improvement. A number of desirable mutants, recombinant lines and somaclones have been have been developed which are in different yield trials. Some pure lines also have been isolated from the collected famers' varieties.

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Introduction

The creation of rice repository is the most important for crop important. India harbours thousands of local land races of rice. As a cause of land and agro-climate diversities, a large diversity of rice genotypes are present in India. Assam and adjoining states is the *primary centre* (The Hindustan Centre of Origin, which includes Myanmar, Assam, Malaya Archipelago, Java, Borneo, Sumatra and Philippinese) of origin of rice. Rice landraces are repository of precious characters and need further care for its conservation, characterization and utilization in plant breeding. Huge number of scented and non-scented traditional Farmers' Varieties (FVs) of rice are available in Indian subcontinent. Some cultivars are being extensively grown in specific problem oriented areas. Most of the FVs are tall, lodging susceptible, low yield potential and highly *photoperiod-sensitive*.There is strong need that the local germplasm of scented and non-scented rice to be collected, preserved and characterized in detail for subsequently utilization of the FVs for rice improvement. The modern high yielding rice varieties were developed following conventional breeding tools, such as pureline selection, hybridization and backcross selection using locally adopted high yielding genotypes. The numbers of parental lines used for rice improvement are extremely limited leading to creation of narrow genetic base. Genetic similarity in crop is undesirable in respects of susceptibility of the crop to disease or insect pest epidemics. A new important source for the introduction of new trait or development of new plant type is the existence of genetically diverse gene pool of scented and non-scented rice in our country. Little effort has been taken to use the local landraces of scented rice for their improvement. Considering the importance of aromatic rice in the international market, and the biotic and abiotic tolerance ability of non-scented rice, in this endeavour about 200 FVs have been collected, characterized and few important FVs have been utilized for rice improvement.

Material and Methods

Collection and Characterization

The collected FVs mostly belong to northern part of West Bengal. A considerable number of FVs were also collected from southern part of West Bengal, Assam and few were from Manipur. Basic information about FVs were gathered from the particular individual conserving or cultivating farmer. To obtain complete distinctive features of individual cultivar, the FVs were characterized following the *Table of Characteristics* in the "Guidelines for Conduct of Test for Distinctiveness, Uniformity and Stability on Rice (*Oryza sativa* L.)" published by PPV&FRA (2007), Government of India. The collected FVs were grown in the University Research Farm, Pundibari, situated at 26°19′N latitude, 99°23′E longitude and at a height of 43 MSL following the standard package of practices for FVs as described by Roy (2015).

Ex situ conservation

About 200 FVs are being conserved *ex situ* by cultivating during every *Kharif* season at Rice Repository, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal.

Utilization in rice improvement

The important FVs were used as donor for rice improvement, such as, Tulaipanji used in mutation breeding, Kalo Nunia used for development of somaclonal variation, Nilachal, Kalo Nunia, Bhog Jeera-1 were used for development of recombinants etc.

Results and Discussion

Characterization

The FVs were characterized as per the *Table of Characteristics* in the "Guidelines for Conduct of Test for Distinctiveness, Uniformity and Stability on Rice (*Oryza sativa* L.)" published by PPV&FRA (2007), Government of India. Considerable variations were reported for yield and yield attributing characters (Roy, 2013; Roy *et al.,* 2013; Roy and Surjec, 2016; Roy *et al.,* 2016; Mahato *et al.,* 2017; Debbarma and Roy, 2017; Surje *et al.,* 2018; Surje *et al.,* 2019).Genetic variations were also observed for grain quality parameters (Mandal *et al.,* 2021).The FVs were found to be nutritionally unique and having high nutritive value. Kataribhog, Sadanunia, Chakhao were identified as promising in terms of resistant starch content, amylose content, glycemic index and antioxidant content. Kataribhog had low glycemic index (~45.72%) and it was lower than the recommended concentration (Mandal *et al.,* 2021). Regular intake of rice with high glycemic index is associated with risk of type II diabetes, obesity, coronary heart disease and other chronic conditions (Choi *et al.,* 2012). High genetic variability had been reported for number of tillers per plant, days to 50% heading, plant height, number of panicle per plant, panicle length, number of filled grain per panicle, spikelet sterility (%), test weight, grain dimension (length, breadth and thickness) and grain yield. Notable variation was also observed in FVs in terms of qualitative characters (Roy, 2013; Mahato *et al.,* 2017; Surje *et al.,* 2018; Surje *et al.,* 2019), such as panicle shape (compact, loose, erect), awning (awnless, short to long awned), husk colour, (straw, golden, golden brown, purple black), grain shape (long slender, short slender, medium slender, long bold and short bold), lodging (susceptible and tolerant) and aroma (non-aromatic, strong aromatic, mild aromatic).

Ex situ conservation

All the collected FVs are being conserved *ex situ* by cultivating during every *Kharif* season. For crop cultivation, standard package of practices compatible to the humid tropic of Tarai Zone for FVs as described by Roy (2015) is being followed. Seedlings are raised in the puddle condition during second week of June. Thirty days old seedlings are transplanted (singles seedling per hill) in four lines of 6 m length for each traditional cultivars. Row to row and plant to plant spacing were 30 and 20 cm, respectively. Stringent roguing is done during all the critical stages to keep the cultivars genetically pure. FVs are being conserved *ex situ* since 2009 at Rice Repository, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India (figure 1). It is worthy to mention that flood during September-October, 2020 in Alipurduar district completely destroyed the field of traditional rice, Jasoya. The seed of this cultivar was not available to the farmers due to the flood. During 2013, this variety was collected from Tarai Research Society, Alipurduar and is being conserved *ex situ* at Uttar Banga Krishi Viswavidyalaya, Pundibari. When it was come to the notice of the Communicating Author of this article about the non-availability of seeds of Jasoya, 500 g of seeds was supplied to the farmer of Alipurduar for reviving the cultivation of the traditional cultivar, Jasoya at farmers' field. This is a successful and unique example of importance of conservation of rice cultivars, reviving of the cultivar and saved the cultivar from extinction.

Utilization in rice improvement

Pure Line Selection: About 40 pure lines were isolated from Kalo Nunia (Roy, 2013). Few of them are performing well. Uttar Sugandhi (IET 24616) is pure line isolated from Kalo Nunia (table 1 & figure 2) performed well in multi-locational trials conducted by Indian Institute of Rice Research, Hyderabad (Anonymous, 2014 & 2015). Uttar Sugandhi has been submitted to West Bengal State Variety Release Committee for release for cultivation in West Bengal. It is photoperiod sensitive, long duration rice variety bearing medium slender grains with strong aroma. Yield is about double (3.5 t/ha) of the parental cultivar-Kalo Nunia (1.5 t/ha). Another pure line selection, IET 25439 performed well in AICRIP trials (ASG-IVT, 2015-16). It ranked first at Ambikapur in CG (7627 kg/ha), fifth at Pundibari in West Bengal (3469 kg/ha). Its overall mean was 3671 kg/ha (Anonymous, 2015).

Recombination Breeding: A number of crosses have been made using FVs, such as Kalo Nunia, BJ-1, Kalo Nunia/Anjali, Kalo Nunia/IR 64, Kalo Nunia/UBKVR 124, Kalo Nunia/ Pusa Basmati 1637, Kharadhan/MTU 1010, Nilachal/MTU 7029 etc. The promising recombinant derived from those crosses are under different stages of yield trials. IET 28102 developed from the cross in between Bhog Jeera-1 and Gontra Bidhan-1 (Table 1) performing well in AICRIP trials (Anonymous, 2019). It is a medium duration rice variety (120 days, seed to seed) with long slender grains and the yield potential is 6.50 t/ha. It is tolerant to leaf blast, neck blast, sheath rot, stem borer. UBKVR-190 (Nilachal/MTU 7029) also performed well in IVT-*Boro*. Some other promising recombinant lines are IET 28102, IET 28840, IET 24610, UBKVR-154, UBKVR-156, UBKVR 132 and UBKVR 144 (table 1).

Mutation Breeding: Mutation induced variability is an important method in plant breeding to create non-existing desirable genotype(s) for crop improvement. In this endeavour, gamma radiation was used to create variability for improving plant type and yield attributing traits in a local aromatic cultivar, Tulaipanji. Eight desirable mutants were

Table 1:The variety of advance lines developed using FVs as donor

Crop improvement tools	Cultures/varieties	Parents
Pure line selection	Uttar Sugandhi (IET 24616)	Pure line selection from Kalo Nunia
	IET 25439	Pure line selection from Kalo Nunia
Recombinants	IET 28102	Bhog Jeera-1/Gontra Bidhan-1
	UBKVR-154	Nilachal/MTU 7029
	UBKVR-156	Nilachal/MTU 7029
	IET 28840	Nilachal/MTU 7029
	UBKVR 132	Bhog Jeera-1/Gontra Bidhan-1
	UBKVR 144	Kalo Nunia/Anjali
	IET 24610	Kalobhog/PB-1
Mutation Breeding	TP3-2 (IET 28104)	Tulaipanji mutant
	UBKVR-143	Tulaipanji mutant
Somaclonal Variations	TC 5-1, TC 4/4, TC 4/5, TC 4/7	Somaclones of Kalo Nunia

identified from M4 generation. All those eight mutants induced from Tulpanji were photoperiod-insensitive, non-lodging, and semi-dwarf with high yield potential and retained the aroma (Roy *et al.,* 2018). Mutants TP3-2, TP3-4 and TP3-6 showed high increase in yield (> 89%) over the control cultivar, Tulpanji. As the mutants were photoperiod insensitive, they may be recommended for cultivation for both *Boro* and *Kharif* seasons after necessary trials and demonstrations. TP3-2 (IET 28104) is medium duration, medium tall, medium slender grains, aromatic, golden yellow husk colour, tolerant to common diseases and insect pests and moderate yield potential (3.3 t/ha) (Anonymous, 2014). Another non-aromatic Tulaipanji mutant, UBKVR-143 is also performing well in the station trial (Figure 3). It is of medium duration, medium tall, non-aromatic, spikelet sterility is very low, short bold grains, tolerant to common diseases and insect pests, high yield potential (5.5-6.0 t/ha).

Somaclonal Variation: The aromatic FVs of rice possess very low combining ability with the modern high yielding varieties and consequently development of transgressive segregants. Accordingly, the need was felt to develop suitable genotype(s) using biotechnological tools (Figure 4). Somaclonal variations created through seed derived callus induction and regeneration of plantlets. Thus, somaclonal variation may be considered as alternative breeding tool for improvement of aromatic FVs of rice. The somaclones isolated by Roy (2020), such as, TC 4/8, TC 5-1, TC 4/4, TC 4/5, and TC 4/7 showed high yield advantage over Kalo Nunia ranging from 27.21% to 54.78% (Roy, 2020). Thus, plant tissue culture technique may be recommended for creation of genetic variability in rice as a biotechnological tool. *In vitro* response of traditional *indica* rice, namely Black Burma, Black Jeera, White Jeera, Tulaipanji, Kalobhog and Badsha Bhog were studied (Roy *et al.,* 2011). The analysis of variance showed significant differences among the varieties for callus-ability, plantlet regeneration and number of plantlets per culture. Inoculated seeds germinated on the medium within 3-4 days after inoculation. Light, yellow globular calli were found to be initiated at mesocotyle region of germinating seeds. On tenth day after seed implantation on callus maintenance medium, observations were recorded in respect of callus induction. Highest percentage of callus induction was reported in Tulaipanji and White Jeera when MS medium was supplemented with 2 mg/L of 2,4-D and 0.5 mg/L NAA, followed by Black Jeera. The calli of White Jeera were fragile, compact and fast growing. Black Burma had lowest response towards callus induction. Callus induction ranged from 6.20 to 100.00% among the indigenous genotypes considered for this experiment. Calli become more fragile in regeneration medium, particularly the calli of White Jeera. Embryogenic callus started to regenerate in second week of inoculation on the regeneration medium. Highest percentage of plantlet regeneration was also observed in White Jeera followed by Black Jeera. Embryogenic responsive calli produced roots and shoots simultaneously in the regeneration medium. White Jeera had given rise an average of 32.38 plantlets per callus. The study suggested that the callus induction and plantlet regeneration were genotype specific. It was found that traditional scented cultivars also have

Figure 1: Rice repository at Uttar Banga Krishi Viswavidyalaya and traditional cultivar, Jasowa

Figure 2: Uttar Sugandhi. A) Field view; B) Undehusked rice; C) Dehusked rice

Figure 3: Mutation breeding

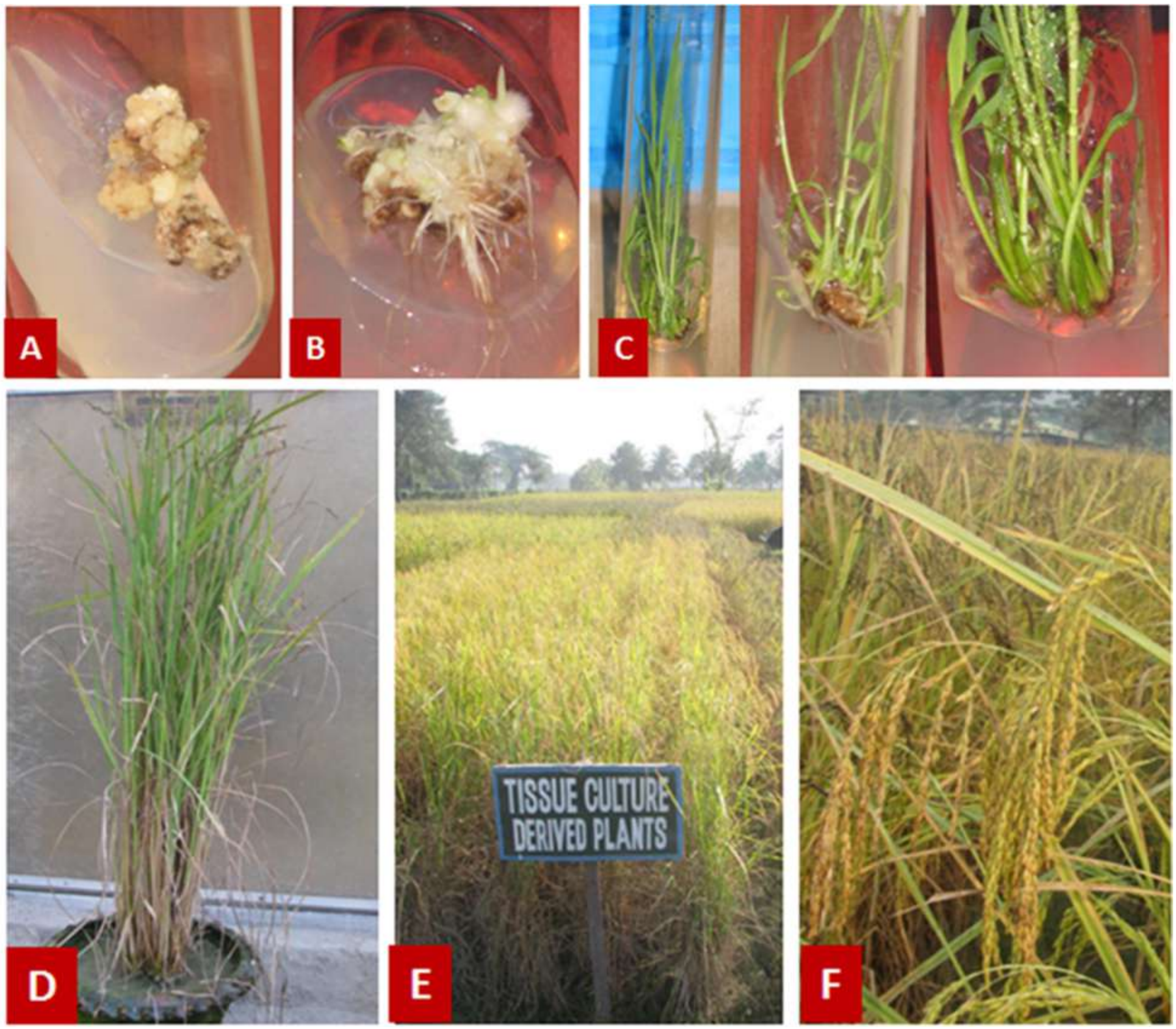

Figure 4: *In vitro* development of plantlets from an *indica* local rice, Kalo Nunia involving mature seed embryos and the performance of somaclones at field (A) Stereomicroscopic view of callus proliferation on callus maintenance medium (MS + 1 mg L^{-1} 2,4-D). (B) Embryogenesis, producing roots and shoots simultaneously in regeneration medium (MS + 1 mg L^{-1} kinetin + 1 mg L^{-1} BAP + 0.5 mg L^{-1} NAA). (C) Regenerated plantlets in culture tubes. (D) S_0 plant after hardening on earthen pot in net-house. (E) S_2 plants in the field. (F) S_4 somaclonal of population of TC4/8 derived from Kalo Nunia

high *in vitro* response towards plantlet regeneration via callus formation. The findings of this study may be used in genetic transformation of those local land races of aromatic rice subsequently mass-multiplication of transgenic derived from those cultivars.

Floating Rice: FVs, viz., Betho, Kauka, Singara etc. are submergence tolerant rice (Roy *et al.,* 2013). Those cultivars are being maintained by Mr. Harendra Nandi of Salsalabari, Alipurduar district (Figure 5A). Betho (Figure 5A-E), Kauka (Registration No. 96 of 2020), Singara have been registered as Farmers' Varieties under Protection of Farmers Rights Authority, New Delhi. Floating rice are being cultivated in low-laying areas, particularly in Cooch Behar, Jalpaiguri and Uttar Dinajpur districts of West Bengal.Those floating rice are direct seeded without sprouting on a marginal ploughed field. It germinate with the grass. Conversely, at onset of monsoon, the water level rises and the plant height also increases by elongation of internode. Upper part of those rice

Figure 5: Floating rice. A) Mr. Harendra Nandi of Salsalabari, Alipurduar district; B&C) Field view of floating rice; D) Branching of Betho; E) Height of Betho

Figure 6: Special characters of FVs. A) Double kernelled rice- Jugal; B) Long sterile lemma- Ramee Galee (arrowheads are the long sterile lemma); C) Black rice- Sadabhat Kalo; D) Purpled leaf blades and leaf sheath- Nilachal; E) Clustered panic- Thuri

plants remain floating on the surface of the water during entire season (Figure 5B&C). After withdraw of the monsoon rain, the plants fall down and initiate branching from the upper nodes (Figure 5D).

Drought Tolerance: Water stress is the most important abiotic stress for low productivity of rice in rain-fed environments. Early tolerance ability of plant to drought is expected to be maintained throughout the productive life. *Ausdhan*, such as Bitti (Roy *et al.,* 2013) are generally drought tolerant. They are being cultivated purely under rain-fed condition. In some parts of northern districts of West Bengal the traditional, *Ausdhan* are dibbled during March-April in the revenue forest areas or in plantations. In another study, Kashiyabinni, Jhagrikartik and Garu Chakua were found to be tolerant and Kashiyabinni as highly tolerant (Debbarma, 2018).

Lodging Tolerance: Lodging trait of FVs of rice is an important criterion for determination of grain yield and their acceptability among the rice farming community. Boichi and Seshaphal were identified as highly lodging tolerant (Debbarma and Roy, 2017). Majority of the FVs were noted to be susceptible to lodging and the reason for susceptibility was their height and weak culm. Lodging susceptibility was recurrent in irrigated condition than the normal terminal drought condition or drought situation created by spraying of potassium iodide along with normal irrigation (Debbarma and Roy, 2017). Consequently, the reduction in yield was more in the drought situation created by spraying of potassium iodide along with normal irrigation (20.62%) than the normal terminal drought (18.66%). It was observed that in most of the cases lodging caused remarkable yield loss.

Medicinal Use: Exact medicinal properties of the FVs are not known, but few FVs are being used in preparation of traditional medicine. Shri Ramesh Roy of Ramsahi, Jalpaiguri district of West Bengal cultivates the FV Sati which is being procured by a traditional medicine practitioner and he uses the powder of this rice as the carrier material for pills of traditional medicine.

Special Characters

Multi-kernelled Rice Spikelets: Rice bears single kernelled spikelets. Very rarely multi-kernelled spikelets are reported. In India, the cultivar *Jugal* had multiple (2-3) kernels per spikelet (Figure 6A). The ratio of single, double and triple kernels per spikelet in *Jugal* was 54, 42 and 4%, respectively (Roy and Surje, 2016; Saha *et al.,* 2020). This was also studied by Chakrabarty *et al*. (2012) and they found similar ratio of single, double and triple kernels per spikelet. *Jugal* had medium bold grain, straw coloured lemma and palea, and brown kernel.

Long Sterile Lemma: Sterile lemmas of rice are usually much smaller in size than the fertile lemma. They do not bear flower, hence they had been named as “sterile lemma” (Figure 6B). The sterile lemmas of *Rami Gelee* most of the time exceeded fertile lemma and palea by length (Roy and Surje, 2016). The average length of the sterile lemma was 9.09 mm, whereas the length of fertile lemma was 8.67 mm. The colour of the fertile lemma of *Rami Gelee* was simple white or off-white. Grain was long bold, lemma and palea colour was dark brown, and colour of the kernel was brown.

Black Rice: Dehusked rice of *Sadabhotkalo* (Figure 1C) and *Chakhao Poiterin* were dark purple to black and cooked rice also black. It has a dark purple to black bran layer. Genotypes with red or purple bran layer are being cultivated since ancient time in Asia (Ahuja *et al.,* 2007). Coloured rice, black rice in particular is reported to be effective sources of antioxidants and their consumption is encouraged (Yawadio *et al.,* 2007; Anggraini *et al.,* 2015). Black rice contains comparatively high anthocyanin, such as, cyaniding-3-O-glucoside and peonidin 3-O-glucoside in the pericarp layer leading to dark purple color (Ryu *et al.,* 1998). Anthocyanin rich rice is known for their bioactive properties and accepted as health-enhancing substances for their antioxidant activities, anti-inflammatory accomplishment, anticancer property, anti-atherogenic execution, and anti-hypoglycemic effects (Wang and Stoner, 2008). Coloured rice is also having low sugar, high fibre and plant compounds that combat heart disease and cancer (Sutharut and Sudarat, 2012).

Clustered Panicle: Rice pedicel bears one spikelet in a panicle. In the repository of FVs in the Rice Repository of Uttar Banga Krishi Viswavidyalaya, *Narkeldari* and *Thuri* showed more than one spikelet borne in a pedicel (Roy *et al.,* 2013). This feature resulted high grain density in a panicle

(Figure 1E). This result also corroborated with the findings of Chakrabarty *et al*. (2012), but the local name of that particular FV was *Khejurchari*.

Purpled Leaf and Leaf Sheath: The colour of fully opened leaves and leaf sheath of Khara dhan (Figure 1D) and Nilachal are deep purple (Roy *et al*, 2013; Roy and Surje, 2016). However, the detail of its importance in photosynthesis and other activities yet to be studied. Sakamoto *et al*. (2001) studied about the purple locus of rice and they stated that the purple leaf (*Pl*) locus of rice affects regulation of anthocyanin biosynthesis.

Conclusion

Conservation of rice landraces has furthermost practical utility in crop improvement. Uttar Banga Krishi Viswavidyalaya is conserving about 200 rice landraces collected from West Bengal and adjoining states. Those collected landraces have been characterized and based on the information derived from pre-breeding programme, landraces have been used as donor for development of high yielding varieties. Different breeding tools, like pure line selection, recombinant breeding, mutation and plant tissue culture technique have been implemented. Uttar Sugandhi (IET 24616) have been developed from Kalo Nunia through pure line selection. Few desirable recombinants, namely IET 28102, IET 28840 and IET 24610 have been developed using traditional rice cultivars. Photoperiod insensitive variety, IET 28104 has been developed using mutation. Desirable somaclonal variants also isolated from Kalo Nunia. In nutshell, the landraces of rice have great potentiality in rice improvement.

Conflict of interest

The authors declare that they have no conflict of interest.

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Integrating weather model & Remote sensing indices for wheat yield prediction in Haryana, India

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ABSTRACT

Wheat is a major food grain crop of main agricultural region *i.e.* northern plain of India. Haryana state holds a premium position in wheat production (*Rabi* Season) in the country. Pre-harvest yield estimation of wheat has key role in policy framing. In Haryana, Agriculture is a big support to its economy which continues to occupy a prominent position in State GDP. In present research, Agromet-Spectrals models have been developed for this purpose *i.e.*yield estimation in Haryana with the help of input data such as meteorological indices and satellite based NDVI(NASA's-MODIS) from 2000-2017. Empirical models were developed for predicting wheat yield for Hisar and Karnal districts representation the two agro-climatic zone of state in Haryana, India.The models were developed used weather variable (Temperature (Minimum and Maximum), Relative Humidity (Morning and Evening) and Rainfall) and spectral indices Normalized Difference Vegetative Index viz. Agromet- model(weather model) and Agromet-spectral model (MODIS-NDVI). Weather or Agromet model was integrated with NDVI values for both location to enhanced the accuracy of models. Regression models were developed using significant weather variables and NDVI data for wheat yield prediction at both location. The result revealed that the models when integrated with remote sensing data (NDVI) gave better prediction as compared to agromet model that depends only on weather variables. Agromet-models (adjusted R^2 = 0.38 to 0.78) whereas satellite data based NDVI i.e. MODIS-NDVI for both stationgave best result (Adjusted R^2 = 0.61-0.86) as compared to weather models. MODIS-NDVI pixel based values observed to be more effective for wheat yield predication in integrated with weather parameters.This study could help the provincial government of Haryana as well as in northern plains in estimation of yield prior harvest at first week of April by using weather spectral (NDVI-MODIS) models.

Introduction

Wheat (*Triticumaestivum* L.) is a major Cereal crop of the world in terms of production. In India, wheat is the second important food crop being next to rice (Ranjan *et al*., 2012) and contributes to the total food grain production of the country to the extent of about 35 per cent. (Anonymous, 2019).Yield prediction is a major step for various policy decisions related to distribution and export-import of food grain. In Haryana, Agriculture is a big support to its economy which continues to occupy a prominent position in State GDP. Despite the decline in the share of agriculture sector in the Gross State Domestic Product to 18 percent (2017-18) about two third population of the state still

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depends upon agriculture for their livelihood. The growing population in agrarian countries like India posing a great pressure on food-grain production. Therefore, for proper planning and management of products, various models and techniques have been developed for accurately prediction of production especially in wheat being main food grain. Mostly, all models use meteorological parameters as input for yield prediction.

Besides meteorological data, remote sensing data have also proved helpful to increase accuracy and timely forecast of yield. A prominent crop weather model was developed by Fisher *et al.,* (1924) and experimentally applied by Agarwal *et al.* (2007) on the basis of different weather parameter combination for forecasting yield. Weather plays a dominated role on growth and overall condition of a crop. Different weather parameters affect differently on different stages of crop growth. The present study is an effort to find out the weather element or their combination that are responsible for crop yield prediction. Correlation and regression analysis was carried out using Excel spread sheet and SPSS package. A regression correlation analysis was carried out between weather parameters and yield of wheat crop. To carry out this task, sum and sum product values (Agarwal *et al.,* 2007) were taken as input independent factor and yield data as dependent factor in SPSS software to find out those parameters or their combination which were most affecting wheat yield. Sisodia *et al.* (2014) developed agromet statistical regression models based on meteorological parameter *i.e* minimum and maximum temperature, relative humidity, wind-velocity and sunshine hours using 20 years data from (1990-91 to 2009-10), to predict wheat yield two month prior to harvest. Saeed *et al.* (2017) developed agromet-spectral model to forecast wheat yield before harvest with root mean square errors (RMSEs) less than 5%. The NDVI shows strong relationship with crop physiological attributes and high value of NDVI is associated with faster growth rate and higher biomass accumulation during the vegetative stage, and a longer grain filling period by delaying leaf senescence during the ripening phase thereby increasing yield (Babar *et al.,* 2006).The NDVI values of wheat during different phonological stages was observed 0.3 to 0.35 at emergence stage, 0.40 to 0.50 at tillering stage, 0.55 to 0.65 at milking stage, 0.35 to 0.45 at maturity and 0.25 to 0.30 at harvesting stage (Parida and Ranjan, 2019). Remotely sensed imagery give the information of crop quality and development at different growth stages but some uncertainty in soil, climatic condition, management and other input data will decrease the prediction accuracy (Jin *et al.,* 2018).

Bognnar *et al.* (2017) also used minimum and maximum temperature, rainfall and sunshine hours with MODIS derived NDVI values that gave better performance in forecasting wheat yield three weeks before harvest in Punjab province of Pakistan. A robust yield model was exercised for estimating and forecasting wheat yield in Hungary at country level in the period of 2003–2015 using MODIS-NDVI data. Keeping in view these efforts worldwide, this study was designed with the objective to develop an integrated model for yield prediction of wheat by taking meteorological data incorporation with Remote Sensing data derived from two sources IRS and MODIS-NDVI for two locations of different Agro-climatic zones of Haryana state in India.

Material and Methods

Study area

The present study was conducted for Haryana state by taking two locations *i.e.* Hisar and Karnal that represent the two agro-climatic zone of the state. Hisar and Karnal districts are located between of 29^0 09' N, 75^0 43' E and 29º 43' N latitude, 76º 58' E longitude of western and eastern part of Haryana respectively (Figure1). The climatic region lies between semi-arid to humid condition.

Data Collection

Satellite based NDVI values taken from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS, 16 days composite imageries of 250 m resolution) were used from 2000-2017. Rabi season MODIS imagery of path 147 and row 41 were downloaded for whole of growing season on fortnight basis. These composite images were spanning from first-November to April (Rabi Season) were obtained for the time period of 2000 to 2017, covering the entire wheat crop cycle at Hisar and Karnal district of Haryana. Meteorlogical parameters viz. Temperature (Maximum and Minimum), Relative Humidity (Morning and Evening) and Rainfall data were collected from

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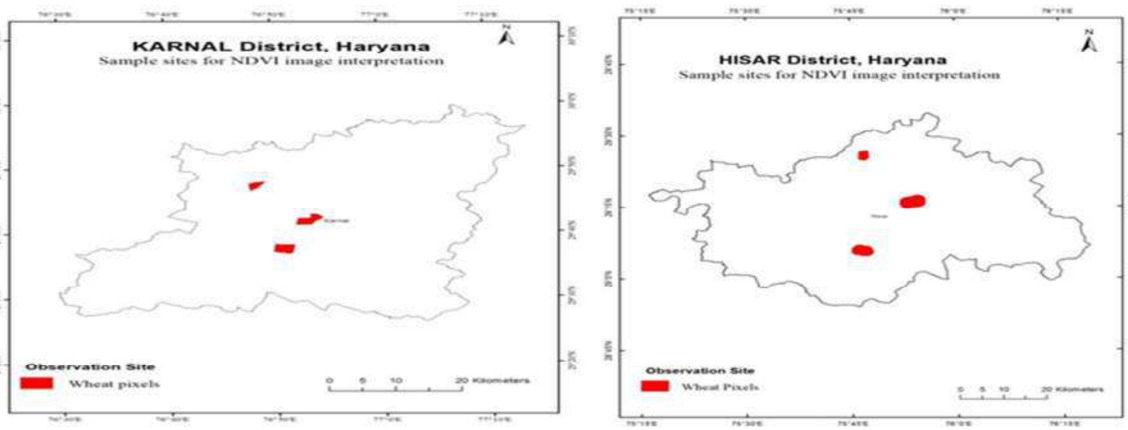

Figure 1: Wheat growing sites for NDVI image interpretation in Karnal and Hisar district

Table 1: Weather and spectral indices used in models using composite weather variables

SIMPLE WEATHER INDICES							**WEIGHTED WEATHER INDICES**					
	T_{MAX}	**T_{MIN}**	**RH 1**	**RH II**	**Rf**	**NDVI**	**T_{MAX}**	**T_{MIN}**	**RH 1**	**RH II**	**Rf**	**NDVI**
T_{MAX}	Z10						Z11					
T_{MIN}	Z120	Z20					Z121	Z21				
RH 1	Z130	Z230	Z30				Z131	Z231	Z31			
RH II	Z140	Z240	Z340	Z40			Z141	Z241	Z341	Z41		
Rf	Z150	Z250	Z350	Z450	Z50		Z151	Z251	Z351	Z451	Z51	
NDVI	Z160	Z260	Z360	Z460	Z560	Z60	Z161	Z261	Z361	Z461	Z561	Z61

University, Hisar (Haryana) and Central Soil Salinity Research Centre, Sirsa (Haryana) from 2000 to 2017. These models integrated with NDVI values from both of sources for corresponding location for above said time period (2000-2017) to enhance the accuracy of models. The statistics of the wheat yield (Kg/ha) from 2000 to 2017 for Hisar and Karnal (Haryana) were collected from the Haryana Statistical Abstract published on annual basis by Department of Economic and Statistical Analysis, Govt. of Haryana. Correlation of different combination of yield and weather parameter and then sum products (Agarwal *et al.,* 2007) were derived using M S Excel.

Coefficient of determination

R-squared also known as the coefficient of determination-is a statistical analysis tool used to predict the future output and how closely it aligns to a single measured model. The adjusted R-squared compares the descriptive power of regression models two or more variables that include a diverse number of independent variables known as a predictor. The validation of these Agromet model equations were execute for the next two consecutive years 2015-16 &2016-17. Different models were prepared viz. Agomet model, and Agromet Spectral Model (MODIS NDVI) for wheat yield estimation at regional level in Haryana and described as under.

Normalized Vegetation Index (NDVI)

Normalized vegetation index (NDVI) is calculated as (Rouse Jr *et al.*, 1974):

$$\mathbf{NDVI = (NIR-RED) / (NIR+ RED)}$$

Where, NIR and RED are the reflectance in the near- infrared and red spectral channels, respectively.

Selection of Region of Interest (ROIs):

The FCC (False Colour Composite) image of Rabi season of Hisar and Karnal districts were analyzed in different location for identification of wheat crop and polygon (region of interest) were generated. Three locations were chosen Figure 1 for both district to minimize of chance of error that may occurred to mixing of pixels with other crops. These polygons were used as a mask to obtain NDVI values of each season.

Generation of NDVl Values:

Average NDVIs of each polygon was calculated through masking the field by overlaying the ROIs with MODIS-NDVI images using Overlay option of ENVI ("Environment for Visualizing Images"). Average NDVI of each polygon was obtained and so obtained 3 NDVI values corresponding to each polygon were further analyzed to get final NDVI value of a season for a station. NDVI, which is measurement of vigour of crop plant, was calculated using following equation:

Results and Discussion

Regression analysis gave summary output that included partial regression coefficient of effective parameter and intercept value to form equation in which yield as dependent and other significant parameters are independent. Table 2 details the variables derived based on sum product-correlation of significant weather variables for developing regression models for Hisar and Karnal districts.

Where, Z131 = sum of product of maximum temperature and morning relative humidity, Z41 = Sum of product of evening relative humidity, Z230 = sum of minimum temperature and morning relative humidity, Z451 = sum of product of evening relative humidity and rainfall.

***Agromet Model*:** The Agromet model worked better for Karnal station with adjusted R^2 value of 0.78. The reason may be climatic variability which is less at Karanl as compared to Hisar where the model could not show better results (Adjusted R^2 0.38). Agromet yield model equation for Hisar and Karnal districts is present in Table 3. Further theAgromet Yield models were validated for 2015-16 & 2016-17 for wheat yield estimation for districts Hisar and Karnal as shown in Table 4.The validation of Agromet models revealed that result were better for first year 2015-16 as compared to 2016-17. The post validation test is done for the fitted model using (Percentage deviation) test. This measure the deviation (in percentage) of forecast yield from the observed yield. For the year 2015-16, percentage deviation is comes out to be 3.80%. there is only one dependent variable in the given model along with intercept term. Validity test based on a single year can't be considered since it can't be because of the changes in the trend of observed value. In order to select a good model, the model validation for multiple years. It is very clear from the 2016-17 (%deviation 16.48) data that the model is not so good to explain the forecasting.The wheat yield was higher in 2016-17 from normal, that's why the errors are on higher side.

Agromet-Spectral Model (MODIS-NDVI): In this model the Agrometmodelswereintegrated with crop specific NDVI values or real ground/pixel based NDVI(MODIS satellite data). The regression yield model developed for Hisar and Karnal districts showed considerable improvements over previous checked models (table 5). Again the model worked better for Karnal region as compared to Hisar and this time the adjusted R^2 value express its applicability for Hisar region also.

MODIS-NDVI (wheat pixel based) satellite data considerably improved the accuracy of agromet models for both of the regions as this NDVI values is pixel based or wheat grown area. Agromet models with integration of satellite based NDVI (MODIS) data can help in predicting wheat yield before two month of harvest upto 90% accuracy. The validation of model shows that prediction of yield was within acceptable limits for 2015-16. The production was exceptionally high in 2016-17 as compared to recent past due to supporting weather condition, which increase the validation errors (table 6). But in normal year the prediction were very close to real values. The R^2 values were 0.66& 0.90 for Hisar and KarnalrespectivelyThis is due to more homogeneity of wheat cropped area in Karnal as compared to Hisar.Similar result found by Singh *et al.,* (2002) estimated the wheat yield in small areas in India using IRS-NDVI and obtained very low error in the range of 1.6-6.7%. Also Nagy *et al.,* (2018) also estimated the wheat and maize yield 6-8 weeks befroe harvest at regional level in Hungary using MODIS-NDVI. Wang *et al.,* (2019) estimation the winter wheat yield with a realtive of about 6% for selected regions of China.Lopresti *et al.,* (2015) found that an empirical model was fit between NDVI and yield, to estimate wheat yield 30 days early before harvest. Ranjan *et al.,* (2012) had developed a regression model to estimate the wheat yield using different weather parameter and NDVI as input. This showed a positive relationship with predicted and observed yield.

Table 2: Effective weather parameters for Hisar and Karnal district (Sum products-correlation)

Location	Year	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Hisar	**Time**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Yield	4447	4283	4182	4062	4135	4162	3704	4392	3920	4829	4139	4600	5098	4477	4180	4310	4758
	Z131	-1934.95	-2363.81	-2167.82	-2282.69	-2067.37	-2791.21	-2614.77	-1770.12	-2466.38	-2039.63	-2522.52	-1940.19	-1946.65	-2120.04	-2693.18	-2018.48	-2696.40
	NDVImax (MODIS)	0.76	0.78	0.73	0.78	0.77	0.77	0.76	0.76	0.80	0.82	0.82	0.79	0.83	0.84	0.83	0.83	0.84
Karnal	**Yield**	4395	4635	4580	4363	4138	4183	4367	4423	4629	4601	4518	4670	5670	4912	4046	4543	5212
	Z41	9.71	8.57	34.04	10.85	-14.22	-1.05	4.02	-12.25	7.73	10.39	12.08	5.12	36.32	4.55	-11.45	-17.03	-3.80
	Z230	16053.73	17847.26	19116.87	19958.49	20369.28	18076.10	20010.13	17108.26	19894.71	18848.47	18855.91	17758.99	17925.56	18083.11	19185.72	19367.65	18480.04
	Z451	-225.09	1586.86	208.84	-341.22	-243.17	-1158.36	877.09	-322.05	486.46	225.44	-183.06	-119.54	6385.68	1413.93	-5144.58	-382.51	-1013.38
	NDVmax (MODIS)	0.82	0.84	0.84	0.83	0.82	0.83	0.8	0.8	0.86	0.82	0.85	0.83	0.86	0.85	0.85	0.85	0.86

Table 3: Agromet regression model equation for Hisar and Karnal districts

Location	Regression Equation	Adjusted R^2	R^2
Hisar	Y= 5942.17+0.73(Z131)	0.38	0.42
Karnal	Y =5237.23+6.44(Z41)-0.04(Z230) + 0.12(Z451)	0.78	0.83

Table 4: Validation of Agromet models

Location	Observed Yield (Kg/hac.)		Regression Equation	Predicted Yield (Kg/ha)			
	2015-2016	2016-2017		2015-2016	% Deviation	2016-2017	% Deviation
Hisar	4310	4758	Y=5942.17+0.73(Z131)	4474.30	3.80	3973.79	-16.48
Karnal	4543	5212	Y=5237.23+6.44(Z41)-0.04(Z230)+0.12(Z451)	4283.46	-5.70	4351.97	-16.50

Table 5: Regression yield model equation developed with addition of NDVI (MODIS) for Hisar and Karnal district

Location	Regression Equation	Adjusted R^2	R^2
Hisar	Y=1850.72 +0.77 (Z131) +5318.85 ($NDVI_{max}$)	0.61	0.66
Karnal	Y=354.78 + 1.99 (Z41)-0.05(Z230) + 0.13 (Z451) + 6155.59($NDVI_{max}$)	0.86	0.90

Table 6: Validation of Agromet-spectral (MODIS-NDVI) Yield models for wheat yield estimation for districts Hisar and Karnal during 2015-16& 2016-17

Location	Observed Yield (Kg/ha)		Regression Equation	Predicted Yield (Kg/ha)			
	2015-16	2016-17		2015-16	% Deviation	2016-17	% Deviation
Hisar	4310	4758	Y=1850.72+0.77(Z131)+5318.85($NDVI_{max}$)	4701.5	8.32	4242.3	10.84
Karnal	4543	5212	Y=354.78 + 1.99 (Z41)-0.05(Z230) + 0.13 (Z451) + 6155.59($NDVI_{max}$)	4479.2	1.42	4590.4	11.93

Conclusion

The main objective of the study was to develop a best fit regression model for early wheat yield forecasting during wheat growing season using weather parameters (viz. max. and min. temperature, morning and evening relative humidity and rainfall). The agromet models were developed on the basis of correlations of wheat yield and weather parameters of*rabi* season (October to March) for the period of fifteen years (2000-2015). The results revealed that weather model alone worked (forecast) well for yield prediction for both Hisar and Karnal regions. Further, to increase the accuracy of models remote sensing data (NDVI) was integrated in weather models that gave high coefficient of determination. The result was better for Karnal as compared to Hisar due to different climatic condition or continuous wheat growing area and high soil moisture retentation capacity. MODIS derived NDVI (exact wheat pixels in field) was tested by integrated with Agrometmodel**.**It was found that the weather model integrated with MODIS-NDVI gave more accurate model for wheat yield estimation. The result revealed that maximum temperature and morning R_H are determining factors for prediction of wheat yield at Hisar. By inclusion of NDVI as another variable the model accuracy was highest (Adjusted R^2=0.61) and error were 8% & 10% for

(2015-16 &2016-17). Similarly, minimum temperature & R_H (morning and evening) were determining factor for yield prediction at Karnal. By Integration of NDVI, the model accuracy reached to highest among all previous models (Adjusted R^2=0.86). The errors were 1.4% and 11.9% for the two year *i.e.* 2015-16 & 2016-17 for validation of wheat yield.The results also emphasis that NDVI values can be a good estimator of crop yield and used for yield estimation and prediction. Agromet models with integration of satellite based NDVI (MODIS) data can help to predict wheat yield with highest accuracy in comparison to Agromet. This study could help the provincial government of Haryana as well as in northern plains in estimation of yield prior harvest at first week of April by using weather spectral (NDVI-MODIS) models.

Conflict of interest

The authors declare that they have no conflict of interest.

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Statistical and temporal trends analysis of rainfall in Bundelkhand region, Central India

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ABSTRACT

Three timescale i.e. monthly, seasonal and annual rainfall data of Bundelkhand region, Central India, was analyzed for 40 years (1981-2020). The annual mean average rainfall for the region ranges between 657.7 mm and 1146.4 mm for the studied period with the month August receiving the highest amount of rainfall. The region receives about 90 % of its annual rainfall during South West Monsoon period i.e. from June to September. Temporal trend of rainfall for different timescale was analysed using nonparametric Mann-Kendall test and Sen's slope estimator. Increasing and decreasing trend were found for the three timescale in which the study was carried out. Annual rainfall trend of Bundelkhand region is found to follow decreasing trend except for Sagar district. A decreasing South West Monsoon rainfall trend was also observed in 11 districts of Bundelkhand region.

Introduction

Producing enough food for growing population is a great challenge for mankind due to persistently growing pressure on finite freshwater and soil resources. According to 2011 census 54.6 % of Indian citizens are dependent on agriculture and its allied sectors to it. Agriculture contributes about 17 % to India's Gross Value added and hence it is very vital for the economic growth in India (GoI, 2016-17). Availability of the required water at the correct time is one of the main factors which affect agricultural production and power consumption in agricultural sector in the country. Irrigated land, covering 40% of India's agricultural land has contributed extensively to meeting 55% of the country's demand for food (GOI,2012). But on the other hand, there is a limited room for further expansion of the irrigation area as it uses nearly 70% of fresh water resources (CWC,2005) .Therefore, development of rainfed agriculture will help in achieving national food security in the future (Wani *et al.,* 2009, 2012).

According to Intergovernmental Panel on Climate Change **(**IPCC), by 2020, India will be negatively affected by greater climate variability, higher temperatures, and significant reductions in summer rains in some areas, as well as water stress (Cruz *et al.,* 2007). Once in every eight years, Bundelkhand region is affected by severe drought (Alam *et al.,* 2012 and 2014). This reveals the inevitable impact of changing climate in Bundelkhand region. Lack of water availability is the main factor which limits production of crop in this region (Alam *et al.,*2016). Agricultural failure has become a repeated trend in this region (Jain, 2009). Analysing the prevailing

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trend of Indian summer monsoon rainfall is a necessity (Guhathakurta and Rajeevan,2008). Precipitation trends have been analysed in several countries at different scales in the last century. Many studies were conducted to find outrainfall trends in India at different spatial scales, but it was found that rainfall trends are different for each regional level (Krishnakumar *et al.,* 2009). Therefore, the current study was conducted to identify the different characteristic of rainfall and its monthly, seasonal and annual trends to present reliable scientific knowledge for the effective preparation, planning, design and managing the limited water resources for the improvement of agricultural production under current climate change scenarios.

Material and Methods

General Features of the Study Area

Bundelkhand region is located in the transitional

Figure 1: Map of study area

zone between peninsular plateau and northern plain and comprises of 7 districts of Uttar Pradesh and 6 districts of Madhya Pradesh. It is located between 23° 8'– 26° 30' N and 78° 11'- 81° 30' E covering a total geographical area of 7.085 million ha and a forest cover of 17.63% (FSI, 2005). The region is located at 230 to 280 m above mean sea level (MSL).The agro-climate is characterized in three distinct seasons, viz. summer, rainy and winter. The mean temperature of region varies from 3 °C to 49 °C. During summer the temperature is about 34 °C and can go up to 46 °C to 49 °C.During winter the area have a mean temperature of 16 °C and it can decrease up to 3 °C to 5 °C during December and January. The relative humidity in Bundelkhand ranges from 40 to 60 %.

Bundelkhand region is receiving an annual rainfall of 800 to 1300 mm. Hard rocks such as Archaen granite, gneiss, metamorphic and igneous rocks are found in its geomorphology. The aquifers are either perched or unconfined with low water storage capacity. In this poorly permeable hard rock aquifer, shallow wells are the main resource of water for different activities. Agricultural productivity is about 0.5-1.5 t/ha which is a result of undulating terrain, low groundwater potential, high temperatures, low and unreliable rainfall. Depending on rain and temperature, different crops in Bundelkhand region have 90 and 150 days growing period. Figure 1 is showing the map of the study area.

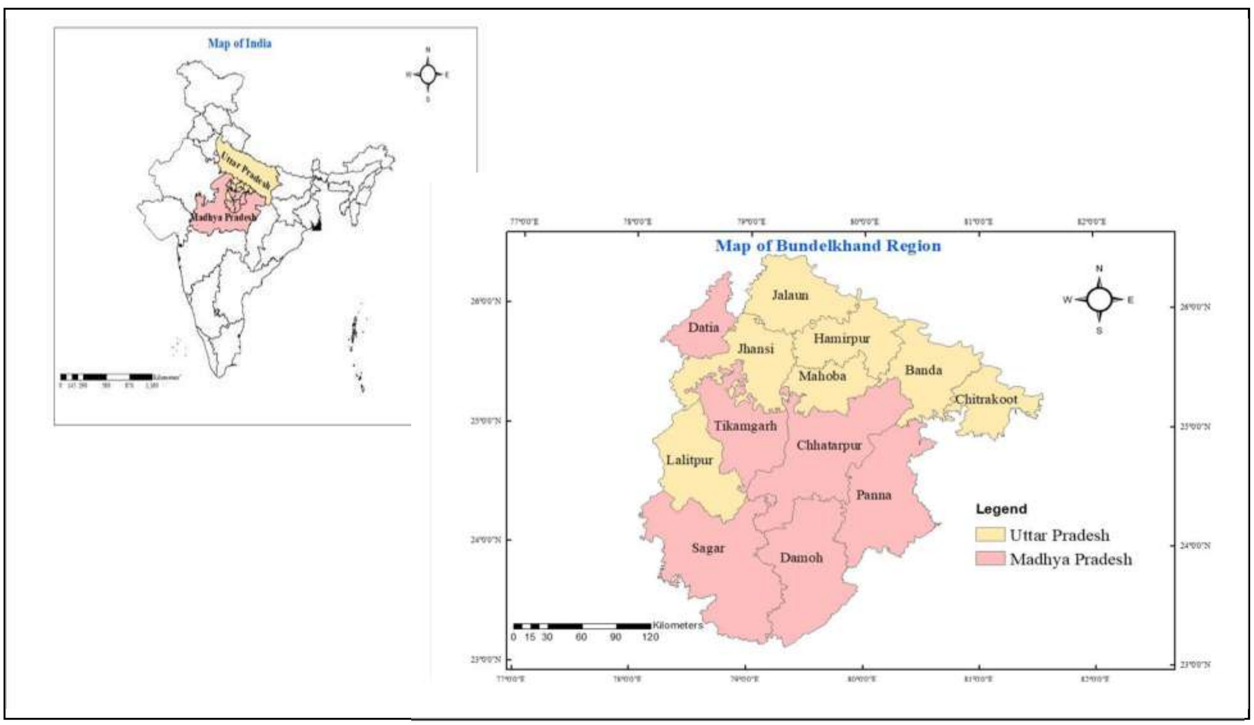


Figure 1 : Map of study area

Data Collection and Methodology

Daily gridded rainfall data of 0.25X0.25 degree spatial resolution covering all the district of Bundelkhand region was obtain from India Meteorological Department (IMD), Pune, India for the period of 1981 to 2020 (Pai *et al.,* 2014) . Monthly, annual and seasonal rainfalls were constructed using the daily rainfall data. The entire year was divided into four seasons viz., Pre monsoon (March-May), South West monsoon (June-September), Post monsoon (October to November) and Winter (December to February) in order to analyze the seasonal rainfall pattern. The mean, standard deviation and coefficient of variations of the rainfall data were analysed.75% dependable rainfall was also calculated for different timescale using Weibull's plotting position method (Weibull, 1939). An attempt was also made to detect rainfall trend using the nonparametric Mann-Kendall test (Mann, 1945; Kendall, 1975: Bayazit and Onoz, 2007). The nonparametric Sen's method (Gilbert, 1987) was used to determined the slope of a linear trend. Figure 2 represents the methods used during trend analysis.

Results and Discussion

Rainfall Characteristics

Statistical parameters of rainfall for 13 districts of Bundelkhand region of Central India are shown in Table 1. The results of average monthly analysis shows that for all the studied districts January, February, March, April, May, November and December received less than 20 mm rainfall for the studied period i.e. 1981 to 2020. A rainfall depth of 66.8 mm to 153.8 mm was received in the month of June. Minimum rainfall depth of 199.2 mm was observed in Jalaun district while Sagar district received a maximum rainfall depth of 348.2 mm for the month of July. The rainfall depth varies between 188.7 mm to 366.6 mm and 125.1 mm to 189.4 mm for the month of August and September respectively. The rainfall depth varies between 22.7 mm in Sagar district to 36.6 mm in Chitrakoot district for the month of October. The average annual rainfall ranges between 657.7 mm in Jalaun district to 1146.4 mm in Sagar district. Figure 3 shows the annual variations of rainfall for different districts of Bundelkhand region from 1981 to 2020. The highest average annual rainfall was 1548.4 mm for Chhatarpur district in the year 2016 while the lowest average annual rainfall was found at Jalaun district with rainfall depth of 205.1 mm in the year 2012. During Pre Monsoon period the region received a rainfall depth of 13.6 mm in Lalitpur district to 25.1 mm in Banda district.

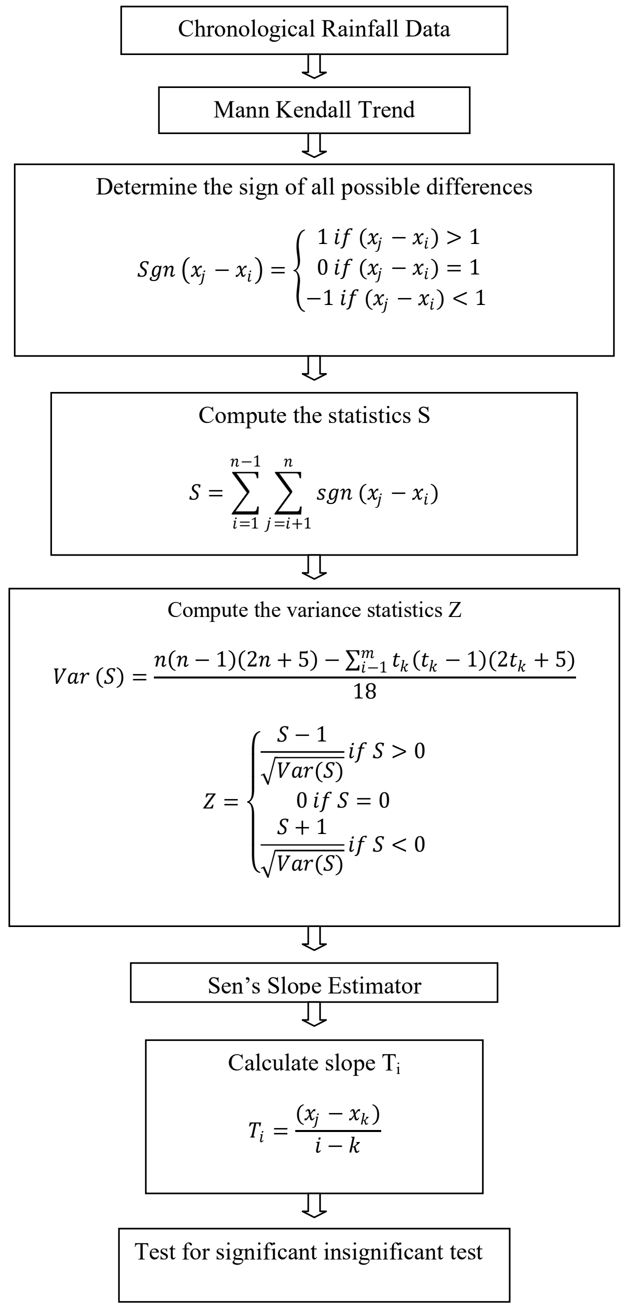


Figure 2: Methodology for calculating trend and slope of rainfall.

Table 1: Statistical parameters of rainfall over Bundelkhand region from 1981 to 2020 for characterization of rainfall.

Districts		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Pre**	**Swm**	**Post**	**WIn**
Jalaun	Mean	12.3	11.2	5.0	3.9	8.3	66.8	199.2	188.7	125.1	30.0	2.7	4.5	657.7	17.2	579.7	32.7	28.0
	S.D	18.4	19.2	9.9	8.2	9.3	54.0	81.7	100.4	105.3	44.0	8.6	7.2	225.5	18.5	203.2	43.9	30.3
	C.V	149.5	171.3	197.1	209.6	112.7	80.8	41.0	53.2	84.2	146.7	316.1	161.6	34.3	107.8	35.1	134.1	108.2
	75%	-1.2	-2.7	-1.9	-1.4	1.3	26.0	139.5	113.6	45.0	-3.0	-2.5	-0.9	496.6	3.5	436.5	-0.5	5.2
	% Con	1.9	1.7	0.8	0.6	1.3	10.2	30.3	28.7	19.0	4.6	0.4	0.7	100.0	2.6	88.2	5.0	4.3
Jhansi	Mean	10.2	12.8	6.3	5.5	9.4	85.4	224.9	243.0	139.8	29.9	2.8	5.0	775.0	21.1	693.1	32.7	28.0
	S.D	14.4	19.7	11.1	11.0	8.5	73.6	77.6	114.7	125.2	48.7	6.8	10.9	232.6	20.1	207.8	48.9	31.4
	C.V	141.5	154.1	178.3	200.4	90.6	86.1	34.5	47.2	89.5	162.9	241.5	217.5	30.0	95.1	30.0	149.5	112.0
	75%	-0.6	-1.8	-1.8	-1.9	2.9	29.7	170.4	156.2	44.7	-6.0	-1.8	-2.4	600.1	5.9	541.6	-3.7	4.2
	% Con	1.3	1.7	0.8	0.7	1.2	11.0	29.0	31.4	18.0	3.9	0.4	0.6	100.0	2.7	89.4	4.2	3.6
Hamirpur	Mean	13.4	12.7	6.9	4.6	11.0	84.9	217.3	231.8	142.2	28.9	2.1	4.5	760.3	22.5	676.2	31.1	30.6
	S.D	16.0	20.2	13.2	8.1	10.8	73.9	92.0	95.6	107.4	41.9	4.8	6.7	201.5	20.1	193.4	41.8	30.0
	C.V	119.8	159.5	191.6	177.8	97.7	87.0	42.3	41.2	75.5	144.7	222.8	147.4	26.5	89.6	28.6	134.5	98.2
	75%	1.2	-2.1	-2.2	-1.0	2.8	28.5	149.7	162.5	60.5	-2.3	-1.1	-0.5	613.9	7.2	535.4	-0.3	7.6
	% Con	1.8	1.7	0.9	0.6	1.4	11.2	28.6	30.5	18.7	3.8	0.3	0.6	100.0	3.0	88.9	4.1	4.0
Mahoba	Mean	12.8	14.8	6.3	4.3	11.5	91.9	240.5	258.3	151.8	27.8	3.5	5.1	828.4	22.0	742.5	31.2	32.7
	S.D	15.5	21.0	10.9	6.7	13.1	84.3	88.1	112.8	123.8	40.5	9.0	12.1	235.7	20.0	239.0	43.3	30.7
	C.V	121.2	141.8	173.7	157.7	113.8	91.8	36.6	43.7	81.6	146.1	260.1	237.1	28.5	91.0	32.2	138.5	93.8
	75%	1.0	-1.0	-1.7	-0.7	1.8	28.4	178.3	175.4	58.5	-2.4	-2.4	-2.9	656.8	7.0	569.0	-1.3	9.3
	% Con	1.5	1.8	0.8	0.5	1.4	11.1	29.0	31.2	18.3	3.4	0.4	0.6	100.0	2.7	89.6	3.8	3.9
Banda	Mean	14.8	14.4	6.7	5.1	13.2	100.8	225.3	247.7	155.6	29.9	2.1	5.8	821.5	25.1	729.4	32.0	35.0
	S.D	18.8	21.0	13.8	8.8	14.8	97.6	101.4	96.5	112.6	44.3	5.0	8.9	200.0	26.1	191.2	44.0	35.6
	C.V	127.0	146.1	205.1	172.8	112.0	96.8	45.0	39.0	72.4	148.2	235.1	153.8	24.4	103.9	26.2	137.4	101.7
	75%	0.6	-1.1	-2.6	-1.1	2.0	27.5	149.5	175.2	69.6	-3.3	-1.3	-0.8	673.0	5.9	590.0	-1.1	8.2
	% Con	1.8	1.8	0.8	0.6	1.6	12.3	27.4	30.2	18.9	3.6	0.3	0.7	100.0	3.1	88.8	3.9	4.3
Chhitrakoot	Mean	12.9	17.2	6.4	4.3	10.7	101.5	247.3	252.5	184.2	36.6	2.6	6.4	882.7	21.4	785.5	39.2	36.6
	S.D	16.6	25.6	13.0	7.9	14.5	90.9	89.7	85.2	109.8	46.2	6.5	8.3	189.1	27.7	168.0	45.7	35.6
	C.V	128.3	148.7	203.0	184.4	136.1	89.6	36.3	33.7	59.6	126.2	249.5	129.7	21.4	129.7	21.4	116.4	97.4
	75%	0.6	-1.5	-2.5	-1.0	-0.2	32.1	183.0	190.0	102.7	1.8	-1.7	0.1	784.6	1.6	667.6	4.8	9.5
	% Con	1.5	1.9	0.7	0.5	1.2	11.5	28.0	28.6	20.9	4.1	0.3	0.7	100.0	2.4	89.0	4.4	4.1

Lalitpur	Mean	10.5	11.9	5.4	2.1	6.0	111.8	278.0	296.5	145.5	25.2	4.2	5.1	902.3	13.6	831.8	29.4	27.5
	S.D	15.2	18.9	10.4	5.1	7.3	124.7	115.7	139.4	143.5	46.6	11.9	12.0	252.6	15.0	236.9	51.0	34.2
	C.V	144.6	159.0	191.7	240.2	121.7	111.5	41.6	47.0	98.6	184.7	282.1	235.8	28.0	110.4	28.5	173.4	124.1
	75%	-0.9	-2.1	-2.0	-1.2	0.5	22.7	192.6	193.1	37.3	-7.7	-3.3	-2.6	714.9	2.3	657.1	-7.4	2.6
	% Con	1.2	1.3	0.6	0.2	0.7	12.4	30.8	32.9	16.1	2.8	0.5	0.6	100.0	1.5	92.2	3.3	3.0
Datia	Mean	9.7	11.6	4.2	4.0	9.6	75.0	209.6	218.3	129.2	27.0	3.3	6.1	707.8	17.9	632.2	30.3	27.4
	S.D	16.1	17.9	8.0	8.0	12.2	59.5	76.6	97.0	111.5	41.8	10.4	16.4	193.8	18.4	172.7	42.2	29.7
	C.V	165.6	153.7	190.3	197.2	126.8	79.3	36.5	44.4	86.3	154.9	313.7	270.5	27.4	103.0	27.3	139.1	108.3
	75%	-1.8	-1.7	-1.4	-1.2	0.5	30.7	153.5	147.2	45.2	-4.2	-2.9	-3.7	562.0	4.1	505.3	-1.5	4.9
	% Con	1.4	1.6	0.6	0.6	1.4	10.6	29.6	30.8	18.3	3.8	0.5	0.9	100.0	2.5	89.3	4.3	3.9
Tikamgarh	Mean	11.4	14.1	7.2	4.4	8.8	98.5	261.1	299.4	158.5	29.0	3.5	5.5	901.4	20.4	817.5	32.5	31.0
	S.D	16.9	19.9	13.6	6.7	10.4	98.6	92.0	137.6	152.0	55.2	7.7	12.2	259.6	21.4	246.9	56.9	36.4
	C.V	148.3	141.8	188.8	152.3	118.6	100.2	35.2	46.0	95.9	190.4	222.9	221.5	28.8	104.8	30.2	175.2	117.5
	75%	-1.2	-0.9	-2.5	-0.6	1.1	25.0	197.7	196.2	45.0	-9.3	-1.9	-2.8	709.6	4.3	639.4	-7.8	3.8
	% Con	1.3	1.6	0.8	0.5	1.0	10.9	29.0	33.2	17.6	3.2	0.4	0.6	100.0	2.3	90.7	3.6	3.4
Chhatarpur	Mean	13.6	15.7	7.0	4.8	9.6	121.3	290.6	334.0	177.4	30.1	4.2	5.4	1013.7	21.3	923.3	34.3	34.8
	S.D	17.4	19.7	11.8	7.9	9.9	103.1	106.2	139.2	140.1	45.4	11.9	12.7	256.1	21.9	253.1	49.4	32.3
	C.V	127.3	125.6	169.5	164.6	103.1	85.0	36.5	41.7	79.0	150.9	280.4	234.4	25.3	102.6	27.4	144.0	92.8
	75%	0.5	0.8	-1.7	-1.0	2.0	43.0	214.9	228.0	71.7	-3.4	-3.3	-2.8	825.5	4.7	738.9	-2.6	10.2
	% Con	1.3	1.6	0.7	0.5	0.9	12.0	28.7	32.9	17.5	3.0	0.4	0.5	100.0	2.1	91.1	3.4	3.4
Panna	Mean	15.7	16.6	7.0	2.8	6.6	128.1	307.2	337.6	185.5	27.6	4.2	4.1	1043.0	16.4	958.4	31.8	36.4
	S.D	22.4	22.0	12.9	4.3	9.0	103.6	139.3	134.1	158.3	37.2	13.1	9.1	278.6	20.5	277.6	44.0	38.3
	C.V	142.5	132.8	184.1	153.8	137.2	80.9	45.3	39.7	85.3	134.8	312.3	220.3	26.7	125.1	29.0	138.4	105.1
	75%	-1.2	0.0	-2.2	-0.4	-0.2	49.0	204.0	236.1	66.9	-0.2	-3.6	-2.1	832.6	1.1	749.2	-0.7	7.7
	% Con	1.5	1.6	0.7	0.3	0.6	12.3	29.5	32.4	17.8	2.6	0.4	0.4	100.0	1.6	91.9	3.0	3.5
Damoh	Mean	14.1	16.9	7.4	4.0	8.0	144.3	328.6	350.8	170.1	24.1	5.9	5.1	1079.5	19.4	993.8	30.0	36.2
	S.D	19.9	24.6	12.4	8.3	10.2	125.2	150.6	136.8	134.4	29.4	17.6	11.4	267.5	21.4	268.7	40.5	36.2
	C.V	140.4	145.5	166.6	209.1	126.8	86.7	45.8	39.0	79.0	121.7	299.6	221.1	24.8	110.2	27.0	134.9	100.1
	75%	-0.8	-1.6	-1.7	-1.6	0.3	50.3	215.8	250.0	68.2	2.2	-4.7	-2.6	879.0	3.3	793.3	0.0	8.6
	% Con	1.3	1.6	0.7	0.4	0.7	13.4	30.4	32.5	15.8	2.2	0.5	0.5	100.0	1.8	92.1	2.8	3.4
Sagar	Mean	12.3	16.4	8.8	3.3	9.6	153.8	348.2	366.6	189.4	22.7	7.9	7.4	1146.4	21.7	1058	30.6	36.1
	S.D	22.7	26.1	14.3	5.7	13.2	135.1	143.1	150.3	160.4	31.2	22.6	16.8	298.9	21.7	292.4	47.2	38.6
	C.V	184.5	158.7	163.5	170.0	137.1	87.9	41.1	41.0	84.7	137.7	287.2	226.5	26.1	99.8	27.6	154.5	106.8
	75%	-3.7	-2.6	-1.8	-0.8	-0.2	53.1	241.1	255.2	68.5	-0.6	-6.2	-3.5	923.1	5.2	839.4	-3.8	7.1
	% Con	1.1	1.4	0.8	0.3	0.8	13.4	30.4	32.0	16.5	2.0	0.7	0.6	100.0	1.9	92.3	2.7	3.2

Sagar district received rainfall depth of 1058 mm during South West Monsoon Period while Jalaun district received only 579.7 mm rainfall depth. The Post Monsoon rainfall varies from 29.4 mm in Lalitpur district to 39.2 mm in Chitrakoot district. A rainfall depth of 27.4 mm to 36.6 mm was received during winter season. Figure 3, 4, 5, 6 and 7 represent the seasonal variations of rainfall respectively over the studied period. Jhansi district in the year 1984, Lalitpur district in the year 2003 and 2012, Tikamgarh district in 1984 and Damoh district in 2003 did not received rainfall during Pre Monsoon season.

Chitrakoot district received the highest Pre Monsoon rainfall of 122.7 mm in 2020. Sagar district in the year 2013 received the highest south west monsoon of 1730 mm while the lowest 186.8 mm was received in 2012 at Jalaun district The Post Monsoon season showed the highest amount of rainfall Tikamgarh district in the year 1985. There was no winter season rainfall received in the year 2006 for all the districts and Lalitpur district have the highest winter season rainfall of 183.6 mm in the year 2014.

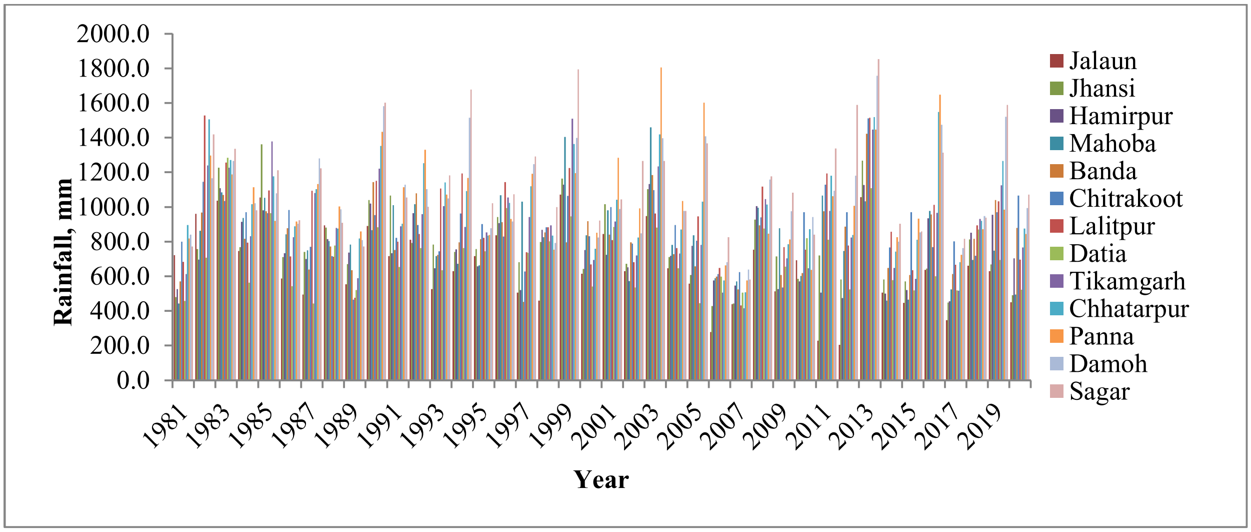


Figure 3: Annual variations of rainfall over Bundelkhand from 1981 to 2020

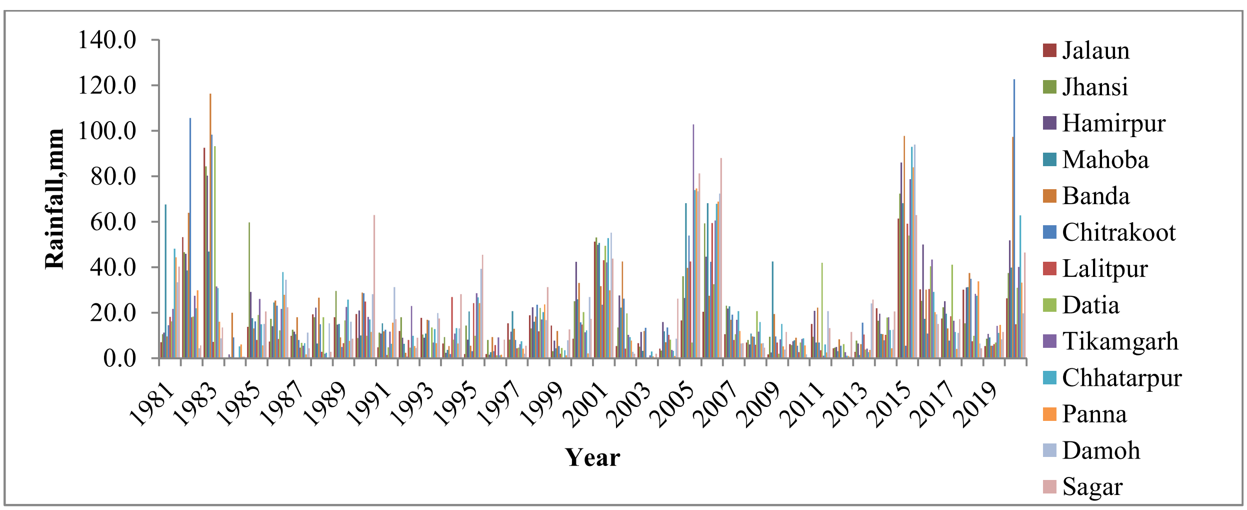
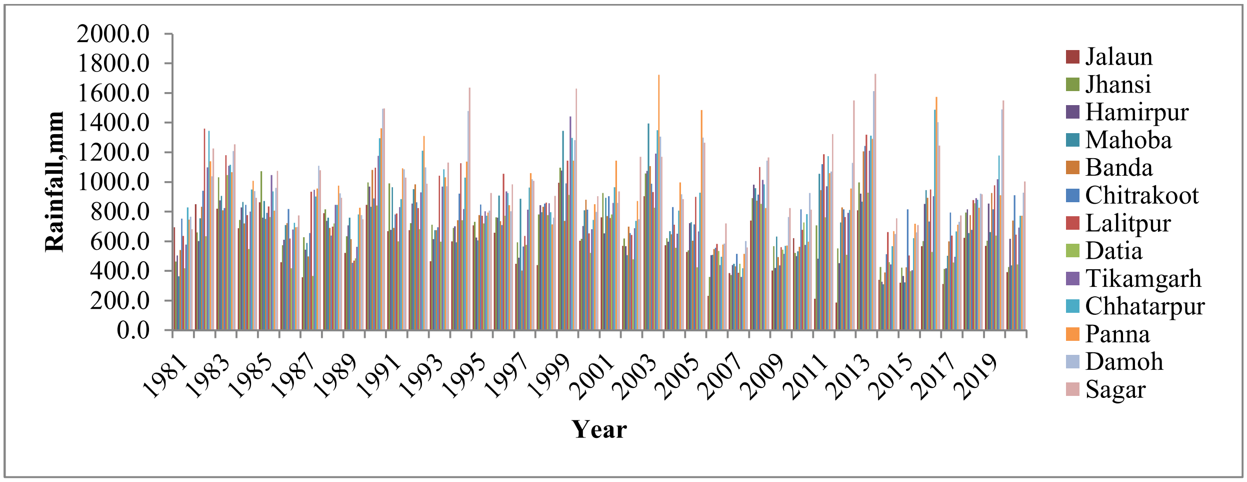


Figure 4: Pre Monsoon (March-May) variations of rainfall of Bundelkhand from 1981 to 2020



.Figure 5: South West monsoon (June-September) variations of rainfall over Bundelkhand from 1981 to 2020

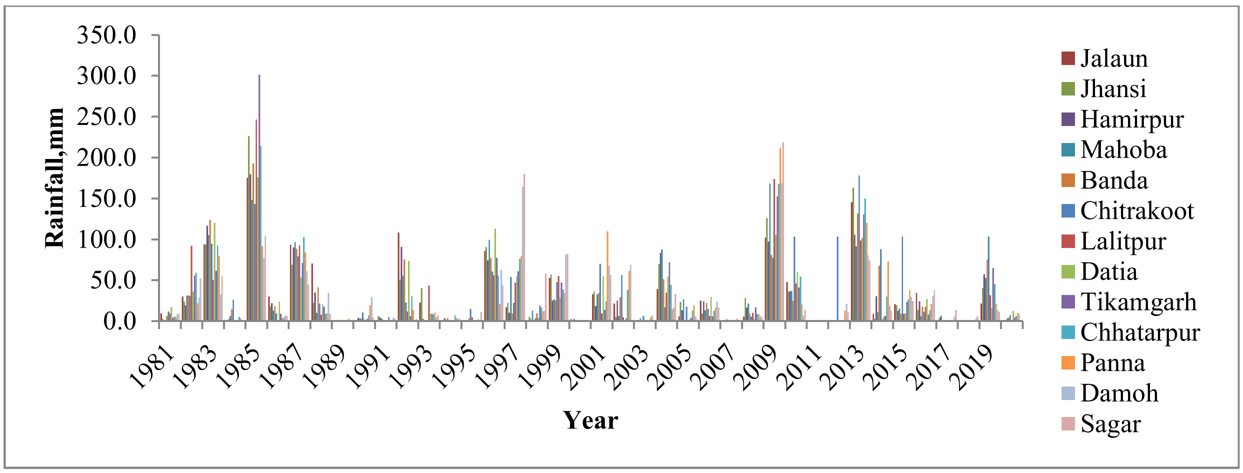


Figure 6: Post Monsoon (Oct- Nov) variations of rainfall over Bundelkhand from 1981 to 2020

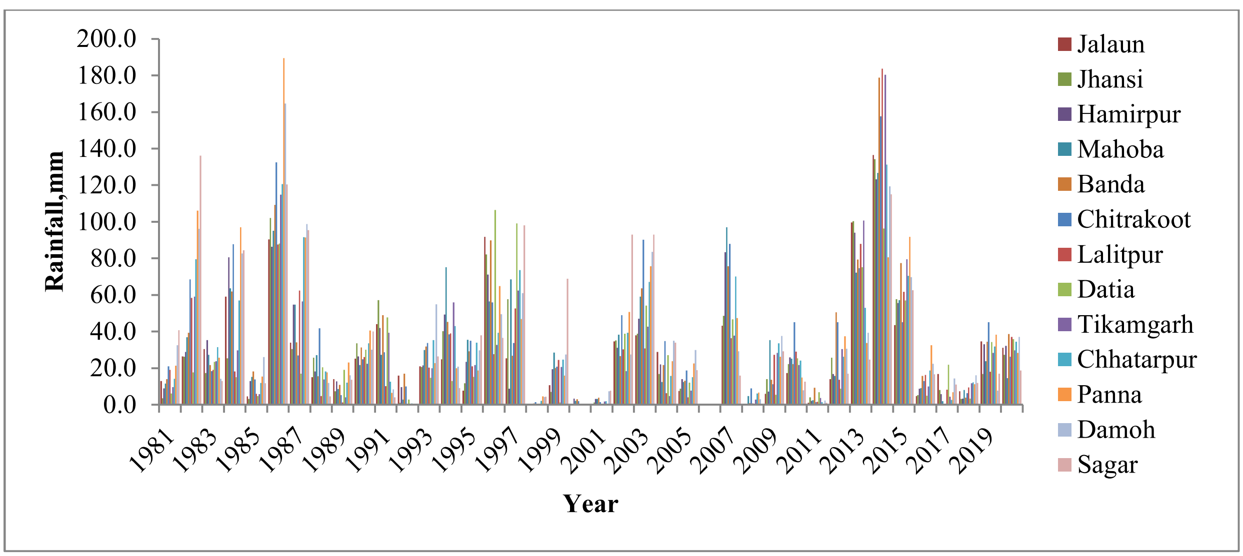


Figure 7: Rainfall variations in Winter Season (Dec- Feb) over Bundelkhand from 1981 to 2020

The monthly standard deviations values show that except for Damoh district, all the remaining district of Bundelkhand region, the month of September have the highest standard deviation. The annual standard deviation ranges from 189.1 mm in Chitrakoot district to 298.9 mm in Sagar district. Minimum 15 mm and maximum 27.7 mm value of standard deviation for Pre Monsoon season was observed in the district of Lalitpur and Chitrakoot respectively. The standard deviation of South West Monsoon season varies from 168 mm in Chitrakoot district and 292.4 mm in Sagar district. The standard deviation of Post Monsoon season and Winter Season were found to be in the range of 40.5 mm to 56.9 mm and 29.7 mm to 38.6 mm respectively.

The coefficient of variation value of the monthly rainfall showed that November has the highest value in the entire district ranging from 222.8 % for Hamirpur district to 316.1 % for Jalaun district. The annual coefficient of variation ranges from 24.4 % in Banda district to 28.8 % in Tikamgarh district. From the seasonal coefficient of variation analysis Tikamgarh district have the highest value of 175.2 % during Post Monsoon Season and lowest value of 21.4 % in Chitrakoot district during South West Monsoon Period.

The annual 75 % dependable rainfall varies from 496.6 mm to 923.1 mm in Jalaun and Sagar districts respectively. Jaluan district have the lowest 75 % dependable rainfall of 436.5 mm for South West Monsoon Period while Sagar district have the highest value of 839.4 mm. Except Chhatarpur district during the winter season, the Pre Monsoon, Post Monsoon and Winter season have less than 10 mm 75 % dependable rainfall. 10.2 mm of 75 % dependable rainfall was observed in Chhatarpur district during the winter season.

Seasonal evaluation showed that South-West monsoon contributes about 90% of the total annual rainfall which is also given by Singh *et al.*(2002). The Post Monsoon and Winter Season contribution to annual rainfall is about 4 % each. About 2 % of the annual rainfall comes from Pre Monsoon rainfall in Bundelkhand region.

Rainfall Trend

The Mann-Kendall trend, its statistical significance and Sen's slope magnitude of rainfall for the period of 1981 to 2020 are shown in Table 2.

Monthly Rainfall Trend

A decreasing rainfall trend was observed for the month of January but only Hamirpur district show a significant trend at 0.1 level of significance. 6 districts viz. Jalaun, Jhansi, Chitrakoot, Panna, Damoh and Sagar show a non-significant decreasing trend while the remaining 7 districts show a non-significant increasing trend for the month of Febuary. All 13 districts show a non-significant increasing trend for the month of March. Sagar district shows an increasing trend for the month of April significant at 0.01 level of significance. No significant increasing or decreasing trend was observed for the month of May, June and July in all the districts. A decreasing trend was observed for the month of August in all the district. Among them Jalaun and Datia show a decreasing trend at 0.1 level of significance while Jhansi district shows a decreasing trend at 0.05 level of significance. Damoh and Sagar districts show an increasing trend for September. Jalaun and Hamirpur districts show a significant decreasing trend at 0.01 level of significance while Jhansi and Mahoba districts show a decreasing trend at 0.05 level of significance. The month of October, November and December show a non-significant increasing and decreasing trend.

Annual Rainfall Trend

Except Sagar district, the other 12 districts show a decreasing annual rainfall trend for the period of 1981 to 2020. Jalaun and Jhansi districts show an annual rainfall decreasing trend significant at 0.01 level of significance. Hamirpur and Mahoba districts show a decreasing annual rainfall trend at 0.1 level of significance.

Seasonal Rainfall Trend

Jhansi, Chritrakoot, Chhatarpur, Panna and Damoh show a non-significant decreasing Pre Monsoon rainfall trend but the remaining districts show a non-significant increasing trend. Banda and Sagar districts show an increasing South West Monsoon rainfall trend but these trends are insignificant. A decreasing South West Monsoon rainfall trend was observed in the remaining 11 districts. Among them two districts i.e. Jalaun and Jhansi show a significant decreasing trend at 0.01 level of significance and 0.05 level of significance respectively. Panna and Chitrakoot districts show a non-significant increasing Post Monsoon trend while the remaining districts show a non-significant decreasing trend.

Table 2: Mann Kendall (Z) values, Significance (α) and Sen's slope (Q) values over Bundelkhand region from 1981 to 2020

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Pre	Swm	Post	Win
Jalaun	Z	-0.40	-0.64	0.32	0.19	0.03	-0.47	-1.19	-1.89	-3.05	-1.21	0.40	-1.04	-2.84	0.23	-3.03	-1.20	-0.42
	α								+	**				**		**		
	Q	-0.03	-0.02	0.00	0.00	0.00	-0.40	-1.48	-2.62	-3.00	-0.02	0.00	0.00	-9.05	0.06	-7.76	-0.13	-0.09
Jhansi	Z	-0.70	-0.11	0.60	1.43	-0.37	-0.48	-0.34	-1.99	-1.99	-0.79	0.08	-0.53	-2.64	-0.43	-2.48	-0.77	-0.07
	α								*	*				**		*		
	Q	-0.03	0.00	0.00	0.04	-0.04	-0.41	-0.34	-3.31	-2.02	-0.02	0.00	0.00	-6.62	-0.07	-6.71	-0.05	0.00
Hamirpur	Z	-1.75	0.07	0.73	0.49	-0.08	0.36	0.10	-1.11	-2.62	-0.47	0.68	-0.69	-1.71	0.62	-1.50	-0.55	-0.85
	α	+								**				+				
	Q	-0.23	0.00	0.01	0.01	-0.01	0.17	0.10	-2.17	-2.45	-0.01	0.00	0.00	-5.81	0.14	-5.12	-0.06	-0.26
Jalaun	Z	-1.45	0.16	0.72	1.23	-0.28	-0.17	-0.29	-1.08	-2.20	-0.44	1.28	0.27	-1.83	0.15	-1.50	-0.64	-0.89
	α									*				+				
	Q	-0.19	0.00	0.00	0.03	-0.03	-0.17	-0.35	-2.12	-2.15	-0.02	0.00	0.00	-6.19	0.02	-5.04	-0.10	-0.24
Banda	Z	-1.29	0.61	0.14	-0.29	0.20	-0.71	0.97	-0.22	-1.41	-1.12	0.05	-1.03	-0.24	0.00	0.00	-1.33	-0.45
	α																	
	Q	-0.25	0.04	0.00	-0.01	0.02	-0.57	1.10	-0.34	-1.76	-0.10	0.00	0.00	-1.05	0.00	0.00	-0.15	-0.21
Chitrakoot	Z	-1.49	-0.06	0.72	0.49	0.30	-0.80	0.76	-0.41	-0.71	0.17	-0.36	0.12	-0.01	-0.57	-0.08	0.10	-0.45
	α																	
	Q	-0.14	0.00	0.02	0.00	0.01	-0.79	0.77	-0.40	-0.69	0.00	0.00	0.00	0.00	-0.09	-0.04	0.00	-0.17
Lalitpur	Z	-0.57	0.73	0.72	1.48	-0.02	1.06	-0.62	-1.01	-0.73	-0.98	0.03	0.02	-0.87	0.68	-0.80	-1.32	0.28
	α																	
	Q	0.00	0.01	0.00	0.00	0.00	0.80	-0.96	-1.44	-0.87	-0.02	0.00	0.00	-2.59	0.10	-3.46	-0.06	0.07
Datia	Z	-0.52	0.26	0.01	1.04	1.12	0.73	1.39	-1.83	-1.34	-1.41	0.71	-0.21	-0.66	0.64	-0.45	-0.98	0.19
	α								+									
	Q	0.00	0.00	0.00	0.02	0.10	0.43	1.35	-3.41	-1.23	-0.02	0.00	0.00	-1.29	0.10	-1.40	-0.04	0.06
Tikamgarh	Z	-1.01	0.28	0.26	0.78	0.16	0.22	-0.57	-1.13	-1.25	-0.46	0.33	-0.06	-1.62	0.13	-1.57	-0.45	-0.07
	α																	
	Q	-0.05	0.00	0.00	0.01	0.01	0.18	-1.18	-2.52	-1.56	0.00	0.00	0.00	-7.00	0.06	-6.36	-0.02	-0.02
Chhatarpur	Z	-0.99	0.08	0.16	0.09	0.22	-0.24	-0.20	-0.87	-1.15	-0.72	0.49	-0.52	-1.53	-0.03	-1.20	-0.80	-0.48
	α																	
	Q	-0.09	0.00	0.00	0.00	0.01	-0.27	-0.16	-1.88	-1.37	-0.05	0.00	0.00	-4.89	-0.02	-4.52	-0.08	-0.18
Panna	Z	-0.55	-0.29	0.71	0.64	-0.16	-0.17	0.41	-1.27	-0.94	0.44	0.00	-0.64	-1.29	-0.17	-1.01	0.13	-0.58
	α																	
	Q	-0.01	0.00	0.00	0.00	0.00	-0.26	0.78	-2.20	-0.94	0.04	0.00	0.00	-4.62	-0.02	-3.93	0.02	-0.28
Damoh	Z	-0.52	-0.71	0.13	1.44	-1.15	0.48	0.87	-1.22	0.24	0.00	0.37	-0.93	-0.34	-0.10	-0.20	-0.05	-0.86
	α																	
	Q	0.00	-0.03	0.00	0.02	-0.07	0.42	1.15	-2.48	0.37	0.00	0.00	0.00	-1.71	-0.01	-0.60	-0.01	-0.31
Sagar	Z	-1.47	-0.51	0.27	3.17	-1.08	0.76	0.99	-1.13	0.10	0.09	0.37	-0.60	0.00	0.50	0.03	-0.29	-1.12
	α				**													
	Q	-0.03	-0.01	0.00	0.07	-0.05	0.80	1.36	-2.62	0.09	0.00	0.00	0.00	0.00	0.12	0.37	-0.04	-0.43

***** if trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance, * if trend at α = 0.05 level of significance and + if trend at α = 0.1 level of significance.**

For winter season rainfall, Lalitpur and Datia districts show a non-significant increasing trend while the remaining 11 districts show a non-significant decreasing trend.

The decreasing trends in rainfall are supported by other researcher. Jana *et. al,*(2017),reported that rainfall pattern over Bundelkhand region is depicting a declining trends, and that the region is heading in the direction of drier time with more erratic rainfall behaviour. A declining annual rainfall trend was also observed in the studies conducted by Rai *et al.,* (2012), Thomas *et al.,* (2014) Deo *et al.,* (2015), Jain *et al.* ,(2017) and Ahmed *et al.,* (2019) which comply with the current findings of the studies.The decreasing trend of rainfall can be due to Chaurasia *et al.,* (2021) reported that the deviation in rainfall correlates with forest cover. Thus increasing forest cover which is far below the average recommended by Nation's Forest Policy can be one of the solution to reduce water woes in the region. Saharwardi *et al.,* (2021), stated that the decrease in rainfall over Bundelkhand region is due warmer sea surface temperature in the eastern Pacific. It was also reported that the increase occurrence of El-Nino events in recent years has led to a drought years in Bundelkhand region.

Gupta *et al.* ,(2014) noted that frequency of drought occurrence is increasing in Bundelkhand region and has become a recurring annual phenomenon since 2004.Thomas *et al.,*(2015) detailed an increase severity of meteorological drought in the region. Dubey *et al.,* (2017) has found a growing trend of drought event in Bundelkhand region. Saharwardi *et al.,* (2021) reported an increase in drought frequency in the since the starting of the 21st century.

Bhusan *et al.,* (1997) revealed that occurrence of dry spell during South West Monsoon season leads to crop failure in Bundelkhand region. Chand *et al.,*(2011) stated that rainfall plays a vital role for agriculture production in the region and reported that the crop production which is lower than the national average is mainly due to decrease trend in rainfall which prevails in the region. Dubey *et al.,*(2011) reported that the declining rainfall have contributed to the yield reduction of pulse crops. Gupta *et. al.*, (2021) reported that cultivated area for *Kharif* crops like paddy, peas and soybean cultivated areas have been declining in Bundelkhand region and that changing rainfall and climate trend corroborated to declining crop production. Ahmed *et al.,* (2019) reported that decreasing South West Monsoon rainfall have negative impact on the production of groundnut. Production of *Rab*i crops like wheat, berseem etc are likely to be affected in the coming era due to water shortages caused by declining rainfall.

Conclusion

The work presents an analysis of rainfall characteristics and its trend of Bundelkhand region in India. Rainfall was characterized using different statistical parameters. Monthly, annual and seasonal rainfall trend was studied using Man-Kendall Test and change in rainfall magnitude was detected using Sen's slope estimator. From the study it was found that the average yearly rainfall over Bundelkhand ranges from 657.7 mm to 1146.4 mm. The rainfall in the region is mainly concentrated in the four South West Monsoon months which are June, July, August and September. An alarming finding of the study is that the annual and south west monsoon is following a declining trend. From the study we suggested that rainfall received during south west monsoon months should be harnessed and conserved through soil and water conservation practices for year round water availability.

Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of scouring and laundering on functional properties of natural colour cotton fabric

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ABSTRACT

Natural color cotton is eco-supportive as they possess colour naturally in varied shades *viz.,* brown, green, cream and other tints and shades of these colours. It has unique comfort and handle property which provides soothing to the wearer. A medium brown natural colour cotton fibre was spun into 20s count yarn on open end spinning and the pure colour cotton fabric was developed on handloom and subjected to scouring. The scoured natural colour cotton fabric undergone with multiple wash cycles and assessed for mechanical, functional properties, colour fastness to sunlight and washing properties. Results revealed that, the scoured natural color cotton fabrics at washing and sunlight was found to be increase in color strength and decrease in reflectance than the pure NCC fabric. After laundering at multiple washes, the scoured natural colour cotton fabric exposed to direct sunlight, it was found that the colour strength was significantly reduced and fabric became lighter, duller and yellower. However, the scoured natural colour cotton fabric subjected to washing and shade dried exhibited significantly greater K/S, which indicates the sample became darker, brighter and greener than the sample expose to direct sunlight. The natural colour cotton fabrics has better mechanical, functional and fastness properties can be suitable for production of diversified cotton products ranging from children garments to trendy outfits. Hence, the promotion of natural colour cotton fabrics is a sustainable approach for green environment.

Introduction

Cotton is one of the world's most socially vital and economically important agricultural crop and also the king of textile. Millions of people depend on cotton cultivation which suffices the basic necessity of mankind and is known for its diversity, enormous utility, applicability, economic viability and advantageous properties. Cotton with natural colour lint other than white is commercially referred as colour cotton and is known to mankind ever since the existence of agriculture and even earlier to vedic period. Generally, due to smaller bolls and low ginning outturn of colour lint varieties are often low yielders with low productivity per unit area. The properties of colour cotton fibre are also poor in fibre length and strength values which is hardly machine spun. Other issues with these cottons include high whiteness percent, higher wax content, isolation distance requirements, the presence of only a few hues in consistency, and non-uniformity of fabric

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colour throughout seasons and locales. In spite of these draw backs, the naturally colour cotton is gaining popularity in the world market due to its eco friendliness. Throughout the value chain of white cotton a large amount of chemicals, acid dyes, reactive dyes and basic dyes are required to make the white cotton as coloured. Added to this, to process the white cotton *i.e.,* fibre to fabric high amount of water is required and large quantity of effluents are generated with high level of BOD, COD, TS and TDS which further leads to environment pollution (Ramesh babu *et al.,* 2007). Usage of synthetic for textile colouration leads to many ecological problems and human health hazards which has forced to driven the attention towards eco-friendly textiles. The eco fashion business has provided an opportunity for creativity to revitalize age-old fibres and environmentally sustainable processes. Naturally coloured cottons are gaining importance in the recent years due to the integration of ecology, fashion and public's rising interest in environmental issues and enviornment-friendly production processes. These naturally coloured cottons reduce or eliminate the costly dyeing and bleaching procedures. Due to its eco-friendly aspect, coloured cottons have created a growing niche market in the developed countries (Parmar and Shanna (2002). Certainly, naturally colored cotton is eco-supportive as they can be finished devoid of chemical dyes. Though it possesses many favorable features and also associated with some limitations *viz.*, short staple length and coarser structure eventually producing coarse quality fabric which in turn exhibit poor aesthetic properties. Cotton, being a natural fibre, contains more natural impurities on its primary and secondary walls which in turn hinders the quality of the fabric. Hence, the scouring is an essential pretreatment for cotton which improves the strength, luster and absorbency. The dyed cotton fabrics with varied dye class (direct, reactive, basic, vat *etc.*) after multiple washing and expose to sunlight leads to colour fading due for photo oxidation. However, reaction to washing of natural colour cotton fabric is quite different from that of synthetic coloured cotton fabrics. On the contrary the natural colour cotton fabrics improve its wash fastness and colour intensify up to 10 washing and thereafter the colour intensity was reduced for sunlight. Many authors studied the chemistry and reactive species involved in photo fading of dyed cotton fabric. The world is moving toward pollution-free organic textiles and products; the naturally colored cotton is going to be the next buzz word in the market, because of the production process of naturally coloured cotton skips the most polluting activity (dyeing) of the textile product manufacturing (Rathinamoorthy and Parthiban, (2019).

Hence the present study is designed with objectives to study the effect of scouring on mechanical and functional properties of natural colour cotton fabrics and to assess the colour strength of natural colour cotton fabric on washing and light fastness and its durability.

Material and Methods

Selection of raw material

Medium brown natural colour cotton fibre was procured from Agricultural Research Station Hebballi UAS Dharwad with following fibre properties (Table 1). The natural colour cotton fibre was spun into 20s count yarn on open end spinning and assessed for yarn evenness properties (Table 2). The yarn evenness properties of natural colour cotton yarn were measured interms of thin places (-50 %), thick places (+ 50 %), neps (+ 200) and total imperfections. The 20s pure colour cotton yarn was found the thin places (07), thick places (62), neps (27) and total imperfection rate of 96. Hairiness percentage of natural colour cotton yarn was found to be 4.10, unevenness percentage was 11.73 and count strength product of 1540.

Table 1. Fibre qualities of natural colour cotton yarn (Brown Colour Hirsutum)

SN	Fibre Properties	Mean	CV%	Std. Dev.
1.	2.5 % SL (mm)	20.39	2.80	0.57
2.	U.R.%	56.10	4.80	2.70
3.	Mic.10 (g/in)	3.78	0.80	0.03
4.	Tenacity(g/tex)	17.10	7.50	1.30
5.	Elongation %	8.11	9.90	0.80

Development of natural colour cotton fabric

The pure natural colour cotton fabric was developed by interlacing 20s count yarn with plain weave on handloom with reed count of 44 and denting order of 2/dents (Plate 1).

Table 2. Yarn evenness properties of natural colour cotton pure and blended yarn

SN	Parameters	NCC pure 20s count
1	Thin Places (-50%)	07
2	Thick Places (+50)	62
3	Neps (+200)	27
4	Total Imperfection	96
5	U %	11.73
6.	Hairiness	4.10
6	CSP (Count Strength Product)	1540

Scouring of natural colour cotton fabric

Scouring is the process wherein cotton fabric is essentially undergoing pretreatment operation with required amount of alkali. The primary purpose of scouring for cotton fabrics is to removes water insoluble materials such as oils, fats, and waxes from the material. Following recipe has used for scouring of natural colour cotton fabric (Table. 3 and plate 2 & 3.

Table 3: Recipe for Scouring of natural colour cotton fabric

MLR (Material liquor ratio)	1:20
Tween 80	3 gpl
NaOH (Sodium hydroxide)	3% owf
Sequencing agent (EDTA-Ethylene diamine tetra acetic acid)	1 gpl
Temperature	40^{o} to boiling point
Time	8 folds

Laundering of natural colour cotton fabric

Fabric durability is one of the most important factors that determine the shelf life of the textile substrates for attaining better performance. The scoured natural colour cotton fabric was subjected for multiple washes (20 washes) using liquid detergent (3gpl) at the MLR of 1:30 and assessed for colour fastness properties.

Assessment of mechanical and functional properties

The pure and scoured natural colour cotton fabrics were assessed for mechanical properties *viz.,* cloth count (Ne), cloth weight (GSM), cloth thickness (mm), cloth crease recovery (degree) and cloth stiffness (cm) using standard test procedures. The functional properties *viz.,* cloth tensile strength, elongation, air permeability and wettability were assessed for pure and scoured natural colour cotton fabrics using standard test procedures (Tables 4 & 5).

Table 4: Standards for assessment of mechanical properties of Natural coloured cotton fabrics

Mechanical properties	Standard test procedure
Cloth density	BS 2862:1957
Cloth thickness	ASTM D177-1975
GSM	IS 1964: 2001
Cloth crease recovery	IS 4681:1968
Bending length	BS 3356-1961

Table 5: Standards for assessment of functional properties of Natural coloured cotton fabrics

Functional properties	Standard test procedure
Cloth Tensile strength and Elongation	IS 1969-Part1-2009
Spray test	AATCC 22-2017
Air permeability test	IS 11056 1984

Colour strength (K/S)

Colour strength (K/S) values of the natural colour cotton fabrics were measured by using spectrophotometer. Five readings recorded for each and an average value was calculated. Where, K is the absorption coefficient and S is the scattering coefficient.

Assessment of colour fastness properties of natural colour cotton fabric

The scoured colour cotton fabric was subjected to multiple washing and assessed for fastness property by using two methods *viz.,* Colour fastness to sunlight and Colour fastness to washing.

Colour fastness to sunlight

The natural color cotton fabrics of 1× 6 cm were wound closely on a black card sheet and was mounted in an exposure rack. The rack was placed at 45° for eight days, and it was exposed from 9 a.m. to 3 p.m. (6 hours every day). The samples were evaluated for colour change after 48 hours of

Plate 1: Natural colour cotton trendy outfits.

Plate 2: Scouring of natural colour cotton fabrics

P1ate 3: Scouring of natural colour cotton fabrics

exposure with the help of spectrophotometer (380-780 nm) compared with blue wool standard.

Colour fastness to washing

The natural colour cotton materials were stitched along all four sides between two adjacent pieces of cloth, one side silk and the other cotton. The composite specimen was agitated in the rotary shaker for 30 minutes with a preheated (402 °C) soap solution (5 g/l) of MLR 1:30. (42rpm). After laundering, the colour fastness of samples was determined using a spectrophotometer and compared with gray scale.

Results and Discussion

Effect of scouring on mechanical properties of natural colour cotton fabrics

Cloth count of the woven textile material is the number of ends and picks per unit area which is influenced by the yarn count and compactness of the weave. From the table 6, it is observed that, the warp density of pure and scoured natural colour cotton fabrics was relatively greater than the weft and the cloth density was found to be significantly greater between both the fabrics. Among the fabrics, the cloth count was found to be greater in scoured natural colour cotton fabric in both warp (56) and weft (35) direction compared to control fabric (warp: 54 & weft: 30) respectively. It may be because of removal of impurities during the scouring process and maximum consolidation of threads takes place resulted into formation of compact structure which leads to increased cloth count. The results are on par with the results of Prabaharan (2003) who reported that, after number of wet processing, treatments the cotton fabric was prone to shrink considerably resulting in high thread density. The total cloth weight of scoured natural colour cotton fabric was found to be significantly greater (130) than pure natural colour cotton fabric (126). The cloth thickness was found to be significantly higher in scoured natural colour cotton fabric (0.50) than pure natural colour cotton (0.47) fabrics. It may be due to the consolidation of threads/unit area resulting into greater cloth thickness which yields to higher cloth weight.

Further, the cloth stiffness was found to be significantly greater in pure natural colour cotton fabric both in warp (2.36) and weft direction (2.23) than scoured natural colour cotton fabric (warp: 2.00 & weft: 1.90) respectively. This may be due to the removal of impurities present in the woven fabric structure that makes the fabric softer and more pliable. The results are on par with the results of Shrikant *et al.* (2005) who revealed that, fabrics become less stiffer after the scouring possibly due to removal of fats and waxes. Moreover, the cloth crease recovery angle was found to be significantly greater in weft of both pure and scoured natural colour cotton fabric than warp direction. Scoured natural colour cotton fabric was found to be greater crease recovery angle (warp: 75 & weft: 81) as compared to pure natural colour cotton fabric (warp: 72 & weft: 77) respectively, which indicates the scoured fabrics become more softer and pliable.

Dimensional stability of fabric calculated in terms of percentage, it refers to change of fabric size when they are washed or relaxed. After scouring the natural colour cotton fabric was increased the dimensional stability in both warp (76.16%) and weft (91.00%) direction as compared to pure natural colour cotton fabric (warp: 70.96%, weft: 88.00%) respectively.

Effect of scouring on functional properties of natural colour cotton fabrics

The tensile strength is a stress applied on a fabric which is measured as force per unit area. It is observed from the table 7 that, the scoured natural colour cotton fabrics exhibited greater tensile strength in both warp (135.9) and weft way (45.8) as compared to pure NCC fabric (warp: 123.2, weft:40.3) respectively. Similarly, the elongation percentage of scoured fabric was found to be greater in both warp (2.4) and weft (2.5) direction than pure NCC fabric. In general, fabric strength and elongation properties were significantly increased after scouring this may be due to consolidation of thread density. The strength of fibers is attributed to the rigidity of the cellulosic chains, the highly febrile and crystalline structure, and the extensive intermolecular and intramolecular hydrogen-bonding (Hsieh, 2007). Further, the alkali has improved the molecular arrangement of the fibre resulting in to greater per cent of crystalline regions in the fibre thus enhancing the strength of the yarn and fabric on scouring (Gandhad and Naik, 1999; Magadi, 2002).

Wettability refers to a fabric's ability to absorb liquid and is determined by the balance of surface energy at the interface of air, liquid, and solid components. The wetting of cotton depends upon the properties of the fibre surface and the liquid which is going to wet it. The surface energy of a textile structure in the uppermost layers is important in the wetting and adhesion of liquids. The fabric surface energy is largely dependent upon the structure of the fibre, as well as on the yarn, fabric, capillary forces, cover factor, area density, level of projected fibres, and surface roughness (Uddin and Lomas (2010). The samples wettability was evaluated using ratings, where the scoured NCC fabrics rated as zero which indicates completely wetting of whole upper and lower

Table 6: Effect of scouring on mechanical properties of natural colour cotton fabrics.

SN	Mechanical Properties	Pure NCC fabric	Scoured NCC fabric	t value
1.	Cloth count (Numerical Expression)			
	Warp	54	56	1.22
	Weft	30	35	3.87
2.	Cloth weight (GSM)	126	130	4.89
3.	Cloth thickness (mm)	0.47	0.50	3.67
4.	Cloth bending (cm)			
	Warp	2.36	2.00	8.52
	Weft	2.23	1.90	6.45
5.	Cloth crease recovery (angle)			
	Warp	75.00	72.00	3.67
	Weft	81.00	77.00	4.89
6.	Dimensional stability (%)			
	Warp	70.96	76.16	3.40
	Weft	88.00	91.00	3.67

Table 7: Effect of scouring on functional properties of natural colour cotton fabrics

SN	Mechanical Properties	Pure NCC fabric	Scoured NCC fabric	t value
1.	Cloth Tensile strength (N)			
	Warp	123.4	135.9	5.49
	Weft	40.3	45.8	5.30
2.	Cloth elongation (%)			
	Warp	1.7	2.4	2.06
	Weft	1.8	2.5	3.36
3.	Wettability (Rating)	70	0	12.24
	Air permeability (c/sec/cm2)	40.56	38.25	7.15

Wettability	Ratings
Complete wetting of whole upper and lower surface	0
Complete wetting of whole upper surface	50
Partial wetting of whole upper surface	70

surface. However, untreated NCC fabric was rated as 70 which depicts partial wetting of whole upper surface of the fabric. This may be due to scouring process which removes the cuticle or wax present in the outer layer of the cotton fibers, which enables cotton to absorb moisture more quickly as stated by Gohl and Vilensky (1987). The amount of air that passes through a specific area of a fabric is measured by its air permeability. This characteristic has a significant impact on the thermal comfort attributes of materials. It is generally accepted that the air permeability of a fabric depends on its air porosity, which in turn influences its openness. It was found that, the air permeability was negatively influenced on scouring process of natural colour cotton fabrics which ascribed to increasing the fabric density, weight and thickness after successive wet processes. These results are in line with the Shrikant *et al.* (2005) who stated that, threads/cm were found to be higher in scoured fabric than grey fabric resulted into higher cloth cover-factor of scoured fabric and lesser air permeability. Further, grey fabrics were found to have high air permeability and contrary, lower values of the air permeability were associated with scoured woven fabrics as stated by Najwa (2019).

Effect of laundering on colour strength of natural colour cotton fabrics

It was observed from the table 8 and Fig. 1 that, the colour strength of natural colour cotton fabric was increased after scouring treatment *i.e.,* 49.770 as compared to control fabric (33.820). These results are on par with the results of Tsaliki *et al.* (2016) who stated that, the influenced of enzymatic treatment on brown cotton was found to be noticed that, the colour fastness properties were improved. However, the effect of washes on scoured natural colour cotton fabric was showed that there was increased in colour strength after every wash compared to control sample. This may be due to the fact that, the natural colour cotton present in the form of pigment inside the lumen of fibre tends to break the core and comes out on the surface during 2nd and subsequent washes, resulting in the enhancement of colour in terms of K/S value thus causing the shade intensification (Parmar and Sharma, (2002).

Table 8: Effect of laundering on colour strength of natural colour cotton fabrics.

SN	Fabrics	Colour strength (K/S)	
		Washing	Sunlight
1.	Control natural colour cotton fabric	33.820	27.190
2.	Scoured natural colour cotton fabric	49.770	48.952
3.	5th wash natural colour cotton fabric	45.856	47.604
4.	10th wash natural colour cotton fabric	44.768	46.996
5.	15th wash natural colour cotton fabric	43.964	39.592
6	20th wash natural colour cotton fabric	43.832	37.420

Source of variation	S.Em. ±	CD5%	CD1%	CV
Factor A	365.497	1.554	2.076	4.060
Factor B	84.633	0.897	1.199	
Treatments (AxB)	122.361	2.198	2.936	

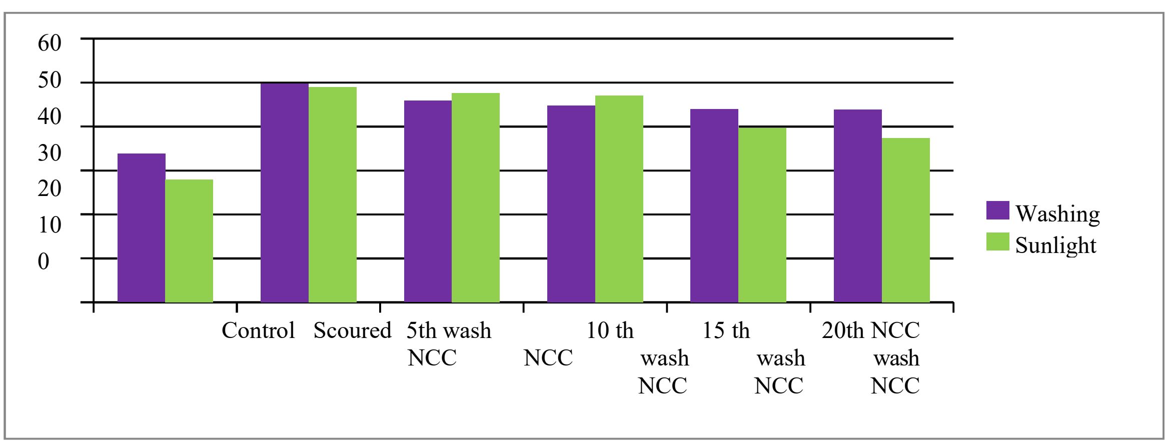

Figure 1. Effect of laundering on colour strength of natural colour cotton fabrics.

Effect of sunlight on colour strength of control and scoured natural colour cotton fabrics describes that, as the number of washes increases and subsequently expose to direct sunlight leads to decrease in colour strength of scoured natural coloured cotton fabric. This may be because of photo oxidation/fading due to oxygen liberation. Among the samples treated with washing and sunlight, the colour strength was found to be greater in washed and shade dried samples than the samples exposed to direct sunlight even after multiple washes. This indicates that, the natural colour cotton fabric were susceptible to photo fading by direct sunlight which may breaks the colour pigment in the fibre structure. Further, after multiple washes, the scoured natural colour cotton fabrics exhibited darker colour shades than the control sample. It indicated that the sample became more darker, greenerand bluer than the control sample. However, after multiple washes with shade dry intensify the colour of the fabrics upto 10 washes, after that the colour intensity was reduced. ANOVA explains that, there was a greater significant difference was found between the colour strength of all the NCC samples for washing as well as sunlight samples.

Effect of laundering on colour reflectance of natural colour cotton fabrics

Colour reflectance is directly associated with colour strength (K/S) of the sample. As the colour strength values increases, there was reduction in reflectance values which indicates samples became more darker and visa versa. Table 9 and figure 2 explains the effect of laundering on colour reflectance of natural colour cotton fabrics. Among the samples, pure natural colour cotton fabric was more lighter than the scoured natural colour cotton fabrics. However effect of laundering on colour reflectance of the samples explains that, as the number of washes increases the samples became slightly lighter and duller as supported by reflectance values of 5th, 10th, 15th and 20th washes (8.248, 8.498, 8.326, 8.672) respectively. Further, the samples subjected to sunlight after multiple washes narrates, there was a slight increase of reflectance value which indicates that the samples became more lighter and results are supported by colour strength values (table.8). Interaction between the factors, the reflectance was significantly increased in all the natural colour cotton fabrics subjected to scouring and washing compared to sunlight samples.

Table 9: Effect of laundering on colour reflectance of natural colour cotton fabrics.

