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(A Peer Reviewed Journal)

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Ph.D. Thesis, Dissertation and Reports

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

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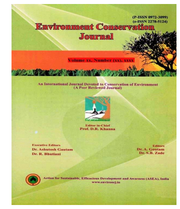

Influence of molybdenum application on soil nutrient status and uptake by cauliflower (*Brassica oleracea* var. *botrytis* L.) in an Acid Alfisol soil

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ABSTRACT

A field investigation was carried out to evaluate the impact of molybdenum (Mo) application on the yield and nutrient status of cauliflower in an acid Alfisol. The experiment comprised eleven treatments, replicated thrice in a randomized block design (RBD). The highest marketable yield of 558.8 g plant^{-1} was recorded in treatment with a recommended dose of NPK + FYM, with an increase of 29.1 percent over control (T_1). The same treatment enhanced the uptake of macro-and micronutrients. Mo application positively influenced the curd productivity and soil nutrient status, with the conjoint application (soil plus foliar) out performing other treatments. In conclusion, cauliflower crop grown on Mo deficient soil responds positively to its conjoint application (soil plus foliar). However, the sole foliar application of Mo @0.1% recorded the highest apparent nutrient recovery (ANR) and bioaccumulation factor (BAF), with corresponding values of 2.2% and 41.2, respectively.

Introduction

Green revolution renovated the agriculture sector in terms of agriculture productivity with its broader impacts on the environment. The unbalanced and unregulated use of fertilizers led to multi-nutrient deficiencies and molybdenum (Mo) not being an exception. Mo is one of the essential ultra-micro nutrient and major component of the enzymes *nitrogenase* and *nitrate reductase* that plays an important role in phosphorus utilization and protein synthesis. Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the major cole crop grown throughout the world. In India, it is being cultivated in an area of 0.45 million hectares (mha) with a production of 8.7 million MT (Anonymous, 2018). In India, 49 mha area is occupied by acid soils, of which 24.4 mha are considered moderately acidic (pH 4.5-5.5) and in the Himachal Pradesh, about 1.57 lakh ha area is under moderately acid soils (Maji *et al.*, 2012). In Himachal Pradesh, cauliflower is grown in an area of 5.56 thousand ha with a production of 131.01 thousand MT (Anonymous, 2018). Cauliflower requires a high amount of fertilizers and is very sensitive to Mo deficiency. Most common Mo