SN	Fabrics	Colour reflectance	
		Washing	Sunlight
1	Control natural colour cotton fabric	10.270	11.972
2.	Scoured natural colour cotton fabric	7.670	9.510
3.	5th wash natural colour cotton fabric	8.248	9.396
4.	10th wash natural colour cotton fabric	8.498	7.940
5.	15th wash natural colour cotton fabric	8.326	7.546
6	20th wash natural colour cotton fabric	8.672	7.368

Source of variation	SEm ±	CD5%	CD1%	CV
Factor A	14.441	0.301	0.402	3.804
Factor B	1.748	0.174	0.232	
Treatments (AxB)	4.565	0.426	0.569	

Effect of laundering on colour difference of natural colour cotton fabrics

The colour difference of natural colour cotton fabrics subjected to wash and light fastness showed in table 10 and figure 3. The colour difference of natural colour cotton fabrics subjected to wash fastness property exhibited increased colour difference of scoured sample (1.502) compared to control sample (0.880) and washed samples. Further in washed samples, increased colour difference was found in 10th wash sample (1.032) followed by 20th wash (0.336), 5th wash (0.204) and 15th wash samples (0.120) respectively. However, in sunlight samples significantly increased in colour difference was noticed in 20th wash sample (1.476) compared to control sample (1.272). Among the washed samples, the more colour difference was found in 20th wash sample followed by 5th wash (0.664), 15th wash (0.586) and 10th wash sample (0.356) respectively. From the ANOVA, observed that the colour difference was increased significantly in sunlight control sample compared to washing natural colour cotton fabric. The sunlight scoured sample has significantly decreased the colour difference compared to wash fastness of scoured sample. Among the washed sample, the significantly increased colour difference was found in 5th, 15th and 20th wash samples of sunlight compared to wash fastness samples. Moreover, the colour difference was found to be increased in the 10th wash sample compared to sunlight 10th wash sample.

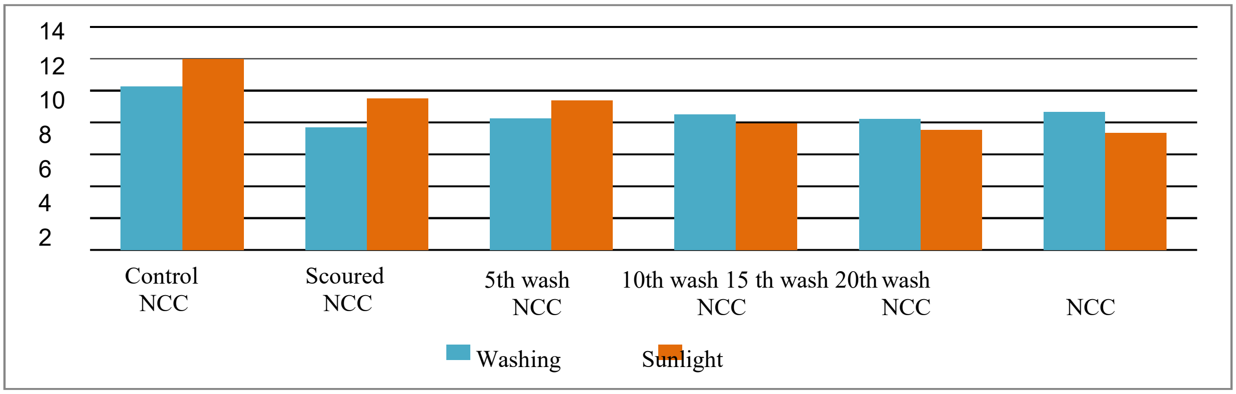

Figure 2: Effect of laundering on Colour reflectance of Natural colour cotton fabrics.

Table 10: Effect of laundering on colour difference (dE) of natural colour cotton fabrics.

SN	Fabrics	Colour difference	
		Washing	**Sunlight**
1	Control natural colour cotton fabric	0.880	1.272
2.	Scoured natural colour cotton fabric	1.502	0.872
3.	5th wash natural colour cotton fabric	0.204	0.664
4.	10th wash natural colour cotton fabric	1.032	0.356
5.	15th wash natural colour cotton fabric	0.120	0.586
6	20th wash natural colour cotton fabric	0.336	1.476

Source of variation	SEm±	CD5%	CD1%	CV
Factor A	1.157	0.235	0.313	33.588
Factor B	0.553	0.135	0.181	
Treatments (AxB)	1.257	0.332	0.181	

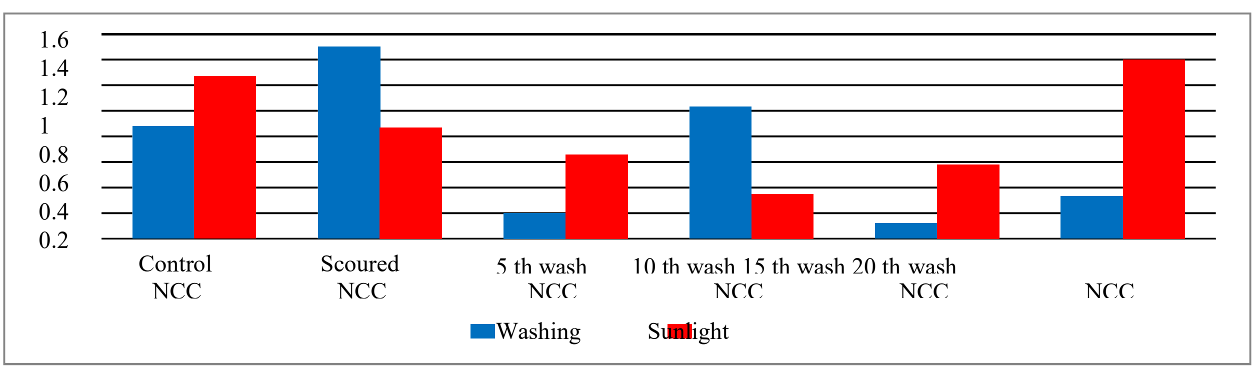

Figure 3: Effect of laundering on colour difference of natural colour cotton fabric.

Effect of laundering on colour fastness to washing and sunlight of natural colour cotton fabric

Table 11 discloses the effect of washing on colour fastness with respect to change in colour and colour on stain material. Scoured natural colour cotton fabric subjected to different washing cycles *i.e.*, 5th, 10th,15th and 20th wash and assessed for colourfastness to washing. It was interesting to observed that all the natural colour cotton fabrics possessed good wash fastness even after 20th wash. There was no much change observed in all the samples subjected to washing cycles *i.e.*, 5 to 15th indicating the samples are good fastness to washing. This may be due to the fact that the natural colour present in the form of pigment inside the lumen of fibre tends to break the core and comes out on the surface during 2nd wash, resulting in the enhancement of colour in terms of K/S value, thus causing the shade intensification (Parmar and Shanna (2002). Further the effect of colour fastness to sunlight on wash durability of scoured natural colour cotton fabric. Irrespective of multiple washes (0, 5, 10, 15 and 20) the treated samples exhibited moderate to excellent fastness properties (4/5-7). Among the washed samples, upto 10th washed samples showed very good to excellent wash fastness to sunlight property. However, after 15th and 20th washes the fastness ratings was found to be good to moderate which indicates that there was colour fading occurred after multiple washes and subsequent expose to sunlight.

Table 11: Effect of laundering on natural colour cotton fabric on colour fastness to washing and sunlight.

SN	Fabrics	Colour fastness property	
		Washing (gray scale)	Sunlight (blue wool)
1.	Scoured natural colour cotton fabric (o wash)	5	7
2.	5th wash fabric	5	7
3.	10th wash fabric	5	6
4.	15th wash fabric	4/5	5/6
5.	20th wash fabric	4	4/5

Conclusion

The scoured natural colour cotton fabric found to be denser, thicker, heavier, soft and pliable than the control sample. It has good tensile, elongation properties, better wettability and air permeability. The scoured natural colour cotton fabrics exhibited greater colour strength and lesser reflectance values with slight colour difference.Colour fastness properties of natural colour cotton fabric exhibited good to excellent (4/5-5) for sunlight with multiple washes. The natural colour cotton fabrics has better mechanical, functional and fastness properties can be suitable for production of diversified cotton products ranging from children garments to trendy outfits.Hence, the promotion of natural colour cotton fabrics is a sustainable approach for green environment. Similarly eco-consciousness is increasing world over and green minded consumers are prepared to pay more for textile eco-friendly products and one among them is natural colour cotton. Natural colour cotton fabrics are eco-friendly with unique handle and comfort property.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Diversity of Geometrid moths (Geometridae: Lepidoptera) in Kashmir valley, India

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ABSTRACT

A total of 2378 geometrid moth specimens were collected from four districts of Kashmir valley during 2018-2019, which comprised of 39 species belonging to 29 genera, 17 tribes and 4 subfamilies. Five species (*Abraxas cashmiria* sp. nov., Antipercnia *pseudoalbinigrata* sp. nov., *Aspitates pseudogilvaria* sp. nov., Chorodna *Baramulia* sp. nov. and *Xenoplia kashmirensis* sp. nov.) are reported for the first time from this area. Diversity indices was highest in Baramulla (H´ = 1.452760) lowest in Srinagar (H´=1.273559). *Alcis repandata* (Linnaeus) was found to be most dominant species (11.02%), while as *Callipia vicinaria* (Dognin) was found least dominant (0.25%).

Introduction

Lepidoptera is the largest insect order with approx. 1,57,424 described species worldwide (Van Nieukerken *et al.,* 2011; Sajjad *et al.,* 2019), out of which 100,000 are moths (Khan and Perveen, 2015) and remaining are butterflies. Family Geometridae (Inchworms or loppers), with approximately 23,002 described species (Nieukerken *et al.,* 2011) is the second most diverse family of Lepidoptera, occurring worldwide except in the Polar Regions. Geometridae is a moth family, its species are nocturnal and tend to be more specific to certain habitats particularly at high altitudes (Axmacher and Fiedler, 2008). Geometrid moths (Lepidoptera: Geometridae) are mostly the forest pests of woody plants, agricultural crops, fruit-berry crops and feed mainly on the leaves of wide range of plants particularly trees and shrubs. Geometrids are abundant and diverse component of most forest ecosystems, this along with their weak flight ability and low propensity to migrate (DeWaard *et al*., 2011) make them excellent indicators of environmental quality (Kitching *et al.,* 2001). The caterpillars are commonly known as loopers or inchworms because of their looping gait resulting from a reduced number of abdominal prolegs. Geometridae are generally secretive and cryptic insects, sometimes moths are green as the leaves on which they rest or have brown, grey and other colours forming mottled bark-like patterns of flecks and wavy lines. Their resting postures enhance camouflage, with the moths spreading their wings flat against the underside of leaves and the caterpillars are often twig-like (Pitkin *et al*., 2007). Many species are bright coloured, but most are drab. Frequently wavy lines transverse the wings but strong and distinct pattern occur often. The geometrids are characterised by the presence of a basal fork between vein A_2 and A_3 in the forewing and vein A_1 is always absent. Almost 2041 species of geometrid moths are reported from India (Kirti *et al.,* 2019) however, their extensive study has not been carried out from different regions of India as it is diverse country in terms of climate, Topography etc.

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Material and Methods

Collection of specimens

For the collection of Geometrid moths from different locations of Kashmir valley various intensive and extensive tours were conducted from April 2018-Nov 2019. Adult geometrid moths were trapped with the help of light traps installed at different places during night time. For collection of specimens portable bucket type light traps fitted with 125 W mercury vapour lamp were used. Moths possess scaly wings which are very delicate and get damaged very easily, so as to avoid the wing damage due to overcrowding in the bucket type light trap, the mercury vapour lamp was hung in front of a white cloth sheet secured to a wall or directly over a plain white wall and moths sitting on the cloth or wall were quickly trapped with the help of wide mouth killing bottle containing benzene for quick killing of moths. Places were electricity was not available rechargeable lamps were used as light source for collection.

Selection of site:

The whole area of Kashmir valley is divided into three regions North Kashmir, south Kashmir and Central Kashmir. The collection was done from four districts of Kashmir namely Anantnag, Baramulla, Budgam and Srinagar, where Anantnag is in south , Baramulla in North, Budgam and Srinagar are in central part of kashmir . From each district two locations were selected, one in Forest ecosystem and other in Agri-Horti ecosystem i.e Verinag (1900 mt) and Achabal (1668 mt) from Anantnag; Drangbal (1650 mt) and Wadoora (1588 mt) from Baramulla; Shalimar (1609 mt) and Bemina (1583 mt) from Srinagar; Dodhpathri (2635 mt) and Ompora (1637 mt) from Budgam (Figure 1).

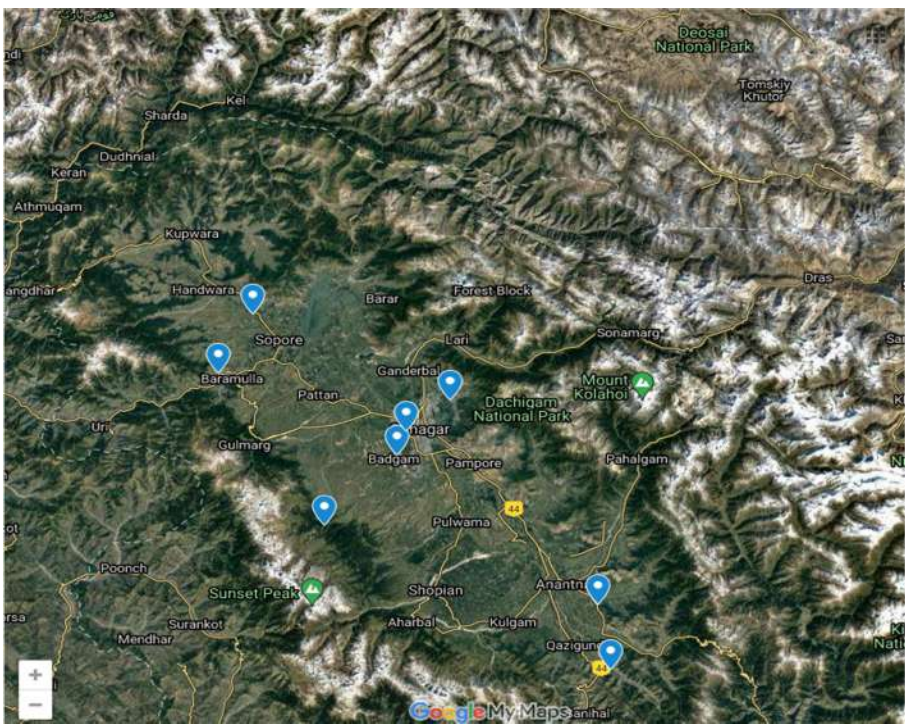

Figure 1: Google image of study areas

Processing and preservation

Collected moths after being killed with benzene or ethyl acetate vapours in killing bottles were transferred into butter paper envelops (to avoid scrapping off of wing scales which is an important morphological character of moths). In laboratory first specimens were placed over water soaked cotton in airtight petridish for relaxation of muscles so that they can be stretched easily. Then Specimens were properly stretched on wooden stretching board after pinning through the mid of mesothorax. Stretched specimens were then oven dried for 72 hours at 60°C and preserved in fumigated insect collection boxes. Each specimen was labelled properly with name, locality, date of collection, name of collector etc.

Sorting of collected samples

Collected adult moths were sorted on the basis of morphological characters like wing pattern, presence of tymphanum on its ist abdominal segment, wing venation, antennae, thoraxic markings, no. of tibial spur etc.

Identification

Sorted specimens were identified by comparing with available relevant literature e.g The Moths of Borneo, Geometrid Moths of the World etc. To confirm the identification of moths, help was also seeked from Dr. Jasbir Singh Kirti, PAU Patiala India who is presently working on family Geometridae in India. For identification moth genetalia were dissected and directly photographed by using stereo zoom microscope attached with digital camera (Olympus SZX16), however Adult moths were photographed with Nikon DSLR camera. Identification was confirmed by sending these photographs to above mentioned expert.

Specimens were later deposited to museum of bio-systematic laboratory, Division of Entomology, SKUAST-K, Shalimar campus, Srinagar.

Statistical analysis

Diversity data of Geometrid moths was analysed for below mentioned indexes:-

I. **Index of species diversity (Shannan and Wiener, 1963).**

Index of species diversity $(H') = \Sigma\ pi \log_{10} pi$

Where

pi= Important probability of each species (Ni/N)

Ni=No. of individuals of one specie.

N=Total no. of individuals of all species

II. **Evenness index (Pielou, 1966).**

Evenness index $(J) = H' / \log_{10} S$

Where

H′=Shannon Wieners index

S=Number of species

III.Index of dominance (Southwood, 1978)

Index of dominance $(D) = 1 - J$

Where

J=Evenness index

IV.Relative Abundance (R)

$$R = n/N$$

n = number of individuals in one species

N = number of individuals in all the species.

Results and Discussion

Total of 2378 geometrid moth specimens were captured from different selected locations of Kashmir valley. This total collection comprised of 39 species belonging to 29 genera, 17 tribes and 4 subfamilies which differed in both abundance and distribution (Table 1). Present results indicated that tribe Boarmiini was found most diverse at species level with 14 species followed by Ourapterygini with 6 species, Gonodontini with 3 species and Pseudoterpini with 2 species while as most of the tribes i.e Thinopterygini, Abraxini, Epionini, Aspitatini, Gnophini, Cidariini, Chesiadini, Larentiini, Gonodontini, Baptini, Hemitheini, Stamnodini and Scopulini were found to be least diverse with one specie each (Table1).

Present investigation revealed that maximum number of species (35) were recorded from Baramulla followed by Anantnag (33) while as minimum (22) were recorded from Srinagar (Table 2). Further *Alcis repandata* (Linnaeus) was the most dominant species in terms of relative abundance (11.02%) followed by *Ascotis imparata* (Walker) (7.53%), while as *Callipia vicinaria* (Dognin) was found least dominant (0.25%) (Figure 1).

Diversity indices at various localities is framed in Table 2 which indicated that species diversity was found highest in Baramulla (H′ = 1.452760) followed by Anantnag (H′=1.413907) and lowest in Srinagar (H′=1.273559). Results of present study also revealed that evenness

Table 1: Classification of reported species.

S.no.	Family	Sub family	Tribe	Genus	Species
1.	Geometridae	Ennominae	Boarmiini	I. *Alcis* Curtis	1. *Alcis variegate* Moore
2.					2. *Alcis repandata* Linnaeus
3.					3. *Alcis jubata* Thunberg
4.					4. *Alcis perspicuata* Moore
5.				II. *Hypomecis* Hubner	5. *Hypomecis infixaria (*Walker)
6.				III. *Arichanna* Moore	6. *Arichanna lapsariata* (Walker)
7.				IV. *Antipercnia* Inoue	7. *Antipercnia cordiforma* (Inoue)
8.					8. *Antipercnia pseudoalbinigrata* sp. nov.
9.				V. *Ascotis* Hubner	9. *Ascotis selenaria* (Dennis and Schiffermuller)
10.					10. *Ascotis imparata* (Walker)
11.				VI. *Lassaba* Moore	11. *Lassaba contaminata* Moore
12.				VII. *Chorodna* Walker	12. *Chorodna baramulia* sp. nov.
13.					13. Medasina albidaria (Walker)
14.				VIII. *Psilalcis* Warren	14. *Psilalcis inceptaria* (Walker)
15.			Epionini	IX. *Opisthograptis* Hubner	15. *Opisthograptis moelleri* Warren
16.			Aspitatini	X. *Aspitates* Treitschke	16. *Aspitates pseudogilvaria* sp. nov.
17.			Abraxini	XI. *Abraxas* Leach	17. *Abraxas cashmiria* sp. nov.
18.			Gnophini	XII. *Psyra* Walker	18. *Psyra bluethgeni (*Pungeler)
19.			Ourapterygini	XIII. *Ourapteryx* Leach	19. *Ourapteryx pluristrigata* Warren
20.					20. *Ourapteryx multistrigaria* Walker
21.					21. *Ourapteryx caschmirensis* Bastelberger
22.					22. *Ourapteryx sambucaria* Linnaeus
23.				XIV. *Eutrapela* Hubner	23. *Eutrapela clemataria* (Smith)
24.				XV. *Cepphis* Hubner	24. *Cepphis advenaria* Hubner
25.			Bistonini	XVI. *Biston* Leach	25. *Biston betularia* (Linnaeus)
26.					26. *Biston suppressaria* Guenee
27.			Thinopterygini	XVII. *Thinopteryx* Butler	27. *Thinopteryx crocoptera* (Kollar)
28.			Baptini	XVIII. *Lomographa* Hubner	28. *Lomographa tributaria* (Walker)
29.			Gonodontini	XIX. *Odontopera* Stephens	29. *Odontopera bidentata* Clerck
30.				XX. *Tanaoctenia* Warren	30. *Tanaoctenia haliaria* (Walker
31.				XXI. *Xenoplia* Warren	31. *Xenoplia kashmirensis* sp. nov.
32.		Larentiinae	Cidariini	XXII. *Heterothera* Inoue	32. *Heterothera quadrifulta* (Prout)
33.			Stamnodini	XXIII. *Callipia* Guenee	33. *Callipia vicinaria* Dognin
34.			Larentiini	XXIV. *Photoscotosia* Warren	34. *Photoscotosia miniosata* (Walker)
35.			Chesiadini	XXV. *Aplocera* Stephens	35. *Aplocera plagiata* (Linnaeus)
36.		Geometrinae	Pseudoterpini	XXVI. *Pingasa* Moore	36. Pingasa ruginaria (Guenee)
37.				XXVII. *Pachyodes* Guenee	37. *Pachyodes amplificata* (Walker)
38.			Hemitheini	XXVIII. *Chlorissa* Stephens	38. *Chlorissa viridata* (Linnaeus)
39.		Sterrhinae	Scopulini	XXIX. *Problepsis* Lederer	39. *Problepsis albidor* (Warren)

Table 2: Diversity indices of geometrid moths in Kashmir valley during 2017-18.

S. No.	District	Total No. of Species	Indices			
			Diversity Index (H)	Evenness Index (J)	Index of Dominance (D)	Species Richness Index (M)
1	Anantnag	33	1.413907	0.931112	0.068887	11.028936
2	Srinagar	23	1.273559	0.948702	0.051297	8.424395
3	Budgam	22	1.284200	0.943066	0.056933	8.660293
4	Baramulla	35	1.452760	0.940865	0.059134	11.466336

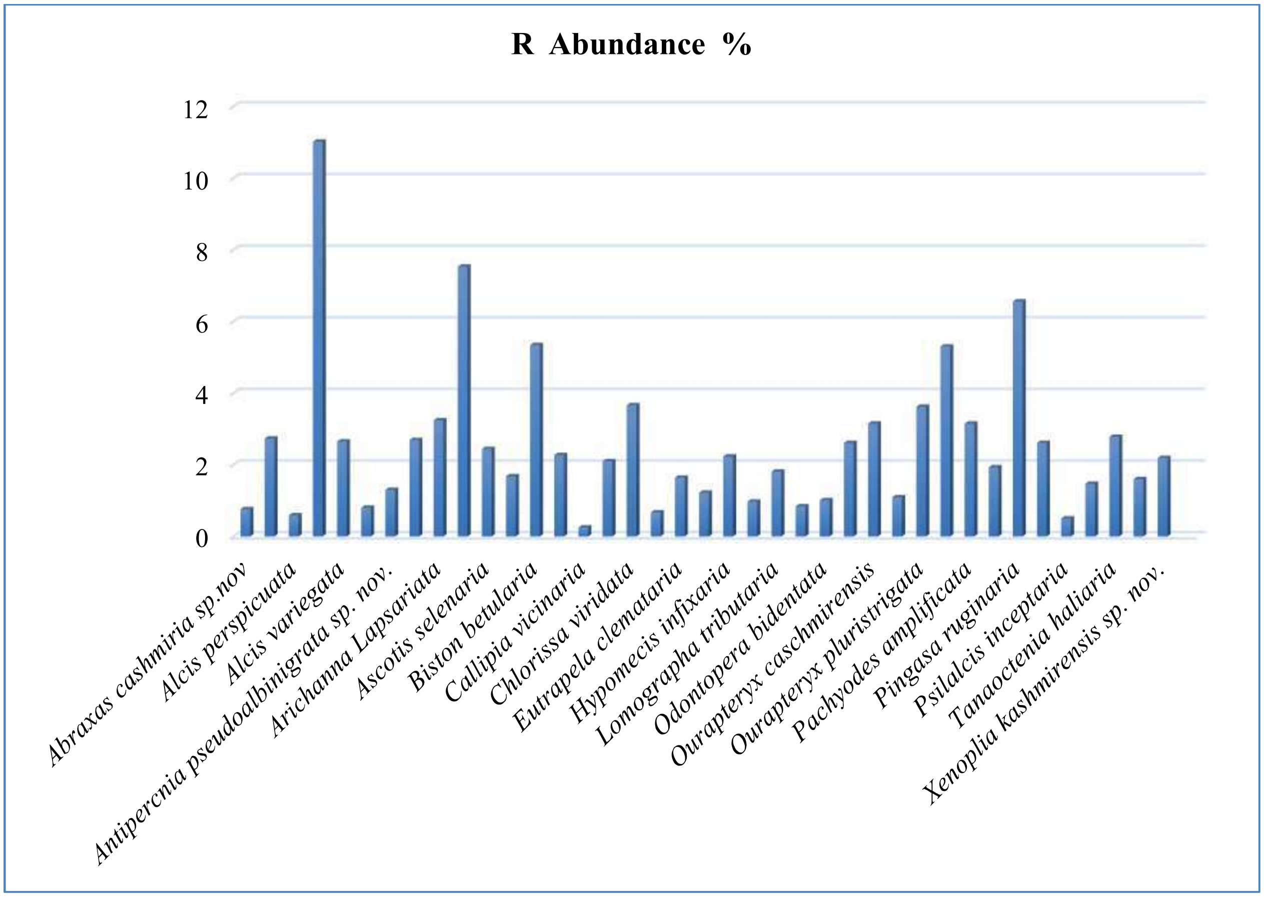

Figure 1: Relative abundance of studied geometrid moth species in Kashmir valley

index, index of dominance and richness were 0.940865, 0.059134 and 11.466336 in Baramulla, 0.931112, 0.068887 and 11.028936 in Anantnag, 0.948702, 0.051297 and 8.424395 in Srinagar and 0.943066, 0.056933 and 8.660293 in Budgam district, respectively (Table 1). Family Geometridae is known for its major and minor pest species, caterpillars of this group occupy diverse habitats as external foliage feeders on trees, defoliators on forest trees, agricultural crops and fruit plants (Kirti *et al*., 2008). Not only these species act as plant pest but some were found to affect both domestic and wild animals. During the present course of study, extensive collection cum survey tours were conducted in four different districts *viz*, Anantnag (South Kashmir), Srinagar and Budgam (Central Kashmir) and

Figure 2: Photo images of Geometrid moths collected from Kashmir valley

1. *Alcis variegate* Moore

2. *Alcis repandata* Linnaeus

3. *Alcis jubata* Thunberg

4. *Alcis perspicuata* (Moore)

5. *Hypomecis infixaria* (Walker)

6. *Arichanna Lapsariata* (Walker)

7. *Antipercnia cordiforma* (Inoue)

8. *Antipercnia pseudoalbinigrata* sp. nov.

9. *Ascotis selenaria* (Denis & Schiffermuller)

10. *Ascotis imparata* (Walker)

11. *Lassaba contaminata* Moore

12. *Chorodna baramulia* sp. nov.

13. *Medasina albidaria* (Walker)

14. *Psilalcis inceptaria* (Walker)

15. *Opisthograptis moelleri* Warren

				
16. *Aspitates pseudogilvaria* sp. nov.	17. *Abraxas cashmiria* sp. nov	18. *Psyra bluethgeni* (Pungeler)	19. *Ourapteryx pluristrigata* Warren	20. *Ourapteryx multistrigaria* Walker
				
21. *Ourapteryx caschmirensis* Bastelberger	22. *Ourapteryx sambucaria* Linnaeus	23. *Eutrapela clemataria* (Smith)	24. *Cepphis advenaria* Hubner	25. *Biston betularia* (Linnaeus)
				
26. *Biston Suppressaria* Guenee	27. *Thinopteryx crocoptera* (Kollar)	28. *Lomographa tributaria* (Walker)	29. *Odontopera bidentata* Clerck	30. *Tanaoctenia haliaria* (Walker)

				
31. *Xenoplia kashmirensis* sp. nov.	32. *Heterothera Quadrifulta* (Prout)	33. *Callipia vicinaria* Dognin	34. *Photoscotosia miniosata* (Walker)	35. *Aplocera plagiata* (Linnaeus)
				
36. *Pingasa ruginaria* (Guenee)	37. *Pachyodes amplificata* (Walker)	38. *Chlorissa viridata* (Linnaeus)	39. *Problepsis albidor* (Warren)	

Baramulla (North Kashmir) of Kashmir valley and the total no of 39 species of adult moths belonging to 29 genera, 17 tribes and four subfamilies i.e. Ennominae, Larentiinae, Geometrinae and Sterrhinae of family Geometridae. All the species were identified with the help of electronic and non-electronic available Literature. Five species (*Abraxas cashmiria* sp. nov., *Antipercnia pseudoalbinigrata* sp. nov., *Aspitates pseudogilvaria* sp. nov., *Chorodna Baramulia* sp. nov. and *Xenoplia kashmirensis* sp. nov.) have been reported as new species. Present findings agree with those of Kumar *et al.* (2018) who conducted the study on biodiversity of geometrid moths in Himachal Pradesh, India to find the status of geometrid moths, during the study he concluded that collected geometrid moths belonged to 27 genera and three subfamilies Ennominae, Geometrinae and Sterrhinae, the subfamily Ennominae was represented with maximum species followed by the subfamily Geometrinae and the subfamily Sterrhinae. Also Walia (2005) published a list of 184 species of family Geometridae from Chandigarh and Himachal Pradesh and out of these, 86 species are under subfamily Ennominae, 46 species under subfamily Sterrhinae, 38 species under subfamily Geometrinae, 13 species belonging to 11 genera of subfamily Larentiinae and a single species under subfamily Desmobathrinae. In present study *Alcis repandata* (Linnaeus) was found most dominant specie in terms of relative abundance (11.02%) followed by *Ascotis imparata* (Walker) (7.53%) while as *Callipia vicinaria* (Dognin) was found least dominant (0.25%). Present records further indicated highest species diversity in Baramulla (H´ = 1.452760) followed by Anantnag (H´=1.413907) and lowest in Srinagar (H´=1.273559).

Conclusion
This paper highlighted the diversity of Geometrid moths from the studied areas of Kashmir valley, total of 39 species are reported which belongs to 4 subfamilies. *Alcis repundata* (Linnaeus) was found most dominant (11.02%) and *Callipia vicinaria* (Dognin) was least dominant (0.25%). Diversity indices was highest in Baramulla (H’ = 1.452760) and lowest in Srinagar (H’ = 1.273559).

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

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Impact of growth hormones on vegetative propagation of *Elaeocarpus ganitrus* Roxb.

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Synergist

ABSTRACT

***Elaeocarpus ganitrus* Roxb. commonly identified as 'rudraksha', belonging to *Elaeocarpaceae* possess a great religious, spiritual and materialistic significance which is placed under the threatened category in the tropical wet evergreen forests of North East India. Because of its over-exploitation, poor germination, low viability rate and hard seed coat, an attempt has been done for mass production of planting materials through cuttings and air layering's. Cuttings trials were conducted during three different periods, mid - March, mid – July and mid – November by using Indol butyric acid and Napthalene acetic acid of 1000, 2000, 4000, 6000 ppm where air layering's were done during mid - May by treating IBA and NAA solution of 500, 1000 and 2000 ppm in combination with para-hydroxybenzoic acid of 2000 ppm as synergist. Application of IBA and NAA of different concentration did not encourage the growth in the cuttings in all three periods. Air layering's treated with NAA 1000 ppm+2000ppm para- hydroxy benzoic acid and IBA 500 ppm +2000ppm para-hydroxy benzoic acid resulted the highest and same value of callusing and rooting percent (70 and 66.67%), respectively while minimum callusing and rooting percentage (56.67 and 51.67%) was recorded in control. The present study focused on the mass production of planting materials in shorter duration with a reasonable cost for enhancing production as well as socio-economic conditions.**

Introduction

The genus Elaeocarpus has about 360 species, spread over from the West (Madagascar) to the East (New Zealand); also covering the regions of Southeast Asia, Southern China, Japan, Australia, Malaysia, New Guinea, Fiji and Hawaii (Coode, 2007). Out of the total species, 120 species belonging to this genus recorded in different parts of South and Southeast Asia including foothills of the Himalayas and different parts of India, Nepal, Bhutan, Tibet, Indonesia, Philippines, Myanmar to Bangladesh at an altitude of 900-1800 mean sea level (Bhuyan *et al.,* 2002), about 25 species are found in India (Khan *et al.,* 2003). *Elaeocarpus ganitrus* Roxb. (Synonym: *E. sphaericus* (Gaertn.) K. Schum) belongs to "*Elaeocarpaceae*", is popularly known as 'Rudraksha' for its hard, ornamental stony endocarp and highly recognized for its medicinal and religious value. It is a medium

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to large-sized evergreen tree with a large spherical crown attaining a height of 50-200' with a girth of 4'. It is naturally found in evergreen forests of West Bengal, Assam, Bihar, Madhya Pradesh, Arunachal Pradesh excluding Tawang and Upper Subansiri and the Konkana Ghats of Maharastra states in India. It is also grown as ornamental tree in the homestead in many parts of the country. The Rudraksha is characterized by three-tier structure in tropical evergreen forest but it is usually present in the second storey.

Hindu mythology described about the great significance of religious, spiritual and materialistic aspect of Rudraksha beads. The word Rudraksha is coined from two Sanskrit words: 'rudra' denotes Lord Shiva and 'aksha' means eyes (Ramadurai, 2007). People of Hindu religion are considered the Rudraksha as link between earth and heaven or as a symbol of light and purity. Since ancient times, the beads were threaded together as rosaries or necklaces ('malas') and an important part of Eastern religions particularly in Hindus, Sikhs and Tibetan Buddhists, to ward-off evil spirit and omens and also for meditation and prayer (Li *et al.,* 2014). Wearing of Rudraksha beads around the neck produce a positive effect on nerves, blood pressure and heart ailments (Sakat *et al.,* 2009). The seed have reported in Ayurveda for the treatment of hypertension, insomnia, psychoneurosis and mental diseases. Bhojvaid and Negi (2003) and Hardainiyan *et al*. (2015) reported that the pulp of the fruit is sour in taste and edible and used for epilepsy, headache and mental illness. The aqueous extract of fruit is mainly used as cardio-stimulant, sedative, hypotensive, spasmolytic, anticonvulsant, chloretic, bronchodilatory, where the stem bark is hypoglycemic (Khare, 2007). The paste of stone is externally applied against small-pox, measles and on organs having burning sensation (Pandey and Das, 2004). Rudraksha bead shows various health promoting effects such as antioxidant (Kumar *et al.,* 2008), analgesic (Nain *et al.,* 2012), anti-inflammatory antifungal (Singh *et al.,* 2010), antimicrobial antidiabetic (Hule *et al.,* 2011). Singh *et al*. (2000) also cited that the fruit contains a significant amount of phytocomponents such as iso-elaeocarpine, elaeocarpine, quercetin, gallic, ellagic acids and rudrakine. The population of this species in natural as well as planted forest stands is gradually declining at an alarming rate due to various factors like microbiotic seed nature, considerable period of seed dormancy, poor germination rate along with fungal rot, hard endocarp, long flowering or fruiting intervals etc. The unscrupulous collection of seeds has also adversely affected the natural regeneration. Rising market prices of beads due to religious belief and its many fold importance play a key role for limited distribution of this species in natural habitat (Dafni, 2006), which makes the species under the threatened category on the verge of extinction in near future. Because of the problem in propagation and its ethnic medicinal importance, the conservation approaches mainly *in-situ* and *ex-situ* are to be recommended to synchronize the gap between the demand and supply. In this aspect, the method of vegetative propagation assumes a great significance over sexual propagation (seed) for mass production of planting stock with quick productive gains. The vegetative propagation has not been popularized particularly in forest trees on a substantial scale which become bottleneck for a tree improvement programme in India. However, recently portentous attention has been focused to propagate trees through vegetative means as a strong alternative over seed propagation. Out of the several vegetative methods, two methods namely cutting and air layering are widely used in forest species because of the simplicity and cheap. These methods will be exceptional to give more advantage if the exogenous plant growth regulators are applied alone or in combination with auxin synergist. Few reports on the propagation through vegetative method (Bhojvaid and Negi, 2003); seed propagation (Khan *et al.,* 2003; Saravanan *et al.,* 2011) and *in-vitro* propagation (Saklani *et al.,* 2015) has been carried out but the method should be suitable to agro-climatic conditions for raising planting stock. Thus, the present investigation was undertaken to find the appropriate combination of plant growth regulators with auxin synergist on the response of rooting through cuttings and air layering's.

Material and Methods

The present experiment was conducted in the plantation plot of Buxa-Cooch Behar Research Range (Silviculture - North Division) of

Rajabhatkhawa forest of West Bengal during the year 2018 which is 40 km away from the campus of Uttar Banga Krishi Viswavidyalaya, Pundibari at an altitude of 120 m above mean sea level with 26^0 36' N and 89^0 40' E in the plains of terai zone.

Preparation of cuttings and hormonal treatments:

The semi hard wood cuttings of 15- 20 cm long and uniform thickness of 1.0-1.5 cm having at least 2- 3 nodes were collected from the disease free and medium sized trees. Each cutting was given a radial cut at the top of the apical bud and a slanting cut at the base with a sharp razor blade to expose maximum absorbing surface for effective rooting. The base portion of the cuttings were dipped for 30 seconds in the solution of IBA (Indole 3-butyric acid) and NAA (Naphthalene acetic acid) of 1000, 2000, 4000, 6000 ppm to a depth of 1 cm and then allowed to dry for 10-15 minutes. After that the cuttings were planted in polybags containing growing media of soil: sand: Farm Yard Manure: coco-pea in the ratio of 2:1:1:1 in three different periods viz., mid-March, mid–July and mid–November and placed in a low cost polyhouse. The upper portion of the cuttings was sealed by either the paste of cow dung or wax to prevent the moisture loss. Irrigation was done twice in a day i.e. in morning and evening. Soil drenching of Bavistin (@2g litre^{-1}) or Captan (@1%) was done in alternate weeks to prevent the disease. The experiment comprised of two growth regulators of four concentrations comprising of nine treatments with a control having three replications. Each replication had twenty numbers of cuttings to the total of sixty cuttings per treatment. The growth attributes like sprouting and rooting percentage, length of the sprout, time taken for sprouting, average length of root and root number per cutting was recorded after 30 days.

Preparation of air-layering and hormonal treatments:

Vigorous and healthy branches of young mature trees of approximately 10 years old were selected for air-layering. Secondary branches of 1.0–1.5 cm diameter was selected randomly from the trees and 2-5 cm length of bark was girdled out cylindrically. Firstly, the girdled portion in the stem were treated with the auxin synergist of p-hydroxybenzoic acid of 2000 ppm by using cotton and allowed to dry for few seconds and then treated with different concentration of IBA and NAA solution of 500, 1000 and 2000 ppm, respectively. The cut area around the stem was enclosed with a suitable media consisting of soil: cow dung: coco-peat at the rate of 2:1:1 to hold moisture and completely wrapped with polythene sheet (20-25 cm square shaped) and tied at both ends to avoid moisture loss. The experiment had two growth regulators with three concentrations comprising of seven treatments including a control comprising 60 numbers of air layers per treatment (20 numbers in each replication). Each treatment was done separately in separate trees whereas untreated layer served as control. Air layering was done in the month of mid-May with the onset of monsoons. Regular spraying of water once in three days was carried out to keep moisten the rooting media or as and when required and constantly monitored for rooting response. At the end of 45 days, the air layered branches are detached from the parent trees for recording the observation like percentage of callus, percentage of rooting, primary and secondary roots number, root length, weight of fresh and dry root per air-layer. The entire recorded data were subjected to statistical analysis using CRD (Completely Randomized Design) following Gomez and Gomez (1984). The DMRT (Duncan's multiple range test) was also performed to relate the significant difference between the mean values.

Results and Discussion

The response of different treatments on cuttings:

Irrespective of different concentration of IBA and NAA, the results revealed that no growth and sprouting were induced in the cuttings in all of the three periods. Even if, either callus or root formation didn't take place, the cuttings were gradually dried up subsequently and finally failed in all aspect. The present study is well supported by Kumar *et al*. (2014) in *Salvadora oleoides* and Thakur (2014) in *Acacia catechu*. On the contrary, Saravanan *et al*. (2011) reported that 16 % regeneration was achieved in stem cuttings having apical meristem where no regeneration was observed in the stem cuttings devoid of meristems in *E. venustus*. The rejuvenation power in the cutting generally varies with species, age and environment. Cuttings of some species regenerate very easily, some with difficulty while others do not regenerate at all and are thus obstinate. The present species, Rudraksha was under the last category. The presence of root inhibitors like lignin, tannin and abscisic acid can't be ruled out in the cuttings of this species. The presence of anatomical barriers such as sclerenchymatous tissue may make a barrier for root development. Absence of 'rhizocline' as well as of 'rooting co-factors' may be responsible for the obstinacy of this tree species to root. Nanda and Kochhar (1985) reported the similar findings in *Bougainvillea glabra, Echitis caryophyllata* and *Jasminum pubescence*. The capacity of absorption of less or higher concentration of plant growth regulators may have inhibitory effect on sprouting as well as rooting. Non-rooting may be due to sensitivity of plant to auxins or genetic and physiological disruption of auxin transport (Esmon *et al.,* 2006). It can't be ignored that high level of secondary metabolites may prevent root formation in the cuttings (Yadav *et al.,* 2006).

Callusing and rooting in air layerings:

At the end of 45 days of layering, the results exhibited the significant (p = 0.05) difference among the various plant growth regulator treatments with respect to the percentage of callusing and rooting, average number of primary and secondary roots, root length and average fresh and dry weight of root (Table 1). Irrespective of the treatments, the average callusing and rooting percentage was 63.33 and 61.67 percent in NAA and IBA, respectively. Maximum callusing (70.00 %) in T_5 (NAA 1000 ppm+2000 ppm phb) was closely followed by 66.67 percent in T_1 (IBA 500 ppm+2000 ppm phb). Callusing (66.67 %) with T_1 (IBA 500 ppm+2000 ppm phb) was statistically at par with T_2 (IBA 1000 ppm+2000 ppm phb) and T_4 (NAA 500 ppm+2000 ppm phb), both recorded same value of 65.00 percent whereas minimum callusing (56.67 %) was recorded in T_7 (Control) which closely preceded by T_3 (IBA 2000 ppm+2000 ppm phb) and T_6 (NAA 2000 ppm+2000 ppm phb) exhibiting 58.33 and 61.67 percent, respectively which showed statistically at par with each other. Similarly, rooting was highest (70.00 %) in T_5 (NAA 1000 ppm+ 2000 ppm phb) statistically at par with T_1 (IBA 500 ppm+2000 ppm phb) having 66.67 % whereas lowest rooting (51.67 %) was exhibited in T_7: Control in air layers (Figure 1). The value of rooting percentage (63.33 %) in T_4 (NAA 500 ppm+2000 ppm phb) was not significantly different with 61.67 % in T_2 (IBA 1000 ppm+2000 ppm phb).

Though, the plant growth regulators exhibited callusing and rooting response but all concentration of NAA slightly showed better results than IBA. Callus and root formation were higher in growth regulator treatment indicating a conduciveness environment in comparison to control and showed the decreasing trend with increase in concentration of IBA while it increased up to certain NAA concentration then declined with further rise in concentration. The present finding is in close agreement with Bhojvaid and Negi (2003) in *E. ganitrus* and Sanchez *et al*. (2009) in *Psidium guajava* where callus formation was reduced with increasing concentration of IBA (2000, 4000 and 6000 ppm) and stopped completely at 6000 ppm. It is proved that IBA and NAA increase elasticity of cell wall and accelerate the cell division but excessive concentrations inhibit the process of formation of callus.

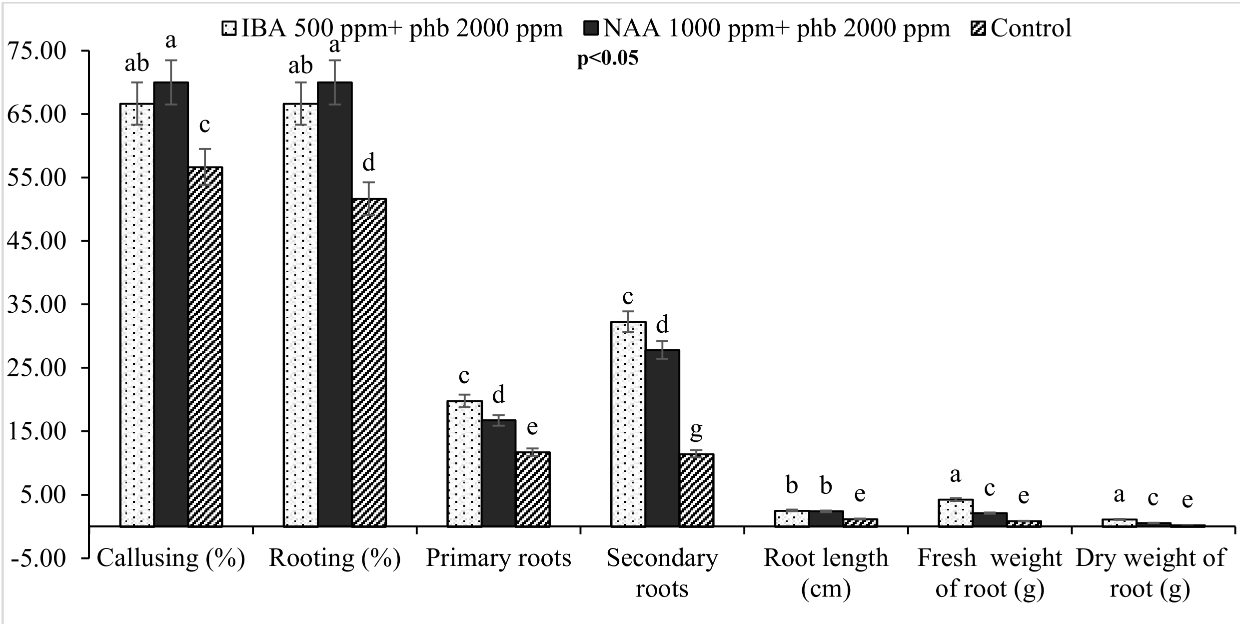
Callus development is common with the totipotency of the meristematic tissue which appears as a thin layer around the wounded end of cuttings of air layers. The newly formed callus consisted of irregular unspecialized parenchymatous cells which further differentiate into root primordial, act as a protective layer for the formation of adventitious root from other tissues of the layered branch (Colodi *et al.,* 2008). Evidently callus formation is an event which generally occurs earlier to the rhizogenesis. Callus and adventitious root formation appear as an independent phenomenon in most tree species but generally occur at the same time and space, resulting competition for same resources. That is the reason why rooting percentage was decreased with increase in hormonal concentration in the present study which contradicts with the results of Tomar and Singh (2011) in *Ficus krishnae* and *F. auriculata* and Bhojvaid and Negi (2003) in *E. ganitrus*. Auxin at lower concentration is found to be more effective for adventitious root formation in *Quercus serrata* (Srivastava *et al.,* 2000). Singh and Ansari (2014) reported that rooting response regulated by a balance of internal translocation of hormonal growth regulators, carbohydrates, nitrogenous substances and co-factors acting

Table 1: Effect of IBA and NAA on callusing percentage, rooting percentage, primary and secondary root number, root length, fresh and dry root weight in air layered branches of *E. ganitrus.*

Treatments	Callusing (%)	Rooting (%)	Primary roots	Secondary roots	Root length (cm)	Fresh root weight (g)	Dry root weight (g)
T_1	66.67^{ab} (54.75)	66.67^{ab} (54.75)	19.80^{c}	32.27^{c}	2.52^{b}	4.25^{a}	1.12^{a}
T_2	65^{b} (53.73)	61.67^{bc} (51.76)	23.13^{b}	45.33^{a}	3.02^{a}	2.84^{b}	0.74^{b}
T_3	58.33^{c} (49.80)	58.33^{c} (49.80)	20.33^{bc}	40.93^{b}	1.76^{cd}	2.00^{c}	0.53^{c}
T_4	65^{b} (53.73)	63.33^{bc} (52.74)	13.07^{e}	22.33^{e}	1.50^{de}	0.82^{e}	0.22^{e}
T_5	70^{a} (56.84)	70^{a} (56.84)	16.73^{d}	27.80^{d}	2.38^{b}	2.11^{c}	0.56^{c}
T_6	61.67^{bc} (51.76)	60^{c} (50.77)	36.33^{a}	17.87^{f}	1.92^{c}	1.36^{d}	0.36^{d}
T_7	56.67^{c} (48.84)	51.67^{d} (45.96)	11.73^{e}	11.45^{g}	1.18^{e}	0.87^{e}	0.23^{e}
Mean	63.33 (52.78)	61.67 (51.80)	20.16	29.14	2.04	2.03	0.54
SE(m) (±)	1.01	1.07	0.95	0.77	0.14	0.14	0.037
CD(p=0.05)	3.07	3.27	2.89	2.33	0.41	0.43	0.11

Values in parentheses are arc-sine value
Mean with same letter is not significantly different among the treatments of the respective parameters

T_1 = IBA 500 ppm + 2000 ppm para-hydroxy benzoic acid
T_2 = IBA 1000 ppm + 2000 ppm para-hydroxy benzoic acid
T_3 = IBA 2000 ppm + 2000 ppm para-hydroxy benzoic acid
T_7 = Control
T_4 = NAA 500 ppm + 2000 ppm para-hydroxy benzoic acid
T_5 = NAA 1000 ppm + 2000 ppm para-hydroxy benzoic acid
T_6 = NAA 2000 ppm + 2000 ppm para-hydroxy benzoic acid



*Mean with same letter is not significantly different among the treatments of the respective parameters

Figure 1: Growth and survival of *E. ganitrus* air layered treatments (control, NAA 1000 ppm+2000 ppm phb and IBA 500 ppm+2000 ppm phb).

synergistically with auxins. Auxins prop up the differentiation of meristematic tissue and helps for the formation of root primordial/callus above the girdling zone of the branch (Tchoundjeu *et al.,* 2002). Besides that, girdling in air layering block in the acropetal and basipetal flow of photosynthates in the phloem which causes the accumulation of secondary metabolites such as organic compounds, carbohydrates, auxins etc. above this region (Alves-de Oliveira *et al.,* 1999) which favours the formation of callus and development of adventitious root primordial to develop into roots (Singh *et al.,* 2004). This finding shows close conformity with the findings of Eganathan *et al*. (2000). The different concentration of IBA and NAA had significant variation in average number of primary and secondary roots per air-layering (Table 1). Maximum mean number of primary root (36.33) was exhibited in T_6 (NAA 2000 ppm+2000 ppm phb) in comparison to all the other treatments where as T_7 (Control) was showed minimum mean number roots (11.73). Among the IBA treatments, T_2 (IBA 1000 ppm+2000 ppm phb) showed the highest (23.13) number of primary roots followed by 20.33 number of roots in T_3 (IBA 2000 ppm+2000 ppm phb acid). Overall, it was observed that a greater number of primary roots was noticed in higher concentration of NAA whereas it was exhibited increasing trend up to certain concentration of IBA and then declined. Similarly, the mean number of secondary roots increased with increase in IBA and NAA concentration but up to certain level. Maximum mean number of secondary root (45.33) was observed in T_2 (IBA 1000 ppm+2000 ppm phb) which was significantly differed among all treatments whereas minimum (11.45) was recorded with T_7 (Control). Both IBA and NAA enhanced the number of secondary roots only up to certain concentration indicating optimum concentration is favorable while higher concentration may be toxic to root regeneration. It is proved that exogenous application of auxins increased lateral roots initiation on the basis of auxin concentration and geotropic response of roots. The present study is in close agreement with the results of Swamy *et al*. (2002) in *Grewia optiva* and *Robinia pseudoacacia*.

IBA and NAA significantly affected the average length of the root in air layers. The root length varied from 1.18 cm to 3.02 cm among the treatment with a mean value of 2.04 cm. Air layering's treated with T_2 (IBA1000 ppm+2000 ppm phb) exhibited highest root length (3.02 cm) followed by 2.52 cm in T_1 (IBA 500 ppm+2000 ppm phb) which was statistically at par with T_5 (NAA 1000 ppm+2000 ppm phb) recording 2.38 cm whereas control (T_7) was recorded minimum root length (1.18 cm). The fresh and dry root weight differed significantly among the treatments. Among the treatments, T_2 (IBA 1000 ppm+2000 ppm phb) significantly recorded highest (4.25 g) fresh weight of roots followed by 2.84 g in T_1 (IBA 500 ppm+2000 ppm phb) and lowest (0.87 g) was in T_7 (Control). Among the NAA treatments, T_5 (NAA 1000 ppm+2000 ppm phb) showed the maximum fresh weight of the roots (2.11 g) followed by 1.36 g in T_6 (NAA 2000 ppm+2000 ppm phb). Dry weight of roots was followed the similar pattern like fresh weight in all treatments. T_2 (IBA 1000+2000 ppm phb) and T_5 (NAA 1000 ppm+2000 ppm phb) recorded the maximum dry weight of the roots (1.12 and 0.56 g) among the IBA and NAA, respectively. The season and effective translocation of the food materials in the form of starch and nitrogen to the girdled zone of the air layers might have encouraged the growth of the root by means the production of more number and lengthier roots. Subsequently, the root absorbed water and nutrients from the media leading to more growth, subsequently showed increasing trend in the fresh and dry root weight. This finding is well in line with the results of Reddy (2004) in *Ficus carica*.

Conclusion

The study indicated that *E. ganitru*s amenable to vegetative propagation by air layering. Exogenous application of NAA 1000 ppm+2000 ppm phb and IBA 500 ppm+2000 ppm phb induced the root initiation in air layers successfully in comparison to control as difficult-to-root in cuttings. This technique provides an efficient, minimum cost and efforts in natural conditions for producing massive superior planting stocks for clonal seed orchard or direct planting in the field to obtain the products in short duration.

Conflict of interest

The authors declare that they have no conflict of interest.

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Response of irrigation scheduling and nitrogen levels on growth and yield contributing parameters of radish (*Raphanus sativus* L.) under mid hills of Himachal Pradesh

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ABSTRACT

An on-farm study of irrigation scheduling and nitrogen level on radish was conducted near Solan, Himachal Pradesh, India. It using a randomized block design (factorial) with 4 irrigation schedules i.e. I_0, 4 cm irrigation at IW/CPE ratio (I_1: 0.8), (I_2:1.0), (I_3:1.2) and three N levels i.e. N_0, (N_1:75 per cent of RD) and (N_2:100 percent of RD). Results revealed that treatment combination N_2I_3 was recorded with maximum number of leaves (27.3 and 25.0), leaf length (32.53 cm and 29.44 cm), root length (22.21 cm and 32.91 cm), root diameter (4.58 cm and 5.28 cm), net root weight (156.2 g and 209.1 g), gross root weight (204.6 g and 341.3 g) and yield (309.0 quintals/ha and 288.1 quintals/ha during 2016-17 and 2017-18, respectively over the N_0I_0. The highest B:C ratio (3.61:1) was worked out under N_2I_3 which was rated as the most profitable combination followed by N_2I_2 (3.39:1). It can be concluded that among different irrigation schedules, I_3 and I_2 schedules were found to be equally good for maintaining optimum soil moisture content as compared to I_1 and I_0. Among different N levels, N_2 was found to be best which might influence the growth and yield of radish (*Raphanus sativus* L.).

Introduction

Agriculture is the primary source of income for the people of Himachal Pradesh and plays a significant role in the state's economy. Himachal Pradesh is the only state in the country with a rural population of 89.96 percent. Although Himachal Pradesh is blessed with natural beauty, perennial rivers, and snow-capped mountains, it also suffers from water scarcity and deteriorating water quality as a result of human intervention and development activities, which is likely to worsen as the population grows and people's lifestyles change. It is the State's responsibility to put the restricted and scarce water resources to the most cost-effective, efficient, and long-term use possible in order to promote their optimal use for irrigation and other purposes in accordance with the priorities. The role of irrigation in ensuring food security is vital as about 40 per cent of world food is produced by irrigated agriculture (FAO, 2002). As the world's population grows, so does the demand for food and fibre, resulting in the use of irrigation to keep plants growing (Delfine *et al.,* 2000). Irrigation is used in all places of the world where rainfall does not provide enough ground moisture (Bhuiya *et al.,* 2003). The amount and frequency of irrigation determined by irrigation scheduling is governed by many complex factors, but climate plays a major role. Therefore, it is necessary to develop irrigation

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scheduling techniques under prevailing climatic condition and due to lack of proper irrigation scheduling techniques, the average yield of these vegetable crops is low which might be due to excess or deficit soil moisture regimes(Imitiyaz *et al.,,* 2000). Various studies have been carried out earlier on irrigation scheduling techniques under a wide range of irrigation system and management, soil, crop and climatic conditions. Water stress is one of the major limitations to the agricultural productivity worldwide, particularly in warm, arid, and semi-arid parts of the world.

Radish is the root crop belongs to family Brassicaceae. Being a shallow rooted crop, radish needs frequent and light irrigations for better growth, development and higher yield of better quality. However, farmers irrigate radish through flooding observing the dryness of soil. Improper irrigation practices not only cause wastage of expensive and scarce water resource but also decrease crop yield, quality, water use efficiency and economic returns. As water for irrigation is a scare resource, its optimization is fundamental to water resource use. It permits better utilization of all other production factors and thus leads to increased yield per unit area per unit time. Inadequate water supply at improper time results in moisture stress reduced nutrient uptake and lower water use efficiency (Olezyk *et al.,* 2000). One of the most important aspects of agro-techniques for optimising carrot yield is irrigation schedule. Water is the only factor that has a direct impact on vegetable yield (Siddiqui, 1995).Water stress reduces crop canopy and biomass growth, resulting in a drop in production. Water application scheduling is critical to make the most efficient use of drip irrigation system, since excessive irrigation reduces yield and insufficient irrigation causes water stress and lowers production (Kashyap and panda, 2003; Wang *et al.,* 2006).Scarcity of irrigation water is an acute problem for successful crop production anywhere in the world (Chowdhury *et al.,* 1999). As a result, efficient use of scarce irrigation water is critical for high-quality carrot production (Islam *et al.,* 2015). The key component that determines the nitrate concentration in vegetables is nitrogen fertiliser, which has been identified as one of the most important factors impacting yield and chemical composition of vegetables. Excess nitrogenous fertiliser is commonly applied to crops as a suitable insurance against production losses and their financial effects (Huang, 2002). Nitrogen is very essential for leafy and root vegetable production. Its application upholds the overall growth, yield and quality of radish (Brintha and Seran, 2009).

Material and Methods

Site description

The field experiment was carried out during the Rabi seasons of 2016-2017 and 2017-2018 at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, in the experimental farm of Soil Science and Water Management (HP).It is situated at 30° 52'N latitude and 77° 11' E longitude, with an elevation of 1175 m above mean sea level and a 7-8% average slope. The study region is located in Himachal Pradesh's sub-temperate, sub-humid agro-climatic zone (zone-2). The area's average annual rainfall is around 1100 mm, with roughly 75% of it falling during the monsoon season (mid June-mid September).During the growing seasons of Radish, the mean minimum and maximum temperatures recorded ranged from 3 to 14°C. Winter rains are scarce, falling primarily in January and February. Rainfall and pan evaporation data for the research region were obtained from the meteorological observatory of the University's Department of Environmental Science for both years of the experiment. According to the USDA's Soil Taxonomy, the soil in the area belongs to the TypicEutrochrept sub-group. The texture of the soil is sandy loam, and its reaction is neutral (Table 1).

Table1: Salient physical properties of experimental soil

Properties	Depth (cm)	
	0-15	15-30
Sand (%)	58.7	59.5
Silt (%)	27.2	28.5
Clay (%)	14.1	12.0
Textural class	Sandy Loam	Sandy Loam
Bulk density (g cm^{-3})	1.29	1.31
Moisture retention at 0.33 bar (w,%)	23.9	21.0
Moisture retention at 15 bar (w,%)	7.2	6.8
Available water (w,%)	16.7	14.2

Trial establishment and observation

The experiment was laid out in randomized block factorial design consisting of combinations of four irrigation treatments included I_oN_o irrigation (control), I_1, I_2, I_3 (4 cm irrigation at 0.6, 0.8, 1.2 IW/CPE ratio respectively) as the main factor and three nitrogen rates were applied N_o no nitrogen (control), N_1, N_2 (75, 100 per cent of recommended dose of N respectively), as the sub main factor applied through surface irrigation. Pusa Himani variety of radish was sown at spacing 30 cm × 10 cm on 3m ×2 m beds. Farm yard manure and recommended levels of P_2O_5 and K_2O nutrient were added in each plot equally as per recommended dose (SSP300 kg/ha and MOP 60 kg/ha respectively) for radish. Nitrogen in the form of urea was applied as per the experiment schedule. After sowing, the light irrigation was given at alternate days till the proper germination of seeds. Thereafter, the crop was irrigated with 4 cm common irrigation. Then as per schedules of irrigation, subsequent irrigations were applied. In schedules I_1, I_2, and I_3 4 cm irrigation was applied at irrigation water (IW) and the cumulative pan evaporation (CPE) ratios were 0.8, 1.0 and 1.2 respectively. All the other recommended package of practices of Dr Yashwant Singh Parmar University of Horticulture and Forestry was followed for successful raising of Radish.

Analysis of growth and yield parameters

In each treatment, fifteen plants were chosen at random to study the plant parameter. From the base of the petiole to the highest point of the leaves, leaf length was measured in centimetres using a metre scale, while root length was measured from crown to distal end. Root diameter was recorded just below the crown with the help of digital vernier calliper. Gross root weight was recorded by weighing the roots along with leaves while for calculating net root weight; roots were properly cleaned to remove the soil sticking to them and weighed individually.

Dry matter content (%)

The roots harvested in each treatment were thoroughly cleaned and one kilogram of fresh roots was drawn from each treatment. Those roots were washed in running tap water and then oven dried at 65±5^{o}C till a constant weight. The dry matter was expressed in percentage using following formula:

$$\text{Dry matter content (\%)} = \frac{\text{Dry weight (g)}}{\text{Fresh weight (g)}} \times 100$$

Statistical analysis

To analyse the influence of treatments on yield and yield attributing features of radish, all data were subjected to analysis of variance (ANOVA) suited to the experimental design. The data recorded was analyzed by using MS EXCEL, SPSS 11.5 Software and the mean values of data were subjected to ANOVA as described by Panse and Sukhatme, 2000) for RBD (factorial). Comparison of treatment means was carried out using the critical difference (CD) at 5 % probability level.

Results and Discussion

Growth parameters

The influence of irrigation schedules and N levels on the number of leaves was significant during both years of the study, according to the data in (Table 2).During both years of study, highest number of leaves (25.2 and 23.4) were recorded with N_2 while minimum (15.5 and 19.8) under control (N_0). Under irrigation levels, significantly higher (21.0 and 23.3) number of leaves were recorded under I_3 schedule and minimum (18.9 and 20.7) under control (I_0) during 2017 and 2018, respectively. Under interaction significantly higher (27.3 and 25.0) numbers of leaves were recorded under N_2I_3 and lower (14.6 and 17.8) under N_0I_0. Irrigation schedules I_3, I_2 and I_1 significantly increased the number of leaves by 10.4, 9.0 and 4.5 per cent over I_0. Among N levels, the increase was 38.1 per cent in N_2 and 21.0 per cent over N_0. The results were found to be in line with those of Acar *et al.* (2008) and Amiri *et al.* (2012) who found that the increasing of irrigation frequency caused an increase in number of leaves in eggplant and lettuce, respectively. The more number of leaves in plant grown under higher N level might have been associated with the application of N in adequate quantity that positively improved the vegetative growth of radish plant. Jilani *et al.* (2010) in radish and Wahocho *et al.* (2016) in turnip found the positive and significant effect of N on number of leaves.Irrigation schedules, N levels, and their interaction had a significant effect on leaf length during both years of the study, according to the data in Table 2.

Table 2: Effect of irrigation schedules and N levels on growth parameters of radish.

Nitrogen levels	Irrigation Schedule									
	No Irrigation (control)	4 cm Irrigation at 0.6 IW/CPE ratio	4 cm Irrigation at 0.8 IW/CPE ratio	4 cm Irrigation at 1.2 IW/CPE ratio	Mean	No Irrigation (control)	4 cm Irrigation at 0.6 IW/CPE ratio	4 cm Irrigation at 0.8 IW/CPE ratio	4 cm Irrigation at 1.2 IW/CPE ratio	Mean
	2016-2017					2017-2018				
	Number of leaves per plant									
No Nitrogen (Control)	14.6	14.9	15.6	16.9	**15.5**	17.8	19.4	20.4	21.3	**19.8**
75 % dose of Nitrogen	18.9	20.9	21.3	18.9	**20.0**	21.8	22.4	22.7	23.4	**22.6**
100 % RDN	23.3	24.5	25.6	27.3	**25.2**	22.4	22.3	23.8	25.0	**23.4**
Mean	**18.9**	**20.1**	**20.8**	**21.0**		**20.7**	**21.4**	**22.3**	**23.3**	
CD (P=0.05) of N			1.7					0.9		
CD (P=0.05) of I			1.9					1.0		
CD (P=0.05) N×I			3.3					1.9		
	Leaf Length (cm)									
No Nitrogen (Control)	21.03	23.31	24.57	27.13	**24.01**	19.89	21.27	22.11	22.50	**21.44**
75 % dose of Nitrogen	27.80	28.53	28.77	29.97	**28.77**	23.08	23.22	24.32	24.72	**23.83**
100 % RDN	31.00	29.53	31.73	32.53	**31.20**	25.33	26.33	26.44	29.44	**26.89**
Mean	**26.61**	**27.12**	**28.36**	**28.88**		**22.77**	**23.61**	**24.29**	**25.55**	
CD (P=0.05) of N			1.17					1.20		
CD (P=0.05) of I			1.36					1.38		
CD (P=0.05) N×I			2.33					2.38		
	Root length (cm)									
No Nitrogen (Control)	19.52	19.58	19.86	19.78	**19.69**	21.68	23.60	22.58	22.47	**22.58**
75 % dose of Nitrogen	20.03	19.75	19.51	21.03	**20.08**	21.55	24.57	28.67	28.77	**25.89**
100 % RDN	21.29	21.43	21.82	22.21	**21.69**	28.74	27.44	28.47	32.91	**29.81**
Mean	**20.28**	**20.25**	**20.40**	**21.01**		**23.99**	**25.20**	**26.57**	**28.03**	
CD (P=0.05) of N			0.89					4.50		
CD (P=0.05) of I			1.02					5.16		
CD (P=0.05) N×I			1.7					8.94		
	Root diameter (cm)									
No Nitrogen (Control)	3.22	3.25	3.55	3.72	**3.43**	3.48	3.68	3.88	4.05	**3.78**
75 % dose of Nitrogen	3.88	3.75	3.88	3.92	**3.87**	4.08	4.25	4.35	4.75	**4.36**
100 % RDN	4.08	4.22	4.32	4.58	**4.30**	4.07	4.95	4.95	5.28	**5.00**
Mean	**3.73**	**3.75**	**3.92**	**4.07**		**4.13**	**4.29**	**4.39**	**4.69**	
CD (P=0.05) of N			0.15					0.22		
CD (P=0.05) of I			0.18					0.25		
CD (P=0.05) N×I			0.3					0.44		

Table 3: Effect of irrigation schedules and N levels on yield parameters of radish.

Nitrogen levels	Irrigation Schedule									
	No Irrigation (control)	**4 cm Irrigation at 0.6 IW/CPE ratio**	**4 cm Irrigation at 0.8 IW/CPE ratio**	**4 cm Irrigation at 1.2 IW/CPE ratio**	**Mean**	**No Irrigation (control)**	**4 cm Irrigation at 0.6 IW/CPE ratio**	**4 cm Irrigation at 0.8 IW/CPE ratio**	**4 cm Irrigation at 1.2 IW/CPE ratio**	**Mean**
	2016-2017					**2017-2018**				
	Net root weight (g)									
No Nitrogen (Control)	106.5	117.5	125.8	138.8	**122.2**	114.2	121.6	123.9	125.8	**121.4**
75 % dose of Nitrogen	134.2	132.5	150.8	139.5	**139.3**	135.9	140.9	152.6	155.0	**146.1**
100 % RDN	153.8	149.2	142.5	156.2	**150.4**	163.1	174.1	180.6	209.1	**181.8**
Mean	**131.5**	**133.2**	**139.7**	**144.8**		**137.7**	**145.6**	**152.4**	**163.3**	
CD (P=0.05) of N			14.5					8.4		
CD (P=0.05) of I			16.6					9.7		
CD (P=0.05) N×I			28.80					16.80		
	Gross root weight (g)									
No Nitrogen (Control)	154.3	157.9	172.6	172.6	**164.3**	213.3	229.3	249.1	264.3	**239.0**
75 % dose of Nitrogen	189.3	186.9	174.3	171.9	**180.6**	269.4	280.0	291.8	311.7	**288.2**
100 % RDN	163.6	212.3	192.6	204.6	**193.3**	321.8	327.3	341.3	357.7	**337.0**
Mean	**169.0**	**185.7**	**179.8**	**183.0**		**268.2**	**278.9**	**294.1**	**311.2**	
CD (P=0.05) of N			18.2					4.7		
CD (P=0.05) of I			20.9					5.4		
CD (P=0.05) N×I			36.2					9.3		
	Yield (q ha^{-1})									
No Nitrogen (Control)	174.0	206.7	222.7	226.0	**207.4**	165.0	180.7	202.7	210.4	**189.7**
75 % dose of Nitrogen	228.7	236.0	243.0	252.0	**239.9**	223.2	232.0	247.6	255.4	**239.6**
100 % RDN	251.0	265.6	288.3	309.0	**278.5**	259.5	265.0	273.9	288.1	**271.6**
Mean	**217.9**	**236.1**	**251.3**	**262.3**		**215.9**	**225.9**	**241.4**	**251.3**	
CD (P=0.05) of N			9.0					24.7		
CD (P=0.05) of I			10.4					28.6		
CD (P=0.05) N×I			18.0					49.4		
	Dry matter content (%)									
No Nitrogen (Control)	5.60	5.50	5.40	6.10	**5.65**	7.83	7.43	7.27	6.50	**7.26**
75 % dose of Nitrogen	6.82	7.53	7.93	8.43	**7.68**	5.93	7.83	7.80	8.40	**7.49**
100 % RDN	8.23	8.07	9.47	10.50	**9.06**	7.80	9.43	9.57	10.80	**9.40**
Mean	**6.88**	**7.03**	**7.60**	**8.34**		**7.19**	**8.23**	**8.21**	**8.57**	
CD (P=0.05) of N			0.72					0.74		
CD (P=0.05) of I			0.83					0.85		
CD (P=0.05) N×I			NS					1.47		

Table 4: Cost economics of different treatment combination in radish.

Treatments	Fixed cost (Rs)	Variable Cost (Rs)	Total Cost (Rs ha^{-1})	Yield (q ha^{-1})	Gross income (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
N_0I_0	21200	**102674**	123874	169.5	339000	215126	1.74
N_0I_1	21200	**105174**	126374	193.7	387400	261026	2.07
N_0I_2	21200	**106424**	127624	212.7	425400	297776	2.33
N_0I_3	21200	**107674**	128874	218.2	436400	307526	2.39
N_1I_0	21200	**103108**	124308	226	452000	327692	2.64
N_1I_1	21200	**105608**	126808	234	468000	341192	2.69
N_1I_2	21200	**106858**	128058	245.3	490600	362542	2.83
N_1I_3	21200	**108113**	129313	253.7	507400	378087	2.92
N_2I_0	21200	**103252**	124452	255.3	510600	386148	3.10
N_2I_1	21200	**105752**	126952	265.3	530600	403648	3.18
N_2I_2	21200	**107002**	128202	281.1	562200	433998	3.39
N_2I_3	21200	**108252**	129452	298.6	597200	467748	3.61

Average leaf length increased with increase in irrigation and N levels. During both years of study, among N levels, significantly higher (31.20 and 26.89 cm) and lower (24.01 and 21.44 cm) leaf length was recorded under N_2 and N_0 levels respectively. Under irrigation levels, maximum leaf length (29.88 and 25.55 cm) was recorded under I_3 schedule and minimum (26.61 and 22.77 cm) under control which was statistically at par with I_1 (27.12 and 23.61 cm) during 2017 and 2018, respectively. During both years of research, interaction had a significant impact on leaf length. During 2016-17, maximum leaf length (32.53 cm) was recorded under N_2I_3 which was statistically at par with N_2I_2 (31.73 cm) while during 2017-18, maximum (29.44 cm) leaf length was recorded under N_2I_3. Minimum (21.03 and 19.89 cm) leaf length was recorded under N_0I_0 during both the years, respectively. Leaf length in N_2 and N_1 being 27.8 and 15.7 percent higher over N_0,it is possible that this is related to beneficial effects of nitrogen on cell division, cell expansion, and protein synthesis. Irrigation schedule I_3, I_2 and I_1 significantly increased the leaf length by 10.3, 6.7 and 2.8 percent over I_0. It could be because of optimal soil moisture content throughout the growing season, which is important for transpiration, stomatal opening, and leaf growth and expansion. Jilani *et al.* (2010) in radish, Wahocho *et al.* (2016) in turnip, and Bhatti *et al.* (2019) in onion reported similar results. During both the years of the study, the data in Table-2 revealed a significant effect of irrigation schedules, N levels, and their interaction on radish root length. In 2016-17 and 2017-18, the I_3 irrigation schedule had the maximum root length (21.01 and 28.03 cm), while the lowest (20.28 and 23.99 cm) was under control. Among N levels maximum root length (21.69 and 29.81 cm) was observed under N_2 level and minimum (19.69 and 22.58 cm) under N_0 (control) which was statistically at par with N_1 (20.08 and 25.89 cm) during both the years of research. In case of interactions during2016-17, significantly higher (22.21 cm) root length was observed under N_2I_3 which was statistically at par with N_2I_2 (21.82 cm) and N_2I_1 (21.43 cm) while during 2017-18 maximum root length (32.9 cm) was recorded under N_2I_3.Irrigation schedule I_3, I_2 and I_1 significantly increase root length by 10.0, 6.1 and 2.7 percent over I_0. Among N levels, the increase was 21.8 in N_2 and 8.9 percent in N_1 over N_0. Environmental and genetic factor strongly effect root length, so plant with more number of leaves have more root length (Tripathi *et al.* 2017). The findings of Alam *et al.* (2010) in carrot, Jilani *et al.* (2010) in radish, and Baloch *et al.,* (2014) in radish support the findings. The observations recorded indicated the significant effect of irrigation schedules, N levels and their interaction on root diameter of radish and trend was almost similar during both the years of study (Table-2). During both the years of study, irrigation schedule I_3 was recorded with highest root diameter (4.07 and 4.69 cm) followed by I_2 (3.92 and 4.39 cm) and minimum (3.73 and 4.13 cm) was under control (I_0). Under N levels, significantly highest (4.30 and 5.00 cm) and lowest (3.43and 3.78 cm) root diameter was recorded with N_2 and N_0 level, respectively. In case of interactions, N_2I_3 was recorded with maximum (4.58 and 5.28 cm) root diameter while N_0I_0 was recorded with lowest (3.22 and 3.48 cm) during both the years of study. While among N levels, significantly higher root diameter (4.65 cm) was recorded under N_2 which was 28.8 percent higher than N_0 (3.61 cm) followed by N_1 (4.12 cm) which was 14.1 percent higher over N_0. In case of interactions, maximum root diameter (4.93 cm) was recorded with N_2I_3 while lowest (3.35 cm) under N_0I_0 which was statistically at par with N_0I_1 (3.47 cm). Maximum root diameter in plot receiving more N had a higher number of leaves. It could be attributed to increased photosynthetic activity, which resulted in increased food production and root storage (Ali *et al.,* 2006). The findings are consistent with those of Sadia *et al.* (2013) in turnip, Alam *et al.* (2010) in carrot, and Moniruzzaman *et al.* (2013) in turnip.

Yield parameters

The influence of irrigation schedules, N levels, and their interaction on net root weight was substantial during both years of study, according to data in (Table-3).Under irrigation schedules, highest (144.8 and 163.3 g) net root weight was recorded under I_4 followed by I_2 (139.7 and 152.4 g) and lowest (131.5 and 137.7 g) under I_0 during both the years of study. Among N levels, significantly higher (150.4 and 181.8 g) net root weight was recorded with N_3 and lower (122.2 and 121.4 g) under N_0 (control). In case of interaction effect during both the years of study, significantly higher (156.2 and 209.1 g) and lower (106.5 and 114.2 g) net root weight was recorded under N_2I_3 and N_0I_0. Irrigation schedules I_3, I_2 and I_1 recorded significantly higher net root weight and increase was to the tune of 14.5, 8.5 and 3.6 per cent, respectively over the control (I_0). Among N levels, the increase was 36.4 percent in N_2 and 17.2 percent in N_1 over the control (N_0). The influence of irrigation schedule, N levels, and their interaction on gross 'root weight of radish was significant throughout both years of study (Table-3). Under irrigation schedules, significantly higher (185.7 g) gross root weight was recorded under I_1 followed by I_3 (183.0 g) and lower (169.0 g) under control (I_0). Among N levels, N_2 level was recorded with highest (193.3 g) gross root weight which was statistically at par with N_1 (180.6 g) and lowest (164.3 g) under control (N_0) during 2016-17. During 2017-18, highest (311.2 g) gross root weight was recorded with I_3 schedule and lowest (268.2 g) under control (I_0). Under N levels, significantly higher (337.0 g) and lower (239.0 g) gross root weight was recorded under N_2 and N_0 levels, respectively. The significant effect of interaction (N×I) was found throughout both the years of study and significantly higher (204.6 and 357.7 g) gross root weight was recorded under N_2I_3 and lower (154.3 and 213.3 g) under control (N_0I_0) during 2016-17 and 2017-18, respectively. The higher net and gross root weight at irrigation schedule I_3 with 100 percent RDN might be due to the optimum soil moisture content (Table-3), because of the split application; N has perfect solubility, mobilisation, and availability at regular intervals in the required quantity. The reports of Goudra and Rokhade, (2001) on cabbage, Jilani *et al.,* (2010) on radish, Kumari, (2013) on turnip and Sadia *et al.,* (2013) on cauliflower corroborate these results.

During both years of the study, the influence of irrigation schedules, N levels, and their interaction on yield was considerable, according to the results showed in Table-3. Under irrigation schedules, significantly higher (262.3 and 251.3 quintal/ ha) yield was noticed under I_3 schedule which was statistically at par with I_2 (251.3 and 241.4 quintal/ ha) and lower (217.9 and 215.9 quintal/ ha) under control (I_0) during 2016-17 and 2017-18, respectively. Among N levels, significantly higher (278.5 quintal/ ha in 2016-17 and 271.6 quintal/ ha in 2017-18) and lower (207.4 quintal/ ha in 2016-17 and 189.7 quintal/ ha in 2017-18) yield was recorded under N_2 and N_0 levels respectively. In case of interactions, highest yield (309.0 and 288.1 quintal/ ha) was recorded under N_2I_3 and lowest (174 and 165 quintal/ ha) under N_0I_0 during both the years of study. The enhanced root yield might be related to sufficient application of N that significantly influenced the plant performance. Boroujerdnia and Ansari, (2007) in lettuce, Aliyu *et al.,* (2007) in onion, and Acar ***et al.,* (**2008) in lettuce have all reported beneficial impacts of N on yield. Higher number of leaves, leaf length, root diameter, net root weight and gross root weight at irrigation level I_3may be attributed to optimal soil

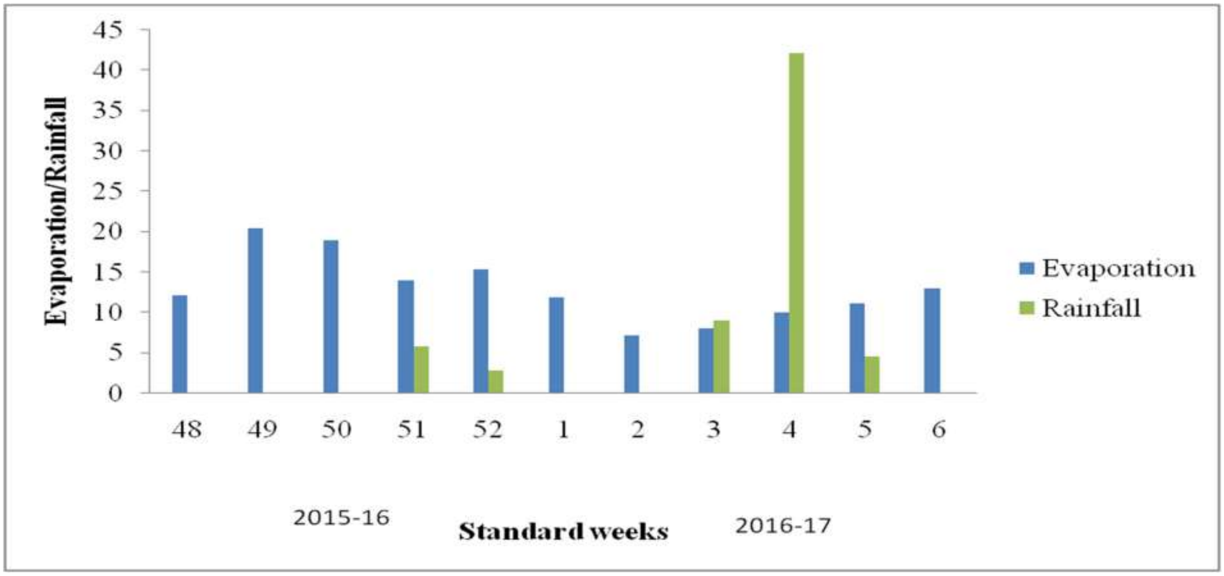

Figure 1: Weekly evaporation and rainfall during the experimentation period 2016-17.

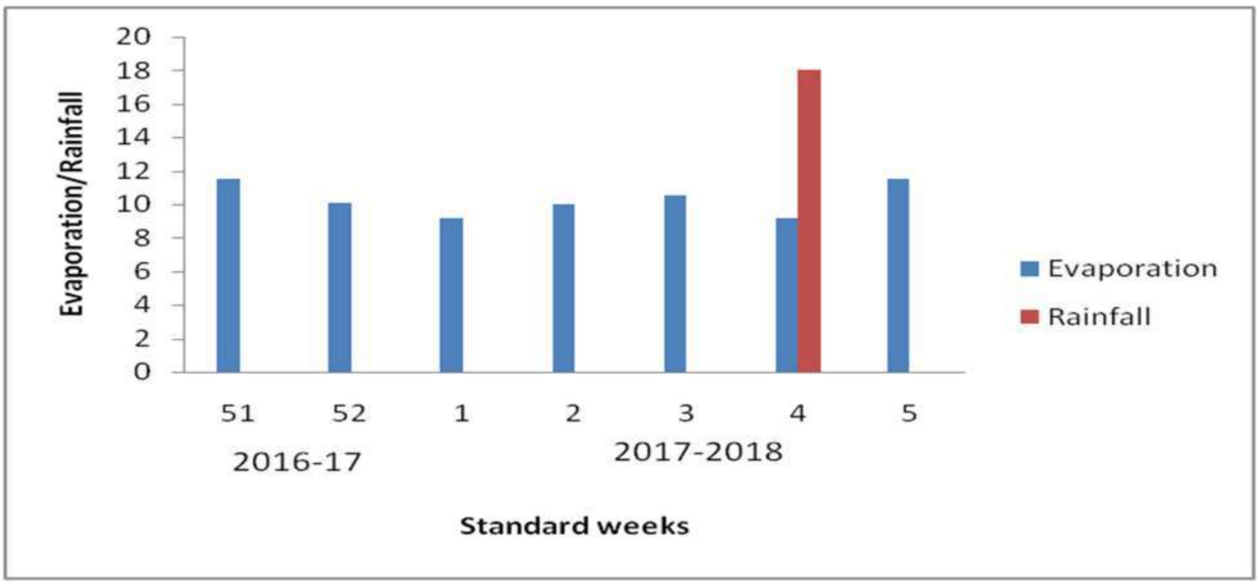

Figure 2: Weekly evaporation and rainfall during the experimentation period 2017-2018.

moisture regimes throughout the growing season, which may have promoted more nutrient uptake and provided the plant with a better soil physical environment to aid in vegetative development and production.Water is the only factor that has a direct impact on the vegetative yield (Siddiqui, 1995). Similarly, Badr *et al.,* 2012 said that applying N to levels required maximising yield during full irrigation will likely result in poor production when the water deficit is significant enough to suppress yield at the optimum N level. The findings of Goudra and Rokhade, (2001) in cabbage, Imitiyaz *et al.* (2000) in cabbage, Kumar *et al.* (2007) in onion, and Kemal, (2013) in shallot are all in agreement. Singh *et al.* (2010) in potato found that higher irrigation and nitrogen levels resulted in better growth and yield expression. The findings in (Table 3) revealed that irrigation schedules, N levels, and interaction (N×I) had a significant effect on dry matter content during both research years (except in first year for interaction effect).Under irrigation schedules, highest dry matter content

(8.34 and 8.57 %) was recorded under I_3 schedule was statistically at par with I_2 (7.60 and 8.21 %) and lowest (6.88 and 7.19 %) under control (I_0) during 2016-17 and 2017-18, respectively. Among N levels, significantly higher (9.06 and 9.40 %) dry matter content was recorded under N_2 and lower (5.65 and 7.26 %) under control during both the years of study respectively. During 2017-18, in case of interaction effect, highest (10.80 %) dry matter content was recorded with N_2I_3 which was statistically at par with N_2I_2 (9.57 %). Lowest dry matter contents (5.93 %) were recorded under N_1I_0 which was statistically at par with N_0I_3 (6.50 %) and N_0I_2 (7.27 %). Dry matter content under I_3, I_2 and I_1 irrigation schedules were significantly higher over I_0 to the tune of 20.2, 12.2 and 8.4 per cent, respectively. Among N levels, the increase was 43.3 percent in N_2 and 17.8 percent in N_1 over N_0. The dry matter content of radish was found to be positively affected by increased watering frequency and increased N levels. Sujatha and Krishnappa, (1995) also found that increased fertility levels resulted in higher dry matter production, which they attributed to more photosynthate synthesis and translocation.Similar findings in potato were reported by Sharma *et al.* (2002), Hurska and Riflug, (1975), Sharma *et al.* (2002) and Lapa *et al.,*(1990). Greater N levels in radish resulted in increased dry matter accumulation, which could be attributed to better vegetative development (Ndang andSema, 1999).

Benefit-cost ratio

Benefit-cost ratio worked out for different treatment combinations has been presented in Table 4. According to the data, the highest gross income was reported in N_2I_3 (Rs597200) followed by N_2I_2 (Rs 562200), N_2I_1 (Rs 530600) and minimum (Rs 339000) under N_0I_0. Similarily, net returns was maximum (Rs 467748) N_2I_3 under followed by N_2I_2 (Rs 433998) and minimum (Rs 215126) under N_0I_0. The highest B:C ratio (3.61:1) was worked out under N_2I_3 which was rated as the most profitable combination followed by N_2I_2 (3.39:1) whereas lowest (1.74:1) under N_0I_0. Comparatively higher root yield due to better root growth under optimum moisture regimes and nutrient availability under N_2I_3 and N_2I_2 might be the reason for higher B:C ratio. These findings are in agreement with the results reported by Imitiyaz*et al.,*2000 in tomato, Alam *et al.* (2010) in carrot, Himanshu *et al.* (2012) and Sumandeep, (2015) in cabbage and Kumari, (2013) in cauliflower who also reported higher gross returns, net return and B:C ratio under higher frequency of irrigation and N level.

Conclusion

The results of study indicated that irrigation scheduling at 1.2 IW/CPE ratio and application of 100 per cent N significantly enhance the growth and yield of radish. It also provides the maximum benefit-cost ratio of radish. Therefore, it may be concluded from the present investigation that deficient irrigation and deficiency of nitrogen may cause reduction in radish yield and lower the soil productivity. This study would help the farmers to increase the productivity of their lands.

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Conflict of interest

The authors declare that they have no conflict of interest.

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The dynamics of the first wave of COVID-19 on environment and wildlife– a boon or a bane?

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ABSTRACT

Even though COVID-19 has drastically weighed upon the humankind, still there is a "silver lining" to see in this dark time. Amidst of this pandemic, most of the human activities were restricted to break the chain of infection which resulted the remarkable change in nature. It has been reported that due to halt in air travel, reduction in the use of fossil fuels, way less functioning of vehicles, shutdown of industries has complied the change in air pollution levels and also change in river water quality. Reports also showed the reduction in particulate matter (PM 2.5 and PM 10), greenhouse gases emissions, massive improvement in the Air quality index (AQI), reduction in the NO_X and SO_X's level has clearly stipulated that nature has got it's time to "revive". Even the global carbon emission has reported to reduced reluctantly which is expected to be the biggest such drop since World War II. Despite conducting water-cleansing projects and spending a lot of money, the situation of the water bodies were far better now during first lockdown. Moreover, migration and breeding of the birds and animals have been reported to be restored to normal pattern due to depletion in man-animal conflict. Apart from the positive, negative impacts on the nature are also being experienced. Our review work is highlighting such impacts witnessed during the first wave of COVID-19, like, the significant improvement in air and water quality, reduction in environmental noise, therefore an in turn cleaner and quieter habitat for the wildlife to mate and also to quench their curiosities by their surprising excursions; but there are also some negative aspects as well, like reduction in recycling and the increase in waste, increased poaching and even lone shuttering of zoo animals.

Introduction

The pandemic induced lockdown, apart from wreaking havoc on human lives, has surely helped us to find a window to a brief time period with clear blue skies and chirping of the birds. The COVID-19 pandemic has brought about a significant upheaval around the world; wrecked economies, human misery, and altered attitudes have caused us to "rethink and re-act." Always in the race of development, there was no time to think what we are doing to our nature and environment but onset of coronavirus had put the world on a pause. There are lot of environmental issues which need to be addressed today and COVID-19 pandemic has set the stage for resolving these issues and coming out with the solutions for betterment of human beings. It has put a question mark on human activities that provokes environmental damage. In amidst of pandemic, most of the human activities were restricted to break the chain of infection and for this it was necessary to be indoors. Soon we noticed the remarkable change in nature be it the quality of air, water quality or biodiversity. Clear skies, fresh air and reduced pollution have made it clear that it's only human intervention that has created the mess

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in environment and overburdened our natural resources. Using less fuel, less industrial activities and less consumption had definitely relaxed the burden on our nature and natural resources and raised a quest for their rational use (Zambrano *et al.,* 2020). Lockdown had not only reduced the vulnerability to COVID-19 but also reduced the exposure time to air pollutants thereby preventing the loss of human lives. Reports showed the reduction in particulate matter ($PM_{2.5}$ and $PM_{10,}$), greenhouse gases emissions, Air quality index (AQI), NO_X and SO_X which has clearly indicated that nature has got it's time to "revive" (Muhammad *et al.,*2020). Despite conducting water-cleansing projects and spending a lot of money, the situations of the water bodies were far better during the first lockdown. Such an improvement in the environment will surely gifted a breath of fresh air to the wildlife, giving them their long lost freedom to breed and breathe in open and clean spaces, which were free from human interventions. Not only the streets were rendered empty, the national parks, zoos were also free from the human eye, which further helped in breeding at a much better and successful rate (Bar, 2021).Though, apart from such positives, some species also had to bear the wrath of humans in the form of illegal hunting due to the less availability of food resources due to the economic crunch and also the restrictions. Definitely there will be a thrust upon "Environmental and Wildlife" issues before and after this outbreak. Apart from the positive, negative impacts on nature are also being experienced.

Positive impact on environment and wildlife-impact on air quality

Air quality index (AQI)- A considerable fall of AQI to 30% was witnessed in almost all the parts of India. Following the closure, the air quality index (AQI) in all Indian states was currently in the two figures (indicating relatively acceptable air quality) (Lokhandwala and Gautam, 2020).The highest drop in AQI was seen in Delhi, where it was 49 percent. Across many areas the air quality index was found to be 20 as compared to 200 and even more in previous years. The air quality index (AQI) in India's North, South, East, Central, and Western regions fell by 44%, 33%, 29%, 15% and 32% , respectively. (Sharma *et al.,* 2020). A remarkable change was seen all over the world with respect to various air pollutants and air quality. Skies were comparatively clear and blue. NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) collected data through Ozone Monitoring Instrument (on AURA satellite) and Tropospheric Monitoring Instrument (on Sentinel-5P satellite) respectively and reported 30% decrease in NO_2 levels showing an improvement in the air quality (ESA, 2020a). Countries such as China, Italy, United Kingdoms, and Germany had experienced about >40% decrease in CO_2 and NO_2 concentration. Particulate matter 2.5 and 10 as well as Nitrogen dioxide and carbon monoxide concentration in India were found to be decreased as 43%, 31%, 18% and 10% respectively during the time of lockdown in comparison to last year's (Kanniah *et al.,* 2020).

Nitrogen dioxide

In urban areas NO_x concentrations are high due to vehicular exhaust, power plants and industries. During the first wave of the pandemic, concentrations of NO_2 were decreased due to restricted human activities in densely populated areas. Remarkable drop of NO_2 concentration was observed in many countries of Europe such as Rome, Madrid and Paris when lockdown was imposed. It has been reported that overall air quality was better resulting in positive health benefits as seen in China. In China, NO_2 levels dropped approximately by 12.9 $\mu g/m^3$ as people were staying indoors (Chen *et al.,* 2020). Similar trends were noticed all over the globe. A decline of 56.2% in NO_2 levels was reported by NCAP (National Clean Air Program) as compared to previous year in India.

Sulphur dioxide

Sulphur dioxide emissions also declined in the period of lockdown according to CPCB (Central Pollution Control Board) who had done analysis of 115 Indian cities. Only 19 percent reduction in SO_2 levels was recorded in Delhi as 70 percent of SO_2 in Delhi comes from power plants in its vicinity. Also some industries were operating at that time in addition to biomass burning. Due to reduction in human activities, an overall decrement of 40% was recorded by Sentinel-5P satellite (ESA, 2020b).

Particulate matter 2.5 and 10

Reduction in particulate matter (PM2.5 and PM10) was also observed worldwide. Particulate matter

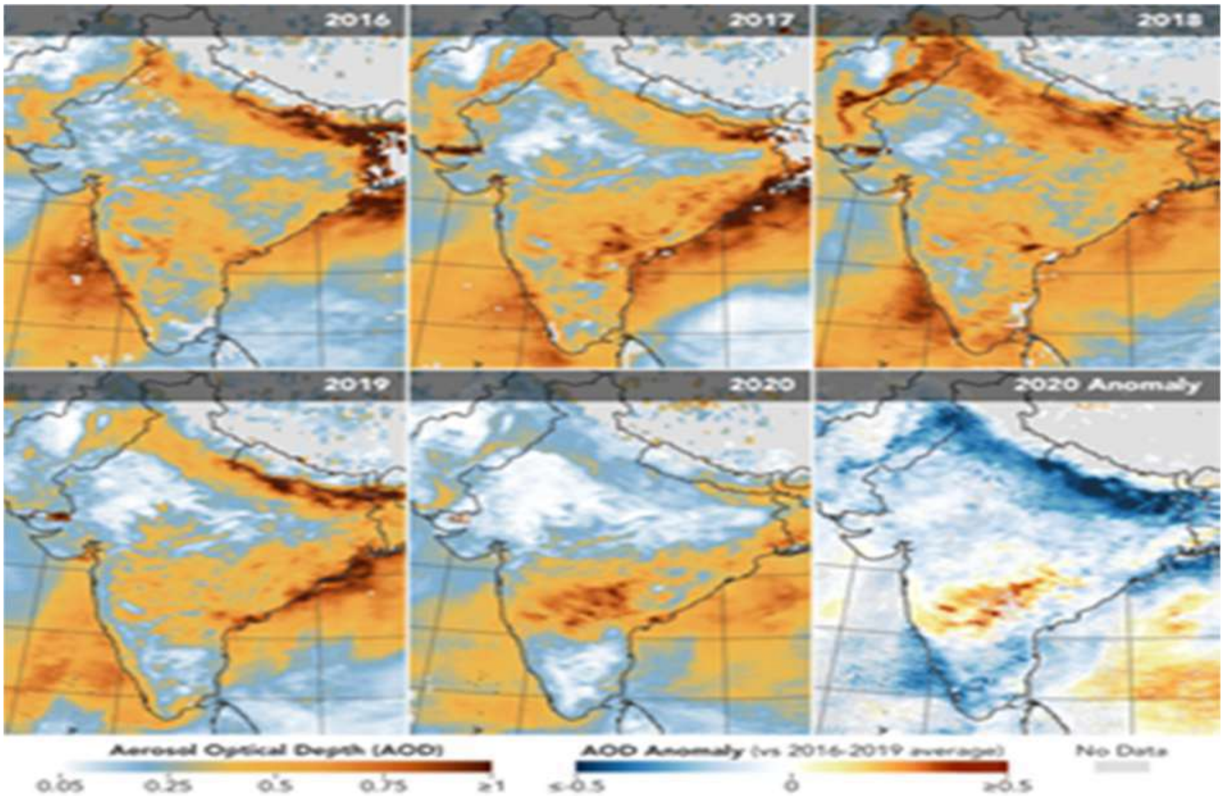

Figure 1: Aerosol optical thickness concentration sequence (month—Terra/Modis), India observed from 31st March to 5th April from 2016 to 2020. (NASA 2020)

2.5 dropped by 1.4 µg/m^3 in Wuhan, declined by 18.9 µg/m^3 across three sixty seven cities (Chen *et al.,* 2020). Similar trends were observed in many countries. In India, the maximum reduction was reported for PM2.5 and a decrease of 34% was reported during the lockdown (Sharma *et al.,* 2020). According to the database of NCAP, in comparison to 2019 a decrease of 35.7% for PM10 and 33.55% for PM2.5 was estimated in 10 Indian cities.

Carbon monoxide and aerosol optical depth

Carbon monoxide also reduced during the months of April and May 2020 in India but it was less than 0.03 mol m^{-2}. Due to vehicular activity restriction, a 30.35% drop was seen in carbon monoxide levels in Delhi (Mahato *et al.,*2020). Aerosol Optical Depth was observed to decrease during the months of March. AOD levels were above 0.75 in many regions of India as the first lockdown preceded it fell down to 0.3 on March 25, 2020 and then 0.2 around April 1st followed by 0.1 on 5th April, 2020. The reduction in AOD concentration was reflected in NASA Earth Observatory imagery of Aerosol optical density observations across India (Gautam, 2020).

Reduced GHG (Green House Gas) emissions

Greenhouse gas emissions reduced during the COVID-19 pandemic as social distancing was promoted and human activities were almost stopped. This was never observed since World War II as suggested by the climate experts (Global Carbon Project, 2020). Countries like the UK, United States of America and China were reported to show a decrease of 30.7%, 31.6% and 23.9% respectively in overall carbon emissions. According to a study, lockdown has resulted in 17% reduction in carbon emissions (Le Quéré *et al.,* 2020). India has also shown a dropdown of carbon emissions by 26%.

Impact on water quality

Due to less human intervention and restricted activities because of the COVID-19 outbreak, a clear effect can be seen on the water bodies. Be it oceans, seas, rivers, lakes, groundwater reservoirs or beaches everything looks cleaner. Due to restriction in lockdown many anthropogenic activities had stopped and therefore the level of water pollution shrank down. Similar patterns were noticed across the World, such as the Grand Canal in Italy, which went clear when the COVID-19 debilitated the entire country, and numerous aquatic species emerged. Ganga and Yamuna, have shown significant decrease in the levels of contamination. As stated by the CPCB's statistics, in Ganga average water quality was recorded to be 27 points during the lockdown period. In Chennai, Perumbakkam lake was seen to be revived. Tourism, fairs, swimming, and textile washing near the ghats were all prohibited. The biochemical oxygen demand (BOD) and coliform levels in the rivers have been reduced. According to reports, the DO levels in the Ganga have risen above 8 ppm, while BOD levels have fallen below 3 ppm in Kanpur and Varanasi (Lokhandwala&Gautam, 2020), which in 2019 were about 6.5 ppm and 4 ppm, respectively. On April 4, 2019, a significant change of 79% in dissolved oxygen was noted in Nagwa Nala of Varanasi. It escalated from 3.8 milligrams/litre to 6.8 milligram/litre (Chakraborty *et al.,* 2021). A notable change can also be observed in the beaches of the world due to the lack of tourists. Beaches in Acapulco, Mexico, Barcelona, Spain, and Salinas, Ecuador, for example, now appear cleaner and have crystal blue water.

Noise pollution reduction

Noise pollution has decreased significantly in most places across the world as the usage of public and private transportation, commercial and industrial activity has plummeted. Delhi's noise pollution was considerably reduced due to empty roads, no honking, closed industries, no commercial events (Times of India, 2020a). Normally the decibel noise level in residential areas is about 55dB in day time and 45 dB at night. During lockdown, these noise levels were expected to reduce to about 30 dB and 40 dB respectively (CPCB).

Impacts on aves

The significant decrease in human activity, implying to decreased air and noise pollution, gave birds the freedom of vocalization, thus helping them out in clearer mating calls and in turn their overall population (Bhat *et al.,*2020). For example, an increase in population of Ruffle feather headed Dalmatian in Divjaka National Park was observed during the first wave induced lockdown. The huge contributors of such positive gifts were overall less human disturbance and less pollution, under such conditions, the birds preferred to expand their flying ranges or to stay within their historical geographical boundaries. As it is clearly known that, changing environmental conditions synchronise and modify bird circannual cycles in a complicated way (Gwinner, 1996). Therefore, birds were found migrating due to extremely less busy migratory ways in larger numbers, for example, pink flamingos were spotted in Navi Mumbai and in Albania due to such surprising migrations.

Impact on fishes

The emergence of the first COVID-19 lockdown resulted in overall less waterways transportation and a steep decrease in the pollutants dumped into the water bodies. Because of a break in industrial activities, waterways were rendered clearer and quieter, allowing fishes to communicate with ease. Thus, it also helped in the recovery of the food chain. A remarkable reduction in the levels of macro and meso-plastic pollution was also reported. Therefore, all of these factors resulted in an increase in the spike of fish biomass. 16 spiny seahorses, an endangered species of seahorse native to the United Kingdoms, were found because of the possible repair of seagrass, which gave them a place to hide (BBC, 2020a). Bronze featherback, a threatened species of fish, was also found in River Gomti as a result of the reduction in disturbances. Barely one of these is spotted once in six month.

The slowing of the worldwide commercial fishing activity has more likely supported species' recovery in the Mediterranean, breeding between March and May, 2020 and the Atlantic, breeding between April and June, 2020. In the shark market of Indonesia, due to the imposed lockdown, a decrease of demand by 70% also helped the revival of shark population (Forbes, 2020).

Impact on amphibians

The empty driveways, streets, vegetative areas around the springs/lakes etc. helped the amphibians to find counterparts of their species during the early warm, damp evenings of spring. These creatures could sense the correct circumstances. Therefore, were noticed to excurse out. After returning to the pool, the adults participated in a number of mating activities before laying eggs in the water for hatching. The increased mating and eggs were found, for example, of American toads; spotted, four-toed and blue-spotted salamanders; spring peepers, and wood frogs, etc. Usually during pre-Covid times, such activity was at times interrupted by human interventions. Frogs have always co-existed with humans, but due to human idleness they were being noticed more. Like, the Indian bullfrog spotted in Narsighpur in Madhya Pradesh, which changes color drastically during mating season in monsoons.

Impact on reptiles-

Replenishing Gharial population in Yamuna

Gharials, an endangered species of reptiles has suffered a 98 percent decline since the 1940s. Destruction of their riverine habitat caused by dams' construction, sand mining, irrigation canals, pollution, agriculture, excessive hunting had resulted in such an exponential decrease in the past. As stated by TOI, in 2011, the gharials ventured in the Yamuna for breeding for the first time. Due to the limited human activity and improvement in Yamuna River's water quality because of the close to null industry and transport interference during the lockdown, baby gharials of the Chambal River returned to the river body after almost a decade. Their number in June-July 2020 was recorded to be around three thousand (Times of India, 2020c).

Increase in egg laying of Turtles

During the pre-Covid time, it can be clearly noticed that humans have wrecked many turtle spawning grounds. Fishing gear, change in climate, pollution, and extreme weather all pose as hazardous to the turtles. But since due to the restricted activity and restrictions due to COVID-19, many residents, visitors, and even wildlife traffickers were deterred from approaching turtle nests and hatchlings. Bumper hatching of rare Olive Ridley turtles was noticed on the beaches of Odisha, Bay of Bengal, and Goa. Generally, only 1 in these 1,000 eggs hatch due to such interferences, but during the lockdown, nearly 20 million and above Olive Ridley hatchlings hatched in Odisha, with half of the 0.4 million nesting making their way to the water. Leatherback sea turtle hatchlings were faring better than they have in years. For example.-Since November 2020, 11 leatherback sea turtle (*Dermochelys coriacea*) nestings were discovered on a Thai beach, the most in the past 20 years (The Hindu, 2020). The 76 Leatherback Sea Turtle nests were found on Juno Beach, Florida, The Guardian (2020). Loggerheads, Greens and Leatherbacks nests were also found in refreshed numbers.

Snakes have always co-existed with humans but due to the induced standstill, they were observed more. Also as snake being alleged as one of the sources of the Coronavirus, it has in some way benefitted the snake population as their consumption, illegal trafficking has stopped in many countries like China etc. There have been few instances of alligators and crocodiles venturing into human settlements or beaches due to less human activity. For example alligators were seen during Spring Break at Barefoot Landing in Myrtle Beach. In India, seven-feet-long crocodile was caught from the Kelanpur village of Vadodara.

Impact on Mammals-

Pangolins Protected

Even after banning hunting and commercial trade of pangolins, their population was seen to be steadily declining as a result of their habitat damage and inadequate penalty for eating them. To correct it, China's top legislature voted to outright prohibit the illicit wildlife hunting trade and to eradicate the harmful practice of consuming wild animals, amid the start of the pandemic in February 2020 (Global times, 2020).

More of Hopping Dolphins

Due to a decrease in waterways activity and less industrial waste dumping, monitored by a system of hydrophones installed on the ocean bed, a freedom to hop around was unlocked by many marine species. Because sound travels significantly longer in the ocean, several dolphin and whale species have evolved extremely sophisticated communication systems, which being free of the industrial noises were noted to be more capable of better communication. The Bosphorus, which runs through Istanbul, Turkey, is one of the busiest international shipping lanes; dolphins were seen swimming and leaping in the seas, now that there was a break in traffic and fishermen were stranded at home due to the lockdown. As stated by the National news of UAE, a pod of 2000 dolphins also surfaced off the shore of Fujairah, UAE, in the Middle East. Ganges Dolphins were back to Ganges shores after a good 30 years. Dolphins were also spotted in the waterways of Mumbai, India. A lot of articles had appeared stating that the water quality of Kolkata's Hooghly River had improved as a result of the present lockdown scenario opening ways to many home species (Bar, 2021).

Collective freedom

Many mammals around the world got intrigued by the deserted cities therefore were found coming out on roads etc. for example sea cows (Sirenia) were found at The Hat Chao Mai National Park, Thailand; cougars in Santiago; Kashmiri goats in Wales; boars in Catalonia. In India too, many such sightings were observed like Nilgai/antelopes in Noida; elephant in Dehradun; bison in Karnataka; leopard in Patna; small Indian civet in Meppayur; one-horned rhino in Guwahati (BBC, 2020b). It was observed that Malaysia's endangered otter population has been dwindling for many years. During the COVID-19 lockdown, however, otters were seen in the normally busy Putrajaya Lake and many other interior Malaysian lakes.

The greater solitude enjoyed by zoo creatures seemed to have some unanticipated advantages. After 10 years of natural mating efforts, Ying Ying, one of Ocean Park's resident pandas, got pregnant (abc news, 2020). Since, natural mating has a greater likelihood of resulting in pregnancy than artificial insemination; it resulted into a successful impregnation. It occurred when the park had been restricted for tourists since late January, 2020 owing to COVID-19 pandemic. Due to the scare of the virus, tourism in all aspects had stopped, therefore giving a heave of sigh to animals that were physically manipulated and were forced to work despite their injuries, like elephants, etc. in India and Thailand.

Overall positive impact- global wildlife trade being at the centre of the stage

The COVID-19 outbreak was suspected to have started at a Chinese market trading wild creatures, shining a focus on the worldwide wildlife trading. The Wildlife Conservation Society, located in New York, pushed governments to outlaw live animal marketplaces and wildlife trading, as well as to put a halt to illicit wildlife trafficking and poaching. Following the initial breakout in Wuhan, China imposed a ban on the rearing and intake of live animals, which is due to become an official law later. To stop any potential pandemics, nations throughout the world are increasingly calling for the prohibition of “wet markets”, which peddle living and dead animals for human use (Roe *et al.,* 2020).

Negative impact on environment and wildlife

An increase in the concentration of ozone at the ground level- a negative impact-

Increase of about 17% ozone (O_3) levels was recorded (Sharma *et al.,* 2020). Ozone was even found in high concentrations in clean areas. When compared to the preceding two years, the influence of COVID-19 on ozone was noticed in European cities such as Nice, Rome, Valencia, and Turin, as well as Wuhan (China). According to the NCAP tracker, an increase of 24.8% in ozone was observed in Mumbai. Other cities like Aurangabad, Nagpur and Pune had high ozone concentration. Reason for the increased ozone concentration as given by the Centre for Science and Environment (CSE) is that high NO_x levels mop the ozone out but the reduced level of nitrogen dioxide was not available to react with ozone and the ozone levels were thus increased. Also high temperatures increased the formation of hydrocarbons from biogenic sources such as trees resulting in high ozone concentration over urban areas. So the improved condition has a disguised effect on air quality and thus human health in the form of increased ozone levels.

Increase in solid waste and reduction in recycling

There is an increase in biodegradable waste, hazardous waste, packaging waste and reduction in other recyclables and inert waste due to the increased use of disinfectants and other sanitary chemicals. To avoid the risk of spreading of the coronavirus, many countries like USA and Italy have even suspended the “recycling” programs and centers that perform such recycling actions. Waste management has also been limited in European countries. Some sectors, on the other hand, have embraced the chance to repeal throwaway bag prohibitions. Single used packaging is widely encouraged due to the risk of Coronavirus. Household organic and inorganic garbage was also found to be expanding as a resultant to the situation created by the virus.

Expansion of biomedical waste

There was a high rise in the “medical waste” due to the outbreak. Hospitals generated tons of medical waste per day which was far more than before. With the discarded Personal protective equipment

(PPE) kits, masks, gloves risk for sanitization workers has also increased. During the pandemic, Wuhan (China) produced around 240 metric tonnes of biomedical waste each day, up from 50 tonnes earlier (Sangkham, 2020). There has been an upsurge in trash from personal protection equipment like masks and gloves in other nations such as the United States (Zambrano *et al.,* 2020). The weight of biomedical waste in Delhi has grown in tandem with the growth of COVID-19 infections. Previously in 2020, around 6 tons of medical waste was incinerated but after the outbreak this number has raised up to 13 tons.

Impact of pandemic on single use plastic

Panic buying, online delivery, increase in medical bags including face shield, vinyl gloves had resulted in increment of single use plastic. Based on the spread of the pandemic, it is expected that plastic waste in the form of plastic medical bottles, trays, gloves, syringe, sterile liquid containers all were found to be increasing (Silva *et al.,* 2021).

Detrimental consequences on wildlife

Clearly as a result of the shattering economic impact on the human population and a decrease in food availability, illegal poaching for food or for selling expensive parts like rhino's ivory (as seen in Africa) etc. were seen in practice. Poaching of endangered animals and wild cats, including jaguars, had been documented throughout Africa down to Colombia, reason being the visitors kept away and many park officers being laid off. An example being-six black rhinos were reported to be slain in March, 2020 in Botswana, and were removed by the government personnel from the Okavango Delta. Bushmeat harvest and illegal wildlife trade were also noted to be increasing alarmingly in Africa (Manenti *et al.,* 2020). Such intrusions and infliction of harm on wildlife can be kept in check using drones with thermal-imaging technology, thus providing a practical solution to the problem. At zoos, the animals faced their own challenges while the world stayed shut. The intelligent and social animals like gorillas, chimpanzees, monkeys, otters, meerkats etc. still showed up close to their grills, amidst the shuttered zoos, in expectation of catching a pair of eyes. Also there had been instances where animals in national parks or zoos of third world countries were facing less care and food due to the diversion of government funds to fight the coronavirus pandemic. The city dwelling animals like monkeys found at temples were found to be starving because of the significantly decreased footfall as their main source of food was that provided by the devotees visiting such sacred places, as seen in Coimbatore, where the residents had to come together to feed them (Times of India, 2020b); but such coming forward of residents or activists cannot be seen in every such instance. Therefore, during the locked up phase, such animals were not able to obtain food and were compelled to change their behaviour (Zellmer *et al.,* 2020). There had been reports of China prescribing use of an injection shot containing bear bile 'Tan Re Quing' to treat COVID-19 (National Geographic, 2020). Such approaches can also harm India's biodiversity of bears in the North-Eastern region.

As a coin has two sides to it, a pause in tourism apart from relieving the giants from the physical manipulations, also led to a massive fall in income for the elephant owners therefore, affecting the animals in terms of food and veterinary care needed (India Today, 2020). Though in India the government through various programs do tend to help elephant caretakers in economic crises to some extent, but that too isn't reported to be going to every single needy caretaker; while many other countries like Thailand don't even have such incentives (Lo *et al.,* 2021).

Conclusion

The noticeable improvements in nature had made us realize and sensitize that our own actions have an impact on the environment. Post pandemic environmental issues are going to come back in a much worse form as everybody will be just focused on building the economy and dealing with Corona virus on the other hand, the glimpse of which we are already seeing now. Thus, COVID-19 pandemic have no effect on the environment permanently. But it made us learn how we can reduce the degradation of the environment by changing social, economic and behavior patterns and help to promote sustainability of environment and wildlife. The huge positives seen during the first wave, in respect to environment and wildlife have got almost obliterated due to the comeback of human interventions, industries, and transports. Overall, the crisis may have no permanent environmental effects as economic activities has resumed now. What we've learned about the environmental benefits and risks of sharp drops in global economic activity, on the other hand, will help us better understand the mechanics of environmental sustainability, societal consumption patterns, and how we can reduce environmental degradation in a post-crisis world. We as a human race cannot recreate the situation again because of our economy and needs, but also think about the betterment of the environment, for us and especially for the wildlife, as they are the ones facing it head-on while we have sheltered ourselves to face the indirect effects now and also in the future. To conclude, the sign of recovery should not be ignored; our lifestyles, developments and economic concerns have to reflect our concern for nature and least impact on the environment. So the need of the hour is to make balance between nature and human beings for today and tomorrow.

Conflict of interest

The authors declare that they have no conflict of interest.

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Diagnostic analysis of Baroda branch canal of Som Kamla Amba irrigation project, Rajasthan, India

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ABSTRACT

Irrigation projects are of paramount importance in meeting the water demand of agriculture sector. Therefore, evaluating the performance of irrigation systems makes it possible to improve agricultural water management and consequently enhances irrigation efficiency. In this perspective, the present study focuses on diagnostic analysis of the Baroda branch canal of the Som Kamla Amba irrigation project, Rajasthan, India. This study attempts to identify constraints attributed to poor irrigation efficiency and remedial strategies to improve irrigation management. Results revealed that poor maintenance and lacking immediate action of damaged water distribution network were culprits resulting in silting and vegetation infestation. Poor structures viz., tempered pipe outlets and gates, blockage of minors, unauthorized pumping, and poor operations of water distribution systems resulted in poor performance of Baroda branch canal. The performance of Baroda branch canal system can be improved by adoption of appropriate strategies.

Introduction

The land and water available for agriculture are limited in most of the countries in world and therefore their efficient utilization ensures the sustainable development of the nations. In many developing countries, on account of the growth of cities and industries, available land for agriculture is shrinking rapidly. As water is a scarce resource worldwide, efforts should be made to improve the effective utilization of this limited resource for irrigating agricultural land. Irrigated area utilizing surface and groundwater sources is about 308 million ha hectares (ha) of the total land is irrigated worldwide (ICID, 2018). Most of these projects have low productivity (30-50%) and cannot meet their design objectives (Arya et al.,2017) In India & South Asia, the number of irrigation schemes has a low overall efficiency of the performance at different levels of complex hydraulic systems (physical/structural and operational/management) (Sakthivadivel et al.,1999). Therefore, the only viable solution is the effective operation and management of the irrigation system to enhance irrigation efficiency and subsequently food production. In India, irrigation infrastructures were created but it has been seen that created irrigation capacity is not entirely exploited, and there is a difference between the created potential and the used potential. This realization has changed the attention of policymakers and researchers to improve the efficiency of canal irrigation by main system management. Rajasthan state has only 1.04 percent of India's water resources (GOI, 2004). The

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rainfall behavior generally remains abnormal, scanty, untimely, unevenly distributed with prolonged drought periods and mostly local floods. The available irrigation facilities in the state are neither distributed fairly nor completely dependable. This is due to irregular rain distribution and the efficiency of the irrigation infrastructure. On the right side of the Aravallis, the east and southeastern parts of the state are comparatively better placed and fertile. Chambal, Banas, Mahi, and other rivers and tributaries add prosperity to this region (Bhalla, 2010). To address the issues of low overall project performance and insufficient water supply, irrigation system preparation, service, and management must be improved. Monitoring, assessment, and diagnostic status (physical condition of canal system, check gates, cross drainage works, outlets etc.) of irrigation scheme are crucial to appreciate the increase in productivity in irrigation projects. Irrigation and drainage performance assessment can be characterized as the systematic observation, recording, and analysis of irrigated agriculture activities with a view to quality improvement (Molden *et al.,* 2007).

The overall goal of performance evaluation is to ensure efficient and effective use of resources by providing management at all levels with accurate input. The successful functioning and maintenance of the irrigation system play a significant role in the sustainability of irrigated agriculture(Unal *et al.,* 2004). For this purpose, irrigation project success studies are being used to support this aim with increasing frequency (Bos *et al.,* 2005). Diagnostic evaluations are performed to better understand how irrigation works, diagnose issues, and identify opportunities for improving efficiency so that measures could be taken to enhance irrigation water managementDiagnostic evaluations are to be carried out when complex issues are found by regular testing or when stakeholders are dissatisfied with the current performance levels and want improvements in system activity Mishra (2009) had done the diagnostic analysis of the Rajsam and canal network and in the command room, it was discovered that there is no proper water distribution system. The canal lining exists in the entire canal network. The majority of pipe outlets and gates were found tampered, and numbers of oversized outlets were observed in the canal network. Siltation and overtopping were the two major problems in command of Dhoinda minor because of improper bed slope. Water use efficiencies in command of the head, mid, and tail end minors for the wheat crop were 44.3, 49.4, and 48.2 kg/ha-cm, respectively, and for barley 60.12,62.6 and 67.94 kg/ha-cm, respectively. Shah and Dalwadi (2012) carried out the diagnostic analysis of Mehasana district command of Sabarmati right bank main canal (North Gujarat, India) by satellite Remote Sensing. To research crop growth stages and determine the time of full canopy, ERDAS imagine software was used to process multi-temporal, multidate remote sensing data (harvest season). Over the study region, vegetation spectral index and crop evapotranspiration were produced for the full canopy stage of the Rabi season (February month). The reference crop evapotranspiration was estimated at 5.65 mm/day. The distributaries within the command called M3LA and M5L were adequate. The land patches growing wheat were classified using supervised classification, dividing them into three parts: head, middle section, and tail end.

Many authors have noted that in the domain of irrigation system management, there is a notable lack of analytical frameworks to assist irrigation managers and auditors in assessing performance achievements and finding feasible ways to improve performance in the future (Burt and Styles, 2004; Luquet *et al.,* 2002; FAO, 2012; Pereira *et al.,* 2012 and Levidow *et al.,* 2014). Optimum irrigation schedule and rotational water allocations aid in improving the irrigation system performance to achieve the desired goal of the project (Rajput *et al.,* 2018). Technical, maintenance, and comparative performance indicators are essential to assess the performance of canal irrigation schemes globally (Rajput *et al.,*2017a; 2017b; 2017c). These performance indicators are limited to canal systems and equally applicable in tube well/ community tube well irrigation systems for improving system performance (Rajput *et al.,* 2020). As a result, diagnostic methodologies are required to evaluate system actions, assess current and future results, and identify critical aspects and weaknesses in existing irrigation systems' operation. The current investigation used diagnostic analysis to determine the general health of the water distribution network of the Baroda branch canal of the Som Kamla irrigation project.

Material and Methods

Description of Baroda Branch Canal

The planning commission approved the Som Kamla Amba irrigation project in the year 1975. The scheme envisaged construction of storage dam of 83.10 M Cum capacity with surplus arrangements for 3.72 lacs cusecs, across river Som and canal system for providing irrigation facilities to culturable command area of 13878 ha of land in

Aspur and Salumbar tehsil of district Dungarpur and Udaipur respectively in the state of Rajasthan as shown in Table 1. The scheme was intended to benefit tribal areas, irrigating 5714 ha of land annually with a BC ratio of 1.63:1 and financial return of 0.19 %. The project has seen several changes in its perspective since its inception, as shown in table 1.

Table 1: Changes in the scope of the project at various stages

SN	Particulars	1975	1978	1982	1985	1994
1	C.C.A. (ha)	13870	13940	13989	17724	17724
2	Annual Irrigation (ha)	5714	8364	12975	18788	18788
3	Gross storage (Mcum.)	83.1	83.1	118.65	172.8	172.8
4	Probable Max Flood (PMF) lacs cusec	3.72	4.8	8.0	10.63	7.24
5	F.R.L. (m)	209	209	211	213.5	213.5
6	M.W.L. (m)	209	209	213	215.5	215.5
7	T.B.L. (m)	212	212	215	217.5	217.5
8	Types of canals	Partially lined	Partially lined	Fully lined	Fully lined	Fully lined

A detailed study of the Baroda Branch Canal (BBC) of the Som Kamla Amba irrigation project has been done in this paper. This canal consists of 15 distributary, minors, and sub minors with the length of canal 23.19 Km. The canal is off taking directly from the dam site with a CCA of 4832 ha. Discharge of canal at head is 2.71 cumec. Maximum bed width and free board is 1.85 m and 0.60 m respectively. Maximum side slope is ¼:1 and maximum bed slope is 1:2500. Cross regulators are provided across the main canals/branch canals little downstream of each major off taking branch/minor for creation of necessary head to deliver the required discharge. Particulars and Details of structures on Baroda Branch Canal are given in Table 2 and 3, respectively. Figure 1 shows the location map of the Som Kamla Amba irrigation project dam and figure 2 shows the line diagram of Baroda Branch Canal of Som Kamla Amba Irrigation Project. Diagnostic analysis is one of the tools through which scientific management can be accomplished in best manner. Diagnostic analysis is a form of inquiry that tests whether or not an irrigation system is working as it should be.

Existing Physical Status

The physical state of the water distribution system is also influenced by farmers' awareness of how much water should be applied for proper plant growth in the command area. The water distribution system in this area was surveyed by walk along the canals /minors to determine the current physical state of the main channel, minors, and outlets i.e., status of lining, gates and outlets, vegetation infestation, blockage, unauthorized pumping and so on. A variety of locations in the canal network had damaged canal lining, gates, and outlets.

Table 2:Particulars of Baroda branch canal

S.No	Particulars of Baroda Branch Canal	
1.	Length, Km	23.19
2.	Discharge, Cumec	2.7076
3.	Bed Width (max.), m	2.20
4.	Side Slopes (max.)	¼:1
5.	Free Board (max.), m	0.60
6.	Coefficient of Rugosity (N)	0.018
7.	CCA, ha	4832
8.	No. of Minors	15

Silt Deposition in Canals/Minors

Silt deposition was investigated at number of locations in entire canal network before irrigation and after irrigation. The depth of silt deposition measured using scale and the silt deposition was expressed in cm unit. Only thickness of silt deposition was measured. The weed growth / vegetative growth were also observed in main canals and minors. Siltation in canals/minors increases the likelihood of overtopping, resulting in

Table 3: Basic details of Baroda branch canal minors

SN	Minor	Off take	CCA (ha)	Discharge (cumec)
1	Tonkwasa minor	ch 137+20 L	61	0.033
2	Vasunder minor	ch 236 L	135	0.0729
3	Baroda minor I	ch 318 L	461	0.2475
4	Baroda minor II	ch 322 L	66	0.0289
5	Bhatwara minor	ch 370+20 L	145	0.0783
6	Punjpur minor	ch 416+15 L	521	0.3507
7	Chundiyawara minor I	ch 432 R	307	0.0693
8	Chundiyawara minor II	ch 487 R	76	0.0425
9	Jaspur minor	ch 523 L	103	0.056
10	Katisor distributory	ch 637 L	1953	1.081
11	Gada siyalia minor	ch 726 L	75	0.041
12	Badliya mnor	ch 735 L	170	0.097
13	Bankora minor II	ch 750 L	44	0.03
14	Galiyana distributory	ch 769 L	626	0.338
15	Bankora minor	ch 773	89	0.049

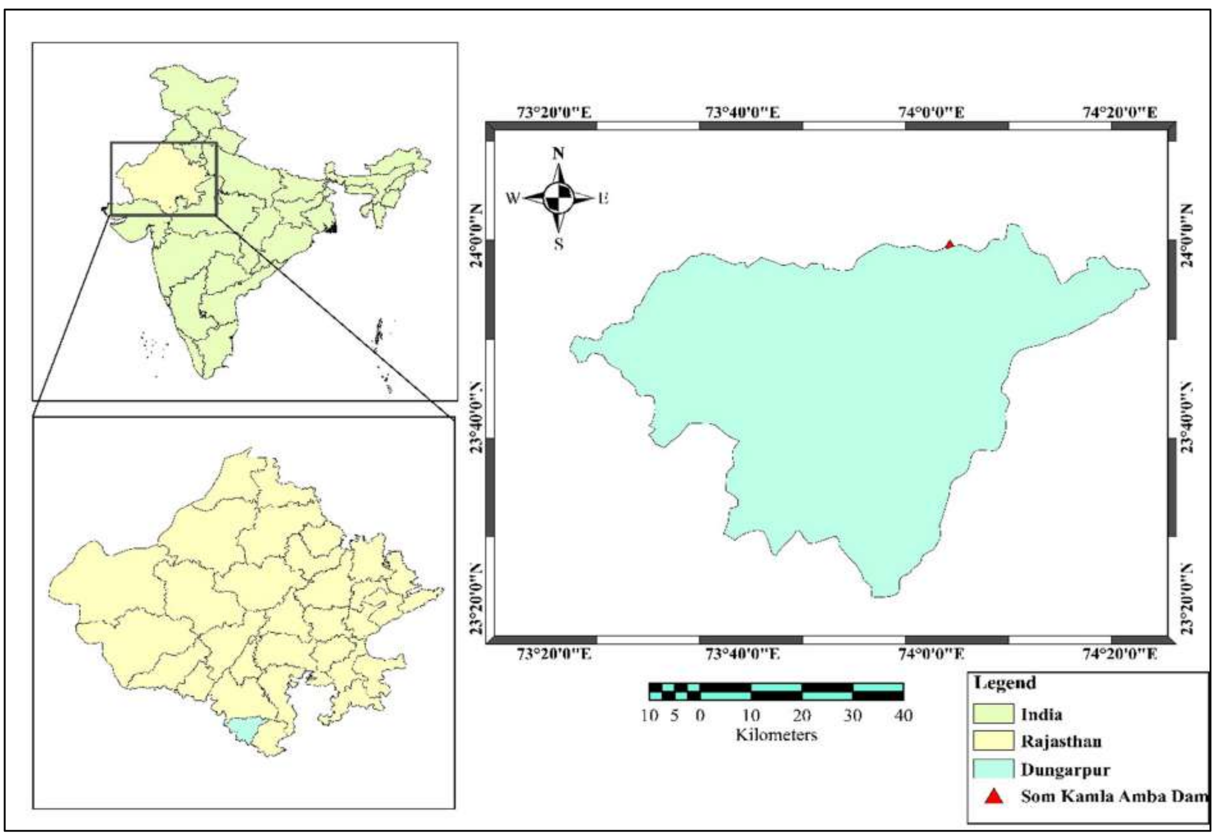

Figure 1: Location map of Som Kamla Amba irrigation dam

water waste. As a result, farmers must deal with

water logging in low-lying areas, necessitating the investigation of siltation in canals and minors. The height of silt accumulated from the canal's bottom was used to determine siltation.

Results and Discussion

Under diagnostic analysis, physical status of water distribution system and siltation of minors was studied. Physical status in terms of general health of the water distribution network, condition of lining, gates and outlets, vegetation infestation, unauthorized pumping etc., were evaluated. Siltation results in reduction in the carrying capacity of canal/minor, therefore, silt deposit was measured in the water distribution network.

Seepage and overtopping were the two major problems in the command area because of blockage of canal water due to sliding of sides of valley (figure 2) and damaged lining (figure 3) therefore maintenance is requiring, but no action is taken on behalf of Irrigation Department due to unavailability of maintenance funds. The second problem is siltation. The depth of silt is ranging between 35-40 cm. The vegetative growth was found at both bank of canal which is also one major problem which covers the canal at many locations.

The trees like babul, neem, khajur, etc. also grown both the sides, which results in damaged lining and also covers canal at both sides (figure 4 & 5). To maintain and preserve ditch and canal banks, vegetative growth, particularly grasses such as Bermuda, Bahia, or St. Augustinegrass, can be employed. The plant species should have broad root systems capable of retaining soil and be robust enough to supply sufficient hydration to the plants throughout the dry spring season, i.e., vegetation should maintain good cover and growth throughout the year to successfully safeguard the banks from eroding (Diaz *et al.,* 2014). However, mismanagement of vegetation can result in restricted access and inspecting capabilities, root damage, operational disruptions, obstructions, and habitat for burrowing animals, all of which increase the probability of canals deteriorating. Each year, a number of canals collapse, which are frequently due to poor vegetation upkeep. These failures can result in major economic losses, loss of project benefits, personal injury, and even death (Reclamation, 2017). The control gates were found improperly working or damaged at 6 places, and damaged lining or broken wall was found at 22 places on the Baroda Branch Canal. Based on verbal enquire from the farmers, it is reported that many times, water is not ending at the tail end of BBC at that time, farmers in these areas irrigate their fields from wells or keep their fields uncultivated during rabi season. Rajput *et al.* (2021) reported that poor up keep of canal water system and lack of appropriate repair and maintenance activities were the main reasons for the poor performance of Bhimsagar irrigation project. They have also reported poor physical condition of the water distribution network and siltation hampering the optimal operation of the irrigation system. The diagnostic analysis of all the minors of Baroda branch canal have been described.

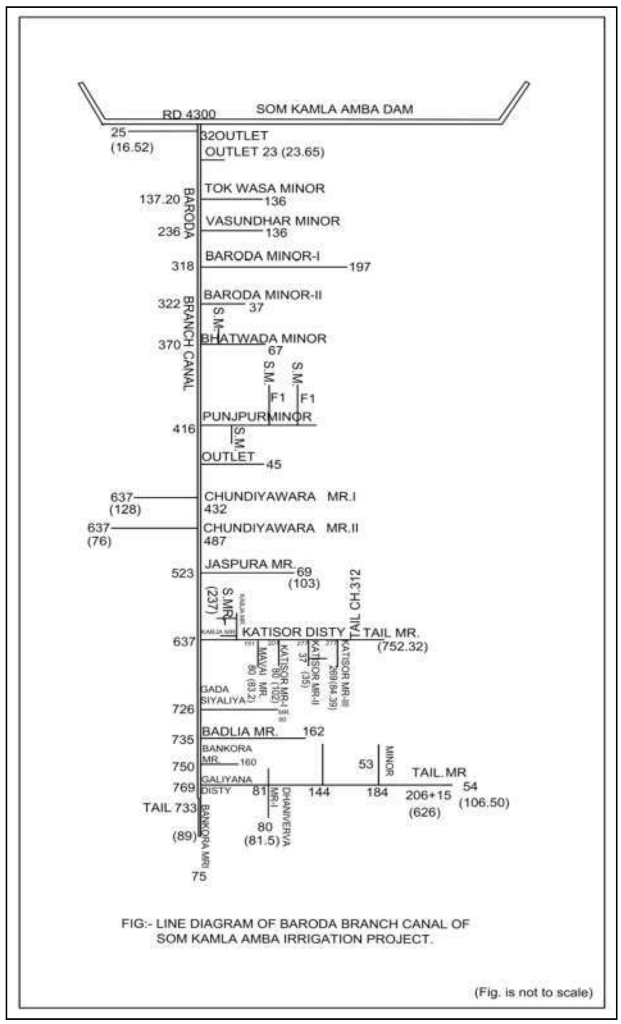

Figure 2: Line diagram of Baroda branch canal of Som kamla amba irrigation project

Figure 3: Blockage of canal water due to sliding of sides of valley in BBC at RD:187 chain

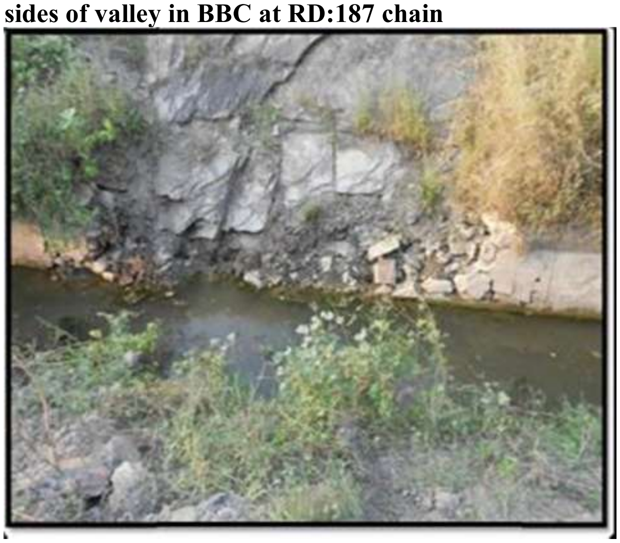

Figure 4: Damaged lining of BBC at RD:223 chain

Figure 5: Damaged lining of BBC due to Babul at RD:310 chain

Tokwasa minor

This minor off takes from head of BBC at RD 137+20 chainage and sluice gate was damaged resulting into uncontrolled flow in the minor. There is excess availability of water in this minor. Seepage and overtopping were the two major problems in the command because of cracks in the lining and improper beds slope. The vegetative growth was also found at both bank of minor which also results in the cracks in the lining. Irrigation is done by this minor in only Tokwasa village. Seepage is undesirable as it leads to ponding of the low lying area. Also, seepage causes a substantial amount of water lost which ultimately leads to unequitable water allocation among head and tail end commands.

Vasundhar minor

This minor off takes from head of BBC at RD 236 chainage. This minor has length of 136 chain. This minor has the culturable command area of 135.0 ha. There was a main problem of seepage in the command of vasundhar minor. Due to the seepage problem, minor had been blocked by villagers of vasundhar.

Baroda minor - I

This minor is situated on head of BBC and off takes at RD 318 chainage. This minor has maximum length 197 chain among all minors in the command with total culturable command area of 461.0 ha. There is a major problem of seepage in this minor. The vegetative growth was found at both banks of minor at many locations. Also, this minor is affected by the problem of siltation. The depth of silt ranges between 20-35 cm. The culturable command area of this minor mainly exists in Vasundhar chhoti and Baroda villages.

Baroda minor - II

This minor is situated on the head of BBC and off takes at RD 322 chainage. This minor has a length of 37 chains with a total culturable command area of 66.0 ha. There is a significant problem of seepage in this minor. Also, this minor is affected by the problem of siltation. The depth of silt ranges between 20-35 cm. Irrigation is done by this minor in only Vasundhar chhoti village.

Bhatwara minor

This minor off takes from the head of BBC at RD 370+20 chainage. The length and culturable command area of this minor is 62 chain and 145.0

ha, respectively. Seepage was the major problem in the command because there was an unlined minor and improper beds slope at many places. The vegetative growth was also found at both banks of minor, resulting in cracks in the lining. Due to improper bed slope and seepage loss due to unlined minors, tail end farmers were not getting enough water. A large area of the command of this minor mainly exists in Bhatwara village and some part in Baroda village.

Punjpur minor

This minor is situated in the middle of BBC and off takes at RD 416+15 chainage. This minor has a length of 131 chains and a maximum culturable command area of 521.0 ha among all minors in the command. The control gate was found damaged at Punjpur minor. The weed growth/vegetative growth are found at both banks of minor at many locations. Also, this minor is affected by the problem of siltation. The depth of silt ranges between 20-30 cm. A large area of the command of this minor mainly exists in Punjpur village and some parts in Nalva (Punjpur) and Talayfala (Punjpur) villages.

Chundiyawara minor - I

This minor is situated on the middle of BBC and off takes at RD 432 chainage. This minor has a length of 81 chains. The culturable command area of this minor is 129.0 ha. The sluice gate was found damaged (figure 6) of Chundiyawara minor-I. The vegetative growth was found at both banks of the minor, which covers the minor at many locations. The problem of seepage was also found, and also this minor is affected by the problem of siltation. The depth of silt ranges between 20-25 cm. The culturable command area of this minor mainly exists in Chundiyawara village.

Jaspur minor

This minor is situated on the middle of BBC and off takes at RD 523 chainage. This minor has a length of 69 chains. The culturable command area of this minor is 103.0 ha. The vegetative growth was found at one bank of the minor, which covers the minor at many locations. There is a significant problem of vegetative growth in the course of the minor. The culturable command area of this minor mainly exists in Jaspur village. The depth of silt ranges between 20-30 cm.

Katisor distributary

This distributary is situated on the middle of BBC and off takes at RD 637 chainage. This distributary has a length of 312 chains. The culturable command area of this distributary is 1953.0 ha. This distributor has a fixed gate which cannot be opened or closed. Seepage and overtopping were the two major problems in the command because of cracks in the lining and improper beds slope and requiring maintenance. Still, no action was taken by Irrigation Department due to the unavailability of maintenance funds. Approximately 35 percent of the total area of a distributary is unlined, which results in the problem of seepage and siltation. The depth of silt ranges between 30-35 cm. The vegetative growth was found at both banks of the distributary, which covers the distributary at many locations. No control gate is found at off takes of Movai minor and Katisor minor - I, II, and III. Based on verbal enquire from the farmers, it is reported that water is not ending at the tail end of Katisor distributary. Approximately 25 percent of the area in the tail end of the Katisor distributary network is not getting any water for irrigation. Farmers in these areas irrigate their fields from wells or keep their fields uncultivated during the Rabi season. The culturable command area of this distributary mainly exists in Movai, Kabja, Antiya (punjapur), Lapiya, and Katisor villages.

Gada siyaliya minor

This minor is situated on the tail of BBC and off takes at RD 726 chainage. This minor has length of 90 chains. The culturable command area of this minor is 75.0 ha. The vegetative growth was found at both banks of minor, which covers the minor at many locations. This minor is having the problem of siltation. The depth of silt ranges between 10- 20 cm. The culturable command area of this minor mainly exists in Gada siyaliya village.

Badliya minor

This minor is situated on the tail of BBC and off takes at RD 735 chainage. This minor has a culturable command area of 170.0 ha with a minor length of 162 chains. There is a significant problem of vegetative growth in this minor. The vegetative growth was also found at both minor banks, which covers the minor at many locations. The problem of siltation was also one of the significant problems in this minor. The depth of silt ranges between 10-20 cm. Based on verbal enquire from the farmers, it is reported that water is often not ending at the tail end of the minor. Irrigation is done by this minor in only Badliya village.

Figure 6: Damaged lining and trees are grown on sides of BBC at RD:517 chain

Figure 7: Damaged sluice gate at the head of Chudiyawara minor-I in BBC at RD:432 chain

Bankora minor - II

This minor is situated on the tail of BBC and off takes at RD 750 chainage. This minor has a culturable command area of 44.0 ha with a minor length of 160 chains. There is a significant problem of vegetative growth in this minor. The weed growth was also found at both banks of minor, which covers the minor at many locations. Based on interaction with farmers, it is noted that most of the time, water is not ending at the tail end of the minor and sometimes even not ending the minor's head. The problem of siltation was also one of the significant problems in this minor. The depth of silt ranges between 10-20 cm. Irrigation is done by this minor in only Bankora village.

Galiyana distributary

This distributary is situated on the tail of BBC and off takes at RD 769 chainage. This distrtibutory has a length of 206+15 chain. The culturable command area of this distributary is 626.0 ha. Seepage and siltation were the two major problems in the command because of cracks in the lining. The depth of silt ranges between 10-25 cm. The vegetative growth was found at both banks of the distributary, covering the distributary at many locations. Based on verbal enquire from the farmers, it is reported that water is not ending at the tail end and sometimes even not ending the head of Galiyana distributary. Approximately 30 percent of the area in the tail end of the Galiyana distributary network is not getting any water for irrigation. Farmers in these areas irrigate their fields from wells or keep their fields uncultivated during the Rabi season. The culturable command area of this distributary mainly exists in, Galiyana, Dhaniverwa, Dhanibhevdi, and Dhanikateshvar villages.

Bankora minor - I

This minor is situated on the tail end of BBC and off takes at RD 773 chainage. This minor has the culturable command area of 89.0 ha with the minor length of 75 chains. There is a significant problem of vegetative growth in this minor. The weed growth was also found at both minor banks, which covers the minor at many locations. By the interaction with farmers, it is noted that most of the time, water is not ending the tail end of the minor and sometimes even not ending the minor's head. Most of the area in the tail end of Bankora minor - I network is not getting any water for irrigation. Farmers in these areas irrigate their fields from wells or keep their fields uncultivated during the Rabi season. Irrigation is done by this minor in only Bankora village.

A comparison of maintenance issues of minor/distributary located on Baroda branch canal is given in table 4. It is evident from the table that, the common issue of minor/distributary is seepage and vegetation growth which is due to neglected repair and maintenance of canal network system components. Minor/distributary located in the tail end of Baroda branch canal found were not getting adequate water and thus no assured irrigation water in the tail end command system. The siltation problem is prominent due to irregular bed slope and poor maintenance of canal sidewalls. Many of the sluice gates were damaged, which resulted in the uncontrolled entry of water into the minor/distributary from the branch canal. It was observed that less attention was given to the mid and tail section of the Baroda branch canal than the head section, resulting in inequitable water distribution. Overtopping of water is due to reduced capacity of minor by silt deposition.

Physical / Structural lining of the canal

The lining of the canal was impaired at a variety of places in the entire network of canals. The farmers of the command area damage the lining of the canals or minors for getting the excess quantity of water and avoid an extra laborer in irrigating fields that have to do due to being outlets at significant distance from their fields. This is causing a large quantity of water loss through seepage from the damaged portion and affecting designed discharge in the canal section. Similar results were observed in the Bhimsagar irrigation system's water distribution network in Rajasthan state (Rajput *et al.,* 2017).

Water courses

Farmers' water courses were not maintained regularly, particularly by head end farmers. As a result, nearly all water courses were damaged and weed-infested in several locations. The water courses off taking even from the head of distributary or minor were not able to supply the sufficient quantity of water to its tail end fields due to improper maintenance and tempering of networks by the farmers.

Gates and pipe outlets

The majority of the gates are tempered or damaged. As a result, there is no flow or control (opening or closing) power available. In the canal network, the pipe outlets were often found tempered or oversized. The results for additional illegal outlets were also made and seen as nine outlets on BBC, several outlets on the minors.

Obstructions in the canals

Farmers block canals and do not allow water to pass down the stream. During the night time, this issue emerges more. In canals, stone barriers were placed to lift the head and increase the discharge at the outlets. At five BBC locations, obstructions to reduce flow in canals and redirect further water in the water course were found.

Siltation / Weed infection in canals

The silt that is carried by the river is not significant. Nevertheless, canal water is generally silt-free, but silting in the canal takes place in certain areas due to the entry of run-off water into the channel. With the deposition of silt and debris, the canal parts were marked. At different places, it is as high as 40 cm. The growth/vegetative growth of weeds is also observed at a variety of canal network locations. The department did not carry out the maintenance operations due to a shortage of human resources. Siltation also affects river flow and the number of times water flows out of the canal and accumulates in low-lying areas. Similar work had been done by (Mishra 2009). She found that the canal lining exists in the entire Rajsam and Canal Network. The majority of gates were found tempered. The siltation and overtopping were the two significant problems in canal command. In the present study, approximately 35 % of the total area of Katisor distributary was unlined. The major problems were the vegetation growth and seepage in the entire canal network of the Baroda Branch Canal. The results found in the present study are in contrast with past research work because the Som Kamla Amba dam is too old, and the Rajsamand is comparatively new. To improve the overall functioning of the Baroda branch canal, the following measures should be adopted.

Measures to correct system deficiency and to improve the Baroda branch canal irrigation system performance

1. Inspection and repair & maintenance of canal water distribution network twice a year during the non-flowing season before Rabi crops are sown.
2. Formation of outlet water level monitoring committees comprises of irrigation department personal, water user associations (WUA), and irrigators for the judicious operation of the system.
3. Linkages and effective communication network between irrigators, WUA, and irrigation department to address issues related to the operation, monitoring, and maintenance of canal distribution network.
4. Development and effective implementation of water rostering system as per the crop water

the requirement in the different segments (head, mid, and tail end) of the canal system.
5. Training to irrigators on aspects such as water conservation and agronomical practices should be imparted to develop an understanding of water-saving.
6. Adoption of drip irrigation system and sprinkler/micro-sprinkler system to save water, energy and improve crop production.
7. Implementation of automatic sensor-based water delivery mechanism/check gates to tackle the tail end farmers problem by decreasing overuse of water in the head and middle sections of the canal network.
8. Conjunctive use of surface water and groundwater should be encouraged for sustainable crop production in the canal system.
9. Utilization of in-situ moisture for crop production in the tail end section to decrease gross water demand.

Conclusion

The diagnostic research was carried out to investigate the operational issues in the Som Kamla Amba irrigation project's Baroda Branch Canal network. In this command zone, there is no proper water delivery system. By inserting obstructions in canals, farmers at the head use more water than the actual requirement and restrict water from ending to tail end farmers. Farmers were not getting enough water for irrigation at the tail end of the network. Therefore, they irrigate their fields from wells or keep their fields uncultivated during the Rabi season. The waterlogging problem is examined in low-lying areas during the irrigation season on account of seepage from the canals. The majority of pipe outlets and gates were tempered, and the number of oversized outlets was observed in the canal network. Seepage and overtopping were the two significant problems in command of minors at head end. This means Tokwasa minor, Baroda minor-I, Baroda minor-II, because of cracks in lining and improper beds slope of this minor. Based on verbal inquiry from the farmers, it is reported that approximately 25 % of total command of Katisor distributary is not getting any water for irrigation in the tail end for many years, and the command at tail end of Baroda Branch Canal also not getting the sufficient water. In Bankora minor-I, there is a significant issue of water scarcity because it is located on the tail end and water seeps through cracks formed in the minor.

Conflict of interest

The authors declare that they have no conflict of interest.

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Agroforestry: Viable alternatives for ensuring green fodder production around the year

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ABSTRACT

Agroforestry is an integration of tree species with agricultural crops or livestock that can be directly used to enhance agro biodiversity, rural livelihood and to meet the demand of green fodder throughout the year. Considering this fact, a study was done at Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana to assess the productivity of fodder crops under poplar based agroforestry system. In February 2016, poplar was planted in six different spacing of 3× 3 m, 4×3 m, 5×3 m, 6×3 m, 7×3 m and 8×3 m. In this study, fodder crops (sorghum during *Kharif* season and oat and berseem during *Rabi* season) were intercropped in different spacing's of poplar and compared with control in three replications. The results revealed that the maximum DBH (13.92 cm), basal diameter (16.90 cm) and crown spread (6.79 m) attained in 8×3 m spacing while maximum height (9.61 m) is attained in 3×3 m spacing. The highest pH (7.94) and EC (0.27 dS/m) were recorded in 8×3 m spacing while highest SOC (0.47 %), N (158.5 kg/ha), P (16.8 kg/ha) and K (343.8 kg/ha) were recorded in 3×3 m spacing. Green fodder biomass of sorghum (38.45 t/ha), berseem (64.56 t/ha) and oat (52.62 t/ha) was recorded higher in wider spacing (8×3 m) as compared to sole crops. The maximum light intensity (672.4 Lux) was recorded in 8×3 m at 1.00 pm in the month of July, 2018. Higher value of BCR was observed for poplar with oat (2.44) followed by poplar with sorghum (2.31) and poplar with berseem (2.28) under 3×3 m spacing indicating that closer spacing of 3×3 m of poplar is more economic than the other spacings due to more number of trees per unit area and more production of wood.

Introduction

Animal husbandry is an important sector of India, as it contributes 4.1 per cent to national GDP and 25.6 per cent to agricultural GDP (Gupta *et al.*, 2020). Despite of this, the dairy industry is relatively not so much beneficial and competitive as compared to global productivity and profitability scenario (Patel, 2016). The low productivity of animals is affected by factors such as lesser cultivation of fodder crops, insufficient and unbalanced diet, different kind of diseases and disorders due to the lack of proper feed and traditional way of animal husbandry (Malhi *et al.*, 2020). An animal keeper generally invests around 60-70 per cent of his expenditure in arranging feed

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to animals (Gupta *et al.,* 2020). Hence, in order to make animal husbandry a profitable and productive enterprise, it is important to provide them balanced and sufficient diet. The major components of nutritious diet are dry fodder, green fodder, chuni-chokar, grains, oilcakes and mineral mixtures. Green fodder is an important component of animal nutrition which is required to be accessible throughout the year. During the year the availability of green fodder can be assured through adaptation of fodder crops production with conservation approach.

Agroforestry has potential for taking a leading and catalytic role in providing green fodder throughout the year. Due to its inherent integrative, multidisciplinary nature and the optimization rather than component-maximization aims, great interest shown in it today (Lundgren, 1987). It is a land use system characterized by the combination of forestry and agriculture and an alternative to foster the much needed balance between food production and biodiversity conservation (Salinas, 2016). It is recognized as an efficient ecological basis for increasing crop productivity, more dependable economic returns, and greater diversity (Amatya *et al.,* 2018). Agroforestry has a long tradition in the Indian subcontinent. The socio-religious fabric of the people of the subcontinent is interwoven to a very great extent with raising, caring and respecting trees. Trees are integrated extensively in the crop and livestock production systems of the region according to the agro climatic and other local conditions. The aim of agroforestry is to optimize the positive interactions between components in order to achieve a more productive, sustainable and diversified (in relation to need of land users). Agroforestry plays a significant role in increasing agricultural productivity by nutrient recycling, reducing soil erosion, and increasing soil fertility and farm income compared with conventional system of crop production (Kang & Akinnifesi, 2000). Furthermore, agroforestry offers a range of ecological, economic, social and religious functions (Idol *et al.,* 2011). The immense potential of agroforestry has helped to improve the livelihoods of the rural farmers.

Material and Methods

The study was conducted at CCSHAU, Hisar, Haryana, situated in the north-western India. Figure 1 presents the monthly mean data of meteorological parameters during the interval of study (July, 2018-April, 2019) at the experimental site. The experiment was carried out on sandy-loam soil and medium in available nitrogen, phosphorus and potassium and organic carbon. The poplar plants were planted during February, 2016 at six different spacings (3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m and 8 × 3 m). The present study was carried out during *Kharif*, 2018 and *Rabi* 2018-19. Intercropping of fodder crops, viz. sorghum (*Sorghum bicolour*), berseem (*Trifolium alexandrinum*) and oat (*Avena sativa*) were taken under six geometries of poplar and compared with monocropping (devoid of trees). During *kharif* season, sorghum var. (HC-171) was sown during first week of July,2018 and oat (var. HJ-8) and berseem (var. HB-1) were sown in all spacing's of poplar under study during first fortnight of November, 2018 and also in control (sole crop) in three replications employing the standard package of practices developed by CCSHAU, Hisar to cultivate fodder crops.

Tree height and diameter at breast height (DBH) were measured randomly using Ravi altimeter (m) and measuring tape (cm) respectively. The crown spread (m) was measured in north-south and east-west directions with the help of a measuring tape. In case of fodder crops, plant population, plant height and leaf area were measured at different time intervals using quadrant in three replications under different spacing's of poplar as well as in control (sole crop). The leaf area index was calculated using the formula;

$$Leaf\ area\ index\ \Rightarrow \frac{Leaf\ area}{Ground\ area}\ X\ 100$$

Quadrate-basis fodder biomass yield (fresh and dry) was taken and converted to tones per hectare, and price of fodder crops was considered on the basis of market rates during the respective years. The soil samples were taken randomly in three replicates from 0-15 cm and 15-30 cm soil depth before sowing and after harvesting of both season crops from all six geometries of poplar and control field (devoid of trees). The soil pH, EC, available nitrogen, available phosphorus, available potassium and organic carbon were analyzed using standard methodologies.

Light intensity: Light intensity was recorded with lux meter in different spacings of poplar and in control (open area) at two hour interval from 7.00 am to till 5.00 pm.

Economic evaluations: Economic analysis was quantified by comparing poplar based agroforestry system with sole fodder crops including trees by estimating the land rent, cost of cultivation and price of fodder crops and trees (according to girth of trees). The cost-benefit parameters used for comparison of systems were net returns, net present value (NPV) @ 12% discounting rate, internal rate of return (IRR) and benefit/cost ratio (BCR). Cost and income from intercropping as well as trees were calculated. The replicated data of all the characters recorded (yield and biomass of fodder crops, soil parameters and growth traits of the trees) were analyzed statistically using model suggested by Panse and Sukhatme (1989).

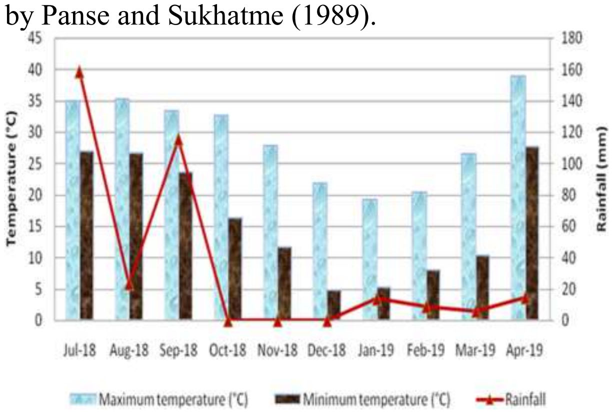

Figure 1: The monthly mean meteorological data of the experimental site from July, 2018 to April, 2019.

Results and Discussion

Growth of poplar

Tree growth parameters revealed that with the advancement of age, a gradual increase in DBH and height was observed. While with the increasing space in between tree rows, tree height decreases with maximum height (9.61 m) is attained in 3×3 m spacing (Figure 2 a) this may be due to increasing competition in between trees for light, while DBH (Diameter at breast height), basal diameter and crown spread increases with increases in tree spacing, maximum DBH (13.92 cm), basal diameter (16.90 cm) and crown spread (6.79 m) attained in 8×3 m spacing (Figure 2 b, c, d) as they have more space to grow wider. The height and DBH of poplar plantation was affected significantly in different spacing geometries under agroforestry, this may be due to more intra-line competition of poplar plants for different growth resources. Similar findings have been highlighted by (Ajit *et al.,* 2011; Chauhan *et al.,* 2011). The rate of increase in crown spread is more than DBH and basal diameter due to more availability of space in wider spacings for crown spread as compared to narrow spacing of poplar plantation.

Influence of poplar spacing's geometry on soil properties

Table 1 shows data on soil chemical properties (0-15 cm depth) under different spacing's geometries of poplar plantation before sowing of fodder crops (July, 2018) and after harvesting of both season fodder crops (April, 2019). The soil pH and available potassium content were found non-significant among different spacing geometries of poplar and control (devoid of trees). Among different spacing geometries, the highest pH (7.94) and EC (0.27 dS/m) were recorded in the 8×3 m spacing after harvesting of fodder crops. The soil organic carbon (SOC) was significantly influenced by tree spacing and increased (0.47%) from its initial status (0.43%) under 3×3 m spacing of poplar based agroforestry system which is higher as compared to sole cropping (0.30%). Available nutrients (nitrogen, phosphorus and potassium) were also significantly influenced by tree spacing and the magnitude of increase in available nutrients was highest under 3×3 m spacing and lowest in control (sole crops). The average available nitrogen content in 3×3 m, 4×3 m, 5×3 m, 6× 3 m, 7×3 m and 8×3 m spacing geometries was higher by 22.29%, 19.67%, 17.51%, 13.58%, 11.72% and 9.95% respectively, over sole crop (129.6 kg/ha). The higher build-up of soil organic carbon and nutrients on the surface layer (0-15 cm) of soils may be attributed to the regular accumulation of litter fall of poplar on the soil surface, fine root biomass and availability of sufficient moisture level. Similar trends of improvement in the nutrient status of soil due to intercropping in an agroforestry as reported by Chavan and dhillon (2019), Dhillon *et al.* (2020) and Kumar *et al.* (2019).

Yield performance of fodder crops in intercropping with various spacing's of poplar

It is evident from Table 2 that green fodder biomass of sorghum, berseem and oat was found to be higher in wider spacing (8 × 3 m) followed by 7 × 3 m, 6 × 3 m, 5 × 3 m, 4 × 3 m and 3 × 3 m spacing,

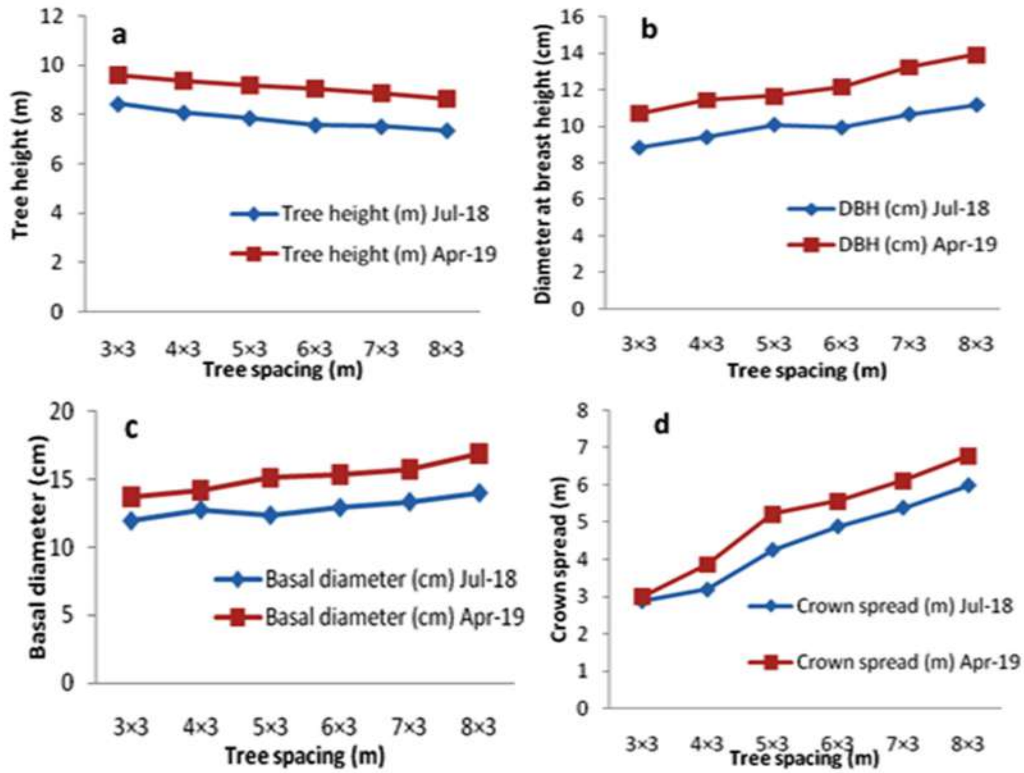

Figure 2: (a) Plant height (m), (b) diameter at breast height (cm), (c) basal diameter (cm) (d) crown spread (m) of poplar in different planting geometries.

Table 1: Soil properties under different spacing's of poplar-based agroforestry systems

Tree spacing's (m)		pH	EC (dsm-1)	Organic carbon (%)	Available nutrients (Kg/ha) N	P	K
3×3	**BS**	7.82	0.22	0.43	151.5	13.6	325.8
	AH	7.75	0.19	0.47	158.5	16.8	343.8
4×3	**BS**	7.85	0.23	0.40	148.0	13.4	315.8
	AH	7.77	0.20	0.44	155.1	16.5	342.0
5×3	**BS**	7.87	0.25	0.38	144.0	13.1	332.6
	AH	7.80	0.22	0.42	152.3	16.2	339.3
6×3	**BS**	7.91	0.26	0.37	141.0	13.0	318.6
	AH	7.85	0.24	0.41	147.2	16.0	338.1
7×3	**BS**	8.01	0.28	0.34	138.6	12.8	317.9
	AH	7.88	0.26	0.39	144.8	15.9	335.5
8×3	**BS**	8.18	0.29	0.30	137.2	12.5	316.4
	AH	7.94	0.27	0.33	142.5	15.5	332.9
Control	**BS**	8.26	0.34	0.28	126.6	11.3	310.8
	AH	8.08	0.33	0.30	129.6	12.3	330.3
CD at 5%		NS	0.017	0.026	6.84	0.75	NS

Table 2: Green fodder yield of fodder crops under different geometries of poplar-based agroforestry systems.

Tree spacing's (m)	Fresh green fodder yield		
	Sorghum	Berseem	Oat
3×3	24.27	47.70	40.68
4×3	27.78	51.30	41.99
5×3	34.38	54.75	45.32
6×3	35.85	57.62	47.55
7×3	37.98	62.68	50.65
8×3	38.45	64.56	52.62
Control	43.37	68.52	60.11
CD at 5%	1.78	3.28	2.28

but lower than sole cropping (devoid of trees). The performance of both *Kharif* and *Rabi* season fodder crops was strongly influenced under poplar based agroforestry system with reduction of spacing geometries of the trees because of increased competition for solar radiation, moisture and nutrients between the trees and fodder crops. The overall yield of *Rabi* season (Berseem and Oat) fodder crops (Table 2) was higher than *Kharif* season (Sorghum) fodder crop (Table 2) under different spacing geometries of poplar. Dry fodder yield was obtained maximum in sorghum followed by berseem and oat. Under control (sole cropping) maximum dry fodder yield was recorded as compared to different spacing of poplar (Figure 3). Green fodder biomass was reduced from 11.34% to 44.03% in sorghum (Figure 4) under various plant geometries of poplar over control (sole crop). There was significantly more reduction in yield of sorghum under 3×3 m spacing i.e. 44.03% and 35.94 % under 4×3 m spacing as compared to wider spacings of poplar. The production of winter crops (berseem and oat) in the open (devoid of trees) was higher than intercropping under different spacing of poplar plantation. Yield reduction varied from 5.77% to 30.38% in berseem and 12.46% to 32.32% in oat under different spacing's of poplar over control. In poplar based agroforestry system, fodder yield of crops increased with the increased distance between tree rows. In winter season, crop yield started decreasing considerably in narrow spacing; however, reduction in yield was less under wider spacing's (Figure 4).

It is widely acknowledged that the yield of agricultural crops grown in an agroforestry system

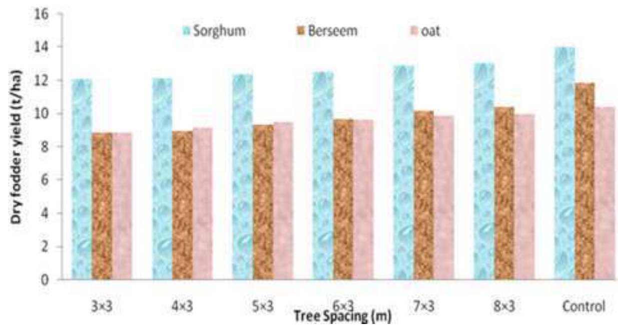

Figure 3: Dry fodder yield of fodder crops under different geometries of poplar-based agroforestry systems

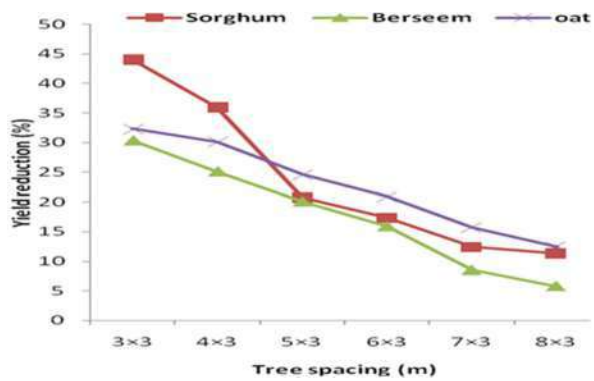

Figure 4: Green fodder yield reduction (%) of fodder crops under different spacing of poplar-based agroforestry system

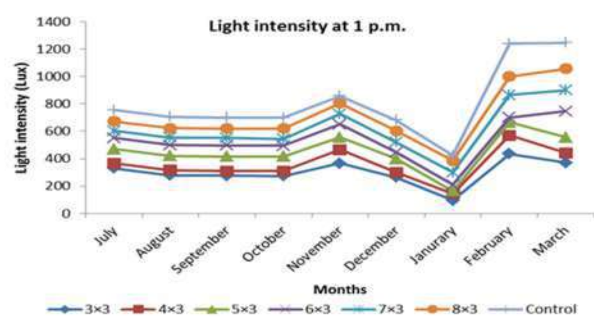

Figure 5: Light intensity (Lux) underneath different spacing's of poplar and control

is lower than that of crops grown in a monoculture system. The fact that the yield of rainy-season crops is significantly lower than that of winter-season crops has been pointed out by numerous researchers (Chauhan *et al.,* 2012; Chaturvedi and Pandey, 2001 and Nandal and Hooda, 2005). This is due to the heavy shade cast by poplar trees during the rainy season, which prevents light from reaching the crop and reduces its yield. In contrast, the

Table 3: Leaf area indexof fodder crops under different spacing's of poplar

Tree spacing's (m)	Leaf area index (at harvest)		
	Sorghum	Berseem	Oat
3×3	5.2	3.6	4.2
4×3	5.3	3.7	4.4
5×3	5.4	3.9	4.5
6×3	5.6	4.0	4.7
7×3	5.9	4.1	4.8
8×3	6.0	4.2	4.9
Control	6.4	4.6	5.3
CD at 5%	0.54	0.38	0.45

absence of leaves on poplar trees during the winter season allows for ample light to reach the crops, which results in a higher yield as compared to the rainy season. Agroforestry systems also compensate for year-to-year yield reductions of various crops by producing woody biomass, which has been shown to be effective in a number of economic evaluations (Jain and Singh, 2000 and Singh and Mavi, 2016).

Leaf area index

Under poplar based agroforestry system, the higher leaf area index of sorghum (6.00), berseem (4.20) and oat (4.90) was recorded under 8×3 m and minimum under 3×3 m spacing at harvest. However, the highest leaf area index was recorded under control (sole cropping) in all fodder crops (Table 3). The decrease in the leaf area index with the decrease in the spacing may be due to the light, nutrients and moisture between tree and crop components. Thus, competition for utilization of growth resources adversely affected the leaf area index of intercropped fodder crops under different spacing's of poplar. Kumar *et al*. (2014) revealed the similar results that leaf area index increased significantly with wider spacing and also with stage of growth.

Light intensity on fodder crops under different spacing's of poplar

Trees reduce the amount of sunlight reaching to soil and crops through shading. Light capture is influenced by both environmental and plant factors such as tree leaf area, leafing phenology, crown structure and management. Unless trees are leafless during the cropping season or heavily pruned, competition can be substantial (Luedeling *et al.,* 2016). The light intensity available to fodder crops of both seasons (rainy and winter season) was noticed on monthly interval at two hours interval of the day (7A.M. to 5 P.M.) under different spacing's as well as in open condition (devoid of trees). Results highlighted that the light intensity to fodder crops is significantly affected by poplar trees at different stages of growth. The highest light intensity (672.4 Lux) was recorded in 8×3 m followed by 7×3 m (604.4 Lux), 6×3 m (550.1 Lux), 5×3 m (469.8 Lux), 4×3 m (365.4 Lux) and minimum under 3×3 m (331.4 Lux) at 1.00 pm in the month of July (2018) as shown in figure 5. The light intensity trends under different spacing's of poplar was observed in decreasing order from July to October, 2018 and then it follows increasing trend from November, 2018 to February,2019. From the month of March, 2019 it starts to reduced due to the appearance of new foliage in poplar. The light intensity available to the sole crop found greater than various spacing's of poplar tree. From December to February, the difference in the light intercepted by sole crop and poplar-intercropped was less but after mid of March it starts to increase as the dense foliage in the poplar. Among different spacing's of poplar, the maximum light intensity was observed in 8×3 m however, in closer spacing (3×3 m) it was significantly less. These findings are also supported by the findings of Bhandari *et al.* (2015).

Economic analysis of poplar-based agroforestry systems

In the present study, detailed observations in terms of accurate record of rental value of land, input costs, expenditure on labour and inter-cultural operations, tree and crop growth and their yield, and market price help portray the economic overview of agroforestry systems. *Populus deltoides* based silvi-pastoral systems fetched higher net returns as compared to sole fodder crops (Table 4 and 5). It can be clearly observed from the data that the cost of cultivation, gross return and net return increased with the increase in number of trees per hectare in different spacing's of poplar. The figures presented in Table 4 that the maximum gross return was obtained from poplar + sorghum system, *i.e*. Rs. 241943/ha under 3×3 m spacing due to more number of trees in this spacing. The gross return decreased with the increase in the spacing of poplar, however the minimum gross return was obtained under sole cropping of sorghum *i.e*., Rs. 61392/ha. The maximum net

Table 4: Economics of sorghum with poplar and control (sole fodder crops)

Tree spacing (m)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
3×3	104679	241943	137264	2.31
4×3	101409	194781	93373	1.92
5×3	99447	173675	74228	1.75
6×3	98139	154916	56777	1.58
7×3	97827	143244	45417	1.46
8×3	96504	132687	36183	1.37
Control	35892	61392	25500	1.71

Table 5: Economics of berseem and oat with poplar and control (sole fodder crops)

Tree spacings (m)	Cost of cultivation (Rs./ha)		Gross return (Rs./ha)		Net return (Rs./ha)		B:C ratio	
	P + B	**P + O**	**P + B**	**P + O**	**P + B**	**P + O**	**P + B**	**P + O**
3×3	111867	105291	255001	257058	143134	151767	2.28	2.44
4×3	108597	102021	204743	206315	96146	104294	1.89	2.02
5×3	106635	100059	175492	178405	68857	78346	1.65	1.78
6×3	105327	98751	157748	158856	52421	60105	1.50	1.61
7×3	105015	98440	148317	146681	43302	48241	1.41	1.49
8×3	103692	97116	138044	137500	34352	40383	1.33	1.42
Control	45081	38505	66164	64499	21083	25994	1.47	1.68

***P + B, Poplar and Berseem P + O, Poplar and Oat**

return (Rs. 137264/ha) was obtained under poplar + sorghum at 3×3 m, while the minimum net return was obtained under sole cropping of sorghum *i.e.*, Rs. 25500/ha. The figures indicate (Table 5) that the cost of cultivation of winter season fodder crops increased with the decrease in poplar spacing's. Poplar + oat cropping system gained maximum gross returns (Rs. 257058/ha) and net return (Rs. 151767/ha) closely followed by poplar + berseem system Rs. 255001/ha (gross return) and Rs. 143134/ha (net return) respectively under 3×3 m spacing of poplar due to more number of trees. On the other hand, the gross and net return decreased with the increase in the spacing of poplar and minimum was obtained under sole cropping of berseem and oat.

Benefit cost ratio

BCR is the most important and accepted parameter in agricultural production systems. Higher value of BCR was observed for poplar with oat (2.44) followed by poplar with sorghum (2.31) and poplar with berseem (2.28) under 3×3 m spacing. It indicates that closer spacing of 3×3 m of poplar is more economic than the other spacing's due to more number of trees per unit area and more production of wood (Table 4 and 5). The lowest value of BCR (1.33) was reported in poplar + berseem followed by poplar + sorghum (1.37) under 8×3 m spacing. Thus poplar + oat is found to be more profitable than other fodder crops in poplar based silvi-pastoral systems. Some researchers have reported the higher BCR (more than 2.0) for poplar based agroforestry system in the Indo-Gangetic plains. Banerjee *et al*. (2010), Chisanga *et al.* (2013) also reported that benefit cost ratio (BCR) was maximum (6.63) from silvi-pasture and least from sole agriculture (without trees).

Conclusion

Economic evaluation for adoption of various agroforestry systems is essential due to increasing land pressure and diversification of traditional cropping system. Agroforestry based on poplar is more beneficial than the other traditional cropping system. The study pointed out that poplar based agroforestry system at spacing of 8×3 m is superior over other spacing geometries in terms of tree growth and fodder yield. The benefit cost ratio (BCR) of poplar with oat (2.44) was highest followed by poplar with sorghum (2.31) and poplar with berseem (2.28) at 3×3 m spacing due to more number of trees per unit area. Poplar also plays an important role in adaptation and mitigating climate change because it sequesters more atmospheric carbon in plant parts and soil and reduces the concentration of green house gases in environment.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Forewarning of insect incidence based on weather variables for management of cropping practices in Sugarcane

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ABSTRACT

The early shoot borer, top borer, root borer, internode borer are major insect occurs in most of the sugarcane growing areas of the Gujarat and cause extensive damage to the sugarcane crop, which leads to losses in the crop yield. The weather discrepancies acting an important role in development of sugarcane insect and pest. The proper management of cropping practices may leads to overcome on it. Therefore it need to develop weather based approaches for forewarning the insect incidence which helps to farmers takes timely control measures to reduce the damage and yield losses due to this borer complex. Current study, relationship between insects incidence with weekly average weather parameters has been workout by using Karl-Pearson's correlation approach on the 18 years of the data (2000-01 to 2017-18) in the Navsari district. The some of the weather variables were found significantly correlated with insect incidence. The multiple linear regression (MLR) and discriminant function analysis approach were adopted for statistical forewarning of the insect incidence. It was observed that MLR technique found better than discriminant function analysis for forecasting of insect incidence for forewarning of early shoot borer at 90 DAP and top shoot borer incidence at 5th month of crop season respectively.

Introduction

Sugarcane is main source of sugar in India. Sugarcane is predominantly grown in tropical and subtropical regions. Sugarcane is main source of raw material for the production of white sugar, jaggery and *khandsari*. Sugar industry is second largest agro based industry in India after textile industry. The Sugarcane cultivation and Sugar industry in India plays a vital role in socio-economic development of rural areas by mobilizing rural resources and generating higher income and employment opportunities. Gujarat is the sixth largest sugarcane producing state in India with a production of 11.61 Million tonnes and account for about 3.21% of total sugarcane production in a country. In Gujarat, area under sugarcane is more than 1.65 lakh hectares of land (Anonymous, 2020). A sugarcane crop is sensitive to the climate, irrigation, fertilizers, soil type, diseases, insects-pest, varieties, and the harvesting time. The sugarcane crop is attacked by a varied range of insect pests all through its plant stages (Williams *et al.,* 1969). The early shoot borer, top borer, root borer, internode borer are major insect additively cause considerable damage to the sugarcane crop,

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which results in yield losses. The weather based forewarning provides information about the time and severity of outbreak of this borer infestation of sugarcane. Insect-pest monitoring data along with corresponding weather data is crucial to improve insect-pest forewarning models and provide forecasts for operational use. Understanding the nature of this combined interaction needs an inter-disciplinary approach to identify critical components needed to develop management tools to address the pest and disease concerns of a farmer. Notwithstanding many years of implementation of pest management strategies, some pests remain difficult to manage and their dynamics are still largely unpredictable, with sometimes dramatic yield reduction (Kiritani, 2006; Gregory *et al.*, 2009).

The several efforts have been attempted to study the relation between insect-pest incidence, weather parameters and yield losses. Srivastava (2002) has also been attempted to forecast the frequency and intensity of occurrence of insect-pests and diseases of various crops like cotton, grain sorghum, wheat, corn, soybean, alfalfa, peanuts, dry beans, potato, millets, tomato, sugarcane etc. Paswan *et al.* (2017) studied relationship between borer incidence and weather parameters and developed forewarning models for borers of sugarcane under Bihar agro ecosystem. Deb and Bharpoda (2017) studied relationship and found the impact of meteorological factors on population of major insect pests in tomato under middle Gujarat conditions. Chattopadhyay *et al.* (2019) studied the effect of weather parameters on the population dynamics of *Spodoptera litura* in soybean and cotton during kharif season using six years pest data. It was shown that incidence of *S.litura* in soybean and cotton can be predicted well in advance using the observed relationship of the pest with weather parameters as well as weather forecast. Mohankumar *et al.* (2020) studied the seasonal incidence of phytophagous mite pests on different varieties of sugarcane crop. Laterally with this Priya and Suresh (2009), Kumar *et al.* (2014), Sattar *et al.* (2014), Marcari *et al.* (2015) and Kumar *et al.* (2015) developed forecast models based on agro-meteorology for forecasting of yield and quality of sugarcane crop. The advanced techniques were adopted by Laxmi and Kumar (2011), and Hossain and Abdulla (2015) and Dubey *et al.* (2018) for forecasting sugarcane yield.

Looking to the scope and importance of the forewarning of insect incidence in relation to weather variable, the current study was carried out to develop statistical forewarning model for predicting insect incidence well in advanced for effective management cropping practices in sugarcane.

Material and Methods

The study was conducted in Navsari district of south Gujarat. The Navsari is located at 20.95° N 72.93° E. In completion of the objective of the development of forewarning of insect incidence the weather data were collected from the Nodal officer (IMD project), Dept. of Agril. Engineering, NMCA, NAU, Navsari for the year 1991 to 2016. The different weather parameters were considered *viz.* weekly average maximum temperature, weekly average minimum temperature, the total weekly rainfall, weekly average morning relative humidity (RH-I), weekly average evening relative humidity (RH-II). The study utilized the past data (2000-01 to 2017-18) on per cent incidence of early shoot borer (60 and 90 DAP) and top borer (5^{th} month and 7^{th} month of crop season) which were collected from annual reports (Entomology) of Main Sugarcane Research Station, Navsari Agricultural University, Navsari.

Statistical data analysis

In present investigation analysis of data was carried out by using following different kind of statistical tools.

Association of insect-pest incidence with weekly weather parameters

The relationship between incidence of early shoot borer and top shoot borer (Y_i) with weekly average weather parameters (X_i) were studied by using Karl-Pearson's correlation coefficient (r) approach. The significance of correlation coefficient was tested by t-test statistics at 5 or 1 per cent level of the significance.

$$r = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2 \sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \quad (1)$$

Statistical forewarning models

The statistical forewarning models were developed using multiple linear regression (MLR) and discriminant function analysis approach (Sisodia *et al.*, 2014 and Garde *et al.,* 2020). The weakly weather variables were utilized for development of weather indices (Agrawal *et al.,* 2007; Garde *et al.,* 2015). The forewarning model was developed using observed weekly weather variables as explanatory variable and per cent incidence of insect as response variable. The form of the developed model is as follow:

- Model 1

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_n X_n + e \qquad (2)$$

Where,
Y is per cent insect incidence
$\beta_0, \beta_1, \beta_2, \ldots, \beta_n$ are regression coefficients
X_i is the average effect of the ith weather variable in each year (i=1, 2,..., n).
e is the error term

Further MLR model was developed using weather indices as independent variable and per cent incidence as dependent variable through stepwise regression method.

- Model 2

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{1} a_{ij}Z_{ij} + \sum_{i\neq i'=1}^{p}\sum_{j=0}^{1} a_{ii'j}Z_{ii'j} + cT + e \qquad (3)$$

Where,
Y is observed per cent insect incidences
A_0 is the intercept
$Z_{ij} = \sum_{w=1}^{m} r_{ij}^{j} X_{iw}$ and $Z_{ii'j} = \sum_{w=1}^{m} r_{ii'j}^{j} X_{iw}X_{ii'w}$ are the weather indices
a_{ij} and $a_{ii'j}$ are the regression coefficients
p is the number of weather variables to be used
c is the regression coefficients of trend variable
T is the trend variable
e is the error term

The Discriminant function analysis was attempted to develop forewarning model using weighted weather indices. Total fifteen weighted indices were considered. Two discriminant score have been obtained from these weighted weather indices. Two discriminant score along with trend were used to develop the model through stepwise regression technique (Agrawal *et al.,* 2012, Garde *et al.*, 2015, Kumari *et al.*, 2017). The form of the developed model is as follow:

- Model 3

$$Y = \beta_0 + \beta_1 ds_1 + \beta_2 ds_2 + \beta_3 T + \varepsilon \qquad (4)$$

Where
Y is sugarcane yield (t/ha)
β_i are regression coefficient, i =0,1,2,3
ds_1 and ds_2 are discriminant scores,
T is the trend variable
ϵ is error term assumed to follow $N(0, \sigma^2)$
The comparison of developed forewarning models were done with help of Adj. R^2, Forecast error %, Mean Absolute Percentage error (MAPE) and Root mean Square error (RMSE).

Results and Discussion

Association of insect incidence with weekly weather parameters

The association between insect incidence and weekly weather parameter were observed. It was observed the significant correlation coefficient between early shoot borer incidence at 60 DAP (Days after transplanting) and weekly average weather parameters *viz*. morning relative humidity (7th SMW) and evening relative humidity (6th SMW). It was indicated that relative humidity was found to profoundly influence the borer infestation. At 90 DAP, the significance of correlation coefficient were observed between early shoot borer incidence and morning relative humidity (5th SMW) and evening relative humidity (3rd, 12th and 13th SMW). It is also observed rainfall during 60-90 DAP was observed to reduce borer infestation though the association was not significant. The significance of correlation coefficient was observed between top shoot borer incidence at 5th month after transplanting and maximum temperature (2nd and 17th SMW), minimum temperature (19th and 20th SMW). It observed that the association between mean temperature and the pest seems to be dominated by minimum temperature. At 7th month, the significant correlation coefficient were observed between top shoot borer incidence and weekly average maximum temperature (11th SMW), minimum temperature (11th, 19th and 27th SMW), and morning relative humidity (29th and 30th SMW).

Forewarning model: MLR using weekly weather variables

The forewarning models were developed using MLR techniques with weekly weather variables for per cent incidence of early shoot borer (ESB) at 60 and 90 days after transplanting (DAP) and top shoot borer (TSB) at 5th month & 7th month. The observed resulted were presented in Table 1 along with adj. R^2. No variable were found significant in forewarning model for top shoot borer at 7th month. It was observed from the Table 1 that Model-1.1 have high value of adjusted R^2 (32.2) and low RMSE (0.45). The value of MSE, RMSE and MAPE ranges from 0.11 to 0.80, 0.33 to 0.90 and 17.75 to 22.25, respectively. It indicated that none of the models were found suitable for Forewarning insect incidence, therefore study utilized modified approach for forewarning insect incidence.

Forewarning model: MLR using weekly weather indices

Further model was developed by taking weather indices as independent variable for per cent incidence of early shoot borer (ESB) at 60 and 90 DAP and top shoot borer (TSB) at 5th month & 7th month. Stepwise multiple regression technique was used to obtain significant weather variables. The obtained forewarning model equations are presented in Table 2. It was observed from the Table 2 that Model-2.2 show high value of adjusted R^2 (74.7 %) and acceptable RMSE (0.69) than Model-2.1. Thus Model-2.2 found suitable for forewarning early shoot borer incidence at 90 DAP ($Y = 1.237 + 0.001\ Z_{251}$). The interaction between minimum temperature and morning relative humidity showed impact on incidence of ESB at 90 DAP. It was also found from Table 2 that Model-2.3 found suitable for forecasting of top shoot borer at 5th month with respect to high value of adjusted R^2 (88.9) and RMSE (0.72) ($Y = 9.583 + 0.026Z_{41} - 0.046T$). The weighted morning relative humidity (Z_{41}) and weighted average interaction between maximum temperature and morning relative humidity (Z_{141}) along with trend T have significant effect on top shoot borer incidence. Similar results for morning relative humidity were observed by Paswan *et al.* (2017) for top shoot borer of sugarcane in Bihar.

Forewarning model: using discriminant function analysis

The discriminant function analysis techniques was adopted for development of models for forewarning the incidence of early shoot borer at 60 and 90 DAP, top shoot borer at 5th and 7th month. The obtained forewarning model equations are given in Table 3. The Table 3 revealed that Model-3.1 indicated that 79.1 per cent variation in early shoot borer incidence at 60 DAP was accounted by ds_2 and T ($Y = 1.504 + 0.158ds_2 + 0.094T$) and found low RMSE (0.75) which indicated appropriate forewarning model for early shoot borer. Similarly, the Model-3.3 indicated 54.1 per cent variation in top shoot borer incidence at 5 month was accounted by ds_1. ($Y = 1.545 + 0.111ds_1$) and lower RMSE (0.73) which showed suitable forewarning model for top shoot borer. The similar statistical approach was carried out by Agrawal *et al.* (2012) in Kanpur and similar result were observed for wheat yield.

Table 1: Forewarning model equations for insect incidence using weekly weather variables

Models	Model 1	Model equation	Adj.R^2
ESB (60DAP)	Model-1.1	$Y = 4.859 - 0.095\ X_5$	32.2
ESB_(90DAP)	Model-1.2	$Y = 1.662 + 0.055\ X_3$	26.1
TSB_(5 Month)	Model-1.3	$Y = 12.009 - 0.131\ X_4$	25.9

Table 2: Forewarning model equations for insect incidence using weather indices

Model	Model 2	Model equation	Adj.R^2
ESB(60DAP)	Model-2.1	$Y = 4.872 + 0.038\ Z_{51}$	53.9
ESB(90DAP)	Model-2.2	$Y = 1.237 + 0.001\ Z_{251}$	74.7
TSB(5Month)	Model-2.3	$Y = 9.583 + 0.026Z_{41} - 0.046T$	88.9
TSB(7Month)	Model-2.4	$Y = 11.315 + 0.001\ Z_{141} - 0.088T$	79.6

Table 3: Forewarning model equations for insect incidence using Discriminant Function

Model	Model 3	Model equation	Adj. R^2
ESB(60DAP)	Model-3.1	$Y = 1.504 + 0.158ds_2 + 0.094T$	79.1
ESB(90DAP)	Model-3.2	$Y = 1.753 - 0.032ds_1$	75.7
TSB(5Month)	Model-3.3	$Y = 1.545 + 0.111ds_1$	54.1
TSB(7Month)	Model-3.4	$Y = 2.778 - 0.122$T	43.4

There are several studies on forewarning of insect and pest using weather variables by adopting different statistical methods for different crops has been discussed by Agrawal and Mehta (2007). But limited work has been carried out on the forewarning of insect incidence particularly in sugarcane crop based on weather variables using similar statistical approaches. The overall comparison of the all above developed models it was observed that multiple linear regression approach found better than discriminant function analysis for forewarning of insect incidence. The Model-2.2 found suitable for forewarning of early shoot borer at 90 DAP with R^2 =74.7% and *RMSE*=0.69. Similarly, Model-2.3 found appropriate for forewarning top shoot borer incidence at 5th month of crop season with R^2 =88.9% and *RMSE*=0.52.

Conclusion

Farmers are mainly worried about the current disease and insect-pest severity data, preferably for their localities to support their decision making in crop protection. The current study suggested there is a scope for using other methods to develop predictors that could be used in forecasting models for reliable and dependable forecast. The forewarning models can be helpful in inspiring the farmer to organize and use their own resources in order to gather the benefits. The study showed multiple linear regression approach found better than discriminant function analysis for Forewarning of insect incidence. The study revealed that some of the weather variables were significantly correlated with insect incidence. It is required further studies pertaining to climate change driven changes in serious insect-pests of crops and planning and development of adaptive strategies needs to be undertaken to lessen the yield losses and safeguard the food security of nation.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Evaluation of $F_{2:3}$ rice population resistant to *Rhizoctonia solani* Kuhn inciting sheath blight disease

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ABSTRACT

Rice sheath blight caused by the soil-borne fungal pathogen *Rhizoctonia solani* Kuhn is an economically important disease in rice resulting in enormous yield losses worldwide. In the present investigation, a population constituting F_3 lines resulted from the cross made between IC277332 (susceptible parent) and Tetep (resistant parent) were evaluated for sheath blight resistance and other agronomic traits over a season. The rice population lines were categorized into four groups *viz.*, moderately resistant (11), moderately susceptible (63), susceptible (24), and highly susceptible (8), based on area under disease progress curve (AUDPC) values. During the study, nine moderate resistant lines showed, less AUDPC values in comparison to Tetep. Furthermore, 63 individuals (60%) exhibited moderate susceptibility with AUDPC values (677-987 per day). The principal component biplot analysis PC1 and PC2 showed 47.08% and 13.19% variation, respectively. The employment of Unweighted Pair Group Method of Arithmetic Means (UPGMA) cluster analysis led to the grouping of the 106 individuals into 2 major clusters A and B. The results suggested that none of the rice lines was resistant to sheath blight disease. However, few lines showed moderate resistance to the disease which can be exploited for the development of sheath blight-resistant cultivars.

Introduction

Rice production and productivity are affected by certain abiotic and biotic factors which causes yield losses of up to 45% (Margani and widadi, 2018). Among all the biotic stresses, the fungal diseases in rice are most predominant throughout the world. The productivity of rice is affected by several pathogens (Margani and widadi, 2018), of which sheath blight (ShB) disease caused by *Rhizoctonia solani* Kuhn is one of the destructive pathogens of economic significance, second most prevalent to the blast disease (Zheng *et al*., 2013; Molla *et al*., 2020). Rice sheath blight pathogen, *Rhizoctonia solani* [Teleomorph: *Thanatephorus cucumeris* (A.B. Frank) Donk] is a globally ubiquitous and ecologically diverse soil-borne pathogen with a broad host range infecting many important crops worldwide. The pathogen causes severe yield losses to the extent of 5.9 to 69 per cent to rice crops in advanced crop stages (Richa *et al*., 2016; Neha *et al*., 2016). The typical symptoms include oval or ellipsoidal greenish-grey irregular lesions on leaf sheath initially just above the water level later spreading across other plant parts often with grey-white centres surrounded by brown margins which appear maximum at tillering stage (Uppala and Zhou, 2018). As the lesion progress, the centre of the lesion gets bleached with an irregular purple-brown margin and develops new infection

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structures throughout the entire plant, causing significant necrotic damage (Yellareddygari *et al*., 2014; Singh *et al*., 2016). The sclerotia are produced by the pathogen on basal leaf sheaths serves as a primary source of inoculum which appears white when young, later turns brown to dark brown (Uppala and Zhou, 2018), and can remain viable up to 3 years in soil or water (Kumar *et al.,* 2009). The wide host range of the pathotypes and fluctuations in the pathogen within the local population are the crucial factors influencing the management strategies (Mew *et al*., 2004). The control of ShB in the field so far has mainly relied upon the application of chemical fungicides, but their utility is delimited, primarily due to complications related to timing and application cost, weather dependencies, and a potentially damaging environmental impact by increasing pesticide residues (Mew *et al*., 2004). Due to these situations, the advance and use of resistant genotypes may be a highly effective way to manage the disease.

Several studies suggested the extensive efforts of workers in rice breeding for sheath blight resistance and large-scale germplasm screening of wild species for resistance genes (Turaidar *et al.,* 2017; Praveen *et al.,* 2019; Goswami *et al*., 2019; Pavani *et al*., 2020). Moreover, assessing the resistance to sheath blight in paddy fields is a very challenging task as the resistance is greatly influenced by agronomic traits such as plant height, the density of plants (Pinson *et al.,* 2005), tillering and heading date (Pan *et al.,* 1999). Studies suggested that resistance to *R. solani* in rice is a complex, quantitative trait that is generally controlled by polygenes (Sha and Zhu, 1989; Pinson *et al*., 2005; Koshariya *et al*., 2018). As a result, to date there is no single report of the sheath bight resistant rice germplasm across the world (Zeng *et al*., 2011; Shi *et al.,* 2020; Bhunkal *et al*., 2015). However, a few major resistance genes have been identified from either cultivated rice or wild relatives (Molla *et al*., 2020) and only a few varieties such as Tetep, ARC 10531, Teqing, Jasmine 85, Tadukan (Yadav *et al*., 2015; Zarbafi and Ham, 2019) and some of the landraces such as Jarjan, Nepal 555, Nepal 8 (Shiobara *et al.,* 2013), BPL7-12, BML27-1, BML 21-1 and Kajarahwa (Dubey *et al.,* 2014) were reported to be moderately resistant. Lemont, IR 50, Pusa Basmati-1, BPT-5204 (Yadav *et al.,* 2015) are highly susceptible to the sheath blight disease under field conditions. Therefore, keeping in mind the aforesaid facts, the current research program was planned and designed to discover ShB resistance in the rice population. The present study was undertaken to develop and screen the F_3 population of rice for reaction to sheath blight resistance.

Material and Methods

Plant materials and experimental design

The seeds of 106 rice population lines of F_3 generation resulted from the cross between IC277332 (susceptible parent) and Tetep (resistant parent) were collected from Prof. Vineeta Singh, Department of Mycology and Plant Pathology, Banaras Hindu University, Varanasi, UP, India. All the experiments were conducted during the cropping season 2019-2020 in the Agricultural Research Farm (North Eastern Plain zone, India, 25º18´N, 83º03´E, 75.7 MSL), Banaras Hindu University, Varanasi. The nursery beds were prepared by mixing soil, sand, and FYM (3:1:1, w/w), healthy seeds were sown along with the susceptible (Pusa Basmati-1) (Adhipathi *et al*., 2013) and resistant (Tetep) (Sha and Zhu, 1990) check varieties. Under adequate light and moisture conditions were maintained for the good growth of the seedlings. Alpha lattice design with the plot size of 3×4 m^2 was used to conduct the field experiment. There were three replications for each treatment. Each population line was grown in a 1 m long row with inter and intra row spacing of 30 and 10 cm, respectively. To ensure a good crop, the necessary agronomic measures were followed.

Source of the pathogen culture

The highly virulent isolate of *Rhizoctonia solani,* AG-1 IA (MTCC-12227) procured from the Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi was used in this study.

Pathogen inoculation

Single sclerotia based inoculum of a virulent strain of *R. solani* (MTCC-12227) (anastomosis group AG1-1A), was maintained on PDA medium at 28 $\pm$ 2 $^{\circ}$C. This isolate produces typical ShB symptoms on sheath and leaves and typical mycelial growth and sclerotia production. MTCC-12227 has been used in previous studies (Goswami *et al*., 2018, Goswami *et al*., 2019). Plants at the booting stage were inoculated with the pathogen by placing immature sclerotia or mycelial bits (approx. 0.25 mg) in leaf sheath (Singh *et al*., 2002a, b). After inoculation, the spots were covered with wet absorbent cotton pre-soaked in sterile water to maintain moist conditions that facilitate the development of infection. Inoculation was carried out in the evening hours so that the inoculated site remains moist for a longer duration.

Scoring of disease severity

The disease scoring was done using a 0-9 scale (SES) (IRRI, 2014). The disease severity was calculated at weekly intervals up to the 28th day after inoculation (DAI) (Goswami *et al*., 2019; Pavani *et al*., 2020) by measuring the relative lesion height (RLH) in each tiller was calculated as described by Sharma *et al*., (1990)

$$RLH = \frac{maximum\ heigh\ \ at\ which\ lesion\ appear}{plant\ heigh} \times 100$$

The area under disease progress curve (AUDPC) (Shaner and Finney, 1997) and per cent disease index (PDI) (Wheeler, 1969) were calculated as per the formula

$$AUDPC = \sum_{i=1}^{n=1} \{[(X_{i+1} + X_i) /2] \times (t_i+1 - t_i)\}$$

Where, n = the total number of observations,
Xi = disease index expressed as a proportion at the i^{th} observation,
t_i = time at the i^{th} observations.

$$\text{PDI} = \frac{Sum\ of\ all\ ratings \times 100}{Total\ no.of\ observations \times maximum\ rating\ scale}$$

Data recording on agronomic traits

Data from the following parameters were collected according to the guidelines described in standard evaluation systems for rice (IRRI, 2014).

Plant height (*PHT*): The average height of 5 plants from the ground level to the tip of the tallest panicle was measured in centimetres (cm) at maturity.

Panicle length (*PNL*): The Length of the panicle was measured by a centimetre scale starting from the tip of the neck to the tallest spikelet.

Tiller number per hill (*TNH*): The number of tillers was counted from the primary and secondary culms of a hill.

Grain yield (*YLD*): The Weight of the grains per plant was measured by grams (g).

Test weight (*TW*): 100 seed weight per plant was measured by grams (g).

Statistical analysis

The analysis of the obtained data was carried out following the alpha lattice design using Microsoft Office Excel 2019, 32 bit. The values of data were subjected to population distribution, analysis of variance (ANOVA) for sheath-blight related parameters, and morphological traits. Pearson's correlations analysis was performed by Window stat 7.5 version. Euclidean cluster analysis based on UPGMA was performed in the PAST computer software 4.0 version. Multivariate principal component analysis was executed by XLSTAT 2018 software.

Results and Discussion

Distribution and grouping of population

The frequency distribution of the studied population suggested the presence of wide variation Table 1. The mean, median and mode values were found to be different, which indicated the asymmetric distribution of data. Among the parameters studied, PHT, PNL, and TNH were negatively skewed, whereas the remaining parameters were positively skewed. Kurtosis values ranged between -1 to +1 for all the traits other than PDI on the 7th day (2.89) and 14th day (2.23), kurtosis values were <3, which showed a frequency of the studied population was platykurtic. The coefficient of variation was found to be reasonable and varied from 7.2 (plant height) to 42.1 (PDI of 7th day), which showed the population had higher variability. The analysis of variance (mean sum of squares) for 9 agronomic traits of 106 population lines is presented in Table 2. Among the treatments, all the traits were found to be significantly different other than PNL and TNH, whereas, in replication, YLD, TW, and PDI of the 28th day showed non-significant results. The results of our study indicate that an appreciable level of variability is present among the population concerning sheath blight resistance and agronomic traits recorded. The estimates of Pearson's correlation coefficients (Table 3) among agronomic traits resulted in a highly significant correlation of mean PDI with AUDPC (0.765). Plant height was negatively associated with PDI of the 28th day (-0.630), the mean PDI (-0.571), and the AUDPC (-0.524). TNH and TW have indicated negligible correlation with all other parameters.

Table 1: Descriptive statistics of different traits of rice population lines during wet season 2019-2020

Trait	Mean	Median	Mode	Kurtosis	Skewness	Range	Min	Max	Sum	C.V(%)
PHT	123.12	124.1	128.8	0.72	-0.67	48.4	92.9	141.3	13049.84	7.2
PNL	19.18	19.105	18.6	-0.27	-0.03	6.82	15.2	22.02	2033.51	7.5
TNH	5.35	5.4	6	-0.57	-0.11	4.8	3.1	7.9	567.75	19.4
YLD	11.04	10.93	#N/A	0.22	0.18	15.17	4.503	19.679	1170.67	25
TW	2.39	2.38	2.1	-0.21	0.27	1.18	1.87	3.055	254.03	10.4
PDI of 7th day	18.65	15.55	15.55	2.89	1.71	36.67	10	46.67	1974.72	42.1
PDI of 14th day	20.05	17.77	17.77	2.23	1.48	36.11	11.11	47.22	2125.83	38.8
PDI of 21st day	37.01	35.56	33.33	0.34	0.56	48.89	13.33	62.22	3923	26.6
PDI of 28th day	58.94	57.78	64.44	0.02	0.21	57.78	31.11	88.89	6248.22	18.6
Mean PDI	33.65	31.67	29.44	1.15	1.07	40.56	18.89	59.44	3567.94	23.9
AUDPC	935.89	863.33	770	1.31	1.17	1191.94	521.11	1713.05	99204.58	26.8

C.V- coefficient of variance; min- minimum value; max- maximum value; sum- total summation; PHT-plant height; PNL-panicle length; TNH-tiller number per hill; YLD- yield of plant; TW- test weight (100 grains); PDI- Percent Disease Index; AUDPC- Area Under Disease Progress Curve; N/A- not available

Table 2: Analysis of variance for various traits of rice during wet season 2019-2020.

Source of Variation	Degrees of freedom	Mean squares										
		PHT	PNL	TNH	YLD	TW	PDI of 7th day	PDI of 14th day	PDI of 21st day	PDI of 28th day	Mean PDI	AUDPC
Treatment	105	161.43**	4.15ns	2.18ns	15.18**	0.13**	124.08**	121.53**	194.34**	240.80**	130.30**	126443.74**
Replication	1	405.83*	534.80**	2.63ns	7.26ns	0.0015ns	407.41*	525.86*	1817.11**	422.02ns	706.05**	812814.48**
Error	105	58.81	6.25	1.47	6.68	0.05	49.78	54.87	101.28	106.36	51.51	51508.09

****significance value at 0.01%, * significance value at 0.001%, ns-non significance; PHT-plant height; PNL- panicle length; TNH-tiller number per hill; YLD- yield of plant; TW-test weight (100 grains); PDI- Percent Disease Index; AUDPC- Area Under Disease Progress Curve**

Table 3: Pearson's correlation analysis for various traits of rice during wet season 2019-2020

Variables	PHT	PNL	TNH	YLD	TW	PDI of 7th DAY	PDI of 14th DAY	PDI of 21st DAY	PDI of 28th DAY	Mean PDI	AUDPC
PHT	1	0.287	0.001	0.166	0.185	-0.482	-0.487	-0.398	-0.630	-0.571	-0.524
PNL	0.287	1	-0.265	-0.066	0.016	-0.201	-0.157	-0.102	-0.185	-0.181	-0.165
TNH	0.001	-0.265	1	0.249	-0.130	0.129	0.106	0.195	0.147	0.167	0.166
YLD	0.166	-0.066	0.249	1	0.112	0.099	0.037	0.070	-0.018	0.048	0.060
TW	0.185	0.016	-0.130	0.112	1	0.006	-0.041	-0.095	-0.204	-0.107	-0.082
PDI of 7th DAY	-0.482	-0.201	0.129	0.099	0.006	1	0.966	0.718	0.630	0.911	0.926
PDI of 14th DAY	-0.487	-0.157	0.106	0.037	-0.041	0.966	1	0.741	0.637	0.920	0.940
PDI of 21st DAY	-0.398	-0.102	0.195	0.070	-0.095	0.718	0.741	1	0.648	0.880	0.909
PDI of 28th DAY	-0.630	-0.185	0.147	-0.018	-0.204	0.630	0.637	0.648	1	0.845	0.765
Mean PDI	-0.571	-0.181	0.167	0.048	-0.107	0.911	0.920	0.880	0.845	1	0.990
AUDPC	-0.524	-0.165	0.166	0.060	-0.082	0.926	0.940	0.909	0.765	0.990	1

PHT-plant height; PNL- panicle length; TNH-tiller number per hill; YLD- yield of the plant; TW- test weight (100 grains); PDI- Percent Disease Index; AUDPC- Area under disease progress curve, curve and *PDI* per cent disease index; the range is based on the minimum value of the group plus CD value.

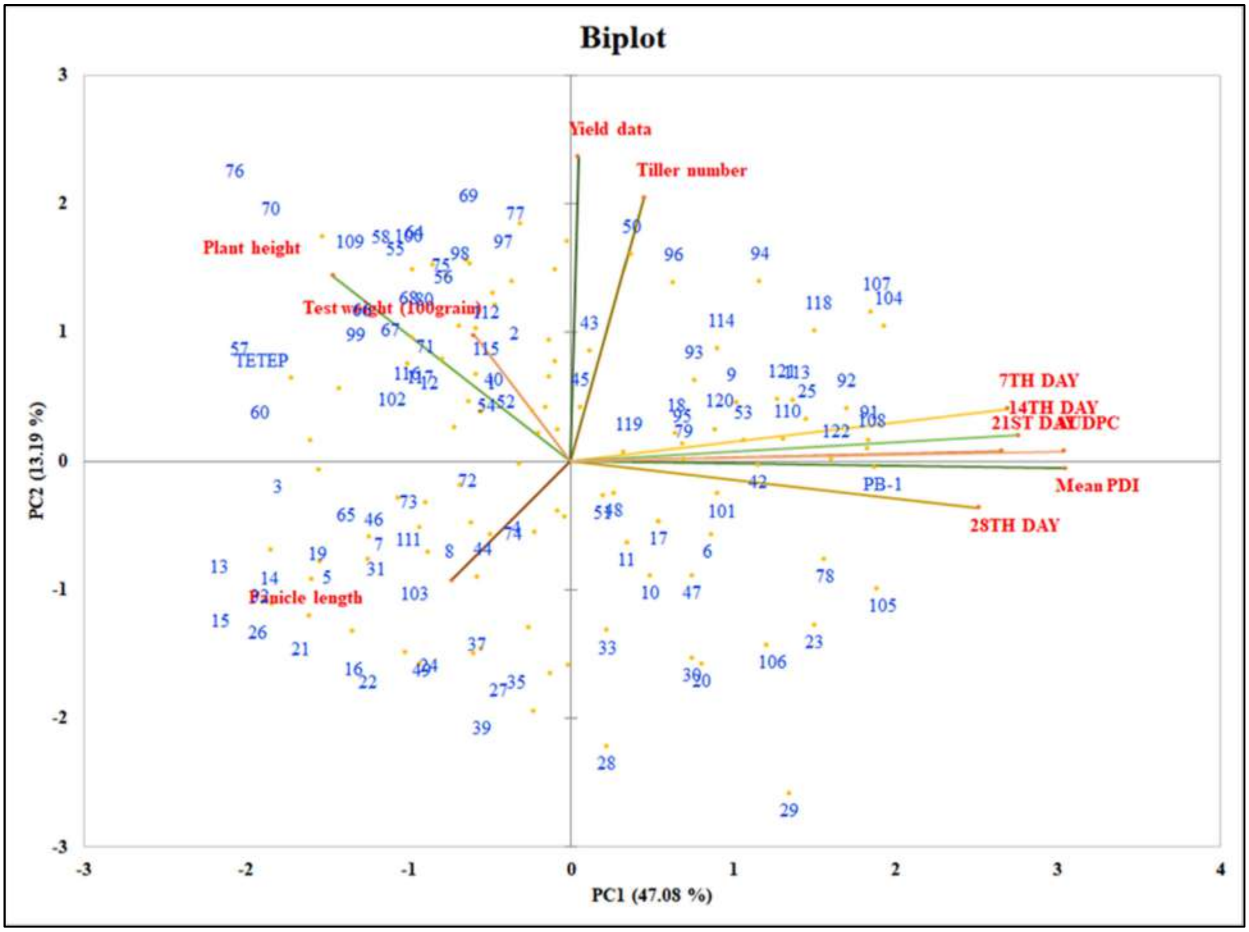

Figure 1: Biplot graph for various traits in the F_3 rice population. PCA biplot graph conceded connection between variables by vector angle. The analysis indicated that the traits *viz.,* mean PDI strong positively correlated with PDI at 7th, 14th, 21st, 28th day, and AUDPC. While plant height has a less strong correlation to tiller number per plant and panicle length. Similarly, yield data is strongly correlated with tiller number per plant.

The PCA biplot analysis for the F_3 population was carried out to find the grouping pattern of various agronomic traits under field conditions. The population by trait biplot analysis accounted for 60.24% of the variation among the F_3 population by the first two components. The PC1 captured 47.08% of variation and PC2 explained 13.19% variation of the total variability (Figure 1). The longest vector load such as mean PDI and AUDPC were observed to be the main distinguishing factors for grouping the population. PCA biplot figure conceded connection between variables by vector angle. The analysis indicated that the traits *viz.,* mean PDI, and AUDPC depicted a negative correlation with PHT and TW but they had no correlation with YLD and TNH. PCA biplot diagram displayed a good separation of the population lines which was high in agreement with the UPGMA clustering. The biplot diagram (Figure 1) indicated significant discrimination of the population lines into quadrangles. The Unweighted Pair Group Method of Arithmetic Means (UPGMA) cluster analysis led to the grouping of the 106 individuals into 2 major clusters, A and B. The dendrogram of the 106 individuals was constructed using correlation coefficient (CP) = 0.62. The largest cluster, A constituted 85 F_3 population lines which were further subdivided into 2 sub-clusters namely, A1 and A2. The sub-group A1 had a total of 11 individuals which were moderately resistant, including Tetep. Subcluster

A2 was further subdivided into A2-1 and A2-2. The dendrogram designated that the sub-group A2-1 contained 20 individuals with varying degrees of SB resistance including 8 susceptible and 12 moderately susceptible individuals. The largest sub-group, A2-2 consisted of 54 moderately susceptible individuals which represent 50% of the total population.

Cluster B, consisting of 21 individuals, was further sub-divided into two groups B1 and B2 with a similarity coefficient of 0.59. Out of these, 14 individuals which were found susceptible were assigned into sub-group B1 and the remaining 7 individuals along with PB-1 were reassigned into sub-group B2 which are highly susceptible (Figure. 2).

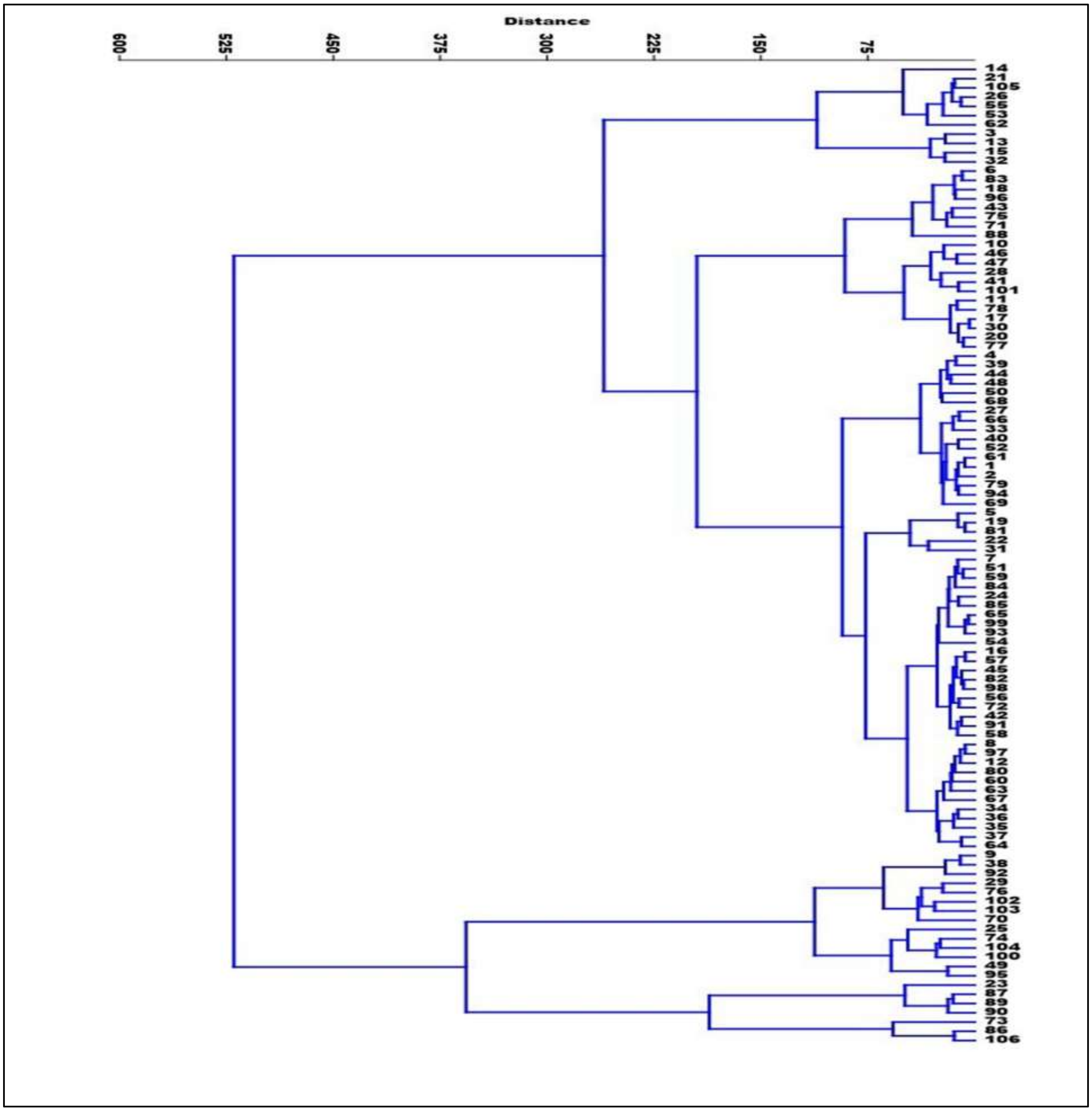

Figure 2: Dendrogram based on UPGMA clustering of rice population based on various traits during the wet season of 2019.

Screening of F_3 population of rice for sheath blight (*Rhizoctonia solani* AG-1 IA) resistance under field condition

Assessment of crop varieties/cultivars against diverse crop diseases is essential (Mew *et al*., 2004), and a continual process required not only for finding the source of resistance genes or QTLs but also for recognizing the incidence of virulence pathotypes in contrast to specific crop diseases (Singh *et al*., 2016). However, various researchers have attempted to screen thousands of rice germplasms including improved accessions, wild types, landraces, and mapping populations but they couldn't come up with any source of resistance to ShB (Zuo *et al.,* 2009; Williocquet *et al.,* 2012; Dubey *et al.,* 2014). In present study, a total of 106 F_3 individuals of rice were screened for sheath blight resistance using highly virulent strain of *Rhizoctonia solani* AG-1 IA (MTCC-12227) under field conditions. Depending on the area under disease progress curve (AUDPC) values, the rice population was classified into four categories viz., (I) moderately resistant (MR: AUDPC = 521-676), (II) moderately susceptible (MS: AUDPC = 677-987), (III) susceptible (S: AUDPC = 988-1314), and (IV) highly susceptible (HS: AUDPC = 1315-1713) (**Table 4**). Eleven lines (9.8%) (SB-T-3, SB-T-13, SB-T-14, SB-T-15, SB-T-21, SB-T-26, SB-T-32, SB-T-53, SB-T-55, SB-T-62, and TETEP) were found moderately resistant with mean percent disease index (PDI) between 12.22 to 23.33. Furthermore, our present experiment, revealed that a relatively higher set of 63 individuals (60%) (SB-T-1, SB-T-2, SB-T-4, SB-T-5, SB-T-7, SB-T-8, SB-T-10,SB-T-11, SB-T-12, SB-T-16, SB-T-17, SB-T-19, SB-T-22, SB-T-24, SB-T-27, SB-T-28, SB-T-30, SB-T-31, SB-T-33, SB-T-34, SB-T-35, SB-T-36, SB-T-37, SB-T-39, SB-T-40, SB-T-41, SB-T-42, SB-T-44, SB-T-45, SB-T-46, SB-T-47, SB-T-48, SB-T-50, SB-T-51, SB-T-52, SB-T-54, SB-T-56, SB-T-57, SB-T-58, SB-T-59, SB-T-60, SB-T-61, SB-T-63, SB-T-64, SB-T-65, SB-T-66, SB-T-67, SB-T-68, SB-T-69, SB-T-72, SB-T-79, SB-T-80, SB-T-81, SB-T-82, SB-T-84, SB-T-85, SB-T-91, SB-T-93, SB-T-94, SB-T-97, SB-T-98, SB-T-99, SB-T-101) exhibited moderately susceptible reaction with mean percent disease index (PDI) between 24.44 to 35.55 when compared to the susceptible control check (Pusa Basmati-1).

Of the remaining population, twenty-four isolates (22.6%) (SB-T-6, SB-T-9, SB-T-18, SB-T-20, SB-T-29, SB-T-38, SB-T-43, SB-T-49, SB-T-70, SB-T-71, SB-T-74, SB-T-75, SB-T-76, SB-T-77, SB-T-78, SB-T-83, SB-T-88, SB-T-92, SB-T-95, SB-T-96, SB-T-100, SB-T-102, SB-T-103, SB-T-104) exhibited susceptible reaction with mean percent disease index 36 to 46.9. Eight (7.5%) population lines (SB-T-23, SB-T-25, SB-T-73, SB-T-86, SB-T-87, SB-T-89, SB-T-90, PB-1) were found to be

Table 4: Grouping the rice F_3 population lines against sheath blight pathogen

Host response	PDI %	AUDPC	Rice Population
MR (11)	≤23.3	521-676	SB-T-3, SB-T-13, SB-T-14, SB-T-15, SB-T-21, SB-T-26, SB-T-32, SB-T-53, SB-T-55, SB-T-62, Tetep
MS (63)	24.4 - 35.5	677-987	SB-T-1, SB-T-2, SB-T-4, SB-T-5, SB-T-7, SB-T-8, SB-T-10,SB-T-11, SB-T-12, SB-T-16, SB-T-17, SB-T-19, SB-T-22, SB-T-24, SB-T-27, SB-T-28, SB-T-30, SB-T-31, SB-T-33, SB-T-34, SB-T-35, SB-T-36, SB-T-37, SB-T-39, SB-T-40, SB-T-41, SB-T-42, SB-T-44, SB-T-45, SB-T-46, SB-T-47, SB-T-48, SB-T-50, SB-T-51, SB-T-52, SB-T-54, SB-T-56, SB-T-57, SB-T-58, SB-T-59, SB-T-60, SB-T-61, SB-T-63, SB-T-64, SB-T-65, SB-T-66, SB-T-67, SB-T-68, SB-T-69, SB-T-72, SB-T-79, SB-T-80, SB-T-81, SB-T-82, SB-T-84, SB-T-85, SB-T-91, SB-T-93, SB-T-94, SB-T-97, SB-T-98, SB-T-99, SB-T-101
S (24)	36 - 45.9	988-1314	SB-T-6, SB-T-9, SB-T-18, SB-T-20, SB-T-29, SB-T-38, SB-T-43, SB-T-49, SB-T-70, SB-T-71, SB-T-74, SB-T-75, SB-T-76, SB-T-77, SB-T-78, SB-T-83, SB-T-88, SB-T-92, SB-T-95, SB-T-96, SB-T-100, SB-T-102, SB-T-103, SB-T-104
HS (8)	> 46.0	1315-1713	SB-T-23, SB-T-25, SB-T-73, SB-T-86, SB-T-87, SB-T-89, SB-T-90, PB-1

***MR* moderately resistant, *MS* moderately susceptible, *S* susceptible, *HS* highly susceptible, *AUDPC* area under disease progressive curve and *PDI* percent disease index; range is based on minimum value of the group plus CD value**

highly susceptible when compared to resistant control (Tetep). According to Chaudhary (2016), disease severity was found to be one of the significant variables for assessing ShB resistance in rice and he evaluated twelve rice genotypes and determined three resistant genotypes of rice *viz.,* Sabitri, Jasmine-85, and Betichikon was affected by low disease severity. Similarly, Yadav *et al*., (2014) also found a landrace, ARC 10351, and a variety Tetep that depicted moderate resistant reaction against sheath blight. Moreover, Shiobara *et al.,* (2013) reported three landraces *i.e*., Nepal 555, Jarjan, and Nepal 8 as resistant against ShB after screening for three years continuously under field conditions. Despite screening thousands of rice germplasms, only a few rice cultivars and lines offer resistance to ShB that have been reported, *viz.,* Teqing (Pinson *et al.,* 2005), Jasmine 85 (Liu *et al.,* 2009), Tetep (Channamallikarjuna *et al.,* 2010), Pecos (Sharma *et al.,* 2009). Moreover, our results are in agreement with the previous reports of several studies (Dey *et al*., 2016; Tejaswini *et al*., 2017; Goswami *et al*., 2019; Pavani *et al*., 2020 and Bal *et al*., 2020). However, few lines showed moderate resistance to the disease which can be exploited for the development of sheath blight-resistant cultivars.

Conclusion

The complete resistance against sheath blight is lacking in rice germplasm. Our study was an effort to screen for resistance in an F_3 population resulted from a cross between IC277332 (susceptible parent) and Tetep (resistant parent). The plants were in turn recorded with certain agronomic traits to study their correlation with PDI. Out of 106 rice population lines, 9.8% of lines depicted moderate resistance (MR), 60% lines were moderately susceptible (MS), 22.5% lines were susceptible (S), and 7.5% lines were highly susceptible (HS). We found nine moderate resistant lines (SB-T-3, SB-T-13, SB-T-14, SB-T-15, SB-T-21, SB-T-26, SB-T-32, SB-T-53, SB-T-55) which showed less AUDPC values than Tetep (R - check). None of the rice lines was resistant to sheath blight disease. The majority of the F_3 population were moderately susceptible (63) in comparison to Pusa Basmati-1 (S-check). Identified resistant lines can be used as donors/pre-breeding lines for the development of sheath blight-resistant rice cultivars. The data gathered in this study will be valuable in developing a breeding program and managing the sheath blight disease in rice. Furthermore, in the coming future, it is necessary to perform breeding experiments and evaluation of a large number of rice population against *R. solani* to determine resistance lines.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Spatial variability map of micronutrients in vegetable growing area of Varanasi

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ABSTRACT

Soil pH and the availability of essential micronutrients is a deciding factor for vegetable production. Major nutrients i.e. nitrogen, phosphorus, potassium, micronutrients are critical elements in enhancing vegetable growth and productivity. The present study focused on the micronutrient status of a vegetable growing area i.e. Shanshahpur village of Varanasi, Uttar Pradesh, India. Spatial variability maps were prepared from 50 samples collected from individual vegetable intercropping system from farmer's field for all the micronutrient element i.e. Fe, Mn, Zn & Cu respectively. Most of the soils of the vegetable growing area of Shanshahpur were alkaline (7.99-8.72) in nature and lies within a safe range of electrical conductivity (<0.20 dSm^{-1}). However, a medium range of soil organic carbon (0.50-0.75%) status was observed throughout the area. According to the variability map for micronutrient status there was a medium to high status for available Cu (0.81 mgkg^{-1}) but in contrast available Fe and Zn content of the vegetable growing lies in low status category(2.00-13.15mgkg^{-1} and 0.02-2.26 mgkg^{-1} respectively). Available Mn status was seen reduced with increased alkalinity (9.08-0.74 mgkg^{-1}). But most of the micronutrients were deficient for vegetable production because maximum number of soil samples lies in alkaline category which throws a scope towards amelioration of the vegetable growing soils for reducing its pH.

Introduction

The micronutrients play important role in Indian agriculture towards sustainable crop production. Thus, the importance of micronutrients need to be viewed in food systems context, as their inclusion in balanced fertilization schedule would optimize micronutrient supply and availability in the entire food consumption cycle (James and Henry, 2020). Indian soils are generally poor in fertility especially in micronutrients as these have consistently been mined away from their finite soil source due to continuous cultivation for a very long time without addition of micronutrient fertilizer resulting in emerging micronutrient deficiency (Hotz and Gibson, 2007). In addition, green revolution led-increased demand of micronutrients by the high yielding crop cultivars (especially rice and wheat) as well as adoption of intensive cropping practices, use of high-analysis fertilizers with low micronutrient content, decreased use of organic manures and crop residues, growing of crops in soils with low micronutrient reserves. Besides, other natural and anthropogenic factors are adversely affecting phyto-availability of micronutrients aggravated the situation. Geostatistics and geographic information system (GIS) provide powerful tools for analysing spatial variability and visualizing spatial classification, as well as other spatial algebraic functions (Hedge *et al.,* 2019). In the last two decades, these techniques have been applied widely in soil science to explore

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spatial variability of physical and chemical properties of soils under grain crops and pasture in developed countries (Blackmore *et al.,* 1998). Site specific nutrient management (SSNM) was developed for large-scale agriculture with high levels of mechanization. The objective of this study is to investigate spatial variability of micronutrients in vegetable growing areas of Varanasi.

Material and Methods

Experimental Site details

Fifty soil samples are collected from vegetable growing fields using hand held GPS 1:50000 scale. Soils are collected from 25.08° to 25.23° N latitude and 82.50° to 83.03° E longitude having altitude of 80.71 meters above mean sea level (MSL).

Evaluation of Soil fertility status

The soil samples are analyzed for pH by pH meter (Jacksons 1978), EC content by EC meter (Jacksons 1978), and organic carbon by Wet oxidation method using Walkley and Black (1934),

Estimation of Micronutrients of the sampled soils

The available Fe, Mn, Cu and Zn of the soil sample were determined with 0.005M DTPA (Diethylene Triamine Penta Acetic Acid) using Atomic Absorption Spectrophotometer using (Lindsay and Norvell, 1978).

Generation of Spatial Variability Map

The spatial variability map of micronutrients was created by descriptive statistics &geostatistical methods as proposed by (Li *et al.,* 2021).

Results and Discussion

Soil fertility status

The pH in soils of Shanshahpur village generally ranged from slightly acidic to alkaline (6.03-8.72). The lowest pH (6.03) value was obtained in S_{19}. The maximum pH (8.72) value was observed inS_{13} i.e. pumpkin field (Table 1). The mean value of pH was 7.99. Most of the samples were slightly alkaline in pH (90%), few were acidic to neutral i.e. 8% and 2 % respectively. Similar result was observed by Singh *et al.*(2016) in the soil of Sevapuri block of Varanasi of Uttar Pradesh. The map indicates that most of the vegetable growing areas were in neutral to alkaline pH. The electrical conductivity in soil of Shanshahpur village were in normal range, with a mean of 0.20 dSm^{-1}, the lowest value being 0.11 dSm^{-1}in S_5, S_9 & S_{50} and highest EC value being 0.52 dSm^{-1} in S_2 (Table 1).Similar results were observed by Chaurasia *et al.* (2013) in the district of Varanasi of Uttar Pradesh. Their above map shows that most of the areas were in low to medium category of EC & ranged from 0.11-0.52 dSm^{-1} and a small portion were in high category.

The maximum and minimum percent of organic carbon content in soils of Shanshahpur village of Varanasi were 0.49% and 0.92% respectively (Table 1). However, the minimum percent of organic carbon were found from pointed gourd field. Most of the samples (86%) were in medium range in terms of organic carbon status followed by high status (10%) and low status (4%). Similar result was observed by Singh *et al*. (2016) in Shikhar block of Mirzapur district of Uttar Pradesh.

Micronutrients status of the sampled soils according to the Variability maps

The available Cu content ranges from 0.22 to 2.46 $mgkg^{-1}$of soil (Table 2). Maximum soil samples were in high category (92%) with mean value 0.81 $mgkg^{-1}$. The similar content of available Cu was also reported by Sahoo *et al*. (1989). However, Panwar and Totawat (2004) reported the range of Cu from 0.27 to 1.04 $mgkg^{-1}$ of soil. The variability map shows (Figure 1) that the available Cu were in medium to high category and a small portion were in low category. The available Mn content in soil ranges from 0.74 to 9.08 $mgkg^{-1}$. (Table 2).However, maximum soil samples were in low category (66%).The similar findings were reported by Panwar and Totawat (2004).The variability map shows (Figure 2) that the soil Mn content in low category. Further, the availability of manganese decreased in alkaline soil.

The available Fe content ranges from 2.00 to 13.15 $mgkg^{-1}$ of soil (Table 2). Maximum soil samples were in low category (92%).Patel *et al*. (1995) also reported the same results in command areas of Gujarat. The available iron content in the vegetable growing areas were in low category as shown by the variability map (Figure 3). Further, the available Zn in soil content in soil ranged from 0.02 to 2.26 $mgkg^{-1}$. (Table 2). Maximum soil samples were in low category (88%). Singh *et al*. (1989) was also reported similar result in plain areas of Haryana. The low content of available Zn in surface horizon was also reported by Singh and Tripathi (1983), Vijay Kumar *et al*. (1996), Sen *et al*. (1997) and

Table 1: pH, EC(dSm^{-1}) and organic carbon(%) content in soils of Shanshahpur village.

SN	pH	EC (dSm^{-1})	OC (%)
S_1	6.10	0.34	0.53
S_2	7.43	0.52	0.49
S_3	7.74	0.15	0.57
S_4	7.95	0.13	0.65
S_5	8.40	0.11	0.49
S_6	8.43	0.16	0.69
S_7	8.46	0.17	0.61
S_8	8.07	0.16	0.69
S_9	8.23	0.11	0.67
S_{10}	8.60	0.17	0.61
S_{11}	8.68	0.17	0.71
S_{12}	8.26	0.16	0.74
S_{13}	8.72	0.15	0.73
S_{14}	7.98	0.14	0.60
S_{15}	8.11	0.15	0.64
S_{16}	7.31	0.15	0.63
S_{17}	7.81	0.21	0.70
S_{18}	6.31	0.26	0.63
S_{19}	6.03	0.39	0.55
S_{20}	7.88	0.19	0.68
S_{21}	7.48	0.17	0.61
S_{22}	8.23	0.16	0.54
S_{23}	8.12	0.27	0.68
S_{24}	8.20	0.20	0.76
S_{25}	8.15	0.20	0.73
S_{26}	8.10	0.23	0.56
S_{27}	7.95	0.22	0.75
S_{28}	8.03	0.20	0.67
S_{29}	7.95	0.22	0.78
S_{30}	8.25	0.22	0.68
S_{31}	8.32	0.19	0.67
S_{32}	8.63	0.20	0.64
S_{33}	8.70	0.24	0.68
S_{34}	7.98	0.17	0.65
S_{35}	8.47	0.26	0.75
S_{36}	8.52	0.23	0.79
S_{37}	8.20	0.23	0.56
S_{38}	8.14	0.19	0.69
S_{39}	8.30	0.18	0.61
S_{40}	8.35	0.21	0.64
S_{41}	8.37	0.18	0.57
S_{42}	8.25	0.17	0.73
S_{43}	8.26	0.19	0.60
S_{44}	7.55	0.15	0.70
S_{45}	8.18	0.16	0.67
S_{46}	8.33	0.23	0.92
S_{47}	7.95	0.19	0.64
S_{48}	7.62	0.19	0.68
S_{49}	7.98	0.21	0.86
S_{50}	6.41	0.11	0.87
Range	6.03-8.72	0.11-0.52	0.49-0.92
Mean	7.99	0.20	0.67
S.D.	0.62	0.07	0.09
C.V. (%)	7.75	35.05	13.43

Table 2: Available DTPA extractable micronutrients ($mgKg^{-1}$) in soils of Shanshahpur village.

Sample no.	Available Cu ($mgKg^{-1}$)	Available Mn ($mgKg^{-1}$)	Available Fe ($mgKg^{-1}$)	Available Zn ($mgKg^{-1}$)
S_1	1.14	2.24	3.05	0.25
S_2	1.17	2.28	2.93	0.34
S_3	2.46	3.76	2.66	0.30
S_4	1.79	9.08	2.54	0.60
S_5	0.67	0.88	3.56	0.15
S_6	1.28	1.24	2.41	0.16
S_7	0.82	0.83	3.77	0.15
S_8	1.02	2.90	2.06	0.20
S_9	0.79	1.15	2.00	0.68
S_{10}	0.94	0.78	2.69	0.16
S_{11}	0.67	0.74	2.39	0.23
S_{12}	0.80	1.61	2.28	0.43
S_{13}	0.51	0.80	3.83	0.18
S_{14}	1.03	1.39	2.14	0.13
S_{15}	0.48	0.74	2.96	0.12
S_{16}	0.85	1.99	3.46	1.41
S_{17}	0.92	1.77	2.57	0.32
S_{18}	0.34	1.79	12.25	0.40
S_{19}	0.24	2.67	3.75	0.21
S_{20}	0.66	1.60	2.87	0.14
S_{21}	0.22	2.20	3.58	0.10
S_{22}	0.02	0.90	3.73	0.12
S_{23}	0.46	2.06	2.25	0.25
S_{24}	0.68	1.45	2.13	0.47
S_{25}	0.56	1.52	2.84	0.46
S_{26}	0.69	1.29	7.26	0.60
S_{27}	0.58	3.33	3.35	0.67
S_{28}	0.75	1.38	2.67	0.33
S_{29}	0.68	1.98	2.20	0.56
S_{30}	0.74	1.53	3.33	0.26
S_{31}	0.73	1.07	2.94	0.14
S_{32}	0.77	1.15	2.52	0.17
S_{33}	0.90	1.24	3.76	0.17
S_{34}	0.70	2.26	4.24	0.14
S_{35}	1.94	1.09	3.49	2.26
S_{36}	1.11	0.75	3.51	0.12
S_{37}	0.42	1.01	2.66	0.11
S_{38}	0.84	0.94	2.34	0.14
S_{39}	0.67	2.38	3.22	0.30
S_{40}	0.69	1.79	2.48	0.27
S_{41}	0.78	2.97	2.28	0.09
S_{42}	0.81	3.39	3.86	0.18
S_{43}	0.52	2.69	2.40	0.03
S_{44}	0.75	2.01	2.34	0.02
S_{45}	0.86	1.07	2.93	0.05
S_{46}	1.14	0.78	2.69	0.38
S_{47}	0.90	1.10	13.15	0.08
S_{48}	0.77	2.56	2.86	0.06
S_{49}	0.8	1.84	2.68	0.22
S_{50}	0.65	3.8	4.84	0.09
Range	0.22-2.46	0.74-9.08	2.00-13.15	0.02-2.26
Mean	0.81	1.91	3.39	0.31
S.D.	0.41	1.32	2.10	0.37
C.V. (%)	50.61	69.10	61.94	119.35

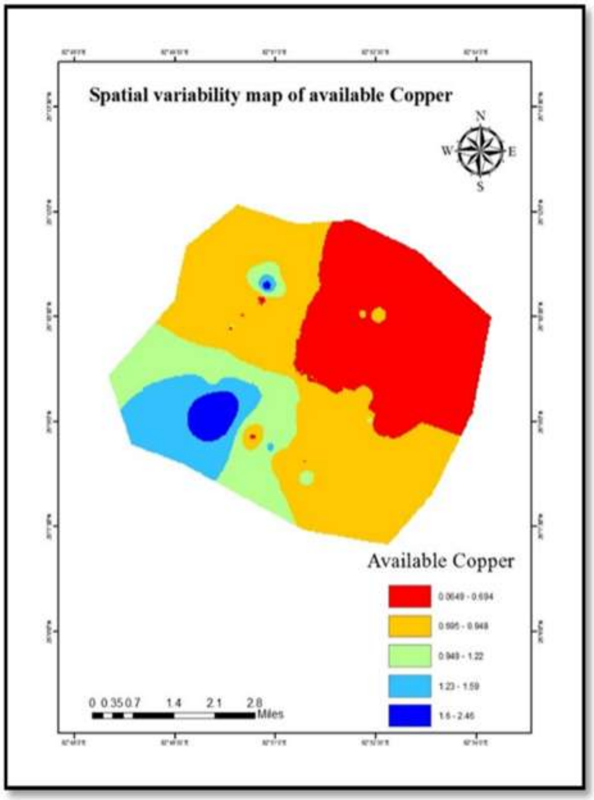

Figure 1: Spatial variability map for available Copper (Cu).

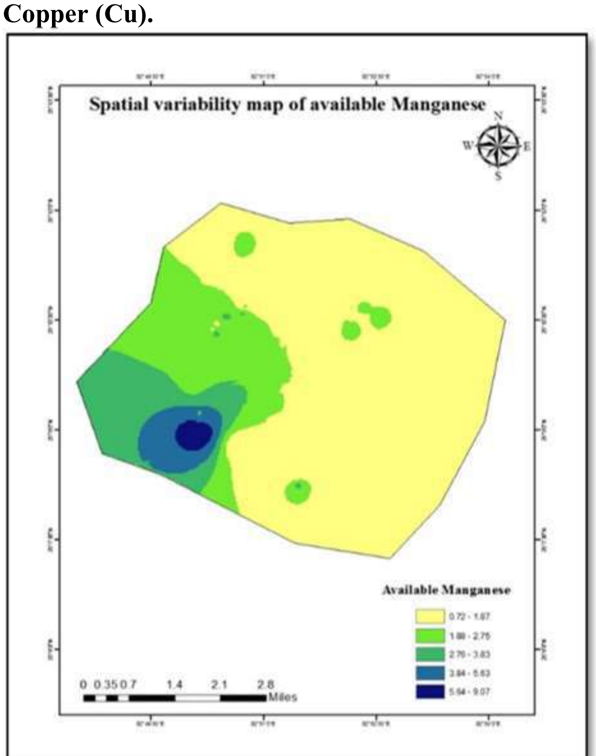

Figure 2:Spatial variability map for available Manganese (Mn).

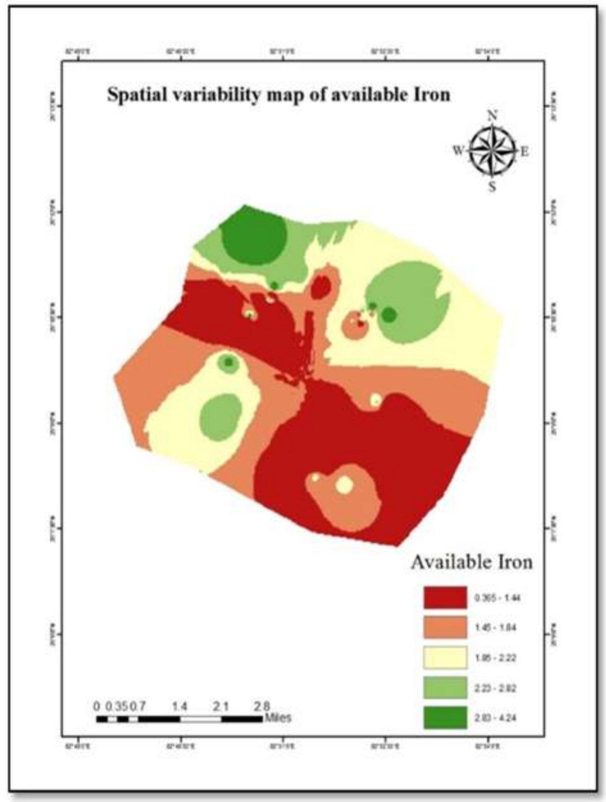

Figure 3: Spatial variability map for available Iron (Fe).

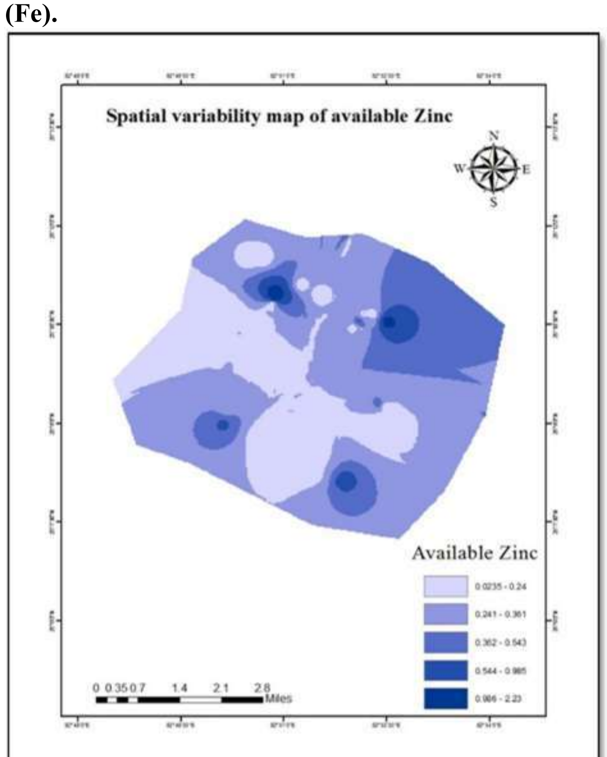

Figure 4: Spatial variability map for available Zinc (Zn).

Sharma *et al*. (2000). According to the variability map (Figure 4) most of the soil samples were Zn deficient. But the low available Zn in surface layer was due to complexing with organic matter.

Conclusion

It is observed that most of the soils of the vegetable growing area of Shanshahpur were alkaline in nature and lied within a safe range of electrical conductivity. However, a medium range of soil organic carbon status was observed throughout the area. According to the variability map for micronutrient status there was a medium to high status for available Cu but in contrast available Fe and Zn content of the vegetable growing lies in low status category. Further, the available Mn status was seen to be reduced with increased the alkalinity.However, most of the micronutrients were deficient for vegetable production as most of the soil samples lies in alkaline category which throws a scope towards amelioration of the vegetable growing soils for reducing its pH.

Conflict of interest

The authors declare that they have no conflict of interest.

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Spatial mapping of groundwater quality using GIS for Jakham River basin of Southern Rajasthan

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ABSTRACT

The physico-chemical analysis of groundwater quality plays a significant role to manage the water resources for drinking as well as irrigation in the sub-humid and semi-arid agro-climatic areas. In this study, the hydrogeochemical analyses and spatial mapping of groundwater quality in the Jakham River Basin located in the southern part of Rajasthan were investigated.The groundwater quality samples were collected from 76 wells marked on the grid map of 5×5 km^2 area.A spatial distribution in sampling location in the basin was prepared using GIS (Geographical information system) tool based on 6 physico-chemical parameters i.e., pH, EC, TDS, Cl, $NO_3$and F.The groundwater quality data from the pre and post-monsoon seasons of 2019-20 were used to carry out a detailed analysis of water quality parameters.The water quality maps for the entire basin have been generated using anIDW interpolation technique for these parameters as per the identified location.The higher value of TDS and EC were found in the south-eastern part and along the roadside of study area, which were dominated by agriculture activities and industrial influence. The concentration was observed higher in the post-monsoon period. For EC and TDS, major part of the (>50%) of the study area comes under the safe limit of potable water. Major part of the basin witnessed fluoride concentration (0.40-80 mg/l) for both the season, which is lower than the permissible limit. Higher NO_3 concentration was observed after the rainy season. The influence of geogenic activities could be clearly seen in the groundwater quality of the basin. Theresultant map shows that the entire basin has optimally goodgroundwater quality for human consumption. Hence, this study provides suggestion to prepare strategies for the proper management and augmentation of the groundwater condition in the Jakham River Basin.

Introduction

Groundwater is a very important component of the human life support system and it is required for drinking, household, industrial and agricultural uses (Bhutiani *et al.,* 2021a; Bhutiani *et al.,* 2021b; Ruhela *et al.,* 2021).The groundwater quality is serious matter in arid and semi-arid areas, which is dominated by irrigation practices. Quality of ground water is adversely affected by the diffuse contamination devising from intensive agricultural practices (Bhutiani *et al.,* 2019; Ruhela *et al.,* 2022; Saidi *et al.,* 2009).Groundwater has been a major and consistent source of drinking and irrigation for a wide range of users (Afzali *et al.,* 2014). There is a need to develop models for efficient prediction of

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pollutants in these soils and water (Sener and Devraz, 2013).The groundwater quality can be analysed by physicochemical parameters compared to permissible limits pre-scribed at Indian water quality standards (BIS) and WHO.Groundwater quality depletion caused by various geogenic and human activities is a serious problem for human being (Buchanan and Triantafilis 2009; CGWB 2010). The demographic changes, also a concerning factor for groundwater quality deterioration. Furthermore, many studies have found untreated sewage to be the most critical issue with respect to water contamination, because 40% of the global population do not have adequate sanitary facilities, changes to land use, land cover or river basins in watershed areas (Shi et. al, 2010; Liyanage *et al.,* 2017), such as high scale agricultural activities, unplanned infrastructure developments, and sand mining, change the water quality and water balance due to human activities (Groppo *et al.,* 2008; Qin *et al.,* 2014). This may be caused by improperly planned urbanization or uncontrolled development (Liu and Chen, 2006). The groundwater quality is generally influenced by the parameters *viz.*, pH, electrical conductivity (EC), total dissolved solids (TDS), Ca, Mg, and NO_3(Gong *et al.,* 2014; Khadri *et al.,* 2013).The physico-chemical analysis is necessary to examine the groundwater quality in the location, where groundwater is used for both agriculture and drinking (Srinivas et al. 2013). The Geographical Information System (GIS) was observed as useful tool for mapping, monitoring and detecting the environmental variations. As such, the purpose of this research is to investigate the hydro-geochemistry of groundwater in various locations in the basaltic hard rock region (El-Hames *et al.,* 2011; Chen and Feng, 2013). Hence, the spatial mapping for selected water quality parameters were used to analyse the groundwater quality in the Jakham River Basin for drinkingpurpose.The different water quality maps were developed using IDW interpolation techniques by identifying the suitable wells based on groundwater quality standards as suggested by the BIS. Dahiphale *et al.* (2019) evaluated the ground water (GW) quality in Jaisamand Lake catchment area for checking its suitability for irrigation and drinking purpose. The spatio-temporal variations of WQ parameters were analysed for 109 wells of study area, by using GIS technique. As clearly explained in the introduction, the objective of this study is (1) To have an overview of status of groundwater quality (2) To explore the hydro-geochemistry of the groundwater in different well locations/villages in the basaltic hard rock areas. (3) To generate spatial distribution of drinking groundwater quality parameters i.e. pH, EC, TDS, Cl, SO_4, F and NO_3 concentrations in the Jakham basin area by using geospatial techniques. Also this study is intended to evaluate and spatially analyze the water quality parameters and accordingly assist to take fruitful decisions to make safeguard quality of the open well waters in Jakham River Basin.

Material and Methods

Study area

The River Jakham originates in the hills south-west of Chotti Sadari of Pratapgarh District, Rajasthan. The basin area lies between the latitudes of 24° 27' 19.81" and 23° 58' 57.81"N, and the longitudes of 74° 30'22.63" and 74° 48' 24.12". The Jakham river basin has a catchment area of 953 km^2 (Figure1).The study area has high geographical and physical diversity varies from mostly dense forest to hilly terrain. The geological set-up of the basin is characterized by different igneous and meta-sedimentary rocks (Gautam *et al*., 2022). The Pratapgarh districtis located on meta-sedimentary rocks of ‘Aravalli’ ‘Bhilwara’and‘Vindhayan’ Supergroup. Aravalli and Bhilwara super group represented by phyllite, greywacke, quartzite, dolomite and Shale, Slates, Phyllites, Meta-grey wackes, Limestone, Dolomitic marble respectively. Vindhayan super group divided in Khorip, Lasrawan, Sand and Satola Groups with Shale, Conglomerate, Limestone formations. This Super Group is exposed mainly in northern part of the district and some exposure in southeastern parts in Chhotisadri block and also partly in Dhariawad, Pratapgarh and Arnod blocks.Southern part of study area has majority of basalt rock formations. Basalts as aquifer occur in southern part of the district. However, these type of rock formations are not considered as a good aquifer. Moderate groundwater potentiality occurs within contact zone of basalt and other lithological units. Exploratory drilling in the district reveals that basalt, granite/gneiss, phyllite etc. form the hard rock

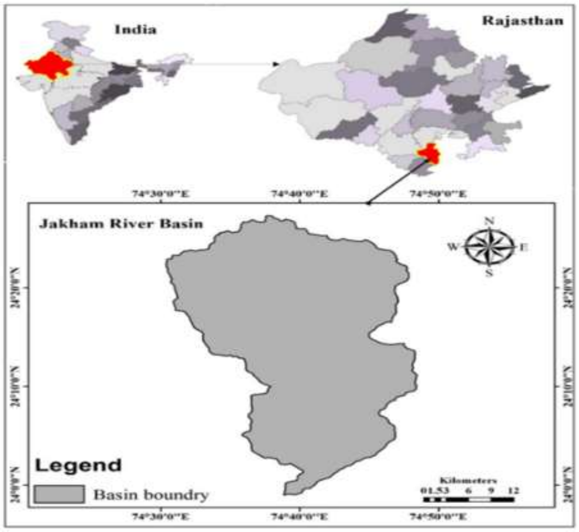


Figure1: Location map of study area

aquifer (CGWB, 2013). The groundwater is very dynamic in nature; owing to recharge by rains and in some areas the flow of Jakham River water has its influence (Gautam *et al.,* 2021). There was fluctuation observed in the depth of water in the open wells due to these factors. Therefore, this study area was selected to provide an overview of groundwater quality condition of the Jakham River Basin. Hence, spatial distribution maps for some selected water quality parameters were generated to detect the quality of ground water in the Jakham River Basin for potable and industry utilization purposes. The maps were digitized using toposheet for identifying the well in the study area. The primary tool used to generate the maps that facilitated analysis was spatial analyst tools in the ArcGIS software. It was observed in the area that, open wells and water bodies influencing the for groundwater quality via recharge in the basaltic hard rock region in lower part of the basin (Gautam *et al*., 2022).

Analysis of groundwater quality

Total seventy six (76) groundwater samples were collected in sterilized plastic bottles from 39 square grids to analyse the physico-chemical properties of the groundwater samples for pre and post-monsoon season,2019-20.The collected groundwater samples were put in an ice box at 4^{o}C from until they arrived at the laboratory.The physico-chemical analysis ofthe collected samples were done for the parameters *viz*. pH, total dissolved solids (TDS), Electrical conductivity (EC), nitrate (NO_3), chloride (Cl) and fluoride (F). Water quality parameters were analysed in the laboratory as per the Standard methods suggested by the BIS (2000& 2012) (Manjeet *et al.,* 2021).The drinking water quality norms suggested by the Indian agencies are listed in the Table 1.

Table 1: Drinking and Irrigation Water Quality (BIS) Standards.

SN	Water Quality Parameter	Prescribed limit	
		Desirable	Permissible
1	pH	6.5	8.5
2	EC	<1500 – Sensitive	
3	TDS	500	2000
4	Cl	250	1000
5	Fluoride	1	1.50
6	Nitrate	45	No relaxation

Spatial mapping of groundwater quality parameters

The inverse distance weighted (IDW) interpolation method of ARC GIS 10.1 software was used to generate spatial distribution maps of groundwater quality parameters i.e. pH, EC, TDS, SO_4, F, and Cl.The inverse distance technique is a spatial interpolation algorithm that estimates values between observations.The IDW estimates the weighted mean values of adjacent sampling locations. The weights are determined by taking the inverse of the distance between an observations and estimated value. The interpolation approachprovides the accurate results, when the samplinglocations are close enough to detect the spatial variation. Selvam *et al.* 2014 found that, if the sampling locations are unequally distributed in the area, the estimates may not accurately depict the anticipated changes. The Figure 2 represents the sampling location of the well in the study area.

Results and Discussion

Physico-chemical parameters of groundwater

The spatial distribution maps of groundwater quality parameters i.e. pH, EC, TDS, NO_3, F and Cl were generated using IDW technique using ArcGIS 10.4 software. These GW quality maps have been shown in the Figure 3-8, highlighting which wells are good for use as drinking purpose in the hard rock region. These spatial maps may help to identify the current status of water quality for drinking as well as irrigation purpose.

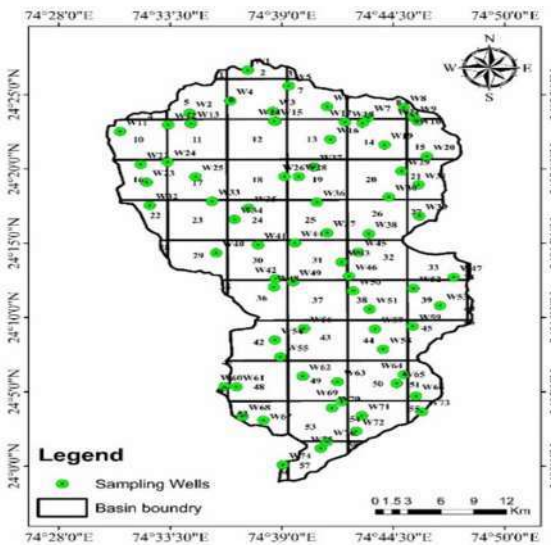


Figure 2: Grid map of groundwater sampling wells

The groundwater quality monitoring for drinking purpose (pre and post monsoon season) was analyzed in terms of physico-chemical parameters based on Bureau of Indian Standards (BIS, 2000, 2012) (Table 2).

pH

pH measures the hydrogen concentration in water, which decides the alkalinity and acidic nature of water sample. The pH ranges from 7.00 to 8.90 in the study area during pre- monsoon, which shows the slightly alkalinity of groundwater. Major part of the study area has pH ranges from 7.80 to 8.20. The highest pH value (8.20- 8.90) was observed in lower-middle part of the basin. The Spatial map of pH value is presented in the Figure 3.

In post-monsoon, pH value ranges from 6.50 to 8.00, which is under safe limit. Most of the samples was found alkaline in nature, in post monsoon. The low value (6.5-7.00) of pH indicates the influence ammonium sulphate and phosphate fertilizer in agriculture (Appelo and Postma, 2005). The highest pH value (7.50-8.00) was observed in middle part of the basin.

Electrical Conductivity (EC)

The EC value varies from < 650 to >1550 µS/cm in the study area, in pre- monsoon. Major parts of the basin has lower EC value (<650), which is suitable for drinking. Spatial distribution map of EC value is presented in the Figure 4. The higher value (950-1550 µS/cm) of EC was found in Top and bottom of the study area. Increase in the EC value decides the groundwater flow path, due to topographic circumstances and ion exchange capacity (Prashanth *et al.,* 2012).Higher value of EC was observed in the location, which is situated along the roadside. During post-monsoon, EC ranges from <650 to >1550 µS/cm. Major parts of the basin has EC value (650-950 µS/cm).Generally, variation in EC was observed due geochemical process in the study area.

Total Dissolved Solids (TDS)

TDS indicates the availability of different minerals (CO_3, SO_4, Si, Ca and Mg) dissolved in the groundwater. The TDS ranges from <300 to >1200 mg/l during pre and post monsoon in the study area. This range comes under highly desirable category (BIS, 2012). The concentration of TDS depends on the characteristics and types of ion. It is also affected by the landfills and animal wastage (Kumar *et al.,* 2018). The variation of TDS during pre and post-monsoon seasons are presented in the Figure 5. Major part of the (>50%) of the area comes under the safe limit of drinking water.

Chloride (Cl)

The concentration of Chloride (Cl) in water samples varies from 0.60 to 9.20 meq/l for pre-monsoon and 2.40 to 12.20 meq/l for post-monsoon season. The higher concentration of Chloride (Cl) seems like to be anthropogenic local contamination associated with sulphate and nitrate concentration. Sedimentary rock leaching, weathering and excess fertilizer application in paddy cultivation also influences the chloride concentration in the groundwater. The utmost area indicates the Cl concentration less than the permissible limit in pre monsoon, 0.60-3.20 meq/l and 3.20-6.20 meq/l in post-monsoon. About 2.50 % of area was observed, higher than the desirable limit for pre-monsoon and 13.74 % for post-monsoon season. Spatial distribution maps of chloride (Cl) concentration for pre and post monsoon seasons are presented in the Figure 6.

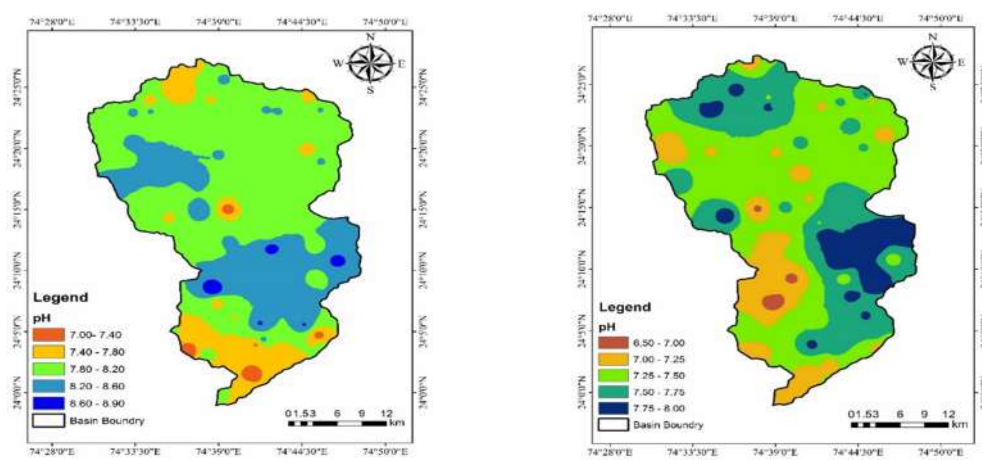
Nitrate (NO_3)

The concentration of Nitrates ranges from 0.05 to 1.90 meq/l in pre-monsoon while, 0.20 to 3.00 meq/l in post-monsoon season. The nitrates in groundwater was probably derived by application of nitrogen fertilizer in the agriculture practices. The Nitrate (NO_3) shows comparatively high concentration, during post-monsoon season.

Table 2: Physico-chemical parameters data of pre and post-monsoon

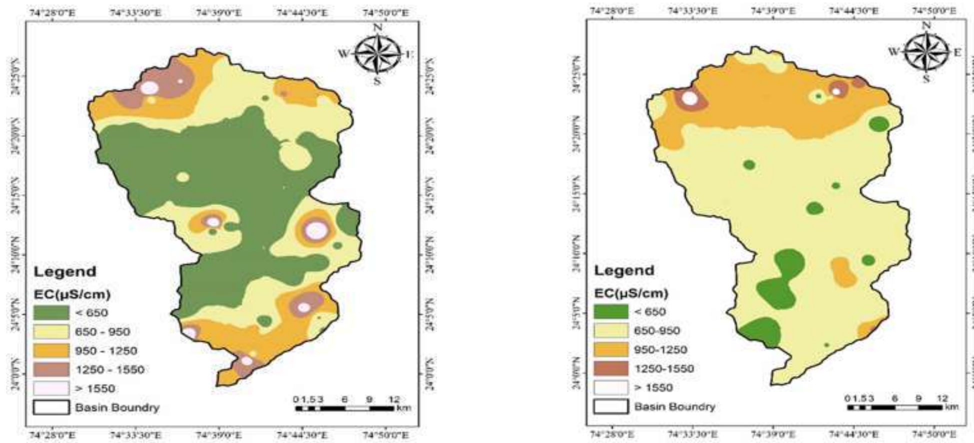
Well No.	Pre monsoon						Post monsoon					
	pH	EC	TDS	Cl	NO_3	F	pH	EC	TDS	Cl	NO_3	F
W1	8.06	835.00	529.17	5.84	0.75	0.52	7.08	755.00	440.00	5.60	0.19	0.39
W2	8.02	1420.00	843.50	9.33	1.74	0.41	7.66	1008.50	575.00	7.36	0.57	0.55
W3	8.05	672.50	384.54	3.24	0.53	0.45	7.46	1115.00	720.00	4.00	0.62	0.57
W4	7.93	1128.00	676.07	2.00	0.73	0.45	7.81	1120.00	737.50	3.70	0.66	0.43
W5	8.42	610.00	361.13	3.02	0.39	0.31	7.62	825.00	530.00	4.60	1.87	0.91
W6	8.15	530.00	326.78	4.96	0.44	0.25	7.39	1215.00	895.00	6.10	1.89	0.61
W7	8.30	960.00	499.71	2.13	0.04	0.39	7.57	1795.00	1167.50	5.60	1.83	0.69
W8	7.98	697.50	404.37	3.67	0.69	0.39	7.77	1355.00	905.00	7.80	1.87	0.61
W9	8.35	970.00	567.88	8.83	0.56	0.40	7.19	970.00	585.00	11.00	1.90	0.82
W10	8.03	727.50	394.97	4.08	0.40	0.24	7.22	1095.00	720.00	4.40	1.69	0.23
W11	8.23	860.00	525.17	4.50	1.64	0.38	7.39	730.00	425.00	7.10	1.70	0.22
W12	8.40	1052.50	627.05	9.26	1.26	0.40	7.65	1825.00	1280.00	7.15	1.60	1.18
W13	8.40	545.00	328.25	2.61	0.12	0.24	8.01	1207.50	890.00	7.50	1.43	0.62
W14	8.35	530.00	302.90	6.91	0.04	0.27	7.66	840.00	505.00	6.05	1.26	0.64
W15	8.19	682.50	413.00	5.66	1.23	0.34	7.92	1320.00	917.50	4.15	2.14	0.52
W16	8.25	495.00	290.99	2.52	0.44	0.70	7.41	1140.00	725.00	5.30	2.49	0.51
W17	8.40	507.50	306.41	1.56	0.27	0.44	7.14	522.50	322.50	5.60	1.77	0.44
W18	8.42	562.50	346.42	2.34	0.68	0.38	7.41	815.00	490.00	3.00	0.94	0.60
W19	8.22	553.00	329.63	3.50	0.81	0.63	7.62	1140.00	730.00	4.10	1.21	0.45
W20	8.23	637.50	367.50	2.62	0.73	0.38	7.11	675.00	415.00	6.70	0.89	0.48
W21	8.45	515.00	296.12	1.92	0.20	0.29	7.39	909.50	520.00	3.60	1.19	0.52
W22	8.37	461.00	276.97	1.92	0.85	0.63	7.06	910.00	550.00	4.30	0.83	0.54
W23	8.30	500.00	282.61	1.10	0.44	1.10	7.07	940.00	550.00	3.60	0.65	0.72
W24	8.40	431.00	275.61	2.18	0.70	0.81	7.29	875.00	515.00	5.10	0.60	0.69
W25	8.39	392.50	236.28	1.47	0.46	0.54	7.21	795.00	465.00	6.85	1.05	0.60
W26	8.40	440.00	255.62	1.60	0.49	0.46	7.19	905.00	540.00	5.40	1.18	0.79
W27	8.18	470.00	328.81	2.71	0.54	0.33	7.59	985.00	567.50	6.10	1.83	0.53
W28	8.33	460.00	278.71	1.40	0.56	0.29	7.32	802.50	487.50	7.40	1.75	0.53
W29	8.00	490.00	265.42	2.01	1.10	0.20	7.53	705.00	425.00	8.00	1.76	0.48
W30	8.25	635.00	350.15	1.68	0.12	0.21	7.42	900.00	550.00	6.10	1.65	0.71
W31	8.40	445.00	283.79	2.22	0.83	0.44	7.38	875.00	500.00	5.60	2.03	0.57
W32	8.44	340.00	206.00	1.32	0.42	0.42	7.74	780.00	470.00	4.70	1.78	0.51
W33	8.43	415.00	254.72	1.33	0.60	0.42	7.50	680.00	395.00	6.00	1.93	0.74
W34	8.30	565.00	344.91	1.37	0.78	0.29	7.26	760.00	455.00	8.10	2.28	0.88
W35	8.50	395.00	298.02	2.28	1.06	0.53	7.50	550.00	315.00	3.90	1.47	0.36
W36	8.33	485.00	291.28	1.25	0.40	0.49	7.14	785.00	465.00	5.50	1.93	0.35
W37	8.35	390.00	206.52	2.30	0.53	0.27	7.21	810.00	515.00	2.40	1.30	0.41
W38	8.30	530.00	323.55	1.89	0.77	0.58	7.75	585.00	335.00	3.30	1.18	0.60
W39	8.20	440.00	271.11	3.01	0.55	0.34	7.43	690.00	415.00	3.10	0.64	0.39
W40	8.08	530.00	311.72	2.00	0.95	0.28	7.93	605.00	355.00	4.60	1.12	0.42
W41	8.58	320.00	178.41	1.16	0.17	0.30	6.95	750.00	460.00	3.70	1.86	0.47
W42	8.15	1610.00	1658.26	6.05	0.12	1.23	7.24	890.00	567.50	3.20	1.82	0.39
W43	8.20	350.00	206.78	1.14	0.50	0.23	7.49	450.00	285.00	8.20	0.65	0.56
W44	7.73	390.00	223.48	1.50	0.88	0.84	7.58	655.00	395.00	8.70	0.59	0.38
W45	8.13	370.00	217.53	1.04	0.48	0.27	7.68	785.00	485.00	4.20	1.24	0.41

W46	8.33	360.00	211.89	1.84	0.19	1.22	7.92	740.00	435.00	4.75	0.95	0.73
W47	8.50	295.00	170.17	1.87	0.44	0.30	7.88	655.00	400.00	7.05	0.65	0.62
W48	8.35	370.00	216.13	1.95	0.48	0.31	7.21	685.00	420.00	4.00	0.67	0.45
W49	8.45	410.00	239.21	1.18	0.56	0.51	7.17	825.00	485.00	4.80	0.20	0.35
W50	8.75	425.00	259.18	2.52	0.45	0.69	7.79	740.00	415.00	4.10	0.69	0.37
W51	8.48	657.50	388.09	1.17	0.67	0.32	7.97	675.00	435.00	3.45	0.82	0.48
W52	8.30	1620.00	646.11	8.62	1.20	0.16	8.00	820.00	557.50	4.70	0.92	0.42
W53	8.70	505.00	349.51	0.86	0.43	0.37	7.38	735.00	485.00	6.10	1.27	0.35
W54	8.88	370.00	218.27	1.11	0.30	0.66	7.16	760.00	465.00	5.45	1.90	0.52
W55	8.03	395.00	234.16	0.60	0.58	0.38	6.76	490.00	290.00	6.45	0.70	0.51
W56	8.45	470.00	263.26	1.60	0.53	0.51	6.94	370.00	215.00	12.20	0.73	0.36
W57	8.40	360.00	235.10	0.80	1.05	0.34	7.37	1045.00	635.00	12.00	0.63	0.48
W58	8.43	435.00	261.74	1.20	0.64	0.33	7.80	1020.00	645.00	10.38	0.82	0.44
W59	8.28	400.00	240.10	1.40	0.70	0.43	8.00	527.50	292.50	7.50	0.61	0.48
W60	8.25	355.00	213.28	1.65	0.66	0.46	7.27	790.00	465.00	6.50	0.48	0.52
W61	7.91	430.00	266.30	2.16	0.57	0.32	7.37	715.00	420.00	7.20	0.77	0.56
W62	8.11	510.00	293.74	3.46	0.72	0.42	7.31	540.00	325.00	4.05	0.95	0.40
W63	8.65	655.00	400.76	2.60	1.04	0.37	7.37	900.00	632.50	4.75	0.96	0.50
W64	8.40	1050.00	565.22	2.40	0.68	0.46	7.78	790.00	480.00	3.70	1.23	0.55
W65	8.65	1290.00	762.25	5.91	0.49	0.96	7.72	735.00	435.00	3.90	1.29	0.47
W66	7.75	519.00	1257.53	4.14	0.56	0.42	7.58	815.00	495.00	6.50	1.39	0.49
W67	8.23	680.00	391.48	2.17	0.27	0.58	7.21	300.00	165.00	8.40	1.27	0.26
W68	7.61	1370.00	776.03	7.86	0.77	0.26	7.21	602.50	310.00	8.60	1.16	0.30
W69	8.43	310.00	840.69	1.87	0.73	0.32	7.69	825.00	505.00	7.10	1.25	0.56
W70	7.83	730.00	432.34	3.12	1.89	0.31	7.86	675.00	390.00	4.80	0.99	1.06
W71	7.98	740.00	435.09	6.57	0.89	0.35	7.59	695.00	395.00	4.20	1.29	1.00
W72	7.87	825.00	488.92	1.40	0.90	0.29	7.10	595.00	335.00	6.30	1.63	0.69
W73	8.20	510.00	301.25	1.42	1.04	0.27	7.08	1270.00	790.00	4.10	2.17	1.03
W74	8.18	715.00	432.43	4.72	0.55	0.36	7.06	745.00	435.00	2.70	2.34	0.57
W75	7.75	1325.00	540.72	6.15	0.82	0.33	7.13	830.00	490.00	4.40	2.95	1.04
W76	8.10	575.00	344.07	2.11	0.95	0.40	7.23	927.00	514.00	4.50	2.20	0.83



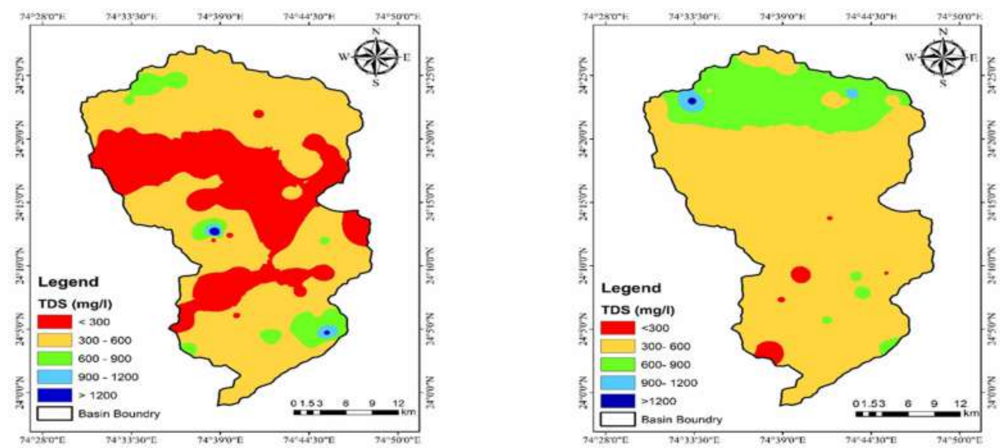
(a) (b)

Figure 3: Spatial Distribution Map pH for (a) Pre-monsoon (b) Post-monsoon



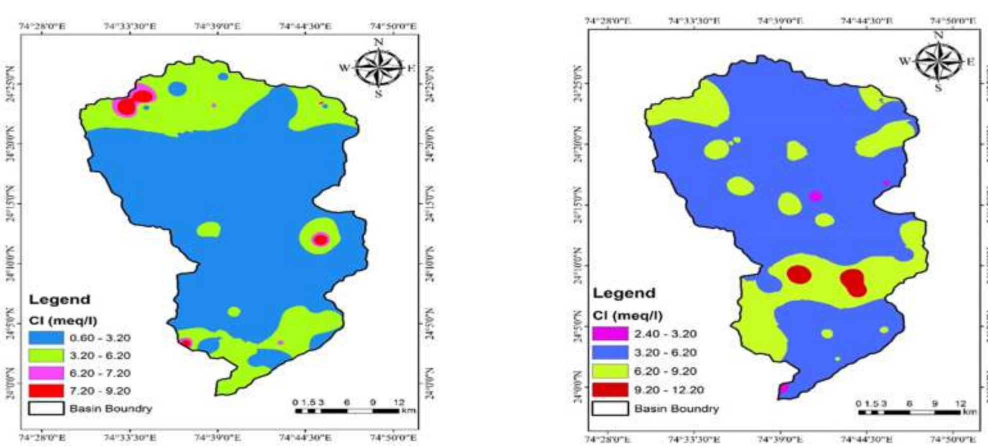
(a) (b)

Figure 4: Spatial Distribution Map EC for (a) Pre-monsoon (b) Post-monsoon



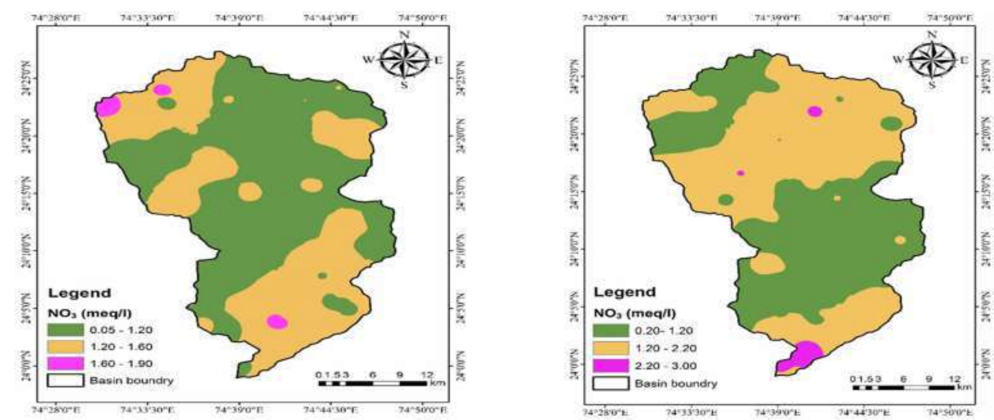
(a) (b)

Figure 5: Spatial Distribution Map TDS for (a) Pre-monsoon (b) Post-monsoon



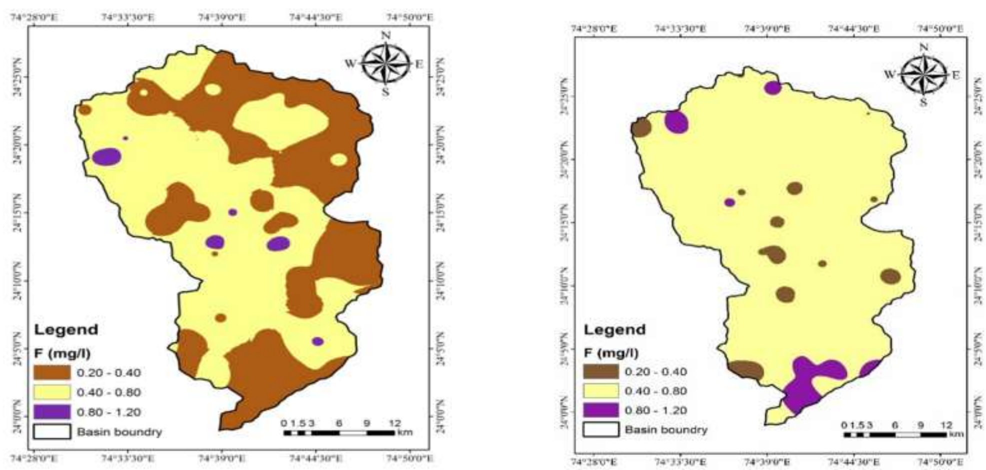
(a) (b)

Figure 6: Spatial Distribution Map Cl for (a) Pre-monsoon (b) Post-monsoon



(a) (b)

Figure 7: Spatial Distribution Map NO_3 for (a) Pre-monsoon (b) Post-monsoon



(a) (b)

Figure 8: Spatial Distribution Map F for (a) Pre-monsoon (b) Post-monsoon

The high concentrations were observed during pre and post-monsoon were 1.90 meq/l and 3.00 meq/l, respectively.Major part of the basin witnessed nitrate concentration (0.05-1.60 meq/l) in pre monsoon and (0.20-2.20 meq/l) in post monsoon, which is slightly higher than the standards suggested by BIS (2012). More NO_3 concentration was observed after the rainy season, due to its loose bounding characteristics to the soil.Spatial distribution maps of Nitrate (NO_3) concentration for pre and post monsoon seasons are presented in the Figure 7.

Fluoride (F)

The concentration of fluoride (F) ranges from 0.20 to 1.20 mg/l for both the seasons. Utmost area was observed with fairly good and safe for the drinking purpose (up to 1 mg/l). Higher value of F content attributed in the study area, due to presence of flour apatite and leaching of phosphate fertilizers in the saturated zone, after irrigation (Handa, 1975). In the upper region, low level of fluoride content indicates, the absence of fluoride bearing minerals in the rock strata, by which groundwater is flowing. Major part of the basin witnessed fluoride concentration (0.40-80 mg/l) for both the season, which is lower than the permissible limit suggested by BIS (2012). Spatial distribution maps of F concentration are presented in the Figure 8.

Conclusion

This study demonstrates the analysis and mapping of the water quality of collected groundwater samples for the Jakham River Basin of southern Rajasthan. The groundwater samples were collected from the different locations i.e. basaltic hard rock region were chemically analysed and database were prepared for detecting the spatial changes within the study area. At different locations, samples were observed fulfilling the standards for drinking purpose, but some were found not good for consumption. The higher value of TDS and EC were found in the south-eastern part and along the roadside of study area, which were dominated by agriculture activities and industrial influence. The concentration was observed higher in the post-monsoon period. For EC and TDS, major part of the (>50%) of the study area comes under the safe limit of potable water. Major part of the basin witnessed fluoride concentration (0.40-80 mg/l) for both the season, which is lower than the permissible limit. Higher NO_3 concentration was observed after the rainy season, due to its loose bounding characteristics to the soil. In the study area, groundwater quality is mainly influenced by the underground rock weathering, geogenic activities and evaporation, which affects the concentration of different parameters i.e. EC, TDS, Ca, Mg, Na, and Cl etc. Therefore, the results quietly indicate the moderate to good potable water quality for Jakham River Basin. This study highlights the significance of GIS (spatial interpolation) application with the integration of physico-chemical analysis of groundwater quality. In this basin, basaltic rock and geochemical weathering process plays key role in hydro-geochemical analysis, which impact the concentration of main ions in groundwater quality. Definitely, this study benefits us to understand the quality of the groundwater resources to improve proper management in the basin.

Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of tillage and cultivars on growth and growth indices of rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment was undertaken at the Experimental Farm of Department of Agronomy of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.) during *kharif* 2019 to study the effect of different tillage system and varieties on yield of rice. The treatments consisted of three rice varieties (viz., HPR 1156, HPR 2656 and HPR 2795) which were tested under three tillage systems viz., conventional tillage, and minimum tillage without residue and minimum tillage with residue treatment. The trial was laid out in split plot design with tillage system in main plot and rice varieties in sub plot and was replicated thrice. Conventional tillage recorded taller plants (124.50 cm) and higher dry matter accumulation (858.49 g/m^{-2}) which was followed by minimum tillage without residue. Among the varieties tested HPR 2795 recorded taller plants (128.31 cm) and higher dry matter accumulation (891.33 g/m^{-2}) which was followed by HPR 2656. Higher value of AGR, CGR and RGR was recorded in conventional tillage and among the varieties; HPR 2795 resulted in higher growth indices.

Introduction

Rice (*Oryza sativa* L.) is the most widely consumed cereal for a large portion of the world's population. Approximately 90% of the world's rice is cultivated and consumed in Asia (Rana, 2018). Rice farming is well-suited to nations and locations with cheap labour costs and abundant rainfall, as it is labor-intensive and water-intensive. Rice, on the other hand, can be grown almost anywhere, including on a steep hill or mountain with the use of water-controlling terrace systems. As a rainfed crop, it also find place in the slopy lands of hills (Angiras *et al.,* 2009). Rice is a photo periodically short-day plant that thrives in a hot, humid environment. It is best suited to areas with high humidity and a reliable water supply. It will be adequate for a profitable rice harvest if an area receives roughly 1500-1800 mm of well-distributed rainfall each year throughout the crop growing season. In India, this crop ranks first in area and production (Rana, 2018). In India rice is cultivated on an area of 43.78 million hectare with the total production of 118.43 million tonnes with the average productivity of 27.05 q/ha (Anonymous, 2020). Even in the state of Himachal Pradesh rice is the most important *Kharif* crop (second only to maize) which was cultivated on an area about 71 thousand hectare with the production of 114.8 thousand tonnes and productivity of about 16 q/ha (Anonymous,

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2018).Traditional tillage methods are simple to implement and create a clean cultivating environment. . However, because it totally inverts the soil and buries rice crop residue / waste, exposing the land to the erosive forces of nature like wind and water. Erosion affects land productivity in the long run. Conservation tillage offers an alternative to all of these issues (Mathew *et al.,* 2012). Conservation agriculture approaches have gained popularity in recent years as farmers have sought to decrease variable cultivation costs, as a large part of energy (25–30%) is used for field preparation and crop establishment.

The intensity of tillage operations can be reduced to reduce this. When compared to traditional sowing procedures, the zero tillage method is more cost effective, energy efficient, and environmentally friendly (Filipovic *et al.,* 2006). Minimum and zero tillage systems can help with timely planting and healthy germination by using leftover moisture in the soil. It can also lower the cost of production. However the performance of rice genotypes can vary depending on a variety of factors including tillage patterns used and the effect of changes in microclimate owing to the adoption of conservation agriculture technologies. Specific genotypes like HD 2967 is recommended in wheat and lalat in rice that are also recommended for no till farming around the world. . Thus it is important to test this new concept in one of the most important cereal crop besides wheat, soyabean, mustard etc. grown in the state. Keeping the above facts in view, the present study is being proposed.

Material and Methods

The present investigation was carried out during *kharif* 2019 at the Experimental Farm of Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur (32°09' N latitude, 76°54' E longitude and at an altitude of 1290 m above mean sea level).

The area represents the mid hills sub humid zone of Himachal Pradesh and is characterized by mild summers and cool winters (Figure 1). The area receives a high rainfall that ranges between 2000-2500 mm per annum, of which 80 per cent is received during monsoon months from June to September. Each treatment was located randomly in plots by using random number table and replicated thrice. The soil of the experimental site was silty

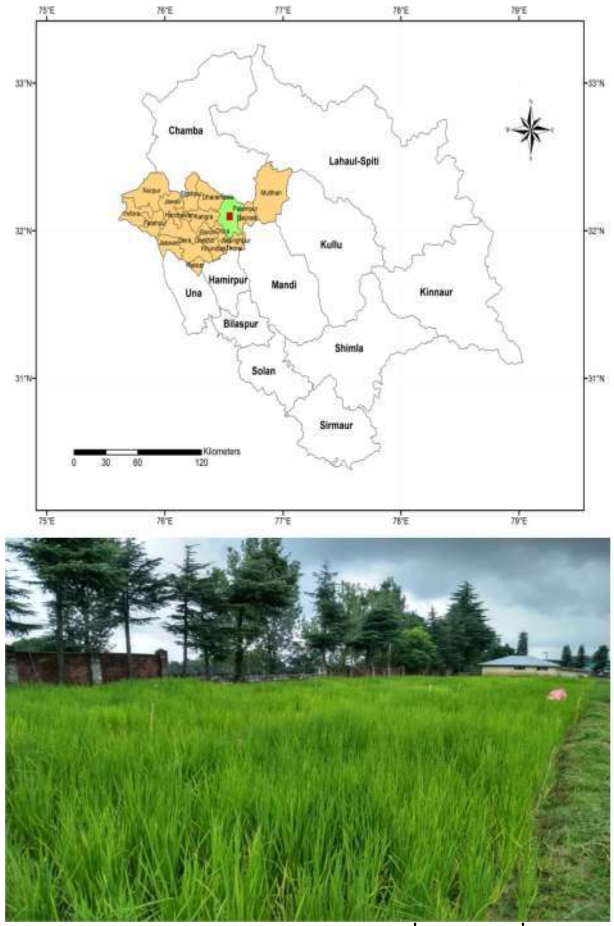

Figure 1: Sampling locations (32°09' N, 76°54' E).

clay loam in texture, acidic in reaction. The soil was medium in available nitrogen, phosphorus and potassium. The meteorological data during the crop season revealed that the weekly maximum and minimum temperature ranged from 23.57 to 31.64 ˚C and 10.14 to 20.39 ˚C respectively. The mean relative humidity ranged from 51.79 to 91.57 % and total rainfall was 197.80 mm. The total sunshine at experimental location was found to be 94.16 hours (Anonymous 2021, Crop weather outlook).

The experiment consisted of nine treatment combinations which included three tillage practices viz conventional tillage, minimum tillage without residue and minimum tillage with residue and three varieties which included HPR 1156, HPR 2656 and HPR 2795. The experiment was laid out in split plot design, replicated thrice, with tillage practices in main plot and varieties in sub plot. The crop was sown on 13th June 2019. Urea (46 % N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) were used to supply the desired quantities of nitrogen, phosphorus and potassium, respectively in relevant treatment. Recommended dose of fertilizers (60:30:30) (Package of practices, kharif, 2019 HP) in the state was applied .The entire dose of phosphorus and potassium was applied at the time of sowing while basal dose of nitrogen was added at the time of sowing and split doses after three week intervals.Mustard straw @ 3t/ha was used as mulch material and applied as per treatment.

For measuring the plant height, ten plants were selected at random from each net plot and tagged. The height was measured at 30 days interval (30, 60, 90 DAS and at harvest) and at harvest from the ground level up to top most leaf tip before the panicle emergence and up to top of the panicle thereafter. The average of these ten plants was taken as mean plant height in centimeter. The progressive tiller count was recorded at 30 days interval and at harvest from two observational units of one m^{-2}, earmarked randomly in each net plot of experiment. The data so recorded were averaged and multiplied by factor 5 to get number of tillers m^{-2}. The second row from both sides of each plot was demarcated as sampling row. The plant samples were harvested from ground surface by using sickle at monthly interval. These samples were dried in an oven at 70°C till the constant weight was achieved. The dry weight was expressed as gram per square meter (g m^{-2}). The data on plant height and dry matter accumulation was recorded at periodic interval (30, 60 and 90 days after sowing, DAS) and at harvest.

The following formulae were used to determine various growth indices:

Absolute growth rate was determined by using the formula given by (Radford, 1967).

$$AGR\ (cm/day) = \frac{\mathrm{h2 - h1}}{\mathrm{t2\ -\ t1}}$$

Crop growth rate was determined by using the formula given by (Watson, 1956).

$$GR\ (g/m2/day) = \frac{\mathrm{w2 - w1}}{\mathrm{P\ x\ (t2\ -\ t1)}}$$

Relative growth rate was determined by using the formula given by (Blackman, 1919).

$$RGR\ (mg/g/day) = \frac{(\log \mathrm{w2} - \log \mathrm{w1})}{\mathrm{t2 - t1}} x\ 1000$$

Where

H_1& H_2: Plant height (cm) of plant at time t_1 and t_2, respectively

W_1& W_2: Whole plant dry weight at time t_1 and t_2, respectively

P is the ground area on which W_1& W_2 are recorded

The data obtained was statistically analysed using (plant height, dry matter accumulation, number of tillers, AGR, CGR and RGR) the Gomez and Gomez technique (1984). The critical difference (CD) was estimated for parameters with significant impacts at the 5% probability level.

Results and Discussion

Data pertaining to growth and growth indices has been presented in table 1 and table 2. A perusal of data revealed that tillage practices had no significant effect on plant height at all stages of observation. The tallest plant at 30 DAS (Days after sowing) were observed in conventional tillage and smallest plant at 30 DAS is observed in minimum tillage with residue. Similar results were observed at 60 DAS. At 90 DAS as well as at harvest conventional tillage produced taller plants as compared to minimum tillage without residue. Minimum tillage with residue produced shorter plants even at these stages also. Higher plant height in case of conventional tillage might be due to more vigorous and healthy seedling at initial growth period of crop. Hazarika and Sarmah (2017) reported that conventional tillage enhance the physical state of the soil by manipulating and pulverising it, which not only offers a good environment for germinating seeds and emerging seedlings, but also delivers free oxygen, increased soil moisture, and critical nutrients to the plants and ultimately improve the growth of plant. Similar results are reported by (Seth, 2019 and Pandey and Tanka, 2020). Among the varieties tested, varieties showed significantly differences in plant height at all the stages of observation. At 30 DAS HPR 2795 recorded significantly higher plant height, which was fb (followed by) by HPR 2656 and in turn was

Table 1: Effect of tillage practices and varieties on plant height, dry matter accumulation and number of tillers of rice

	Plant Height (cm)				Dry matter accumulation (g/m^{-2})				Tillers ($No./m^{-2}$)			
Treatment	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**Harvest**
Tillage Practices												
Conventional tillage	40.88	103.68	124.03	124.50	84.54	524.06	738.41	858.49	174.8	260.2	250.3	238.1
Minimum tillage without residue	39.16	100.14	120.36	120.78	83.42	515.16	718.24	835.61	179.2	265.1	254.1	242.7
Minimum tillage with residue	38.72	98.74	118.12	118.99	81.31	506.32	692.62	796.44	168.1	248.3	240.9	230.6
SEM ±	2.31	3.37	5.56	5.91	0.61	4.16	5.71	8.38	2.4	3.1	2.7	2.5
CD (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**2.39**	**16.32**	**22.40**	**32.90**	**9.4**	**12.2**	**10.6**	**9.8**
Varieties												
HPR 1156	36.38	95.40	116.83	117.17	81.88	490.87	660.32	750.41	176.0	264.6	253.8	246.5
HPR 2656	38.72	99.69	117.82	118.79	83.08	519.83	726.31	848.33	178.1	268.3	258.8	248.7
HPR 2795	43.66	107.48	127.86	128.31	84.32	534.84	762.64	891.33	167.5	240.7	232.7	216.2
SEM±	1.21	2.20	2.46	2.42	0.86	6.06	13.08	17.03	3.2	5.8	5.7	5.6
CD (P = 0.05)	**3.76**	**6.78**	**7.61**	**7.45**	**NS**	**18.67**	**40.32**	**52.48**	**NS**	**17.9**	**17.6**	**17.3**

***SEM ± - Standard error mean *CD – Critical difference *NS- Non significant**

Table 2: Effect of tillage practices and varieties on absolute growth rate, crop growth rate and relative growth rate of rice.

	Absolute growth rate (cm/day)			Crop growth rate ($g/m^2/day$)			Relative growth rate ($mg/g^1/day$)		
Treatment	**0-30 DAS**	**30-60 DAS**	**60-90 DAS**	**0-30 DAS**	**30-60 DAS**	**60-90 DAS**	**0-30 DAS**	**30-60 DAS**	**60-90 DAS**
Tillage Practices									
Conventional tillage	1.36	2.09	0.68	2.82	14.65	7.15	147.91	60.81	11.43
Minimum tillage without residue	1.31	2.03	0.67	2.78	14.39	6.77	147.46	60.69	11.08
Minimum tillage with residue	1.29	2.00	0.65	2.71	14.17	6.21	146.61	60.96	10.44
SEM ±	0.04	0.05	0.02	0.02	0.01	0.05	0.42	0.34	0.22
CD (P = 0.05)	**NS**	**NS**	**NS**	**0.08**	**0.04**	**0.19**	**NS**	**NS**	**0.86**
Varieties									
HPR 1156	1.21	1.97	0.71	2.73	13.63	5.65	146.84	59.70	9.88
HPR 2656	1.29	2.03	0.60	2.77	14.56	6.88	147.33	61.12	11.15
HPR 2795	1.46	2.13	0.68	2.81	15.02	7.59	147.82	61.58	11.83
SEM±	0.03	0.03	0.02	0.04	0.18	0.25	0.68	0.50	0.28
CD (P = 0.05)	**0.10**	**0.08**	**0.05**	**NS**	**0.54**	**0.76**	**NS**	**1.54**	**0.86**

***SEM ± - Standard error mean *CD – Critical difference *NS- Non significant**

at par with HPR 1156. HPR 1156 recorded significantly lowest height due to genetic makeup of plant Similar trend was followed at all the stages of observation. HPR 2795 produced significantly taller plant which was fb HPR 2656 and in turn was at par with HPR 1156. HPR 1156 produced significantly shorter plants.

The data pertaining to the effects of tillage practices and varieties on dry matter accumulation by rice recorded at different stages. A perusal of data revealed significant effect of tillage practices and varieties on dry matter accumulation by the rice crop at all stages of observation except at 30 DAS in case of varieties. Among the tillage practices significantly higher dry matter accumulation at 30 DAS was recorded in conventional tillage, though this treatment was at par with minimum tillage with residue which was in turn at par with minimum tillage with residue. The dry matter accumulation at 60 DAS also followed similar trend. At 90 DAS and harvest, conventional tillage reported the maximum dry matter accumulation, which is comparable to minimum tillage without residue. Significantly lowest dry matter accumulation was recorded in minimum tillage with residue. Higher dry matter under conventional tillage may be due to more plant population. Similar results are reported by Seth (2019). According to seth *et al.,* 2019 data revealed that tillage practices have significant effect at all the stages of observation in rice crop. Varieties also behaved differently with respect to dry matter accumulation at different stages of observation. At 30 DAS dry matter accumulation was not significantly influenced by varieties. Higher dry matter accumulation at 30 Das was recorded in HPR 2795 and lowest was recorded in case of HPR 1156. At 60 DAS significantly highest dry matter accumulation was in HPR 2656. While significantly lowest value was recorded in HPR 1156. Similar trend was followed at 90 DAS and at harvest. HPR 2795 produced higher dry matter which was at par with HPR 2656 and lowest dry matter accumulation was recorded in HPR 1156.

Tillage techniques, as well as rice types, had a substantial impact on the number of tillers per square metre reported at monthly intervals and at harvest. A perusal of data revealed that significantly higher number of tillers per square meter at 30 DAS was recorded in minimum tillage without residue, which was at par with conventional tillage and in turn at par with minimum tillage with residue. Minimum tillage with residue produced significantly lowest number of tillers per meter square. Similar results were recorded at all stages of observation (60, 90 DAS and at harvest). The results so obtained can be explained by the fact that the tillers buds are formed at each node of the rice stem irrespective of varieties (Kakizaki, 1987). Similar results are reported by (Pandey and Kandel, 2020). According to Pandey and Kandel 2020 conventional tillage resulted in higher grain yield, plant height and effective tillers per meter square as compared to zero tillage. Varieties had a substantial impact on the quantity of tillers per square metre except at 30 DAS. At 30 DAS, HPR 2656 produced the most tillers per square metre, while HPR 2795 produced the least. HPR 2656 produces a much larger number of tillers per square metre than HPR 1156 at 60 DAS. HPR 2795 has the lowest number of tillers per square metre at 60 DAS. At 90 DAS and at harvest, a similar trend was seen.

Absolute growth rate (AGR): A perusal of data revealed that the trend of absolute growth rate could not reach level of significance at all stages of observation in case of tillage practices. At 0-30 DAS higher value of AGR was observed in conventional tillage and lowest was in case of minimum tillage with residue. In general higher value of AGR was recorded between 30-60 DAS as compared to 60-90 DAS as the height of rice usually increases till the initiation of flowering after which there is a slight increase in height. The highest AGR value was found in conventional tillage at 30-60 DAS, which might be due to better crop growth under improved soil physical and chemical properties like lower bulk density, higher macro and micro nutrient availability easily due to faster decomposition of crop residue throughout the crop growth stages. According to Karunakaran and Behera (2015) agricultural residues which are retained on or near the soil surface reduce soil erosion, runoff of surface water, summer time soil temperatures and enhance water retention. All these factors help to increase plant height of plant which in turns enhances the absolute growth rate. Similar trend was followed at 60-90 DAS. Amongst the Varieties, they have significant effect on AGR. HPR 2795 recorded significantly higher value of AGR between 0-30 DAS which was fb HPR 2656 and in turn at par with HPR 1156. HPR 1156 had a much higher AGR value between 60 and 90 DAS, which was comparable to HPR 2795. Lowest value of AGR was recorded in case of HPR 2656.

Crop growth rate (CGR): CGR is the rate of daily increment in accumulation of dry matter by the crop of a particular area. The perusal of data reveals that CGR was significantly influenced by tillage practices as well as rice varieties. At 0-30 DAS significantly higher value was recorded in conventional tillage which was at par with minimum tillage without residue and in turn at par with minimum tillage with residue. At 30-60 DAS, conventional tillage, which was followed by minimum tillage without residue, had a considerably higher CGR value. Higher CGR may be due to higher production of dry matter owing to greater LAI and higher light interception. At 30-60 DAS lower value of CGR was in minimum tillage with residue. Similar results were observed at 60-90 DAS. Among the varieties tested, at 0-30 DAS higher value of CGR was recorded in HPR 2795 and lowest was in case of HPR 1156. At 30-60 DAS, the highest CGR value was found in HPR 2795, which was near HPR 2656, while the lowest CGR value was found in HPR 1156. At 60-90 DAS, HPR 2795 had a much higher CGR value than HPR 2656, which was in turn comparable to HPR 1156.

Relative growth rate (RGR): Different tillage practices did not effect RGR at 0-30 DAS and 30-60 DAS, according to a detailed examination of the data. At 60-90 DAS higher RGR value was recorded in case of conventional tillage which was comparable to minimum tillage without residue and in turn at par with minimum tillage with residue. Among different varieties tested HPR 2795 recorded higher RGR value which was fb HPR 2656 at 30 DAS. At 30-60 DAS, HPR 2795 recorded higher value of RGR which was at par with HPR 2656 and in turn at par with HPR 1156. At 60-90 DAS, HPR 2795 recorded higher RGR value which was at par with HPR 2656. At 60-90 DAS lower RGR value was recorded in HPR 1156.

Conclusion

From the present study it can be concluded the research on conservation agriculture is the need of hour. Farmers generally prefer clean cultivation and thus go for traditional agricultural practices. Conservation agriculture is a sustainable way alternative for maintaining soil resource base. From the present study it may be concluded that conventional tillage resulted in higher growth and growth indices as compared to minimum tillage with residue. Also amongst different varieties HPR 2795, a new red rice variety, gave better results under direct seeding.

Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of pre-treatments on nutritional quality of dehydrated spine gourd (*Momordica dioica* Roxb.) powder

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ABSTRACT

An exploration was conducted in the year 2017-2018 at College of Horticulture, Bagalkot, Karnataka, India to evaluate nutritional quality of dehydrated spine gourd (*Momordica dioica* Roxb.) slices as influenced by different pre-treatments. Spine gourd is a high value underexploited vegetable which is rich in nutrition, medicinal value and also having potential to cure many diseases and disorders with good cultivation potential. In order to enhance its availability in the offseason along with proper retention of nutritional property dehydration was carried out with different pretreatments as a preservative method. The effect of pretreatments on nutritional attributes was observed in the present study. The treatment T_2 which include blanching of spine gourd slices for 3 min. and steeping in 0.2 per cent KMS and 2 per cent salt solution for 10 min. showed significantly best results with respect to protein (1.93%), ash (8.11%), total phenols (831.20 mg GAE/100g) and L^*(78.32), a^*(0.68), except b^* (32.28) values and carbohydrate per cent (p>0.01). The effect of pre-treatments showed non-significant results for moisture, water activity, fat, crude fibre and calorific value (kcal/100g). It was concluded form the study that the pretreatment with KMS (0.2 %) and salt (2%) solution along with blanching for 3 min. was considered best with respect to nutritional quality retention.

Introduction

Underutilized crops species are ancient crop species which are used at small scale usually not cultivated commercially but used by the traditional people of the respective location, also they can contribute with higher percentage towards nutritional security. The genus *Momordica* contains nearly about 60 species which belongs to cucurbitaceous family. Spine gourd is a native of tropical and subtropical Africa, Asia and Australia. Karnataka (kodagu and malnad region) and Maharashtra are the main states in India cultivating spine gourd. Since it is an underutilized crop, grown by few farmers for their own consumption in homesteads or those which collected wildly are sold in the market. Although demand and price are high, nobody thought of cultivating it commercially. *Momordica* is an underutilized and wild-gathered vegetable which as both food and medicine value (Sakshi *et al.,* 2020) Indira Kakonda by Indira Gandhi Krishi Viswa Vidyalaya (Raipur) and Arka Neelachal Shree by Central Horticultural Research Station (Bhubaneswar, IIHR) are the two varieties released in India and also few farmers in Dakshina Kannada district have cultivated the Assamese teasel gourd for domestic consumption (Motapalukula *et al.,* 2020). Spine gourd is perennial in nature, with the

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chromosome number of $2n = 28$. It is cultivated up to an altitude of 4,921.26 ft, and is mainly grown in Orissa, Maharashtra, Bihar and West Bengal. In the western ghats of south India it is called by popular names like *Malanada Honnu, Mada Hagala* (Golden Vegetable of the Western Ghats) (Basavaraj *et al.,* 2014). It comes to the market in the Mansoon season (May - August). Indira Kakonda by Indira Gandhi Krishi Viswa Vidyalaya (Raipur), Arka Neelachal Shanti and Arka Neelachal Shree by Central Horticultural Research Station (Bhubaneswar, IIHR) are the two varieties released in India. Fruits weigh around 18-25 g and yield 1.5-2 kg fruits per plant (Motapalukula *et al.,* 2020). Since spine gourd is seasonal and perishable in nature processing techniques are essential to make it available throughout the year and also it reduces postharvest losses. Drying is one of the traditional and commonly used techniques to increase the post-harvest life of the produce. Before drying blanching with hot water or (KMS) helps in retention of colour and texture of the produce by inhibiting enzymatic activity (Prajapati *et al.,* 2009). Blanching was recommended as an effective method for reducing antinutritional compounds (Mosha *et al.,* 1995). The information available on the nutritive value of underexploited crops is less, which may help in combating nutritional insecurity of rural. There are many vegetables available in this part of the country, whose nutritional profile is yet to be documented. More systematic study on these vegetables is required in order to fully utilize them. The nutritional insecurity in many countries, with many children and particularly women suffering from nutritional deficiencies, is a backbone for determining the nutritional composition of traditional crops. In this background, the present study was planned to systematically analyse and document the nutrient content of spine gourd (*Momordica dioca* Roxb.) This exploration can help to address malnourishment from eating a diet in which one or more nutrients are either not enough. It may involve calories, protein, carbohydrates, vitamins or minerals. Standard protocols for biochemical analysis are employed for nutrient analyses.

Material and Methods

Location of the experimental site and climate: Bagalkot is a city in the state of Karnataka, India, which is also the headquarters of Bagalkot district. UHS, Bagalkot established by the Government of Karnataka at Bagalkot district. Bagalkot is located at 16.18°North 75.7°East. It has an average elevation of 1,748.69 feet. Bagalkot was chosen as headquarters of UHS, as the district is known for its rich horticultural production base of grapes, pomegranate, sapota. The area has a suitable climate for different crops making it an suitable place for establishment of the university.

Procurement and sample preparation: The horticulture matured spine gourd fruits were collected from local market (Sirsi, Karnataka, India) in replicates to avoid qualitative and quantitative losses**.** The fruits were sorted, cleaned and graded in order to remove defect or damaged and to maintain uniform maturity, then fruits were thoroughly washed under tap water, dried under fan to remove surface moisture. Fruits of 500g weighed for each replication (each treatment replicated for five times) and cut into 0.20 inches slice with a sharp knife. Slices were succeeded for further processing methods to know nutritional quality parameters of spine gourd slices.

Pre-treatments and Dehydration

T_1: Spine gourd slices without pre-treatment (Control)

T_2: Spine gourd slices + Blanching (3 min) + Steeping in 0.2 % KMS and 2 % Salt (10 min)

T_3: Spine gourd slices + Roasting (Temp 120 ^{0}C for 5 min.)

T_4: Spine gourd slices + Steeping in vinegar (24 hr.)

The slices of 0.20 inches thickness were subjected to pre-treatments as listed above and drying process was carried out using easy tray drier which is positioned at Department of Postharvest Technology, UHS Bagalkot, Karnataka, India. The slices along with seed were dried at temperature of 60^o C until crack sound when break. The dried spine gourd slices along with seeds were weighed in electronic balance and crushed by food grinder into powder. The powder was packed in high density polyethylene bags, sealed and used for further studies.

Analysis of nutritional quality of spine gourd powder: Spine gourd powder colour was measured with a ColorFlex (Model CFEZ 1919, Hunter Associates Laboratory, Inc., Reston) with a 1.7717 inches (diameter) measuring tube using a white tile background. L^* a^* and b^* values indicates lightness, red-green and yellow-blue scales. Moisture content of spine gourd powder was measured by moisture meter. Weighed spine gourd powder (2 g) was placed on plate and then it was inserted inside the instrument. The end point was indicated by three beep sound and the instrument gives constant value for moisture and recorded as per cent moisture content. Water activity of dried spine gourd powder was determined by water activity meter (Labswift-a_w, Novasina). Determination of protein content was carried out by micro Kjeldhal method which consists of wet digestion, distillation and titration AOAC (1980). Fat content was determined by using the Socs plus-SCS-6 AS instrument as described by Ojure and Quadri (2012). Total ash content was determined by burning the spinegourd powder in pre-weighed crucible in a muffle furnace at 500^0 C for 6 hours (Rao and Bingren, 2009). Crude fibre estimation was done by using Fibra plus-FES-6 instrument. Carbohydrate % and calorific value were calculated as per AOAC (1980). Total phenol content of spine gourd powder was estimated by using Folin Ciocalteu reagent (FCR) method and expressed as mg Gallic acid equivalent (GAE) per 100 ml. (Sadasivam and Manickam, 2005).

The data analysis done by Completely randomized design method of analysis. The data was interpreted in accordance with Pause and Sukhatme (1985). The level of significance used in 'F' and 'T' test was p = 0.01. Critical difference values were calculated whenever F test found significant (test was p = 0.01).

Results and Discussion

Colour (L^*, a^*, b^*) values:

Colour is key quality attribute. Because at the time of marketing it play a major role with respect to the appearance which is the prime thing in sales with respect to quality. The L^* value was significantly influenced by the pre-treatments on spine gourd powder and it was ranged from 75.49 to 78.32 (Table 1 and Figure 1). Among the different pre-treatments, the highest value was recorded in T_2 (78.32) and it was statistically significant from other treatments. The minimum L^* value was recorded in T_4 (75.52). The present finding is concordant with the results of Muley *et al.* (1994) who observed that the enzymatic browning in KMS pre-treated samples was lowest in cabbage which confirmed the inhibitory effect of SO_2. The a^* value of pre-treated spine gourd powder ranged from 0.68 to 2.88 (Table 1). The lowest a^* value was recorded in T_2 (0.68) and it was statistically different from all other treatments. This is because blanching retains colour by destruction or inactivation of enzymes. KMS (SO_2) reduces colour deterioration by preventing oxygen solubility. Sodium Chloride (NaCl) reduces oxidative browning due to its osmotic property and also NaCl prevents bleaching by using it with other mixtures Jackson and Mohamed (1971). Hence T_2 showed less colour degradation compared to other treatments. The b^* value of pre-treated spine gourd powder ranged from 30.73 to 33.13 (Table 1). No significant difference was found in-between the treatments.

Water activity (a_w):

Higher concentration of a_w reduces the safety of the food. Statistically no significant difference was found in pre-treated samples. Higher water activity was found in the treatment T_1 (0.42 a_w) (Table 1) and the lower water activity was found in the treatment T_4 (0.34 a_w). The pre-treated samples showed more water removal when compared with the control samples due to the acidic pH activates cell wall loosening proteins (EXPANSINs, EXTENSINs ARABINOGALACTAN), enzymes and breakdown of polysaccharides which helps in maintaining structure of cell wall which in turn leads to loosening of cell wall structure by acetic acid in the vinegar treated samples (Micheli, 2001) and also Lerici *et al.* (1983) observed minimum a_w in the osmotic agent treated samples.

Moisture (%):

Moisture per cent in food influences on weight, taste, texture, appearance and shelf life. Increase in moisture per-cent increases the microbial growth resulting in spoilage. The mean moisture content of spine gourd powder subjected to pre-treatment ranged from 9.78 to 11.10 per cent (Table 1). No significant difference observed in the moisture content in-between the pre-treated samples. The lowest moisture per cent was recorded in T_4 (9.78%) and highest moisture per cent was observed in untreated sample that is T_1 (11.10%). In treatment T_2 sodium chloride (NaCl) helps in

Table 1: Effect of pre-treatments on colour values, moisture, water activity and protein content of spine gourd powder.

Treatments	Colour values			Moisture (%)	Water activity	Protein (%)
	*L**	a*	*b**			
T_1	76.53	0.76	33.13	11.10	0.42	1.66
T_2	78.32	0.68	32.28	10.18	0.36	1.93
T_3	75.49	0.87	32.98	10.72	0.38	1.56
T_4	75.52	2.88	30.73	9.78	0.34	1.36
Mean	76.46	1.28	32.28	10.45	0.37	1.63
SEm ±	0.44	0.23	0.84	0.48	0.02	0.08
CD at 1%	1.83	0.97	NS	NS	NS	0.33
C.V.	1.29	40.79	5.81	10.36	13.17	10.92

T1: Spine gourd slices without pre-treatment (Control)
T2: SGS + Blanching (3 min) + Steeping in 0.2% KMS + 2 % Salt (10 min)
T3: SGS + Roasting at 120 oC (5 min)
T4: SGS + Steeping in vinegar (24 hrs.)
SGS: Spine gourd powder
L* Lightness, a* (+) redness/(-) greenness, b* (+) yellowness/ (-) blueness

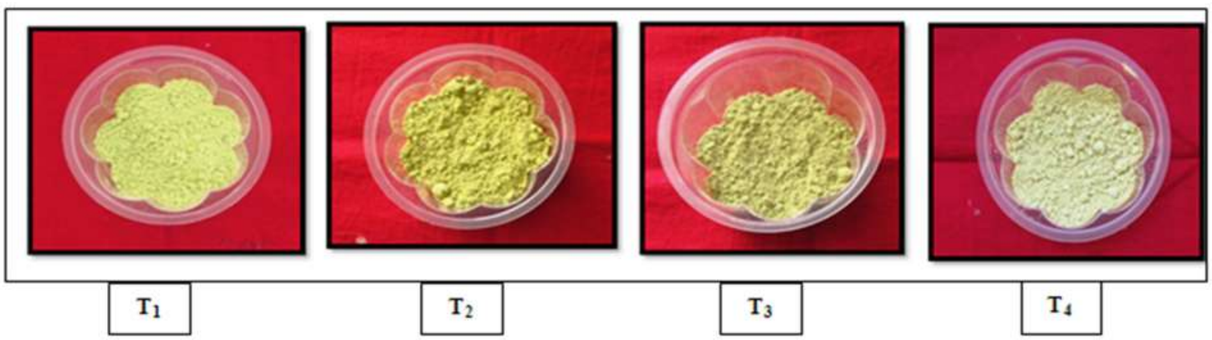

Figure 1: Spine gourd powder of different pre-treatments.

moisture removal by acting as a osmotic agent (Jackson and Mohamed, 1971). Mohseni and Ghavidel (2011) reported that sodium chloride treated tomato slices showed increase in moisture removal. Sample pretreated with brine solution took higher drying time to achieve the final moisture content. The KMS treated slices were achieved higher value of drying rate and brine treated slices were achieved lowest drying rate (Vaishali *et al.,* 2020).

Protein (%):

Significantly highest protein content was observed in T_2 (1.93%) (Table1). The highest protein content in T_2 could be due to prevention of enzymatic browning through blanching and pre-treatment with KMS + citric acid (Take *et al.,* 2012) where non enzymatic browning causes condensation of reducing sugars with amino groups (Utomo *et al.,* 2008) which leads to loss of protein. The results found are in agreement with Mozumder *et al.* (2012) where the protein content of the KMS + $CaCl_2$ pre-treated tomato samples showed higher protein content than untreated samples. The lower protein content in T_4 could be due to leaching of amino acids in the vinegar medium and also thermal degradation reduces the protein content.

Fat (%):

The highest fat content recorded in T_2 (3.12%) and there was no statistical difference among the treatments (Table 2). The lowest fat content was recorded in T_4 (2.64%). This may be due to solubility of fat content with acetic acid which leads to decrease in fat content. The higher fat content in T_2 could be due to decrease in dry matter content by leaching of soluble compounds like minerals, sugar and vitamins into water by blanching (Chapagain *et al.,* 2018), as the fat is insoluble in water the percentage of fat will increase in the remaining dry matter (Nilnakara *et al.,* 2009). The findings of present study are

Table 2: Effect of pre-treatments on fat, ash, crude fibre, carbohydrate, calorific value and total phenol content of spine gourd powder

Treatments	Fat (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)	Calorific value (Kcal/100g)	Total phenols (mg GAE/100g)
T_1	2.68	5.23	12.29	67.14	298.93	698.00
T_2	3.12	8.11	14.78	61.91	283.34	831.20
T_3	2.89	5.17	12.91	66.59	299.05	620.00
T_4	2.64	3.53	14.24	68.45	302.99	758.00
Mean	2.83	5.51	13.55	66.02	296.08	726.50
S Em $\pm$	0.41	0.54	0.68	1.22	5.22	25.93
CD at 1%	NS	2.23	NS	5.06	NS	107.10
C.V.	32.05	21.88	11.16	3.17	3.66	-

supported by Mozumder *et al.* (2012) where fat content of $CaCl_2$ + KMS pre-treated tomato powder showed higher because of lower moisture content.

Ash (%):

The ash content gives presence of mineral composition present in the food. Significantly higher ash content was recorded in T_2 (8.11%) (Table 2) while the lowest ash content was associated with T_4 (3.53%). The higher ash content in T_2 could be due to addition of some sulphites and sodium ions into the vegetables. The similar results were observed by Oboh, (2005) where the ash content of *Cnidoscolus acontifolus* subjected to abration of salt showed higher salt content by abrasion of sodium ions into the vegetable. The lower ash content in T_4 might be due to leaching out of some inorganic salt during pre-treatment (Chapagain *et al.,* 2018). Pre-treatments influence the ash contents of sweet potato flour by leaching of minerals in the citric acid solution during soaking (Vanhal, 2000).

Crude fibre (%):

Crude fibre helps in roughage improvement and bulk, also helps in maintaining intestinal issues (Potter and Hotchkiss, 2004). The maximum mean crude fibre content was recorded in T_2 (14.78%) might be due to the leaching of soluble solids during blanching which in turn result in decrease of total dry matter. Therefore, an increase in proportion of the crude fibre per unit dry matter has been observed in blanched samples (Nilnakara *et al.,* 2009).

Carbohydrate (%):

Carbohydrates provide heat and energy for all forms of body activity. They are a major food source and a key form of energy for most organisms. Significantly higher carbohydrate content was obtained in T_4 (68.45%) (Table 2) and minimum carbohydrate content was obtained in (61.91%) might be due to leaching of soluble components like minerals, sugar and vitamins in water during blanching resulting in decrease in total solids. The energy accumulated in food as protein, fat and carbohydrates.

Calorific value (Kcal/100g):

The highest calorific value in T_4 (302.99 Kcal 100 g^{-1}) and lowest calorific value in T_2 (283.34 Kcal 100 g^{-1}) (Table 2). was due to decrease in carbohydrate content and higher amount ash and crude fibre as per the present study which does not add any calories. Aberoumand (2010) studied on nutritional aspects of spine gourd fruits where he stated that spine gourd powder provides energy of 288.25 Kcal 100 g^{-1} on dry weight basis.

Total phenols (mg GAE/100g):

Total phenol content of spine gourd *Khakra* varied significantly. The maximum phenol content of (831.20 mg GAE 100 g^{-1}) was recorded in T_2 (Table 2) and minimum total phenol content was recorded in T3 (620 mg GAE 100 g^{-1}). The results are supported by Shrinivas *et al.* (2009) where *Momordica dioica Roxb.* contains total phenolic content of about 9.25 mg GAE per gram of dry sample. Maximum phenol content in T_2 might be due to activity of potassium metabisulfate and sodium chloride which causes irreversible changes in the quality of dried produce there by it reduces tissues damages by oxidative reactions (Mwende *et al.* 2017). Bamidele *et al.* (2017) reported that increase in total phenol content of selected green leafy vegetables after blanching for 5 minutes with reduction of enzyme mediated polyphenol degradation (complete inactivation of native polyphenol oxidase) and also increase in total phenolic content could also be due to the release of bound phenolic acids from the breakdown of cellular constituents of the plant cell walls in the leafy vegetable while blanching. Also supported by the study conducted by Chapagain *et al.,* 2018, chemical pre-treatment done before drying showed significant effect on physiochemical properties of solar dried tomato slices. Solar and sun-dried tomato pre-treated with potassium metabisulfite had significantly high carotenoids, lycopene and beta carotene compared with the other pre-treated samples and controls (Owureku-Asare *et al.,* 2018)

Conclusion

Spine gourd powder prepared by employing pre-treatments was evaluated for the nutritional parameters and *L*, a* and b** colour values. Results indicated significant differences among the treatments. The appearance of the spine gourd powder was retained in T_2 which is foremost for consumer acceptance and also it retained higher per cent of protein, fat, ash, crude fiber and total phenol content. Therefore results of this study indicated that treatment T_2 [Spine gourd slices + Blanching (3 min) + Steeping in 0.2% KMS and 2% Salt (10 min)] was found to best for the production of spine gourd powder in terms of nutritional and colour values which can be incorporated to many products for value addition and to enhance therapeutic value.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Water usage pattern in the aftermath of COVID-19

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ABSTRACT

Maintenance of good health and avoiding a viral infection is the prime focus for an individual during COVID-19 pandemic. Water being a universal solvent is used widely to clean the disinfectants in public places and individual household level. This study was designed to find any change in the water consumption pattern among the households after the emergence of COVID-19. To study this, a questionnaire was prepared and sent to the respondents through Google Forms. Collected data was analysed using suitable statistical methods and the results indicate that there was a significant change in the consumption pattern of drinking water from cold to hot (37.98%) among the respondents and also with respect to the total water usage. As the disease is communicable in nature, more water is needed to clean and disinfect the surface areas, washing hands etc. This eventually has a significant burden on the water resources in countries where water is already deficient, like India. It is recommended to adopt water conservation practices/technologies at the individual level by means of rain water harvesting techniques or use of efficient water aerator taps etc. to reduce water consumption.

Introduction

Water, an elixir of life (Mythrey *et al.,* 2012; Bhutiani *et al.,* 2021) without which life on this planet is impossible. It is an essential element for survival (Popkin and Rosenberg, 2011; Wolf *et al.,* 2010; Bhutiani and Ahamad, 2018; Tyagi *et al.,* 2020) of any living being on this planet. People can stay for couple of days without having food (Krecar *et al.,* 2014) but not without sipping water. From the available freshwater, about 70 % of the water is used for agriculture, 23 % for industry and the remaining for domestic usage (de Sherbinin *et al.,* 2007). Domestic consumption of water includes mostly drinking, cooking, washing clothes, surface cleaning and sanitisation etc. Domestic consumption pattern of water varies from country to country. The total fresh surface water withdrawals are more in countries like China followed by India and USA (FAO, 2021). Similarly, within the Nation, the consumption of water varies depending on the availability of water, settlements like Urban or Rural etc. Several factors influence domestic consumption of water like climate, family size, gender, age, education, culture, food habits, urbanization etc. (March *et al.,* 2015; Shaban and Sharma, 2007). As per the Ministry of Housing and Urban Affairs, 135 litres per capita per day (lpcd) is the benchmark for urban and 55 lpcd for rural water supply for domestic usage in India (PIB Delhi. 02 MAR 2020). The use of water appropriately will fetch considerable benefits viz., drinking hot water has more benefits than drinking cold water (Zawn Villines, October 12, 2017; Patel *et al.,* 2015). Hot water consumption helps in reduction in infection level among the general public (Patel *et al.,* 2015). Hydrothermal therapy or Hydrotherapy or hot-cold therapy, wherein water in different forms can be used for the treatment of various diseases. For instance, steam water inhalation provides enormous health benefits in curing different diseases (Galvez *et al.,* 2018; Mooventhan and Nivethitha, 2014). The use of heat in the form of steam inhalations,

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hot springs, saunas, steam rooms etc. helps in enhancing the overall health and wellbeing of an individual (Cohen, 2020). It was rumoured that the Chinese used steam water inhalation technique to get rid of COVID-19. As this information spreads through social media, many Indians started practicing it.

"Drinking clean water, maintaining hygienic conditions, proper sanitation and disinfection are essential to prevent most of the transferable diseases including COVID-19. Government recommended several guidelines about safe water consumption and multi modal strategies for avoiding contact with COVID-19 virus like washing hands frequently, cleaning the surface areas and maintaining proper sanitation measures" (WHO, 29 July 2020). Till now, the consumption of water is increasing due to increase in population but now there is one more reason to use more water i.e., preventing the spread of the Novel Coronavirus through cleaning the surface areas, washing hands etc. Keeping these in mind, the study designed to examine the change in consumption pattern of water among the individuals after COVID-19.

Material and Methods

This study aims to investigate the water consumption pattern among Indian households after COVID-19 using a cross-sectional survey. A questionnaire was framed in English and sent to social media platforms through a link generated using 'Google Forms'. The link was first sent to the close-knit groups and asked them to forward in their friends' group or WhatsApp circle. The Google Forms consist of an inventory of questions related to demographic and water utilisation pattern about the households. The queries related to the water utilisation pattern of the respondents was designed using dichotomous answers like yes or no (Table1; Except Query 1). The study employed a snowball sampling method to collect information from the respondents. The survey started on 4th June 2020 and ends on 7th July 2020. After removing the incomplete and random responses, a total of 848 valid responses were selected for analysis.

Table 1: Water related questions included in the questionnaire (After COVID-19 indicates emergence of COVID-19 in India)

Query 1	What is the source of your drinking water?
Query 2	Do you have access to clean drinking water?
Query 3	Are you drinking hot water or cold water?
Query 4	If you started drinking hot water, is this change due to COVID-19?
Query 5	Do you have the habit of drinking more water after COVID-19?
Query 6	Are you washing your hands more frequently after COVID-19?
Query 7	Do you clean products bought from outside (Milk packets etc.,) with water after COVID-19?
Query 8	Do you take a bath as soon as you come to the house from outside (after COVID-19)?
Query 9	Are you practicing hydro-thermal therapy (hot water steam) after COVID-19?
Query 10	Are you consuming more water to clean your hands/disinfect your house/washing clothes/bathing after COVID-19?

The Hypothesis of the study

Hypothesis 1 (H1a): Water drinking habits (More water drinking/ Hot water drinking/Access to clean water) positively improved after wake of COVID-19.

Hypothesis 2 (H2a)

External consumption of water (Clean hands/Disinfect your house/Washing clothes/Hydrothermal therapy) increased after wake of COVID-19.

Analytical methods

Statistical techniques like descriptive statistics, Z-test, Wilcoxon signed rank test and Random Forest, were used to analyse the data. Z- test is used to test improvement in the proportionate response of individuals about water issues by considering H0: There is no change in proportionate response ($\hat{p} = 0.5$) of individuals towards water consumption. Non parametric Wilcoxon signed-rank test is used to compare the changes in drinking habit after Covid-19 from cold to hot water. H0: No change in median difference between before to after response vs. Ha: the median difference between before response to after response is positive. Random forest is one of the machine learning techniques to choose the variables based on explanatory variables contribution to an outcome (Best *et al.,* 2020; Janitza *et al.,* 2018). Node purity is one of the measures of importance to select variables and is calculated based on the reduction in the sum of squared errors whenever a variable is considered to divide the tree. In this study, the random forest technique was used to identify the contribution of demographic variables and water queries to change in awareness among the respondents about water usage.

Results and Discussion

Demographic profile of the respondents

The analysis of the demographic information revealed that out of total 848 respondents, 36.91 % of the respondents constitute females and the remaining were males (62.97%). The majority of the respondents belong to the age group of up to 45 years (88.68%). In terms of education, as much as 98.23 % had a minimum graduation level of education. More than half of the respondents in the sample constitute bachelors (54.36%), more than half of the respondents (69.2%) had a monthly average income of Rupees less than 50 thousand.

Water usage pattern

The source of drinking water varies among the households, 38 % of the respondents depend on municipal water supply, 29.6% on borewell, 17.70% on open well and remaining on other sources of water (Figure 1). With respect to water consumption pattern among the respondents, it was found that 37.98 % of the respondents started drinking hot water after COVID-19 despite of access to fresh available drinking water (93.27%). It was further found that there was a significant difference in the drinking habit of the respondents from cold to hot water as per the Wilcoxon signed-rank test (p-value <0.01) (Fig 1B). Drinking hot water here refers to normal consumption of drinking and not pertain to drinking tea or boiling the water to kill the pathogens. More than 50 % of the respondents started drinking more water after spread of COVID-19 and about 99 % of the respondents were using more water for their daily needs viz., washing milk packets, washing hands more frequently, etc. (Figure 1). Similarly, Z-proportionate test (Table 2) also indicates significant changes in internal and external usage of water at 5 % level of significance. Whereas, the habit of drinking more water (-13.29**) and Hydro-thermal therapy after COVID-19 (-28.02**) were showing negative significance due to less positive responses.

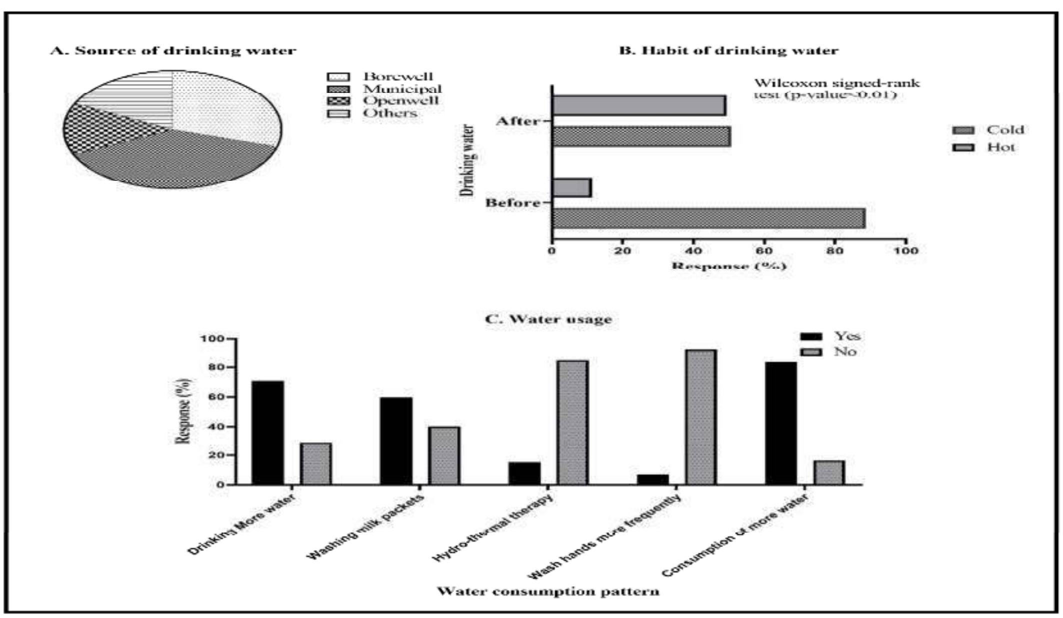

Figure 1: Source and usage pattern of water among the respondents after COVID-19.

Table 2: Changes in water usage pattern after COVID-19.

Water usage	Items	Positive responses	Z score
Internal	a. Access to clean drinking water	791	50.33**
	b. Drinking hot water	525	7.14**
	c. Habit of drinking more water	248	-13.29**
External	a. Washing hands more frequently	788	48.75**
	b. Cleaning food products bought from outside (Milk Packets, etc.)	507	5.81**
	c. Bathing	606	13.84**
	d. Hydro-thermal therapy	130	-28.02**
	e. Consuming more water (overall)	709	26.44**

Based on the water consumption pattern of the households, total water usage level was found out using the total score. Total score is obtained by adding the total score of each attribute measured in the table 2. Thus, the total score indicates the awareness level among the respondents towards the benefits of using water. In the present study, quartile method was used to divide the total score into three parts viz., low (<4), medium (4-6) and high (>6). It was found that 73.94 % of the respondents had moderate level of water usage followed by low (15.10 %) and high (10.96%) (Table 3).

Table 3: Level of water usage by the respondents.

Level of water usage	Score	Frequency	Percentage
Low (<1st quartile)	<4	128	15.10
Medium (1st quartile - 2nd quartile)	4-6	627	73.94
High (3rd quartile)	>6	93	10.96

Personal and social factors will influence the individual awareness level of water consumption and to identify the most influencing factors, we used a Random Forest technique. The relative importance of each factor on water score using IncNode purity values obtained from random forest technique was given in Figure 2A. Respondents monthly income of the family (84.61), age (75.40), child in family (67.50), and education (61.50) were the most influencing factors contributing to the total score. Out of nine queries selected for total score, Figure 2B explains variation of each query with respect to total score. In the present study, consuming more water (overall) (403.44), washing hands more frequently (385.62), taking bath as soon as an individual comes to the house from outside (281.30) and cleaning food products bought from outside (246.86) were shown more weightage to the total score. This indicates that the respondent was given more importance to practicing external consumption of water compared to internal consumption like drinking hot water and consuming more water.

The study also looks into the total water usage of the household and the data collected indicates 83 % of the respondents were using more water after COVID-19 for their daily needs. This includes repeated hand washing, bathing, washing products etc. The average domestic consumption of water was increased more than 210 litres per capita per day (lpcd) in this study as compared to the standard norms of 135 lpcd prescribed by the Central Public Health and Environmental Engineering Organisation of India. This clearly indicates that the households are consuming more water than the normal after COVID-19 due to increased usage. If the people consume water at this rate, there will be an increase in demand for water in the near future. In reality, the availability of water is taking a decreasing trend in India as shown in Figure 3B.

The present study examined the water consumption pattern among the households after COVID-19. The study found that there was a significant difference in the drinking habit from cold to hot water among the respondents. This may be due to the fact that drinking hot water may reduce the symptoms of sore throat that is experienced after COVID-19 infection. Compared to internal consumption of water, like drinking hot water or drinking more water, the respondents gave more importance to external consumption like washing milk packets,taking bath etc. Even the respondents practicing drinking more water and hydro-thermal therapy

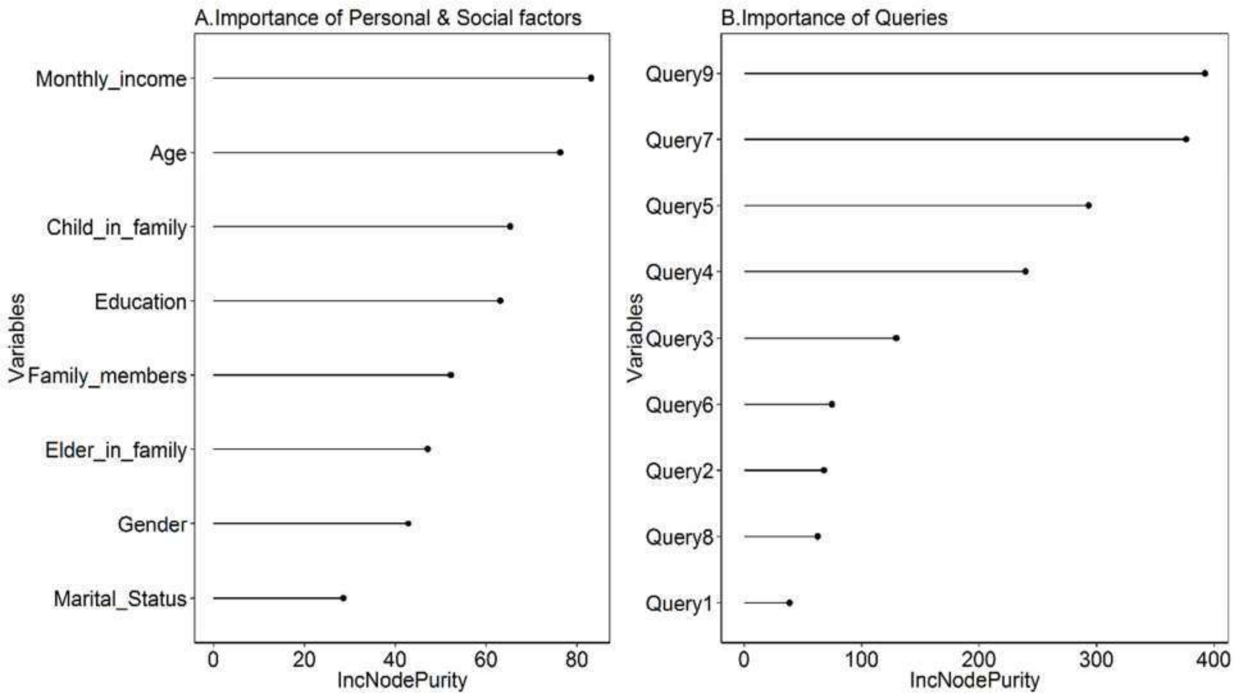

Figure 2: Importance of personal information and queries to total score using Random Forest.

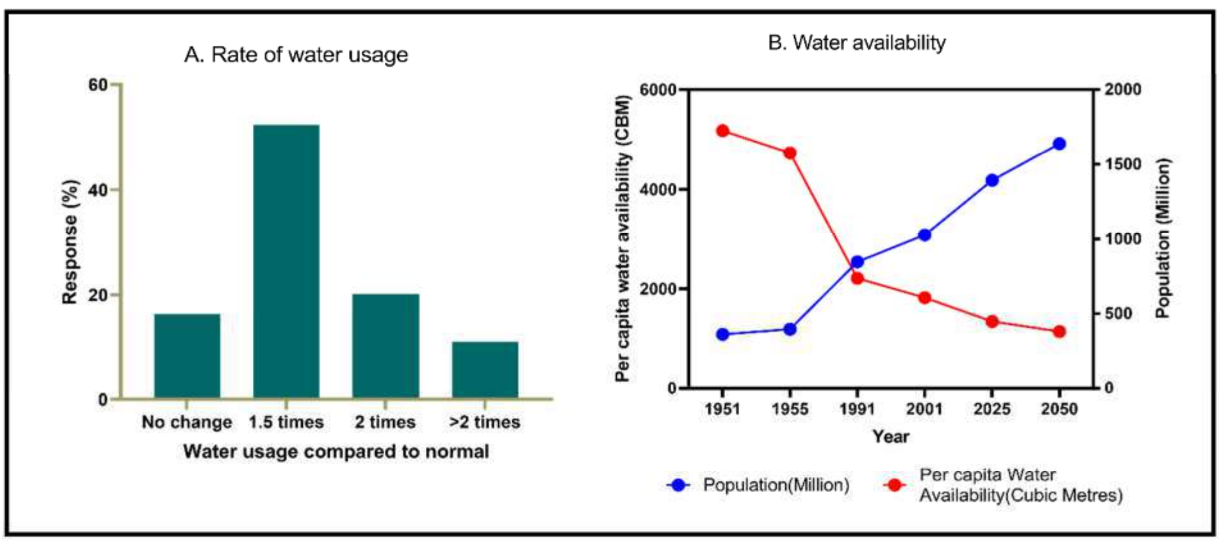

Figure 3: Present availability and domestic usage pattern of water in India. ***Source (B): http://www.Indiastat.com.***

were very few despite the fact that the consumption of more water will remove most of the toxins from the body (Patel *et al.,* 2015) and hydro-thermal therapy may increase the chances of survival (Cohen, 2020; Evans *et al.,* 2016; Pilch *et al.,* 2013; Brenner *et al.,* 1999; Ernst *et al.,* 1990) once the individual gets infected with the virus. Though the studies on hydro-thermal or hot-cold water treatment were few and conducted on a limited sample size, the studies of this nature need to be conducted to fill the research gaps that exist with respect to the benefits of water by looking at both micro and macro level scenarios. It is of utmost important to create awareness among the general public to drink hot water and practice hydro-thermal therapy in order to overcome the effects of viral infection. Age, education and increase in monthly income of the family were the most influencing factors in consuming more water. The findings of this study were associated with the earlier studies of Rathnayaka *et al*. (2017) and Yang *et al*. (2016). As the virus is transmittable in nature, in order to overcome the viral infection, one needs to use more water for washing, drinking, cleaning etc. The International Organisations like United Nations and WHO also recommends washing hands as one of the preventive measures to control COVID-19 pandemic.

Conclusion

This study delves into the domestic usage pattern of water among the households in India through a questionnaire survey and the results revealed that there is a significant change in the consumption pattern of water at the household level and the total consumption of water also increased after the emergence of COVID-19. Practice of drinking hot water and hydro-thermal therapy might reduce the chances of severe infestation of COVID-19. But the awareness about these practices among the households is limited. Hence, Government must ensure to create awareness in these aspects in order to reduce the infection. The study found that the external water usage was increased mainly for cleaning the surface areas and washing hands/sanitisation during COVID-19 pandemic. It is advised to practice water conservation techniques among the households like use of recycled water, practice of rain water harvesting, use of water aerated taps etc. Moreover, Government needs to plan about water demand and supply, as there is already a water deficit in most of the cities in India and ensure quality supply of water to the households, as the consumption of water is increased after the emergence of COVID-19.

Conflict of interest

The authors declare that they have no conflict of interest.

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Evaluation of antibacterial activity and phytochemical investigation of *Azadirachta indica L.* against certain bacterial species

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ABSTRACT

Historically, plants have been a source of herbal medicines and are used for treating various human ailments. *Azadirachta indica*, commonly known as neem, is a multipurpose tree with a wide range of health benefits. Various parts of neem tree have been shown to exhibit antimicrobial effects against a wide variety of microorganisms. The present study was carried out for screening of active components and antibacterial activity of leaves and bark extracts of *A. indica*. Ethanol and methanol extracts of leaves and bark of *A. indica* were tested against Gram positive and Gram negative bacteria viz. *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus,* and *Bacillus cereus.* The agar well diffusion method was used for testing the antibacterial activity. Results revealed that methanol extract of bark and ethanolic extract of leaves exhibited significant antibacterial activity. Methanolic extract of bark of *A. indica* showed maximum antibacterial activity against *B. cereus* and *K. pneumoniae* (16 mm) followed by p. *aeruginosa* (15.6 mm), *E. coli* (15.3 mm) and least was found against *S. aureus* (15 mm). Whereas ethanolic extract of leaves exhibited maximum activity against *P. aeruginosa* (11.3 mm), followed by *K. pneumoniae* (11 mm), *S. aureus* (10.3 mm), *E.coli* (7 mm) and no activity was observed against *B. cereus.* Phytochemical screening of plant extracts gave positive results for alkaloids, flavonoids, saponins and tannins.

Introduction

Since time immemorial medicinal plants, have always been used for treatment of human ailments. Plants possess therapeutic properties and therefore play an essential role in maintaining human health free from disease as well as in healthy state. Ancient, scared holy book such as Rigveda and various Samhitas written by ancient rishis had made significant contribution to the Indian medicine system. Both these ancient literatures provide information regarding the therapeutic properties of medicinal plants and their uses. Rigveda seems to be oldest compilation written between 3500 B.C. to 1600 B.C. Atharveda was written around 1200B.C. Further works of Charka and Sushruta namely Charaka Samhita and Sushruta Samhita respectively were written about 1000B.C. and contain a realistic and clear account of therapeutics of Ayurveda, a traditional healthcare system of Indian medicine. The discovery of antibiotics in 20th century have completely transformed humanity's approach to infectious diseases and substantially reduced the threat passed by infectious disease. However, the emergence of drugs resistant microorganisms reversed the advances of the previous 50 years of research. The drug resistant microorganisms have complicated the treatment of infectious diseases in immune compromised AIDS and cancer patients (Davies, 1994). Under such circumstances, it becomes necessary to find out some suitable substitute of modern medicines from drug plants. Various plant has been discovered which have medical significance like antimicrobial, antibacterial, antioxidant, anti-helminthic, anti-cancerous, ant-inflammatory, anti-fungal activity

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etc. These plant medicine not only cure diseases but also enhance our immunity. Medicinal plant contains a wide variety of secondary metabolites such as tannins, alkaloids, flavonoids etc. Phytochemicals that occur naturally in plants are referred to as secondary metabolites. These phytocompounds possess antimicrobial properties and therefore serve as an effective, cheap, and safe antimicrobial in treatment of infection.

Voluminous information on plants as antimicrobial agents against human pathogens are available. Large no. of workers reported antimicrocrobial activity of drug plants (Mahida and Mohan, 2006; Rajasekaran *et al.,* 2008; Alipour and Khan Mohammadi, 2011; Sudhir *et al.,* 2012; Buzayan and El-Garbulli, 2012; Ibrahim and Abu salem, 2014; Al- Mariri and Safi, 2014; Francine *et al.,* 2015) *Azadirachta indica*, commonly called as neem (margosa) belongs to family Meliaceae. Neem is the traditional medicinal plant of India. It is an evergreen tree, commonly grown in various parts of the Indian subcontinent. The plant is regarded as "village dispensary" in India because of the use of all its parts for various ailments in the indigenous system of medicine. Every part of the tree has been used as household remedy for treatment of various human ailments since ancient times (Rajasekaran *et al,* 2008). Neem is also called as "Arista" in Sanskrit, a word that means Imperishable, Perfect & Complete (Girish and Shankara, 2008). A large number of biologically active compounds have been isolated from *A. indica* such as Flavonoids, flavonoglycoside, dihydrochalcones, tannins etc. Twigs of neem are widely used as toothbrush for its anti pyorrheal property. Neem oil possesses antifungal, antimicrobial and antiseptic properties and are used for treatment of chronic skin diseases, leprosy and ulcers. The objective of the study is to investigate the antibacterial potential of leaves and bark extracts of *A. indica* and to determine the phytochemical constituents present in the *A. indica* bark and leaves extract.

Material and Methods

Collection of Plant material and preparation of Plant extracts: The Leaves and bark of *Azadirachta indica* were collected from from the Greenland Nursery in chunni kalan, Distt. Fatehgharh Sahib.. The plant materials (leaves and bark) were thoroughly washed and dried in shade. After proper drying, the leaves and bark of *A. indica* were grinded to form coarse powder. Extraction of test drug plant material i.e leaves and bark were done in different extractants (methanol and ethanol). 40 gram of grinded plant material was extracted using 300ml of extraction solvent for 24-48 hrs in Soxhlet extractor. Finally the extract obtained after extraction was subjected to filteration through sterile filter paper whatman no.1. Solution was evaporated to dryness to get final volume of 40 ml under controlled temperature conditions. The final concentration of the extract was made at level in which 1 ml of extract solution represented 1 gm of powdered plant material (Barreto *et al.,* 2012). Extract solution thus obtained was designated as 100% concentrated drug solution. This 100% extract solution was further diluted with distilled water to obtain 75%, 50% and 25% concentrations.

Collection of Test organisms: The bacterial test organisms used in the present investigation are *Staphylococcus aureus* (MTCC code 3160), *Pseudomonas aeruginosa* (MTCC code 3542), *Escherichia coli* (MTCC code 443), *Klebsiella pneumoniae* (MTCC code 9544) and *Bacillus cereus* (MTCC code 430). All the culture were collected from Microbial Type Culture collection (MTCC) of IMTECH Chandigarh, India.

Testing for antibacterial activity: The agar well diffusion method was used for evaluation of antibacterial activity of plant extracts (Bell and Grudy, 1968).

Addition of inoculums to culture medium

Nutrient agar medium was seeded with inoculums i.e (Nutrient broth culture of test organisms) 2ml of bacterial suspension was added into 100 ml of molten and cooled Nutrient agar medium. The flask was rotated gently for uniform distribution of test organisms.

Preparation of agar plates:

The inoculated culture medium was then poured into sterile petri plates in Laminar Air Flow and allowed to solidify completely.

Pouring of extract:

Sterile cork borer of 8mm in diameter was used to make 5 wells in the set of each petriplates, with 4 well in the periphery and one well in the center. 0.1ml (100µm) solution from each differ concentration i.e (100%, 75%, 50% and 25%) of plant extract was added to four peripheral wells. Central wells were filled with 0.1ml solution of control.

Methanol, Ethanol and Sterilized water were used as control for methanolic, ethanolic and aqueous extract. These petriplates were then incubated at 37ºC for 24 hours. After incubation the diameter of zones of inhibition were measured and tabulated for each test bacterial strain. Each sample was assayed in triplicate and value was measured and recorded. Inhibition zone was measured in millimetres with the ruler. It was measured from center of the well to the edge of the area with no growth (zero growth) and was multiplied by two. Further average value of inhibition zones was calculated. Effective inhibition zone was calculated by deducting the well size(cork borer size) from average value of inhibition zone.

Phytochemical analysis: The qualitative phytochemical screening of plant extracts was carried out for alkaloids, flavonoids, saponins, tanins and glycosides.

Test for alkaloids by Mayer's reagent: 1 ml of extract was treated with few drops of mayers reagent. Formation of white precipitates indicates the presence of alkaloids (Sheel *et al.,* 2014).

Test for Saponins: About 1ml of extract was diluted separately with distilled water to 20ml and shaken in graduated cylinder for l5 minutes. 1cm layer of foam indicate the presence of saponins (Sheel *et al.,* 2014).

Test for flavonoids: Take sample extract in a test tube and add few drops of conc. H_2SO_4 . If flavonoids present in sample, yellow colour appears in solution.

Test for tannins:

To 1ml of the extract, few drop of 1% (w/v) Ferric chloride $FeCl_3$ solution were added. A green or brown color indicated the presence of tannins (Joshi *et al.,* 2013).

Test for glycosides by Keller- killiani test:

To the test tubes containing 2ml of extract and 1ml of glacial acetic acid, 3 drops of 5%(w/v) ferric chloride and concentrated sulphuric acid were added and observed, appearance of reddish brown color at the junction of 2 layers and bluish green in upper layer indicates the presence of glycosides (Shukla *et al.,* 2013).

Results and Discussion

The antibacterial activity of *A. indica* leaves and bark (methanol and ethanol) extracts was evaluated against both Gram positive and Gram negative bacterial strains. The qualitative phytochemical analysis was carried out for detection of alkaloids, flavonoids, glycosides, tannins and saponins in plant extracts.

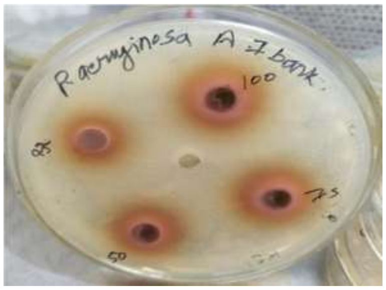
Antibacterial activity: Antibacterial activity of methanol and ethanol extracts of *A. indica* was studied against *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus,* and *Bacillus cereus*.

Antibacterial activity of Methanolic extract of leaves of *Azadirachata indica* (Table-1)

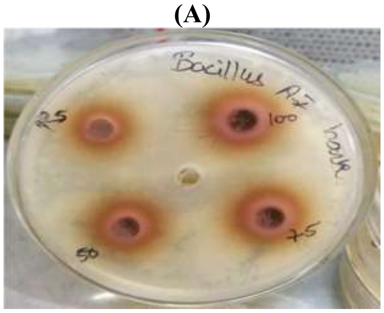
The maximum antibacterial activity at 100% concentration was recorded against *E.coli* (9mm), *Bacillus cereus* (7.6mm), *Pseudomonas aeruginosa* (6.3mm), *Klebsiella pneumoniae* (6mm) followed by *Staphylococcus aureus* (5.6mm).At 75% maximum inhibitory effect was found against *E. coli* (7.6mm) and minimum against *P. aeruginosa* (3.6mm) whereas at 50% concentration maximum inhibition was found against *E.coli* (6mm), *S. aureus* (2.3mm), followed by *K. pneumoniae* (2.6mm) . No activity was found against *B.cereus* and *P. aeruginosa* at 50% concentration. No activity was observed in 25% concentration.

Antibacterial activity of ethanol extract of leaves of *Azadirachata indica* (Table-1;Photoplate-2)

The maximum antibacterial activity at 100% concentration was recorded against *P. aeruginosa* (11.3mm) followed by *K. pneumoniae* (11mm) *S.aureus* (10.3mm)and *E.coli* (7mm). 75% concentration showed maximum inhibition against *P. aeruginosa* (9.6mm) and minimum against *E. coli* (6mm). while at 50% concentration maximum activity was found against *P. aeruginosa*(7.6mm) and minimum activity was observed against *K. penumoniae* (3mm).At 25% Concentration maximum antibacterial activity was found against *S.aureus* (5mm) and minimum against *E.coli* (4mm). *K pneumoniae* exhibited no activity at 25 %



(A)



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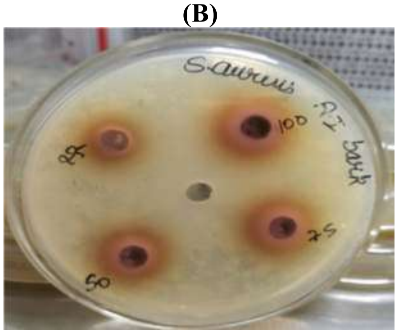

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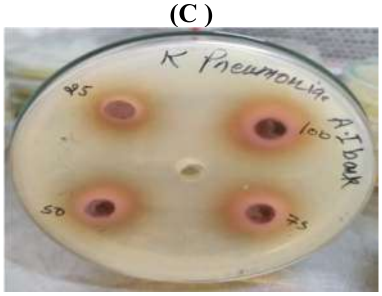

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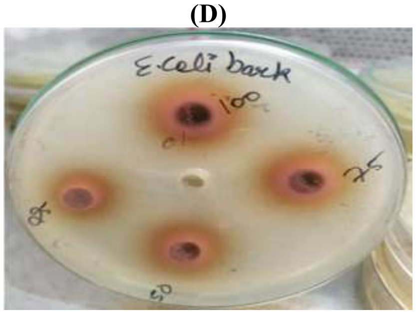


(E)

Photoplate 1: Antibacterial activity of methanolic extract of bark of *Azadirachta indica* against: (A) *P.aeruginosa* (B) *B.cereus* (C) *S.aureus* (D) *K.pneumonia* (E) *E.coli*

concentration. All extract concentration did not exhibited any inhibitory activity against *B. cereus*.

Antibacterial activity of methanolic extract of bark of *Azadirachata indica* (Table-2;Photoplate-1): The maximum antibacterial activity at 100% concentration was recorded against *Bacillus cereus* and *Klebsiella pneumoniae* (16mm) followed by *Pseudomonas aeruginosa* (15.6mm), *E.coli* (15.3mm) and *Staphylococcus aureus* (15mm).At 75% maximum inhibitory effect was found against *B. cereus* (14.6mm) and minimum against *P. aeruginosa* and *E. coli* (13.6mm)

Maximum inhibition at 50% concentration was found against *S.aureus* (12mm), and minimum against *P. aeruginosa* (10.6mm) and Bacillus cereus(11.3mm). While at 25% concentrations maximum activity was revealed against *Bacillus cereus, S.aureus, P.aeruginosa*, *K. .pneumoniae* (8.6mm) and minimum against *E.coli* (6.6m)

Antibacterial activity of ethanolic extract of bark of *Azadirachata indica* (Table-2)

The maximum antibacterial activity at 100% concentration was recorded against *S.aureus* (8mm) followed by *P. aeruginosa* (7mm), *E. coli* (6mm) **,** *B. cereus* and *K. pneumoniae* (5mm). Maximum inhibition at 75% was observed against *S.aureus* (6.6mm) and minimum inhibition was found against *K. pneumoniae* (3.6mm). 50% concentration exhibited maximum antibacterial activity against *S.aureus* (5mm) and minimum activity against *K. pneumoniae* (2mm). No activity was observed at 25% concentration.

Results of Phytochemical analysis: The preliminary phytochemical analysis of leaves extract revealed that methanolic and ethanolic extract were found rich in tannins, flavonoids and saponins. Alkaloids were only detected in ethanolic extract of leaves. Glycosides were found absent (Table-3). Similarly tannins, flavonoids and saponins were found in bark extracts (methanol and ethanol) of *A. indica.* Alkaloids and glycosides were found absent (Table-4). The phytoconstituents alkaloids, glycosides, flavonoids , saponins and tannins forms the defensive mechanism of the plants against pathogens.

The present findings revealed that methanolic bark extract of *A. indica* was superior and effective against all test bacterial strains. Whereas moderate activity was observed in ethanolic and methanolic extract of leaves. Ethanolic bark extract of *A. indica*

Table 1: Antibacterial activity of different extracts of *Azadirachta indica* leaves

EXTRACT TYPE	TEST ORGANISMS	EFFECTIVE ZONE OF INHIBITION (mm)			
		Extract Conc. 100%	Extract Conc. 75%	Extract Conc. 50%	Extract Conc. 25%
METHANOL	*E. coli*	9 mm	7.6 mm	6 mm	--
	P. aeruginosa	6.3 mm	3.6 mm	--	--
	K. pneumoniae	6 mm	5 mm	2.6 mm	--
	S. aureus	5.6 mm	4 mm	2.3 mm	--
	B. cereus	7.6 mm	4.3 mm	--	--
ETHANOL	*E. coli*	7 mm	6mm	5.3 mm	4 mm
	P. aeruginosa	11.3 mm	9.6 mm	7.6 mm	4.6 mm
	K. pneumoniae	11 mm	7.6 mm	3 mm	--
	S. aureus	10.3 mm	8 mm	6.3 mm	5 mm
	B. cereus	--	--	--	--
CONTROL	--				

Effective inhibition zone (mm)*= Average value of inhibition zones of three replicates -Well size (-)= No activity
*Effective inhibition zone is zone which is measured after deducting the cork borer size from from total inhibition zone.

Table 2. Antibacterial activity of different extracts of *Azadirachta indica* bark

EXTRACT TYPE	TEST ORGANISMS	EFFECTIVE ZONE OF INHIBITION (mm)			
		Extract Conc. 100%	Extract Conc. 75%	Extract Conc. 50%	Extract Conc. 25%
METHANOL	*E. coli*	15.3 mm	13.6 mm	11.3 mm	6.6 mm
	P. aeruginosa	15.6 mm	13.6 mm	10.6 mm	8.6 mm
	K. pneumoniae	16 mm	14.3 mm	11.6 mm	8.6 mm
	S. aureus	15 mm	14 mm	12 mm	8.6mm
	B. cereus	16 mm	14.6 mm	11.3 mm	8.6 mm
ETHANOL	*E. coli*	6 mm	4.3 mm	2.3 mm	--
	P.aeruginosa	7 mm	6 mm	3 mm	--
	K. pneumoniae	5 mm	3.6 mm	2 mm	--
	S. aureus	8 mm	6.6 mm	5 mm	--
	B. cereus	5 mm	4 mm	2.3 mm	--
CONTROL	--				

Effective inhibition zone (mm)*= Average value of inhibition zones of three replicates -Well size (-)= No activity
*Effective inhibition zone is zone which is measured after deducting the cork borer size from from total inhibition zone.

Table 3: Phytochemical screening of leaves extract of *Azadirachta indica*

Chemical Constituents	Test performed	Methanol extract	Ethanol extract
Alkaloids	Mayer's test	-	+
Tannins	Ferric chloride test	+	+
Flavonoids	Sulphuric acid test	+	+
Saponins	Foam test	+	+
Glycosides	Keller's Killiani test	-	-

- '+' indicates the presence of plant constituents.
- '-' indicates the absence of plant constituents.

Table 4. Phytochemical screening of bark extract of *Azadirachta indica*

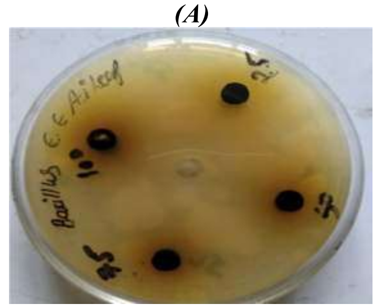
Chemical Constituents	Test performed	Methanol extract	Ethanol extract
Alkaloids	Mayer's test	-	-
Tannins	Ferric chloride test	+	+
Flavonoids	Sulphuric acid test	+	+
Saponins	Foam test	+	+
Glycosides	Keller's Killiani test	-	-

- '+' indicates the presence of plant constituents.
- '-' indicates the absence of plant constituents.

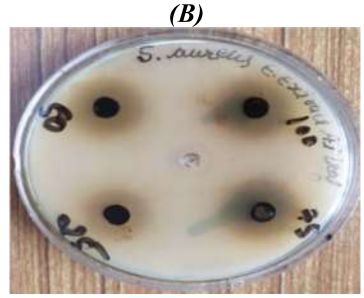
failed to exhibit inhibitory activity at 25% concentration. The zone of growth inhibition of bacteria corresponded to the drug concentration of plant material. A declined trend of inhibition zone was found with the dilution of extract.

The phytochemical analysis of plant extract was done in order to detect the phytoconstituents. Methanolic and ethanolic extracts of *A. indica* bark as well as methanolic extract of *A. indica* leaves showed the presence of tannins, flavonoids and saponins. Whereas alkaloids and glycosides were found absent in all three extracts. On the other hand, ethanolic extract of leaves were found rich in alkaloids, tannins, saponins, flavonoids and glycosides showed absence. More inhibitory activity in methanolic bark extract may be due to higher solubity of tannins, flavonoids and saponins in methanol extract. Moreover the amount of dissolved phytoconstituents may be higher in methanolic bark extracts as compard to other extracts. Previous studies have showed that *Azadirachta indica* extracts were found effective against a wide variety of microorganisms. Our results coincides with findings of previous researchers. Chaturvedi *et al.,* (2011) studied antibacterial activity of methanolic extract of Neem bark against *S. aureus, Klebsiella and Pseudomonas species*. The extracts were found inhibitory to S. aureus, Klebsiella and Pseudomonas species. Maragathavali et al., (2012) reported that methanolic extract of leaf had inhibitory effect on the test organisms i.e. *E. coli, P. aeruginosa* and *S. aureus.* Singh *et al.* (2015) reported the antibacterial efficacy of methanolic extract of *A. indica* leaves against *S. aureus* Nigussie *et al.*(2021) evaluated the antibacterial

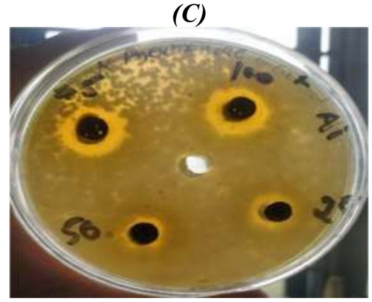
(A)



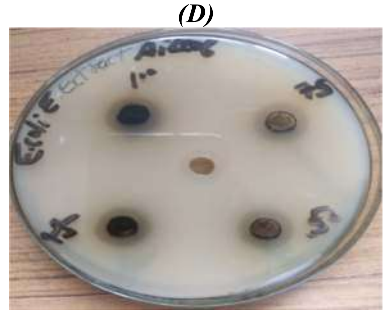
(B)



(C)



(D)



(E)

Photoplate 2: Antibacterial activity of ethanol extract of leaves of *Azadirachta indica* against: *(A) P.aeruginosa (B) B.cereus (C) S.aureus (D) K.pneumoniae (E) E.coli*

activity of methanolic extract of leaves of *A. indica* against bacterial strains isolated from the wounds of lymphoedema patients i.e. *Staphylococcus aureus, Streptococcus pyogenes, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa*, and *Shewanella alage.* They found that methanolic extracts of *A. indica* leaves exhibited antimicrobial activity against selected bacterial isolates involved in wound infections.

Conclusion

Azadirachta indica (neem) is the most versatile medicinal plant with therapeutic properties. It is rich in large number of bioactive compounds having antimicrobial, antioxidant, antiviral, antifungal and anti-inflammatory activities. From this study, it can be concluded that crude extracts of *A. indica* (leaf and bark) have antibacterial activity against bacterial test strains. Our findings support the traditional medicinal usage of plant. Neem plant contain a number of active phytoconstituents having beneficial effects in control of pathogenic microbes and therefore can be used in preparation of herbal formulations in future.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Evaluation and validation of disease management module for Alternaria Blight in Mustard

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ABSTRACT

Leaf blight of mustard is one of the major constraints for its successful cultivation and may be attributed to cause substantially high yield losses. Integrated Disease Management (IDM) practices, found suitable against Alternaria blight, developed and evaluated elsewhere, are here by tested and validated as IDM module with slight modifications as per local requirements. This is basically to demonstrate the benefit of good available technology to farmers as on farm trials (OFT). The comparative efficacy of four different treatments were incredibly convincing for the farmers. It was realized that all three modules were significantly superior over prevailing farmers' practice. Overall, seed treatment with aqueous garlic bulb extract @ 5% (w/v) along with one spray of aqueous garlic bulb extract @5% (w/v) at 45 DAS followed by one foliar spray of Mancozeb-75% WP @ 2.5g/l at 75 DAS (T_4) found most effective in reducing disease incidence consecutively for three years and average reduction in disease severity of 71.90%. Besides, reduction in disease severity significant increase in yield and yield attributing characters could be observed using this treatment. The average yield increase of 37.30% could be recorded with maximum B:C of 2.56. In this way, treatment improved production and other yield parameters without imposing any drastic input burden to farmers, as evidenced by cost and benefit estimates. Therefore, it can be concluded that T_4 can be considered for improved sustainable package of practice for Alternaria blight management of Mustard.

Introduction

Oilseed constitutes the second largest agricultural commodity in India after cereals accounting for nearly 4 per cent of gross national product and 14 per cent of the gross cropped area (Rathur *et al.,* 2021). Despite the fact that India is one of the leading oilseeds producing countries in the world, we are unable to fulfill the edible oil requirements for our own country. Among the oilseeds, mustard is an important oilseed crop of India next to ground nut in terms of both area and production. India is one of the largest producers of rapeseed – mustard in the world and comprised of 17.3 per cent and 10.3 percent of total area and production, respectively during 2017-18 (FAOSTAT, 2018). However, the average productivity remained 1511 kg/ha during 2018-19 which is far below the world average productivity of 1979 kg/ha. The total area of mustard cultivation in the country is 6.12 million hectares with production of around 9.26 million tonnes (Chauhan *et al.,* 2020). Madhya Pradesh, being a leading state of mustard production in India after Rajasthan, Gujarat and West Bengal, encompasses nearly 11.76% to the total mustard production in the country (Sharma *et al.,* 2019). In Madhya Pradesh, rape seed and mustard are grown in an area of 0.78 million hectare, with total

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production of 0.75 million tonnes and the average productivity of 1305 kg/ ha (Directorate of Economics and Statistics, 2019). The actual yield potential of mustard is still not achieved by the farmers because of incidence of different diseases and pest. Among the different diseases, Alternaria blight of Mustard caused by caused by *Alternaria brassicae* (Berk) Sacc. and *A. brassicicola* (Schw.) have been accounted from all the continents of the world (Meena *et al.,* 2010). It is one of the chief diseases of Brassica and causes 10-70 yield losses depending upon the severity of disease in different parts of northern India (Kumar and Kolte, 2001).

To combat the losses due to Alternaria blight in standing crop, use of chemical fungicides is the only option among the growers. However, chemicals fail to control the disease at several occasions because of prevailing of several environmental factors like rain fall, temperature coinciding with stage of crop and amount of inoculum. Further, unscrupulous use of pesticides is imposing serious health risks and environmental hazards. In this way, the need of the hour is to envisage alternatives of chemical fungicides for eco-friendly management of Alternaria blight. In the recent era, biological control has provided prolific achievements in plant disease management in modern agriculture leading to low level of environmental vulnerability. Besides phytoextracts, different biocontrol agents have also been used to manage different plant diseases (Srivastava *et al.,* 2009; Kumar *et al.,* 2009). However, there is still inconsistency in their performance because of their living nature and exposure to different biotic and abiotic factors in soil and/or environment. Therefore, use of phytoextracts could be a better choice in integration of need based chemical use for plant disease management. Owing to high economic value of Mustard and extensive damage caused by Alternaria blight in Madhya Pradesh, the present study, was conducted to find out the suitable Integrated Disease Management (IDM) module comprising of botanicals in integration of judicious use of chemicals and other means mitigate the disease incidence in an economically viable and sustainable manner which would also reduce the quantum of toxicants used per season in addition to disease management.

Material and Methods

Field Experiment

A field experiment was conducted during Rabi season for three consecutive years 2016-17, 2017-18 and 2018-19 at 15 farmers' fields of Gopalpur,and Chorgahi villages of Sidhi District by Krishi Vigyan Kendra (KVK), Sidhi (MP) with an aim to find out the effective IDM treatments for the management of Alternaria blight of mustard under the On Farm Trial (OFT) programme of KVK. The trials were laid out in randomized block design having four treatments (Table 1) including control (farmers practice) maintaining five replications. The experimental field was laid down by applying recommended standard agronomical practices for mustard crop (Singh *et al.,* 2019).To exclude the effect of cultivar variability, highly susceptible mustard variety Varuna was chosen for all locations. A 25 m^2 plot was prepared with planting of mustard at 45 x 15 cm during last week of October every year. 100 g fresh bulbs of garlic were crushed in 100 ml of sterilized distilled water to prepare 1 per cent w/v aqueous extract. Prepared extract was then filtered through double layer muslin cloth. The filtrate, thus obtained was considered as 100% plant extract. The observations of Alternaria blight severity on leaves were recorded 40 days after sowing (DAS) and up to one week before harvesting at an interval of 15 days.

The percent infection was measured on the basis of number of leaves infected per ten plants and disease severity was recorded on leaves and siliqua at each 15 days interval following 0-5 scale (Sharma and Kolte, 1994).

Where,

0 = No visible symptoms of Alternaria blight;
1 = 1-10% leaf area blighted;
2 = 10-25% leaf area blighted;
3 = 26-50% leaf area blighted;
4 = 51-75% leaf area blighted and
5 = 76-100% leaf area blighted.

The disease severity was recorded on randomly selected plants in each treatment and replications and per cent disease index was calculated. Further, reduction in disease severity was also calculated over control plants according to following formula given by Nene, 1972.

Percent Disease Index = (Sum of all numerical ratings / Total no. of leaves observed x maximum rating) x100

Reduction in disease incidence (%) = {(Disease severity in untreated plots- Disease severity in treated plot) / Disease severity in untreated plots} x 100

Economics of Integrated Alternaria Blight Management

Further, grain yield of each treatment was recorded from whole population separately in all the five replications. The yield was calculated by cumulating the successive plucking from respective field and computing to kilogram per hectare. The number of siliquae per plant, number of seeds per siliqua and weight of 1000 grains (test weight) were also recorded in all the treatments. The data were tabulated, pooled and ranked on the basis of their yield and yield component performance. The benefit cost ratio (B:C) of different modules was calculated by estimating different costs of cultivation and return from yield after converting them to one hectare land. The gross income from mustard of all treatments was calculated on the basis of minimum support price (MSP) of crop of respective year.

Table 1: Details of treatments for management of Alternaria blight in Mustard.

Treatment no.	Treatment details
T_1	Control (Water spray)
T_2	Seed treatment with aqueous garlic bulb extract @ 5% (w/v)
T_3	T_2+ Two foliar sprays of aqueous garlic bulb extract @5% (w/v) at 45 and 75 DAS
T_4	Seed treatment with aqueous garlic bulb extract @ 5% (w/v) + One spray of aqueous garlic bulb extract @5% (w/v) at 45 DAS + One foliar spray of Mancozeb-75% WP @ 2.5g/l at 75 DAS

Results and Discussion

The impact of four different integrated disease management treatments on severity of Alternaria blight in mustard was recorded. Results presented in Table 2 clearly indicated that the Alternaria blight incidence was significantly reduced in all the treatments. The minimum disease severity of Alternaria blight was recorded in treatment T_4 consistently in during all the years and the minimum mean disease severity of 10.40% was recorded in T_4. In control, maximum mean disease severity of 36.60% was recorded and in this way seed treatment with aqueous garlic bulb extract @ 1% (w/v) along with its one spray at 45 DAS and one foliar spray of mancozeb-75% WP @ 2.5g/l at 75 DAS maximum reduced the Alternaria blight and maximum mean reduction in disease severity of 71.90% was recorded.

This was followed by treatment T_3, where seed treatment and two foliar sprays (45 and 75 DAS) of aqueous garlic bulb extract @ 1% (w/v) were imposed, mean disease severity and its reduction of 15.30% and 48.56 % respectively were recorded. However, seed treatment of aqueous garlic bulb extract @ 1% (w/v) resulted in minimum reduction in mean disease severity of 43.50%. The results, so obtained indicated that although individual treatments showed significant effect in disease management, but when integrated together in a suitable manner along with practicing spray schedule at an early stage of disease occurrence, provided augmented results in disease management. The performance of Garlic aqueous extract had been studied by earlier workers viz. Singh *et al.,*(2016), Mahapatra and Das (2013), Meena *et al.,* 2008 and Rajendra & Lalu, 2006 who also observed

Table 2: Effect of integrated management practices on Alternaria blight severity

Treatments	Disease severity (%)				Reduction in Disease severity (%)			
	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean
T_1	37.00	37.08	35.83	36.60	0.00	0.00	0.00	0.00
T_2	18.50	19.66	23.83	20.70	50.00	46.97	33.49	43.50
T_3	14.00	13.41	18.43	15.30	62.16	63.83	48.56	58.20
T_4	9.25	10.16	11.47	10.40	75.00	72.59	67.98	71.90
CD at 5%	2.56	2.14	2.46	2.39	-	-	-	-
CV	10.48	8.61	8.85	9.31	-	-	-	-

Table 3: Effect of integrated management practices on yield attributing characters in mustard

Treatments	No. of siliquae/ plant				Increase in no. of siliquae / plant (%)				No. of seed / siliqua				Increase in no. of seed/ siliqua (%)			
	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean
T_1	74.16	73.66	74.66	74.16	0.00	0.00	0.00	0.00	13.75	13.10	13.25	13.37	0.00	0.00	0.00	0.00
T_2	82.66	82.00	82.33	82.33	11.46	11.32	10.27sss	11.02	14.8	14.00	14.0	14.27	07.63	06.87	07.63	7.38
T_3	90.33	88.66	89.33	89.44	21.80	20.36	19.64	20.6	14.85	14.10	14.20	14.38	08.00	07.63	08.00	7.88
T_4	96.33	93.16	95.33	94.94	29.89	26.47	27.69	28.02	15.0	14.30	14.50	14.60	09.09	09.16	09.43	9.23
CD at 5%	7.30	8.94	6.65	7.63	-	-	-	-	1.68	1.59	1.58	1.62	-	-	-	-
CV	6.82	8.38	6.20	7.13	-	-	-	-	9.57	8.89	8.73	9.06	-	-	-	-

Table 4: Effect of integrated management practices on test weight and yield of mustard

Treatments	Test weight (g.)				Increase in Test weight (%)				Yield (qt./ ha)				Increase in Yield (%)			
	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean
T_1	3.76	3.78	3.79	3.78	0.00	0.00	0.00	0.00	10.16	10.76	10.38	10.43	0.00	0.00	0.00	0.00
T_2	3.85	3.88	3.90	3.88	02.66	2.64	02.90	2.73	12.50	12.81	12.58	12.63	23.08	19.05	21.19	21.10
T_3	4.01	4.02	4.05	4.03	06.93	06.34	06.06	6.44	13.66	13.63	13.59	13.63	34.43	26.67	30.92	30.70
T_4	4.05	4.11	4.10	4.09	07.71	08.73	8.17	8.20	14.51	14.16	14.26	14.31	42.81	31.59	37.37	37.30
CD at 5%	0.3	0.35	0.32	0.32	-	-	-	-	1.41	1.14	1.04	1.20	-	-	-	-
CV	6.19	7.08	6.49	6.59	-	-	-	-	8.98	7.14	6.26	7.46	-	-	-	-

Table 5: Economic of different IDM modules for management of Alternaria blight in Mustard

Treatments	Cost of cultivation (Rs./ha)				Grass return (Rs./ ha)				Net return (Rs./ ha)				B:C Ratio			
	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean	2016-17	2017-18	2018-19	Mean
T_1	19452.5	20105	20226	19927.83	37592	43040	43596	41409.33	18139.5	22935	23370	21481.5	1.93	2.14	2.15	2.07
T_2	20594	21219.5	21329	21047.5	46250	51240	52836	50108.67	25656	30020.5	31507	29061.17	2.24	2.41	2.47	2.37
T_3	21008	21633.5	21740	21460.5	50542	54440	56952	53978	29534	32806.5	35212	32517.5	2.4	2.51	2.61	2.51
T_4	21984.5	22001.5	2298.5	22061.5	53687	56640	59892	56739.67	31702.5	34638.5	37693.5	34678.17	2.44	2.57	2.69	2.56

disease management effects of Garlic bulb extract in mustard crop for Alterneria blight. The findings of present investigations are in tune to their results. Latif *et al.,* 2006 also reported the efficacy of garlic extract in controlling the seed-borne fungi from mustard. In an another study by Meena *et al.,* 2011, the results pertaining to use of garlic extract along with mancozeb/ cow urine revealed the lowest leaf blight severity on leaf (33.1%) and pod (26.3%) of mustard when garlic extract was used along with mancozeb. However, when garlic extract was used along with cow urine respectively 34.4% and 27.3% disease severity was recorded on leaves and pods by Meena *et al.,* 2011.

Yield attributing factors like number of siliquae/plants, numbers of seeds/ siliqua were also recorded highest in treatment T_4 in all the three years and mean number of siliquae/plants of 94.94 could be recorded with an increase of 28.02% over control. The maximum average no. of seed/siliqua of 14.60 with an increase of 9.23% were recorded in treatment T_4. This was followed by treatment T_3 where increase in mean number of siliquae/plants and no. of seed/siliqua of respectively 20.6% and 7.88% could be recorded over control (table 3). Another observations regarding, test weight (weight of 1000 grains) also recorded maximum in treatment T_4 followed by treatment T_3 in all the three years. Overall, 8.20% and 6.44% increase in test weight could be recorded in treatment T_4 and T_3 respectively over control. With respect to yield enhancement, the maximum mean yield increase of 37.37% was recorded in T_4 over control. However, in T_2 and T_3 mean yield increase of respectively 21.19% and 30.92% was recorded (table 4). The similar findings have been reported by Meena *et al.,* (2011) who reported maximum grain yield (2052 kg/ha) of Mustard using two foliar sprays of mancozeb @ 0.25% at 45 and 75 days after sowing which was significantly at par with two spray of garlic bulb extract (2006 kg/ha). The findings of Mahapatra and Das (2016) are also in accordance with our recent observations where they stated that the treatment having seed soaking with salicyclic acid (10-3 M) along with one spraying of Mancozeb (0.3%) at 45 days after sowing and spraying of garlic bulb extract (5%) at 75 DAS gave maximum yield as well as maximum profit with minimum disease severity under gangetic alluvial zones of West Bengal. In a similar study by Kumar *et al.,* 2019 using garlic extract in combination with bio-control agent *Trichoderma*, effective management of Alternaria blight of mustard has been reported. They not only identified the disease management activity by garlic extract but also reported significant yield enhancement (more than 40%) over control. The results of present study are in agreement to their findings.

The economics was also calculated after the experimentation based on the expenditure incurred for different treatments under trial. The income data from the yield of mustard are presented in table 5. While comparing the economics of all the treatments, maximum net returns was obtained from treatment T_4 in all the three years with an average net return of Rs. 34678.17 per hectare which is significantly higher than the usual practice done by the farmers of the area (Rs. 21481.50 per hectare). This led to highest B:C ratio of 2.56 in treatment T_4 compared to 2.07 in control. Similar trends of cost benefit ratio in Alternaria blight management in mustard using garlic extract were found by Kumar *et al.,* 2019 who recorded it as 1:4.003 while using 1% w/v garlic bulb extract.

Conclusion

Therefore, looking to the disease control potential, grain yield gain, and maximum protection due to disease losses, net return and favorable benefit cost ratio as well as sustainability, the seed treatment with aqueous garlic bulb extract @ 5% (w/v) along with its one spray 45 DAS followed by one foliar spray of mancozeb-75% WP @ 2.5g/l at 75 DAS can be used and recommended for the management of Alternaria blight of mustard.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of plant size on growth and flower production of *Phaius tankervilleae (Banks ex L'Hérit.) Blume* - an endangered orchid of North-Eastern India

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ABSTRACT

A pot experiment was conducted at Horticultural Research Station, Kahikuchi, Guwahati, to study the effect of different sizes of plants on vegetative growth and flower production of *Phaius tankervilleae*. Five different plants with varying sizes and numbers of pseudo bulb were adopted as treatments which were replicated 4 times. The flowers bloom from April and the experiment shows T3 produces the maximum number of spikes (2.38) per plant and earliest spike initiation (250.77) days while T5 produces the least number of spikes (0.5) plants and took longest days for spike initiation with (255.13) days. Meanwhile, T1 produce more new pseudo bulbs (4.0) and the least number was seen in T5 with (2.14). But T5 plants produced the biggest new pseudo bulbs (2.85cm diameter). Irrespective of the numbers of the pseudo bulb, plants with bigger pseudo bulb produced a bigger plant, long spike, more spike, bigger and more number of flowers which are a superior trait for a good quality cut flower. Beyond the production of flowers, this experiment further promotes the multiplication of pseudo bulbs, which are necessary for increasing the population of the plants for restoring and conserving the plant population without further exploitation.

Introduction

Phaius tankervilleae commonly known as nun's-hood orchid, Swamp Lily, Greater Swamp-orchid or veiled orchid is a critically endangered terrestrial orchid known to have large, spectacularly, beautiful, and fragrant spikes. It is native to Northeastern states of India and found growing wild in shady, cool, and moist forested areas of Arunachal Pradesh, Manipur (Hengbung, Ukhrul district), Nagaland (Kiphire, Tuensang, and Zunhebeto district) and Assam (Bongaigaon, Darrang, Dhemaji, Golaghat, MNP, Sanitpur) (Deb and Jakha, 2019; Dey *et al.,* 2007; Sadananda *et al.,* 2019). It has been categorized as endangered species, under the Environmental Protection and Biodiversity Conservation Act. It is also found in Taiwan, the Eastern seaboard of Australia, Indonesia, Malaysia, Sri Lanka, Thailand, Southern China, and India (Shu *et al.,* 2012). The Orchid is a large one, having firm fleshy pseudo bulbs, with several large pleated leaves that favor high temperatures and wet environments (Tsai and Chang, 2009). The inflorescence is a simple raceme that can attain up to 100cm in height, and bear up to 30 large flowers that bloom from April to July. The flower of P. tankervilleae is of great ornamental and economic value and is grown as a potted plant, a garden plant, or as cut flowers (Chang and Jian, 2010). In Northeast India, the pseudo bulb of

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Phaius tankervilleae has various medicinal uses viz: healing of edema, used as a pain killer, and for treating boils and bone fracture (Medhi, and Chakrabarti, 2009; Kanwal, 2014). However, as a result of unscrupulous harvesting from the wild by plant collectors to be grown as potted plants, deforestation to make way for agriculture, and disturbance of habitat, the population of *P. tankervilleae* has been drastically reduced and is on the verge of extinction. At present, it in small numbers are present only in governmental and university botanical gardens. *Phaius tankervilleae* can be asexually propagated through pseudo bulbs, swollen parts of stems at the base of orchid plants that support leaf growth and a pseudo bulb produces two to three daughter pseudo bulbs every season. A pot experiment was conducted at Horticultural Research Station, Kahikuchi, Guwahati to study the effect of different plants size on vegetative growth and flower production of *Phaius tankervilleae*. This horticultural research can be useful for the production of Pseudo bulbs for propagation, improving the yield and quality of *P. tankervilleae* flowers. This experiment demonstrates the ornamental value and economic potential of this endangered orchid. Besides, it help promote its conservation, restoration, and expansion as an ornamental plant.

Material and Methods

Planting materials

A population of *Phaius tankervillae* plants was collected and grown in 25cm diameter earthen pot in growing media containing Soil: Sand: FYM @ 1:1:1 and NPK (19:19:19) @ 10gm/m² were applied. The experiment consists of 5 different plant types/treatments of *Phaius tankervillae* which were replicated 4 times. T1 consists of plant having 4 pseudo bulbs (2 old and 2 new), T2 consists of plant having 3 pseudo bulbs (2 old and 1 new), T3 consists of plant having 3 pseudo bulbs (1 old and 2 new), T4 consists of plant having 2 pseudo bulbs (1 old and 1 new) and T5 consist of plant having only 1 new pseudo bulb. All the plants were 2-3 years old when taken and have not been repotted before while the plant with only 1 pseudo bulb was 1 year old freshly harvested plant.

Plant growth and development

The vegetative and flowering parameters of each plant were studied and recorded, including the growth and development of the new plant (3 months after flowering). Complete Randomized Design was adopted to compare the effects of treatments.

Table 1: Treatment specification

Treatment	Specification		
	No. of Pseudo bulb	Mean diameter (old pseudo bulb) (cm)	Mean diameter (new pseudo bulb) (cm)
T1	2 old and 2 new	5.38	6.33
T2	2 old and 1 new	5.53	6.45
T3	1 old and 2 new	5.44	6.49
T4	1old and 1new	5.45	6.50
T5	1 new pseudo bulb	-	6.08

Results and Discussion

The different sizes of plants significantly influenced the vegetative and flowering characters of *Phaius tankervilliae*. The results obtained from the experiment are discussed below.

Effect on Vegetative characters of *Phaius tankervilliae*

It can be seen from the data presented in Table 2 that the maximum plant height was observed in plants from T2 (86.31 cm) while the least was observed in T5 (80.29 cm) which was only one 1 year old at the time of the experiment. Plants from T3 (1 old and 2 new pseudo bulbs) recorded significantly greater plant width (92.04 cm), leaf production (14.37 leaves/ clump), and leaf length (73.13 cm). On the other hand, minimum plant width (72.08 cm), leaf production (5.21 leaves/ clump), and leaf length (60.85cm) were all recorded in T5 (1 new pseudobulb) plants. Lastly, maximum leaf width (13.48 cm) was recorded in the T4 (1 old and 1 new pseudobulbs) plants while the minimum leaf width (11.4 cm) was recorded in T5 (1 new pseudobulb).

Table 2: Effect of plant size on vegetative characters of *Phaius tankervilliae*

Treatment	Plant height (cm)	Plant width (cm)	No. of leaves per clump	Leaf length (cm)	Leaf width (cm)
T1	85.57	98.46	12.45	68.44	11.45
T2	86.31	89.50	13.89	66.83	11.7
T3	84.80	92.04	14.37	73.13	12.5
T4	82.22	87.17	10.32	67.4	13.48
T5	80.29	72.08	5.21	60.85	11.4
S. Ed. (±)	0.02	0.01	0.20	0.02	0.11
C.D.	0.05	0.03	0.45	0.04	0.25

Table 3: Effect of plant size on flower characters of *Phaius tankervilliae*

Treatment	No. of Spikes/ plant	Floret per spike	Spike length (old pseudo bulb) (cm)	Rachis length (cm)	Diameter of fully opened flower (cm)
T1	2.1	11.14	56.75	16.17	8.93
T2	2.0	11.69	54.57	15.86	9.10
T3	2.38	12.14	54.33	14.57	9.30
T4	1.06	11.80	52.25	14.45	9.28
T5	0.5	11.50	45.80	12.00	8.97
S. Ed. (±)	0.21	0.05	0.64	0.08	0.08
C.D	0.47	0.12	1.45	0.17	0.19

Table 4: Effect of plant size on flower characters of *Phaius tankervilliae*

Treatment	Spike length from new Pseudo bulb (cm)	Days took for the initiation of the spike.	First color showing Days after spike emergence	Days to the opening of the first florets	Days took for the last flower to fade
T1	46.13	255.10	25	18.5	36
T2	48.24	254.54	26	18.8	38
T3	53.77	250.77	23	19.3	41
T4	52.36	252.40	24	19.1	40
T5	52.54	255.13	21	19.25	39
S. Ed. (±)	0.03	0.16	1.03	0.10	0.84
C.D	0.06	0.35	2.33	0.22	1.84

Table 5: Effect of plant size on characters of the newly developed plant after flowering at Kahikuchi

Treatment	New plant height (cm)	Leaves/ Pseudo bulb	New pseudo bulbs /Plant	Diameter of new pseudo bulb (cm)
T1	32.75	5.53	4.00	2.55
T2	45.88	5.57	2.00	2.58
T3	48.52	5.64	2.42	2.63
T4	55.43	5.62	2.33	2.75
T5	60.31	5.50	2.14	2.85
S. Ed. (±)	0.03	0.02	0.37	0.02
C.D	0.07	0.04	0.83	0.05

plants. The inferior performance of T5 plants may be because they are the youngest plants. However, the harvest of pseudo bulbs of an orchid diminishes its nutrient and water capital thus lowering the growth and reproduction of the orchids (Zimmerman, 1990).

Effect on flowering characters of *Phaius tankervilliae*

The yield and quality of flowers produced in *Phaius tankervilliae* are greatly influenced by the size of the planting materials, as is evident from Table 3 and Table 4. T3 produces the maximum number of spikes (2.38) per plant and it was at par with T2 and T1 (2 and 2.1 spikes/plant) respectively. However, the least number of spikes (0.5) was recorded in T5. Longest Spike and Rachis lengths (from old pseudo bulb) were found from the T1 plants, with the length of 56.75 cm and 16.17 cm respectively while the shortest were from T5 plants, where the spike length is 45.8 cm and Rachis length is 12. However, from the new pseudo bulb, the longest spike was recorded from T3 (53.77 cm) and the shortest from T1 (46.31). The maximum number of florets/ spike (12.14) and biggest flower diameter (9.30 cm) were recorded from T3 plants and the minimum from T5 plants with a record of (11.14) floret per spike and (8.93 cm) flower diameter. Earliest spike initiation (250.77 days from planting) was recorded from T3 plants while T5 plants took maximum duration (255.13 days from planting) for spike initiation. Among the treatments, flower bud color was first observed in T5 (within 21 days after spike initiation) followed by T3 and T4, taking 23 and 24 days, respectively. On the other hand, T2 took the longest duration (26 days) for flower bud color initiation. The first floret to open and the first plant to fade all floret were all recorded from T1 with 18.5 days and 36 days respectively. While the last floret to open and the Last plant to fade all floret were from T3 with 19.3 days and 41 days respectively.

Effect on newly developed plants

The morphological characteristics of the newly developed plants were studied 3 months after flowering. The height of newly developed plants was significantly influenced by the size of the pseudo bulb. T5 produced significantly taller plants (60.31 cm), followed by T4 (55.43 cm). The smallest plants with 32.75 cm plants height were observed in T1 which had the maximum number of pseudo bulbs. However, the maximum number of newly developed leaves (5.64) and (5.62) emerged from treatments T3 (1 old and 2 new pseudo bulbs) and T4 (1 old and 1new pseudo bulbs) respectively meanwhile the minimum number of leaves (5.50) was from T5. It was observed that new pseudo bulbs had started to grow from the mother plants. A significantly higher number (4.0) of new pseudo bulbs were found in T1 (mother plant with 2 old and 2 new pseudo bulbs). Meanwhile, the least number (2.14) could be seen in T5 (mother plant with 1 new pseudo bulb) which was at par with T2, T3, and T4 producing 2.0, 2.42, and 2.33 numbers of new pseudo bulbs respectively. The smallest mother plant T5 (1 new pseudo bulb) produced the biggest new pseudo bulbs (2.85cm diameter) and it was followed by T4 and T3, recording 2.75 cm and 2.63 cm diameter respectively.

Conclusion

Pseudo bulbs are involved in innumerable physiological processes that are important for the growth and survival of *Phaius tankervilliae*. Plants from T3 recorded significantly greater plant width (92.04 cm), leaf production (14.37 leaves/ clump), leaf length (73.13 cm), maximum number of spikes (2.38) per plant, longest spike (53.77 cm), maximum number of floret/spike (12.12) and biggest flower diameter (9.30 cm) while the plants from T5 recorded the least. Where Odontioda Orchids, with a greater pseudo bulb diameter produces better plants and the occurrence of floret/spike was positively correlated ($P \leq 0.01$) to pseudo bulb diameter. Similarly in the newly developed plant after flowering T5 with biggest size pseudo bulbs (2.85) produces the tallest plant (60.31) meanwhile T1 plants with smallest pseudo bulbs (2.55) produces the smallest plant (32.75) although it produces maximum number of new pseudo bulbs. From this experiment, it can be concluded that the presence of more number pseudo bulbs did not improve vegetative growth and flower production. The bigger size of new pseudo bulbs resulted in bigger plants, earlier spike emergence, bigger size of spikes, more florets per spike compared to smaller bulbs.This is because pseudo bulb can store water, mineral, and carbohydrates and mineral allocation to pseudo bulbs constitutes an important source of reserve for the subsequent development of the inflorescence and new shoots. So, the larger the pseudo- bulb betters the performance of the plant. Meanwhile, diseases like black spots with water-soaked patches were observed on the leaves of the old pseudo bulb plants while the newly emerged leaves and leaves from the new pseudo bulb were devoid of diseases. Apart from being plants which has economical and medicinal importance, the leaves and flowers and flower of *Phaius tankervilleae* are also used to yield natural dyes and produce indigo colour.

Conflict of interest

The authors declare that they have no conflict of interest.

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Fluctuations in soil nutrients and physico-chemical properties following controlled fire in North-Western Himalayas

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ABSTRACT

Controlled fire effect on nutrients and physico-chemical properties of soil was investigated after a span of one year of controlled fire under four land uses viz. chir pine forest (*Pinus roxburghii*), grassland, scrubland and non-fire site in chir pine (control). In March 2018, a controlled fire was caused, and soil samples were taken after one year of burning at different soil depths (*viz.* 0-5 cm, 5-10 cm and 10-15 cm). The experiment consisted of five replications in factorial randomized block design. The results revealed that in comparison to pre-fire assessment, available nitrogen, phosphorus and potassium slightly increased, whereas, soil organic carbon decreased slightly in post-fire assessment. The soil pH, electrical conductivity, bulk density and soil texture did not show any significant change after one year of burning. The study concludes that controlled fire did not cause any drastic fluctuations in nutrients and physico-chemical properties of soil and can be used as an effective management practice for combating the negative effects of wildfire on soil.

Introduction

Fires in forests are a very prevalent hazard. During the summer, the woods are strewn with dry, senescent leaves and twigs that can catch fire and be ignited by the smallest spark. Due to the widespread expansion of chir forests in many parts of the Himalayas, the frequency and intensity of forest fires has also increased. They devastate not only the forest, but also the entire fauna and flora regime by drastically disrupting a region's biodiversity and ecosystem. Natural wildfires are uncommon in grasslands and scrublands, however, fires are intentionally induced in these landuses for habitat management of various species of grasses and shrubs (Hore and Uniyal, 2008). Over the past 15 years, the global annual area burnt has averaged 348×10^6 ha i.e. 2% of global land area (Giglio *et al.,* 2013). By causing volatilization and ash transfer, fire removes organic debris and nutrients from a location (Raison *et al*., 1986). Snyman (2003) describes fire as an active agent capable of mobilizing soil nutrients and restoring fertility. However, especially in severe wildfires, nutrient loss by volatilization, leaching and erosion is a major source of soil degradation. In fact, it is regarded as a substantial disturbance in many ecosystems resulting in significant changes in characteristics of soil (Certini, 2005) and plant community (Granged *et al.,* 2011a). The alteration in the nature (Knicker, 2007) and amount of soil organic matter is one of the most typical impacts of fire (Terefe *et al.,* 2008). Many studies found a decline in soil organic carbon (C) following fire (Fernández *et al.,* 1997; Novara *et al.,* 2011), while others (Kavdir *et al.,* 2005) found no significant alteration in soil organic C compared to pre-fire level. Dooley and Treseder (2012) observed decline in microbial biomass by an average of 33.2% following wildfires in several field

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studies.Viswanathan *et al.* (2006) reported an increase in CO and NO_2 concentration by an average of 250% and 100% respectively, following wildfire resulted in environment pollution. Highly intense fires resulted in increase in sand and silt percentage and bulk density, however, soil nutrients, C stocks, N stocks, soil microbial biomass were observed to decrease by Jhariya and Singh (2021) in Bhoramdeo wildlife sanctuary, Chhattisgarh, Kumar *et al.* (2013) in Garhwal Himalayas, India and Chandra and Bhardwaj (2015). The impact of fire is very variable in time and place owing to the large number of regulating factors. Intensity, severity and regimen of fire, type of plant community, distribution of fuel on the soil, type of ash produced di, topography and aspect, soil properties, region's climate and meteorological conditions in the immediate period following fire are among these factors. According to Fernandes *et al*. (2013) controlled fire or prescribed burning is the deliberate use of fire having low intensity to accomplish a variety of objectives such as habitat management of various plant species, to reduce fuel load to prevent destructive wildfires, insect populations and invasive plants etc. under specific meteorological, fuel, and terrain circumstances. It is recognised as a management tool for minimising carbon emissions (Bennet *et al.,* 2014) and mitigating other harmful activities due to occurrence of wildfires. Major goal of controlled fires is to eliminate the fuel load which otherwise can cause a severe wildfires as well as preserving ecological processes and biodiversity (Santin and Doerr, 2016; Valkó *et al.,* 2016).We hypothesized that there would be short-term infinitesimal alteration in nutrients and physicochemical properties of soil following controlled fire and can be used as an effective management tool to put out wildfires.

Material and Methods

The study was conducted at Solan district of Himachal Pradesh, India. The research sites consists of chir pine forest, grassland, scrubland and unburnt chir pine area in same burnt chir pine plantations (control) under the Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry. The region lies at 30º52′ North latitude and 77º11′ East longitude (1260 m above mean sea level). The research site lies under the sub-temperate, sub-humid agro-climatic zone-II of Himachal Pradesh, with an annual precipitation of nearly 1115mm (approximately three-fourth of it is received during June to September. Winter rains are few and far between, falling mostly in January and February. May&June are the hottest and December&January are the coldest months. Soil texture of experimental site was worked out to be gravelly silty clay loam. Rao (1998) reported that the soil of study site is derived from inferakasol which consists of calcareous shales, carbonaceous shales and dolomitic limestone with bands of intermittent shales. The soils of the experimental sites lies in the order Inceptisol and sub group Eutrochrept according to Soil Taxonomy of USDA.

Experimental Design

Four experimental sites representing three different ecosystems and a control of unburnt chir pine site were selected. Initial soil samples were taken in the month of March, 2018 at three soil depths (0-5 cm, 5-10 cm and 10-15 cm) from a square having plot size of 50m× 50m for each land use. There were five replications in factorial randomized block design and each sampling square was nearly 5m apart from neighbouring square. A controlled fire was caused using stacks of vegetation which are ignited across a tract on the top of slope and then, burnt downslope at low-intensity under the supervision of officials and fire-fighters of Himachal Pradesh Forest Deparment in all selected land uses in order to simulate natural wildfire.

Sampling and Analysis

After one year of controlled fire, soil samples were collected in March, 2019 from the same place from where pre-fire samples were collected in order to avoid sampling error at sites. Soil samples were collected using 50 mm × 54 mm cylindrical steel cores from five different locations from each treatment plot (chir pine forest, grassland, scrubland and unburnt chir pine) at three different depths (0-5 cm, 5-10 cm and 10-15 cm soil depth). A total of 60 soil samples were collected for assessment of post-fire conditions of soil. The samples were then air-dried, crushed in a wooden pestle mortar and passed through 2-mm sieve and then used. For determination of organic C in soil, soil samples were passed through 0.5 mm sieve and then used. The soil samples were analysed for available nitrogen (N), phosphorus (P), potassium

(K), organic carbon (C), soil pH, electrical conductivity (EC), bulk density and soil texture. Available N was estimated with the help of method given by Subbiah and Asija (1956). Available P was extracted by sodium bicarbonate having pH 8.5 and further determined by method given by Olsen *et al*. (1954). Available K was extracted with the help of procedure given by Mervin and Peech (1951) and K content in the filtrate was determined on the flame photometer. Rapid titration method was used for the determination of soil organic C (Walkley and Black, 1934). The soil pH and EC were estimated as described by Jackson (1973). Core sampler method given by Black (1965) was used for the estimation of bulk density of the unprocessed soil samples.

Statistical Analysis

Data on soil nutrients and physicochemical properties post-fire were analysed by two-way analysis of variance (ANOVA) as per the model suggested by Panse and Sukhatme (2000). The data recorded was analysed using MS-Excel, OPSTAT and SPSS 16.0 package software as per design of the experiment.

Results and Discussion

Fire effects on available N, P and K

After twelve months of controlled fire, a slight increase in available nitrogen was observed under all the landuses compared to pre-fire level. At 0-5 cm depth, the highest % increase in available N was observed under burnt chir pine forest reaching upto 2.84 % (Figure 1) whereas, lowest was found under grassland soil (0.73 %) (Figure 2). At 5-10 cm and 10-15 cm soil depth, % increase in available N was found highest under scrubland (1.39 % and 3.17 %, respectively). On comparison of different depths, available N was found maximum at 10-15 cm depth in all the land uses except for burnt chir pine forest. The nitrogen content increased by 0.70 to 3.17 % in burnt sites, and 0.47 to 1.17 % in unburnt chir pine.

Available P and K were observed to increase infinitesimally after one year of controlled fire in all the land uses in all three depths. Highest increase of 5.76 % in available P was found under burnt chir pine forest and grassland soil at 10-15 cm depth and 5-10 cm soil depth, respectively, whereas lowest increase was found under control one (0.84 %) (Figure 4). In burnt chir pine forest, grassland and scrubland soil (Figure 1, 2, 3), % increase in available potassium was found highest at 5-10 cm soil depth *viz.*1.27 %, 1.84 % and 1.06%, respectively. In unburnt chir pine, highest % increase (0.77 %) was observed at 10-15 cm soil depth (Figure 4). The data on soil nutrient content post-fire revealed that controlled fire had positive impact on available N, P and K. Weston and Attiwill (1990) reported similar results who observed increase in N after 200 days of controlled fire. However, Fisher and Binkley (2000) reported decrement in available N following fire because of some loss through volatilization. Serrasolsas and Khanna (1995), Romanya *et al*. (1994) and Macadam (1987) reported that fires resulted in an enrichment of available P. Similarly, Lavoie *et al*. (2010) and Shakesby *et al*. (2015) found that prescribed fire resulted in an increase in available K. After prescribed fire, an increase in nutrients in the mineral soil was found (Kennard and Gholz, 2001; Úbeda *et al.,* 2005; Shakesby *et al.,* 2015; Alcañiz *et al.,* 2016) due to two reasons: 1. Formation of and its further incorporation into the soil and 2. Release of basic cations from the soil organic matter. Inorganic N content was found higher in burnt sites over unburnt sites (Singh and Singh, 2014). Increase in available potassium post-fire in upper layers of soil was reported by Kumar *et al.* (2013).

Fire effects on soil physico-chemical properties

Organic C

After one year of experimental fire, there was a slight decrease in soil organic C in comparison to initial levels. At 0-5 cm depth, highest % decrease in organic C was found under burnt chir pine forest (1.63%) (Figure 5), whereas lowest decrease of 0.76 % was found under scrubland soil (Figure7).

At 5-10 cm depth, % decrease in organic C was found highest under scrubland (3.28%) which differs slightly from grassland (2.46%) after one year of controlled fire. Lowest decrease of 0.86 % was found under burnt chir pine forest. At 10-15 cm soil depth, grassland soil (1.68%) was found to have highest decrease in organic C (Figure 6), whereas lowest decrease was found under scrubland (0.85%) (Figure7). In unburnt chir pine forest (control), organic C was found to increase in all three depths at the end of experiment (9.76% in

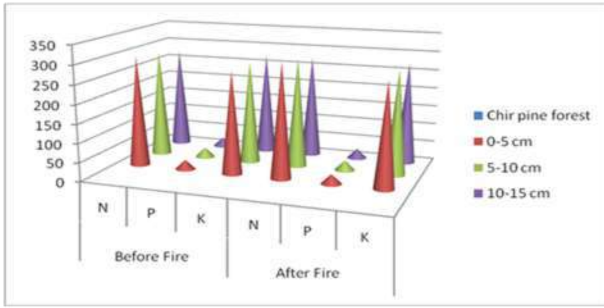

Figure 1: Available nutrient content in chir pine forest before and after fire

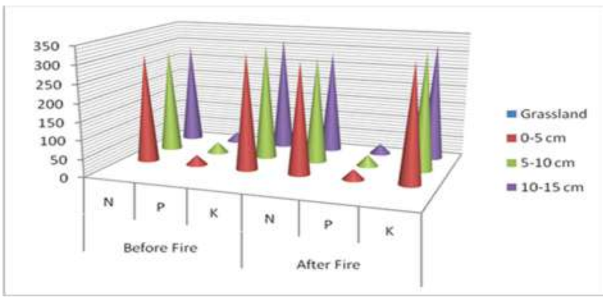

Figure 2: Available nutrient content in grassland before and after fire

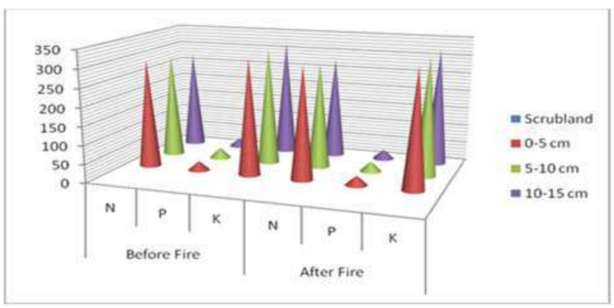

Figure 3: Available nutrient content in scrubland before and after fire

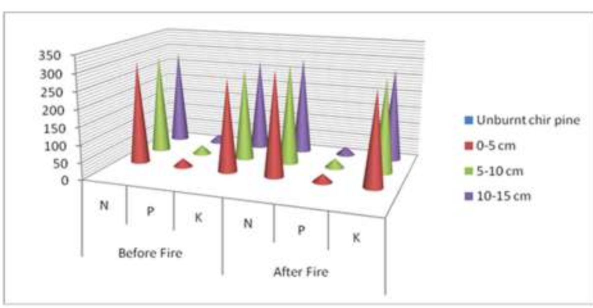

Figure 4: Available nutrient content in unburnt chir pine forest before and after fire

0-5 cm, 7.76% in 5-10 cm and 11.4% in 10-15 cm soil depth). The data on organic C inferred that controlled fire did not alter organic C content drastically, however, it was slightly lower than pre-fire level. Decrement in soil organic C content was ephemeral. This corroborates the findings of Andreu *et al*. (1996) and Johnson and Curtis (2001) who found that less intense prescribed fire may cause little loss in soil C initially as compared to unburnt site, but may result in later gains due to the addition of unburned residues with time (including charcoal). Chandra and Bhardwaj (2015), Verma *et al.* (2019) and Jhariya and Singh (2021) also reported lower levels of soil organic C in burnt sites over unburnt sites. However, Úbeda *et al*. (2005) and Granged *et al*. (2011b) reported no significant alteration in soil organic C content after controlled fire.

Bulk density

After controlled burning, bulk density in all the land uses was found to increases extremely small i.e. less than 1 %, except for grassland (1.74%). Highest % increase in bulk density was found in grassland at 5-10 cm soil depth. Overall, change in bulk density was found non-significant under all land uses (Figure 5, 6, 7). Similar result were reported by some other scientists (Phillips *et al.,* 2000; Grady and Hart (2006); Pierson *et al*. (2008); Meira-Castro *et al.,* 2014) who reported that bulk density did not differ significantly after prescribed fires.

Electrical conductivity and Soil pH

After one year of controlled fire, an infinitesimal increase in electrical conductivity of soil was observed in all the land uses (Figure 5, 6, 7) i.e. 2.14% in burnt chir pine forest, 1.92% in grassland and 1.84% in scrubland, except for unburnt chir pine forest. At 10-15 cm depth, in scrubland and unburnt chir pine forest, EC was found to decrease by -1.85% and -2.12%, respectively. This corroborates the findings of other scientist who reported that electrical conductivity was slightly increased after fire in burnt plots than in unburnt plot due to the release of inorganic ions from the combusted soil organic matter (Naidu and Srivasuki, 1994; Hernandez *et al.,* 1997 and Verma et al., 2019). Soil pH was found to increase in all land uses post-fire. When different land uses were compared for 0-5 cm depth (Figure 5,6,7), highest increase was observed under burnt chir pine forest and lowest was observed under scrubland, whereas, no change was observed under control one. Our results were supported by the findings of Arocena and Opio (2003), Scharenbroch *et al*. (2012);

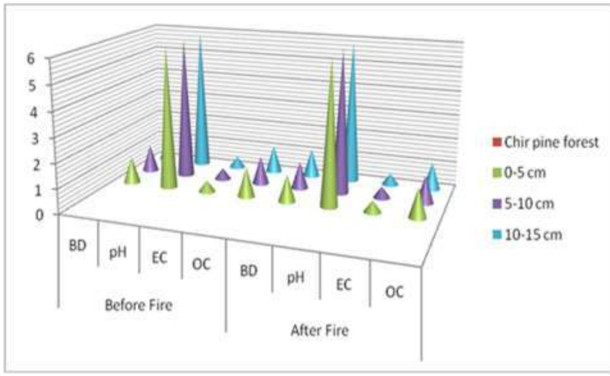

Figure 5: Soil physico-chemical properties in chir pine forest before and after fire

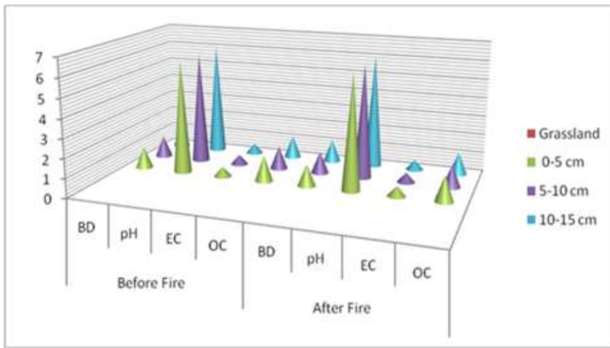

Figure 6: Soil physico-chemical properties in grassland before and after fire

Switzer *et al*. (2012) and Verma *et al.* (2019) who observed post-fire increase in soil pH due to burning of fuel and the consequent release of bases. On the contrary, Meira-Castro *et al*. (2014) and Alcaniz *et al*. (2016) reported that pH values remain unaltered post-fire.

Soil texture

The texture of soil after the fire season (12 months) remained the same and was worked out to be gravelly silty clay loam. The research findings of Pierson *et al*. (2008) also supported our results.

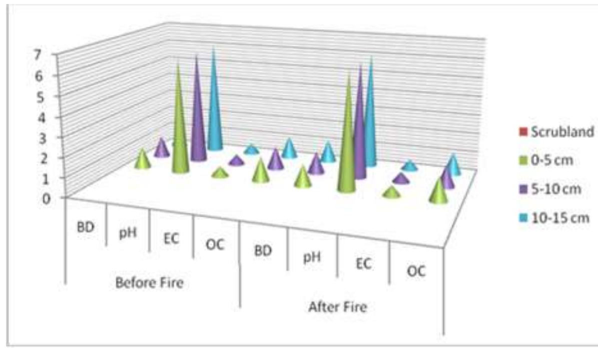

Figure 7: Soil physico-chemical properties in scrubland before and after fire.

Conclusion

We concluded that controlled fire causes slight alterations in nutrient content and organic C of soil and that too for a shorter period of time in comparison to wildfires. Therefore, controlled fire can be used as a management tool for controlling wildfires which otherwise can cause a huge damage to fauna, flora and also results in environment pollution.

Conflict of interest

The authors declare that they have no conflict of interest.

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Drought in Indian perspective, its impact on major crops and livestock and remedial measures

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ABSTRACT

Drought is one of the important natural disasters which lead to maximum severity to human among all others. The vulnerability increases with the resource poor nature of developing and under developing nations. Considering the extent of rainfed area in India, the vulnerability to drought is higher compared to other peer nations. It has implications on agriculture, livestock, fisheries, rural employment, human nutrition and health. However, the impact initiates with crop production and encompasses livestock in medium term which has severe economic implications for farmer. Therefore, it is desirable to present an extensive study on the impact of drought on major crops and livestock in India. Further, we have also emphasized on the remedial measures to be followed for crop production and livestock.

Introduction

Drought is one of the several atmospheric phenomena which has catastrophic implication for life and livelihoods of the particular country. It is defined in various contexts from shortage of rainfall compared to the long period average, reduction in soil moisture and levels of water resources to the shortfall in ET demands of the crops. Increased incidence of disasters is the new normal, and drought incidence (along with other weather and climate related disasters) frequency has quadrupled from average 40 per decade in 1970s to 150 in 2010s (FAO, 2021). Drought is among the other extreme meteorological events such as heat waves, storms etc which can worsen other high impact events such as flooding, landslides, wildfires and avalanches (WMO, 2020). Drought causes short and medium term water shortage and reduces yield of crop and livestock under extreme heat stress (FAO, 2021). Drought is an extreme climatic event whose intensity and duration increases slowly and can have hydrological and socio-economic impacts including wild-fires, loss of crops and livestock, water scarcity, migration, increase in food prices and health effects (Mukherjee *et al.,* 2018). The severity of drought can be gauged from the fact that it is dependent on twin atmospheric conditions *i.e.* prevailing precipitation and the temperature. While the former supplements the water, later put a demand on it and thus balance of two determine the drought conditions. Historically, precipitation is considered as the major cause of drought, however, with global warming scenario, rising evaporative demand is considered as major cause of drought events (Zhao and Dai, 2015). Drought is classified as meteorological, hydrological, agricultural and socio-economic, depending on the extent and severity of its impact. At individual plant level, it can bring physiological and biochemical stress which is manifested in the form of reduced growth and yield and at crop level, it impacts the gross harvesting of solar radiation and consequent yields which ultimately disrupts the food security and economy of the nation(s). Drought has impacted parts of interior South America in 2020 with an

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estimation of loss of $ 3 billion in agriculture in Brazil alone whereas in parts of South Africa, it is continued to persist (WMO, 2020); however, prolonged drought along with conflict has resulted in the famine in Somalia between October, 2010 to April, 2012 (FAO, 2017) .Globally agriculture supports livelihood of 2.5 million peoples and on account of its direct interaction with the environment, reliance on natural resources for production and importance in socio-economic development of nation, urgent actions are needed to build resilient agricultural systems (FAO, 2021).If only impact of drought is considered agriculture share rose to 84% whereas it is upto 25% with climate related disasters (FAO, 2017).There are evidences of the shift in climatic regimes which has increased the vulnerability towards the drought. It is evident from the recent impact of climatic extremes that ecosystems and human lives are vulnerable to heat waves, drought, floods, cyclones and wildfires (IPCC, 2014).It is important to have a comprehensive strategy for the drought management as it starts as small event of precipitation deficit and affects the soil moisture, hydrology and agriculture of the particular place (Rajasivaranjan, 2015). To mitigate impacts of drought along with other extreme events, it is suggested to integrate crop production with livestock, horticulture, apiculture, fisheries and agro-forestry (MoEFCC, 2021).

Drought in Indian perspective

The importance of drought situation to the country as whole can be gauged from the trailing facts. Agriculture contributes around 16 % of gross value addition and supports 48 % of the employment. 68 % of the total agriculture is rainfed. Around 74 % of the total rainfall is obtained during the south west monsoon. Overall drought risk to agriculture is higher in India due to the deviated monsoon, depleted ground water and food demand of population of 1.252 billion (Zhang *et al.,* 2017). The monsoon in India is characterized by its erratic behavior in terms of its spatial and temporal distribution.. The monsoon has the impact of various atmospheric phenomena such as Rossby waves/ jet streams and El-Nino which are strong in reducing rainfall over Indian sub-continent. Most of the drought conditions of the Indian summer monsoon rainfall are associated with El Niño (13 of the 18 years) indicating that about 72% of the drought years are associated with the influence of Pacific Ocean (Varikoden *et al.,* 2015). Though every El Nino year is not associated with drought, however, there is strong inverse relationship between strength of El Nino and monsoon occurrence which negatively impacts the Indian agriculture (Pandey *et al.,* 2019). Dry areas constitute 94 mha where one-third of Indian population resides and 50 % of the region is hit by drought once in four years (Sonawane *et al.,*2016).Around 28 % of total agriculture area in India is susceptible to critical water shortage (Gautam and Bana, 2014). Rainfed area in India extends over more than 100 mha (Kumar *et al.,*2014) and according to Badatya, (2005) out of total rainfed area of 104 mha, 32 % fall under the high rainfall (>1125 mm) and rest 68 % under the low and medium rainfall with states of Punjab, Haryana, Rajasthan, Gujarat, Maharashtra and Karnataka having most of the low rainfall regions. There are several criteria for assessing the severity of drought. In India, the meteorological rainfall variability of ±19 % is considered to be the normal, and deficit between 20 to 59 % is moderate drought and more than 60 % is categorized as severe drought (Samra, 2004; Badatya, 2005). In recent past, India has experienced 22 droughts, of which 5 were severe(Samra, 2004; Gautam and Bana, 2014) and there had been 12 major droughts in past five decades with successive droughts in 1965-66 and 1966-67 and the recent one in 2002-03 (Badatya, 2005). Drought is characterized by non-uniformity of its occurrence and impact. Drought has hardest impact on the Southern and Western regions, however, these states have better adaptations whereas it has significant impact on North and Central regions, but the adaptation level is lower (Amarsinghe *et al.,* 2020). It is considered that frequency of drought is once in 15 years in North Eastern India, however, it has been reported by Parida and Oinam (2015) that in the period 2000-15, eight years has experienced meteorological drought in this region. In a prediction study of 48 years (2050-2099). Ojha *et al.* (2013) predicted increase in drought incidence in west central, peninsular, and central northeast regions of India. In a study on drought characterization in India over projected climatic scenario in different time frames i.e. near-future (2010–2039), mid-future (2040–2069), and far-future (2070–2099) in comparison with reference period (1976–2005), increasing trend in drought severity, duration, occurrences, and the average length of drought under warming climate scenarios was concluded (Bisht *et al.,* 2018). Drought studies in India are important not only in context of her own food security but also for nations which are dependent on imports of food grain from India (Udmale *et al.,* 2020).

Impact on crop production

Agriculture is mainstay of Indian economy and any prolonged drought condition can jeopardize food security and bring the famine conditions. Understanding the impact of drought on crop production is itself challenging as it is complex interaction of temperature, precipitation, vapour pressure and solar radiation (Leng and Hall, 2019).In the crop production, drought can have impact from preparation of field, sowing operations, weakening of standing crops, increased vulnerability to the pest incidence and final impact on the quantity and quality of yield obtained (Gautam and Bana, 2014). The reproductive stages of the crops are more sensitive to the drought stress than vegetative stages leading to reduced flowers, pods, fruit set and number of seeds and is more severe when accompanied with heat stress and these two will be more common in current and future climate change scenario (Sehgal *et al.,* 2018).The impact of drought on the crop production shows fluctuations. In the twelve drought years, the loss in crop production when compared to previous years varied from 2.8 % in the year 1982-83 to 19 % in 1965-66 and 13.2 % in 2002-03 (Badatya, 2005). Average crop loss of 86.1 % (for both Kharif and Rabi) was reported in 2012 in Southern Maharashtra, which varied from 67.8 % in maize to 98.2 % in cotton (Udmale *et al.,* 2015).

The impact of drought among major crops of India is presented below

Rice

In India around 42 percent of the total 44 mha area under rice cultivation is rainfed (Mention the area of which country or region) (Birthal *et al.,* 2015) and drought is major constraint of rainfed rice production (Kumar *et al.,* 2014; Sharma *et al.,* 2016). Drought has been reported to reduce relative leaf water content, inhibition of cell enlargement leading to reduced leaf size, reduced tillering and plant height and increase in the mean root length (Sharma *et al.,* 2016). Multi stage drought led to the 86% reduction in yield in rice along with reduction in yield attributes; and deterioration of physiological parameters including decrease in chlorophyll content, relative water content, photosynthesis, transpiration rate, starch content and increase in proline content and lipid peroxidation when compared to non-stress, however, differences exist among growth stages and genotypes (Kumar *et al.,* 2020). Similar findings were reported by Nahar *et al.* (2018) in rice.

Wheat

Out of 29 mha under wheat cultivation in India, 3-5 mha is susceptible to drought (Sheoran *et al.,* 2015). The vegetative stage of wheat is more sensitive to drought as the root growth is reduced consequently reducing the leaf area, leaf number per plant, leaf size and leaf longevity (Zhang *et al.,* 2018). Drought reduces chlorophyll content, membrane stability, relative water content, reduction in chlorophyll fluorescence and the yield and yield components, reduction in NPK uptake and increased the catalase, peroxidase and superoxide dismutase content (Abdullah *et al.,* 2011; Nawaz *et al.,* 2012; Sheoran *et al.,* 2015), however the effect was pronounced with late stage drought stress than early season (Nawaz *et al.,* 2012). 57-59 per cent reduction occurs in iron and zinc content per hectare with drought stress in wheat (Velu *et al.,* 2016).

Sugarcane

Drought stress significantly reduces the juice quality including decrease in sucrose percentage, purity coefficient, (=Sucrose%/ Brix), commercial cane sugar %{ = (1.022 × Sucrose %) – (0.292 × ^{0}Brix)}, total soluble solids or brix, marginal decrease in pH, increase in reducing sugar content (Hemprabha *et al.,* 2004; Mishra *et al.,* 2016). Increase in proline content, SOD and peroxidase enzyme activity and decrease in plant height, single cane weight, number of millable canes, cane yield, relative water content, chlorophyll and cartenoids content was recorded with drought stress (Pawar and Bhutkar, 2011; Jain *et al.,* 2015; Santeshwari, 2021).

Oil seeds

The morphological and physiological impacts of drought on oilseeds will be similar as described under rice and wheat. In oilseeds, drought can impact the fatty acid synthesis and can lead to increase in saturated fatty acid (palmitic and stearic acid) content and decrease in unsaturated fatty acids (linoleic and linolenic acid) (El Sabagh *et al.,* 2019). Drought stress reduces rate of flower production, peg elongation rate, seed growth rate and its weight; number of mature pods; pod yield; shelling percentage; harvest index and adequate pod zone soil moisture is important for development of pegs into pods; also leads to reduction in oleic: linoleic acid ratio which reduces the keeping quality and increases aflatoxin content which was independent of the drought tolerance of genotypes (Kenchanagoudar *et al.,* 2002; Reddy *et al.,* 2003; Hamidou *et al.,* 2014), however, Dwivedi *et al.*(1996) reported increase in oleic acid content with end season drought in groundnut. Oil content reduces under the end season drought, however, it was not affected by mid-season drought (Dwivedi *et al.,* 1996; Kenchanagoudar *et al.,* 2002). Drought stress reduces the growth parameters and isoflavone content in soybean (Akhita Devi and Giridhar, 2013). There had been varying impact of drought stress on the growth and physiological parameters, yield attributing characteristics and yield of mustard depending on the genotypes (Chauhan *et al.,* 2007; Singh *et al.,* 2009). Though sunflower is considered moderately drought tolerant, any incidence of drought at critical stages can reduced photosynthesis, water potential, xylem and phloem transport, nutrient uptake, reduced capitulum diameter, number of achene per capitulum, achene weight per capitulum and ultimately achene yield, reduced oil content depending on the intensity of drought and its fatty acid composition (Nezami *et al.,* 2008; Jaleel *et al.,* 2009; Hussain *et al.,* 2018). The bud initiation stage is more critical for drought stress than seed filling in sunflower (Jaleel *et al.,* 2009).

Pulses

Pulses are generally grown under the rainfed conditions in India, therefore, more susceptible to the drought conditions. Chickpea being grown under residual moisture conditions, therefore, susceptible to terminal drought or moisture stress situations causing 40-50% global yield losses (Basu *et al.,* 2004; Jha *et al.,* 2014; Devasirvatham and Tan, 2018; Muruiki *et al.,* 2018; Sinha *et al.,* 2019). Drought stress leads to stunted growth, non-uniform plant stand, pale colored lower leaves, early senescence, reduction in days to maturity, chlorophyll content, Rubisco activity, sucrose synthesis, average reduction of 23% in number of seeds per pod, upto 54% reduction in seed size and increased incidence of dry root rot and black root rot (Kumar, 1997; Awasthi *et al.,* 2014; Sinha *et al.,* 2019). Though there had been reduction in the relative water content, photosynthetic apparatus was not impacted showing ability of chickpea to maintain turgor even under water stress conditions (Basu *et al.,* 2004). Drought stress in pigeonpea led to reduction in relative water content, stomatal conductance, transpiration rate, total chlorophyll content, enhancement in proline content, superoxide dismutase, malondialdehyde and peroxidase activity, reduction in specific nitrogenase activity and leghaemoglobin content (Nandwal *et al.,* 1991; Kumar *et al.,* 2011; Vanaja *et al.,* 2015). Flowering stage is most sensitive stage for drought stress in pigeonpea leading to 48% reduction of yield and upto 62% when combined with drought at pre-flowering (Lopez *et al.,* 1996; Nam *et al.,* 2001). Pigeonpea owing to its long duration nature will see least reduction in area under drought incidence as its sowing can be adjusted according to receipt of rainfall (Kumar *et al.,* 2014). Moisture stress at seed filling in lentil significantly reduced above ground biomass, pod number, pod weight, seed number by 41%,71%,71%,77%, respectively (Sehgal *et al.,* 2017). In greengram and blackgram, drought stress leads to reduced leaf number, plant height, shoot and root biomass, leaf area index, leaf water potential, protein content, yield and increased proline, anthocyanin, flavnoids (Baroowa and Gogoi, 2015; Baroowa and Gogoi, 2016).

Impact on livestock

Livestock has an important role in the Indian agriculture. This is more important in dryland areas where the crop yields are unpredictable and these serve as a income assurance during stress period. Drought incidence reduces the availability of the green forage as well as the dry reservoirs makes a scarcity of water for the livestock. Around 113.5 million bovines were affected in nine states of India, with seven states facing fodder shortage (except Odisha and Tamil nadu) in drought year of

2002 (Patil, 2012). Purchase of fodder and crop residues like legume hays, rice straw and sorghum stover increases with simultaneous increase in fodder cost and there is reduction in purchase of concentrate feed and rice bran (Biradar and Sridhar, 2009; Chand and Biradar, 2017). During drought years there is decrease in feed intake, loss of body weight, decline in fertility, disturbance in reproductive performances, average lactation length and yields, worsening of milk to adult female cattle ratio, increase in dry and unproductive cattle, decrease in livestock population probably due to animal death due to lack of quality fodder, distress sale of cattle and unbearable cost of livestock; it also leads to migration of livestock especially cattle and sheep (Patil, 2012; Maurya and Tripathi, 2013; Mishra, 2017; Kanwal *et al.,* 2020). To lessen the drought impact, farmers practice distress sale of cattle fetching lower prices than normal (Toulmin, 1986; Biradar and Sridhar, 2009; Udmale *et al.,* 2014; Chand and Biradar, 2017).

Mitigation measures

Agriculture is the foremost sector where mitigation should receive the priority. Singh *et al.* (2011) concluded that Indian food grain production is more vulnerable to drought than floods and among the two major seasons, kharif food grain production is more vulnerable than rabi season. Various agronomic measures for drought proofing includes availability of quality seeds, optimizing plant population, spray of anti-transpirants, application of polymers e.g. Pusa hydrogel, practicing life saving irrigation, nutrient management, practicing conservation tillage, intercropping to reduce runoff losses, selection of efficient varieties, shifting sowing according to expected rainfall pattern, mulching and *in-situ* moisture conservation, use of zero till seed drill to accomplish late sowing of wheat (Gautam and Bana, 2014; Tyagi *et al.,* 2020). Application of pusa hydrogel had improved growth and physiological parameters in rice; significantly higher yields in cotton; pusa hydrogel @ 2.5 kg/ha + organic mulch @ 5tonnes/ha in pigeonpea recorded highest yields and net return (Sen *et al.,* 2019; Ashraf *et al.,* 2020; Jadhav *et al.,* 2020).

Krishna and Ramanjaneyulu (2012) reported effectiveness of life saving irrigation through sprinkler, ridge and furrow method over flatbed method and intercropping of Castor+redgram (1:1) in terms of yield and net returns. Some of the critical stages for irrigation in pulses are given table 1. However, the drought areas should have supplementary irrigation scheduled on the basis of incidence of dry spell rather than critical stage concept, generally 10-15 days depending on the soil texture (Reddy and Reddy, 2016). Water harvesting for this supplemental irrigation can be done by construction of some feasible system like earthern dam on gully head, community tanks, small tanks for individual farmers preferably located at the lowest point of the catchment, with capacity to completely full at the end of monsoon, maximum volume with minimum exposed surface so as to reduce evaporation losses and lining for reducing the seepage losses (Verma, 1981).Mulching is effective under drought stress. Yield levels were significantly higher with plastic mulch under 75% moisture stress in capsicum; with double mulching with organic material for crops in rotation with maize; fruit yield in ber with black polythene or date palm leaves mulch along with supplementary irrigation; 24-28% higher okra yields with organic mulches compared to no mulch under moisture stress; mulching with crop residues along with compartmental bunding reported highest groundnut yield and water use efficiency (Thakur *et al.,* 2000; Bahadur *et al.,* 2013; Meghwal and Kumar, 2014; Ngangom *et al.,* 2020; Pandian *et al.,* 2020). *Insitu*water conservation measures involving alteration in land configuration also proved successful in enhancing yield in drought prone rainfed areas (Table 2).

Mineral nutrition has an important role in inducing drought tolerance in plants. The metabolic role of nutrients is presented in table 3. Moderate nitrogen supply in maize enhanced drought tolerance through enhanced nitrate concentration, nitrate reductase activity, abscisic acid content; higher N supply increased cell membrane stability in soybean; foliar application of N at flowering enhanced seed yield and protein content under terminal drought stress in chickpea; moderate dose of nitrogen recorded highest wheat yield under drought stress (Palta *et al.,* 2005; Premachandra *et al.,* 2009; Song *et al.,* 2019; Sedri *et al.,* 2019). Phosphorus application enhanced relative water content, photosynthetic rate and yield of mothbean under drought stress; grain yield was compensate by application of P, Fe and Si under moisture stress with that of irrigated rice crop; number of tubers

Table 1: Critial stages for various pulses for yield maximization under limited irrigation water availability (Praharaj*et al.,* 2016)

Pulse crop	Critical stage
Chickpea	1 irrigation at 50% flowering/ pod development stage; 2 irrigations at branching and pod formation.
Pigeonpea	2 irrigations at branching and pod formation.
Fieldpea	50% flowering.
Lentil	Early pod filling stage.
Rabi pigeonpea	25 days crop stage.

Table 2: Yield gain by practicing various in-situ moisture conservation practices under drought conditions

Conservation measures	State and crop	Yield gain over control (%)	Reference
Trenching	Uttarakhand; Rice	32.9- 58.4	Kumar *et al.,* 2014
Continous Trenching	Maharashtra; Mandarin	29.2	Panigrahi*et al.,* 2009
Modified Crecsent bund	Karnataka; Cashew	32.2	Rejani and Yadukumar, 2010
Scooping	Karnataka; Sorghum	11-12	Mishra and Patil, 2008
Field Bunding	Rajasthan; Chickpea	18	Regar*et al.,* 2010
Field Bunding	Rajasthan; Sorghum	10.5	Rao *et al.,* 2010
Paired row planting with conservation furrow between two rows	Telangana; Pigeonpea	34.25	Rao *et al.,* 2018

Table 3: Specific metabolic functions of various mineral nutrients under drought stress in plants (Hawkesford *et al.,* 2012; Broadley *et al.,* 2012)

Nutrient	Specific metabolic functions under drought conditions.
Nitrogen	Synthesis of betaine which act as compatible solute and counteracts high vacuolar concentration of inorganic ions like Na^+ and Cl^- which inhibits Cytoplasmic metabolism.
Potassium	Regulates the stomatal movement by changing turgor of guard cells; maintaining osmotic pressure in vacuole; avoidance of oxidative stress; pH stabilization of chloroplast stroma.
Sulphur	Strong disulphide bridge (-SH group) in proteins which provides cellular resistance to dehydration caused by drought.
Magnesium	Deficiency leads to impairment of root growth and thus impacting drought resistance.
Calcium	Increase in cytosolic Ca concentration act as signal under drought stress.
Manganese	Mn SOD induces enhanced drought tolerance.
Molybdenum	Component of aldehyde oxidase enzyme which causes coversion of abscisic aldehyde to abscisic acid (ABA) which is important for inducing drought tolerance in plants.

and yield was increased with P application under moisture stress (Garg *et al.,* 2004; Motalebifard *et al.,* 2013; Kumar *et al.,* 2019). Spray of 2 % KCl at flowering and siliqua formation stage in toria recorded significantly higher yields and yield attributes under rainfed conditions (Sarma *et al.,* 2015); ameliorating effect of K application on relative water content and chlorophyll in sugarbeet (Aksu and Altay, 2020); K application at pre-flowering and pod development stage improved mungbean performance under drought (Umar *et al.,* 2019); split K application improved yield parameters in groundnut under drought stress (Patro *et al.,* 2018); enhanced seed yield of mustard and sorghum under drought stress with higher K dose and of groundnut under moderate K dose (Umar, 2006). Crop diversification can be practiced in form of crop rotation and intercropping/ mixed cropping. Mixed/ intercropping have variable adaptations to climate threats and can enhance the productivity in extreme weather and low input farms whereas crop rotation can reduce soil degradation, can improve water use efficiency and can enhance productivity (Patel *et al.,* 2020). Substituting maize with sorghum, sesame, blackgram, groundnut, greengram, clusterbean under low and erratic rainfall pattern proved efficient increasing maize equivalent yields, rain water use efficiency and B:C ratio (Jat *et al.,* 2011). Strip cropping was most suited for pearlmillet+ legumes compared to their mixed and intercropping under severe moisture stress giving yields greater or at par to the sole pearlmillet and LER value> 1 (Singh and Joshi, 1994).Selection of genotypes has a larger role in mitigation. A drought tolerant variety developed by IRRI, released as *Sahbhagidhan* in India, is short duration variety, have genetic drought tolerance and more efficient in extracting moisture (Dar *et al.,* 2020) and its short duration nature escapes high temperature and allow farmer to grow another crop after harvest (Yamano *et al.,* 2018). Some other drought tolerant varieties developed are CR Dhan-201, CR Dhan 801 an CR Dhan, 802 for rice (MoEFCC, 2021). Birthal *et al.* (2012) reported 23 per cent yield advantage with ICGV91114 compared to dominant groundnut variety TMV-2 in Ananthpur district. Among eight varieites, SPV-1591 and among six hybrids, CSH 15R had significantly higher yields under rainfedrabi season at Bellary (Patil, 2007). Among the fifteen wheat varieties, NI-5439, WH-1021, HD-2733 found to be best suited for moisture stress conditions (Meena *et al.,* 2015). Livestock has important role to play in drought prone regions, some of the important breeds of dry areas are *Tharparkar, Rathi, Kankrej*(Cattle);*Marwari, Jaisalmeri, Patanwadi, nail* (sheep);*Marwari, kutchi*(goats) and *Bikaneri, Jaisalmeri*(camel) (Patil *et al.,* 2006). The various measures suggested for feed maintenance are thinning of the crop to increase their vegetative growth, increasing grass production in fallow and community areas, maximum utilization of the green herbage and agro-industrial waste, chaffing of forage, feeding of chopped forage for better digestion, hay making, enriching forage with urea treatment (Mishra, 2017). Some other important measures for livestock management includes controlled grazing, introduction of high yielding perennial grasses, silvipastoral system for areas having rainfall< 200mm,strategic feeding of cattle includes preferential feeding to productive stock such as pregnant and lactating cattle, feed supply for maintenance of minimum body weight, urea/ ammonia treated straw saves the cost of concentrate feed; multinutrient bricks/ blocks of molasses, urea, mineral and vitamins as lick for large animals and feed for small ruminants (Patil *et al.,* 2006).

Conclusion

Drought has serious implications for the agriculture and livestock sector and thus, can disrupt the life in vulnerable areas. It is possible to avert the dark consequences of spontaneous drought through the preparedness in form of early warning and drought proofing. Drought has varying impact on production of crops depending on the adaptation of the particular state. In the drought year of 2009, there was rainfall deficit of 23, 34 and 35 % for the Jharkhand, Punjab and Haryana respectively, however, Punjab and Haryana has shown a net increase of paddy production (6.6 and5.8 respectively) from triennium (2006-08) average and Jharkhand had witnessed reduction of 52.6 % owing to only 8 % of net sown area under irrigation compared to 86 and 98 % in Haryana and Punjab, respectively. Though we have discussed the specific impacts of drought on agriculture and livestock, it is needed to have holistic approach in its management considering availability of timely credit, other non farm employment, food grain supply. Long term area wide planning in form of water shed, water harvesting structures etc are necessary, however, short term mitigation measures such as availability of drinking water, fodder and concentrates, seed and technical inputs, government intervention are equally desirable.

Conflict of interest

The authors declare that they have no conflict of interest.

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Assessment of water footprint based on estimated crop evapotranspiration for paddy, sugarcane and banana under semi-arid climate

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ABSTRACT

Climate change impact has adverse effects on water use in crop production. A better crop water use indicators to decide upon the water use policies of that region or country is necessary. Water footprint indicates relationship between water use and crop yield. Rice, sugarcane and banana are the major crops which require a significant amount of water in Lalgudi block of Trichy district in Tamil Nadu. This study analyzed the total water requirement, blue and green crop evapotranspiration, blue and green crop water use and blue, green and total water footprint for paddy, sugarcane and banana in Lalgudi block. The crop water footprint estimated by using FAO56-K_c for paddy, sugarcane and banana was 2173 m^3 ton^{-1}, 304 m^3/ton and 501 m^3/ton respectively. And by using ClimAdj-Kc, the crop water footprint for paddy, sugarcane and banana was 2228 m^3 ton^{-1}, 307 m^3/tonand 503 m^3/tonrespectively. It was found that quantity of water used for producing per ton of yield was higher in paddy in comparison to banana and sugarcane.

Introduction

A great stress occurs on water resources because of increasing consumptive use and non-consumptive use of water and changing climatic conditions (Jose *et al.,* 2010). The outcome in agricultural production is greatly affected by reduced supply of freshwater for irrigation in many river basins located in the semi-arid and arid regions. Burning problem of water scarcity is forcing the water managers to evolve a better crop water use indicators to decide upon the water use policies of that region or country. Water Footprint is a relatively new indicator that look in to the water use from production and consumption perspectives (Hoekstra and Hung, 2002). It is defined as the "*total volume of freshwater used to produce the goods and services consumed by the individual or community or produced by the business*". Crop water footprint is used for quantifying the crop water requirement based on the source of water and also addresses the amount of water used for producing a unit quantity of crop yield. For agricultural products, the water footprint is commonly expressed in terms of volume of water used per quantity of crop produced (m^3 ton^{-1} or litres kg^{-1}). Hoekstra *et al.* (2011) defined green water footprint as "*volume of rainwater consumed during the production process and is particularly relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainwater evapotranspiration (from*

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fields and plantations) plus the water incorporated into the harvested crop or wood". Blue water footprint is defined as "*volume of surface and groundwater consumed as a result of the production of a good or service. Consumption refers to the volume of freshwater used and then evaporated or incorporated into a product*".
Maximizing the land productivity (ton ha^{-1}) is the primary objective in agriculture when land is scarce and freshwater is abundant. Maximizing water productivity is more important when water is scarcer than land. Hence, less irrigation water (blue water) is applied in a smarter way and higher yield per cubic meter of water evaporated is obtained (Hoekstra *et al.,* 2011). Prasad *et al.* (2013) quantified the blue and green proportions of crop evapotranspiration of six important crops of Kothakunda sub watershed in Andra Pradesh. Kar *et al.* (2014) quantified field level water footprint of rice production in eastern India based on measured ETc. The measured values were compared with other three methods like Pan Evaporimeter, Bowen ratio and Penman Monteith methods. Mali *et al.* (2015) assessed blue and green components of evapotranspiration of 15 major crops grown in agricultural production units of Gomati basin. CROPWAT model was used for estimation of green and blue components of evapotranspiration. Veettil and Mishra (2016) indicated that due to changing pattern in climate variable and sectorial water demands, studies related to spatio-temporal variability of water footprints indicators is desirable for formulating water management practices. Zhao *et al.* (2016) investigated the scenario of blue and green water resources under various land use, irrigation and climate variability in spatial and temporal aspects.
In this paper, the total water requirement, blue and green crop evapotranspiration, blue and green crop water use and blue, green and total water footprint for paddy, sugarcane and banana was estimated in Lalgudi block Lalgudi block of Trichy district in Tamil Nadu.

Material and Methods
Study Area
Lalgudi block, located at Tiruchirapalli District, Tamil Nadu, India was selected for this study (Figure 1). Lalgudi block is situated at 10°52'27" N and 78°48'57" E geo-coordinate and located 70 m above mean sea level. The total geographical area of the block is 20558 hectares. Lalgudi block has semi-arid climate with an average rainfall of 877 mm. Agriculture is the main occupation of Lalgudi block. Around 45 percent of area in Lalgudi block is used for agriculture. In Lalgudi block, 90 percent of the crop production is done by irrigation and the remaining 10 percent is under rainfed cropping. The major sources of irrigation are canals, bore wells, tanks and ponds. Paddy, sugarcane, banana and other vegetables are grown in the study area. In recent decades, water demand always exceeds rainfall and at the same time, exploitation of groundwater has increased greatly particularly for agriculture.

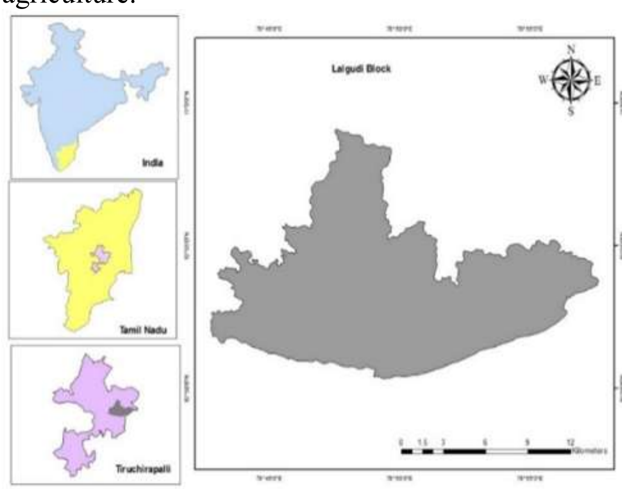

Figure 1: Location of study area – Lalgudi block (Trichy district)

Meteorological Data
The daily maximum and minimum air temperature and relative humidity for the period 1995-2017 was collected from the meteorological observatory located at Agricultural Engineering College and Research Institute, Kumulur, Lalgudi Block of Trichy district.

Estimation of Crop Water Requirement Using Cropwat
CROPWAT 8.0 was used to estimate the crop water requirement. Firstly, monthly reference evapotranspiration was estimated by FAO56 – Penman Monteith equation in CROPWAT from the meteorological data collected from the observatory.

The equation for estimating the daily grass-reference evapotranspiration is given by

$$ET_0 = \frac{0.408 * \Delta(R_n - G) + \gamma \frac{900}{[T+273]} * u * (e_a - e_d)}{\Delta + \gamma(1 + 0.34 * u)} \quad (1)$$

Where ET_0 reference evapotranspiration [mm day^{-1}], Δ is slope of vapour pressure curve [kPa °C^{-1}], γ is psychrometric constant [kPa °C^{-1}], R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}], T is mean daily air temperature [°C], G is soil heat flux density [MJ m^{-2} day^{-1}], u is wind speed at 2 m height [m s^{-1}], e_s is saturation vapour pressure [kPa], e_a is actual vapour pressure [kPa], and e_s-e_a is saturation vapour pressure deficit [kPa].

The full dataset used in estimating reference evapotranspiration was collected from the meteorological observatory located at Agricultural Engineering College and Research Institute, Kumulur, Lalgudi Taluk, Trichy. The effective rainfall (P_{eff}) was calculated by using Soil Conservation Service method. The rainfall data was also collected from the meteorological observatory located at Agricultural Engineering College and Research Institute, Kumulur, Lalgudi Taluk, Trichy. The crop evapotranspiration (ET_c) under optimal conditions was estimated which is equal to crop water requirement (CWR). ET_c was estimated at a ten day time step throughout the total growing season.

The model calculates ET_c as follow as:

$$ET_c = ET_o * K_c \quad (2)$$

Here, ET_o represents the reference evapotranspiration and K_c refers to the crop coefficient. The crop coefficient is calculated by two methods as explained below.

Estimation of crop coefficients

Crop coefficients are used to estimate the crop water requirement. Generally, the value of crop coefficient is taken from the FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998) for different crops at different stages and the crop water requirement is calculated. There are numerous other methods to estimate the site-specific crop coefficients. The following two methods were used in determination of K_c for paddy, sugarcane and banana.

FAO56 Tabulated K_c

In this method, the value of Kc was taken from the tabulated Kc values (hereafter referred as FAO56-Kc) given in the FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998) for different crops at different stages, mean maximum plant height, non-stressed, well-managed crops in sub-humid climates.

Adjusted Kc for Local Climatic Conditions

The adjusted Kc values with respect to the local climatic effect (hereafter referred as ClimAdj-Kc) were estimated for mid and end stage for paddy, sugarcane and banana by using the following equations as given in FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998). For mid-season growth stage, Kc is given by:

$$K_{c\_mid} = K_{c\_mid(Tab)} + \left[0.04(u-2) - 0.004(RH_{min} - 45)\right]\left(\frac{h}{3}\right)^{0.3} \quad (3)$$

Where Kc_mid(Tab) is crop coefficient value tabulated in FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998) for midseason growth stage; u is as indicated in equation 1, RHmin is average daily minimum relative humidity and h is the mean plant height during the mid-season stage. Similarly, for end-season growth stage, the adjusted Kc value is obtained by using the following equation:

$$K_{c\_end} = K_{c\_end(Tab)} + \left[0.04(u-2) - 0.004(RH_{min} - 45)\right]\left(\frac{h}{3}\right)^{0.3} \quad (4)$$

Where Kc_end(Tab) is crop coefficient value tabulated in FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998) for end season growth stage and u, RHmin and h are as indicated in equation 3. Allen et al. (1998) suggested that in planning studies, the typical value for initial crop coefficient (Kc_ini) given in FAO56 Crop Evapotranspiration guidelines can be used in estimation of crop evapotranspiration. Hence for initial stage alone the crop coefficients given in FAO56 Crop Evapotranspiration guidelines was used.

Estimation of blue and green water evapotranspiration

Green water evapotranspiration (ET_{green}) was calculated as the minimum of total crop evapotranspiration (ET_c) and effective rainfall (P_{eff}) at ten day time step.

$$ET_{green} = \min\left(ET_c, P_{eff}\right) \quad (5)$$

The blue water evapotranspiration (ET_{blue}) was calculated as the difference between the total crop evapotranspiration (ET_c) and the total effective rainfall (P_{eff}) and if the effective rainfall is greater than total crop evapotranspiration ET_{blue} is equal to zero..

$$ET_{blue} = \max\left(0, ET_c - P_{eff}\right) \quad (6)$$

Adding ET_{blue} over the whole growing period, total ET_{blue} is obtained. Also, percolation loss of 5 mm day^{-1} was included with total crop evapotranspiration for paddy (except during the end stage). For banana and sugarcane, other water losses of 1 mm day^{-1} was included with total crop evapotranspiration.

Estimation of crop water footprint

First, the estimated crop evapotranspiration in mm is converted to m^3 ha^{-1} by applying a factor 10 which is called as crop water use.

$$CWU_{green} = 10 * ET_{green} \quad (7)$$

$$CWU_{blue} = 10 * ET_{blue} \quad (8)$$

The green component of water footprint ($WF_{proc,green}$, m^3 ton^{-1}) was calculated as the green component in crop water use (CWU_{green}, m^3 ha^{-1}) divided by the crop yield Y (ton ha^{-1}). The blue component of water footprint ($WF_{proc,blue}$, m^3 ton^{-1}) was calculated from blue component in crop water use (CWU_{green}, m^3 ha^{-1}) in the similar way. The equations used are listed below:

$$WF_{proc,green} = \frac{CWU_{green}}{Y} \quad (9)$$

$$WF_{proc,blue} = \frac{CWU_{blue}}{Y} \quad (10)$$

Thus the methodology adopted to achieve the framed objectives is clearly presented in the above section.

Results and Discussion

FAO56 tabulated Kc

The FAO56-Kc for paddy, sugarcane and banana at different stages are presented in Table 2. The number of days in Initial (Ini), Development (Dev), Middle (Mid) and End stages during the crop period was taken from FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998) and shown in Table 1. The K_c coefficient incorporates crop characteristics and averaged effects of evaporation from the soil.

Adjusted K_c for local climatic conditions

The ClimAdj-K_c values with respect to the local climatic effect estimated for mid and end stage for paddy, sugarcane and banana by using the FAO56 Crop Evapotranspiration guidelines is presented in the following table 2. (Allen *et al.,* (1998)) suggested that in planning studies, the typical value for initial crop coefficient (Kc_ini) given in FAO56 Crop Evapotranspiration guidelines can be used in estimation of crop evapotranspiration. Hence, for initial stage alone the crop coefficients given in given in FAO56 Crop Evapotranspiration guidelines was used and presented in table 2. The ClimAdj-K_c values of sugarcane obtained in this study is comparable to the values determined by Dingre and Gorantiwar (2020) during grand growth and maturity stages of sugarcane (1.20 and 0.78, respectively). Dingre and Gorantiwar (2020) also determined the K_c value for sugarcane in a semi-arid region of India.

Crop water footprint

The crop water requirement was estimated in CROPWAT 8.0, by using the K_c values obtained by the two methods as discussed in the previous section. The total water requirement, blue and green crop evapotranspiration, blue and green crop water use and blue, green and total water footprint for paddy, sugarcane and banana is presented in Table 3-5 respectively. The total water requirement estimated by ClimAdj-Kc was higher for paddy, sugarcane and banana compared to FAO56-Kc. Since ClimAdj-Kc considers the local climatic and agronomic conditions of crops, the total water requirement estimated with ClimAdj-Kc values is high.

Water footprint for paddy

The water footprint in paddy by using FAO56-Kc and ClimAdj-Kc was 2173 and 2228 m^3 ton^{-1} respectively. The water footprint for paddy is high compared to banana and sugarcane. But when compared to banana and sugarcane, the total water requirement for paddy is low. Kar *et al.* (2014) also reported that the water footprint for two varieties of paddy (varieties: 'Lalat' and 'Gayatri') was 2470 and 2704 m^3 ton^{-1} respectively in Puri, Odisha. In paddy only 12 % of total water requirement is satisfied by green water (effective rainfall) whereas remaining amount of water in satisfied by blue water resources like groundwater, canals, wells and lake. The following strategies may be adopted to reduce the water footprint without affecting the yield and income of the farmers. The practice of deficit irrigation strategy instead of full irrigation helps in reducing water consumption while having

Table 1: Tabulated Kc values and crop parameters

Crop	Stages (Days)				K_c		
	Ini	Dev	Mid	End	Ini	Mid	End
Paddy	30	30	60	30	1.05	1.2	0.85
Sugarcane	40	70	170	30	0.45	1.25	0.75
Banana	120	90	120	60	0.50	1.10	1.00

Source: FAO56 Crop Evapotranspiration guidelines (Allen *et al.,* 1998)

Table 2: ClimAdj-Kc value for different crops in Lalgudi Block

SN	Crop	Ini	Mid	End
1	Paddy	1.15	1.23	0.90
2	Banana	0.50	1.11	1.00
3	Sugarcane	0.45	1.26	0.80

Table 3: Crop water footprint for paddy crop

Approach	Total Water Requirement (mm)	ET_{Green} (mm)	ET_{Blue} (mm)	CWU_{Green} (m^3 ha^{-1})	CWU_{Blue} (m^3 ha^{-1})	WF_{Green} (m^3 ton^{-1})	WF_{Blue} (m^3 ton^{-1})	Total Water Footprint (m^3 ton^{-1})
FAO56 Kc	1304	165	1139	1651	11389	275	1898	2173
Adjusted Kc	1337	165	1172	1651	11718	275	1953	2228

Table 4: Crop water footprint for sugarcane crop

Approach	Total Water Requirement (mm)	ET_{Green} (mm)	ET_{Blue} (mm)	CWU_{Green} (m^3 ha^{-1})	CWU_{Blue} (m^3 ha^{-1})	WF_{Green} (m^3 ton^{-1})	WF_{Blue} (m^3 ton^{-1})	Total Water Footprint (m^3 ton^{-1})
FAO56 Kc	1825	605	1220	6050	12199	101	203	304
Adjusted Kc	1839	605	1234	6050	12337	101	206	307

Table 5: Crop water footprint for banana crop

Approach	Total Water Requirement (mm)	ET_{Green} (mm)	ET_{Blue} (mm)	CWU_{Green} (m^3 ha^{-1})	CWU_{Blue} (m^3 ha^{-1})	WF_{Green} (m^3 ton^{-1})	WF_{Blue} (m^3 ton^{-1})	Total Water Footprint (m^3 ton^{-1})
FAO56 Kc	2105	698	1408	6977	14077	166	335	501
Adjusted Kc	2116	698	1417	6977	14175	166	337	503

negligible effects on yield. The irrigation interval recommended in this study may be prolonged one day so that total water footprint of crops will be reduced. Alternate wetting and drying in paddy cultivation may be practiced to save water which additionally reduces greenhouse gas emissions by maintaining yields. Kar *et al.* (2014) suggested that better rainwater management and efficient application methods will reduce the blue water foot print. Higher percolation need in the first phase of the land preparation can be reduced by water saving seeding/planting methods of rice like direct dry seeding, System of Rice Intensification (SRI).

Water footprint for sugarcane

The water footprint in sugarcane by using FAO56-Kc and ClimAdj-Kc was 304 and 307 m^3 ton^{-1} respectively. In sugarcane, around 33% of total water requirement was satisfied by green component and the remaining was given through irrigation in Lalgudi block. The results are on par with that of total water requirement of sugarcane obtained by Dingre and Gorantiwar (2020). Dingre and Gorantiwar (2020) reported that, for sugarcane irrigation water requirement and effective rainfall was 991 mm $year^{-1}$ and 424 mm $year^{-1}$ respectively in semiarid India. When drip or subsurface drip irrigation for sugarcane is recommended, it will reduce the water footprint, but at a significant cost.

Water footprint for banana

The estimated total water requirement for banana by using FAO56-K_c and ClimAdj-K_c was 2105 and 2116 mm respectively. While compared to paddy and sugarcane, the total water requirement for banana is high. The water footprint in banana by using FAO56-K_c and ClimAdj-K_c was 501 and 503 m^3 ton^{-1} respectively. While comparing banana and sugarcane, the water footprint of banana was higher. Around 33% of total water requirement was satisfied by green component and the remaining was given through irrigation in Lalgudi block. For banana crop, the use of organic mulching can significantly reduce the water footprint at a relatively low cost. Paul *et al.* (2008) also reported that use of drip, either alone or in combination with mulching, can increase the banana yield up to 33% over basin irrigation along with a saving of 20% of irrigation water. Besides high yielding banana varieties like Poovan, Rasthali and Elarasi which starts yielding at seven months may be cultivated.

Conclusion

The total, water requirement, blue and green crop evapotranspiration, blue and green crop water use and blue, green and total water footprint for paddy, sugarcane and banana were estimated. The crop water requirement was estimated using CROPWAT 8.0. The crop water footprint of paddy was higher compared to sugarcane and banana. It means that quantity of water used of producing per ton of yield was higher in paddy compared to banana and sugarcane since paddy is water loving crop. In paddy, only 12 % of total water requirement is satisfied by green water (effective rainfall) whereas remaining amount of water in satisfied by blue water resources like groundwater, canals, wells and lake. Similarly for sugarcane and banana, around 33% of total water requirement was satisfied by green component and the remaining was given through irrigation. The water footprint of paddy was 86 percent higher than sugarcane and 76 percent higher than banana water footprint. Hence water footprint is necessarily to be reduced to alleviate overexploitation of groundwater and increase national food security. The results will be useful for water management and effective operation of water supply system. It can be applied in establishing long-term policies for agricultural water resources.

Conflict of interest

The authors declare that they have no conflict of interest.

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Regulation of soil organic carbon stock with physical properties in alluvial soils of Bihar

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ABSTRACT

Soil temperature and water content govern the breakdown of soil organic matter (SOM), which has a large impact on SOC storage. Apparently soil organic carbon is an excellent indicator of soil health. In this experiment, the association between several soil health indices such as soil organic carbon (SOC), soil texture, and wet aggregate stability was investigated (WAS). It was discovered that there is a substantial positive relationship between wet aggregate stability and soil organic carbon storage. Soil carbon store in East Champaran soils ranged from 5.27 to 19.60 mg/ha, with an average of 12.98 mg/ha. The wet aggregate stability ranged from 3.82 to 36.43 %, with a mean of 16.11 %. Wet aggregate stability was shown to increase as the organic carbon storage in the soil increased. This experiment also indicated that clay (%) and silt (%) had a direct impact on wet aggregate stability and, as a result, soil organic carbon storage. As a result, wet aggregate stability and soil texture have a direct and favourable influence on soil organic carbon storage in East Champaran, Bihar soils.

Introduction

In the worldwide terrestrial carbon cycle, soil organic carbon (SOC) is the single greatest carbon store (Abdalla *et al.,* 2018). It has a carbon content of around 1500 Pg, which is higher than the carbon content of plants and atmospheric reservoirs on average (Zhang *et al.,* 2018). Due to its high percentage, even modest changes in its concentration can result in significant increases in CO2 emissions, resulting in global warming (Zhao *et al.,* 2006, 2018). Mineralization of SOC is a critical phase in the release of fertiliser, soil nutrients, quality improvement, greenhouse gas emissions, and, ultimately, food production (Cai *et al.,* 2016; Mustafa *et al.,* 2020; Wang *et al.,* 2008; Soderstrom *et al.,* 2014). To better soil fertility management, climate change mitigation, and food safety, a complete examination of all the features and variability of SOC mineralization processes is necessary (Mustafa *et al.,* 2020). Aggregate stability is a soil quality indicator that is linked to the quantity of organic matter in the soil. Soil organic matter makes soil surface aggregates more stable, allowing them to withstand moisture and mechanical forces from tillage equipment and vehicle activity (Hernanz *et al.,* 2002, Tisdall and Oades, 1982; Oades, 1984). A substantial link between SOC and macro and micro aggregate structural stability (250 mm) has been discovered in several research on diverse soils and climatic situations (Hernanz *et al.,* 2002;Cannell and Hawes, 1994). Complete SOC is widely recognised as a dynamic process with several components, and increasing the amount of carbon sequestered in these components is critical for reducing carbon

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conversion to greenhouse gases and avoiding climate change. (Mustafa *et al.,* 2020; Mikha & Rice, 2004) The breakdown of organic matter in soil is one of the most significant processes that contribute to the long-term sustainability of SOC and carbon sequestration in soil aggregation (Mustafa *et al.,* 2020, Lal, 2004; Six *et al.,* 2004; Abrar *et al.,* 2020). By physically protecting SOC from mineralization, soil aggregates serve a crucial role in soil fertility maintenance and structure. It is also recognised as a crucial indicator of the formation, deterioration, and stability of soil structures (Mustafa *et al.,* 2020, Six *et al.,*2004; Abiven *et al.,* 2009). In recent decades, the amount of inorganic and organic fertilisers used in agricultural operations has increased, raising the danger of soil depletion, which is connected to unsustainable resource use practises (Mustafa *et al.,* 2020, Bronick and Lal, 2005; Guo *et al.,* 2019). As a result, it is strongly advised to adopt optimal fertilisation strategies to improve soil quality, soil C sequestration, and agronomic efficiency (Mustafa *et al.,* 2020, Guo *et al.,* 2018; Tanveer *et al.,* 2019). The primary goal of this study was to determine if aggregate stabilisation, in association with soil texture, plays a major influence in SOC storage management.

Material and Methods

Description of the site, the experimental setup, and soil sampling:

Muzaffarpur is geographically located in Bihar between 26°07′N and 85°24′E with sub-tropical climate. East Champaran is geographically located in Bihar between $26^0$38'N and $84^0$54'E at an elevation of 62 m above sea level (a.s.l.). The area is characterized by a Hot Subhumid (moist) climate, with hot, humid summers and mild winters. The yearly average rainfall is 1202 mm. The major soil types are Udifluvents, Haplaquents, Paleustalfs alluvial with silty to sandy loam texture, and calcareous nodules (kankar).

Soil samples were collected at 0-15 cm soil depth, air-dried for 6 days, passed through a 2 mm sieve and kept for analysis of wet aggregate stability (WAS), soil texture, and SOC.

Assessment of soil texture:

14g (+/- 0.1g) of sieved soil was added to a 50 ml centrifuge tube holding 42 ml of a dispersant 3% sodium hexametaphosphate solution. To completely disperse soil into suspension, it was continuously agitated for 2 hours on a shaker. The whole contents were sieved onto a 0.053 mm sieve assembly over a plastic funnel above a 1L beaker. The sand that has accumulated on top of the sieve is collected in a metal container and put aside.

Silt and clay particles were collected in a 1L beaker and stirred to re-suspension before being allowed to settle for 2 hours. Before measuring dry weight, both the sand and silt fraction cans were dried at 105°C to a consistent weight. Percent sand, silt,and clay were then calculated as follows:

Sand % = **(**mass of oven dry sand/ mass of original sample) x 100%

Silt % = (mass of oven dry silt / mass of original sample**)** x 100%

Clay % = 100 - **(**Sand % + Silt %**)**

Assessment of wet stable aggregate:

4g of air-dried, 2-mm aggregate soil sample was included in each 0.25-mm sieve. Initially, the precise weight of each sample was recorded. Each soil sample was reproduced in replication, resulting in a total of four samples per eight-sieve batch. In an Eijkelkamp machine, soil samples were dispersed for 3 minutes with 100mL distilled water and then for 10 minutes with a 2g/L sodium hexametaphosphate solution. Both solutions were filtered using pre-weighed filter sheets. After being oven-dried at 105°C, each filter paper was weighed. % stable aggregate was calculated using the following equation:

$$\textbf{\% stable aggregates} = \frac{\textbf{Weight of soil in dispersing solution}}{\textbf{Weight of soil in dispersing solution + weight of soil in water}}$$

Assessment of soil organic carbon, soil organic matter, and soil organic carbon stock:

The amount of soil organic carbon (SOC) was calculated using the Walkley and Black technique (1934).The calculated SOC was then multiplied with Von Bemlen factor (1.724) to determine soil organic matter (SOM). SOC stock was calculated by multiplying area (m^2), bulk density (Mg m^{-3}),soil depth (m), and SOC (percent).

Statistical analysis

Statistical analysis was done using SPSS software version 16.0.

Results and Discussion

Variation of soil organic carbon (SOC) and soil organic matter (SOM) in Alluvial soils of Bihar

The soil system regulates plant growth in the terrestrial ecosystem (Nath *et al.,* 2021). SOM and SOC play a vital role in good plant growth and soil health. SOM is one of the sources and sink of SOC. SOC in these studied soil samples of Muzaffarpur varied between 0.32 – 0.73 % and in case of East Champaran varied between 0.24-0.99 % with a mean of 0.66 %. SOM ranged from 0.46 to 1.71 % with a mean of 1.13 % (Figure 1).The data of SOC and SOM revealed that increase in SOC improves SOM content. Both SOM and SOC were positively correlated. One of the most important elements affecting soil stability is organic matter (Hernanz *et al.,* 2002; Follett and Peterson, 1988; Ekwue, 1990).The surface layer of soil was found to be stable with greater SOC content (Hernanz *et al.,* 2002, Kay *et al.,* 1994).

Wet aggregate stability and soil organic carbon stock

Soil carbon stock in soils of Muzaffarpur varied between 6.43 to 14.63 Mg ha^{-1} and East Champaran varied between 5.27-19.60 Mg ha^{-1} with an average of 12.98 Mg ha^{-1} respectively. Wet aggregate stability of Muzaffarpur varied between 5.17 to 40.17 % and in case of East Champaran varied between 3.82-36.43 % with a mean of 16.11 % (Figure 2). WAS increase with increase in SOC store. Aggregate protects SOM by physical disconnection (Chaplot *et al.,* 2015; Schmidt *et al.,* 2011). This experiment revealed that soils with the highest aggregate stability are characterzied by more SOC stock.

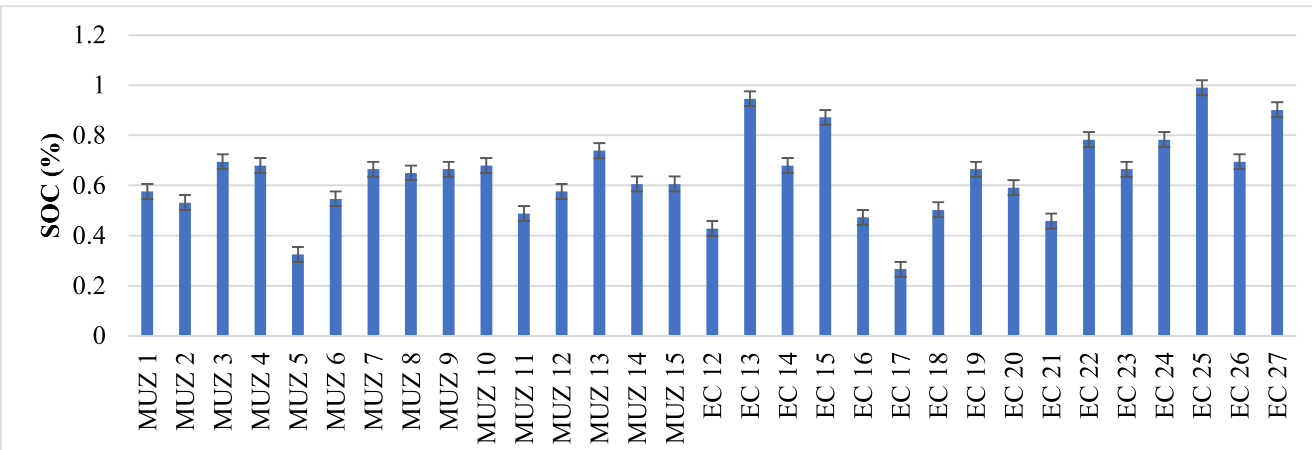

Figure 1: Level of soil organic matter (SOM) and soil organic carbon (SOC) in Alluvial soils of Bihar.

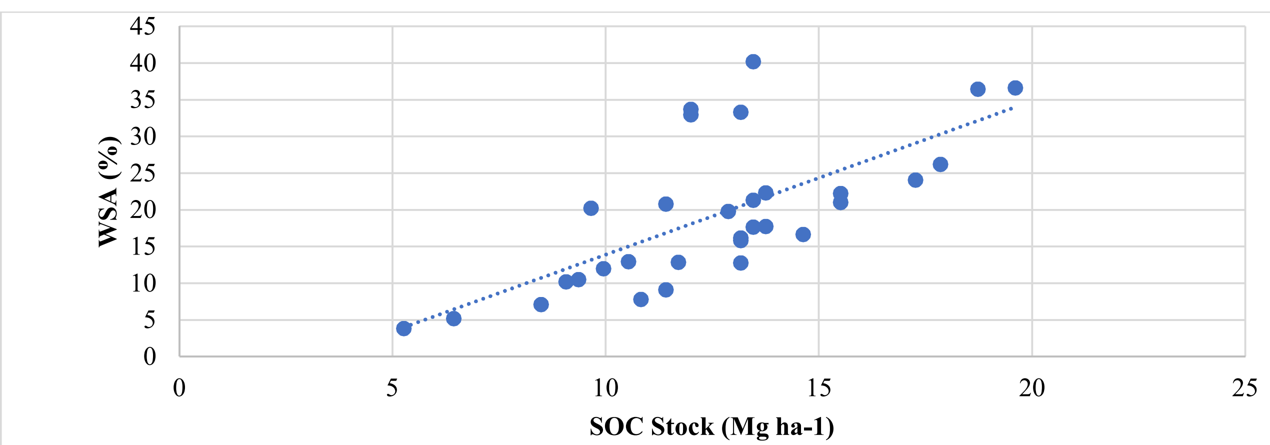

Figure 2: Relationship between wet aggregate stability (%) and SOC stock in alluvial soils of Bihar.

A possible explanation of this result could be attributed to soil organic matter content and quality.Binding agents, which are typically polysaccharides derived from exocellular mucilages and root exudates, situated between aggregates may create an active pool (Chaplot *et al.,* 2015;Von Lützow *et al.,* 2008), resulting in significant SOC storage.In high aggregate stability soils, fresh plant residues, as well as various faunal and microbial residues, which constitute alternate pools of easily accessible SOM to decomposers (Chaplot *et al.,* 2015;Von Lützow *et al.,* 2008), are more likely to be found than in low aggregate stability soils.Plant organic residue, as well as microbial and microfaunal waste, including fungal hyphae in various stages of decomposition, make up the light fractions (Chan and Heenan, 1999; Jansen *et al.,* 1992). According to the soil aggregation hierarchal model, there are efficient stabilizing agents for soil macroaggregates (Tisdall and Oades, 1982).The increased microbial activity led these light fraction materials to disintegrate preferentially and they are primarily associated with macro-aggregates which played a major role in aggregate stability (Chan and Heenan, 1999).

Descriptive statistics of sand, silt, and clay content in Alluvial soils of Bihar

The textural class of studied soil samples was silt loam. The sand % varied between 6.16-41.58 % with a mean of 19.60 and while the clay % ranged from 52.46 to 83.11% with a mean of 71.49 (Table 1). The maximum and minimum data of clay were 3.22 and 17.94 respectively with a mean of 8.95. The positive skewness data of sand (0.67) and clay (0.48) revealed that the right side of the distribution has a longer or flatter tail, and also data are fairly symmetrical. The negative skewness data of silt (-0.60) suggests that the left side distribution is longer or flatter than the tail on the right side. Besides the negative skewness (-0.60) revealed that the data are highly skewed (Table 1). The negative kurtosis of sand (-0.82), silt (-0.91), and clay (-0.60) revealed that the distribution curve had flattened top than the normal curve and platykurtic distribution is found.

Table 1: Descriptive statistics of sand, silt and clay content in soil samples of alluvial soils of Bihar.

Descriptive parameters	Sand (%)	Silt (%)	Clay (%)
Mean	19.60 (+2.04)	70.69 (+1.81)	9.71 (+0.91)
Median	16.60	74.59	9.11
Std. Deviation	11.89	10.11	4.28
Variance	141.29	102.13	18.34
Skewness	0.67 (+0.41)	-0.60 (+0.41)	0.48 (+0.41)
Kurtosis	-0.82 (+0.85)	-0.91 (+0.85)	-0.60 (+0.81)
Range	35.46	30.65	14.72
Minimum	6.14	52.46	3.22
Maximum	41.60	83.11	17.94

Correlation among SOC (%), SOM (%), SOC stock, WAS, Sand (%), Silt (%), and Clay (%) in in Alluvial soils of Bihar

The correlation coefficient among SOC (%), SOM (%), SOC Stock, WAS, Sand (%), Silt (%), and Clay (%) was highly significant (Table 2). It was also observed that soil organic carbon (SOC) was positively significant correlated (0.696**) with wet aggregate stability (WAS) and negatively significant correlated (-0.682**) with sand percentage at 0.01 level of significance. Similarly, SOCstock was significantly correlated with water aggregate stability (WAS), silt and clay percent. However, negative correlation observed between SOC and sand (%). Sand has a negligible contribution towards the SOCstock build-up in the soil. Table 2 displays that water aggregate stability (WAS) has a negative correlation with sand (%) and a positive correlation with both silt (%) and clay (%). Silt (Thomasson, 1978), sand (Williams, 1970), and clay fractions (Kemper & Koch,1966) have been identified ashaving a significant impact on the stability of soil aggregates.

Table 2: Correlation between SOM (%), SOC (%), Soil Organic Carbon stock, WAS, Sand (%), Silt (%) and Clay (%) of alluvial soils of Bihar

	SOM (%)	SOC (%)	SOCstock (Mg/ha)	WAS (%)	Sand (%)	Silt (%)	Clay (%)
SOM (%)	1						
SOC (%)	0.806**	1					
SOCstock (Mg/ha)	0.806**	1.000**	1				
WAS (%)	0.397**	0.696**	0.695**	1			
Sand (%)	-0.493**	-0.682**	-0.683**	-0.480**	1		
Silt (%)	0.438**	0.655**	0.658**	0.462**	-0.937**	1	
Clay (%)	0.336**	0.348**	0.343**	0.243**	-0.565**	0.241	1

****Correlation is significant at the 0.01 level.**

Conclusion

The link between wet aggregate stability, soil texture, and soil organic carbon was studied in this study (SOC). The preceding experiment indicated a considerable positive association between soil aggregate stability (WAS) and SOCstock. Clay (%), silt (%), and soil organic matter (SOCstock) properly proxied wet aggregate stability (WAS) and SOCstock (SOM). SOCstock was much higher in soils with the highest stable aggregate stability than in soils with the lowest stable aggregate stability. The main influential factors on clay (%), silt (%), soil organic matter (SOM), and mineralization of organic carbon (aggregate associated) in the soil studied were SOC stocks and aggregate stability, according to correlation analysis. Future study should focus on the primary reasons of SOC sequestration in component C fractions, as well as potential protective factors.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Development of interspecific hybrids between urdbean & mungbean

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ABSTRACT

Interspecific hybridization was performed between five genotypes of urdbean & three genotypes of mungbean to check the crossability relationship. Thirteen cross combinations of urdbean x mungbean were successfully developed. Interspecific seeds showed no germination under soil conditions so various growth media were used for germination. Interspecific seeds germinated only on the salt solution. F_1 seeds of cross UG-218 x Suketi exhibited highest crossability and showed maximum response on salt solution. The study put emphasis on the different kinds of fertilization barriers. In future genetic improvement studies can be carried out with the genotypes showing substantially high percent of crossability.

Introduction

Protein is an important source of individual diet which is mostly taken form milk, eggs and pulses. The fourth most important food legume in India is Urdbean [*Vigna mungo* (L.) Hepper] also known as blackgram, black lentil, mash, mungo bean belongs to family *Leguminoseae* and subfamily *Papilionaceae*, domesticated from *V. mungo* var. *silverstris* (Bhareti *et al*., 2011). Urdbean is short duration, self-pollinated crop and found in most of parts of India. India is center of genetic diversity for urdbean with its secondary center of origin in Central Asia (Singh *et al*., 2016).

Urdbean is valuable source of protein, minerals and amino acids like lysine and methionine, as well as vitamins like niacin, riboflavin and thiamine, as well as phosphorus and iron (Gill *et al*., 2017). Plant parts are used as fodder for animals and green manuring. India is the world's greatest producer and consumer of urdbean, producing 2.93 million tonnes per year from 4.49 million hectares of land, with an average productivity of 500 kg per hectare (Anonymous, 2019). In Himachal Pradesh, it is mainly cultivated on low and mid hills & grown as intercrop with maize as well as a monocrop. However, yield potential of urdbean is low as compared to other grain legumes. Narrow genetic base of urdbean often results in low yield and productivity due to poor plant type, cultivation in marginal and harsh environment, common ancestry of various superior genotypes and its vulnerability to abiotic and biotic stresses viz., Cercospora leaf spots (*Cercospora canescens, C. cruenta*), anthracnose (*Colletotrichum truncatum*), powdery mildew (*Erysiphe polygoni*), and Mung Bean Mosaic Viruses (Ali *et al.,* 2006). The related species *V. radiata* (mungbean) has been found to be nutritive, easily digestible & early maturity as compared to urdbean. As urdbean is self-pollinated crop to get its better understanding of crossability relationship among the species is helpful in chosing methods for making successful crosses. Interspecific seeds developed shows no germination under normal soil condition due to which different media composition were attempted in the present

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investigation to check the efficacy of growth media's on germination of interspecific seeds and for studying the crossability of *V. mungo* with *V. radiata*.

Material and Methods

For the study, a total eight different genotypes i.e. five of blackgram (HPBU-111, Him Mash-1, Palampur-93, UG-218 & PDU-1) taken as female and three of mungbean (Suketi, SML-668 & ML-818) taken as male were used to study the crossability relationship & germinability of their hybrids (Table 1).

Table 1: List of genotypes along with their sources used in the study.

Species	Genotype	Source
Urdbean	Palampur-93	CSK HPKV, Palampur
	Him Mash-1	DPU 91-5 x Mash 338
	HPBU-111	CSK HPKV, Palampur
	UG-218	IIPR Kanpur
	PDU-I	Selection from IC-8219
Mungbean	Suketi	CSKHPKV Palampur
	SML-668	Selection from AVRDC material
	ML-818	5145/87 x ML 267

During summer & *Kharif* 2017 & summer 2018, staggered sowings were done at interval of 10 days starting from 15th March to 31st July to have synchronized flowering in the glasshouse of Department of Genetics & Plant Breeding, COA, CSKHPKV Palampur located at an elevation of 1,290 m above mean sea level with geographical co-ordinates of 36^{0}6'N latitude and 76^{0}3'E longitude representing the mid-hill zone of Himachal Pradesh and is characterized by humid sub-temperate climate with high rainfall (2,500 mm per annum). Crossing was performed from 15th April to 15th October of 2017 & 15th April to 30th June of 2018. In evening, the emasculation of female parent(s) at plump bud stage was done (3:00 – 5:30 P.M.) followed by pollination in morning (6:00 to 8:00 A.M.). Three immuno- suppressants i.e. giberellic acid (GA_3), indole acetic acid (IAA) and Σ- amino caproic acid were used at two concentrations (500 ppm & 1000 ppm) about half an hour after pollination to prevent premature flower abscission. This was repeated for three consecutive days after pollination at an interval of 24 hours. Fifteen interspecific crosses of urdbean x mungbean were attempted. Observations on number of buds pollinated and number of pods harvested were recorded to calculate the crossability percentage. The seeds obtained from the interspecific crosses were grown on various media i.e. Salt solution (Sander *et al*., 1959), Gamborg B5 and Half & full strength MS medium to study the response of different growth media on germinability of F_1 seeds. Under aseptic conditions, F_1 seeds were surface sterilized with 0.02 % mercuric chloride for two minutes, washed three to four times in sterilized distilled water and placed in petri-plates with sterilized salt solution, MS medium (Half & Full Strength) & Gamborg B5 media. Petri plates with sterile F_1 seeds were placed in incubator at 25±1ºC for four to five days and salt solution was changed every day under sterile conditions. On second transfer on fresh salt solution seed coat of imbibed F_1 seeds were removed and allowed to develop on salt solution for one or two days. Four to five days old seeds showing radicle formation/seedling were transferred to paper cups having mixture of sand + cocopeat + vermicompost which were then transferred to field and glasshouse after the development of cotyledonary leaves (Figure 1). Data were recorded with respect to:

- Number of buds pollinated
- Number of pods harvested
- Total seeds harvested of each cross
- Total seeds cultured
- Number of seeds showing radicle formation
- Number of interspecific plantlets obtained

Crossability percentage was calculated as follows:

$$\text{Crossability percentage (\%)} = \frac{\text{Number of crossed pods set}}{\text{Total number of urdbean buds pollinated}} \times 100$$

% radicle formation (Germination Percentage) & % hybrid plants obtained was calculated as follows:

$$\text{\% radicle formation} = \frac{\text{Number of seeds showing radicle formation}}{\text{Total seeds cultured}} \times 100$$

$$\text{\% hybrid plants obtained} = \frac{\text{Number of interspecific plantlets obtained}}{\text{Total seeds cultured}} \times 100$$

Simple t-test

Simple t-test was performed to test the mean difference of radicle and hybrid plant production in the study.

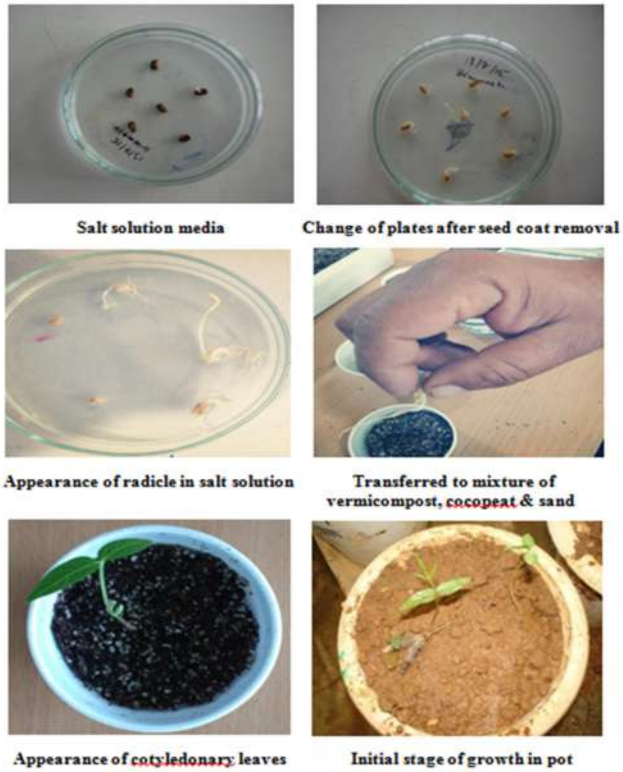

Figure 1: Germination of F_1 seeds

Results and Discussion

Interspecific hybridization is a promising tool to transfer the desirable traits and to widen the gene pool of any crop. However, wide crosses are not always successful because of the existence of pre and post fertilization barriers that are operative at various stages of development and also various incompatibility barriers limit the potential for recombining the important characters for improving production and adaptation. The present study was taken with the objective to study the crossability relationship between urdbean & mungbean and to study the efficacy of different growth media on germination of interspecific seeds. There is high incidence of abscission of crossed flowers within 72 hours from pollination & young fruits dropping between 3 to 30 days after pollination implying the presence of fertilization barriers. Some of pods harvested had no seed or had very minute seeds. The range of crossability percentage was observed to be 0-19.64 % in case of urdbean x mungbean hybridization. The analysis of results revealed that cross combinations UG-218 x Suketi, Palampur-93 x Suketi, Him Mash-1 x ML-818, HPBU-111 x Suketi & PDU-1 x SML-668 were found to be significantly superior over other crosses. Interspecific cross combination UG-218 x Suketi exhibited highest crossability (19.64 %) followed by Palampur-93 x Suketi (19.25 %) and Him Mash-1 x ML-818 (18.54 % in case of *V.mungo* x *V. radiata* hybridization (Table 2). Crosses having high crossability percentage were considered as successful crosses suggesting the parents of these cross combinations are ideal for transfer of useful genes from one species to another species. Similar results in relation to crossability were also reported by various research workers viz; Bhanu *et al*., (2018) in *V. mungo* x *V. umbellata* with 16.27 % & in *V. mungo* x *V. radiata* with 37.50 % and Lekhi *et al*., (2017) in *V. mungo* x *V. radiata* with 5.50 to 24.10 %. The percent crossability among different sets of crosses varies from species to species due to substantial heterogeneity in the genetic architecture of species involved in interspecific hybridization, resulting in differences in cross compatibility. Some of the pods which were formed were without seed or had shriveled seeds with ruptured seed coat. In the crosses which had HPBU-111 as one of the parent had large number of empty pods. F_1 seeds developed were of two types, viz. highly shriveled, minute, brown coloured and the second was bold and comparatively brown coloured but very weak as compared to self-ones. The number of seeds per pod in the interspecific hybrids varied from 1-4. The results are in agreement with the earlier studies of Sehrawat *et al*. (2016a) for number of F_1 seeds per pod in interspecific crosses of urdbean and ricebean. The F_1 seeds obtained from all cross combinations were small, wrinkled and shrunken (Figure 2). The F_1 seeds were small in size and shriveled because of the poor development of the endosperm and embryo which is due to incompatibility between the two parental genomes or due to the failure of embryo to reach maturity (Rashid *et al*., 1987). Even though crossability barriers were present, few interspecific hybrids were produced. The seeds obtained from the interspecific crosses under study shows no germination under normal soil conditions so attempts were made to grow them on various media. To study the response of different growth media on germination of interspecific seeds, 30 seeds comprising of all the cross combinations of urdbean & mungbean were put on different growth media i.e. Salt solution, Gamborg B5 media and

Table 2: Pod set & Crossability percentage in *V. mungo* and *V. radiata* crosses

SN	Cross Combination	Number of buds emasculated & pollinated	Number of pods harvested	Total Seeds Collected	Crossability percentage
1.	UG-218 x Suketi	331	65	235	19.64**
2.	Palampur-93 x Suketi	322	62	226	19.25**
3.	Him Mash-1 x ML-818	302	56	205	18.54**
4.	Him Mash-1 x Suketi	314	39	166	12.42
5.	Him Mash-1 x SML-668	307	22	128	7.17
6.	HPBU-111 x Suketi	309	41	149	13.27*
7.	HPBU-111 x SML-668	313	17	99	5.43
8.	HPBU-111 x ML-818	310	29	136	9.35
9.	Palampur-93 x ML-818	304	0	0	0.00
10.	Palampur-93 x SML-668	319	16	98	5.02
11.	UG-218 x SML-668	312	20	117	6.41
12.	UG-218 x ML-818	315	15	91	4.76
13.	PDU-1 x Suketi	318	26	125	8.18
14.	PDU-1 x SML-668	316	50	210	15.82**
15.	PDU-1 x ML-818	306	0	0	0.00

****, * = significantly positive at 1 & 5 % level of significance; Mean=16.46, SE± =2.12**

Figure 2: Interspecific F_1 pods & seeds

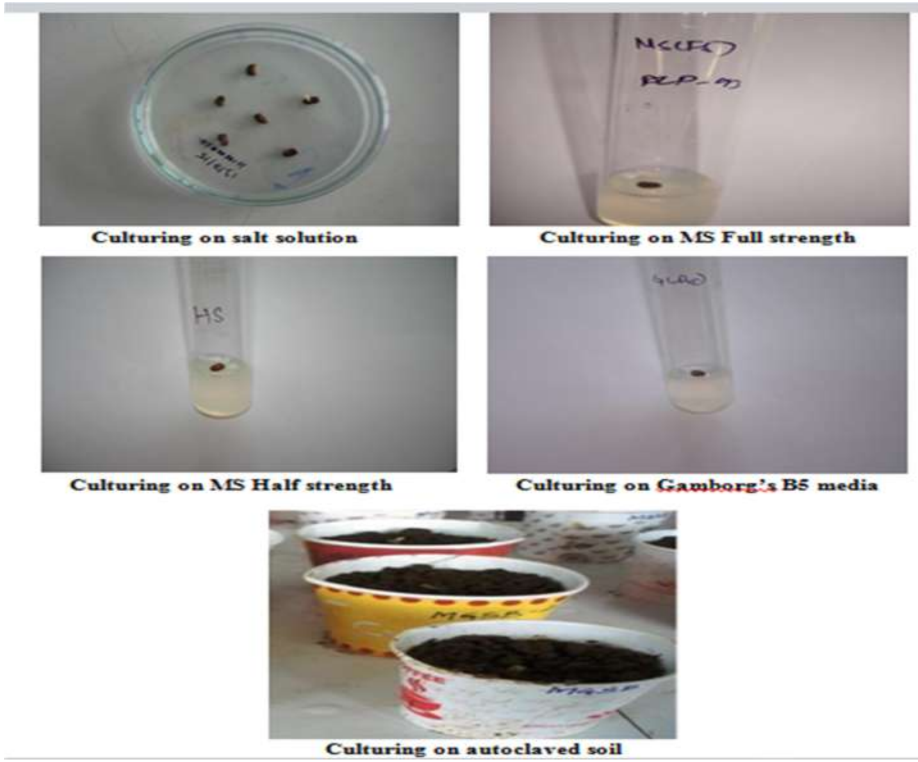

Figure 3: Germination of interspecific F_1 seeds in different media.

Half & full strength MS medium (Figure 3). Successful results were only obtained on the salt solution, in rest of media's seeds of interspecific crosses of urdbean and mungbean showed no germination (Table 3). Mittal *et al*. during 2005 and 2008 obtained similar results in interspecific crosses between urdbean and ricebean. The range of % radicle & hybrid plant production were found to be 0-25.56 % & 0-17.49 % respectively. The analysis of results revealed that cross combinations UG-218 x Suketi, Palampur-93 x Suketi, Him Mash-1 x ML-818 & PDU-1 x SML-668 were found to be significantly superior for % radicle formation. As per the present results, the response of cross combination UG-218 x Suketi (25.56 %) was maximum with respect to radicle formation followed by cross Palampur-93 x Suketi (19.63 %) & PDU-1 x SML-668 (19.20 %) respectively. Cross combinations UG-218 x Suketi, Palampur-93 x Suketi, Him Mash-1 x ML-818, Him Mash-1 x Suketi, HPBU-111 x Suketi & PDU-1 x SML-668m were significantly superior for % hybrid plants obtained. Radical formation & hybrid plantlet formation in F_1 seeds obtained highest in cross formed between UG-218 x Suketi (17.49 %) followed by Palampur- 93 x Suketi (14.02 %) (Table 4). The results are in agreement with the findings of Bindra *et al*., (2020), they reported germination percentage upto 59.34 % in *V. mungo* x *V. umbellata* hybridization whereas, Basavaraja *et al*., (2018) found germination percentage of 36.84 % in interspecific crosses between *V. radiata* & *V. umbellata*, Lekhi *et al*., (2017) noted germination percentage upto 30.56 % in interspecific crosses of urdbean and mungbean. Some of the F_1 seeds did not imbibe, some showed distorted cotyledons, poor root development whereas in some cases roots developed but died before shoot formation so success rate in germination was low. Mittal *et al*., (2005) reported similar results in interspecific crosses of urdbean & ricebean. The parents involved in interspecific hybridization showed differential genotypic response which indicates the use of more number of genotypes and large number of crosses should be attempted to get more F_1 plants. Differential genotypic response of parents involved in interspecific hybridization also reported by Mittal *et al*. (2005).

Table 3: Response of different growth media + Autoclaved Soil on germination of interspecific F_1 seeds of urdbean and mungbean

SN	Media used	Seeds cultured	Seeds germinated
1.	Autoclaved soil	30	0
2.	Salt solution (Sanders et al. 1959)	30	11
3.	MS-Full strength	30	0
4.	MS- Half strength	30	0
5.	Gamborg's B5 Media	30	0

Table 4: % radicle formation and hybrid plants production in interspecific crosses of urdbean & mungbean

SN	Name of Cross	Seeds Cultured (No.)	Seeds showing radicle formation (No.)	Radicle formation (%)	Interspecific plantlets obtained (No.)	Hybrid plants obtained (%)
1.	UG-218 x Suketi	223	57	25.56**	39	17.49**
2.	Palampur-93 x Suketi	214	42	19.63**	30	14.02**
3.	Him Mash-1 x ML-818	193	30	15.54*	18	9.33**
4.	Him Mash-1 x Suketi	154	18	11.69	10	6.49*
5.	Him Mash-1 x SML-668	116	10	8.62	0	0.00
6.	HPBU-111 x Suketi	137	18	13.14	9	6.60*
7.	HPBU-111 x SML-668	87	5	5.75	0	0.00
8.	HPBU-111 x ML-818	124	11	8.87	0	0.00
9.	Palampur-93 x ML-818	0	0	0.00	0	0.00
10.	Palampur-93x SML-668	86	5	5.81	0	0.00
11.	UG-218 x SML-668	105	7	6.67	0	0.00
12.	UG-218 x ML-818	79	3	3.80	0	0.00
13.	PDU-1 x Suketi	113	11	9.82	0	0.00
14.	PDU-1 x SML-668	198	38	19.20**	27	13.64**
15.	PDU-1 x ML-818	0	0	0	0	0.00

****, * = significantly positive at 1 & 5 % level of significance; Mean=16.92, SE± =2.23 for % radicle formation**
****, * = significantly positive at 1 & 5 % level of significance; Mean=7.72, SE± =2.61 for % hybrid plants obtained**

Conclusion

The study put emphasis on the different kinds of fertilization barriers that are responsible for complete sterility to low fertility. Even though the fertilization barriers were predominant, some interspecific hybrids were produced. Salt solution was most efficient growth media for germinability. The parents involved in interspecific hybridization showed differential genotypic response which indicates the use of more number of genotypes and large number of crosses should be attempted to get more F_1 plants. In future genetic improvement studies can be carried out with the genotypes showing substantially high percent of crossability.

Conflict of interest

The authors declare that they have no conflict of interest.

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Performance of timely sown wheat (*Triticum aestivum* L.) genotypes under irrigated condition

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ABSTRACT

A field experiment was carried out during Rabi season, 2020 at Wheat Breeding Experimental Field, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P). The soil of experimental site was sandy loam in texture and nearly neutral in soil reaction with (pH 6.7). The experiment was laid out in Randomized Block Design and fourteen wheat genotypes were replicated fourfold. Study revealed that the genotype G_{12}, i.e., NERI-312 recorded significantly higher plant height (100.50 cm), number of tillers/hill (10/hill), plant dry weight (26.14 g), length of the spike (13.5 cm), number of grains per spike (42.95), test weight (40.05 g), grain yield (4.18 t/ha) and straw yield (6.04 t/ha). It was evident that the genotype NERI-312 was found to be productive.

Introduction

Wheat belongs to family poaceae and is very important crop as it contribute major portion of staple food for world's population. It provides more calories and protein within the world's diet than any other cereal (CIMMYT, 2002). Wheat acts as the staple food in more than 40 countries of the world (Sharma *et al.,* 2019). It is the world's most generally cultivated cereal crop. It has been described as the ''King of cereals'' due to the acreage it occupies, high productivity and prominent position it holds within the international food grain trade (Coasta *et al.,* 2013). Wheat is principally grown during *Rabi* season with wider adaptability and requires relatively low temperatures for their growth. The foremost favourable climatic condition for wheat cultivation is cool and moist weather during the vegetative phase, followed by dry warm weather for the grain to mature and ripening. In India, growing season for wheat is restricted by high temperature at maturation and moreover there is also concern for changing climate scenario. Time of sowing in wheat is the most significant factor that governs the crop development phenologically. It also plays a prominent role in conversion of biomass in to economic yield. Proper irrigation at the critical growth stages aids the wheat crop for withstanding unfavourable conditions. Providing irrigation at critical growth stage affects the yield in a positive way. Irrigation is such a vital and costly factor which influences the growth and yield of the wheat. So, the development of high yielding genotypes under limited water resources and limited environmental conditions are necessary in the

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current scenario. Improved varieties must be productive with higher yield and should be economical to the farmers. Therefore, with above facts to seek out the promising genotypes under prayagraj condition this present investigation was carried out.

Material and Methods

The experiment entitled ''Performance of Timely Sown Wheat (*Triticum aestivum* L.) Genotypes under Irrigated Condition'' was carried out during *Rabi* season of 2020, at the Wheat Breeding Experimental Field, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. The Wheat Breeding Experimental Field is situated at 25°24'33" N latitude, 81°51'12" E longitude (Google, 2021) and 98 m altitude above the mean sea level. The experimental field soil texture was sandy loam. The experiment was laid out in a randomized block design and fourteen genotypes were replicated four times each. The wheat was sown on 25th November 2020 with plant geometry of 20 x 10 cm. The genotypes were G_1 - NERI-301, G_2 - NERI-302, G_3 - NERI-303, G_4 - NERI-304, G_5 - NERI-305, G_6 - NERI-306, G_7 - NERI-307, G_8 - NERI-308, G_9 - NERI-309, G_{10} - NERI-310, G_{11} - NERI-311, G_{12} - NERI-312, G_{13} - NERI-313, G_{14} - NERI-314 respectively. The experimental data recorded was subjected to statistical analysis by adopting the Fishers method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984). The data collected from the experiment was subjected to statistical analysis using ICAR WASP software. Critical difference (CD) values were calculated by the 'F' test was found significantly at 5% level.

Results and Discussion

A. Growth parameters

Plant height (cm)

Data regarding the plant height (cm) of wheat is given in Table 1. The plant height increased significantly, at each crop stage up to crop harvest. Data pertaining the plant height of the wheat genotypes was recorded at 60, 90 DAS and at harvest shown significantly higher plant height (67.59 cm, 99.46 cm 100.50 cm) in the genotype G_{12}. The Genotypes G_{11}, G_8 and G_{13} were statistically at par with the genotype G_{12} at 60 DAS. The genotypes G_{11}, G_8, G_{13}, G_{10}, G_3 and G_1 were statistically at par with the genotype G_{12} at 90 DAS and at harvest. Each genotype has its own feature from the growth viewpoint. The variation in the plant height was recorded based on their genetic character. Larger leaf area, amount of chlorophyll pigments and other traits play an important role in the crop growth. These results were found close conformity with the results of Poudel *et al*. (2020) in wheat.

Number of Tillers per hill

Data pertaining to number of tillers per hill at 60, 90 DAS and at harvest was presented in Table 1. Number of tillers per hill was increased with the advancement of the crop growth up to 90 DAS and later on it was declined at harvest stage. The number of tillers per hill of wheat at 60, 90 DAS and at the time of harvest differed significantly in different genotypes. There was a significant increase in the number of tillers per hill (11.65/hill and 12.92/hill) and found maximum at 60 and 90 DAS in the genotype G_{12}. At harvest there was a slight decline in number of tillers per hill (10/hill) in the same genotype G_{12}, but found to be significant. However the genotypes G_{11}, G_8 and G_{13} were statistically at par with the genotype G_{12} at 60 DAS and at the harvest stage. At 90 DAS G_{11} and G_8 were found on par with the genotype G_{12}. Most of the economic yield of the grain crops is determined by number of tillers, number of tillers per hill affect the productive tillers respectively. This is in agreement with the findings of Shuaib *et al.* (2019) and Chopde *et al.* (2015).

Plant dry weight (g/hill)

Data on plant dry weight (g/hill) was given in Table 2. At 60, 90 DAS and at harvest showed that the maximum plant dry weight (8.5 g/hill, 20.86 g/hill and 26.14 g/hill) was recorded in the genotype G_{12} and was significantly superior over all the genotypes. The genotypes G_{11} and G_8 were statistically on par with the genotype G_{12} at both 60 DAS and at harvest. At 90 DAS only genotype G_{11} was at par to the genotype G_{12}. From 60 DAS the dry weight has shown significant increase. This is due to the formation of tillers and the occurrence of jointing which leads to dry matter accumulation in the genotypes.These results were in close onformity with Alam *et al.* (2013) and Shahzad *et al.* (2002).

Crop growth rate (g/m^2/day)

Data pertaining to crop growth rate is presented in the Table 2. Maximum crop growth rate (13.528 g/m2/day and 20.603 g/m2/day) was recorded significantly higher in the genotype G_{12} during 30 - 60 DAS and 60 - 90 DAS intervals. The genotypes G_{11} and G_8 were at par with the genotype G_{12} during 30 - 60 DAS interval. But during the interval of 60 - 90 DAS, the genotypes G_{10}, G_{13}, G_8, G_{11}, G_3, G_1 and G_4 maintained the crop growth rate at par with the G_{12} genotype. The crop growth rate trend is depicted in the Figure 1. There was a significant increase in the crop growth rate of the wheat from 30, 60 and up to 90 DAS. Later on, there was a sudden decline in the crop growth rate after 90 DAS. This is due to the completion of the vegetative phase and maximum production of dry matter in the early growth stages of the plant. These results are similar to Alam (2013).

Relative growth rate (g/g/day)

Higher relative growth rate was recorded in initial growth stages during 30 - 60 DAS, in all the genotypes and is presented in Table 2. Relative growth rate curve is depicted in Figure 2. The genotype G_{11} recorded maximum relative growth rate (0.109 g/g/day) during 30 - 60 DAS. Later on, in the further intervals during 60 - 90 DAS, genotypes G_{10} and G_4 with relative growth rate (0.036) and during 90 - 120 DAS, genotypes G_7, G_6, G_9 and G_2 with relative growth rate (0.010) were found to be higher. There was a declining trend recorded in all the genotypes. Relative growth rate decreased steadily due to lower dry matter accumulation with the advancement of the crop growth stages. These results are in match up with those reported by Akhtar *et al*. (2018).

Yield and yield attributes

Observations regarding the yield and yield attributes viz., Length of the spike (cm), Number of grains per spike, Test weight (g), Grain yield (kg/ha) and Straw yield (kg/ha) of Wheat were depicted in Table 3.

Length of the spike (cm)

On perusal of data it is apparent that length of spike varied significantly due to different genotypes. The maximum spike length (13.5 cm) was recorded significantly higher in genotype G_{12}. However, the genotypes G_{11} and G_8 were statistically at par with the genotype G_{12}. Maximum spike length is a genetic trait and the variation in different spike lengths are due to the genetic variability among the genotypes which is in close conformity with results of Mushtaq *et al*. (2011).

Table 1: Evaluation of wheat genotypes on plant height and number of tillers per hill

Genotypes	Plant height (cm)			Number of tillers per hill		
	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
NERI-301	60.36^{bcd}	95.46^{abcd}	96.30^{abcd}	8.05^{c}	9.05^{de}	7.65^{cde}
NERI-302	54.59^{e}	87.13^{f}	89.10^{f}	7.45^{c}	8.20^{e}	6.70^{e}
NERI-303	60.76^{bcd}	95.49^{abcd}	96.44^{abcd}	8.25^{c}	9.80^{cde}	7.85^{bcde}
NERI-304	59.81^{cd}	94.52^{bcd}	95.38^{bcd}	8.05^{c}	8.90^{de}	7.15^{de}
NERI-305	59.05^{cde}	91.74^{def}	92.98^{def}	7.45^{c}	8.50^{e}	6.80^{e}
NERI-306	59.64^{cde}	92.58^{cde}	94.38^{cde}	7.50^{c}	8.55^{e}	6.85^{e}
NERI-307	59.72^{cd}	94.18^{bcde}	94.85^{cde}	8.25^{c}	8.80^{de}	6.85^{e}
NERI-308	63.70^{abc}	98.48^{ab}	99.65^{ab}	9.65^{abc}	11.45^{abc}	8.80^{abc}
NERI-309	56.70^{de}	89.51^{ef}	90.49^{ef}	7.45^{c}	8.35^{e}	6.70^{e}
NERI-310	62.43^{bc}	96.01^{abcd}	97.09^{abcd}	$9.10b^{c}$	10.65^{bcd}	8.50^{bcd}
NERI-311	65.45^{ab}	98.84^{ab}	100.18^{a}	10.88^{ab}	12.00^{ab}	9.25^{ab}
NERI-312	67.59^{a}	99.46^{a}	100.50^{a}	11.65^{a}	12.92^{a}	10.00^{a}
NERI-313	63.26^{abc}	97.17^{abc}	98.48^{abc}	9.50^{abc}	10.85^{bcd}	8.70^{abc}
NERI-314	48.95^{f}	81.25^{g}	82.95^{g}	7.35^{c}	8.20^{e}	6.60^{e}
SEm (±)	1.79	1.68	1.67	0.84	0.72	0.50
CD (P = 0.05)	5.11	4.80	4.76	2.40	2.07	1.44

Table 2: Evaluation of wheat genotypes on dry weight, crop growth rate and relative growth rate

Genotypes	Dry weight (g/hill)			Crop growth rate (g/m2/day)			Relative growth rate (g/g/day)		
	60 DAS	90 DAS	At harvest	30 - 60 DAS	60 - 90 DAS	90 - At harvest	30 - 60 DAS	60 - 90 DAS	90 - At harvest
NERI-301	5.68^{cd}	16.14^{de}	20.44^{de}	8.76^{cd}	17.43^{abc}	7.16	0.088	0.035	0.008
NERI-302	5.06^{d}	13.02^{gh}	17.25^{h}	7.91^{d}	13.27^{d}	7.04	0.093	0.033	0.010
NERI-303	5.88^{cd}	16.96^{cd}	21.5^{cd}	9.43^{cd}	18.49^{ab}	7.55	0.110	0.035	0.008
NERI-304	5.42^{d}	15.78^{def}	19.84^{ef}	8.29^{d}	17.27^{abc}	6.78	0.083	0.036	0.008
NERI-305	5.17^{d}	13.86^{gh}	18.27^{gh}	8.07^{d}	14.49^{cd}	7.37	0.093	0.034	0.009
NERI-306	5.22^{d}	14.09^{fg}	18.78^{fgh}	8.17^{d}	14.78^{cd}	7.83	0.093	0.033	0.010
NERI-307	5.24^{d}	14.49^{efg}	19.5^{efg}	8.20^{d}	15.42^{bcd}	8.35	0.093	0.034	0.010
NERI-308	7.50^{ab}	19.02^{b}	24.73^{ab}	11.81^{ab}	19.20^{a}	9.52	0.097	0.031	0.009
NERI-309	5.09^{d}	13.44^{gh}	17.95^{gh}	7.94^{d}	13.92^{cd}	7.52	0.092	0.033	0.010
NERI-310	6.03^{cd}	17.96^{bc}	22.16^{c}	9.48^{cd}	19.86^{a}	7.02	0.095	0.036	0.007
NERI-311	8.05^{ab}	19.29^{ab}	25.18^{ab}	12.88^{ab}	18.73a^{b}	10.05	0.109	0.029	0.009
NERI-312	8.50^{a}	20.87^{a}	26.14^{a}	13.53^{a}	20.60^{a}	8.80	0.104	0.030	0.008
NERI-313	6.90^{bc}	18.69^{bc}	23.88^{b}	10.87^{bc}	19.64^{a}	8.67	0.098	0.033	0.008
NERI-314	4.98^{d}	12.07^{h}	15.62^{i}	7.86^{d}	11.82^{d}	5.92	0.100	0.030	0.009
SEm (±)	0.47	0.62	0.54	0.76	1.28	0.78	0.01	0.00	0.00
CD (P = 0.05)	1.33	1.79	1.55	2.17	3.66	NS	NS	NS	NS

Table 3: Evaluation of wheat genotypes on yield and yield attributes

Genotypes	Length of the spike (cm)	Number of grains per spike	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
NERI-301	12.20^{bcd}	40.75^{de}	37.65^{cd}	3.73^{abc}	5.70^{abcd}
NERI-302	11.89^{cd}	37.97^{hi}	34.95^{gh}	2.97^{ef}	4.94^{fg}
NERI-303	12.25^{bcd}	40.85^{de}	38.35^{bc}	3.79^{abc}	5.79^{abc}
NERI-304	12.17^{cd}	40.65^{de}	37.30^{cde}	3.51^{bcd}	5.59^{abcde}
NERI-305	12.03^{cd}	38.95^{fg}	35.82^{fg}	3.24^{de}	5.33^{def}
NERI-306	12.10^{cd}	39.5^{f}	36.22^{ef}	3.26^{de}	5.34cdef
NERI-307	12.12^{cd}	40.40^{e}	36.52^{def}	3.37^{cde}	5.44^{bcde}
NERI-308	12.70^{abc}	41.70^{bc}	39.37^{ab}	3.92^{ab}	5.94^{a}
NERI-309	11.98^{cd}	38.70^{gh}	35.77^{fg}	3.16^{de}	5.24^{efg}
NERI-310	12.36^{bcd}	41.25^{cde}	38.90^{ab}	3.83^{ab}	5.82^{ab}
NERI-311	13.00^{ab}	42.35^{ab}	39.55^{ab}	3.94^{ab}	5.96^{a}
NERI-312	13.50^{a}	42.95^{a}	40.05^{a}	4.18^{a}	6.04^{a}
NERI-313	12.55^{bc}	41.40^{cd}	39.15^{ab}	3.86^{ab}	5.87^{ab}
NERI-314	11.72^{d}	37.80^{i}	34.15^{h}	2.71^{f}	4.85^{g}
SEm (±)	0.29	0.25	0.42	0.16	0.16
CD (P = 0.05)	0.83	0.71	1.21	0.45	0.46

Number of grains per spike

Maximum number of grains per spike (42.95) was recorded significantly higher in the genotype G_{12} and the genotype G_{11} was statistically at par with the genotype G_{12}. Number of grains per spike mainly depends on the genetic variability. Each genotype exhibits its own hereditary characters and genetic traits. These results were found similar with the results of Kilic and Gursoy (2010).

Test weight (1000 seed weight in g)

Genotype G_{12} recorded significantly higher 1000 seed weight of (40.05 g). The genotypes G_{11}, G_8, G_{13} and G_{10} were statistically at par with the genotype G_{12}. Test weight is influenced by both environmental and genetic factors. Genetic characters include both the hereditary and variability traits that are directly responsible for the

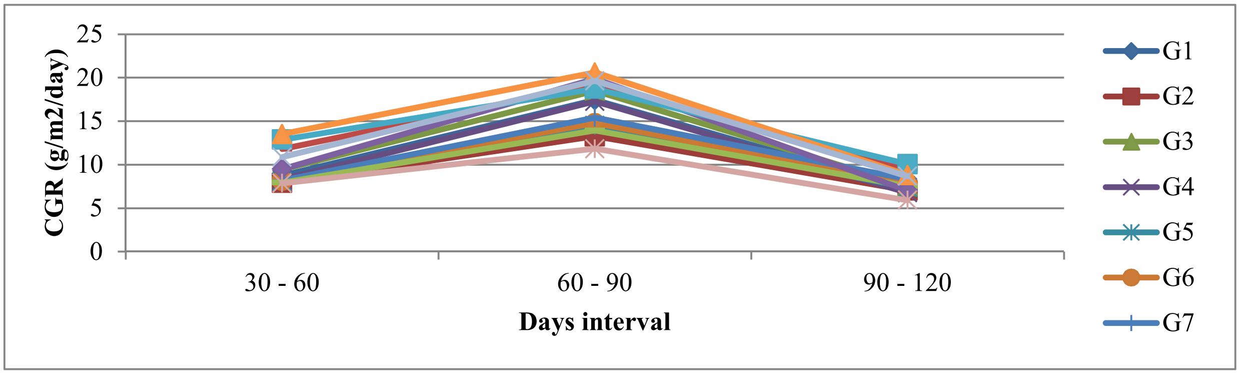

Figure 1: Crop growth rate (g/m2/day) of wheat in different genotypes

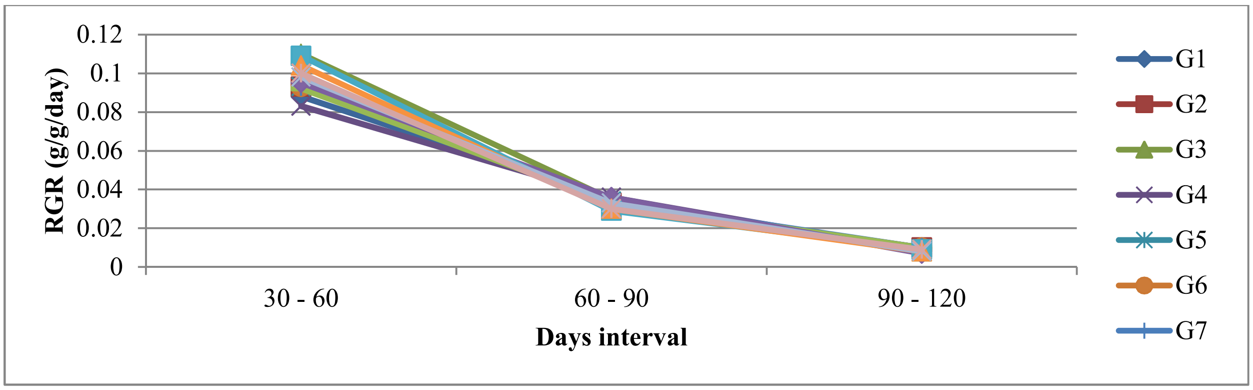

Figure 2: Relative growth rate (g/g/day) of wheat in different genotypes

1000 seed weight. Environmental factors like nutrient uptake, irrigation and etc., influence the test weight of the genotypes. Grain filling pattern and the other factors also influence the test weight of seeds in wheat crop (Banker *et al*., 2018).

Yield

Grain yield (t/ha)

Data pertaining to grain yield of wheat depicted in Table 3. It was specified that significant differences were due to variability in the genotypes. The maximum grain yield (4.18 t/ha) in the genotype G_{12} was found to be significantly superior over all the other genotypes. Genotypes G_{11}, G_8, G_{13} and G_{10} were at par with the genotype G_{12}. The maximum yield in genotype G_{12} is due to the yield attributes like higher number of grains per spike, maximum spike length and maximum thousand grain weight of the seeds which were significantly higher. These findings are similar with Sar *et al*. (2020). The higher grain yield was correlated with longer spike, growth duration and grain spike weight ratio at anthesis phase Gill (2009).

Straw yield (t/ha)

Data related to straw yield was recorded after harvesting of crop and tabulated in Table 3. It revealed that the genotype G_{12} recorded significantly higher straw yield (6.04 t/ha). However, the genotypes G_{11}, G_8, G_{13}, G_{10} and G_3 were statistically at par with the genotype G_{12}. Higher straw yield in G_{12} genotype is due to the achievement of the significantly higher growth attributes like plant height, dry weight and number of tillers. Nutrient uptake, irrigation at the critical growth stages and some environmental factors affect the straw yield of the wheat. These findings were in close conformity with Donaldson *et al*. (2001).

Conclusion

This study concluded that the wheat genotype NERI-312 was found more productive with maximum plant height, maximum number of tillers per hill, higher plant dry weight, higher number of grains per spike, maximum Test weight, higher grain yield and biological yield.

As the cost of cultivation is same for all the wheat genotypes, among them NERI-312 genotype will be economically viable due to the achievement of higher yield by that genotype.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Evaluation of production and environmental aspects of different pig production systems in the Northern State of India, Punjab

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ABSTRACT

Pig farming is stepping out from subsistence farming to commercial farming. In order to enhance the commercialized pork production for gaining self-sufficiency, it is necessary to study the production and related parameters of pig at farm level. This study aims to investigate the production parameters and disposal pattern of farm waste adopted by pig farmers in the Punjab. 90 piggery units were surveyed out of which sample size of total of 82 breeding-cum-finisher units of pig were categorized into small farms (< 10 sows), medium farms (10-25 sows) and large farms (> 25 sows). The study reveals that large size category favoured the ideal pig production parameters. It was observed that the 5.17 % of breedable sows were kept on an average for producing finisher pigs for sale (44.60 %). Large category was found having largest average litter size at birth (10.2). Similarly, average weight at saleable age of finisher pig is found to be highest in large size category (102.86 kg). Majority (59.07 %) of the small pig farmers dump the manure at waste heap or dispose it in the sewage posing environmental problems.

Introduction

Livestock sector contributes about 25.80 % and 38.77 % of agricultural gross domestic product (GDP) in India and Punjab respectively and is continuously improving over time. India has the world's largest livestock population, accounting for over 37.28 % of cattle, 21.23 % of buffalo, 26.40 % of goats, 12.17 % of sheep and 1.7 % of pigs. Punjab, located in the north-western part of India, is a predominantly agricultural state having 83 % of its area under cultivation with an average cropping intensity of 180 %. Northern state of Punjab is epicenter of green revolution and is regarded as "food bowl" of the country for sustaining food security. In last 20 years, farm environmental crises of air and water have increased and allied enterprises are being promoted by government for diversification. Livestock sector is an integral part of rural economy which contributes about 25.80 % and 38.77 % of agricultural gross domestic product in India and Punjab respectively (Statistical Abstract of Punjab, 2019). Due to decreasing input over output agricultural returns, there is a need of adapting allied occupations. As compared to other livestock species, Pig is one of the most productive and fast growing livestock species that can convert food waste to significant products (Rodriguez-Estevez *et al*., 2010). Pigs have higher turnover rate due to large litter sizes i.e., higher fecundity rate (average 6-12 piglets in each farrowing), and can farrow twice in a year with shorter gestation period (average 115 days), and dressing %age ranges from 70 - 80 in comparison to other livestock species whose dressing yields in the range of 50-60 % (Tewe and Adesehinwa, 1995). Pig farming

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provides quick returns to the small and marginal farmers since the marketable weight of fatteners can be achieved with in a period of 6-8 months. Pigs require minimal input in terms of family labour and feeding (Mutua *et al*., 2010) and it is the best option due to cost factor (Sahu *et al*., 2018).

Punjab accounts for only 0.57 % of total pig population of the country (Basic Animal Husbandry Statistics, 2019). The indigenous pig population of Punjab is 0.09 lakhs and the exotic/crossbred pig population is 0.44 lakhs (20th Livestock Census, 2019). As the growth rate of pig population in Punjab has been increasing over the time i.e. 7.18 % in the period of 2012-19, there is opportunity for farmers to adopt pig farming for consumption within the state and export across the country. Punjab ranks 7th with respect to pork production with the growth rate of 11.2 % in the country. Pig meat production in Punjab accounts for 0.47 % of the total meat production of the state and 0.27 % share of total pork produced in the country in 2018-19 (Statistical Abstract of Punjab, 2019).

Despite the fact that pigs are largely nondescript low-quality animals, the state and central government has made efforts to improve their poor production capacity by cross-breeding local pigs with well-known exotic breeds such as Large White Yorkshire, Middle White Yorkshire, Land Race, New Hampshire, and others. In reality, most state governments maintain breeding farms with exotic pigs from which pig farmers may obtain male breeding animals for cross-breeding their female breeding stock. Pig productivity is determined by mortality and growth rate, both of which are linked to feed conversion efficiency. In pig farming, the management system is critical because it creates the environment that allows the animals to perform to their full potential. In fact, the traditional system of rearing local breeds, as well as production patterns used on most piggery farms, such as poor feeding, housing of animals in filthy sheds, improper housing (either overcrowded or over spacious), and improper orientation, pose a serious threat to the pig industry. Furthermore, we must succeed in improving the body weight and carcass quality of the pigs by employing cost-effective feed made mostly from agricultural waste and unusual byproducts.

So far, none of the study has been conducted in Punjab state in context with production traits, breeds in pig farming and management of farm waste by pig farmers. So the present study would benefit farmers to get acquainted with the different production parameters of pig in order to start pig farming for better farm management and to generate handsome returns.

Material and Methods

From the Punjab state, three districts with highest concentration of pig population in the year 2018-19 (Ludhiana, Mohali and Sangrur) were selected (Statistical Abstract of Punjab, 2019). From each district, based on the number of adult sows kept, 30 pig farmers were selected for the present study and that make total sample size of 90 pig farmers. From the survey of 90 pig farmers, 82 breeding-cum-finisher units were taken for the analysis purpose as only number of pig breeding or only finisher units were very few in number. For the selection of piggery units, a complete list of all pig farmers who had breeding-cum-finisher units was prepared. This compiled list was arranged in ascending order of number of adult sows kept by the farmer at the time of the study. By using cumulative cube root frequency method of stratification (Jain, 1998), piggery units were divided among the small, medium and large farmers and the final list of farmers for the study was obtained and presented in Table 1.

Primary data pertaining to following parameters were collected using a specially designed schedule, containing the relevant questions to be answered by the respondents, by personal interview method for the agricultural year 2018-19. Before starting the actual data collection work, pre-testing of the questionnaire schedule was done among randomly selected ten pig farmers in the state. Certain questions which emerge during the course of pretesting and considered important will be included in the final schedule.

I. Production Parameters of pigs at sampled pig farms such as average litter size at birth, mortality %age, average birth weight of piglet, weaning age, average maturity age, average weight at breeding/maturity, male and female ratio of piglets, number of farrowing per year, farrowing interval, average productive life of sow etc.

II. Breeds reared at different sized pig farms in Punjab.

III. Breeding boar kept at different sized pig farms.

IV. Farm waste management e.g. total manure produced, amount utilized and disposed, etc.

Statistical tools and techniques like averages, %ages and other descriptive statistics were used and relevant inferences were drawn.

Table 1: Categorization of farms in selected districts on the basis of number of Sows.

Category	Number of sows	Average size of the farm	Number of pig farms
Small	0 – 10	6+1	44
Medium	10- 25	16+2	24
Large	25 & above	44+2	14
Total		66+5	82

Results and Discussion

The composition of number of sows, boar and piglets and their physiological status such pregnant sow, dry sow, weaner, grower, finisher at different size of farm is described as below.

Structure components of pig farms in Punjab:

The breeding-cum-finisher unit categorizes the herd size into breeding and finisher pigs. The existing herd strength includes piglets and growing pigs for disposing purpose while breedable sows and boars are maintained for further breeding purposes. The distribution of herd size from small, medium and large pig farms has been presented in Table 2.

A perusal of Table 2 revealed that sows were categorized under two types i.e. pregnant and dry sows. The overall average number of breedable sows was found to be 66, from which 40 (60.61 %) were found to be pregnant and 26 (39.39 %) was found to be non- pregnant/ dry sows.

The piglets on the farm were categorized into three categories depending on the age and weight of piglets as weaner (0-1 month, 1-7 kg), grower (2-6 month, 7-75 kg) and finisher (6-12 month, 75-135 kg). In study, an average of 1204 piglets were found in total out of which 194 (16.11 %), 473 (39.28 %) and 537 (44.60 %) were found to be weaner, grower and finisher respectively. The results of the study are in line with Jain, (1998) who revealed that the total herd strength was more or less same, amongst these three feeding patterns while the pig rearer of medium size category had herd strength between 33 and 57 and the piggery herd strength amongst large farmer category ranged between 68 and 95. Mahto, (2006) also reported that majority of the respondents (92.00%) of organized pig farms were keeping large size of stock (>15 pigs), 8.00 % respondents had medium size of stock (11-15 pigs) and no one respondents had small size of stock (< 10 pigs). Whereas, majority of the respondents (44.00%) of un-organized pig farms were keeping large size of stock, 32.00 % respondents had small size of stock and 24.00 % had medium size of stock.

Production traits of pig farming in Punjab state

The various parameters regarding category wise production traits of pig farm have been presented in Table 3. Data presented in the table compares the category wise production parameters at pig farms. A scrutiny of the table reveals that the various production traits viz., average litter size at birth, average birth weight of piglet, average litter weight at pre-weaning and post- weaning, average maturity age, average productive life of adult sow, etc. were found to be effectively highest in the large category due to better management, housing and feeding conditions. Thus, Large farmers were found to sale finisher pigs at an average age of 9.93 months and average weight of 102.86 kg followed by medium and small farmers at an average age of 9.23 and 8.77 months and average salable weight of 99.58 kg and 93.41 kg respectively resulting in remunerative returns.

Mortality of piglets at birth was found to be highest in small size category i.e. 13.93 % due to early maturity age of sow (7.01 month), feeding constraints, lack of proper housing facilities, etc. Piglets were found to be weaned early in large farms i.e. 34.42 days because of higher average birth weight of piglet as compared to other categories where the piglets were found to be weaned at average 35.23 days and 37.01 days in medium and small size category respectively.

Mahto, (2006) also reported that the average litter size (number) was found to be 11.72±1.57 in the organized pig farms and 6.48±1.23 in the un-organized pig farms. Average weight of male piglet at birth(kg)was found to be 1.17±0.21 in the organized pig farms and 0.76±0.16 in the un-organized pig farms. Average weight of female piglet at birth (kg) was found to be 1.06±0.14 in the organized pig farms and 0.74±0.13 in the un-

Table 2: Composition of pig at different size of farms in Punjab state (in numbers).

Particulars	Small (6+1)	Medium (16+2)	Large (44+2)	Punjab (66+5)
Sow				
Pregnant sows	4 (66.67)	10 (62.5)	26 (59.09)	40 (60.61)
Non-pregnant sows	2 (33.33)	6 (37.5)	18 (40.90)	26 (39.39)
Total breedable sows	6 (100.00)	16 (100.00)	44 (100.00)	66 (100.00)
Boar				
Boars (for breeding)	1 (100.00)	2 (100.00)	2 (100.00)	5 (100.00)
Piglets				
0-1 m (weaner)	17 (19.32)	57 (20.07)	120 (14.42)	194 (16.11)
2-6 m (grower)	30 (34.09)	108 (38.03)	335 (40.26)	473 (39.28)
6-12 m (finisher)	41 (15.91)	119 (41.90)	377 (45.31)	537 (44.60)
Total piglets	88 (100.00)	284 (100.00)	832 (100.00)	1204 (100.00)

Table 3: Production traits of pig farms in Punjab state

SN	Production parameters	Small (6+1)	Medium (16+2)	Large (44+2)	Punjab (66+5)
1	**Average litter size at birth (No.)**	8.51	9.61	10.02	10-12
2	**Mortality at birth (%)**	13.93	7.69	7.31	10-12
3	**Average birth weight of piglet (gm)**	1055.21	1100.30	1200.21	1000-1400
4	**Weaning age (days)**	37.01	35.23	34.42	21-35
5	**Average litter weight at pre weaning (kg)**	4	4.5	5	5
6	**Average litter weight at post weaning (kg)**	17.45	18.55	20.04	20-22
7	**Average maturity age (month)**				
(a)	**Boar**	7.25	7.95	8.01	8
(b)	**Sow**	7.01	7.06	7.11	8
8	**Average weight at breeding/maturity (kg)**				
(a)	**Boar**	85.86	87.87	90.09	85-90
(b)	**Sow**	83.64	88.57	90.61	85-90
9	**Ratio in kids**				
(a)	**Male piglet**	49.66	51.25	48.57	51
(b)	Female piglet	50.34	48.75	51.42	49
10	Number of farrowing per year	2.01	2.01	2.04	2
11	Farrowing interval (days)	142	143	145	145-147
12	Average productive life of adult sow (yr.)	3.58	3.87	3.98	3.6-3.8
13	Average saleable age of finisher (month)	8.77	9.23	9.93	9-10
14	Weight at saleable age of finisher (kg)	93.41	99.58	102.86	100-120

organized pig farms. Average age for maturity of male was found to be 7.40±0.50 in the organized pig farms and 11.32±1.14 in the un-organized pig farms. The average age of maturity of female, was found to be 7.20±0.64 in the organized pig farms and 11.04±1.06 in the un-organized pig farms.

Similar results were observed by Jain, (1998) who reported that most of the sows maintained by the small farmers farrrowed twice and average litter size ranged between 6.5 and7. Piglets below 2 months of age had higher mortality (ranged between 8.3 to 14.2%), as compare to piglets above 2 months. Sows maintained by medium farmers farrowed twice and their average litter size ranged between 6.6 and 8.5. Piglets below 2 month had higher mortality ranging between 13.1 and 17.2% whereas sows maintained by large farmers farrowed twice and average litter size ranged between 6.8and8.5. The age at first service varied across farm size categories mostly between 9 and 10 months. Gestation period ranged in most of the cases between 117 and 120 days. The mortality rate of piglets was high before weaning ranged between 11 and 16%. The marketing age of pigs across farm category was mostly either 2-3 months or above 9 months.

Breeds of Pigs in Punjab, 2018-19:

A perusal of the table 4 revealed that highest proportion (54.88 %) of breeds kept by the pig farmers was found to be crossbred of LWY* Landrace in Punjab followed by the crossbred of LWY* Duroc accounting to be 42.68 %. Apart from indigenous breeds, only Ghungroo was found be reared only by 4.54 % of small farmers in Punjab. Thus, small farmers need better breeding facilities for improving production traits.

Category wise analysis reveals that 64.28 % of large farmers rear crossbred of LWY* Landrace followed by small (56.82 %) and medium (45.83 %) pig farmers whereas majority of medium farmers (54.17 %) rear crossbred of LWY* Duroc followed by small (38.64 %) and large (35.71 %) farm size category. Najuki *et al.*, (2010) also observed that 54 % of the households kept large black pig breed, 21% the indigenous/local breeds and 13% the cross breeds. The exotic breeds were preferred because of their rapid growth rate (32%), easy feeding (24%), and high littering ability (15%). Thirty seven % of the entire sample practiced controlled mating.

Breeding Boar of pig farmers in Punjab, 2018-19

A perusal of the table 5 reveals that amongst the breeding boar, the proportion of owned boar was highest in pig farming in all the categories in Punjab i.e. 89.02 % farmers were having their own boar whereas the proportion of farmers who used other farmers' boar was found to be 10.97 %. All the farmers of medium and large farm size category were found to have their own breeding boar at the farm whereas 20.45 % of only small farmers were found using boars of other farmer's for breeding purposes due to small farm size and less initial capital investment on animals as compared to medium and large farm size category.

Economic Assessment: Management of farm waste under different production systems in Punjab, 2018-19

The production and disposal of farm waste is crucial to know the importance of pig manure in other integrated farming systems e.g. in fish farming, crop farming, etc. Moreover, the disposal pattern of farmers can be known that do not use it in the field rather dispose it in the sewage which might pose environment problems. The various parameters regarding the management of farm waste by pig farmers of Punjab has been presented in the Table 6. The study indicates that the majority of the large and medium farms were organized while small farms were unorganized. The waste management of the pig production systems in all the categories was unorganized. Total manure produced at large farm was found to be 4697.55 qtls/ farm/year followed by medium (2660.85 qtls/ farm/year) and small farms (1182.60 qtls/ farm/year). Majority (59.07 %) of the small pig farmers dump the manure at waste heap or dispose it in the sewage whereas 40.91 % used it in their own farm out of which major proportion (34.08 %) is used at the agricultural field and 6.82 % is used at the fish farm. Medium farmers were found to use 91.67 % of farm waste at their own farm out of which 69.67 % was used at agricultural field and 25.00 % was used at the fish farm whereas only 8.33 % of total farm waste was disposed off. In large farm size category, 92.86 % of the farmers were found to use farm waste at their own farm i.e. 69.23 % at the agricultural field and 30.77 % at the fish farm. The disposal pattern of pig farmers in the sewage poses environment problems. As preventing measures government should restrict the dumping of pig farm waste into the sewage as it ultimately leads to the environmental degradation especially of the urban section of the society. Thus, policies are required for waste management produced at pig farms especially for landless farmers who ultimately have to dump the waste into sewage.

Similar findings were made by Najuki *et al.* (2010) who reported that 58% of the households had a compost pit to which the waste from the sty was collected. The main use of the waste was manure

Table 4: Breeds of Pigs in Punjab, 2018-19

Breeds	Small (6+1)	Medium (16+2)	Large (44+2)	Punjab (66+5)
Crossbred				
LWY* Landrace	25 (56.82)	11 (45.83)	9 (64.28)	45 (54.88)
LWY* Duroc	17 (38.64)	13 (54.17)	5 (35.71)	35 (42.68)
Indigenous				
Ghungroo	2 (4.54)	0 (0.00)	0 (0.00)	2 (2.44)
Total	44 (100.00)	24 (100.00)	14 (100.00)	82 (100.00)

*LWY= Large white Yorkshire

Table 5: Breeding Boar of pig farmers in Punjab, 2018-19

Particulars	Small (6+1)	Medium (16+2)	Large (44+2)	Punjab (66+5)
Own boar	35 (79.54)	24 (100.00)	14 (100.00)	73 (89.02)
Other farmer's boar	9 (20.45)	0 (0.00)	0 (0.00)	9 (10.97)
Total	44 (100.00)	24 (100.00)	14 (100.00)	82 (100.00)

Table 6: Management of farm waste by pig farmers in Punjab, 2018-19

Particulars	Small (6+1)		Medium (16+2)		Large (44+2)		Punjab (66+5)	
	Average pdtn/ farm/ year (qtl)	Frequency	Average pdtn/ farm/ year (qtl)	Frequency	Average pdtn/ farm/ year (qtl)	Frequency	Average pdtn/ farm/ year (qtl)	Frequency
Total manure production	1182.6 (100.00)	44 (100.00)	2660.85 (100.00)	24 (100.00)	4697.55 (100.00)	14 (100.00)	8541 (100.00)	82 (100.00)
Own farm	483.79 (40.91)	18 (40.91)	2439.14 (91.67)	22 (91.67)	4362.01 (92.86)	13 (92.86)	5520.48 (64.63)	53 (64.63)
Agricultural field	403.05 (34.08)	15 (83.33)	1773.92 (66.67)	16 (72.73)	3019.86 (64.28)	9 (69.23)	4166.4 (48.78)	40 (75.47)
Fish farm	80.61 (6.82)	3 (16.67)	665.22 (25.00)	6 (26.09)	1342.16 (28.57)	4 (30.77)	1354.08 (15.85)	13 (24.53)
Dispose (sewage, waste heap)	698.62 (59.07)	26 (31.71)	221.74 (8.33)	2 (8.33)	335.54 (7.14)	1 (7.14)	3020.64 (35.37)	29 (35.36)

for crops (94%), while 3% reported that the waste was given out to friends and neighbours. Eleven % of the households in Wokha district sold manure at the farm gate to other farmers. Eleven % of the households reported that family members complained that the environment around the homesteads was smelly. 39% of all sampled households, 60% in Phek, 50% in Kohima, 30% in Wokha and 10% in Mokokchung reported that these problems posed a health risk to their families.

Conclusion

Pig production systems of Punjab provide wide opportunity to further enhance the commercialised pork production for gaining self sufficiency in pork production. Value addition adds to the additional income at the large pig farms besides the availability of better feeding, management and waste management. Majority of the landless small farmers were lacking ideal productions and waste management at the farm. Indigenous breeds hinder the production system at commercial scale. The proliferation of indigenous breeds like ghungroo is not much appreciated as that of crossbreds and exotic breeds. So, farmers should be encouraged to use exotic or crossbred breeds of pigs so as to get the maximum returns possible and to minimize some of the production constraints. In addition to poor veterinary, transportation of pigs to hospitals is difficult as it requires extra labour and transportation costs. The regular check up of the animals with timely vaccination (for FMD and swine fever) and deworming is necessary which needs to be easily available locally. Small farmers which do not have their own boar, hire the services from unorganised sector, which increase the risk of disease and other issues. Farmers should be made aware of using good quality semen by consulting government piggery units and veterinary doctors so that production constraints like high mortality, diseases, lower litter size, etc. can be combated. Boar of good germ plasm and of pure exotic breed should be encouraged by the local veterinary hospitals. Mechanism for piggery waste disposal in the state is required so that it can be utilized properly. In addition, it can be used in the fish farm to support the integrated model of pig-cum-fish farming. Management awareness through training and extension education is required in the state of Punjab to up-lift the entrepreneur behavior of pig farmers for better returns. Policy implications at farm level by the state governments for the development of piggery sector are required.

Conflict of interest

The authors declare that they have no conflict of interest.

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Garrett scoring technique for assessing the constraints faced by dairy farmers of Madhepura district, Bihar

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ABSTRACT

The present investigation is entitled as Garrett scoring technique for assessing the constraints faced by dairy farmers of Madhepura district, Bihar. The primary data were collected from 120 cooperative farmers through the random sampling method. During the study, various constraints under economics and marketing of milk were evaluated as per the response of sample dairy farmers of the study area. Major economic constraints recognised among the group of sample farmers were higher cost of cattle feed, easy availability of veterinary facilities, high cost of the improved animal, while major marketing constraints were low price of milk, lack of suitable transportation, delay in getting milk price. It was also found that the number of dairy farmers decreased in the cooperative milk collection centre with the increase of distance. There was also scope for reduction in the cost of milk production by using modern methods and technologies of dairy farming that was completely absent in the study area.

Introduction

Dairy farming is the major component of livestock farming. It has a long tradition in our country. Cow, buffalo and goat are the main domesticated dairy animals. In many nations, agriculturists regard the promotion of the milk production system as one of the most widely favoured paths to rural and overall economic development. It provides dairy farmers with a consistent source of revenue at a low-risk level (FAO, 2017). The care and management of milking animals provide socially desirable work opportunities. Nowadays people sell milk where the market is available. Many small dairy plants also have been established in rural areas. Dairy farming is developing as a dairy enterprise in many parts of our country. In the state of Bihar, milk production is a significant source of income among small and marginal farmers. Small dairy farmers produce around 80% of the total milk. Bihar's share of the total milk in India rose from 3.2% in 2001–02 to 5.2% in 2018–19 (Department of Animal Husbandry, Dairying and Fisheries, 2020). Most of the dairy farmers sell their milk in milk collection centres for earning a good income. The Bihar State Milk Co-Operative Federation Ltd. (COMFED) is supporting dairy farmers in various ways for decades. This research has been done to throw some light on the constraints faced by the dairy farmers while selling milk to the milk cooperatives and some suggestions will be given to cope with problems and enhance income in the dairy sectors.

Material and Methods

The present study involves the detailed sampling design nature and mode of collection of data and analytical tools employed in achieving the objective of the study. The present research was taken up in the Madhepura district of Bihar. The study area and the cooperative milk collection centre was purposively selected as the milk cooperative centre as it is newly started in the study area. The study was predominantly based on primary data that were collected by using a pretested questionnaire. 120 cooperative dairy farmers were randomly selected for getting primary data and some secondary

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information were also collected from the Secretary of the Cooperative Society. Dairy farmers were being further categorized under three heads small dairy farmers (less than 5 milking animals), medium dairy farmers (5-10 milking animals) and large dairy farmers (more than 10 milking animals). The collected data were coded, classified so that the findings become meaningful. Garratt ranking tool is applied for analysis of constraints faced by respondents.

Research objective

This study was for potential beneficiaries from those villages which had not much awareness about cooperative milk-collection centres. It will also be helpful to small and medium farmers to provide interest in dairy farming as a security against any failure of agriculture crops and it can help farmers to get additional income through milk production. Dairy cooperatives replace all the action of middlemen which helps the farmers to get the proper value of their produce. Dairy plays a very vital role in increasing farmers' income (Gadad *et al.,* 2020). The demand for milk and milk products is increasing day by day due to rapid population growth and urbanization. But, because of inadequate milk supply and ill management of its marketing system, still, dairy farmers are suffering from "Milk Holiday". Milk holidays become more severe, farmers of this study area are facing this problem due to various reasons: Banda, Strike and other technical problems of the adequate alternative milk market. There is a lack of reasonable prices of milk products in the local market. So, the farmers increase their consumption (Shuya *et al.,* 2014).

Keeping view of the above points, data through questionnaire investigations were conducted in with following objectives:

1. To study the demographic conditions of dairy farmers in the study area.
2. To identify constraints and suggestions of the respondent in the study area.

Tools of analysis

The total number of respondents was fixed as 120. The samples were randomly collected from the farmers from every one of these communes, which were dispensed a few of the four villages *viz*., Mirganj, Dighi, Rahta and Belari in probability proportion. The respondents have been decided on at random in every village. The sample farmers under each category were decided on in proportion to their respective total population, the chosen villages with the pattern respondents in every of the selected villages are furnished in the following Table 1.

Scoring technique

To study the constraints faced by the dairy farmers in running dairy farm and marketing of milk, the scoring technique was adopted, as suggested by Garrett for converting the ranks into scores, when the preference of a particular constraint differ from respondent to respondent. The conversion method was as follows:

As a first step the per cent position of each rank was found out by the given formula:

$$\textbf{Percent position} = \frac{\textbf{100 (Rij} - \textbf{0.5)}}{\textbf{Nj}}$$

Where,

Rij = Rank given for ith item by the jth individual

Nj= Numbers of items ranked by jth individual

The percent position was then converted into scores by referring to the table given by Garrett. Following this procedure, the order of merit given by each of the respondents as the problems in the financial management of dairy farms and marketing of milk was converted into scores. Then for each reason, the scores of individual respondents were added together and divided by the total number of respondents were added. These mean scores for all reasons were arranged in descending order and ranks were given. By this method, the accuracy in determining the preference was obtained.

Table 1: Details of number of villages and dairy farmers under cooperative milk collection centre.

SN	Village Name	Number of dairy farmers		
		Small	Medium	Large
1.	Mirganj	10	10	10
2.	Dighi	10	10	10
3.	Rahta	10	10	10
4.	Belari	10	10	10
	Total	40	40	40

Results and Discussion

Economic constraints faced by Dairy farmers

The study has shown the various economic problems faced by dairy farmers. From Table 3, it could be seen that six problems were identified by the respondents. It could be observed that the higher cost of cattle feed was ranked as the foremost reason which caused difficulties in obtaining better income for dairy farmers. Poor health services and no easy availability of veterinary facilities were ranked second. Farmers also stated that they were facing problems due to the high cost of improved animals and ranked this third. Lack of loan facilities, lack of nutritional fodder and lack of technical facility were ranked 4th, 5th and 6th respectively.

Rank estimation

The samples were collected randomly from small, medium and large dairy farmers of the Madhepura district. The sample size is fixed to 120. Where, the number of small, medium and large farmers were 40 in each category. It can be simply understood by considering the following Table 1.

Table 2 describes the total rank given by each respondent on different factors which causes problems in the management of the dairy farm. From Table 2, it is observed that maximum respondents *i.e.*, 34 respondents were given 1st rank to one problem that is the high cost of the improved animal. On the other hand, the 2nd highest rank given to another problem that is the higher cost of cattle feed, and so on which briefly explains the rank given by the total dairy farmers on different factors which causes problems on maintaining the dairy farm.

Percent Position Value Estimation

Percent position values were calculated by considering the formula *i.e.*, 100(Rij-0.5)/Nj; to evaluate the Garrett value, the percent position value was essential to rank the exact causes for a particular phenomenon or problem.

Estimation of the total score given by sample dairy farmers

The total score of each factor rank will be estimated by multiplying the Garrett value with the respect given value. Hence, the total score is essential to calculate the average score given by the total respondents under different factors of a particular phenomenon. Table 4 describes the calculation procedures of the Total Score of the sample respondents. The total score was calculated by multiplying Garrett Value with the respective rank given by the respondents on each factor of the sample. Hence, on the first rank, the Garrett value is 77 and the number of respondents given Rank 1 is 34. So, by multiplying this two, we were getting the total score *i.e.,* 2618. Hence, all the estimation processes go in the same direction on every factor with their respective rank given by the number of respondents.

Estimation of Average Score

Under Garrett value ranking techniques, the average score will be calculated by dividing the total score by the total respondents of the selected sample. The highest percentage average score indicates the 1st rank whereas the lowest percentage average score indicates the last rank of the total estimated factors rank. The study has shown the various problems in obtaining institutional credit, which is presented in Table 5. From this table, it could be seen that six problems were identified by the respondents. Out of those six, the higher cost of cattle feed was ranked as the foremost one which caused inconvenience to the dairy farmers in maintaining the cattle. This might be due to the lesser availability of grazing lands because the majority of the farmers in the research region were landless and marginal. In recent years, population growth, industrialization, and urbanization have all contributed to a scarcity of grazing land. These results are in line with Singh *et al.* (2000), Gopi *et al.* (2020). The lack of veterinary facilities was the next most significant restriction. Manivannan (2008) also mentioned a lack of effective field-level extension support for livestock-related operations. Policymakers and administrators can take the required steps to replace vacant Veterinary Assistant Surgeons posts at the block or village level, and the Veterinary University and Animal Husbandry Department can execute appropriate awareness initiatives about the latest dairy technologies. The problem of the high cost of improved breed of animal was ranked third. Because improved breeds are harder to get by in the study area, farmers are forced to buy them from other states, raising the animal's cost. The sample farmers also faced problems in lending loans for their dairy business, which ranked fourth. Because the majority of farmers in the research area are marginal and small, a problem with loan lending could be attributed to a lack of documentation and items for a mortgage by the farmers. Lack of nutritional fodder and technical facility was at rank fifth and sixth, respectively. These results are in conformation with Paudel (2014).

Table 2: Rank estimation of total sample dairy farmers

SN	Problems	R1	R2	R3	R4	R5	R6	TOTAL
1	High cost of improved animal	34	11	15	20	14	26	120
2	Higher cost of cattle feed	27	34	17	11	20	11	120
3	Easy availability of veterinary facilities	15	24	25	25	21	10	120
4	Lack of loan facility	13	19	29	22	21	16	120
5	Lack of technical facility	11	14	14	22	27	32	120
6	Lack of nutritional fodder	24	17	16	15	16	32	120

Source: Primary source, *Note: R1- Rank 1, R2- Rank 2 and so on.

Table 3: Estimation of Garrett value for each percent position value

Rank	100(Rij-0.5)/Nj	Percent Position Value	Garrett Value
R1	100(1-0.5)/6	8.33	77
R2	100(2-0.5)/6	25.00	63
R3	100(3-0.5)/6	41.67	54
R4	100(4-0.5)/6	58.33	46
R5	100(5-0.5)/6	75.00	37
R6	100(6-0.5)/6	91.7	23

Table 4: Estimation of total score by multiplying Garrett value with the respective rank Garrett value

SN	Problems	R1*77	R2*63	R3*54	R4*46	R5*37	R6*23	TOTAL
1	High cost of improved animal	2618	693	810	920	518	598	6157
2	Higher cost of cattle feed	2079	2142	918	506	740	253	6638
3	Easy availability of veterinary facilities	1155	1512	1350	1150	777	230	6174
4	Lack of loan facility	1001	1197	1566	1012	777	368	5921
5	Lack of technical facility	847	882	756	1012	999	736	5232
6	Lack of nutritional fodder	1848	1071	864	690	592	736	5801

Source: Primary survey

*Note: R1*77 means Total number of respondents given first factor as Rank 1 multiply with respective Garrett value i.e.,77 and others are estimated like that.

Table 5: Estimation of average score of the total sample dairy farmers

SN	Problems	Total	Average score	Rank
1	High cost of improved animal	6157	51.31	3rd
2	Higher cost of cattle feed	6638	55.32	1st
3	Easy availability of veterinary facilities	6174	51.45	2nd
4	Lack of loan facility	5921	49.34	4th
5	Lack of technical facility	5232	43.60	6th
6	Lack of nutritional fodder	5801	48.34	5th

Source: Primary Survey

***Note: Average Score = Total score/ Total Respondents**

Marketing constraints faced by dairy farmers

The study has shown the various marketing problems faced by dairy farmers. From Table 6 it could be seen that five marketing problems were identified by the respondents. It could be observed that the low price of milk was ranked as the foremost reason which affect the prices received by dairy farmers in milk marketing. Lack of suitable transportation facility was ranked second as some of them live far away from the collection centre. Farmers also stated that they are facing problems due to delays in getting the price of milk and ranked this third. Milk holiday and timing of milk collection and measurement of milk at collection centre were ranked 4th and 5th, respectively in milk marketing.

Rank estimation

The samples were collected randomly from small, medium and large dairy farmers of the Madhepura district. The sample size is fixed to 120. Where, the number of small, medium and large farmers were 40 in each category. It can be simply understood by considering the following Table 6. Table 6 describes the total rank given by each respondent on different factors which caused the problem in marketing and sales of milk to the milk cooperative centre. It was observed that maximum respondents i.e., 39 dairy farmers were given 1st rank to the lesser prices paid by milk cooperative. On the other hand, the 2nd highest rank was given to lack of suitable vehicle for carrying milk to cooperative centre and so on which briefly explain the rank given by the total sample dairy farmers on different factors which causes problems in selling milk to cooperative centre.

Table 6: Rank estimation of total sample dairy farmers.

SN	Constraints	R1	R2	R3	R4	R5	TOTAL
1	Lack of suitable transport	29	37	26	19	11	120
2	Low price of milk	39	35	18	13	13	120
3	Delay in getting price of milk	24	22	44	13	17	120
4	Milk holiday	14	13	15	35	43	120
5	Timing of milk collection	10	13	15	40	42	120

Source: Primary source ***Note: R1- Rank 1, R2- Rank 2 and so on.**

Table 7: Estimation of Garrett value for each percent position value.

Rank	100(Rij-0.5)/Nj	Percent Position Value	Garrett Value
R1	100(1-0.5)/5	10.00	75
R2	100(2-0.5)/5	30.00	60
R3	100(3-0.5)/5	50.00	50
R4	100(4-0.5)/5	70.00	40
R5	100(5-0.5)/5	90.00	24

Table 8: Estimation of total score by multiplying Garrett value with the respective rank Garrett value.

SN	Problems	R1*75	R2*60	R3*50	R4*40	R5*24	TOTAL
1	Lack of suitable transport	2175	2220	1300	760	264	6719
2	Low price of milk	2925	2100	900	520	312	6777
3	Delay in getting price of milk	1800	1320	2200	520	408	6248
4	Milk holiday	1050	780	750	1400	1032	5012
5	Timing of milk collection	750	780	750	1600	1008	4888

Source: Primary survey

*Note: R1*77 means Total number of respondents given first factor as Rank 1 multiply with respective Garrett value i.e.,77 and others are estimated like that.

Table 9: Estimation of average score of the total respondents.

SN	Problems	Total	Average score	Rank
1	Lack of suitable transport	6719	55.99	2nd
2	Low price of milk	6777	56.47	1st
3	Delay in getting price of milk	6248	52.07	3rd
4	Milk holiday	5012	41.77	4th
5	Timing of milk collection	4888	40.73	5th

Source: Primary Survey

***Note: Average Score = Total score/ Total Respondents**

Percent position value estimation
Percent position values were calculated by considering the formula i.e., 100(Rij-0.5)/Nj; to evaluate the Garrett value, the percent position value is essential to rank the exact causes for a particular phenomenon or problem.
Estimation of Total Score given by Sample respondents
The total score of each factor rank will be estimated by multiplying the Garrett value with the respect given value. Hence, the total score is essential to calculate the average score given by the total respondents under different factors of a particular phenomenon. Table 8 describes the calculation procedures of the Total Score of the sample respondents. The total score is calculated by multiplying Garret Value with the respective rank given by the respondents on each factor of the sample. Hence, on the first rank, the Garrett value is 75 and the number of respondents given Rank 1 is 39. So, by multiplying this two, we are getting the total score i.e., 2925. Hence, all the estimation processes go in the same direction on every factor with their respective rank given by the number of dairy farmers.
Estimation of Average Score
Under Garrett value ranking techniques, the average score will be calculated by dividing the total score by the total sample of dairy farmers. The highest percentage average score indicates the 1st rank whereas the lowest percentage average score indicates the last rank of the total estimated factors rank. The study had shown the various problems in marketing and sales of milk to the cooperative centre, which is presented in Table 9. From this table, it could be seen that five marketing problems were identified by the dairy farmers. Out of those, lower prices of milk paid by cooperative was ranked as the foremost one. These results might be due to the huge difference between buying and selling prices of milk by the milk cooperative. Similar results were also validated by Paudel (2014). The non-availability of automated milk transporting vehicles ranked second. Lack of knowledge and non-availability of advanced mechanized vehicles among dairy farmers for milk transportation in the study region lead to acidification of milk due to higher temperature exposure (Paudel, 2014). The third most challenging problem faced by dairy farmers was a delay in credit of milk price by the cooperative. Some other factors responsible for causing problems in the marketing of milk were milk holidays due to strike or banda, improper timings of milk collection by the cooperative as identified by the sample dairy farmers. Farmers suffer a significant loss in this case since there is no other milk market. Despite their desire to sell their extra milk output, farmers are obligated to consume it.

Conclusion
The present investigation was focused on identifying the various constraints faced by the sample dairy farmers in the study area. Therefore, based on the survey, interview and secondary data it can be concluded that dairy farmers of Madhepura district were facing both economic and marketing constraints in selling milk to milk cooperative recentres and running the dairy business. In economic constraints, high cost of improved animals, cattle feed, lack of veterinary facilities were found commonly in the study area. Dairy farmers are getting lower prices for the milk, lack of transporting vehicles, delay in credit of money were the major marketing constraints.

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

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Soil biological properties as affected by the conjunction of chemical fertilizers, bacterial consortia and bio-enhancers in foxtail millet cultivation

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ABSTRACT

During *Kharif* 2019, a field experiment was conducted with eight treatments replicated three times in Randomized Block Design at College farm, PJTSAU, Rajendranagar, Hyderabad. The aim of the study is to investigate the combined effect of chemical fertilizers and bio-agents (bacterial consortia and bio-enhancers) on soil biological parameters (bacterial population, urease, dehydrogenase, acid phosphatase and alkaline phosphatase) under foxtail millet cultivation in semi-arid region where soil and climatic constraints prevail in general. The bacterial population in the rhizosphere soil was found to be greater in all the treatments that received bacterial consortia appended with bio-enhancers compared to the remaining treatments as they are rich in microbial population. The soil enzyme activity was found to be higher when bioagents were used in conjunction with fertilizers, similar to bacterial population. The use of bacterial consortia or bio-enhancers alone also improved enzyme activity when compared to the control, while fertilizers alone, were poor in the activity of above enzymes. The percentage increase in the overall biological activity over the initial value was found to be highest when bioagents were used along with the chemical fertilizers at 50% flowering and harvest stages whereas it was found least in the control and lower in the treatments applied with chemical fertilizers alone.

Introduction

Soil should not be regarded as a simple medium for crop growth; rather, it should be considered as a complex biological ecosystem. This was understood by Indian farmers and they used to follow natural laws, which aided in the preservation of soil health over a substantial period of time. But, with green revolution, the use of fertiliser responsive varieties and agrochemicals has resulted in a huge increase in yield which enabled India to become self-sufficient in food grain production but caused serious damage to the soil health due to dumping of huge chemicals into the agricultural soils. Eco-friendly technologies must be developed and made available to farmers in order to restore the soil health. As a result, scientists and policymakers are rethinking agricultural systems that rely heavily on bio- inputs rather than synthetic/chemical fertilizers alone. Preserving long-term soil fertility by protecting organic content and supporting biological nature of the soil are important measures. Using biofertilizers, bacterial consortia (combination of biofertilizers), bio-enhancers (*beejamrutha* & *jeevamrutha*), green manures, farm yard manures, composts etc. are the

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options found to enhance the biological activity of the soil (Ananda *et al.,* 2017; Boraiah *et al.,* 2017; Hameedi *et al.,* 2018; Krishnaprabhu (2018); Vinay *et al.,* 2020). Use of such organic manures was found to be more feasible and beneficial in low fertilizer requiring crops like millets (Maitra *et al.,* 2020) compared to other crops which are mostly fertilizer responsive type (cereals) and need voluminous amounts of manures (cash crops). Infact, millets grown in some areas are by default organic in nature. This might be a reason for poor millet production levels leading to a large gap between demand and supply leading to escalating price of millets. Proper combination of chemical fertilizers and bioagents can enhance the productivity of the crop as well as the quality (Basha, 2015; Ravi *et al.,* 2012). Since the efficiency of organic manures in meeting crop nutrient requirements is not as certain as it is with mineral fertilizers, the combined use of chemical fertilizers and organics is capable of improving soil quality as well as productivity over a period of time. Organic and mineral fertilizers used together have been proven to be more successful in sustaining higher productivity and soil fertility on the one hand, and favourable soil ecological conditions on the other (Chhonkar, 2002).

Soil fertility is also influenced by the biochemical activities of microflora, particularly in the rhizosphere, which, when influenced by roots, can change the degree of nutrient availability to higher plants (Mallikarjun and Maity, 2017). These microbes also play a major role in the organic matter decomposition, as well as the degradation of toxic materials and other contaminants. Several other soil parameters, such as soil reaction, moisture, temperature, and so on, influence the type and amount of these microorganisms. Soil biological research sheds light on this lively nature of the soil. Further, soil enzyme measurements can be used to determine the biological activity in the rhizosphere soil. These are important in agriculture because they play a crucial part in the biochemical process of organic matter decomposition in the soil, as well as catalysing several vital reactions required for the life processes of microorganisms in the soil. These enzyme activities commonly correlate with microbial population (Kandeler and Murer, 1993; Vinay *et al.,* 2020). Urease is an essential extracellular enzyme that affects the availability of plant utlilizable nitrogen forms in soils. It's one-of-a-kind enzyme that catalyses the conversion of urea to ammonia (NH_4), which is then converted to ammonium (NH_4^+) and nitrate (NO_3^-) ions. Whereas, dehydrogenase is involved in the biological oxidation of soil organic matter, which releases nutrients into the accessible pool. It calculates overall microbial activity in the soil (Taylor *et al.,* 2002). The phosphorus cycle in soil is linked to phosphatase activity (Aon and Colaneri, 2001). The phosphate molecule is removed from organic substances such as phospholipids and nucleic acids by this enzyme in the soil. When phosphate is split, it becomes soluble and can be absorbed by microbes or plants. Thus enzyme assay can predict the biological activity of the soil which is an important soil health indicator.

With these facts in view, a unique effort was made to study the biological parameters under the influence of combined application of recommended dose of chemical fertilizers and bioagents with bacterial consortia and bio-enhancers (*beejamrutha* and *jeevamrutha*) as organic sources which are gaining importance among farming community these days.

Material and Methods

A field study was performed during *kharif*, 2019 at College of Agriculture, Rajendranagar, PJTSAU, Hyderabad. The experimental site is located at an altitude of 534 m above mean sea level on 17°32'22''N latitude and 78°41'11''E longitude. It is in the Southern Zone of Telangana State. The site consists of sandy loam soil with 6.42 pH, 0.08 ds/m EC, 0.45% OC, low available Nitrogen (172 kg/ha), medium in Phosphorus (22 kg/ha), high in Potassium (398 kg/ha) and sufficient in Zinc status (0.65 ppm). The initial values of biological properties of soil are furnished in Table 1. The size of gross and net plots was 4.8 m x 3.9 m and 4.2 m x 3.3 m respectively. The experiment was laid out in Randomized Block Design with 3 replications and 8 treatments. The treatment details are mentioned in the Table 2.

Preparation of *beejamrutha*

Cow dung was collected, tied in a cloth and dipped in a container with 50 litres of water for overnight. Next day, the dung was squeezed into the water.

Table 1: Initial values of biological properties of soil

Biological properties	Initial value	Method adopted
Bacteria (X 10^5 CFU/g soil)	18	Vlassak *et al.* (1992)
Urease (µg NH_4^+/ g/2h)	17.5	Tabatabai and Bremner (1972)
Dehydrogenase (µg TPF/ g/day)	8.56	Casida *et al*. (1964)
Alkaline phosphatse (µg pNP/ g/soil h)	17.08	Tabatabai and Bremner (1969)
Acid phosphatase (µg pNP/ g/soil h)	18.50	Tabatabai and Bremner (1969)

Table 2: Treatment details imposed in the experiment

Treatment no.	Treatment	Dose and method of application
T_1	Control	No chemical fertilizers/ bacterial consortia/ *beejamrutha* and *jeevamrutha*
T_2	Chemical Fertilizers	Full recommended dose (40:20:0 kg N:P_2O_5: K_2O/ha) Entire p (SSP) as basal, N (Urea) in two splits, one as basal and other as top dressing at 30 DAS
T_3	Chemical Fertilizers	Half of recommended dose (20: 10:0 kg N:P_2O_5: K_2O/ha)
T_4	Bacterial consortia	2.5 kg / 250 kg FYM/ha through soil application before sowing
T_5	Bio-enhancers	*Beejamrutha* @ 50 L/ha through seed treatment and *Jeevamrutha* @ 500 L/ha through soil application at fortnightly interval
T_6	Bacterial consortia + Bio-enhancers	2.5 kg / 250 kg FYM/ha 50 L/ha and 500 L/ha
T_7	Bacterial consortia +Bio-enhancers +Chemical fertilizers	2.5 kg / 250 kg FYM/ha 50 L ha^{-1} and 500 L/ha Full recommended dose
T_8	Bacterial consortia + Bio-enhancers +Chemical fertilizers	2.5 kg / 250 kg FYM/ha 50 L/ha and 500 L/ha Half of recommended dose

Table 3: Ingredients required for preparation of *beejamrutha* hectare^{-1}

a)	Water	50 lit
b)	Desi cow dung*	12.5 kg
c)	Desi cow urine*	12.5 lit
d)	Ant hill soil	250 g
e)	Lime	125 g

Later cow urine and lime were added to this extract. The above solution was stirred well before application (Table 3).

*Dung and urine were collected from the same desi cow (Gir) during the entire cropping period.

Preparation of *jeevamrutha*

All the ingredients (Table 4) were mixed in 500 litres water in a drum and kept for 72 hrs under shade. The above solution was stirred twice a day with a stick. *Jeevamrutha* was prepared for each application three days ahead of application date.

The preparation of *beejamrutha* and *jeevamrutha* is in accordance with Vinay *et al.* (2020). Microbial population found in *beejamrutha* and *jeevamrutha* are 20 x 10^6 CFU/ml and 13 x 10^6 CFU/ml respectively.

Bacterial Consortia

Bacterial consortia, a combination of biofertilizers such as *Azotobacter*, Phosphorus Solubilizing Bacteria (PSB), Potassium Releasing Bacteria (KRB) and Zinc Solubilizing Bacteria (ZnSB) obtained from the Department of Microbiology and Bioenergy, Rajendranagar, PJTSAU. 2.5kg/ha of this consortia is mixed @ 250 kg of FYM/ha.

Table 4: Ingredients required for preparation of *jeevamrutha* hectare^{-1}

a)	Water	500 lit
b)	Desi cow dung*	25 kg
c)	Desi cow urine *	25 lit
d)	Jaggery	5 kg
e)	Flour of any pulse	5 kg
f)	Ant hill soil	250 g

Bacterial population

Soil bacterial population was enumerated from soil samples of rhizosphere zone collected from 0-15 cm depth at 50% flowering and harvest stage of crop in each treatment plot randomly using serial dilution- agar plating method (Vlassak *et al.,* 1992). A gram of soil sample was placed into 10 ml of distilled water, mixed thoroughly and diluted tenfold. 1 ml of soil suspension was transferred to another 9 ml water blank with a sterile pipette and vigorously mixed, resulting in a sample diluted to 10^{-2}. In a similar way, dilutions were made up to 10^{-6}. These 1 ml of diluted samples were transferred into sterile petri-plates in a laminar airflow chamber. Then 15 ml of Nutrient agar media (45^0C) was poured into each plate and mixed the contents by gentle rotation and allowed to solidify. The plates are then, incubated for about 2-3 days at 37°C temperature in BOD incubator. Colonies found on plates were recorded and population per gram of soil was enumerated by using digital colony counter. The number of colonies were multiplied by the dilution factor and expressed as colony forming units (CFU).

Urease activity

Urease activity was analysed by the release of NH_4^+ from the hydrolysis of urea (Tatabai and Bremner, 1972). 5 grams of soil sample was taken into a 50 ml volumetric flask, after adding 0.2 ml of toluene and 9 ml THAM buffer, the flask was shaked to mix the contents thoroughly and 1ml of 0.2M urea solution was added and swirled once again. The flask was stoppered and placed in an incubator at a temperature of 37^0C. After 2 hours, 35 mL of KCL-Ag_2SO_4 solution was added and the flask was left to stand until the contents had cooled to room temperature. By adding KCL-Ag_2SO_4 solution, the contents were increased to 50 mL, and the flask was sealed and inverted several times to mix the contents. By pipetting out a 20 ml aliquot of the soil solution and distilling it with 0.2 g of MgO for 4 minutes, $NH4^+$-N was measured in the resultant soil suspension. Controls were made by using the same protocol as the urease activity assay, but adding 1ml of 0.2 M urea solution after the KCL-Ag_2SO_4 solution was added.

Dehydrogenase Activity

In a 50 ml glass tube, 1 g of soil was added, followed by 50 mg of $CaCO_3$, 2.5 ml of distilled water, and 1 ml of 3 percent 2,3,5-triphenyl tetrazolium chloride. Swirled for a few minutes before incubating for 24 hours at 37°C. The TPF red precipitate was dissolved in 10 ml methanol, agitated for 30 minutes, filtered, and the volume was increased to 25 ml by adding methanol. At 485 nm, the intensity of the red colour was measured using a twin beam UV-Visible spectrophotometer (Casida *et al.,* 1964).

Acid and Alkaline Phosphatase Activity

The activity of phosphophatase was determined using a conventional technique (Tatabai and Bremner, 1972). Enzyme activity was determined by mixing 1 g of soil with 0.2 ml toluene, 4 ml modified universal buffer (MUB) (pH 6.5 and 11 for acid and alkaline phosphatase respectively) and 1 ml p-nitrophenyl phosphate solution in a 50 ml flask. 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH were added after an hour of incubation. The suspension was filtered and the absorbance of the filtrate was measured at 420 nm using UV-Visible spectrophotometer. Controls were prepared by repeating the phosphatase activity assay technique but adding 1ml of p-nitrophenol solution after the additions of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH.

Results and Discussion

The bacterial population count in the form of colony forming units (CFU) was taken in the rhizosphere soil at 50% flowering and harvest stage apart from the initial status (Table 5). Before sowing of the crop, the count was 18 x 10^5 CFU/g soil. The perusal of the data at 50% flowering stage reveals highest bacterial population in T_7 in which the conjunctive application of 100% RDF + bacterial consortia + *beejamrutha* and *jeevamrutha* was imposed. It was superior to all the other treatments except T_6 (bacterial consortia + *beejamrutha* and *jeevamrutha* alone) and their combination at 50% RDF (T_8). However, compared to control plot, the population was significantly superior with their individual application (T_3 or T_4) and combination (T_6) but not with 50% RDF (T_3). At harvest, the population was reduced and in control it reached to the initial level. The treatments which received the conjunctive application of bacterial consortia + *beejamrutha* and *jeevamrutha* (T_6, T_7 and T_8) were at par but superior to control. At harvest also, the bacterial population with 50 % RDF (T_3) was found to be similar with control plot (T_1).The percentage increase in the bacterial population in treatment T_7 (combined application of 100% RDF, bacterial consortia and bio-enhancers) is 124.06 and 114.78% over the initial status at 50% flowering and harvest stage of the crop respectively. Whereas application of bioagents (bacterial consortia and bio-enhancers) i.e., in $T_{6,}$ the percentage increase is about 107.39 and 91.67% at 50% flowering and harvest stage of the crop respectively. This indicates a complementary effect between the chemical fertilizers and bioagents in improving the microbial status of the soil. But application of chemical fertilizers alone at 50% and 100% level showed 50, 37.22% at 50% flowering and 30.56, 12.94% increase only at harvest stage over initial value (Figure 1&2). The enhanced growth of bacteria with the combined application of bacterial consortia + *beejamrutha* and *jeevamrutha* alone (T_6) or with inorganic fertilizers (T_7 or T_8) might be due to increased colonization of the bacteria owing to the increased root growth and their exudates which might have supported the growth of bacteria. As the micro-organisms are well activated in soil following the *jeevamrutha* application (Manjunatha *et al.,* 2009; Kiran *et al.,* 2015; Kumar *et al.,* 2016) increase in the total soil bacterial population was attributed to the addition of bacterial consortia as well as repeated application of *jeevamrutha* which further improved the conditions congenial for the microbial growth.

The activity of the urease enzyme was assessed at 50% flowering and harvest stage and compared to the activity before sowing (17.5 µg NH_4^+ g/2h). It was improved in all the treatments including control at both the observations. Higher activity of the enzyme was observed at 50% flowering and declined at harvest (Table 5). Corresponding to the bacterial population, peak activity of the enzyme was observed with the combination of 100% RDF + bacterial consortia + *beejamrutha* and *jeevamrutha* applied at fortnightly interval (T_7) followed by 50% RDF and bioagents (T_8) and combination of the bioagents alone (T_6) which were at par at both the observations. The next best treatment was *beejamrutha* and *jeevamrutha* alone (T_5) and bacterial consortia alone (T_4), both of which were superior to 100% RDF (T_2), 50% RDF (T_3) and control (T_1). It is evident that urease activity was higher in the biological treatments compared to application of inorganic fertilizers alone.

This might be ascribed to the fact that fortnightly application of *jeevamrutha* might have served as source of carbon, energy and other nutrients essential for the ureolytic micro-organisms (Reddy, 2002). The lower urease activity in inorganic treatments (T_2 and T_3) might be due to lack of sufficient number of colony forming microbes as well as substrate *i.e*., organic matter which is the energy source for multiplying the microbe number (Nagendra, 2015). The activity of dehydrogenase is high even before sowing, which might be due to the fact that the soil was kept fallow continuously for 5-6 years before the experiment. It was further enhanced in all the treatments including control at 50% flowering and harvest stage (Table 5). The activity of the dehydrogenase had the similar trend to that of the urease activity among the treatments, except that the inorganic treatments alone (T_2 or T_3) were comparable to control (T_1) at both the observations. Higher dehydrogenase in the biological treatments might be due to the improved microbial activity (Mallikarjun and Maity, 2018). Addition of manures or carbon and energy sources enhances the population of heterotrophs and enzymatic activities. Dehydrogenase activity increases with increasing active viable cells as it occurs intracellular in all living microbial cells.

Alkaline and acid phosphatase enzyme activities were analysed at 50% flowering and harvest stage and the data is furnished in Table 5. Compared to the initial activity, it was increased at 50% flowering and reduced at harvest, irrespective of treatments. Both the enzymes followed the similar trend. Highest activity was recorded with 100% RDF + combination of bioagents (T_7) which was at par with 50% RDF + combination of bioagents (T_8) and bioagents alone (T_6). Similarly, (T_6) was also at par with the individual application of bioagents (T_4 or T_5). But the activity of the enzymes was lower with chemical fertilizers alone (T_2 and T_3)

Table 5: Bacterial population and soil enzyme activity in the rhizosphere of foxtail millet @ 50% flowering and harvest stage as influenced by combined application of chemical fertilizers and bio-agents

Treatment	Bacterial population		Urease		Dehydrogenase		Alkaline phosphatase		Acid phosphatase	
	50% flowering	harvest	50% flowering	Harvest	50% flowering	harvest	50% flowering	harvest	50% flowering	harvest
T_1	20.00	18.66	20.00	18.50	8.98	8.61	18.73	17.38	20.87	19.10
T_2	27.00	23.50	23.75	22.50	9.18	8.93	20.27	18.30	22.17	20.17
T_3	24.70	20.33	22.50	21.00	9.12	8.82	19.94	17.98	21.47	19.82
T_4	33.17	28.67	26.00	24.75	11.00	10.46	23.02	21.80	25.07	22.93
T_5	34.33	32.00	27.50	25.50	11.11	10.63	22.37	20.83	24.99	22.80
T_6	37.33	34.50	31.25	30.00	12.43	11.57	24.06	22.60	27.78	24.73
T_7	40.33	38.66	32.00	31.00	12.67	12.08	25.97	24.37	28.47	25.83
T_8	38.00	35.50	31.75	30.75	12.5	11.98	24.72	23.87	27.67	25.03
SEm±	1.66	1.58	1.01	0.85	0.44	0.44	0.86	0.75	0.89	0.86
CD (P=0.05)	5.02	4.78	3.07	2.58	1.33	1.35	2.62	2.27	2.70	2.59

compared to T_7 and T_8, respectively. Among all, lowest phosphatase activity was recorded with control. The enhanced activity of phosphatase is attributed to the application of PSB through bacterial consortia. Among the macronutrients, P is the less mobile in the soil and gets adsorbed by 'Fe' and 'Al' oxides. PSB plays a major role in phosphorus nutrition by increasing its availability through release soil P pools by solubilization (Khan *et al.,* 2007). The percentage increase in enzyme activity over the control was depicted clearly in figure 1& 2 at flowering and harvest stages.

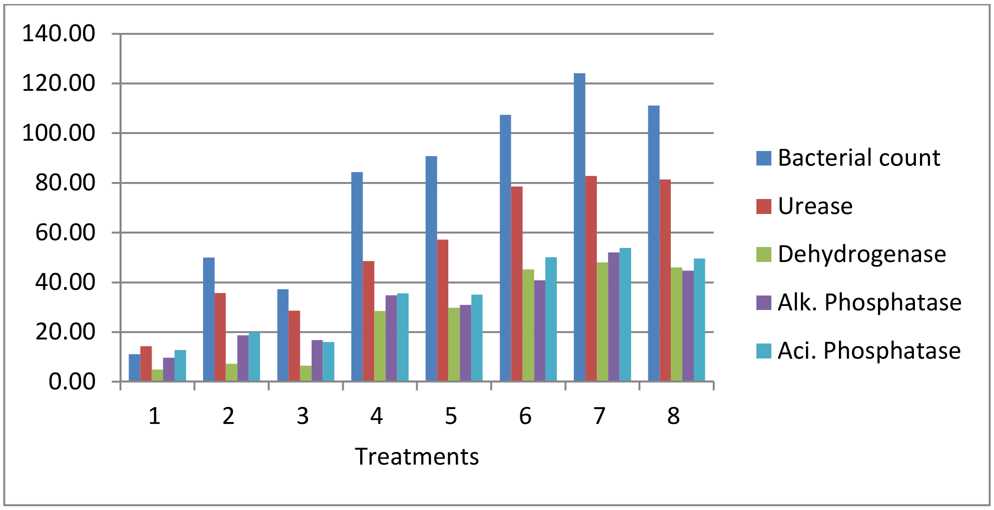

Figure 1. Percentage increase in the biological parameters at 50% flowering stage over initial value as influenced by the treatments

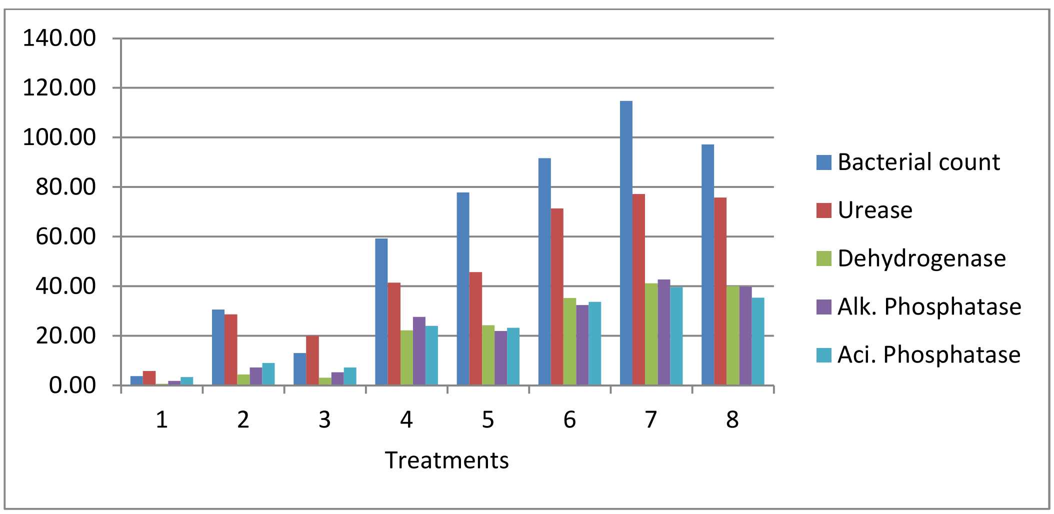

Figure 2. Percentage increase in the biological parameters at harvest stage over initial value as influenced by the treatments

Increased enzymatic activity in the soil can be attributed to the key role played by the microbial population due to the addition of bacterial consortia and application of bio-enhancers which acted as a tonic for better bacterial growth. Thus, overall congenial conditions for microbes might have resulted in enhanced enzymatic activity in the soil.

Conclusion

Bacterial population was significantly more in all the treatments which received bioagents compared to others at both the observations. Similar to bacterial population, the rhizosphere soil enzyme activity was found to be the highest with conjunctive use of bioagents either alone or with chemical fertilizers. Thus, with the application of bioagents like consortia of biofertilizers and bio-enhancers like *beejamrutha* and *jeevamrutha* along with recommended dose of fertilizers, the biological activity of the soil under millet cultivation in semi-arid regions can be boosted without any negative effects on the soil health and productivity by maintaining natural cycling of nutrients.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Analysis of climate variability and influence of climate variables on major crop yields in Nalgonda District of Telangana State, India

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ABSTRACT

Climate change has become a major concern globally, demanding immediate attention and action. In view of the extreme climatic uncertainties, it is obvious that Indian agriculture is highly vulnerable to climate change as climate is the direct input for production. This scenario emphasizes the dire need to understand the patterns of climate change and thus prepare agricultural systems for future climatic uncertainties. Therefore, the present study was conferred to analyse the climatic variability of Nalgonda district in Telangana State, considering 30 years (1988 to 2017) of historical weather data pertaining to rainfall and temperature (maximum and minimum). Climatic variability of the district was systematically analysed using box-and-whisker plot, Coefficient of Variation (CV), and trend analysis. The association between climatic variables (rainfall, maximum and minimum temperatures) and the major *Kharif* crop yields was calculated using Pearson's correlation coefficient. The results revealed that the recent decade (2008-2017) had a stable increase in seasonal rainfall in almost all the months compared to the earlier two decades but with the least consistency in rainfall (CV 29.03 %) and higher fluctuations in the maximum temperature (CV 2.38%). September month had shown the higher risk of recording low rainfall conditions compared to July and August months in the district. The rice crop yields during the recent decade (2008-2017) were found to have significant positive and negative associations with the rainfall in September and October months, respectively. Similarly, the lint yields of cotton crops were found to have a significant negative association with the maximum temperatures of the October and November months of the district. The major finding of the study realized was that climate variability and change exist in Nalgonda district, and the climate variables had significant effects on the crop yields of the district.

Introduction

The importance of earth is apodictic, as it is the only known planet suitable for the sustenance of living organisms due to the favorable climatic conditions that prevail on this blue planet. The atmosphere on earth protects the life forms from lethal ultraviolet radiations, maintains moderate temperatures, transports water vapour, and provides all kinds of useful gases. The climate and weather on earth are dependent on the atmosphere. Intergovernmental Panel on Climate Change (IPCC) defined climate in simple terms as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to many years.

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Climate change has become a major concern globally, necessitating immediate attention and action due to the rise in global temperatures, extensive melting of ice, changes in precipitation patterns as well as intensity and frequency of occurrence of uncertain events. The effects of climate change are more detrimental in a densely populated country like India, considering its highly vulnerable nature. The IPCC projections for the Indian region (South Asia) have revealed that the temperature rise would be 0.88-3.16°C by 2050 and 1.56-5.44°C by 2080, subject to the scenario of future development (IPCC, 2007a). The projected change in climate for 2100 indicated an increase in the temperature and rainfall between 2.5- 4.4°C and 15 and 24%, respectively (Bal *et al.,* 2016). The erratic and extreme rainfall events could result in drought and floods. These evidences are escalating to suggest the importance of building resilience into the system in order to sustain the vital ecosystem.

In the present context, the Government of India has conferred high priority for research and development to cope up with climate change in the agriculture sector. Accordingly, the Indian Council of Agricultural Research (ICAR) initiated a major network project, *i.e.,* National Innovations in Climate Resilient Agriculture (NICRA) in February 2011 to address the development needs of extremely vulnerable populations of the country. Nalgonda district of Telangana State was one among the 100 vulnerable districts which were selected for the Climate Resilient Agricultural (CRA) technology demonstration and dissemination to the farmers. Hence, the present study was undertaken with an objective to analyse the climate variability of the Nalgonda district, which may aid in providing advisory services to the farmers towards improving their preparedness for climatic aberrations.

Material and Methods

Climate variability is a regular phenomenon that occurs within a shorter time span, such as a month, season, or a year whereas climate change considers changes that occur over a longer period of time, typically over decades or even longer. For the present study, erstwhile Nalgonda district of Telangana state was purposively selected as it was one among the 100 vulnerable districts selected for the National Innovations in Climate Resilient Agriculture (NICRA) project implementation across India. The important climatic vulnerabilities of the district are higher drought proneness, mid and terminal dry spells, extreme heat stress, *etc*.

The 'in season' climate variability and change, which occurred at the decadal scale was analysed by considering 30 years (1988 to 2017) historical weather data of Nalgonda District. The secondary data of climate variables *viz.,* rainfall and temperature (maximum and minimum), and yields of major crops (rice and cotton) were acquired from the Directorate of Economics and Statistics (DES) of Telangana State for analysis.

Climatic variability of the Nalgonda district was analysed by calculating the coefficient of variations (CV) and Box-and-whisker plot. Trend analysis of the climatic variables was done, and the association between climatic variables and the *Kharif* crop yields was calculated using Pearson's correlation coefficient.

Results and Discussion

Rainfall

Annual Rainfall trend

The annual rainfall data were summed for each year from 1988 to 2017 and plotted as a line graph (Figure 1). The trend line shows that there was a slight increase in annual rainfall over 30 years. However, the year-to-year variability was more in the recent decade (2008 to 2017). The annual rainfall deviation from normal was plotted in figure 2 conformed that the year to year deviations in annual rainfall was very high during the recent decade.

Decadal rainfall trend

To get more detailed information on rainfall trend, the historical rainfall (30 years) data was divided into three decades, and the mean was computed for each decade separately and presented in table 1. The obtained results indicated that the annual rainfall of the third decade (788.7 mm) was higher than the first (707 mm) and second (688.3 mm) decades, as well as 30 years' annual mean rainfall (717.1 mm). However, the rainfall variability of the third decade was very high (29.03%) as compared to the first (19.7%), second (13.1%) decade, and 30 years' variability (21.9%). Among the three

Table 1: Annual and decadal rainfall (mm) trends of Nalgonda district during 1988-2017

Annual/Decade		Average rainfall (mm)	Range		CV (%)
			Min (mm)	Max (mm)	
Annual rainfall		717.10	505.30	1267.40	21.86
First decade	1988-1997	707.20	523.00	945.40	19.72
Second decade	1998-2007	688.27	559.90	870.90	13.10
Third decade	2008-2017	788.71	505.30	1267.40	29.03

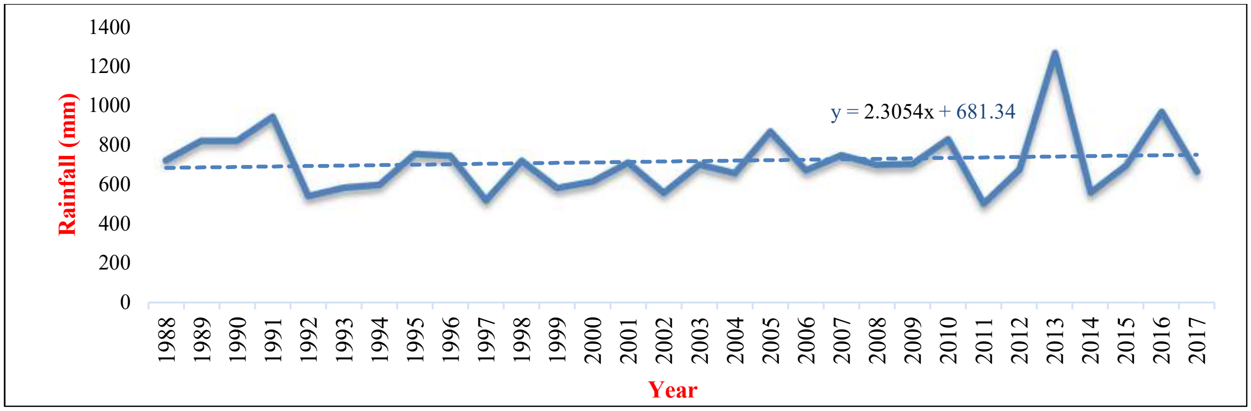

Figure 1: Annual rainfall (mm) trend of Nalgonda district from 1988 to 2017

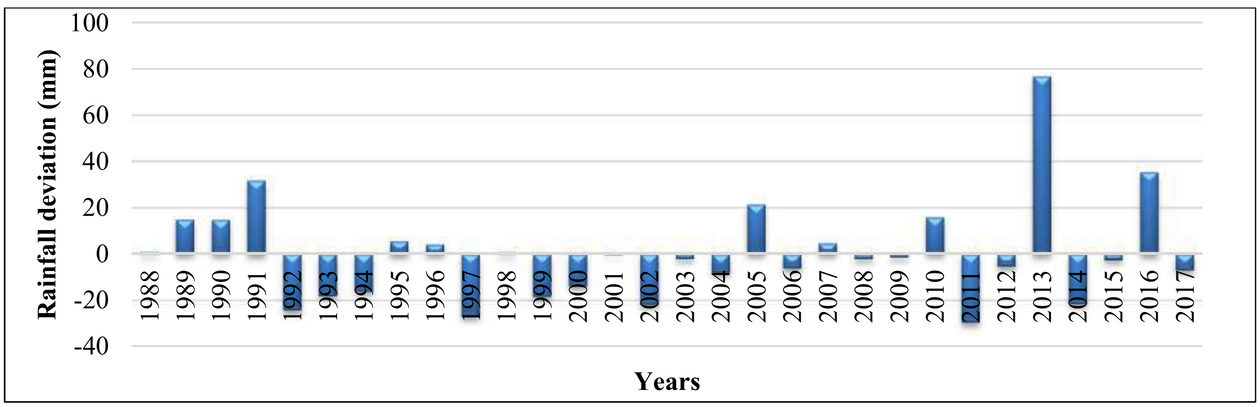

Figure 2: Mean annual rainfall deviation of Nalgonda district during 1988-2017

decades, the second decade had low rainfall. However, there was more consistency in receiving rainfall with the lowest coefficient of variation (CV 13.10%) as compared to its preceding (19.72%) and succeeding (29.03%) decade as well as the historical 30 years (21.86%) data. The present investigation clearly designated that there was an apparent decadal change in the trend of rainfall. In the recent (third) decade, though the annual rainfall increased, this beneficial effect is being nullified due to increased variability in annual rainfall. The results are similar to the findings of Chanapathi *et al.* (2020), wherein they reported an increase in fluctuations in the annual rainfall.

Decadal change in monthly rainfall pattern

Drawing a conclusion on the impact of rainfall on crop growth and yield based on annual rainfall doesn't make more sense as the crops selected (rice & lint cotton) for the study were season bound. Therefore, an attempt was made to understand the shift in rainfall pattern on a monthly scale from June to November among three decades, as shown in figure 3. On perusal of data, it was noticed that there was a clear and consistent increase in rainfall of August month from the first to the third decade. This trend was also reflected in June and September

Table 2: Monthly rainfall (mm) distribution of Nalgonda district during 1988-2017

Month	Average rainfall (mm)	Range		CV (%)
		Min (mm)	Max (mm)	
June	85.40	30.05	204.14	54.50
July	119.07	47.58	314.70	47.03
August	143.88	76.99	247.45	31.86
September	163.45	43.57	357.76	44.03
October	101.04	15.00	456.15	84.48
November	20.59	0.00	64.44	100.82
Season (June-November)	630.14	408.89	1546.50	22.18

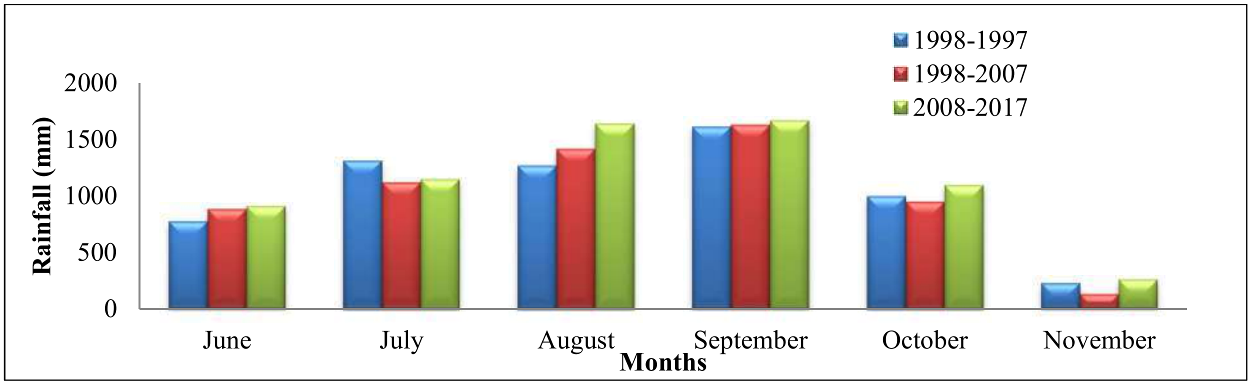

Figure 3: Monthly decennial seasonal rainfall (mm) variability in Nalgonda district

rainfall. However, the decadal change was meagre. In contrast to this, there was a decrease in rainfall of July month during the third decade as compared to the first decade. The decrease in July month rainfall may hamper the establishment and growth at an early stage of the rainfed cotton crop and delay the rice nursery in Nalgonda district. Hence, farmers may be advised not to go for early sowing or prepare a contingency plan in order to face the risk of aberrant rainfall during July month. The increase in rainfall during the October months in the recent decade may be beneficial for rainfed cotton as it coincides with the boll development stage. But, it is inevitable for rice crops as it coincides with the flowering stage during October month, and the rains may result in the aborted ovary and chaffy grains.

Monthly rainfall variability

On perusal of 30 years (1988 to 2017) historical monthly rainfall data from June to November, it was noticed that the rainfall ranged from 409 mm to 1547 mm with a mean of 630 mm (Table 2.). The highest average monthly rainfall was observed during the month of September (163.45 mm), followed by August (143.88 mm) and the least in the month of November (20.6 mm). Based on the coefficient of variation in monthly rainfall, it was observed that August month was more consistent in receiving rainfall with the lowest CV of 31.90% followed by September with CV of 44.00% whereas November and October months were found to be highly variable in rainfall with CV 100 % and 84.50%, respectively. The highest variability during these two months could be due to low influence of the North-East monsoon on the Nalgonda District. Therefore, the probability of occurrence of rainfall events during the October and November months was very low.

Monthly rainfall distribution

The detailed analysis on the deviation of rainfall was further deepened in every month under investigation and summarised in a box plot which was depicted in figure 4. The results revealed that September month had received the highest rainfall with reference to its median value. However, the lengthier lower side whisker indicates a higher risk of recording lower rainfall compared to the July and August months. As rainfall in September month is crucial for crop growth and development, farmers may be advised to prepare with supplemental irrigation to face the events of low rainfall during September month. In the case of

August month, though the median rainfall value is slightly lower than September month, the lengthier upper side whisker shows that the chance of receiving high rainfall is more in comparison to all the other months under investigation. Similarly, the lengthier upper side-whiskers in June, July, October, and November months indicated that the chance of receiving higher side rainfall events with respect to their corresponding median values was more.

Maximum Temperature

Annual maximum temperature trend

The annual mean maximum temperature data were averaged for each year from 1988 to 2017 and plotted as a line graph as depicted in figure 5. The trend line shows a conspicuous increase in the annual mean maximum temperatures over the years. It can be observed that the year-to-year variability was more during the first decade (1988-1997) and the recent third decade (2008-2017).

Decadal maximum temperature pattern

In order to obtain further information on the maximum temperature trend, the historical maximum temperature (30 years) data was divided into three decades, and the mean was computed for each decade separately and presented in table 3. The results showed that the third and second decades had the mean maximum temperature of 33.9^{o}C, which was 0.3^{o}C higher than the first (33.6^{o}C) decade and 0.1^{o}C more than the 30 years' annual mean maximum temperature (33.8^{o}C). The results are in concordance with the findings of Chettri *et al.* (2020), where they reported an increased rate of maximum temperature. The mean maximum temperature of the third decade (2008-2017) had the higher coefficient of variation (2.38%) as compared to the first (2.24%), second (0.99%) decades, and 30 years mean maximum temperature (1.96%) which indicates that the recent decade (2008-2017) had higher fluctuations in maximum temperatures compared to the earlier two decades. The second decade was found to have the least fluctuations in maximum temperature with the lowest coefficient of variation (0.99%) as compared to its preceding (2.24%) and succeeding (2.38%) decade as well as the historical 30 years (1.96%) data. This detailed investigation clearly showed that there was a change in the decadal maximum temperature pattern. The results are in line with the report of IPCC (2007b), wherein it was mentioned that there would be constant warming of 0.2°C per decade during the future decades.

Further, Sreenivas and Raji Reddy (2010) also revealed that, in Andhra Pradesh, the temperatures are projected to increase by at least 3^{o}C throughout the state due to climate change from 2041 to 2060. In the context of climate change, temperature is one of the major environmental factors which influence the growth, development, and yields of rice crops. Vaghefi *et al.* (2011) projected a decline of 0.36 t/ha in rice crop yields when there is an increase in temperature of 2°C at a CO_2 concentration of 383 ppm.

Decadal change in the monthly maximum temperature pattern

A shift in maximum temperature pattern on a monthly scale from June to November between the three decades was depicted in figure 6. On perusal of data, it was observed that there was a slight increase in the maximum temperature in June, July, and August months from the first to the third decade, while the September month had shown consistent maximum temperatures during the three decades. Further, in October, there was an increase in the maximum temperature of 0.6^{o}C and 0.3^{o}C during the second and third decades, respectively, compared to the first decade. A Similar trend was also observed in November month.

Monthly maximum temperature variability

On perusal of 30 years (1988 to 2017) historical monthly maximum temperature data from June to November, it was noticed that the maximum temperatures ranged from 31.5^{o}C to 34.6^{o}C with a mean of 32.9^{o}C (Table 4). The highest average monthly maximum temperature was observed during the month of June (36.6^{o}C), followed by July (33.1^{o}C) and the least in the month of November (30.8^{o}C). It can be inferred that July month has highly variable maximum temperatures (CV 5.59%) followed by June month (4.97%), which may increase the risk of germination during the early stages of crop growth.

Monthly maximum temperature pattern

The detailed analysis on the deviation of maximum temperature was further expanded every month under investigation and summarised in a box plot which was depicted in figure 7. The results indicated that June month had the highest

Table 3: Annual and decadal maximum temperature in Nalgonda district during 1988-2017

Annual/Decade		Mean MaxT (^oC)	Range		CV (%)
			Min (^oC)	Max (^oC)	
Annual mean maximum temperature		33.8	32.6	35.4	1.96
First decade	1988-1997	33.6	32.6	34.8	2.24
Second decade	1998-2007	33.9	33.4	34.4	0.99
Third decade	2008-2017	33.9	33.0	35.4	2.38

Table 4: Monthly and seasonal mean maximum temperature in Nalgonda district during 1988-2017

Month	Mean MaxT (^oC)	Range		CV (%)
		Min (^oC)	Max (^oC)	
June	36.6	32.2	40.0	4.97
July	33.1	29.8	37.0	5.59
August	32.3	29.6	35.2	4.96
September	32.3	30.6	34.7	3.41
October	32.4	29.7	35.7	3.90
November	30.8	28.8	32.6	3.11

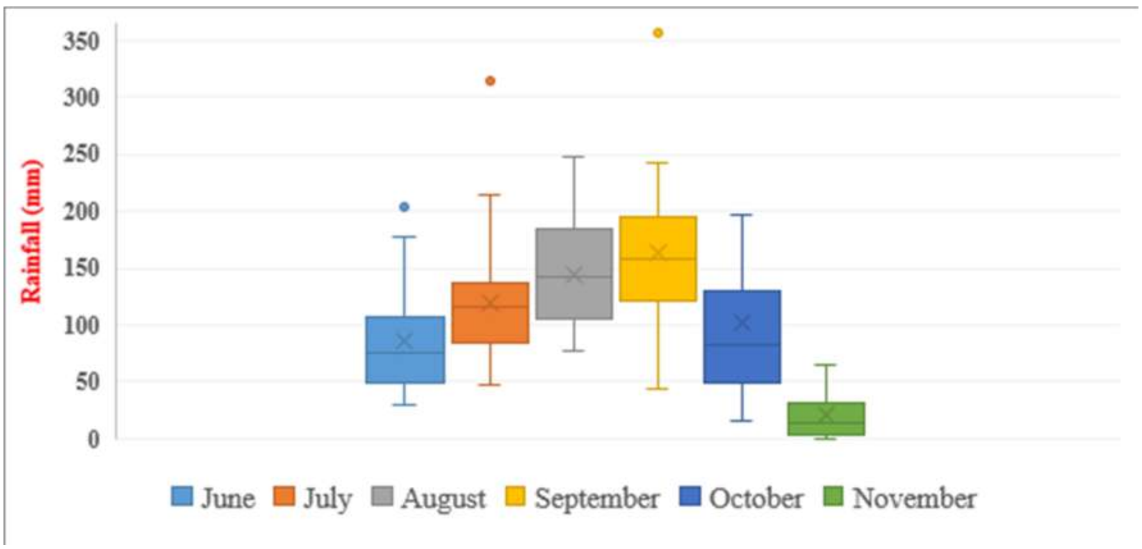

Figure 4: Box whisker plot of rainfall (mm) grouped by months

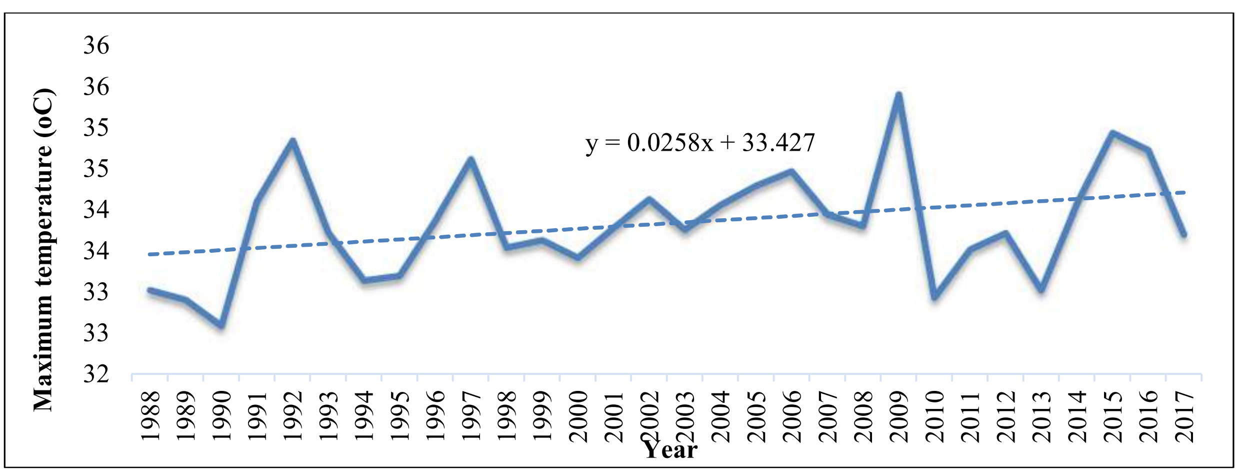

Figure 5: Linear trend of annual maximum temperature in Nalgonda district during 1988-2017

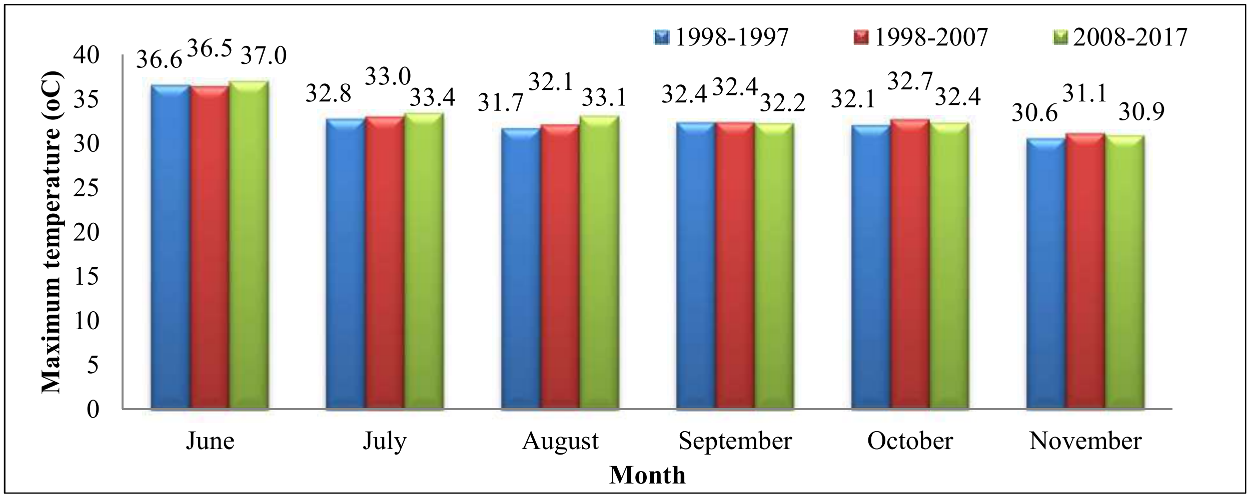

Figure 6: Monthly decennial seasonal maximum temperature variability in Nalgonda district

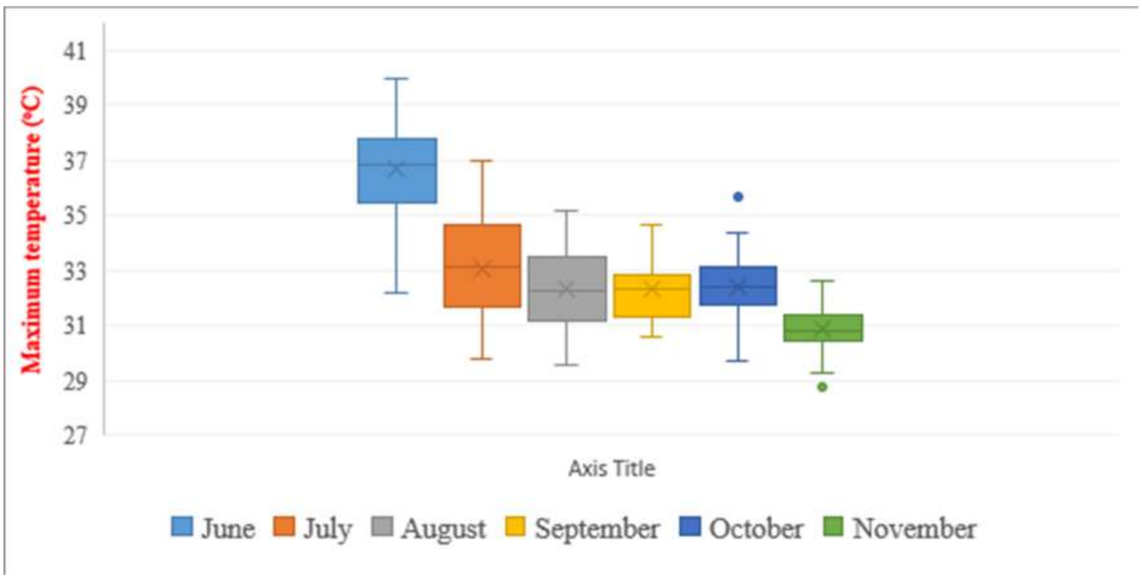

Figure 7: Box whisker plot of maximum temperature (^{o}C) grouped by months

maximum temperatures with reference to its median value, followed by July month. However, the lengthier upper side whisker of July and September months shows that the events of recording higher maximum temperatures over its median value were more frequent as compared to June month. Whereas, in the case of October month, the lengthier lower side whisker shows that the chance of recording maximum temperatures below its median value is more. Similarly, it can be inferred that the November and August months have equal chances of recording high or low maximum temperatures with respect to their corresponding median values.

Minimum temperature

Annual minimum temperature trend

The annual mean minimum temperature data from 1988 to 2017 was plotted as a line graph as depicted in figure 8. The trend line shows a slight increase in the annual mean minimum temperature over the years. It can be observed that the year-to-year variability was very high during the first decade (1988-1997) compared to the second (1998-2007) and third decade (2008-2017).

Decadal minimum temperature pattern

For further investigation on the minimum temperature trend, the historical minimum temperature (30 years) data was divided into 3 decades, for which the mean was computed separately for each decade and presented in table 5. The results indicated that there was a 0.5°C fall in mean minimum temperature during the second decade as compared to its preceding as well as succeeding decades. The results are similar to the findings of Chettri *et al.* (2020). The coefficient of variation of the first decade (3.41%) was very higher than the second (1.68%) and third (1.69%) decades, as well as 30 years, mean minimum temperature (2.54%) specifying the higher degree of instabilities in the minimum temperatures during the first decade. The second decade was found to have the least fluctuations in minimum temperature with the lowest coefficient of variation (1.68%). This detailed investigation clearly showed that there was a change in the decadal minimum temperature pattern.

Decadal change in monthly minimum temperature pattern

A shift in minimum temperature pattern on a monthly scale from June to November between the three decades was depicted in figure 9. On perusal of data, it was noticed that there was an increase in mean monthly minimum temperature in the third decade (2008 - 2017) when compared to a second decade (1998 - 2007) in all the months under investigation. This analysis is clear evidence of a change in mean minimum temperature. These results are in line with the prediction of IPCC (2007b) wherein, it was mentioned that there would be constant warming of 0.2°C per decade in the next few decades.

Monthly minimum temperature variability

On perusal of 30 years (1988 to 2017) historical monthly minimum temperature data from June to November, it was noticed that the minimum temperatures ranged from 21.8°C to 25.6°C with a mean of 23.8°C (Table 6.). The highest average monthly minimum temperature was observed during the month of June (26.5°C), followed by July (24.8°C) and the least in the month of November (20.3°C). It can be inferred that November month has shown high variability in minimum temperatures (CV 7.5%) followed by October month (5.69%). The September month has shown more consistency in the minimum temperatures followed by August month with the coefficient of variation values 3.52 % and 3.98 %, respectively.

Monthly minimum temperature pattern

The detailed analysis on the deviation of minimum temperature was further extended in every month under investigation and summarised in a box plot, which was depicted in figure 10. The results indicated that June month was found to have the highest minimum temperatures with respect to its median value, followed by July month. However, the lengthier lower side whisker of July, August, and October months shows that the events of recording lower minimum temperatures were more frequent when compared to their corresponding medians. Whereas the months of June, September and November have equal chances of recording high or low minimum temperatures with respect to their corresponding median values.

Historical yields of rice and cotton (kg/ha) during *Kharif* season

The district-level yield data of rice and cotton pertinent to *the Kharif* season was collected from DES, Govt. of Telangana to analyse the yield trend and correlate with climate data. The yield data were grouped into decadal yields and presented in figure 11 and figure 12 of rice and cotton, respectively. The mean grain yield of rice during the first, second and third decades were found to be 2870, 2800, 3120 kg, ha^{-1} respectively (Figure 11). Similarly, the historical yields (kg/ha) of lint cotton (kg/ha) were presented in figure 12. The mean yields of lint cotton during the first, second and third decades were found to be 1130, 1430, 1820 kg/ha, respectively.

Effect of climate variability on rice and cotton yields during *Kharif* season

Rice and lint cotton crops are the major crops grown in terms of their area in the Nalgonda district. The relationship between the climate variables during the crop period (June to November) and yields of rice and lint cotton were studied by considering 30 years (1988-2017) rainfall and temperature data of the Nalgonda district. The data sets were divided into three decades, and Pearson's correlation analysis was performed separately for each decade, keeping in view of decadal variability in climatic variables and technological advancement in crop management. The correlations between weather parameters and yields of rice and lint cotton crop yields were presented in table 7 and table 8, respectively.

Table 5: Annual and decadal minimum temperature in Nalgonda district during 1988-2017

Annual/Decade		Mean MinT (^oC)	Range		CV (%)
			Min (^oC)	Max (^oC)	
Annual mean minimum temperature		22.6	21.4	23.9	2.54
First decade	1988-1997	22.8	21.4	23.9	3.41
Second decade	1998-2007	22.3	21.6	22.9	1.68
Third decade	2008-2017	22.8	22.2	23.4	1.69

Table 6: Monthly and seasonal mean minimum temperature in Nalgonda district during 1988-2017

Month	Mean MinT (^oC)	Range		CV (%)
		Min (^oC)	Max (^oC)	
June	26.5	23.0	29.1	5.13
July	24.8	22.0	26.8	4.53
August	24.4	22.5	25.9	3.98
September	24.1	22.4	25.6	3.52
October	22.8	21.0	27.7	5.69
November	20.3	18.2	25.3	7.50
Season (June-November)	23.8	21.8	25.6	3.72

Table 7: Association of climatic variables and *kharif* rice crop yields (kg/ha) of Nalgonda district (1988-2017)

Decade	Kharif crop Season months					
	June	July	August	September	October	November
Rainfall (mm)						
1988-1997	-0.34	0.15	0.51	-0.42	0.02	0.04
1998-2007	0.36	0.25	0.43	0.12	-0.01	-0.11
2008-2017	0.23	0.00	-0.41	0.76***	-0.53**	0.09
Minimum temperature (^oC)						
1988-1997	0.03	-0.32	-0.55	-0.77	-0.32	-0.63
1998-2007	0.25	-0.31	0.29	0	-0.32	0
2008-2017	0.29	0.33	0.54	0.08	-0.55*	0
Maximum temperature (^oC)						
1988-1997	0.03	-0.08	-0.53	-0.1	0.02	0.06
1998-2007	0.08	-0.64**	-0.16	-0.43	-0.12	0.1
2008-2017	0.09	0.24	0.52	-0.52	0.15	0.24

***- 1 % level of significance **- 5% level of significance *- 10 % level of significance

Correlational analysis of Rice crop yields with rainfall

The correlation between rainfall and rice crop yield was found to be positive and highly significant in September month and negatively correlated in October month during the third decade (2008-2017). The negative effect of rainfall on crop yield during October month may be due to increased rainfall (Table 1) that might have coincided with the flowering stage leading to aborted ovaries and a higher percentage of chaffy grains. Rice crop needs a clear sky and bright sunshine during the flowering stage. Some studies (Alam *et al*., 2013., Alam *et al*., 2012) showed that a 1 % increase in rainfall causes a 0.12 % decline in current paddy yield and 0.21 % decline in the subsequent season. Low light and cloudy weather during the heading stage evidently resulted in sterile panicles in rice crops, while shading after the heading stage leads to loss of photosynthesis. Consequently, relocation of photosynthates, sink capacity, and dry matter accumulation are reduced, which further leads to a significant reduction in the yield contributing characters, *viz.,* spikelet fertility which leads to poorer grain yields (Liu *et al*., 2013).

Table 8: Association of climatic variables and *kharif* lint cotton crop yields (kg/ha) of Nalgonda district (1988-2017)

Decade	Crop Season months					
	June	July	August	September	October	November
Rainfall (mm)						
1988-1997	0.03	-0.59*	-0.48	-0.32	0.57	0.24
1998-2007	-0.43	0.13	-0.49	0.74***	0.19	0.64**
2008-2017	0.39	0.02	0.28	0.11	0.54	0.26
Minimum temperature (^oC)						
1988-1997	0.25	0.46	0.22	0.02	0.92***	0.39
1998-2007	0.29	0.38	0.43	0.43	0.25	-0.04
2008-2017	0.2	0.03	-0.13	-0.18	-0.07	0.06
Maximum temperature (^oC)						
1988-1997	0.11	0.47	0.36	0.64**	-0.49	-0.3
1998-2007	0.29	0.14	0.46	-0.21	-0.26	-0.25
2008-2017	-0.26	-0.29	-0.36	-0.19	-0.64**	-0.72**

***- 1 % level of significance **- 5% level of significance *- 10 % level of significance

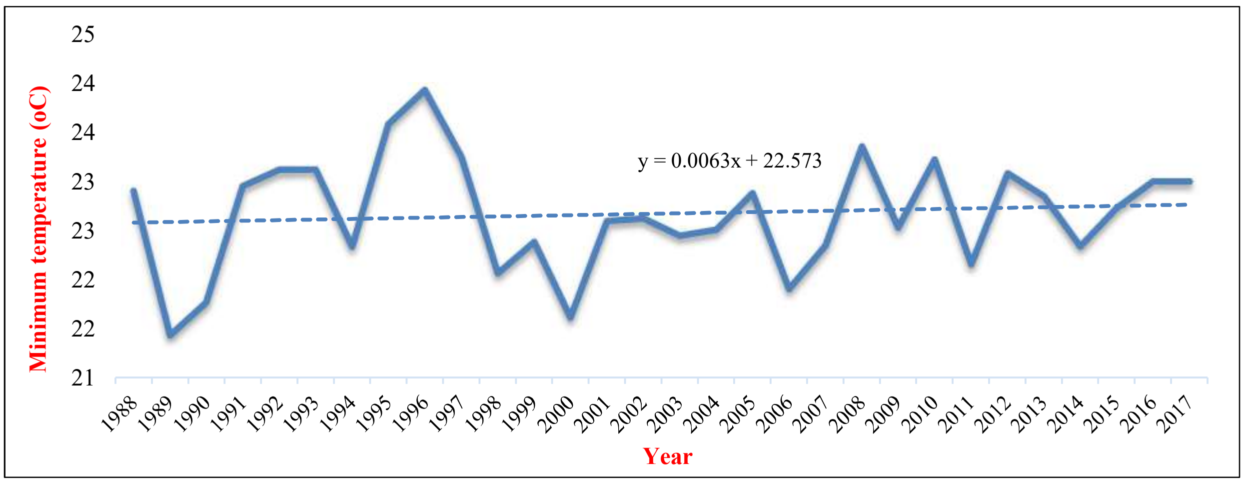

Figure 8: Annual minimum temperature trend in Nalgonda district during 1988-2017

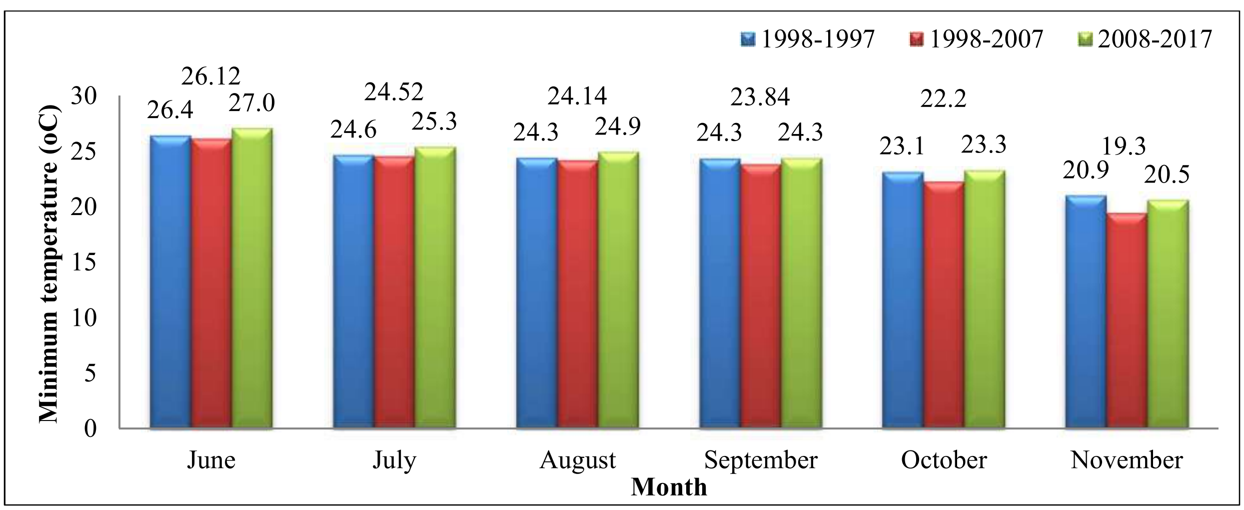

Figure 9: Monthly decennial seasonal minimum temperature variability in Nalgonda district

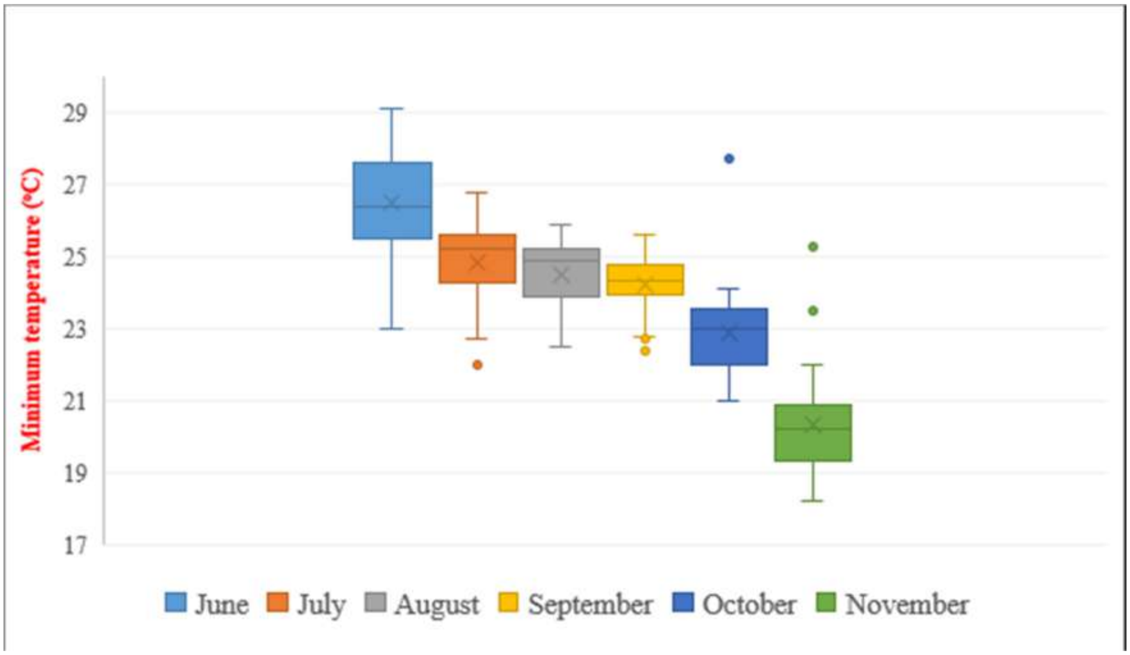

Figure 10: Box whisker plot of minimum temperature (^{o}C) grouped by months

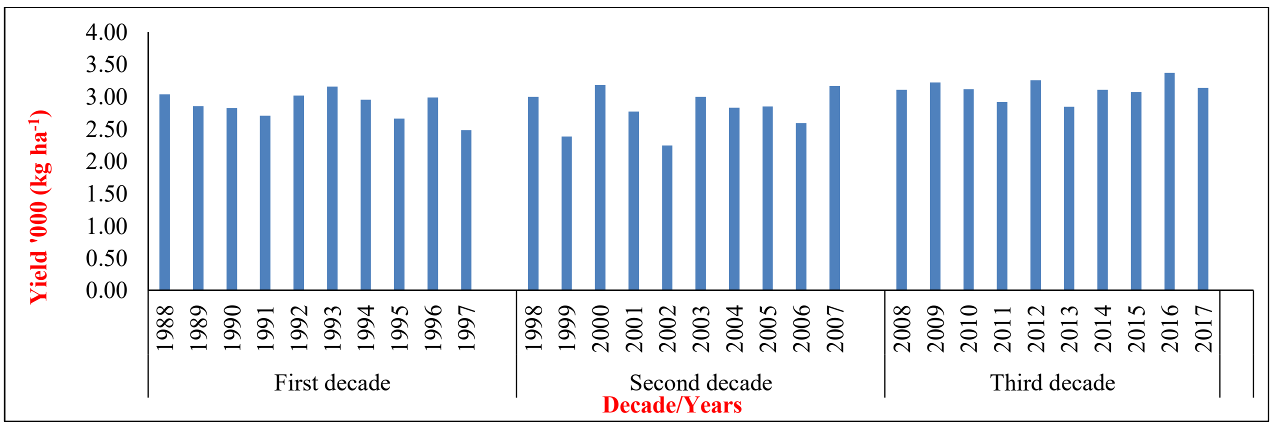

Figure 11: Historical yields of rice (kg/ha) during *kharif* season

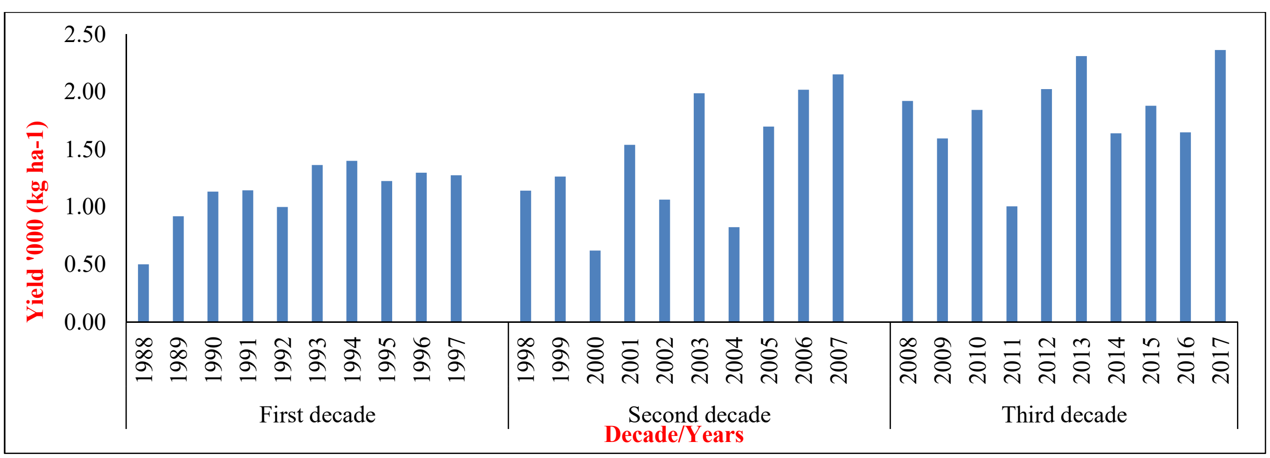

Figure 12: Historical yields of lint cotton (kg/ha) during *kharif* season

Correlational analysis of Rice crop yields with temperature (maximum and minimum)

The grain yield of rice was negatively correlated with a minimum temperature of October month at a 10 % level of significance during the third decade (2008-2017)**.** The rise in mean minimum temperature by about 0.2 ^{o}C and 1.1 ^{o}C in the third decade as compared to the first and second decades, respectively (Figure 9), might have coincided with the flowering stage of the rice crop, causing increased spikelet sterility and thus reduction in yield. Further, the elevated temperature at the reproductive stage reduces the grain filling period in rice crops (Palanisami *et al.*, 2019). The current climate change scenario indicated that a rise in temperature above 25 ^{o}C might lead to the loss of grain mass up to 4.4 % per 1^{o}C rise in temperature and decline in yield as much as 9.6-10.0 % for each 1^{o}C increase in temperature, respectively (Alam, *et al.,* 2012., Baker and Allen, 1993). Further, Saxena and Kumar (2014) and Padakandla (2016) reported that rice yield is negatively affected by maximum temperatures, which causes a decrease in the yields.

Correlational analysis of Cotton crop yields with rainfall

Table 8 reveals that the rainfall (mm) during September month in the second decade and October month during the third decade was positively correlated with the lint yield of cotton. The positive association with lint yield of the cotton crop (kg/ha) might be due to the favourable conditions for boll formation and increase in boll weight. Cotton is mainly a rainfed crop that is dependent on rainfall in all stages, *viz.,* vegetative stage, reproductive stage, boll formation *etc*. (Guntukula, 2020., Padakandla, 2016).

Correlational analysis of Cotton crop yields with temperature (maximum and minimum)

The minimum temperatures have shown a significant positive association with the cotton crop yields during the October month in the first decade, which might have triggered the seed set, increased size of bolls, number of seeds per boll, and the number of fibres per seed (Soliz *et al.,* 2008). During the third decade, the association of maximum temperatures of October and November months with the lint yields of cotton was significantly negative. The rise in maximum temperature by about 0.3^{o}C over the first decade in the months of October and November (Figure 6) might have affected the retention of bolls due to increased abortion of squares and young bolls. These results are in compliance with the findings of Reddy *et al.* (1991). Oosterhuis (1999) also reported that despite the cotton crop's origin from hotter climates, it does not essentially produce better yields at high temperatures. Besides that, a negative correlation was reported between the cotton lint yield and high temperature during flowering and early stages of boll development.

A brief summary of the key findings from the analysis are,

1. The rainfall variability of the recent decade was very high (29.03%) as compared to the first (19.7%), second (13.1%) decades, and 30 years' mean annual rainfall (21.9%), indicating the least consistency in rainfall received.
2. A decrease in the average rainfall of July month was observed in the third decade as compared to the first decade.
3. The lengthier lower side whisker of September month indicated the higher risk of recording low rainfall conditions as compared to the July and August months.
4. The mean maximum temperature of the third decade (2008-2017) had the higher coefficient of variation (2.38%) as compared to the first (2.24%), second (0.99%) decades, and 30 years mean maximum temperature (1.96%) which indicates that the recent decade (2008-2017) had higher fluctuations in maximum temperatures than the earlier two decades.
5. The mean minimum temperature of the first decade had the highest coefficient of variation (3.41%) than the second (1.68%), third decades (1.69%), and 30 years mean minimum temperature (2.54%), which indicates that the first decade had the higher fluctuations in the minimum temperatures as compared to the latter two decades.
6. The rice crop yields during the recent decade (2008-2017) were found to have a significant positive association with the rainfall in September month and a significant negative association with October month.
7. A significant negative association was observed between the maximum temperatures of October and November months and lint yields of cotton, probably due to the affected boll retention and greater abortion of squares and young bolls.

All the above results have clearly indicated that climatic variability exists in the Nalgonda district, which was a major concern to farmers and the major crops grown in the district. In order to minimize the adverse effects of climate change and variability on agricultural production, farmers tend to use Indigenous Technical Knowledge (ITK) and innovative practices as climate-resilient initiatives. Further, these climatic variability concerns necessitate the administrators, policymakers, and researchers to come out with suitable interventions to combat the detrimental effects of climate change.

Conclusion

The obtained results clearly pointed out that there is an apparent decadal change in the trends of rainfall minimum and maximum temperatures in the district. The key finding realised was that there exists climate variability and change in the Nalgonda district, and the climate variables had significant effects on the major crop yields of the district. Therefore, it is important in the present scenario to provide necessary assistance to the farming community towards enhancing their preparedness for climatic aberrations. This could be possible by upscaling CRA technologies on a large scale in the social system. The in-depth climate variability analysis of the district could assist the institutions promoting CRA technologies in preparing contingency plans precisely for each month and several crops grown in the district, thus providing advisory support to the farmers accordingly. The findings of the study may have large implications in designing climate change adaptation programmes keeping in view the existing climatic variability pattern of the district.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of different tillage systems and cultivars on yield and yield attributes of rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment was conducted during *Kharif* 2019 at the Experimental Farm of the Department of Agronomy of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (H.P.) to investigate the effect of different tillage systems and varieties on yield of rice. The treatments consist of three rice varieties (HPR 1156, HPR 2656 and HPR 2795) which were tested under three tillage systems viz., conventional tillage, and minimum tillage without residue and minimum tillage with residue retention. The experiment was set up in a split plot design, with the tillage system in the main plot and rice cultivars in the sub plots, and it was triple replicated. The texture of the soil at the test site was silty clay loam in texture, acidic in reaction and in terms of nitrogen, phosphorus, and potassium, it was evaluated as medium. Significantly higher no. of panicles per meter square were observed in minimum tillage without residue though this treatment was at par with conventional tillage while significantly lower number of panicles m^{-2} were recorded with minimum tillage with residue retention. Significantly greater number of grains per panicle and panicle length were recorded in conventional tillage while minimum tillage with residue retention recorded lower values of number of grains per panicle and panicle length. Different tillage practices had no effect on the test weight of rice. Among different varieties tested, HPR 2656 recorded greater number of panicles per square meter which was at par with variety HPR 1156. Significantly higher number of grains per panicle and panicle length were recorded with HPR 2795 while the other two varieties were at par with each other. Rice variety HPR 1156 produced grains that had significantly greater test weight while the other two varieties (HPR 2795 and HPR 2656) were at par with each other with respect to this parameter. In terms of yield, conventional tillage produced much larger grain yield, straw yield, and biological yield and was at par with minimum tillage without residue. Among different varieties tested, HPR 2795 recorded much greater grain, straw and biological yields.

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Introduction

Rice (Oryza sativa L.) is a staple meal for half of the earth population, and it plays a critical role in the food and nutritional security of the world's poorest and malnourished people. The importance of this crop in the global food security scenario can be judged from the fact that this grain supplies more than 50% of the world’s staple food while also making up for 20 % of the world’s dietary energy supply, which is more than 19 % and 5 % that is contributed by wheat and maize, respectively (Schatz *et al.,* 2014). In India rice is cultivated on an area of 43.78 million hectare with the total production of 118.43 million tonnes with the average productivity of 27.05 q/ha (Anonymous, 2020) Even in the state of Himachal Pradesh rice is one of the most important *kharif* crop (second only to maize) which was cultivated on an area about 71 thousand hectare with the production of 114.8 thousand tonnes and productivity of about 16 q/ha (Anonymous, 2018).

The conventional tillage methods are easy to adopt and provide clean cultivation. However it leads to high erosion hazard as it completely inverts the soil and buries crop residues, making the land much more exposed to erosive forces of wind and water. Erosion eventually reduces the productivity of land (Mathew *et al.,* 2012). The alternate for all these problems is conservation tillage. Tillage systems such as ridge-till, minimum tillage and no-till leave more crop residues and offer greater erosion control. Conservation agriculture aims to increase agricultural yields and also provide economic and environmental advantages. It is referred as "future agriculture" (Pretty *et al.,* 2011). Minimum soil disturbance, rational organic soil cover utilising crop residues or cover crops, and the adoption of innovative and economically feasible farming methods, as well as steps taken to decrease soil compaction through regulated traffic, are all important components. Fuel and labour requirements are also reduced with conservation tillage. Further plant residues used as mulch not only cover the soil surface but help to supply plant nutrients on decomposition by micro-organisms. As a result it’s critical to discover technologies that may generate larger yields with less resource, lowering cultivation costs and increase farmers profit margins (Singh *et al.,* 2006).

Adoption of conservation agriculture practices atters the microclimate of soil leading to better crop growth. However the varieties may differ in their suitability for cultivation under conservation agriculture system. Also specific genotypes have been recommended for no-till cultivation all over the world. However, very little work has been done in Himachal Pradesh for the identification of rice genotypes for conservation agriculture. Thus it is important to test this new concept in one of the most important cereal crop grown in the state. Keeping the above facts in view, the present study was conducted to identify varieties suitable for conservation agriculture.

Material and Methods

The current study took place in the Experimental Farm of the Department of Agronomy, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur (32°09' N latitude, 76°54' E longitude, at an altitude of 1290 m above mean sea level) during the kharif of 2019. The region reflects Himachal Pradesh's mid-hills sub-humid zone, which has moderate summers and chilly winters. The soil at the test location had a silty clay loam texture, was acidic in response, and had a medium amount of accessible nitrogen, phosphate, and potassium.

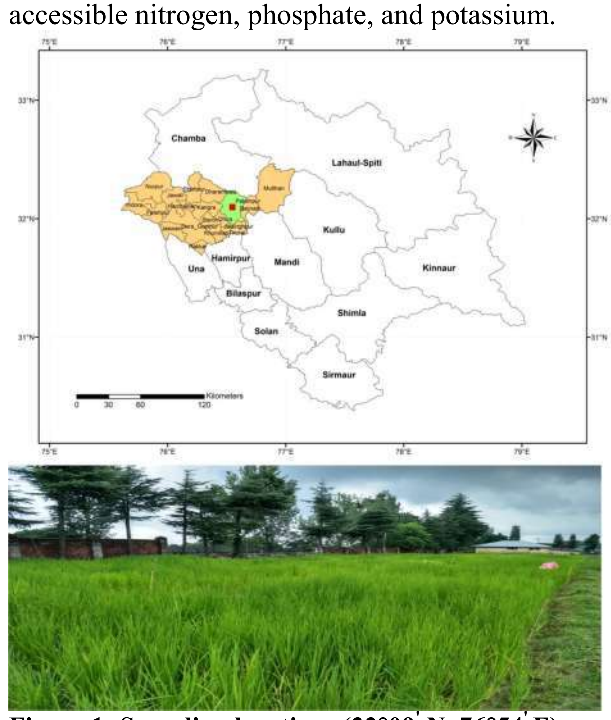

Figure 1: Sampling locations (32°09' N, 76°54' E)

There were nine treatment combinations in the trial, including three tillage techniques (conventional tillage, minimum tillage without residue, and minimum tillage with residue retention) and three cultivars (HPR 1156, HPR 2656, and HPR 2795). The experiment was conducted out in a split plot design, with tillage techniques in the main plot and varieties in the sub plot, and was repeated three times. The crop was planted on June 13th, 2019. The crop was grown with recommended package of practices and was supplied with 60:30:30 kg NPK. The complete amount of phosphorus and potassium, as well as half of the prescribed nitrogen, was administered at the time of sowing, with the remaining nitrogen applied in two equal splits during the tillering and panicle initiation stages. Mustard straw @ 3t/ha was used as mulch material and applied as per treatment.

The data on different yield attributes (number of panicles per meter square, number of grains per panicle, panicle length and test weight) as well as on grain and straw yield and harvest index was recorded. The data obtained was statistically analysed using the method educated by Gomez and Gomez (1984). The critical difference (CD) was estimated for parameters with significant impacts at the 5% probability level.

Results and Discussion

The data on different treatments effect on yield attributes of different rice varieties has been given in Table 1 while that on yield has been given in Table 2. A perusal of data (Table 1) reveal that significantly higher number of panicles per square meter were recorded in the minimum tillage without residue treatment which was at par with conventional tillage while significantly lower number of panicles per square meter was recorded in minimum tillage with residue. However in case of number of grains per panicle and panicle length significantly higher values for both these parameters were recorded in conventional tillage which was comparable to minimum tillage without residue. Significantly lower number of grains per panicle and panicle length were recorded in minimum tillage with residue retention. Tillage practices had no effect on the weight of 1000 grains. The higher values of yield attributes (number of panicles m^{-2}, number of grains panicle^{-1} and panicle length) observed in conventional tillage can be attributed to the effect of tillage in loosening the soil, increasing porosity thereby allowing good air exchange and root growth. This better root growth allows the plant to absorb nutrients and water from a wider soil profile resulting in better crop establishment and early growth which results in higher values of yield and its attributes (Gupta and Seth, 2007; Seth 2019). The treatment in which residue was retained on the soil led to the immobilization of nitrogen particularly during the initial stages of crop growth resulting in poor growth and yield attributes. The 1000 grain weight is more of a genetic character and hence was not influenced by different tillage practices.

Among rice varieties significantly higher number of panicles per square meter was observed in the variety HPR 2656 which was at par with HPR 1156 and lowest count was recorded in HPR 2795. In case of grains per panicle significantly higher value was recorded in HPR 2795 which was followed by HPR 2656 and HPR 1156 in that order, the latter two varieties being at par with each other. The data on panicle length revealed that significant longer panicle was observed in variety HPR 2795, while the lowest panicle length was recorded in variety HPR 2656 though it was at par with HPR 1156. 1000-grain weight is an important yield attribute which affect yield of any crop. The data on 1000-grain weight reveals that variety HPR 1156 produced grains having significantly higher 1000-grain weight while the other two varieties were at par with each other.

The data on yields and harvest index of rice has been presented in Table 2. Results revealed the significant influence of both tillage practices and varieties on grain yield, straw yield and biological yield. Significantly higher grain yield was recorded in conventional tillage which was at par with minimum tillage without residue while lowest yield was recorded in treatment in which the minimum tillage was practiced alone with residue retention. As discussed earlier the conventional tillage improved porosity as well as air circulation in the soil enabling better root and shoot growth and better nutrient availability and uptake resulting in better yield. In minimum tillage with residue higher immobilization of nitrogen could be the cause of the reduced yield. Similar results have also been

Table 1: Effect of tillage practices and varieties on yield attributes of rice

Treatments	No. of panicles m^{-2}	No. of grains panicle $^{-1}$	Panicle length (cm)	1000 grain weight (g)
Tillage practices				
Conventional tillage	219.4	91.0	22.74	26.31
Minimum tillage without residue	222.2	87.3	22.41	25.91
Minimum tillage with residue	211.7	83.8	22.06	25.56
SEM ±	2.4	1.1	0.08	0.16
LSD (P= 0.05)	9.4	4.2	0.33	NS
Varieties				
HPR 1156	226.6	76.1	22.04	26.41
HPR 2656	230.9	82.7	21.43	25.58
HPR 2795	195.8	103.3	23.73	25.79
SEM ±	**5.1**	**2.8**	**0.25**	**0.13**
LSD (P= 0.05)	**15.6**	**8.5**	**0.78**	**0.41**

Table 2: Effect of tillage practices and varieties on yield of rice

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest Index (%)
Tillage practices				
Conventional tillage	28.53	54.96	83.49	34.17
Minimum tillage without residue	28.05	52.48	80.53	34.83
Minimum tillage with residue	26.28	49.68	75.96	34.59
SEM ±	0.40	0.88	1.10	0.14
LSD (P= 0.05)	1.52	3.28	4.32	NS
Varieties				
HPR 1156	24.04	47.83	71.87	33.43
HPR 2656	28.53	53.44	81.97	34.79
HPR 2795	30.29	55.85	86.13	35.15
SEM ±	**0.64**	**1.04**	**1.82**	**0.18**
LSD (P= 0.05)	**2.08**	**3.20**	**5.60**	**0.60**

reported by (Singh *et al.,* 2006; Seth, 2019; Seth 2020; Mitra and Patra, 2019 and Pandey and Kandel, 2020). Among the varieties tested significantly higher grain yield was recorded in variety HPR 2795 which was comparable to HPR 2656 and lowest grain yield was recorded in HPR 1156. The higher yield in HPR 2795 was due to significantly longer panicle and due to higher number of grains panicle per square meter. The data on straw yield and biological yield revealed that significantly higher values of both parameters were recorded in conventional tillage which was 9.6 and 9.0 % higher over minimum tillage without residue, respectively. The higher straw yield obtained in conventional tillage was due to better root growth and enhanced nutrient availability and uptake which resulted in better initial growth and higher photosynthetic activity. Among the varieties tested significantly higher straw yield and biological yield was recorded in variety HPR 2795 which was at par with HPR 2656 while lowest straw yield and biological yield was recorded in variety HPR 1156. The harvest index of rice was not significantly influenced by tillage practices with all the treatments exhibiting almost similar harvest index. Contrary to this harvest index of different rice varieties varied significantly with HPR 2795 showing significantly higher harvest index while HPR 1156 showed significantly lower harvest index.

Conclusion

It is possible to draw a conclusion from the current research that conventional tillage gives better productivity of rice as compared to minimum tillage with residue on short term basis. Also amongst different varieties HPR 2795, a new red rice variety, gave better results under direct seeding.

Conflict of interest

The authors declare that they have no conflict of interest.

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Evaluation of spring water quality using water quality index method for Bageshwar District, Uttarakhand, India

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ABSTRACT

The quality of spring water is highly important to the people of hills for their everyday lives in Bageshwar district, which is located in Uttarakhand's Eastern Kumaon area between latitudes 29.49° N and 79.45° E, at an elevation of 1,004 meters above mean sea level. The study area map was created using the open-source freeware software QGIS, and the geocoding of the selected area was performed by entering Latitude and Longitude coordinates. Spring water were collected and analysed based on the standard methods for the eleven springs of Bageshwar city and its nearby villages for two seasons during the winter (December 2019) and in summer (March 2020). The present study assessed the drinking water quality of perennial spring in and around Bageshwar using the WQI by Weighted Arithmetic Water Quality Index Method. For calculating the WQI, 15 physicochemical parameters, namely, pH, alkalinity, Chloride, Electrical Conductivity, Total Dissolved Solid, Turbidity, Total Hardness, Potassium, Sodium, Fluoride, Iron, Nitrate, Calcium, Magnesium and Total Hardness were taken. The WQI values show that spring water with WQI values ranging from 4.57 to 17.83 in winter season 6.72 to 27.72 in summer season falls under excellent category, except for Bhaniya Dhaar-1 (BS_8) village spring, which were classified to good water category. A paired t-test was applied to compare significant variations in water quality between two seasons, revealing a significant difference (p value<0.05) in water quality between seasons. Water from all of the evaluated spring sources is safe to drink, despite the fact that some parameters exceed permitted limits. To ensure the quality and security of the water supply to the people of these regions, it is preferable to conduct a simple filtration process before drinking the water sampled from the springs.

Introduction

Sustainable utilization of natural resources (water sources, biomass and other renewable materials) is one of the prime concerns pertinent to mankind, and as such serious efforts are being put to prevent direct and indirect routes (Pasqual and Souto, 2003). The entire ecosystem, its preservation and the upliftment mankind depend on these resources, especially primarily on water resources (Baunthiyal *et al*., 2015; Tiwari, 2015). Due to increasing anthropogenic activity, spring ecosystems are under great threat, which needs urgent attention and management plans (Krishnan *et al*., 2005; Daghara *et al*., 2019). The increasing human population has led to urbanization and other development activity resulting in the degradation of groundwater (Gupta *et al*., 2019). Spring water is inexpensive and high-quality which flows out to the surface due to natural gravity and hydrostatic pressure. When the spring waters interact with the surface, it undergoes rapid contamination (Vilane *et al*., 2016). The springs are a vital source of water in the entire Himalayan region, particularly for

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isolated villages at higher altitudes. The village population of the Indian Himalayan region especially Uttarakhand has largely depended on spring water since time immemorial and as a result a numerous studies evaluating the quality of spring water and other water bodies have been conducted (Baunthiyal *et al*., 2015; Bhutiani *et al*., 2019; Ruhela *et al.,* 2018). Very few water quality assessments have been done in high-altitude regions like Bageshwar, Uttarakhand. The springs found in the study area are primarily of depression, gravitational and contact category and belong to the sedimentary rocks (limestone, shale and sandstone), metasedimentary and low-grade metamorphic rocks like dolomite, phyllite, quartzite and slate. The occurrence and movement of groundwater are influenced by the type of the litho units and the interspaces/interstices, as well as the degree of interconnection between them, the vertical and aerial extension of faults, joints, and/or shear zones, and the local and regional geomorphology. Groundwater arises as springs and seepage in ideal physiographic conditions, such as smooth sloping slopes, vast river valleys, and lithological connections. Based on the lithology of the area, there are three types of spring prominent and these are categorized under depression spring, gravitational spring and contact spring. Most of the spring water consumed by the local community is of open-source type. Therefore, regular testing and proper treatment of water are recommended for human consumption. Thus, in the present study, physicochemical analysis for spring water was conducted adopting standard methodologies to perceive the degree of contamination/pollution. As per the analysis of the obtained results, the parameters of water samples collected from all eleven perennial springs are of excellent quality with a significant difference in Water Quality Index during two seasons for both years. The paper presents a detailed analysis of the chemistry of spring water quality regarding the drinking water standards. Both the quantity and quality of spring water are depleting at an alarming rate due to various factors. Awareness programmes on the importance of springs, conservation and rejuvenation of the spring among the local communities can help protect the springs in Himalayas.

Material and Methods

Study Area

Uttarakhand, formerly known as Uttaranchal, located in northern India with 13 districts with coordinates between latitude 28°45'N and 31°30'N and longitude 77°30'E to 81°05'E, with an altitude of 200 to 7,800 m above mean sea level. Bageshwar district is located in the hilly region of Uttarakhand. Bageshwar district has a moderate to subhumid climate. While the centre and southern parts of the region are relatively warm and humid, the northern part is entirely sub-zero throughout the year. The primary climatic characteristic of Bageshwar district is a harsh winter. The total annual rainfall at Bageshwar is 1360 mm and the total number of rainy days is 119 days. Major physiographic units of the district are Central and Lesser Himalayan Zone and its main drainage rivers are Bhadrapati, Gomti, Pindar, Pungar and Saryu. The soils of the Bageshwar district are categorised into lesser and greater or central Himalaya soils. The first type covers the majority of the area. The geological framework of Bageshwar region is so vast that the region is divided into different litho-tectonic units. The geology of the area consists of three Stratigraphic and tectonic units, namely (a) The Central Crystalline, (b) The Baijnath Crystalline and (c) The Garhwal Group.

Sampling Site and Water Quality Parameter Analysis

Spring water samples were obtained from eleven sampling locations of Bageshwar district, namely Banri (BS_1), Manikhet (BS_2), Darsu Aare (BS_3), Kukudagaad (BS_4), Kamedi (BS_5), Bilauna (BS_6), Bhaniya Dhaar-1 (BS_7), Bhaniya Dhaar-2 (BS_8), Bhitaal Gaon (BS_9), Nye Basti Chaurasi (BS_{10}) and Shri Naula Dhaara (BS_{11}). The spring water samples were collected in two seasons (one during the winter season (December 2019) and another in the summer season (March 2020)) in narrow necked polyethylene plastic bottles of one litre volume. Before sampling these bottles were washed and triple-rinsed with distilled water followed by rinsing with collected sampled water of spring. pH, total dissolved solids (TDS) and electrical conductivity were measured at the sampling site using Hand-handle pH-meter and TDS meter (TDS-3, HM digital)) then remaining parameters tested in the laboratory using the methods of APHA (2012) and (Tripathi and Govil, 2001).

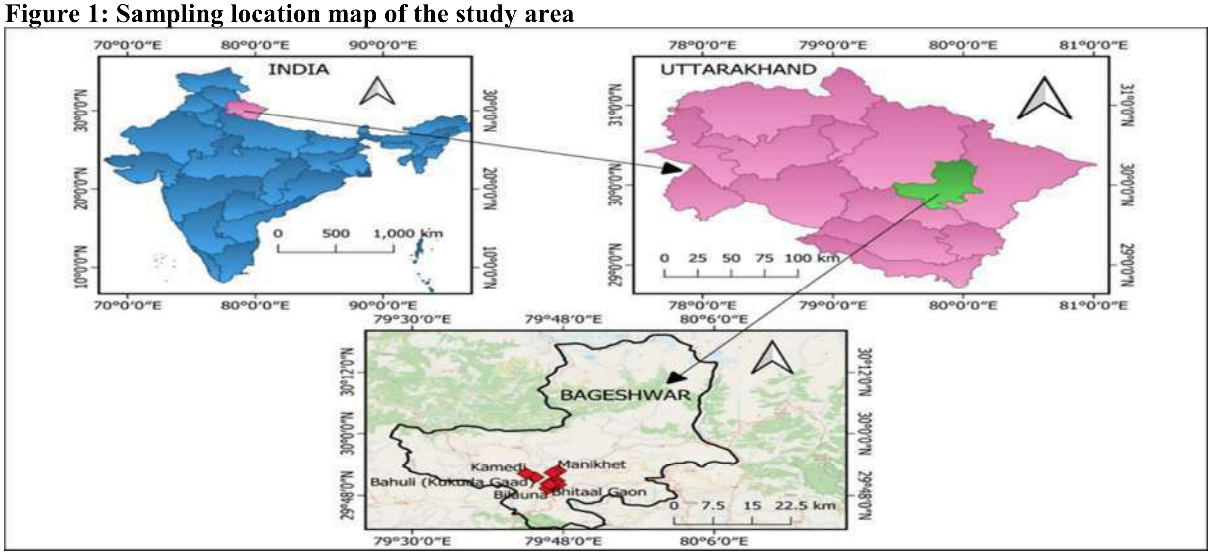
Preparation of Study Area Maps and Springs Location Points

The elevation, latitude and longitude of each of the locations sampled was measured (Table 1) using an app Kobo Collect working on Global Position System (GPS). The X (Latitude) and Y (Longitude) axis findings were expressed in Universal Transverse Mercator (UTM) system units, which are employed in a software application (QGIS) to construct the location map of the examined area displayed in Figure 1. Study area map was created using the open-source freeware software QGIS, and the geocoding of the selected area was performed by entering latitude and longitude coordinates. The GPS maps marks the study area's chosen spring water sources on the Google Earth map. The chosen analysis area and its borderlines are mapped and saved as a QGIS file on the QGIS application. The research area was digitised using QGIS tools. The chosen springs' latitude, longitude, and location were obtained using the app Kobo Collect. The spring positions were marked on the QGIS map using a point attribute. The water quality data derived from the non-spatial database were saved in excel format and combined with the spatial data. The spatial and non-spatial databases produced are combined to delineate the spatial distribution of groundwater pollutants to create Spatio-temporal distribution maps of water quality parameters. All the selected eleven springs were given spring id from BS_1 to BS_{11} (Table 1).

Table 1: The location and altitude of the springs sampling sites within the Bageshwar district

Name of the Site/Village	Spring ID	X (Latitude)	Y (Longitude)	Z (Altitude)
Banri	BS_1	29º 50′ 49"	79º 47′ 9"	899.09 m
Manikhet	BS_2	29º 52′ 52"	79º 47′ 23"	780.23 m
Darsu Aare	BS_3	29º 52′ 24"	79º 46′ 47"	878.92 m
Kukudagaad (Bahuli)	BS_4	29º 51′ 30"	79º 44′ 38"	888.87 m
Kamedi	BS_5	29º 52′ 9"	79º 43′ 12"	956.1 m
Shri Naula Dhaara	BS_6	29º 52′ 22"	79º 46′ 27"	830.8 m
Biluana	BS_7	29º 49′ 41"	79º 46′ 15"	789.28 m
Bhaniya Dhaar-1	BS_8	29º 50′ 26"	79º 46′ 48"	935.3 m
Bhaniya Dhaar-2	BS_9	29º 50′ 5"	79º 47′ 18"	975.93 m
Bhitaal Gaon	BS_{10}	29º 50′ 7"	79º 46′ 23"	876.26 m
Nye Basti Chaurasi	BS_{11}	29º 50′ 7"	79º 46′ 23"	894.57 m

Figure 1: Sampling location map of the study area



Water Quality Index (WQI)

The Water Quality Index (WQI) was first developed by (Horton, 1965). Later, a new modified WQI similar to Horton's index was introduced by Brown (1970). To determine the suitability of spring water for human consumption, we have used WQI by Weighted Arithmetic Water Quality Index Method. Various scientists widely used this method to assess water quality (Adimalla and Venkatayogi, 2018; Aly *et al*., 2015; Bhutiani *et al.,* 2018; Balan *et al*., 2012; Brown *et al*., 1972; Chowdhury *et al*., 2012; Rao *et al*., 2010; Ramakrishnalah *et al*., 2009; Ruhela *et al.,* 2022). The WQI was calculated using the following formula: Following three steps are followed for computing WQI:

Each parameter's unit weight is inversely proportionate to its standard permissible value.

1. Each parameter's unit weight is inversely proportional to its

standard permissible value. Unit weight of ith water quality parameter,

$$W_i = \frac{K}{S_i}\text{, where}$$

K= constant of proportionality, given as

$$K = 1/\sum_{i=1}^{n}\left(\frac{1}{S_i}\right)$$

n= number of parameters,

S_i= standard permissible value of the ith parameter.

2. Development of quality rating scale

$$Q_i = \frac{V_i - V_o}{S_i - V_o} \times 100$$

where

Q_i= quality rating of ith water quality parameter,

V_i= measured concentration of ith water quality parameter,

V_o= ideal value of ith water quality parameter

Generally, the value of V_o is zero for all water quality parameters except for pH and dissolved oxygen (DO); for pH, V_o= 7; For DO, V_o=14.6 mg/l.

3. Calculating WQI

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

The Weighted Arithmetic Water Quality Index (WAWQI) method converts several water quality criteria into a mathematical equation that assigns a numerical value to the health of the water body.

The obtained value of WQI of all parameters were then classified according to range Value into five categories in order to determine degree of purity of spring water and its suitability for human consumption (Table 2).

Table 2: WQI classification range.

Range	Type of Water
0-25	Excellent water
26-50	Good Water
51-75	Poor water
76-100	Very Poor water
>100	water unsuitable for drinking purpose

Statistical Analysis

To determine any significant differences in WQI for two selected seasons (Winter and summer), a paired *t-test* at 0.5 significant level (at 95% confidence level) was performed using R-studio software.

Results and Discussion

The results of studied physicochemical parameters are given in Table 4 and Table 5 shows that the average values of all 15 physicochemical parameters are below the maximum allowable limits of the Bureau of Indian Standard 10500: 2012 given in Table 3 for drinking water.

pH: The pH value indicates a change in the source's quality. Water that is extremely acidic or alkaline has a sour or alkaline flavour. Furthermore, higher pH values limit chlorine's germicidal potential. The pH values from all the spring sites were within the desirable limits except from the spring- BS_1, BS_4 and BS_7 (6.93, 6.93 and 6.71, respectively), which were recorded slightly acidic during winter. Bhat *et al.* (2010), Chauhan *et al*. (2020) and Kumar *et al.* (1997) discovered the acidic composition of water samples while researching natural springs in Kashmir, Pauri (Uttarakhand) and Almora (Uttarakhand), respectively. The highest value of pH was measured in summer at the spring-BS_7 8.38 (Table 5). The rise in pH in some springs could be due to bicarbonate and carbonate of calcium and magnesium in water which may be due to the geology of the region in which limestone is the most common (Zeb *et al*., 2011). The pH values of all the spring water were within the permissible limits of BIS (2012) and WHO (2011).

EC: To measure the concentration of soluble salts in water, the electrical conductivity (EC) is used. Drinking water with a high concentration of dissolved solids has an unpleasant flavour. The

Table 3: Standards values of physicochemical parameters given by BIS and WHO

SN	physicochemical Parameters	BIS 10500: (2012)		WHO (2011)	
		Acceptable Limit	Permissible Limit	Acceptable Limit	Permissible Limit
1.	pH	6.5-8.5	No relaxation	6.5-8.5	No relaxation
2.	EC (µS/cm)	770	1500	770	1500
3.	TDS (ppm)	500	2000	500	No relaxation
4.	Alkalinity as $CaCO_3$ (mg/L)	200	600	200	No relaxation
5.	Chloride (mg/L)	250	1000	250	No relaxation
6.	Hardness as $CaCO_3$ (mg/L)	200	600	100	300
7.	Potassium (mg/L)	12	No relaxation	12	No relaxation
8.	Sodium (mg/L)	200	No relaxation	200	No relaxation
9.	RFC (mg/L)	0.2	1	5	No relaxation
10.	Turbidity (NTU)	1	5	1	4
11.	Fluoride (mg/L)	1	1.5	0.5	1
12.	Iron(mg/L)	0.3	No relaxation	0.5	No relaxation
13.	Nitrate(mg/L)	45	No relaxation	50	No relaxation
14.	Calcium (mg/L)	75	200	75	No relaxation
15.	Magnesium(mg/L)	30	100	30	No relaxation

maximum amount of EC was measured from Manikhet spring-BS2 (552.03 µS/cm and 553.29 µS/cm for winter and summer, respectively), while minimum amount of EC was measured from Bahuli spring-BS_4 (37.21 µS/cm and 38.92 µS/cm for winter and summer, respectively). The electrical conductivity values of all the spring water were within the permissible limits of BIS (2012) and WHO (2011).

TDS: Total Dissolved Solid (TDS) is a term that refers to dissolved solids and colloids in the form of chemical compounds and other substances. The maximum amount of TDS was measured from the spring-BS_2 (356.69 ppm and 287.19 ppm for winter and summer, respectively). In comparison, the minimum amount of TDS was measured from the Bahuli spring-BS_4 (24.35 ppm and 18.55 ppm for winter and summer, respectively). All of the TDS values were within the BIS (2012) and WHO (2011) permissible limits.

Alkalinity: The presence of dissolved minerals such as carbonate, bicarbonate, and hydroxide results in the alkalinity of water. The total alkalinity value of all the spring water was lower than the permissible limits (BIS, 2012) in the winter season. However, it exceeded the acceptable limit at two springs sites in the summer season, i.e., Manikhet-BS_2 and Darsu Aare-BS_3 (225.31 mg/L and 215.28 mg/L), respectively given in Table 5. This may be due to higher carbonate, bicarbonate compounds in the soil or bedrock around these two spring water sources which gets dissolved and travel with the water in summer. This difference in summer in two in springs might be associated with the human activities during the summer season (Barakat *et al.,* 2018).

Potassium: Based on the prescribed limit of (WHO,2011) and (BIS,2012) difference in potassium concentration has been recorded during two seasons. Winter month recorded the highest value of potassium at spring site BS_5 (5 mg/L) are within the permissible limit, but at three spring sites, BS_4, BS_7 and BS_{10} are zero in both seasons. The potassium content of all of the spring water samples is within the permissible range in both seasons.

Sodium: Sodium is a vital component required by the human body for a variety of tasks such as muscle and nerve function. Blood pressure and kidney failure are both linked to an increased concentration of Na^+ in the blood. The presence of sodium in low concentration was also detected in all spring water samples (lower than the permissible range of 200 mg/L); during both seasons (winter and summer), the maximum value of sodium was recorded from a spring and BS_6 (15 mg/l and 12 mg/L) and minimum value of sodium, i.e., 1 mg/L reported from the springs BS_2, BS_4, BS_7 and BS_9 in

Table 4: Physicochemical properties of springs during Winter (2019).

SN	Physicochemical Parameters	BS_1	BS_2	BS_3	BS_4	BS_5	BS_6	BS_7	BS_8	BS_9	BS_{10}	BS_{11}
1.	pH	**6.93**	7.89	8.07	**6.93**	**6.71**	7.3	8.28	7.11	7.46	7.92	7.82
2.	EC (µS/cm)	438.13	552.03	316.8	38.92	136.13	399.57	344.05	116.5	80.46	95.76	287.37
3.	TDS (ppm)	285.15	356.69	200.2	24.35	89.93	248.55	215.15	71.85	49.88	96.56	179.05
4.	Alkalinity as $CaCO_3$ (mg/L)	103.09	185.56	144.33	51.55	41.24	113.4	123.71	82.47	30.93	61.85	92.78
5.	Chloride (mg/L)	47.45	12.35	8.79	5.27	14.06	24.66	7.03	7.03	10.54	8.79	26.36
6.	Hardness as $CaCO_3$ (mg/L)	**377.19**	**438.6**	**333.33**	192.98	**219.3**	**350.88**	**342.11**	**210.53**	**201.75**	**228.07**	**324.56**
7.	Potassium (mg/L)	3	1	3	0	5	4	0	2	1	0	4
8.	Sodium (mg/L)	15	1	4	1	5	15	1	2	1	5	11
9.	RFC (mg/L)	0	0	0	0	0	0	0	0	0	0	0
10.	Turbidity (NTU)	0	0	0	0	0	0	0	0	0	0	0
11.	Fluoride (mg/L)	0.35	0.45	0.35	0.45	0.55	0.6	0.25	**1.5**	0.2	0.55	0.4
12.	Iron(mg/L)	0.04	0.03	0.05	0.02	0.03	0.04	0.08	0.03	0.02	0	0.03
13.	Nitrate(mg/L)	6	4	3	2	3	5	4	2	3	4.5	1.5
14.	Calcium (mg/L)	38	46	40	14	28	38	44	20	16	18	37.2
15.	Magnesium(mg/L)	**39.54**	**58.26**	28.49	5.24	12.16	**48.29**	**38.29**	22.39	8.19	11.78	20.69

Table 5: Physico-chemical properties of springs during summer (March, 2020).

SN	Physicochemical Parameters	BS_1	BS_2	BS_3	BS_4	BS_5	BS_6	BS_7	BS_8	BS_9	BS_{10}	BS_{11}
1.	pH	7.48	8.01	7.51	7.3	7.44	7.88	**8.38**	7.81	7.76	7.35	8.03
2.	EC (µS/cm)	434.35	553.29	267.28	37.21	141.98	404.86	348.14	114.78	78.25	120.69	352.18
3.	TDS (ppm)	232.16	287.19	140.59	18.55	72.87	212.09	184.49	59.38	38.46	61.13	183.78
4.	Alkalinity as $CaCO_3$ (mg/L)	129.38	**225.31**	**215.28**	88.48	81.73	159.64	189.47	118.58	68.35	89.49	157.29
5.	Chloride (mg/L)	64.19	35.46	20.26	49.59	52.28	88.65	53.19	29.14	26.32	53.19	54.16
6.	Hardness as $CaCO_3$ (mg/L)	**358.19**	**381.49**	**309.36**	76.67	189.43	**328.34**	**389.82**	173.38	155.69	143.63	**334.18**
7.	Potassium (mg/L)	2	1	3	0	4	4	0	2	1	0	3
8.	Sodium (mg/L)	13	2	3	1	4	12	2	3	4	6	12
9.	RFC (mg/L)	0	0	0	0	0	0	0	0	0	0	0
10.	Turbidity (NTU)	0	0	0	0	0	0	0	0	0	0	0
11.	Fluoride (mg/L)	0.25	0.5	0.5	0.4	0.65	0.5	0.5	2.5	0.4	0.45	0.6
12.	Iron(mg/L)	0.05	0.05	0.04	0.05	0.06	0.05	0.1	0.03	0.02	0.02	0.04
13.	Nitrate(mg/L)	7	5	4	3	3	10	5	2	4	5	2
14.	Calcium (mg/L)	32	30	44	12	26	40	50	18	14	20	38
15.	Magnesium(mg/L)	**37.66**	**54.67**	12.15	6.07	10.94	**42.53**	30.37	19.44	12.15	14.15	14.58

the summer season. The salinity of the water is mainly due to the presence of sodium chloride (NaCl) in water. The sodium content of all of the spring water samples is within the permissible range.

Chloride: Chloride is a significant indication of water quality and is abundant in nature in the form of sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride ($CaCl_2$). During the summer season, higher and lower values of chloride were detected at spring-BS_6 (88.65 mg/L) and BS_3 (20.26 mg/L), respectively given in Table 5, and in the winter season, higher and lower values of chloride were detected at spring-BS_1 (47.45 mg/L) and BS_4 (5.27 mg/L) respectively given in Table 5. Comparatively, chloride concentration in spring-BS_6 was higher during summer which may be attributed to anthropogenic factors that contribute to chloride levels in spring water, including geological weathering, leaching from rocks, domestic effluent, irrigation discharge, agricultural use, etc. (Barakat *et al*. 2018), although it remained below the permitted level prescribed by (WHO, 2011) and (BIS, 2012).

Calcium: Magnesium and Calcium are also significant indicators for evaluating water quality since they have a direct relationship with the development of water hardness of water. Natural water contains different concentrations of these two elements depending on the type of rocks in the area. The maximum calcium concentration in both winter and summer seasons was found at spring-BS_7 and BS_2 (50 mg/L and 46 mg/L), respectively. The minimum calcium concentration in both seasons was recorded at the same spring-BS_4 (12 mg/L and 14 mg/L), respectively. The calcium content in all the spring water samples were within the permissible limit.

Magnesium: During the winter season, the highest concentration of magnesium recorded was 39.54 mg/l, 58.26 mg/l, 48.29 mg/l and 38.28 mg/L at the spring sites of BS_1, BS_2, BS_6 and BS_7, respectively and also in the summer season highest concentration of magnesium recorded were 37.66 mg/L, 54.67 mg/L, 42.53 mg/L and 30.37 mg/ L at the same springs as in winter season, which is beyond the acceptable limit prescribed by (BIS, 2012) (Table 3). This variation in Mg level might be related to the weathering of rocks and mineral content of each ion, such as sedimentary rocks, limestone, dolomite, gypsum, aragonite, the mineral of igneous rock, feldspars amphibole and pyroxene, and the pH value of each source (Hem, 1985). As a result, a basic physical treatment of the spring water is desirable in order to limit nutrient loading. However, magnesium values in all other spring water samples are within the permissible limit during two seasons.

Total Hardness: Spring water is considered hard due to the presence of a high concentration of calcium ions and magnesium ions. The higher value of total hardness was recorded for both seasons. During winter the season, the hardness values of all the spring sites were found to be above (BIS, 2012) the acceptable limits, except at spring-S_4 (192.98 mg/L) and maximum value of hardness found at the spring of BS_2 (438.6 mg/L) given in (Table 5). Similarly, total hardness was also found to be exceeding the acceptable limits in the spring-BS_1, BS_2, BS_3, BS_6, BS_7 and BS_{11} (358.19 mg/L, 381.49 mg/L, 309.36 mg/L, 328.34 mg/L, 389.82 mg/L and 334.18 mg/L) respectively, and the lowest value recorded at the spring-BS_4 (76.67 mg/L) given in (Table 4) during the summer season. The reason for higher value of total hardness could be attributed to anthropogenic activity and weathering action of host carbonate rock (Bui & Lodhi, 2020). To reduce the hardness of spring water of study area, a simple filtration treatment is preferable.

Fluoride: Traces of fluorides are present in many water samples, with higher concentrations often associated with groundwaters. During both seasons (Winter and Summer), the maximum amount of Fluoride was recorded from a spring-BS_8 (1.5 mg/L and 2.5 mg/l), which exceeded the permissible limit of BIS (2012) and in winter minimum amount found at spring-BS_{10} (0.20 mg/L) and in summer at the spring-BS_1 (0.25 mg/L). The probable reason of elevated fluoride may be the abundance of fluorspar, cryolite, fluorapatite and hydroxyapatite around the spring-BS_8 (Agarwal *et al.,* 1997). Fluoride can cause dental fluorosis and skeletal fluorosis if the concentration is too high. Filtration through a membrane Fluoride may be removed from water using reverse osmosis and electrodialysis membrane filtration methods.

Iron: Iron encourages the formation of "iron bacteria," which obtain their energy from the

Table 6: WQI and Paired t -test analysis (at 0.05 Significance level).

Spring Code	WQI (Winter 2019)	WQI (Summer 2020)
BS_1	8.309	8.727
BS_2	9.018	10.868
BS_3	10.042	9.840
BS_4	6.427	9.361
BS_5	8.697	13.239
BS_6	11.072	11.586
BS_7	12.308	16.052
BS_8	17.826	27.721
BS_9	4.571	6.718
BS_{10}	6.113	6.867
BS_{11}	8.196	10.443
t Stat	-3.081	
P value one-tail	0.012	
t Critical one-tail	-4.518	
t Critical one-left tail	-0.726	

oxidising of ferrous iron to ferric iron, depositing a slimy layer on the piping in the process. During both seasons (Winter and Summer), the maximum and minimum amount of Iron was reported from a spring-BS_7 (0.08 mg/l and 0.1 mg/L) and at spring-BS_{10} (0 mg/l and 0.02 mg/L). The iron content of all of the spring water samples was observed within the permissible range.

Nitrate: Nitrate (NO_3^-) is a plant nutrient that can be found naturally in the environment. Excessive nitrate and nitrite levels in drinking water can result in significant ailments such as "blue baby syndrome," increased cancer risk, starchy deposits, and spleen haemorrhage. During the winter season, the maximum amount of Nitrate was reported from a spring-BS1 (6 mg/l), and the minimum amount of Nitrate was rerecorded from a spring-BS_1 (1.5 mg/L). In the summer season, the maximum amount of Nitrate was reported from a spring-BS_6 (10 mg/l) and the minimum amount of Nitrate was rerecorded from a spring-BS_8 and BS_2 (2 mg/L). The nitrate concentration of all of the spring water samples was found to be within the permissible range.

WQI: The WQI is the highly effective way to communicate water quality because it presents the overall water quality results, rather than the results for each separate parameter (Toma *et al*. 2013). In order to know the degree of purity of spring water and its suitability for human consumption, a weighted arithmetic WQI method was applied. WQI values for all the water samples of springs for two seasons are shown in the (Table 6). All springs' water quality index value falls below 25 in winter season, indicating an "excellent" class for drinking purposes, except BS_8 spring which lies in a good class for drinking purposes with water quality values between 25 and 50 in summer season. The variation in water quality during different seasons may be due to the contact of rainwater with the sedimentary rock in the region leading to dissolution of ions into the aquifer or could be due to various anthropogenic activities, such as agricultural activities and anthropogenic pollution from the nearby area.

In general, the parameters of all the spring water samples were recorded to be in potable and excellent water category (Table 6), except the water sample of Bhaniya Dhaar-1 spring (BS_8) lies in the good quality category in the summer season. The paired *t-test* analysis was conducted at a significance level of 0.05 and 95% confidence level. These were calculated to compare the variation change in WQI during two seasons. Computation of paired *t*-test results shows that p-value ($p = 0.012$) is less than significant value 0.05, which revealed that the difference in WQI of the winter and summer seasons is significant. The results revealed that most of the springs' water quality is potable and excellent, with a significant variation in water quality during the two seasons.

Conclusion

Based on the results, individual parameters indicated that the majority of water samples were suitable for drinking and within permissible range according to the (BIS, 2012) standard, with the exception of a few samples where Total Hardness, Fluoride and Magnesium were found to be near or above the acceptable range of (BIS, 2012), which indicates that the water is safe to drink without any further treatment after a simple physical treatment of the spring water is preferable to minimise the risk of contamination. For Fluoride, Membrane filtration process reverse osmosis and electrodialysis are two membrane filtration processes which can be used for removal of fluoride. The overall WQI found that, when all physicochemical criteria were considered, all spring water samples were categorised as "excellent" quality during the winter season, with the exception of one site, Bhaniya Dhaar-1 spring (BS_8), which was categorised as "good" quality during the summer season. Additionally, there is a significant difference in WQI for all spring water during the two seasons. In the present scenario, Himalayan springs are gradually turning non-perennial. The anthropogenic activities within the catchment of springs are also significantly affecting the water quality. Water quality and discharge of the springs need to be checked at regular intervals, particularly during the rainy season, as many water-borne diseases are prevalent during this season. In the future, more studies should be conducted on the monitoring of discharge and water quality of springs in the Himalayan region. Awareness and capacity building of local community members is also needed to rejuvenate the Himalayan springs.

Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of varying altitudes on energy consumption and wheat production in Himachal Pradesh

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ABSTRACT

A field trial was conducted for the wheat crop at four different altitudes in Himachal Pradesh namely Palampur, Malan, Dhaulakuan and Bajaura. Energy is one of the most important inputs in agricultural production. It is used for farm operations, chemical fertilizers, insecticides, herbicides and is obtained from different renewable and non-renewable sources like diesel/petrol, human labour, animal draught, and electricity. The variation in crop production and energy consumption was determined at various altitudes. The most important set of features responsible for increased wheat yield, technology, input energy, and agro-climatic zone. At location, Bajaura produced the highest output energy (171081.7 MJ/ha) which means maximum grain and straw yield. The maximum energy consumption at Bajaura because of the long spell and good crop health to provide more irrigations required more labour for harvesting and threshing. The Increase in energy inputs enhances the output such as yield, biomass and productivity in different ecosystems. This involves making the most use of available energy inputs to boost output even higher in the key wheat growing regions.

Introduction

Wheat is the world's second-most important cereal crop, after corn and the second most important cereal in India, after rice. Wheat is a key contributor to the food security mosaic. Worldwide, wheat is regarded as the king of grains since it feeds 36 % of the world's population and accounts for 20% of the food calories (Kumar *et al.,* 2013). In India, wheat occupies an area of 31.2 million hectares with a total yield of 96.0 million tonnes and an average production of 31.40 q/ha. Being staple food, in Himachal Pradesh wheat occupied the largest area during 2016-17 when it was grown over an area of 338 thousand hectares with a total production of 650 thousand tonnes with average productivity of 19.21 q/ha (Anonymous 2017). During the production of the crop, energy is one of the most important inputs. Energy is used for a variety of purposes like farm operations, application of chemical fertilizers, insecticides, herbicides and is obtained from different sources like diesel/petrol, human labor, animal draught, and electricity. Due to the population explosion, the

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amount of energy consumption in agriculture has also increased for the production of sufficient food. A developing country like India has a large population of which the majority reside in rural areas and are involved in the agriculture sector. The information of agriculture energy resources and their consumption patterns becomes critical for creating effective food production systems. Increasing the energy inputs enhances yield, crop biomass output and productivity in different ecosystems.

The selection of the source of energy is also very important in sustaining agriculture and reducing the negative impact on the environment. Depletion of non-renewable sources due to the insatiable hunger of humans has led to the energy crisis. Renewable energy can play a critical part in addressing global energy needs or crises. A review of renewable energy technology reveals that enhanced approaches have the potential to cover around half of the US's future energy needs. Another key factor is inefficient energy management in crop production, which can be enhanced by collecting data from field energy consumption and its resources. This will not only aid in the formulation of different policies for enhancement of the crop production but also help in the protection of the environment from the negative effects of excessive and inefficient energy consumption. India has diversified topographic range from vast Gangetic plains to the Thar Desert and coastal regions of south to Himalayas in north. The power availability in Himachal Pradesh is quite low as compared to border sharing states like Punjab and Haryana.

In Himachal Pradesh, there is very diminutive data available on commercial and non-commercial energy availability and use patterns. A study was conducted in which energy–crop yield link was investigated and the variation in crop production energy consumption were determined at various altitudes. High yielding varieties, pesticides, fertilizers and other energy inputs altogether play a role in wheat production, since it is the most widely produced cereal grain on the planet. The most important set of factors responsible for increased wheat yield is energy input, technology and agro-climatic zone. Using a variety of different energy sources which includes renewable, non-renewable power, direct and indirect energy. The eventual input-output ratio is influenced by the energy input and output as yield of each system. Wheat growing has become more vigorous in recent years as Indian cultivation has been switched from human and animal-based production system to a mechanized farming methods. This involves making the most use of available energy inputs to boost output even higher in the key wheat growing regions. The main goal of energy consumption is to raise the output of farms and reduce the input energy as well as the different harmful effects. To achieve this by calculating, analysing and utilization of the energy for wheat production in different wheat growing regions of Himachal Pradesh, taking into account technology, energy input and agro-climatic zones.

Material and Methods

Field experiment was conducted during rabi season at research stations of Department of Agronomy, CSK HPKV, Palampur, Malan, Bajaura and Dhaulakuan in Himachal Pradesh (Table 1) to evaluate the different energy consumption in wheat production with changing altitudes. The different energy input resources are distributed in different categories, like direct, indirect energy, renewable and non-renewable energy. The direct energy source of input in farms i.e., human, water, and diesel were used for different procedures of wheat production, like land preparation, sowing, fertilizer application, weeding, harvesting, threshing, and transportation. Likewise, the indirect form of energy input sources like seed, fertilizers, farmyard manure, weedicides, tractor and implements, were collected for determining the energy consumption as well as economics in production of wheat in the relevance of location. The input energy was compared based on renewable and non-renewable energy. According to the labour usage, operations are listed for the labour requirement per operation and calculated the total usage of direct power in particular operation for the energy requirement (Table 2). The calculation was done in hours of labour-power used in wheat production.

All these energy inputs were multiplied with their respective energy coefficients and the total energy input in crop production was computed. Output energy sources consisted of different products such as grain yield and by-products like straw. The ratio of grains and straw in wheat is 1:1.5. The calculation was done using data of yield per ha and multiplying it with their respective energy equivalents (Table 3). Farmyard manure was transported to the field and spread over the land manually. The land preparation practices involved were ploughing, levelling, bund making and seedbed preparation with tractors and different field implements. The farmyard manure and harvested grains were transported by the tractor. The sowing and fertilizer application were done by spreading manually. After 30 days of sowing, weeding was done by two methods viz. manual weeding and spraying weedicides (Chemical weed control). Harvesting was done manually and threshing was performed by a tractor-operated thresher with the help of labour.

The maximum operations were performed with direct energy i.e., human power as compared to indirect energy i.e., tractor and diesel. Different energy levels of different operations were calculated and the computed input-output energy of the wheat crop was used to study the relationship. To evaluate the different energy-related parameters such as net energy gain, efficiency, total energy, ratio and specific energy the following formulae were used (Mani *et al.,* 2006; Chamsing *et al.,* 2006; Modi *et al.,* 2018).

The energy data available from different direct energy sources of farm energy e.g., human and mechanical and different operations of wheat crop cultivation was collected. Likewise, the data on indirect energy sources were also collected for defining complete energy utilization in the production of wheat crop at different locations.

Total energy invested in complete process is calculated by adding both total direct energy and total indirect energy. Net energy is calculated by subtracting energy output to total input energy (MJ/ha) and ratio is calculated by dividing energy output by total energy input. Specific energy is calculated by dividing the energy input (MJ/ha) by yield (Kg/ha). The experiment was laid out in one sample t test to determine the significant differences between means of energy consumption in crop production in the selected altitudes. The following different energy related efficiency parameters were determined (Mani *et al.,* 2006; Chamsing *et al.,* 2006; Modi *et al.,* 2018).

Total Energy Output (MJ/ha) = (Yield x Energy equivalent) + (Wheat straw x Energy equivalent).

Table 1: Detail of Geographical location of the study area.

SN	Province	Zone	Altitude (m)
	Himachal Pradesh		
1.	Dhaulakuan	I	411
2.	Malan	II	1109
3.	Palampur	II	1291
4.	Bajaura	III	1074

Table 2: Labour Used in different operations of wheat production (MJ).

Operation (Human Power)	Labour Man-hours	Machine Operator Machine-hours	Total
Land preparation	8	8	16
Sowing	80	-	80
FYM transportation and spreading	160	-	160
Application of fertilizers (urea, SSP, MOP)	64	-	64
Weeding and intercultural operation	200	-	200
Application of weedicide	16	-	16
Harvesting	120	-	120
Threshing	40	5	45
Cleaning	50	-	50
Transportation	4	4	8

Table 3: Energy equivalents for various sources of input energy (Jat *et al.,* (2020); Modi *et al.,* (2018); Parveen *et al.,* (2020); Mani *et al.,* (2007)).

Direct and Indirect Energy Input	Units	Energy equivalent (MJ/unit)
Labour	Man-hour	1.96
Diesel	litres	56.31
Seeds/yield seeds	Kg	13.47
Straw	Kg	12.5
FYM	Kg	0.30
Urea	Kg	27.88
Nitrogen	Kg	60.0
MOP	Kg	11.1
SSP	Kg	6.7
Herbicide	Kg	254.45

Results and Discussion

Amongst all locations, Bajaura consumed more energy i.e., 20880.16 (MJ/ha) for wheat production. The total energy consumed in Palampur, Malan, Dhaulakuan was recorded as 20385.4, 20431.6, 20326.8 and 20880.2 MJ/ha respectively (Table 4). This may be due to low rainfall at Dhaulakuan and Bajaura, the number of irrigations was more as compared to Palampur and Malan. So, the input energy of irrigation, harvesting and threshing were at Dhaulakuan and Bajaura as compared to other locations. The basic and standard treatment processes for wheat sowing at the different locations were the same but area-based conditions were different with altitudes like irrigation, weeding and transportation. So, proper management of natural or rain water streams which were suggested for optimum energy use too enhances the crop output. Maximum output energy (Table 5) was obtained at location Bajaura (171081.7 MJ/ha) and lowest at Palampur (134215.1 MJ/ha) and at Malan (148787.4 MJ/ha) and Dhaulakuan (160174.3 MJ/ha) per hectare energy was obtained. The highest net output return (energy) at location Bajaura because the grain and straw produced is maximum (171081.7 MJ/ha) (Table 6 and Figure 1). This may be due to wheat grain yield which was recorded to be highest (5110 kg/ha) and at Palampur, the grain yield was (3830 kg/ha) recorded lowest.

Table 4: Energy input (MJ/ha) for wheat production in different locations of H.P.

OPERATIONS	Dhaulakuan	Malan	Palampur	Bajaura
Zone	**I**	**II**	**III**	**IV**
Land (ha)	1	1	1	1
Source of power	TRACTOR	TRACTOR	TRACTOR	TRACTOR
Land Preparation	921.4	921.4	921.4	921.4
Sowing	156.8	156.8	156.8	156.8
Energy of Operator	15.7	15.7	15.7	15.7
Seed	1347	1347	1347	1347
Irrigation	648	400	320	467
Weeding by Manually	109.8	125.4	125.4	156.8
Herbicide	591.1	591.1	591.1	591.1
Fertilizer	10661.4	10661.4	10661.4	10661.4
Application of Fertilizer	125.4	125.4	125.4	125.4
FYM	3000	3000	3000	3000
Transportation & application of FYM	466.4	632.2	707.1	962.1
Harvesting	203.8	250.9	219.5	266.6
Threshing	2313.2	2313.2	2313.2	2313.2
Transport	291.8	370.2	300.5	420.5
Total input energy	**20851.8**	**20910.7**	**20804.5**	**21405.2**

Table 5: Total Energy output (MJ/ha) relation for wheat in different locations of H.P.

OPERATIONS	Dhaulakuan	Malan	Palampur	Bajaura
Output energy of grain yield	63174.3	59537.4	51590.1	68831.7
Output energy of straw yield	97000	89250	82625	102250
Total output energy	160174.3	148787.4	134215.1	171081.7

Table 6: Net energy, Energy ratio, Specific energy relation for wheat in different locations of H.P.

OPERATIONS	Dhaulakuan	Malan	Palampur	Bajaura
Net Energy	139322.475	127876.64	113411.1	149676.7
Energy Ratio	7.68	7.12	6.45	8.0
Specific Enegy	0.33	0.35	0.40	0.31

Conclusion

From this research, it is concluded that higher the energy input more will be the output (grains and straw). The yield varies with increase in altitude and there is a direct relation among energy consumption and crop productivity. The data required for results was obtained from different energy sources on the basis of utilization. The maximum use of energy was at location Bajaura

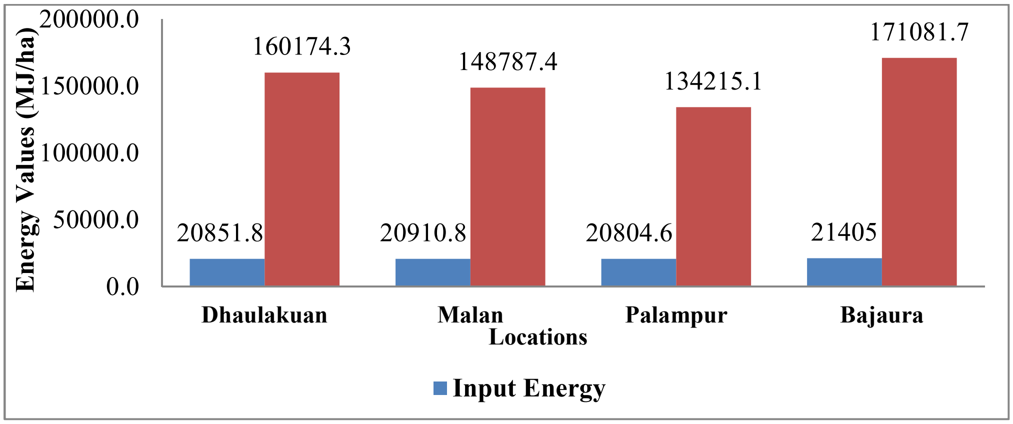

Figure 1: Graph between energy input and output.

because the long spell, good crop health to provide more number of irrigations required more labour for harvesting, threshing and more crop yield.

Conflict of interest

The authors declare that they have no conflict of interest.

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Carbon dioxide sequestered by trees in an urban institution: A case study

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ABSTRACT

The geographical location, climate, topography and most important human interference has contributed to the characteristic flora of the old campus of University of Jammu. A total of 24 tree species having 153 individuals belonging to 14 families have been recorded. Out of 24, 23 species belong to Angiosperms (22 dicots and 1 monocot) whereas, only 1 species belong to Gymnosperms. Overall, Moraceae was found to be the dominant family. The total growing stock, total biomass, total carbon content within university campus has been assessed to be 215663.99cm^{3,} 107.83kg, 50.68kg respectively. The total CO_2 sequestered by trees and net oxygen produced have been estimated to be 185.84kg and 495.65kg, respectively. Thus, the old campus of University of Jammu with lot of built-up area, roads, lawns, parking places, garden, etc. has sequestered considerably good amount of carbon and also produced considerable amount of oxygen as compared to its size, and its potential for sequestration can be enhanced with the help of management practices and plantation of more trees/shrubs within the permissible areas.

Introduction

The Urban Forest structure i.e., tree species composition, size and location, etc. provide the basis for understanding its functions that can affect urban inhabitants and also help to improve the management system to maximize the environmental and social benefits. As urban forests sequester and affect the emission of CO_2 from urban areas, which have 50% of global population across the globe, consume up-to 75% of total energy and 60% of water sources and contribute about 80% of GHG emissions despite being concentrated only on 2.5% of world geographical area (McGranahan *et al.,* 2005), thus, can play a critical role in combating increasing levels of atmospheric carbon dioxide. They also play an important role in affecting atmospheric concentration of CO_2, act as sink of atmospheric carbon, modulate earth's carbon balance and help in mitigation of climate change (Chavan and Rasal, 2010; Eneji *et al*., 2014; Marak and Khare, 2017). Tree vegetation constitutes an important natural resource having productive, protective, aesthetic and regulatory functions of tangible and intangible nature. Growth of tree vegetation in an urban area is a function of several simultaneous factors. Higher population density, more fossil fuel and other resources consumption, presence of more concretised and artificial surfaces in urban regions have led to accelerated climatic differences and their impacts on vegetation in urban environment than rural. Tree canopies provide a cooling effect on the microclimate of the region, reduces vehicular pollution and also capture large-size particulate matter (Beckett *et al.,* 2000) which have far reached implications towards air quality standards along with sequestration in mitigation strategies. Trees simultaneously sequester carbon as they grow and emit the carbon to the atmosphere after their death/decay, there by influencing air

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temperatures and building energy use and consequently alter carbon emission and absorption from urban sources. The net carbon sequestration can be achieved by urban plantings up to 18 kg CO_2 per year per tree which will correspond to 3 to 5 forest trees of similar size as well as health (Ferrini and Finni, 2011).

Therefore, effective management and manipulation of the urban tree cover in a planned and cost-effective way by understanding its structure and function can potentially yield a wide range of benefits to the urban region (McPherson *et al.,* 1994). Many studies related to tree biomass and carbon content have been conducted across the world by Nowak and Crane (2002), Nowak *et al.* (2013), Fares *et al.* (2017), Brack (2002), Kiran and Kinnary (2011), Ugle (2010), Velasco *et al.* (2016), Nowak *et al.* (2007) and Zhao (2015) etc. Similarly, few studies in Jammu and Kashmir on forest biomass and carbon have been carried out by Dar and Sundarapandian (2015), Wani *et al.* (2017), Handa *et al.* (2017), Dar and Sahu (2018), Gairola *et al.* (2020) while, few studies on biomass and carbon sequestration potential of trees of forest area, outside forest area, urban and of sacred grooves were investigated by Jasrotia and Raina (2017), Sharma *et al.* (2020), Mahajan *et al.* (2021), Devi (2017), Kour and Sharma (2017), Ahmed and Sharma (2018), Bhat *et al.* (2019) and Priya and Sharma (2018). So, keeping in view the importance of tree vegetation in urban habitat our main aim of the study was to evaluate the carbon content and sequestration potential of urban trees especially in an institution to understand and to comply with aim of sustainable living.

Material and Methods

Study area

The Old Campus of University of Jammu (Lat. 32°43'28.59" and Long. 74°50'58.61", Altitude: 336m above msl and Area: 410.5 acres) located near Canal Road, Nawabad, Jammu, J&K (UT) and is now utilized only for residential accommodation of teaching, non-teaching staff and students (Boy's hostel). It lies in the foot-hills of outer Shivaliks with climate typically of sub-tropical type having hot summers and cold winters with an average summer and winter temperature of 30.7 °C and 10.5 °C, respectively. June is the warmest and January is the coldest months of the year with average yearly precipitation of 42 inches (1,100 mm) where the bulk of the rainfall is contributed by monsoon in the months from June to September.

Data collection

Field surveys for total enumeration of trees with diameter of ≥ 10cm [at breast height (dbh) i.e., 1.37m above from the ground] were conducted within area of university campus. Circumference (in cm) at dbh was measured and recorded (Ravindranath and Ostwald, 2008).

Data analysis

Volume was calculated using volumetric equation based on diameter (FSI,2013) (Table 1). The volume (kg) was converted into above-ground biomass (kg) by multiplying it with wood density (g/cm^3) (FAO 1993) (Table1) and biomass expansion factor (BEF) which is calculated using Exp {3.213-0.506*Ln (Volume)}. The below ground biomass (kg) of the trees was calculated using root to shoot ratio of 0.26 (Mokany *et al*., 2006). Above-ground biomass (kg) and belowground biomass (kg) were added to get the Total Biomass(kg). Finally, the carbon storage (kg) was estimated by multiplying total biomass using the default value of carbon fraction of 0.47 (IPCC, 2006). The estimated carbon stock was converted into CO_2 sequestrated by multiplied it with 3.667. The oxygen production (kg) was calculated by multiplying CO_2 sequestered with 2.667.

Results and Discussion

Floristic analysis

A total of 24 species belonging to 14 families have been recorded from the area. Moraceae has been found to be the dominant family. Total number of individuals of all the tree species has been observed to be 153 within the campus, *Mangifera indica* being the most dominant species with 21 individuals followed by *Alstonia scholaris* (20 individuals) and *Morus alba* (14 individuals). List of the observed species has been presented in alphabetical order with their common name and family in **Table 1**.

Biomass C stocks, CO_2 sequestered and O_2 produced by trees.

Live biomass includes both the aboveground biomass and below ground biomass. This pool is likely to change frequently, even annually, much faster than other pools and is an important indicator of the impact on benefits related to carbon

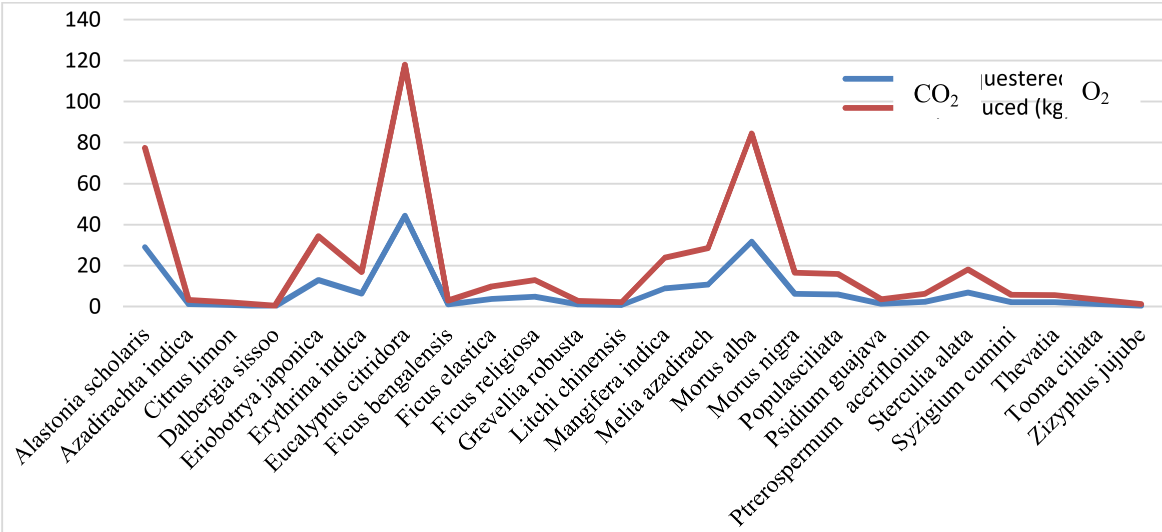

Figure 1: CO_2 Sequestered and O_2 produced by tree Species

mitigation and other matters (Ravindranath and Ostwald, 2008). Globally, live forest biomass in aboveground tissues and belowground contributes ~80% and ~20%, respectively while, in the Indian forests, aboveground and belowground biomass contributes 79% and 21% (Chhabra *et al.,* 2002). In the present investigation, total live tree biomass within the campus has been estimated to be 107.83kg contributed by aboveground (85.58kg i.e., 79%) and belowground (22.25kg i.e., 21%) and thus, is in line with the reports of above and below ground biomass of Indian forests.Total carbon content possessed by trees in the present study area has been recorded as 50.68kg which has been contributed by 40.22kg of aboveground and 10.45kg of belowground biomass carbon, respectively. From this, it has been estimated that 185.84kg of CO_2 has been sequestered by trees in the study area. Dubal *et al.* (2013) in their studies at Shivaji university campus with an area of 874 acres reported that 1314 individuals of trees (belonging to 38 species) have sequestered 158268kg of carbon. Though the area is little more than double, the number of individuals of trees and sequestered carbon is ~8.5 times more, thereby reflecting that almost same amount of carbon has been sequestered by individual trees.While, Chavan and Rasal (2012) reported 1650kg (1.65t) of carbon stock among 1658 individuals (belonging to 20 species) within university campus of Dr. B.A.M. University, Aurangabad. Though the number of individuals studied was ~10times more than the present investigation, the carbon stock was ~33 times higher. Similarly, Villiers *et al.* (2014) and Sarel *et al.* (2017) and Flora *et al.* (2018) reported 15000kg (15ton), 580900kg and 4565.928 kg carbon content in their university campuses which is ~80, 3000, 24 times higher than present study, respectively. Whereas, Gulcin *et al.* (2021) reported 5.2kg C/m^2 above ground biomass which was ~60 times higher in an area i.e., 2.5 times (988.425 acres) more than study area. Over all, the comparative studies were found to have more carbon content because of larger area as well as a greater number of individuals within their study area. Since, one ton of carbon storage in the tree species represents removal of 44/12 or 3.67t of carbon from the atmosphere and the releasing of 2.67t of oxygen back. Net oxygen produced by trees within the study area has been workout to be 495.65kg which is lower than 2959.68 t ha^{-1} y^{-1} of oxygen produced by the 28 tree species in Konnagar Municipality estimated by Abhijit *et al.* (2017). While, Sharma *et al.* (2019) reported 5777818.399 kg in Jiwaji University campus. As the O_2 produced is affected by the density of trees, the less amount of O_2 produced in the present area may be due to the smaller area as maximum area is covered as built-up area in the campus. The total biomass, carbon content, carbon sequestered as well as oxygen produced was recorded maximum for *Eucalyptuscitridora* having 6 individuals followed by *Morus alba* (14), *Alastonia scholaris* (20), *Eriobotrya*

Table1: List of the observed tree species within the campus of University of Jammu.

SCIENTIFIC NAMES	LOCAL NAME	FAMILY	VOLUMETRIC EQUATION	WOOD DENSITY (g/cm^3)
Alastonia scholaris(L.) R. Br.	Satpatra	Apocynaceae	$V=0.193297-2.267002D+10.679492\ D^2$	0.629
Azadirachta indica A.Juss.	Neem	Meliacea	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.69
Citrus limon (L.) Osbeck	Lemon	Rutaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.6
Dalbergia sissoo Roxb. ex DC.	Indian rosewood	Fabaceae	$V=0.25412D^2H-1.83911D^2+0.07907H-1.40296$	0.34
Eribotrya japonica (thunb.) Lindl.	Laquat	Rosaceae	$V=0.00471+1.79326\ D^2$	0.7758
Erythrina variegate L.	Parijat	Fabaceae	$V=0.00471+1.79326\ D^2$	0.6
Eucalyptus citriodora(Hook.) K.D. Hill & L.A.S. Johnson	Safeda	Myrtaceae	$V=0.02894-0.89284*D+8.72416*D^2$	0.64
Ficus benghalensis Linn.	Bargad	Moraceae	$V=0.00471+1.79326\ D^2$	0.49
Ficus elastica Roxb. ex Hornem.	Rubber tree	Moraceae	$V=0.00471+1.79326\ D^2$	0.6071
Ficus religiosa Linn.	Peepal	Moraceae	$V=0.00471+1.79326\ D^2$	0.443
Grevillea robusta A.Cunn.ex R.Br.	Silver oak	Protoaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.6
Litchi chinensis Sonn.	Litchi	Sapindoideae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.88
Mangifera indica L.	Mango	Anarcardiaceae	$V=0.193297-2.267002D+10.679492\ D^2$	0.37
Melia azedarach L.	Dreank	Meliacea	$V=-0.0351+5.32981D^2$	0.4629
Morus alba L.	Shahtoot	Moraceae	$V=0.167174-1.735312D+12.039017D^2$	0.6224
Morus nigra L.	Toot	Moraceae	$V=0.00471+1.79326\ D^2$	0.6156
Populus ciliate Wall. ex Royle	Poplar	Salicaceae	$V=0.193297-2.267002D+10.679492\ D^2$	0.3887
Psidium guajava L.	Guava	Myrtaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.6
Pterospermuma cerifolium (L.) Willd.	Kanankchampa	Sterculiaceae	$V=0.00471+1.79326\ D^2$	0.6
Pterygotaalata (Roxb.) R. Br.		Malvaceae	$V=0.00471+1.79326\ D^2$	0.6
Syzigium cumunii L.	Jamun	Myrtaceae	$V/D^2=0.2421/\ D^2 2.68191/D+14.77955$	0.468
Thevetia peruviana (Pers.) K. Schum.	Luckynut	Apocynaceae	$V=0.00471+1.79326\ D^2$	0.6
Toona ciliate M. Roem.	Toon	Meliacea	$V=0.193297-2.267002D+10.679492D^2$	0.427
Ziziphus jujuba Mill.	Baer	Rhamnaceae	$V/D^2=0.007602/D^2 0.033037/D+1.868567+4.483454D$	0.597

Table 2: Biomass and Carbon stocks in observed tree species within the campus of University of Jammu.

Species	Total Individuals	Total Volume (cm^3)	Basal area (cm^2)	Total ABG (kg)	Total BGB (kg)	Total Biomass (kg)	Total Carbon (kg)	Total CO2 Sequestered (kg)	Total O2 produced (kg)
Alastonia scholaris	20	134392.00	46422.00	13.38	3.48	16.85	7.92	29.05	77.47
Azadirachta indica	3	391.12	3391.20	0.57	0.15	0.72	0.34	1.24	3.30
Citrus limon	3	194.07	1657.90	0.35	0.09	0.44	0.21	0.76	2.03
Dalbergia sissoo	4	6.33	7134.10	0.08	0.02	0.10	0.05	0.17	0.45
Eriobotrya japonica	8	22821.40	9507.90	5.93	1.54	7.47	3.51	12.88	34.36
Erythrina indica	4	13438.00	6003.70	2.90	0.75	3.65	1.71	6.29	16.77
Eucalyptus citridora	6	327794.00	18275.00	20.38	5.30	25.68	12.07	44.25	118.02
Ficus bengalensis	3	624.58	1256.00	0.50	0.13	0.63	0.30	1.09	2.91
Ficus elastica	4	3503.56	3454.00	1.70	0.44	2.14	1.01	3.69	9.84
Ficus religiosa	4	11411.70	6267.40	2.23	0.58	2.81	1.32	4.85	12.94
Grevellia robusta	4	255.91	2185.40	0.46	0.12	0.58	0.27	1.01	2.69
Litchi chinensis	2	146.52	1256.00	0.36	0.09	0.46	0.22	0.79	2.11
Mangifera indica	21	5640.68	49273.00	4.11	1.07	5.18	2.43	8.93	23.81
Melia azadirach	9	23790.20	7661.60	4.92	1.28	6.20	2.91	10.69	28.50
Morus alba	14	78075.00	11317.00	14.57	3.79	18.36	8.63	31.65	84.40
Morus nigra	8	4982.08	5727.40	2.86	0.74	3.61	1.70	6.22	16.58
Populas ciliata	3	30108.40	3629.80	2.74	0.71	3.45	1.62	5.95	15.87
Psidium guajava	5	347.73	2976.70	0.60	0.16	0.76	0.36	1.31	3.49
Ptrerospermuma cerifloium	3	1867.00	2172.90	1.06	0.28	1.33	0.63	2.30	6.13
Sterculia alata	7	6909.87	6414.40	3.12	0.81	3.93	1.85	6.77	18.05
Syzigiumcumini	8	594.07	10035.00	0.99	0.26	1.24	0.58	2.14	5.72
Thevatia peruviana	3	1519.44	1984.50	0.97	0.25	1.22	0.57	2.10	5.61
Toona ciliata	4	728.53	6342.80	0.58	0.15	0.73	0.34	1.26	3.36
Zizyphus jujuba	3	225.35	1318.80	0.21	0.06	0.27	0.13	0.47	1.24
Total	**153**	**669767.40**	**215663.99**	**85.58**	**22.25**	**107.83**	**50.68**	**185.84**	**495.64**

japonica (8) and the minimum values was recorded for *Dalbergia sisoo* (4) followed by *Zizyphus jujube* (3), *Citrus limon* (3) and *Litchi chinensis* (2).

Conclusion

Thus, the old campus of University of Jammu with lot of built-up area, roads, lawns, parking places, garden, etc. has sequestered considerably good amount of carbon and also produced considerable amount of oxygen ascompared to its size, and its potential for sequestration can be enhanced with the help of management practices and plantation of more trees/shrubs within the permissible areas.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Assessment of the effects of fungicide (Thiram) on somatic cells of broad bean (*Vicia faba* L.)

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ABSTRACT

Present study was carried out to know the impact of fungicide (Thiram) on somatic cells of broad bean (*Vicia faba L.)*. Thiram is one of the most effective fungicide. Significant inhibition of mitotic index and increase in the frequencies of chromosome aberrations were observed. Results of the study indicate that both the plant bioassay found to be sensitive indicators for the genotoxicity assessment as the outcome of majority test system. Using plant bioassays for testing and monitoring environmental chemicals or pollution has many advantages. The mitotic index decreases due to exposure of plant extract with thiram in higher concentration as 150, 300, 550, 800 ppm for 8h and show reducing effect that is 21.00, 20.70, 18.61 and 16.77 in comparison to control that is 21.19. The higher concentrations of fungicide showed the genotoxic effects and damage the chromosomal integrity.

Introduction

Fungicide are the chemical substances, which is applied worldwide in public sectors and agriculture areas. Due to its high biological activity and in few cases of their persistence in the environment, the use of fungicide can lead undesired effects on animal health especially human and to the environment. On the other hand, fungicide play a significant role in rural health program comprises of the control of biting, noxious, irritating, annoying or contaminating insects and other pests, which infest human and animals (Crosby, 1981). Fungicide residues enters in food chain due to their indiscriminate use in public and agriculture areas. The residues of fungicides can be detected in different feed crops, food stuffs, flesh and meat, poultry, fish and in milk products. The modern agricultural practices represent a very large input of toxic chemicals in our environment (Crosby, 1981; Ajay and Sarbhoy, 1987). Chemical fungicides have contributed greatly to the increase of yields in agriculture by controlling diseases and also towards checking the diseases (Amer and Farah, 1974). The need to increase the production of food for the rapidly growing world population is a big challenge. Fungicides are used to control the population of pests. The biological activity of fungicide is attained by different mode of action. A large number of synthetic fungicides are under use. They belong to different chemical groups and are classified on the basis of their chemical structure and properties. Chemical structure of fungicide is a key to the action of these pesticides. Their usage has increased manifolds in disease control management without considering their harmful side effects on plants, animals and human beings (Ajay and Sarbhoy 1987). Although, the use of these chemicals has become essential, but their ingredients have induced acute toxic effects (Amer and Farah, 1974) (Badr and Elkington, 1982). The toxic effect of endosulfan is not necessarily a result of direct application, some pesticides accumulate into the food upto a toxic level and affect the public health (Dryanovska, 1987; Yadav, 1986; Cantor *etal*., 1992; Mehmet & Huseyin, 2017). *Vicia faba* L. (2n = 12), of the family Fabaceae, have homozygous genotype because of self-pollination (Gulfishan *et al.,* 2010). Thus, *Vicia faba* based bioassays have established role to study chromosome anomalies due to their large and visible chromosome (Asthana and Kumar, 2014;

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Zehring *et al*., 2022). Present study was carried out to know the impact of fungicide (Thiram) on somatic cells of broad bean (*Vicia faba* L.).

Material and Methods

Thiram is a fungicide and belongs to the ethylene bisdithiocarbamate (EBDC) chemical class. The fungicide of EBDCs class are used in agriculture area to prevent crop damage and to protect harvested crops from fungal infections during storage or transport. Thiram is a widely used, broad-spectrum fungicide and a metabolite. The roots of plants were cut off when the length of roots become 1.5-3.0 cm in length and then fixed in a chemical acetic acid-ethyl alcohol (1:3) V/V. After that the process of hydrolysis is done in 1N HCL. At last, the sample/replicate is stained by using Feulgen squash technique. For each treatments and control, three replicates were used and examined. The experiments were done in laboratory at normal room temperature (22±2ºC).

The mitotic index and the mitotic inhibition were calculated according to the standard formula. Mitotic Index (MI) and chromosomal aberrations (CA) in mitotic cells frequency were scored from the slides observation. Many cells were observed to score the mitotic index and chromosomal aberrations in each concentration. All observations were taken from temporarily prepared slides. In each sample, many cells were observed to record data of mitotic index and different chromosomal aberrations (Yuzbasioglu *etal*., 2003).The formula for calculating mitotic index and abnormality percentage are :-

Mitotic Index (MI %) = Total No. of dividing cell / Total No. of cells observed X 100

Results and Discussion

Present study was carried out to know the impact of fungicide (Thiram) on somatic cells of broad bean (*Vicia faba* L.). Thiram is one of the most effective fungicide. Significant inhibition of mitotic index and increase in the frequencies of chromosome aberrations were observed. Results of the study indicate that both the plant bioassay found to be sensitive indicators for the genotoxicity assessment as the outcome of majority test system. Using plant bioassays for testing and monitoring environmental chemicals or pollution has many advantages. The mitotic index decreases due to exposure of plant extract with thiram in higher concentration as 150, 300, 550, 800 ppm for 8h and show reducing effect that is 21.00, 20.70, 18.61 and 16.77 in comparison to control that is 21.19. The higher concentrations of fungicide showed the genotoxic effects and damage the chromosomal integrity (Table 1).

Table 1: Effects of fungicide on mitotic index in root meristem of Faba bean (*Vicia Faba)* after 8h exposure

Treatment	Concentration (PPM)	Mitotic Index
Control	0	21.19
Thiram	150	21.00
	300	20.70
	550	18.61
	800	16.77

Thiram affects the duration of each mitotic stage of each replicate as compared to control. It also play an important role in reducing mitotic index, indicating mitotic inhibition and increase in the frequency of abnormal mitosis, significantly. Star metaphase was one of the chromosomal abnormalities observed. Such type of abnormality was also observed after treatment of *Vicia faba* L. root tips with Thiram and considered as being a fore step of disturbance of the spindle completely. The effect of Thiram on root mitosis stimulates that of colchicine in the type of abnormal metaphase and anaphase and the induction of polyploidy cells as well as accumulation of metaphases. The threshold dose (dose of pesticides on which they retain their fungicidal property but have little or no cytotoxic/ genotoxic effect. The result show that the metaphase stage in treated root tip cells (*Vicia faba)* was also the most influenced stage by extract treatment and the total percentage of its abnormalities was higher than other mitotic stages. In this respect, abnormalities in the other mitotic stages was observed in the following sequence as Prophase> anaphase>telophase for all replicates / treatments. The study revealed that Thiram had a detrimental effect on the test material, there was inverse relation between the mitotic index and the dosage and time of treatment, and the direct relation between the mitotic index and the dosage and the time of treatment of percentage of abnormalities, treatments not only brought down the frequency of dividing cells, but also produced a good number of anomalies in the mitotic cells. There was a notable decrease in the mitotic index and gradually increase in the chromosomal abnormalities as the concentration of the experimental solution and the time of treatment increased. The cytotoxic effects of fungicide were assessed employing chromosomal aberration bioassay in root tip cells. Different cytological aberrations viz., non-orientation and mis-orientation of chromosomes and stickiness, bridges, preconscious movement, laggards and fragments, diagonal spindle formation were observed in increased frequency with increasing concentrations of fungicides. These abnormalities have also been reported for several extracts and chemicals already observed by many workers (Yadav, 1986; Nwakanma *et al.,* 2009; Mohamed and El-Ashry, 2012; Yuzbasioglu *et al.,* 2003).

Conclusion

Finally, this work provides the information about the effect of fungicide Thiram on plant cells. Results of the study indicate the genotoxicity of Thiram as compared to biopesticides. According to the earlier study, the biopesticide also affect the cells but not significantly. So, conclusively we can say that the biopesticides are safer alternative as compared to chemical pesticides. Increasing use of agricultural chemicals for improving the field crops is now in routine use. Now a day, biopesticides are achieving a modicum of growth as alternative to conventional pesticides. However, their full potential has yet to be reached.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Species richness and abundance of Coccinellids (Coleoptera: Coccinellidae) in agricultural ecosystem of Doiwala region, Dehradun (U.K), India

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ABSTRACT

Present study was carried out to know the community structure of coccinellid beetles (Coleoptera: Coccinellidae) in agricultural ecosystem of Doiwala region, Dehradun (U.K.), India during January 2021 to December 2021. During the study period, a total of 8 species of ladybird beetles, which belong to 7 genera under 1 family, 3 subfamilies and 3 tribes were recorded, viz., *Brumoides suturalis* (Fabricius), *Coccinella septumpunctata* (Linn.), *Coccinella transversalis* (Fab.), *Cheilomenes sexmaculata* (Fab.), *Hippodamia variegata* (Goeze), *Harmonia dimidiata* (Fabr.), *Oenopia sauzeti* (Mulsant) and *Henosepilachna vigintioctopunctata* (Li). Out of these eight species, seven were predatory and one was phytophagous. The only phytophagous species was *H. vigintioctopunctata* (Li). Maximum species of coccinellids were collected from site-3 (7 species), then followed by site-4 (6 species), site-1 and site-2 (5 species each).

Introduction

Coccinellids are predatory and phytophagous in nature and belong to family Coccinellidae of order Coleoptera. Coccinellidae is distributed worldwide and classified into 06 subfamilies: Coccinellinae, Scymninae, Coccidulinae, Chilocorinae, Sticholotidinae and Epilachninae (Vandenberg, 2002). The coccinellids are small in size with an oval, oblong or hemispheral body shape (Majerus, 1994). Most species of coccinellid beetles are an important biocontrol agent of pests such as thrips, aphids, mealybugs, scale insects, coccids, adelgids, aleyrodids and mites (Sharma *et al*., 2021). The family Coccinellidae is composed of 5,200 described species throughout the world. Fleming (2000) described 4,000 species of predatory coccinellids including more than 300 species from India and Pakistan. Saeed *et al.* (2016) reported 13 species of ladybeetles belong to 11 genera and 3 subfamilies from district Buner, Khyber Pakhtunwa-Pakistan. Ahmad *et al.,* (2017) reported 9 species from district Sargodha, Pakistan. Dorji *et al.* (2019) reported 91 species of coccinellids and out of them 17 were recorded for the first time from Bhutan. Poorani (2002) have described 400 species of ladybird beetles from Indian subregion. Joshi and Sharma (2008) have recorded 31 species of coccinellid beetles from district Haridwar and out of these, 19 species of coccinellids were reported for the first time from the district Haridwar, (U.K.), India. Joshi *et al.* (2010) have reported 21 species of coccinellids from Pauri-Garhwal district (Uttarakhand), India. Sharma *et al.,*(2014) have observed the feeding potential of *Coccinellla septumpunctata* Linn. on cowpea aphid, *Aphis craccivora* Koch. Harit (2015) reported 13 species (9 predatory and 4 polyphagous) of coccinellids from Champhai district of Mizoram state (North East India). Sharma (2016) have described the life-

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cycle of a predatory ladybird beetle *Coccinella transversalis* (Fabr.). Sharma *et al.*, (2017) reported 65 species from Himachal Pradesh. Sharma and Joshi (2019) have described the detailed morphological and taxonomical descriptions of two coccinellid beetles *Micraspis discolor* (Fabr.) and *Micraspis vincta* (Gorham) recorded from Haridwar district, (Uttarakhand), India. Das *et al.* (2020) have reported 44 species of coccinellids that belong to 22 genera and 6 tribes from Arunachal Pradesh, East Himalaya, India. Sharma *et al.* (2021) reported 9 species of coccinellids from district Sambhal (U.P.). The coccinellids fauna of the Indian subcontinent is diverse and rich, but scanty studied by scientists as compared to those from other continents of the world. The objective of present study was to know the species richness and abundance of ladybird beetles in agriculture ecosystem of Doiwala Block, Dehradun (U.K.), India.

Material and Methods

Study Area

Present study was conducted in and around Doiwala region of Dehradun District (U.K.). The Climate of the district is temperate and varies from tropical to severe cold throughout the year. The study area shows three distinct seasons winter, summer and monsoon. Paddy is the important kharif crops. Wheat is the main crop of rabi and is grown in all parts of the study area. Sugarcane, Rice and mustard are other important crops. Present study was conducted at four different study sites having agricultural field (Table-1).

Sampling of Coccinellid beetles

Sampling of insects was conducted at an interval of 30 days during January 2021 to December 2021. Coccinellids were collected by visual hand-picking method. The study area is divided in 4 sites. Each site was divided and studied into a quadrate of 10x10m. Random sampling was done at a fix interval of 30 days.

Taxonomic Study of Coccinellid beetles

The insects were collected into plastic medium sized vials and then transferred into an insect collecting bottles having ethyl acetate-soaked cotton. After insect collections, these bottles were brought to the laboratory and the coccinellid beetles were taken out from the bottles for stretching and pinning. The entomological pins No.2 were used to fix the individuals. The coccinellids beetles were dried in oven at 60 °C for three days in order to preserve them. The coccinellids were labelled with paper having all necessary information regarding taxonomic position and then set into insect boxes. The adult specimens of coccinellid beetles were properly studied under binocular microscope. The insects were separated and identified into different genus / species with the help of taxonomic keys of coccinellids.

Results and Discussion

Present study was conducted at four sites, representing agricultural ecosystem of Doiwala region, Dehradun (U.K.), India during January 2021 to December 2021. During the study period, a total of 8 species of ladybird beetles were collected from all four sites.

(A) Vegetational Composition

During the study period, specimens of coccinellids were collected from four sites representing agricultural ecosystem of wheat, mustard, sugarcane, paddy and some other herbs and weeds plants (Table-1). The descriptions of each site are as follows:

Site-1: The site-1 having the agriculture field of Sugarcane *(Saccharum officinarum)* and Loki (*Lagenaria sp.*).

Site-2: The site-2 having the agriculture field of Sugarcane *(Saccharum officinarum)*, Loki (*Lagenaria sp.*), Pumpkin (*Cucurbita sp.*), Pigeon pea (*Cajanus cajan*) and Pea (*Pisum sativum*).

Site 3: The site-3 having the agriculture field of wheat (*Triticum vulgare*), mustard (*Brassica campestris* L.), Rice (*Oryza sativa*), Loki (*Lagenaria sp.*) and Pumpkin (*Cucurbita sp.*).

Site 4: The site-4 having the agriculture ecosystem having Wheat (*Triticum vulgare*), Rice (*Oryza sativa*), Mustard (*Brassica campestris* L.), and Loki (*Lagenaria sp.*).

(B) Taxonomic Composition of Ladybird beetles

During the study period, a total of 8 species of ladybird beetles belong to 7 genera under 1 family, 3 subfamilies and 3 tribes were recorded, viz., *Brumoides suturalis* (Fabricius), *Coccinella septumpunctata* (Linn.), *Coccinella transversalis* (Fab.), *Cheilomenes sexmaculata* (Fab.), *Hippodamia variegata* (Goeze), *Harmonia dimidiata* (Fabr.), *Oenopia sauzeti* (Mulsant) and *Henosepilachna vigintioctopunctata* (Li). Out of

Table 1: Crops combination of four different sites of Doiwala Block during Jan. to Dec. 2021

SN	Sites	Locations	Crop Combinations of Sites
1.	**Site-1**	Balawala	Sugarcane and Loki
2.	**Site-2**	Doiwala	Sugarcane, Loki, pumpkin Pigeon Pea and Pea
3.	**Site-3**	Harrawala	Wheat, Mustard, Rice, Loki and Pumpkin
4.	**Site-4**	Nakraunda	Wheat, Rice, Mustard and Loki

Table 2: Taxonomic composition of coccinellids in four sites during Jan. to Dec. 2021

SN	Coccinellidae species	Sites			
(A) Subfamily: CHILOCORINAE (I) Tribe Chilocorini		**S-1**	**S-2**	**S-3**	**S-4**
1.	*Brumoides suturalis* (Fabricius)	+	-	+	-
(B) Subfamily: COCCINELLINAE (II) Tribe Coccinellini					
2.	*Coccinella septumpunctata* (Linn.)	+	+	+	+
3.	*Coccinella transversalis* (Fabricius)	+	+	+	+
4.	*Cheilomenes sexmaculata* (Fabricius)	+	+	+	+
5.	*Hippodamia variegata* (Goeze)	-	+	+	+
6.	*Harmonia dimidiata* (Fabricius)	-	-	-	+
7.	*Oenopia sauzeti* (Mulsant)	+	-	+	-
(C). Subfamily: EPILACHNINAE (III) Tribe Epilachnini					
8.	*Henosepilachna vigintioctopunctata* (Li)	-	+	+	+
	Total	**05**	**05**	**07**	**06**

+ Species Present, - Species Absent

Table 3: Abundance of coccinellid beetles in four sites during Jan. 2021 to Dec. 2021

SN	Coccinellidae species	Sites				
(A) Subfamily: CHILOCORINAE (I) Tribe Chilocorini		**S-1**	**S-2**	**S-3**	**S-4**	**Total Ni**
1.	*Brumoides suturalis* (Fabricius)	24	-	23	-	**47**
(B) Subfamily: COCCINELLINAE (II) Tribe Coccinellini						
2.	*Coccinella septumpunctata* (Linn.)	51	39	68	53	**211**
3.	*Coccinella transversalis* (Fabricius)	37	44	52	39	**172**
4.	*Cheilomenes sexmaculata* (Fabricius)	29	23	40	57	**149**
5.	*Hippodamia variegata* (Goeze)	-	19	27	23	**69**
6.	*Harmonia dimidiata* (Fabricius)	-	-	-	12	**12**
7.	*Oenopia sauzeti* (Mulsant)	17	-	14	-	**31**
(C). Subfamily: EPILACHNINAE (III) Tribe Epilachnini						
8.	*Henosepilachna vigintioctopunctata* (Li)	-	17	23	21	**61**
	Total	**158**	**142**	**247**	**205**	**752**

Table 4: Species richness, population density and %age of coccinellids during Jan. to Dec. 2021

Parameters	Site-1	Site-2	Site-3	Site-4
Species Richness	05	05	07	06
Density/hectare	53	47	82	68
Percentage	21	19	33	27

these eight species, seven were predatory and one was phytophagous. The only phytophagous species was *H. vigintioctopunctata* (Li). The only phytophagous species was *H. vigintioctopunctata* (Li) (Table-2). From this study, it was observed that *Coccinella septumpunctata*, *C. transversalis* and *Cheilomenes sexmaculata* were the dominant species as they were recorded in all four sites. Two species viz., *Henosepilachna vigintioctopunctata* (Li) and *Hippodamia variegata* (Goeze) were moderately common and were present in only three sites. Two species viz. *Brumoides suturalis* (Fabricius) and *Oenopia sauzeti* (Mulsant), were less abundant and were present in only three sites. One Species *Harmonia dimidiata* were less abundant and were present only in one site. Highest number of coccinellids species were collected from site-3 (7 species), then followed by site-4 (6 species), site-1 and site-2 (5 species each).

(C) Abundance of Ladybird beetles

A total of 752 individuals of ladybird beetles were collected at four sites having agricultural ecosystem. Maximum numbers of ladybird beetles (247) were collected from site-3 followed by site-4 (205), site-1 (158) and site-2 (142). From above study, it was observed that *Coccinella septumpunctata* (Linn.) was the most abundant species (211) followed by *C. transversalis* (Fab.) (172), and *Cheilomenes sexmaculata* (Fab.) (149) in terms of no. of individuals and were recorded from all four sites. *Hippodamia variegata* (Goeze) (69) and *Henosepilachna vigintioctopunctata* (Li) (61) were moderately abundant species in terms of no. of individuals and were present only in three sites. *Brumoides suturalis* (Fabricius) (47) and *Oenopia sauzeti* (Mul.) (31) were less abundant species in terms of no. of individuals and were present only in two sites. *Harmonia dimidiata* (Fab.) (12) were less abundant species in terms of no. of individuals and were present only in one site. From above study, it was also observed that three species were common and recorded from all four sites. Two species were moderately common and were present only in three sites. Two species were less common and were present only in two sites. One species were less abundant and were present only in one site (Table-3).

(D) Population Density

Highest number of coccinellids species were collected from site-3 (7 species), followed by site-4 (6 species), site-1 and site-2 (5 species each). Density of Ladybird beetles species was 53/ha in site-I, 47/ha in site-II, 82/ha in site-III and 68 in site-IV (Table-4). In site-I, *C. septumpunctata* had the highest density (17/ha), followed by *C. transversalis* (12.33/ha) and *C. sexmaculata* (9.66 /ha). In site-II, *C. transversalis* had the highest density (14.66/ha) followed by *C. septumpunctata* (13/ha) and *C. sexmaculata* (7.66 /ha). In site-III, *C. septumpunctata* had the highest density (22.66/ha) followed by *C. transversalis* (17.33/ha) and *C. sexmaculata* (13.33/ha). In site-IV, *C. sexmaculata* had the maximum density (19/ha) followed by *C. septumpunctata* (17.66/ha) and *C. transversalis* (13/ha). Maximum percentage sharing (33 %) of coccinellids fauna was shared by site-3, then followed by site-4 (27 %), site-1 (21 %) and site-2 (19%) (Table-4).Pajni and Singh (1982) reported 30 species of ladybird beetles from different study sites of Chandigarh. Pajni and Verma (1985) discussed male genitalia of 25 coccinellids from Chandigarh region. Singh and Singh (1990) have recorded four new species of coccinellids viz., *Epilachna shilliensis*, *E. convextata*, *E. septemocellata* and *E. crecentomaculata* from Shilli, Himachal Pradesh. Omkar and Bind (1996) have recorded 05 species viz., *B. suturalis* (Fabr.), *I. cincta* (Fabr.), *M. discolor* (Fabr.), *M. vincta* (Gorham) and *P. bisoctonata* (Muls.) from Lucknow (U.P.), India. Joshi and Sharma (2008) have reported 31 species of coccinellids from Haridwar district. Joshi *et al.*, (2010) reported 21 species of Ladybird beetles from different study sites of district Pauri-Garhwal (U.K.), India. Sharma and Joshi (2010) reported 25 species of ladybird beetles from different study sites of district Dehradun.

Conclusion

The occurrence of 08 species of ladybird beetles in four different study sites recorded in only one-year study indicate that Doiwala region have good community structure of coccinellids. The chances of disturbances in environment of agriculture ecosystem are high, as due to heavy infestations of pests, the economic cash crops are a target of a lot of toxic chemicals and insecticides that also affect the non-target insect fauna of that ecosystem. Any change in agricultural environment may lead the disappearance or repulsion or migration disappearance of coccinellids. As a result, the community size of coccinellid beetles may be decreased. Further observation is required in those regions that were not studied to fully explore the coccinellids fauna. Thus, the present study points out that the distribution, species richness and abundance of insect species may depend on plant community structure, availability of prey species and climate of the study area. As coccinellids play a principal role in suppression of crop pests, hence, this study may be useful in understanding the prey-predator interactions.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Present status and future directions for management of root lesion nematode (*Pratylenchus thornei*) in chickpea

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ABSTRACT

Chickpea is a popular legume crop in Asia and Africa's semi-arid regions. Crop production gains, on the other hand, have been modest, owing to biotic and abiotic stressors. Among the different biotic stresses, nematodes portray serious threat to chickpea production and colossal losses have been reported due to stress-free infection by other pathogens on infection with root lesion nematode (RLN). The worldwide distribution of two major species of RLN namely *P. thornei* and *P. neglectus* made them a focus research area especially on management aspect. In dryland farming areas of southeastern Australia, the *P. thornei* alone can cause yield losses of up to 40% in cereals and legumes. Despite the fact that chickpea breeders have been working persistently to generate superior chickpea varieties with increased resilience or tolerance to biotic and abiotic challenges, contemporary biotechnology technologies can help to speed up this process. To incorporate these tools and/or accelerate breeding programmes, identification of RLN resistant source with its genetic factor is first step in developing improved cultivars. However, study of resistance screening methods for chickpea against RLN is limited and standardization of different factors for development of a stable screening methodology distinguishing various levels of resistance is the need of the hour in RLN research.

Introduction

One of the most commercially important food legume crops is chickpea (*Cicer arietinum* L.). It is grown on an estimated 14.56 million hectares in more than 55 countries, producing 14.78 million tonnes (FAOSTAT, 2017). India, Australia, Myanmar, Ethiopia, Turkey, Pakistan, Russia, Iran, Mexico, the United States, and Canada are the top chickpea producers (FAOSTAT, 2019). It is planted on 10.22 mha in India, with a production of 9.53 mt and a productivity of 967 $kgha^{-1}$. Madhya Pradesh, Chhattisgarh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh, and Karnataka collectively produce 95.71 per cent of the country's chickpea production and 90 per cent of the country's area (Anon, 2013-14).

Chickpea is a nutrient-rich cool-season pulse crop that plays a critical role in ensuring global food security as a source of dietary protein and key

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amino acids. Fixing atmospheric nitrogen, contributing to soil fertility, acting as a disease break, and suppressing weeds are all essential roles it performs in farming systems. The global average yield of chickpea is less than 1 t/ha, significantly less than the 6 t/ha potential output under favourable and irrigated circumstances (Varshney *et al.,* 2017). This huge gap between actual and predicted chickpea yields is attributable to biotic challenges including insects, bacteria, fungi, nematodes, and viruses, as well as abiotic factors like drought, nutritional shortages, salinity, and cold (Roorkiwal *et al.,* 2016; Kumar *et al.,* 2021).

Since 1961, chickpea productivity has consistently increased, but its vulnerability to biotic and abiotic stressors has also increased, presumably due to the restricted number of germplasm accessions/donor parents used and reused (Muehlbauer and Sarker, 2017). Chickpea is attacked by air borne, seed borne, and soil borne pathogens (Chattopadhyay *et al.,* 2001). More than 75 pathogens have been reported to infect chickpea (Nene *et al.,* 1984). Globally, the loss of chickpea output due to plant parasite nematodes is estimated to be 14 per cent among the various biotic stressors (Sasser and Freckman, 1987). Accurate nematode species determination necessitates a thorough understanding of nematode taxonomy and/or the use of molecular diagnostic methods. Root-knot nematodes (*Meloidogyne artiella*, *M. incognita*, and *M. javanica*), chickpea cyst nematode (*Heterodera ciceri*), and root-lesion nematode (*Pratylenchus thornei*) are the most common worms that infect chickpea.

The root lesion nematodes, *Pratylenchus* spp. [*Pratylenchus thornei* Sher & Allen, 1953 (Tylenchida, Pratylenchidae)], is among one of the most important constraints to legume production and have a wide distribution in many regions in Turkey (82% of chickpea fields) and affect many agricultural crops around the world (Tanha *et al.,* 2009; Behmand *et al.,* 2019). *Pratylenchus thornei, P. neglectus*, *Pratylenchus penetrans* Cobb, 1917 and *Pratylenchus crenatus* Loof, 1960 (Tylenchida: Pratylenchidae), are the most important root lesion nematodes in the world (Vanstone *et al.,* 1998). Among the root lesion nematodes, *P. thornei* and *P. neglectus* are globally distributed and they enter the root tissue of host plant for feeding and reproduction (Nicol *et al.,* 2004). Also, some studies indicated that in terms of damage caused by these nematodes is of second importance as a nematode problem in the world after root-knot nematodes (Barker & Noe, 1987; Jatala & Bridge, 1990). *P. thornei* is one of the most dominating species of plant parasitic nematodes that can cause yield losses of up to 40% in cereals and legumes in dryland cropping areas of southeastern Australia (Thompson *et al.,* 1995; Vanstone *et al.,* 1998), chickpea in India with particular refence to Madhya Pradesh (Tiwari *et al.,* 1992). Chickpea, infested with RLNs showed symptoms of stunted growth and leaf chlorosis and causes yield losses greater than 50% in chickpeas (Castilo *et al.,* 1998; Castilo & Vovlas, 2007). Conventional breeding technologies are being continusly employed for development of elite chickpea varieties. However, success is limited and time consuming for incorporation of resistance factor against different biotic and biotic factors. The modern biotechnological tools have significantly facilitated generation of huge amount of genomic resources development to accelerate such activities. To incorporate these tools and/or accelerate breeding programmes, identification of RLN resistant source with its genetic factor is first step in developing improved cultivars. However, study of resistance screening methods for chickpea against RLN is limited and standardization of different factors for development of a stable screening methodology distinguishing various levels of resistance is the need of the hour in RLN research. Recent advancement in generation of genomic resources in chickpea (Hiremath *et al.,* 2011, 2012; Gujaria *et al.,* 2011) will certainly lead to identify of QTL conferring resistance to RLN in chickpea which can be utilized further for incorporation in molecular breeding platform.

Root Lesion Nematode

The Root Lesion Nematode (RLN), *Pratylenchus thornei* Sher and Allen, is a migratory endoparasite (Figure 1) that causes large yield losses and is regarded one of the most important plant-parasitic nematodes (Tiwari *et al.,* 1992). Inside the root cortex, RLNs penetrate, feed, and migrate, causing necrotic lesions and root cavities (Figure 2). Under ideal conditions, the nematode reproduces mitotically and parthenogenitically (Fortuner, 1977), producing eggs in the cortex and completing its life cycle in 6 weeks. More than 60 species of

Table 1: Successful management of nematodes in crops using eco-friendly approaches.

Management approach	Crop	Reference
Soil amendment by different plant bi-products		
Oil cakes of neem, castor bean, groundnut, linseed, sunflower and soybean	Chickpea	Tiyagi and Shamim, 2004
Powdered (seed kernel, seed coat, and Achook at 20 per cent w/w) neem formulations	Chickpea	Mojumder, 1999
Liquid (Neemark and Nimbecidine @5 per cent v/w) neem formulations	Chickpea	Mojumder, 1999
Mustard and Linseed cakes	Groundnut	Sebastian and Gupta, 1995
Jatropha cake @ 2 t/ha	Tomato	Patel and Patel, 2007
Mustard, castor and Jatropha cakes @ 30 g/plant	Bottle guard	Verma and Nandal, 2007
Bioagents		
Trichoderma harzianum	Chickpea	Pant & Pandey, 2002
	Maize	Windham *et al.,* 1989
	Tomato	Rao *et al*. 1997
T. koningii	Maize	Windham *et al.,* 1989
T. harzianum with neem cake	Tomato	Reddy *et al.,* 1998
Trichoderma and *Gliocladium*	Sunflower	Shankaranarayanan *et al.,* 1999
Trichoderma viride	Chickpea	Pandey *et al.,* 2003, Dwivedi *et al.,* 2008
Pseudomonas fluorescens	Chickpea	Dwivedi *et al.,* 2008
Paecilomyces lilacinus	Chickpea	Zaki and Maqbool, 1992; Vyas *et al.,* 1997
	Mashbean	Shahzad *et al.,* 1996
	Groundnut	Vyas *et al.,* 1997
	Tomato	Lin *et al.,* 1993; Ekanayake and Jayasundara, 1994; Parveen and Gaffar, 1998; Khan and Saxena, 1996
	Medicinal herbs	Park *et al.,* 1993
	betelvine	Jonathan *et al.,* 1995; Nakat *et al.,* 1998; Hazarika *et al.,* 1998; Pathak and Saikia, 1999
	Mung bean, Okra	Shahzad and Gaffar, 1987, 1989; Esteshamul-Haque *et al.,* 1995
Pochonia chlamydosporia	Vegetables	Kerry and Diaz, 2004
	Okra	Dhawan *et al.,* 2007
	Pistachio	Ebadi *et al.,* 2018
	Monocot and dicot hosts	Tolba *et al.,* 2021

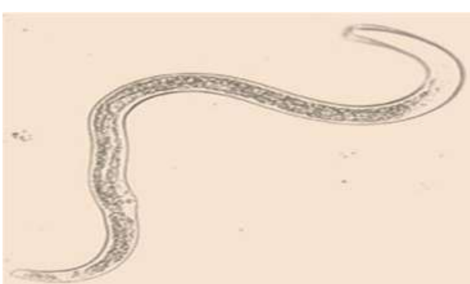

Figure 1: *Pratylenchus thornei*, a root lesion nematode of chickpea.

Figure 2: Symptoms due to *Pratylenchus thornei*, a root lesion nematode on chickpea roots as lesions.

Pratylenchus exist (Loof, 1991), all of which can be distinguished only by small morphological and morphometric changes. In North Africa (Di Vito *et al.,* 1994a), Turkey (Di Vito *et al.,* 1994b), and Spain (Castillo *et al.,* 1996), RLNs are the most common plant-parasitic nematode detected in chickpea crops.

The root-lesion nematode *Pratylenchus thornei* is the most common species that causes damage to chickpea crops around the world. *P. thornei* is found in major chickpea-growing countries such as Australia (Thompson *et al.,* 2000), India, and Pakistan, India (Sharma *et al.,* 1992), North Africa (Di Vito *et al.,* 1994a), Turkey (Di Vito *et al.,* 1994b), and Spain (Castillo *et al.,* 1996). *P. thornei* is emerging as a serious threat to chickpea production in India, which is the world's largest producer and consumer of gram. High populations of *P. thornei* have been reported in Madhya Pradesh (Baghel and Singh, 2013), Rajasthan (Ali and Sharma, 2003), Maharashtra (Varaprasad *et al.,* 1997), and Uttar Pradesh (Sebastian and Gupta, 1995). During chickpea crop surveys in North Africa and the Mediterranean region, Brazil, and North America, numerous more Pratylenchus species have been identified and reported.

Root-lesion nematodes are migratory endoparasites that cause severe necrosis of epidermal, cortical, and endodermal cells in chickpea roots by feeding in the cortical parenchyma. A combination of stylet thrusting and enzymatic weakening of the host cell walls facilitates both root penetration and migration inside root tissues (Castillo & Vovlas, 2007). Wheat, in addition to chickpea, has been identified as a possible RLN host (Di vito *et al.,* 1987).

Chickpea-RLN interactions

Taylor *et al.* (2000) established parasitic behavior of *Pratylenchus thornei* in chickpea and further specified that it's life cycle can be from 45 to 65 days depending upon different environmental features and host availability. However, under artificial conditions using carrot disk culture, *P. thornei* can take 25 to 35 days to complete its life cycle ubder the temperature incubation at 20 to 25°C (Castillo *et al.,* 1995). Therefore, many generations of *P. thornei* can happen in one crop season (Sikora *et al.,* 2018). Bridge and Starr (2007) affirmed that all the motile stages of *Pratylenchus* are parasitic. They further specified the behavior of migratory endoparasites and their feeding was confined inside the cortex, deposited eggs singly in the cavities formed by migration of nematode inside the paranchymatic cells of plant roots. De Waele and Elsen (2007) reported that reproduction in the females *of Pratylenchus thornei* is by mitotic parthenogenesis and males are rare. Pudasaini *et al.* (2008) confirmed that females of *P. thornei* deposit eggs in the soil. The eggs and nematodes of *P. thornei* can withstand in the soil under the conditions when host plants are not available. Under the circumstances of slow drying of soil, a high proportion of these nematodes can withstand and survive under these prevailing dry vicinity (Thompson *et al.,* 2017, 2018).

Depending upon the population of *P. thornei*, damage may vary and as a consequence of its infection huge segments of cortex are degraded, and subsequently absorption capacity of roots is also significantly reduced (Jaques and Schwass, 1956). The population of *P. thornei* remained inside the cortical tissues of chickpea roots, according to Tiwari *et al*. (1992). *P. thornei* infection results in dark brown to black lesions on chickpea roots. Root-lesion nematode damage is often less noticeable than root-knot or cyst nematode damage (Sharma *et al.,* 1992), and signs of *P. thornei* root damage do not necessarily manifest themselves on above-ground plant parts. In addition to these symptoms, sometimes plant weight reduction, reduced per cent pollen fertility, lesser number of pods, lower water absorption capacity and lesser chlorophyll content of leaves could also be witnessed due to RLN when compared with healthy chickpea plant (Tiyagi and Parveen, 1992). The above ground symptoms imitate nutrients and water deficiencies symptoms (Taylor *et al.,* 1999). The lesions generally first appear on roots as water-soaked area after initiation of penetration of root epidermis by *P. thornei*. The elliptical shaped water-soaked lesions of 1 to 2 mm in length are formed over time and change in colour takes place to olive green and finally to radish brown colour (De Waele and Elsion, 2007).

The roots of chickpea are significantly damaged upon infection by *P. thornei*. However, chickpea plant inoculation with different numbers of lesion nematodes (10, 100, 1000, and 10000 RLN/plant) identified 100 nematode/kg soil as threshold value for significant growth character reductions. At the lowest inoculum level, nematode multiplication

Table 2: Identification of resitance sources for *P. thornei* in chickpea.

Total No. of lines screened	No. of lines		Source of germplasm	Reference
	Resistant	Moderately resistant		
215	35	68	Indian Institute of Pulse Research (IIPR), Kanpur; JNKVV, Jabalpur, India	Tiwari *et al.,* 1992
600	0	17	International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Pantancheru, Telangana, India and IIPR, Kanpur, India	Ali and Ahmad, 2000
453	1	14	International Center for Agricultural Research in the Dry Areas (ICARDA), ICRISAT, Australian cultivars and breeding lines	Thompson *et al.,* 2011
147	21	18	Collection of primary, secondary and tertiary gene pool (Primary: *C. echinospermum, C. reticulatum*; Secondary: *C. bijugum, C. judaicum, C. pinnatifidum, C. chorassanicum*; Tertiary: *C. cuneatum, C. yamashitae*)	Di Vito *et al.,* 1995
96	2	0	ICRISAT accessions	Jatav and Tiwari, 2019
174	13	40	Collection of primary, gene pool (*C. echinospermum, C. reticulatum*)	Reen *et al.,* 2019

was at its peak (Walia and Seshadri, 1985). Threshold damage level of RLN in chickpea has been identified as 2 nematodes/g of soil (Bhatt, 1994). The nematode's reproduction index decreases with increase of inoculum densities greater than 5000 nematodes per plant (Castillo *et al.,* 1995). The temperature ranging from 10 - 25°C, favours the egg hatching in *P. thornei* with steady increase in root penetration in the first 11 days after inoculation. All the migratory stages of *P. thornei* are proficient enough for root penetration and give rise to syptom expression (Castillo *et al.,* 1996). In total, 47% to 84% of the population of RLN is could be identified in the vertical layer of soil from the top 0–10 cm, and 64–94% of the RLN population could be recovered from the top 20 cm soil zone (Taylor and Evans, 1998). However, it may be present upto 30 cm (Smiley *et al.,* 2008; Jatav, 2019)

Management strategies for nematode population

Nematicides are nematode-killing chemicals which include two primary categories of synthetic nematicides, fumigants and nonfumigants. Fumigants are often sold as liquids that react with soil water to release gases that kill a variety of organisms (including plants). They're biocides that can be used in a variety of situations. When the soil temperatures are acceptable, fumigants should be used in the fall or spring. In soil water, nonfumigant nematicides do not volatilize. In some cases, they can be used before, during, or even after planting. The range of these substances is frequently not as extensive as that of fumigants. They not only control nematodes, but also reduce the population of beneficial nematodes. Besides using nematicides, eco-friendly management strategies like use of different plant bi-products and bioagents are eco-friendly approaches for management of nematodes. Plant-parasitic nematode management has traditionally relied on organic amendments. When disintegrating materials emit poisonous substances, nematode population levels may drop quickly, but longer-term impacts could include an increase in nematode antagonists. Plant-parasitic nematodes tolerance may be enhanced due to improved crop nutrition and plant development as a result of amendment application. The success in nematode control may be governed by several factors including the type of used material, processing/composting of material, rate of application, test arena, crop rotation practice adoption and different agronomic techniques, soil type, climate conditions, and other environmental factors. The suppressive effects of different plant bi-products as organic amendements have been reported to exhibit not only detrimental effects on nematode populations but also in improvement of structure of soil and water holding capacity (WHC) ultimately resulting in enhanced growth and yield. Chickpea root-knot nematodes can be effectively suppressed adopting pre-sowing seed treatment practice using different biopesticides, insecticides, and bioagents (Mishra *et al.,* 2003).

Apart from soil amedments, different biagents have also been identified in the capacity of controlling nematode population in soil. Seed or soil application of bioagents not only increases the egg parasitization but also significantly enhances plant growth parameters. Successful application of these plant bi-products and bioagents in chickpea and other crops is listed in table 1.

Resistance sources for RLN

When it comes to screening germplasm for sources of resistance, precise and reliable phenotyping is critical. For generating the phenotypic data of different lines/varieties, precise phenotyping is required under controlled environmental conditions using a known initial population of nematodes and/or eggs. The RLNs need to be extracted and quantified (in terms of nematode population) either from both roots and soil or any one of them before and after experimentation in case of migratory root-lesion nematodes. *P. thornei* resistance levels have been reported in connection to the reproduction factor (final nematode population/initial nematode population) by researchers (Tiwari *et al.,* 1992; Di Vito *et al.,* 1995), or as number of nematodes (population count) per unit of root and/or soil (Thompson *et al.,* 2011; Reen *et al.,* 2019). Visual lesions observed on infected roots should not be counted and measured for consideration od nematode population or indicator of resistant reaction because these lesions are just symptoms and not a direct indicator of population of nematodes (Ali and Ahmad, 2000).

In India (Tiwari *et al.,* 1992; Ali and Ahmad, 2000, Gautam, 2021) and Australia (Thompson *et al.,* 2011), sources of *P. thornei* resistance and moderate resistance have been recognized in the *C. arietinum* cultigen, in breeding lines and in accessions in the ICRISAT genebank. Tiwari *et al.,* 1992 reported 35 resistant and 68 moderately resistant varieties out of 215 screened varieties of chickpea for the resistance against *P. thornei* and found. Di Vito *et al.,* 1995 screened 141 varieties taken from primary and secondary gene pool and observed seventeen different varieties in each catgory of resistant and moderately resistant. A comprehensive list of chickpea varieties screened against *P. thornei* is provided in table 2. In general, it has been reported that wild chickpea exhibited higher level of resistance in comparison to of *C. arietinum* cultivars (Reen *et al.,* 2019; Zwart *et al.,* 2019).

Conclusion

Human population expansion coupled with stunning changes in global food consumption patterns under unpropitious climatic alterations is posing formidable obstacles towards attaining sustainable global food security. Chickpeas are recognised as cost-effective sources of plant-based protein for human consumption, as well as being good to the environment due to their intrinsic nitrogen-fixing capacity. Chickpea development is critical in the rapidly transitioning global landscape where booming anthropogenic activities are causing irreversible natural resource depletion. Nematodes are important pests of agricultural crops, causing annual global economic losses of more than 100 billion dollars. Furthermore, chickpea damage from nematodes can make it more susceptible to disease and other pressures. Three essential aspects for the integrated control of plant-parasitic nematodes in chickpea are accurate diagnosis, effective crop rotations or fallow times, and identification, development of tolerant/ resistant crop cultivars. To accomplish these elements in nematode management, extensive expertise of nematode taxonomy and/or application of molecular diagnostic tools are essential. Due to the extensive host range of nematodes, crop rotation options are limited in nematode-infested farms, and nematicides are avoided for environmental and economic reasons. The employment of bioagents with resistant cultivars is the most successful and long-term technique for overcoming restrictions to chickpea production induced by plant-parasitic nematodes. Growing resistant cultivars offers the benefit of avoiding nematode reproduction and lowering existing crop output losses. Furthermore, when resistant cultivars are grown, nematode populations remaining in the soil to damage later crops are reduced, benefiting the entire farming system.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Chemical and morphological variations in *Terminalia bellirica* (Gaertn.) Roxb. – a species of commercial ayurvedic formulation triphla from central India

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ABSTRACT

Terminalia bellirica **is one of the high traded medicinal plant species, mainly known for its fruits which are bestowed with numerous biological activities and used in treatment of various ailments. The fruits are one of three ingredients of well-known Ayurvedic formulation 'TRIPHLA'. The purpose of this study was to determine the variations for Gallic acid (GA), a chemical marker compound, as well as for key morphological traits (height, girth at breast height, clear bole height, fruit size) in trees from central Indian states viz. Madhya Pradesh, Chhattisgarh and Maharashtra. In this investigation, we also explored the correlation between the chemical marker and morphological features. The study suggested the maximum GA content (0.98±0.42%) in populations of Keregaon range of Dhamtari forest division of Chhattisgarh state which can be considered as superior chemotypes/ populations. The correlation analysis exhibited the positive association between fruit size and GA content.**

Introduction

Terminalia bellirica (Gaertn.) Roxb., commonly known as 'Baheda' or 'Belleric myrobalans' is a prime member of Combretaceae family. It is a widely distributed tree species especially in the Indian subcontinents. There are numerous traditional systems of medicines such as Ayurveda, Siddha, Unani & Chinese medicine that use this plant and its parts. *T. bellirica* itself has been reported to be effective against cancer, diabetes, diarrhoea, microbial infection, wound healing, bronchitis, spasm, fever, and liver disorder (Deb *et al.,* 2016). The pharmaceutical importance of the plant is due to an ample variety of phytochemical constituents in the plant. Some of the important phytoconstituents of the plant are β-sitosterol, gallic acid, chebulagic acid, ethyl gallate, ellagic acid, galloyl glucose (Gupta *et al.,* 2017). The fruit is the most important part of *T. bellerica* which is substantially used in traditional medicines along with fruits of *Terminalia chebula* and *Phyllanthus emblica* for a well-known formulation 'Triphala' (Zhang *et al.,* 2019). This miraculous combination is described to treat a myriad of health disorders. The annual demand of fruits of this species is approximately 2000-5000 metric tonnes (NMPB). The fruit is diarrhoeic, laxative,

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astringent, anthelmintic, antipyretic; used to aid digestion, bronchitis, asthma, dyspepsia, piles, diarrhoea, cough, blisters, eye diseases, scorpion-stings, and as a hair tonic (Mallik *et al.,* 2012).

GA (3,4,5-trihydroxy benzoic acid), one of the subtypes of phenolic acid (Figure 1) is a colourless or slightly yellowish crystalline compound is one of the most profusely found compounds in various parts of *T. bellirica* (Fernandes and Salgado, 2016).

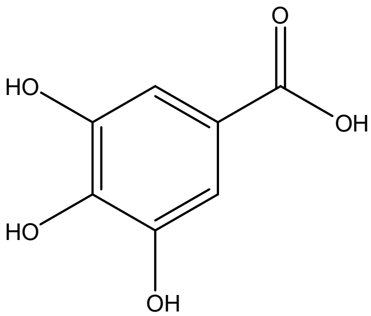

Figure 1: Chemical structure of GA (3, 4, 5-trihydroxybenzoic acid).

This compound for a long has been a keen point of interest for researchers due to its extensive pharmaceutical properties. The anti-microbial property of GA is exhibited due to its ability to disrupt the integrity of bacterial cell membrane, along with inhibition of enzymes in DNA replication, electron transport chain, and cellular respiration (Omojate *et al.,* 2014). The HIV-1 enzymes, attachment, and penetration of HSV-1, HSV-2, and HCV are obstructed by GA (Kahkeshani *et al.,* 2019). GA escalates the activity of superoxide dismutase (SOD), catalase (CAT), glutathione reductase (GR). Thus, the substance inhibits ROS-induced carcinogenesis and works effectively as an anti-cancerous agent. It is also effective against gastrointestinal (Chatterjee *et al.,* 2012), cardiovascular (Priscilla and Prince, 2009), inflammatory (Bai *et al.,* 2021), metabolic (Gandhi *et al.,* 2014), and neuropsychological diseases (Nagpal *et al.,* 2013).

Bioactive marker compounds are responsible for the quality and efficacy of medicinal plants and their products which have specific physiological action on the human body (Joshi and Uniyal, 2008; Akinmoladun *et al.,* 2007). WHO and modern herbal pharmacopoeia strongly stressed on the need of quality assurance of medicinal plants with respect to their bioactive ingredients (Kaushik *et al.* 2010; Vasudevan, 2009). GA is reported as a chemical marker compound in fruits of *T. bellirica* (Gupta *et al.,* 2003). The present investigation has been planned for selection and evaluation of natural populations of *T. bellirica* in terms of GA content in its fruits for identification for superior populations in three central Indian states i.e. Madhya Pradesh, Chhattisgarh and Maharashtra. The correlation study between morphological traits of *T. bellirica* with GA content in its fruits was also accomplished.

Material and Methods

Chemicals and reagents

GA standard was purchased from Sigma Aldrich, India. Solvents and chemicals used in the experiments were of AR grade.

Collection of *T. bellirica* fruits and recording of morphological data

Mature fruits of *T. bellirica* were harvested in the last week of February from forest divisions of Madhya Pradesh, Chhattisgarh and Maharashtra states (Figure 2), and brought to the laboratory where they were washed in tap water to remove dust particles, depulped, dried, powdered, and stored in airtight containers for further chemical analysis. Morphological data viz. tree height, GBH, CBH, and fruit size (Figure 3) were also recorded along with GPS coordinates of collection sites.

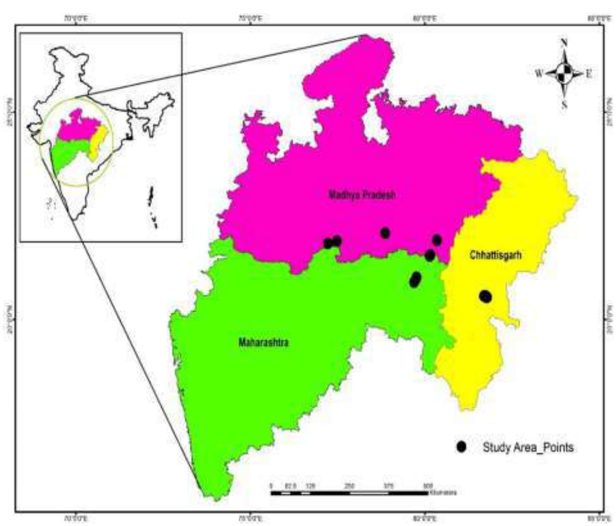

Figure 2: Study sites of *T. bellirica* in central India.

Processing and extraction fruit samples

2.5 gm dried and finely powdered fruit pulp samples were taken in conical flasks containing 50 mL of 2N HCl and heated for 30 minutes over a boiling water bath, cooled and filtered.

Figure 3: (a) Recording GBH of tree (b) Fruits of *T. bellirica* (c) Recoding size of fruit with vernier caliper

The filtrate was transferred to a separating funnel and extracted twice with 75 mL (50; 25) of diethyl ether. The pooled diethyl ether layers were washed two times with distilled water, dried over anhydrous sodium sulphate and filtered. The filtrate was evaporated and the concentrated extract was dissolved in 10 mL of methanol for analysis (Saxena *et al.,* 2015).

High Performance Liquid Chromatography (HPLC) analysis for quantification of GA

GA content in fruit pulp was determined by using the reported HPLC method with some modifications (Saxena *et al.,* 2015).

Preparation of standard solution

Standard solution of 1 mg/mL of GA was prepared. Working solutions having concentration range of 100 - 300 µg/ mL was prepared by further diluting with methanol.

Chromatographic analysis

Mobile phase	: Methanol: Water: Acetic acid (25: 75:0.1)
Injection volume	: 20 μl^{-1}
Flow rate	: 1.0 mL min^{-1}
Wavelength	: 254 nm
Run time	: 10 min

The standard solution and fruit samples were filtered separately using 0.2 µm filters, and 20 µL of each were injected into an HPLC Water 515 series column with a C-18 Xbridge equipped with a Photo Diode Array (PDA) detector, samples were run for 10 minutes. Peak identification was performed by comparison of retention times and diode array spectral characteristics with the standard. The calibration curve was generated by linear regression based on the peak areas. Linearity was obtained over five different concentration range of 2 - 6 µg per injection with r^2 = 0.997.

Specificity ascertained by comparing the peak purity of standard and samples through their HPLC chromatograms. Peak corresponding to GA in the sample was completely in agreement with the standard. Quantity of GA in fruit samples was calculated using the obtained linear regression equation.

Morphological traits

Morphological data viz. tree height, girth at breast height (GBH), clear bole height (CBH) and fruit size of *T. bellirica* trees were recorded (Mohammad *et al.,* 2020). A hypsometer (Model - Vertex 5, Make - Haglöf Sweden AB, Sweden) was used to measure tree height and clear bole height. Girth at breast height was measured by looping a measuring tape around the tree trunk at a height of 1.37 m above ground level in a plane perpendicular to the trunk's axis. Size of fruits was measured using vernier caliper.

Statistical analysis

Correlation analysis was conducted between morphometric traits and GA content (Mohammad *et al.,* 2020). For HPLC analysis, the samples were analysed in triplicates and the results are expressed as Mean±SD.

Results and Discussion

Representative HPLC chromatograms of GA standards and samples resolved under the chromatographic conditions is described in Figure 4 and 5. The retention time of GA fruit sample and standard was frame at 5.4±0.01 min.. Chromatographic analysis of extracted fruit samples revealed the presence of GA.

Chemical and morphological variations

Results showing the variations in GA content in fruit samples of *T. bellirica* collected from 07 forest ranges of Madhya Pradesh, Chhattisgarh and Maharashtra states are given in Table 1. GA concentration varies from 0.43±0.09 to 0.98±0.42 per cent among different locations. The highest GA concentration (0.98%) was observed in the fruit sample collected from Keregaon range belonging to Dhamtari forest division of Chhattisgarh state and the lowest GA concentration (0.43%) was found in the fruit sample collected from Chhindwara range of West Chhindawra forest division of Madhya Pradesh state. The results showed significant variation ($P< 0.05$) in GA content among the 07 locations of different states. Morphological traits showed significant variability among the populations of different locations of three states (Table 1). The tree height ranged from 8.77 m to 19 m, GBH of tree from 0.91 m to 2.43 m, CBH from 3.04 m to 6.75 m and average size of fruit from 323 mm^2 to 725 mm^2.

Table 1: Morphological traits and gallic acid (%) of *T. bellirica*

States	Forest Divisions	Forest Ranges	Height (m)	Girth at Breast Height (m)	Clear Bole Height (m)	Avg. size of fruit (length x width) in mm^2	Gallic acid (%) Mean ± SD
Maharashtra	Bhandara	Bhandara	14.87±6.10	1.59±0.82	4.10±2.48	537.67±175.29	0.84±0.30
	Gondia	Gondia	11.00±1.73	1.07±0.38	3.87±1.86	725.00±147.10	0.60±0.04
Chhattisgarh	Dhamtari	Keregaon	9.53±2.40	0.91±0.13	4.95±3.23	652.75±105.90	0.98±0.42
		Singpur	8.77±2.29	0.95±0.23	3.04±1.59	640.25±85.15	0.71±0.19
Madhya Pradesh	West Chhindwara	Chhindwara	19.00±3.56	1.68±0.19	6.75±0.50	494.00±101.60	0.43±0.09
	South Balaghat	Lougur	18.50±3.54	2.43±0.30	5.50±2.12	423.00±89.10	0.65±0.02
	Betul Forest	Mohada	11.00±3.0	1.80±0.20	4.00±1.00	323.00±23.0	0.60±0.30

Table 2: Inter-character correlation between different traits of *T. bellirica*

	Avg. size of fruit (length x width) in mm^2	Girth of tree (m)	Height of tree (m)	Clear bole (m)	Gallic acid (%) in fruits
Avg. size of fruit (LxW) in mm	1	-0.82	-0.47	-0.31	0.36
Girth of tree (m)	-0.82	1	0.79	0.48	-0.41
Height of tree (m)	-0.47	0.79	1	0.80	-0.50
Clear bole (m)	-0.31	0.48	0.80	1	-0.37
Gallic acid (%) in fruits	0.36	-0.41	-0.50	-0.37	1

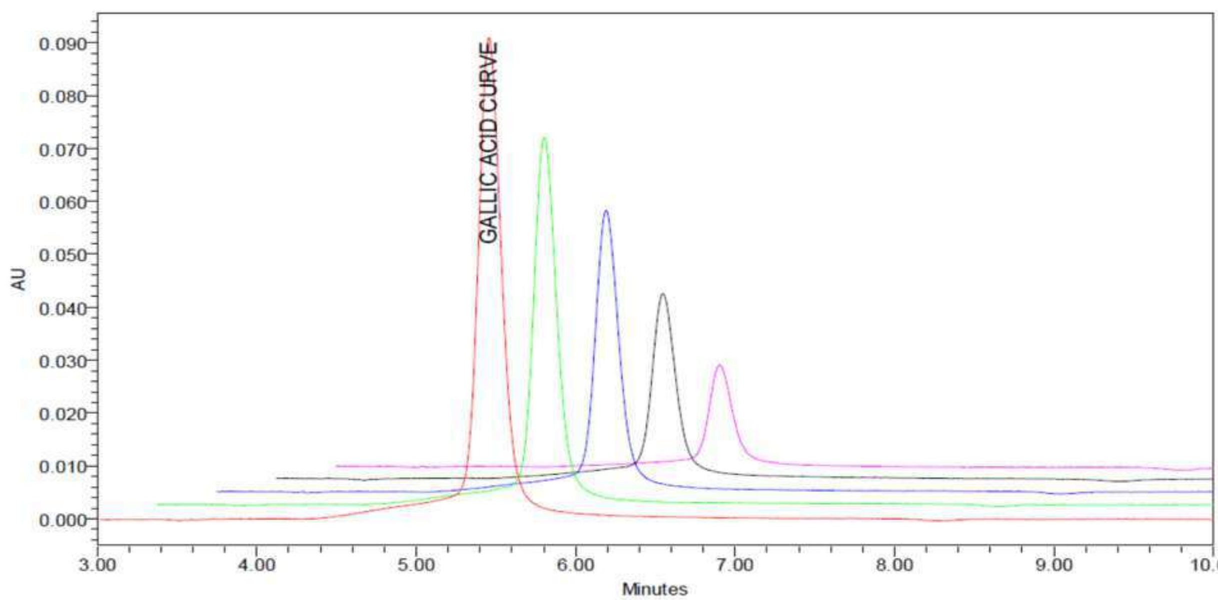

Figure 4: HPLC chromatogram of gallic acid standard

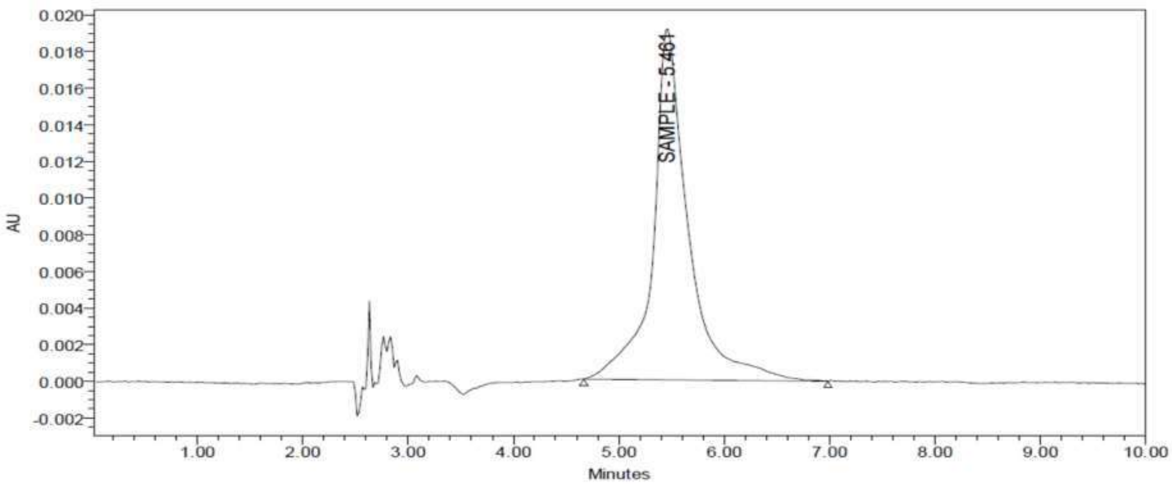

Figure 5: HPLC chromatogram of fruit sample

	Avg. size of fruit (length x width) in mm^2	Girth of tree (m)	Height of tree (m)	Clear bole (m)	Gallic acid (%) in fruits
Avg. size of fruit (length x width) in mm^2	1	-0.82	-0.47	-0.31	0.36
Girth of tree(m)	-0.82	1	0.7864	0.48	-0.41
Height of tree (m.)	-0.47	0.79	1	0.80	-0.5
Clear bole (m.)	-0.31	0.48	0.80	1	-0.37
Gallic acid (%) in fruits	0.36	-0.41	-0.5	-0.37	1

Figure 6: Shaded correlation matrix depicting relationship between different morphometric traits with GA (%) in fruits of *T. bellirica.*

Correlation study

Phenotypic inter-character correlation in all the possible combinations were computed and showed as shaded correlation matrix that depicting relationship between different morphometric traits and GA content (Figure 6). A close examination of the correlation analysis between morphological and chemical parameters revealed that GA content showed positive and significant correlation only with fruit size. With rest of characters, GA content showed a non-significant association (Table 2).

The positive correlation between fruit size and GA content may be explained by the hypothesis that the fruit colour modifies the chemical composition of phytochemicals, bioactive (phenolics) compounds etc. In case of *T. bellirica*, with the maturity, the fruit colour and size modify which may be the reason for increased GA content in bigger fruits. Our notion is corroborated by previous research revealing more coloured and larger fruits with improved pomological features and altered nutritional components and phenolics in the 'Kordia' sweet cherry (*Prunus avium* L.) (Usenik *et al.,* 2014). Moreover, another study reported the inconstant change in phytochemicals with respect to the fruit size (Kesta, 1988). Thus, it can be concluded that there is no specific trend of correlation of chemical content with the fruit size and it may vary according to the species, locations and environmental conditions.

Conclusion

Present work is the first comprehensive investigation revealing the high level of variations in chemical and morphological traits of *T. bellirica*. The study showed the populations of Keregaon range belonging to Dhamtari forest division of Chhattisgarh state contained maximum GA content, hence the superior chemotypes. Further, since the fruit size was found to have positive association with GA content, it should be given high weightage during the selection of superior chemotypes of *T. bellirica*. The work carried out in this study will be of great help in management and conservation of this valuable species.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Morphometric analysis for sustainable development of natural resource management by using remote sensing and GIS techniques in Tikamgarh District, M.P., Central India

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ABSTRACT

Study of morphometric parameters decides the suitable location and adjustable natural resource management (NRM) practices along with durability and sustainability. Morphometric study of a region provides the various geological, topographical and others parameters which supports during the design and implantations of various water conservation approaches. Garhkundar –Dabar (GKD) watershed having two parts as first treated watershed and second control watershed, located in Tikamgarh District of Madhya Pradesh, Central India was selected for this analysis. ArcGIS ver. 10.3 was used for analysis and found IVth order stream in treated watershed area of 850 ha (8.50 km^2) and IInd order stream in control watershed area of 268 ha (2.68 km^2). In treated watershed, 19 streams were found in first order while 12, 5 and 1 streams were obtained in second, third and fourth order respectively. Similarly, 6 and 4 streams were found in first and second order respectively in control watershed. This study conclude all aspects of morphometric parameters *viz.* linear, areal and relief which elaborate the geometric as well as topographic features to support and identified the best location for various conservation interventions and their implementation with a long sustainability. RS and GIS based morphometric analysis provides the way of replication of conservation practices and suggested for sustainable conservation treatment and watershed development.

Introduction

Development of a basin and its drainage pattern over space and time is influenced by soil, area of vegetation, geology, geomorphology and structural components and their location. All the hydrologic and geomorphic process of a watershed is mainly depend on the basin of an area and their flowing pattern. Earth's surface, its shape and dimension of its landforms all such configurations elaborated by morphometric measurement and mathematical analysis (Agarwal, 1998; Obi Reddy *et al.*, 2002). Morphometric study of a region was carried out by thematic map generated in GIS environment to identify the appropriate places for artificial groundwater recharge structures. The field survey also required to find out the suitability and sustainability of proposed artificial groundwater recharge structures. Thereby, by RS and GIS recharge structures implemented and found 264.82 Mm^3 (30%) groundwater recharge (Kumar *et al.*, 2016). Due to high demand of water and depletion of groundwater recharge, RS and GIS provided a great opportunity during master plan for artificial

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recharge to groundwater in India (Pati, 2019). Due to the increase in demand of natural resources such as land and water, management of these resources at a watershed scale has become one of the important strategies for attaining a sustainable environment (Hema *et al.,* 2021). The information as a result of morphometric analysis of watersheds could be used as decisive tool in water resource management, conservation of soil erosion, landslide susceptibility mapping, evaluation of groundwater potential, and prioritization of watersheds (Salvi *et al.,* 2017; Jena and Dandabat, 2019). In view of the importance of morphometric analysis for Sustainable Development of Natural Resource Management, this study had been taken in Garhkundar–Dabar (GKD) located at Tikamgarh district of Madhya Pradesh, Central India.

Material and Methods

Selected watershed named Garhkundar –Dabar (GKD) was located at Tikamgarh district of Madhya Pradesh, Central India (figure 1). Watershed widely spread in longitudinal direction between 78° 52' 41" to 78° 54' 44" E and latitudinal direction between 25° 26' 24" to 25° 28' 31" N. Watershed categorized into two parts based on its geographical area first treated watershed area of 850 ha and second control watershed area of 268 ha. Watershed comprises four Panchayati villages namely Shivrampur, Dabar, Rautiana and Kundar in the Tikamgarh District of Madhya Pradesh, India. The range of watershed altitude above mean sea level (MSL) varies from 208 to 285 m.

Watershed is agro-climatic in nature among the Central Plateau Hill Region and suffers ecologically by hot moisture semi-arid and typical semi-arid sub-tropical features. The mean temperature of region varies from 3 ^{0}C to 49 ^{0}C. The geology and geomorphology of the watershed is characterized by hard rock terrains of archaen granite found below 8 m depth and disintegrated rock fragments locally called 'murram' are found between 25 to 800 cm depth. The soil of watershed is shallow (10-50 cm) variants of red soils, known as Parwa (Entisol) and Rakar (Alfisol) with having poor water holding capacity.

Base map of the basin is prepared in GIS environment by using ArcGIS ver. 10.3. Watershed geometry is systematic description which is understood by morphological characteristics of watershed. To understand the geometry of drainage basin and its stream channel system, basically three morphometric measurements were adopted i.e. (i) linear aspect (ii) areal aspect (iii) relief aspect. The proper way of analysis is presented by the flow chart (figure 2) and formulations for morphometric measurements are tabulated in Table 1. DEM of watershed was downloaded from USGS by digital elevation through SRTM with spatial resolution of 30 m (figure 3). For best land use, slope map and contour map of the study area is shown in figure 4 and 5 respectively.

Results and Discussion

Various thematic maps including slope map, contour map and drainage network has been carried out for the GKD watershed. Percent areal extent in different DEM classes at GKD watershed is shown in Table 2. Slope was divided into eight classes as per guidelines of IMSD (1995) and tabulated in table 3. Similarly, various contours are listed in table 4. Natural drainage system of watershed is shown in figure 6. Various parameters of drainage network *viz.* drainage area, stream order, no. of stream, stream length and maximum length were calculated in GIS software and from these parameters various drainage characteristics such as bifurcation ratio (Rb), drainage density (D_d), stream frequency (Fs) circulatory ratio (Rc), elongation ratios (Re) were estimated for sustainable development of natural resource management. The field survey of study area was also carried out to find out the suitability of proposed artificial groundwater recharge structures.

Stream order is the first step for morphometric characteristics of the watershed and thereby, the stream ordering was ranked based on hierarchic ranking method proposed by Strahler (1964). Streams of the watershed were counted along with their length from mouth to drainage divide and measured with the help of ArcGIS 10.3 based on the law by Horton, (1945). The order wise stream numbers and stream length of the area was designated as first to fourth order and first to second order for treated and control watershed respectively.There was a decrease in stream frequency as the stream order increases (figure 7 & 8). The main stream (outlet) of watershed was found in 4th order stream of 0.02 km. Total length of stream segment was maximum in the first order stream of 8.46 km for treated watershed while in case of control watershed, total length of stream segment was 2.92 km (Table 5). The length of drainage path in treated and control watershed was found 3.18 km and 2.14 km respectively. There was a decrease in stream length as the stream order increases (figure 9 & 10). Such type of result indicated flowing of streams from high altitude, lithological variations, and moderately steep slopes. The mean stream length (L_{sm}) and stream length ratio (R_L) was also calculated which provided a

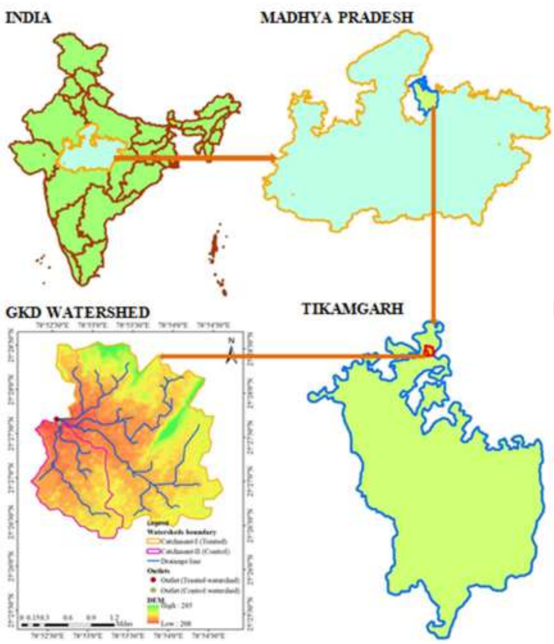

Figure 1: Location map of Garhkundar-Dabar (GKD) watershed

general idea about the permeability and its status in the region. The value of bifurcation ratio varied between 1.58 to 5 in treated watershed are characteristics of minimum structural disturbances while mean bifurcation ratio is observed as 2.99 and 1.5 in treated and control watershed respectively (Table 6). This indicated that the drainage pattern of the basin has not been affected by the structural disturbance (Nag, 1998).

The area enclosed by watershed boundary line is called drainage area. Drainage area of treated and control watershed was measured with the help of ArcGIS and recorded 850 ha (8.50 km^2) and 268 ha (2.68 km^2) respectively. The ratio of total number of stream segments of all orders to the area of watershed is called stream frequency or channel frequency (Horton, 1932). The value of stream frequency (Fs) indicated positive correlation with the drainage density of the basin and suggesting that increase in stream population with respect to increase in drainage density. The estimated value of stream frequency for treated and control watershed was 4.35 and 3.73 exhibit positive correlation with the drainage density value of the area, indicating the increase in stream population with respect to increase in drainage density (Table 6). The value of drainage density of the area was recorded 2.09 and 2.10 km/km^2 for treated and control watershed respectively indicates low drainage density. This low drainage density shows the coarse drainage

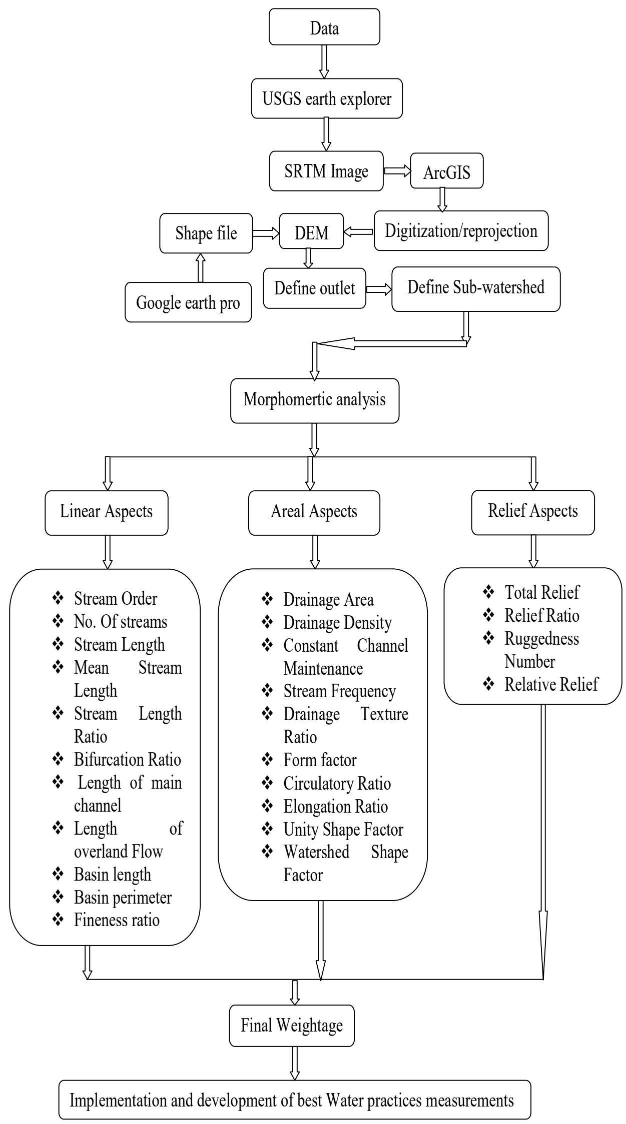

Figure 2: Way for morphometric measurements in GKD watershed.

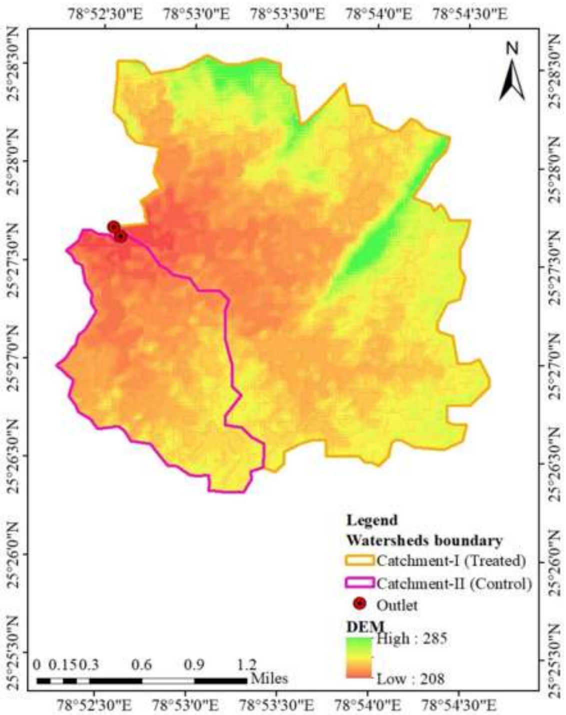

Figure 3: DEM of GKD Watershed

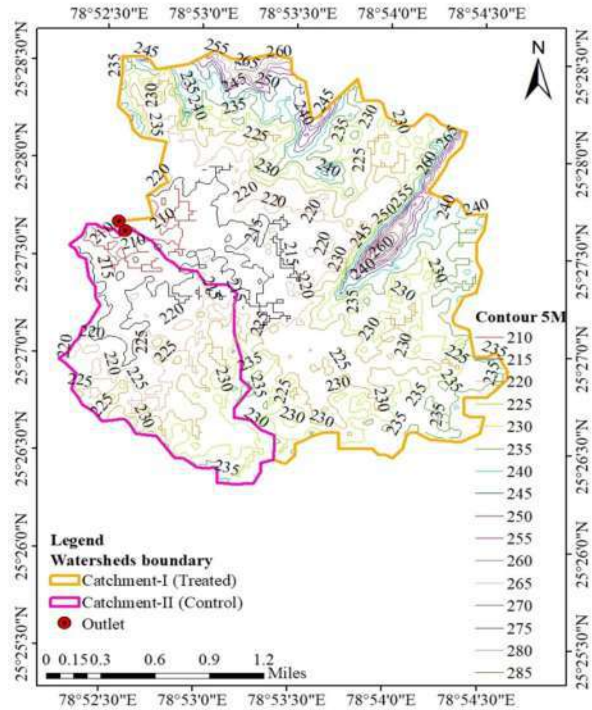

Figure 5: Contour map of GKD Watershed.

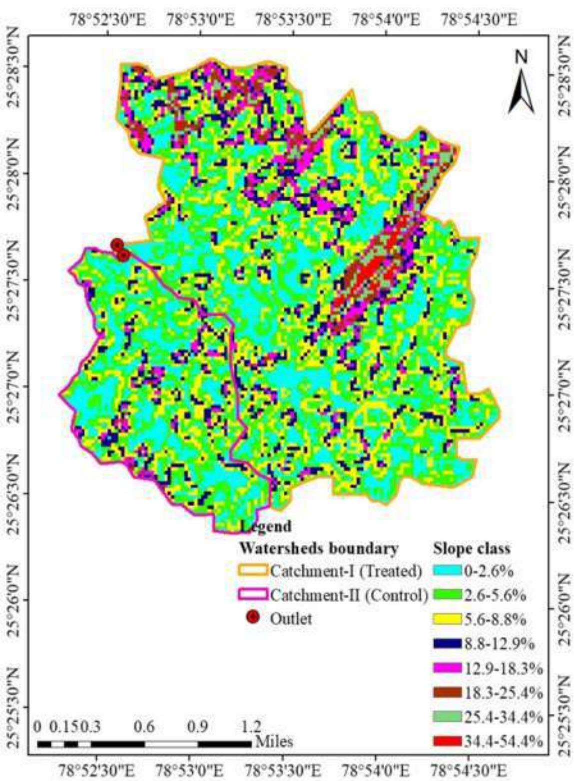

Figure 4: Slope map of GKD Watershed.

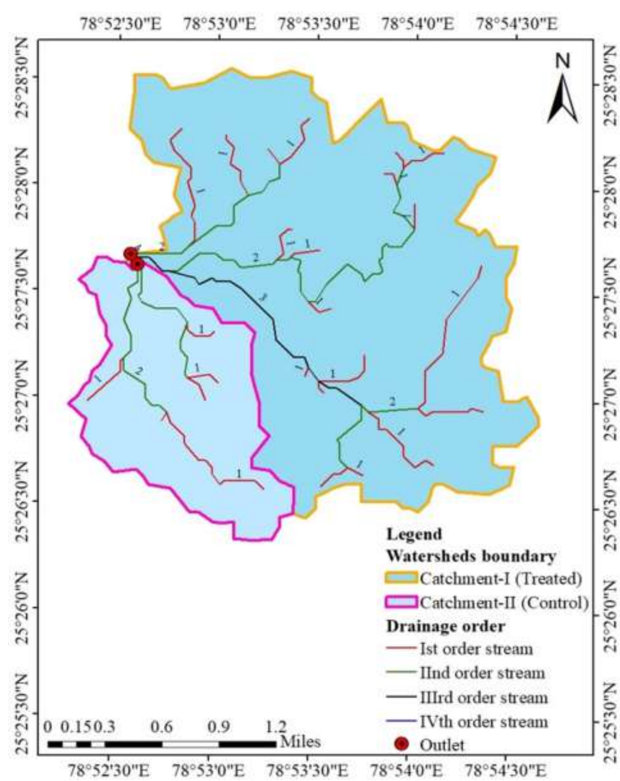

Figure 6: Drainage map of GKD Watershed.

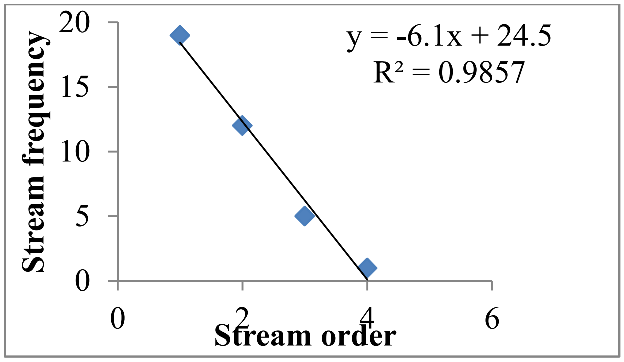

Figure 7: Relationship between stream number and stream order for treated watershed.

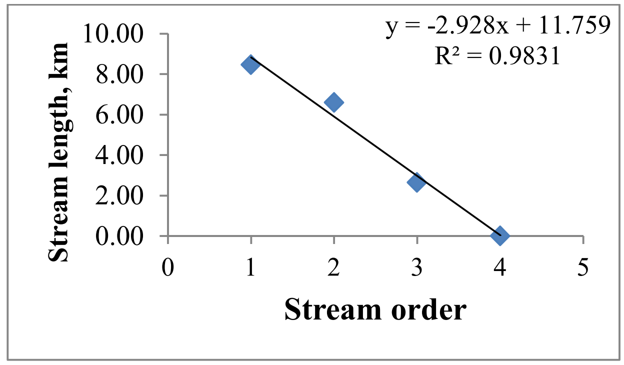

Figure 9: Relationship between stream length and stream order for treated watershed.

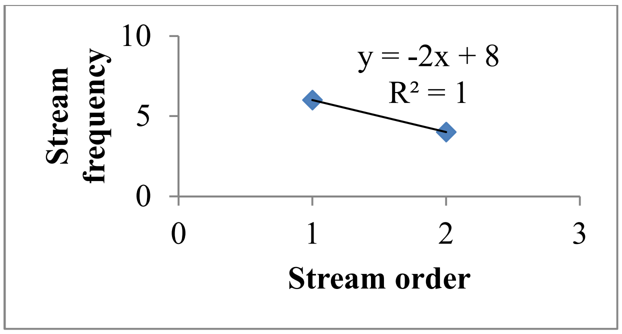

Figure 8: Relationship between stream number and stream order for control watershed

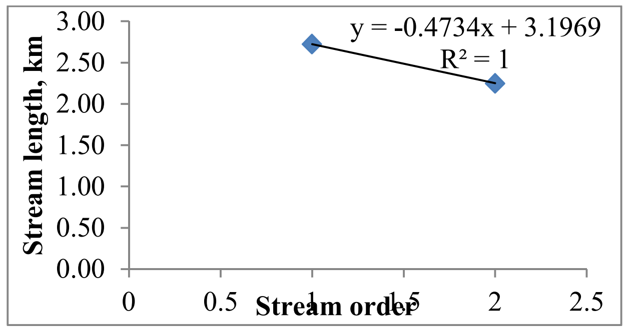

Figure 10: Relationship between stream length and stream order for control watershed.

pattern and semi-arid climate of the study area. The coarse texture gives more times for overland flow and hence leads to groundwater recharge. Smith (1950) has classified drainage density into five different classes. The drainage density less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. According to Horton (1932), form factor (R_f) may be defined as the ratio of basin area to square of the basin length. The value of form factor (R_f) was observed 0.49 and 0.25 for treated and control watershed respectively as per definition given by Horton (1932), suggested that the basin is elongated and would have lower peak flow foe longer duration. The value of elongation ratio (R_e) was found 0.79 and 0.57 for treated and control watershed respectively. The values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic conditions. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler 1964). These values can be grouped into three categories namely (a) circular ([0.9), (b) oval (0.9–0.8), (c) elongated (\0.7). The value of elongation ratio of the area was 0.79 indicated that the study area was elongated with high relief and steep ground slope.
The circulatory ratio (R_c) was recorded 0.39 and 0.53 for treated and control watershed respectively (Table 6). Circulatory ratio influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. Circularity ratios range 0.4–0.5 which indicates strongly elongated and highly permeable homogenous geology. The value of circulatory ratio was 0.39 indicated that the basin is elongated in shape, has low discharge of runoff and is highly permeability of the subsoil condition. Vertical distance from the highest elevation point of watershed to the point of mouth of that particular watershed is called basin relief or total relief.

Table 1: Analytical approaches for morphometric measurements.

Morphometric parameters		Methods	References
Linear aspect	Stream order (U)	Hierarchical order	Strahler, 1964
	Stream number (Nu)	Number of streams of each order	Strahler, 1964
	Stream length (Lu)	Length of the stream	Horton, 1945
	Mean stream length (Lsm)	Lsm = Lu/Nu where, Lu=Stream length of order 'U' Nu=Total number of stream segments of order 'U'	Horton, 1945
	Stream length ratio (R_L)	R_L =Lu/Lu-1; where Lu=Total stream length of order 'U', Lu-1=Stream length of next lower order.	Horton, 1945
	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream segment of order'u'; Nu+1=Number of segment of next higher order	Horton, 1932
	Length of overland flow (Lof)	Lof = 1/2Dd where, Dd=Drainage density	Horton, 1945
Areal aspect	Drainage density (D_d)	D_d = L/A where, L=Total length of streams;A=Area of watershed	Horton, 1945
	Constant channel maintenance (C)	Lof = 1/D_d where, D_d=Drainage density	Horton, 1945
	Stream frequency (Fs)	Fs = N/A where, N=Total number of streams; A=Area of watershed	Horton, 1945
	Drainage texture ratio (T)	T = N_1/P where,N_1=Total number of first order streams; P=Perimeter of watershed	Horton, 1945
	Form factor (R_f)	R_f=A/(L_b) 2 ;where, A=Area of watershed, L_b=Basin length	Horton, 1932
	Circulatory ratio (Rc)	Rc=4πA/P2 ;where, A=Area of watershed, π=3.14, P=Perimeter of watershed	Miller, 1953
	Elongation ratio (Re)	Re=2√(A/π)/L_b ;where, A=Area of watershed, π=3.14, L_b=Basin length	Schumn,1956
Relief aspect	Basin relief (B_h)	Vertical distance between the lowest and highest points ofwatershed.	Schumn, 1956
	Relief ratio (R_h)	R_h=B_h/L_b; where, B_h=Basin relief; L_b=Basin length	Schumn, 1956
	Ruggedness number (R_n)	R_n= B_h × D_d; where, B_h =Basin relief; D_d=Drainage density	Strahler, 1958
	Relative relief (R_r)	R_r = B_h/B_p; where,B_h=Basin relief; B_p=Basin perimeter	Melton (1957)

Table 2: Areal extent of various DEM classes in GKD watershed

Sr. No.	DEM classes (m)	Area (ha)	Area (%)	DEM classes (m)	Area (ha)	Area (%)
	Catchment-I (Treated)			**Catchment-II (Control)**		
1	208-217	129.96	15.29	208-211	17.73	6.61
2	218-224	175.69	20.67	212-214	31.41	11.72
3	225-230	196.46	23.11	215-217	36.9	13.76
4	231-236	192.80	22.68	218-220	50.94	19.00
5	237-242	73.27	8.62	221-224	37.44	13.96
6	243-250	39.96	4.70	225-228	44.64	16.65
7	251-259	19.98	2.35	229-231	25.65	9.57
8	260-269	14.85	1.75	232-233	13.05	4.87
9	270-285	7.03	0.83	234-239	10.35	3.86
Total		850.00	100.00		268.11	100.00

Table 3: Areal extent of various slope classes in GKD watershed

Sr. no.	Slope (%)	Area (ha)	Area (%)	Slope (%)	Area (ha)	Area (%)
	Catchment-I (Treated)			**Catchment-II (Control)**		
1	0-2.50	200.34	23.57	0-1.77	51.48	19.20
2	2.64-5.56	262.71	30.91	1.86-3.58	66.33	24.74
3	5.59-8.76	190.17	22.37	3.73-5.83	67.41	25.14
4	8.84-13.08	105.39	12.40	5.89-7.93	39.42	14.70
5	13.18-18.46	48.09	5.66	8.01-10.09	25.2	9.40
6	18.50-25.34	23.31	2.74	10.14-12.49	11.43	4.26
7	25.53-34.32	14.03	1.65	12.5-15.15	4.95	1.85
8	34.42-54.80	5.96	0.70	15.47-20.17	1.89	0.70
Total		850	100.00		268.11	100.00

Table 4: Linear extent of various contour classes in GKD watershed

Sr. No.	Contour (m)	Number of contours	Length of contour (km)	Contour (m)	Number of contours	Length of contour (km)
	Catchment-I (Treated)			**Catchment-II (Control)**		
1	210	5	3.45	210	6	3.98
2	215	9	12.00	215	10	6.71
3	220	19	11.94	220	19	11.11
4	225	18	25.60	225	11	5.56
5	230	26	27.86	230	12	5.23
6	235	37	22.95	235	11	1.69
7	240	19	10.87			
8	245	9	7.58			
9	250	5	5.55			
10	255	5	4.47			
11	260	5	3.97			
12	265	6	2.48			
13	270	3	1.48			
14	275	3	0.83			
15	280	1	0.46			
16	285	1	0.06			

Table 5: Characterization of drainage network

Parameters	Ist order	IInd order	IIIrd order	IVth order
Treated watershed				
No. of streams	19	12	5	1
Min. length (km)	0.08	0.08	0.08	0.02
Max. length (km)	1.43	1.49	1.65	0.02
Mean stream length (km)	0.45	0.55	0.53	0.02
Total length(km)	8.46	6.61	2.66	0.02
Control watershed				
No. of streams	6.00	4.00		
Min. length (km)	0.09	0.53		
Max. length (km)	1.25	0.89		
Mean stream length (km)	0.45	0.72		
Total length(km)	2.72	2.91		

Table 6: Morphometric characteristics of Garhkundar Dabar watershed

Linear aspect:

	Stream order	No of streams	Stream length (km)	Mean stream length (km)	Stream length ratio	Bifurcation ratio	Mean bifurcation ratio	Length of main channel (km)	Length of overland flow (km)	Basin length (km)	Basin perimeter (km)	Fineness ratio
Treated watershed	Ist	19	8.46	0.45	0.00	1.58	2.99	4.55	0.24	4.16	16.63	0.25
	IInd	12	6.61	0.55	0.78	2.40						
	IIIrd	5	2.66	0.53	0.40	5.00						
	IVth	1	0.02	0.02	0.01	0.00						
Control watershed	Ist	6	2.92	0.49	1.07	1.50	1.50	2.84	0.24	3.27	7.99	0.41
	IInd	4	2.71	0.68								

Areal Aspect:

	Drainage area (sq km)	Drainage density	Constant of channel maintenance	Stream frequency	Form factor	Circulatory ratio	Elongation ratio	Unity shape factor	Watershed shape factor	Drainage texture ratio
Treated watershed	8.5	2.09	0.48	4.35	0.49	0.39	0.79	1.43	1.38	2.23
Control watershed	2.68	2.10	0.48	3.73	0.25	0.53	0.57	2.00	1.54	1.25

Relief Aspect:

	Total relief (m)	Relief ratio	Ruggedness number	Relative relief
Treated watershed	77	0.02	0.16	0.005
Control watershed	31	0.01	0.07	0.004

In this study, total relief was recorded 77 and 31 m for treated and control watershed respectively. The relief ratio was found as 0.02 and 0.01 for treated and control watershed respectively showed the major portion of the basin having gentle slope (Table 6). The relief ratio normally increases with the decreasing drainage area and size of the sub-watersheds of a given drainage basin (Gottschalk, 1964). It measures the overall steepness of a drainage basin and is an indicator of the intensity of the erosion processes operation on the slope of the basin.

Conclusion

The morphometric analysis carried out for the GKD watershed confirms that stream length decreases as the stream order increases and such type of result indicates flowing of streams from high altitude, lithological variations, and moderately steep slopes. Mean bifurcation ratio indicated that the drainage pattern of the basin had not been affected by the structural disturbance. Low drainage density of the area showed the coarse drainage pattern and semi-arid climate of the study area. The value of form factor indicated that the basin was elongated and would have lower peak flow for longer duration. The value of elongation ratio of the area indicated that the study area was elongated with high relief and steep ground slope. The value of circulatory ratio indicated that the basin was elongated in shape, had low discharge of runoff and highly permeability of the subsoil condition. This analysis will be used as a guideline for site suitability and sustainable development of natural resource management. Study also shows that GIS techniques have efficient tools in delineation of the drainage pattern to understanding the status of land form and their processes, drainage management and evolution of groundwater potential for watershed planning and management. This work will be useful for sustainable development of natural resource management.

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Conflict of interest

The authors declare that they have no conflict of interest.

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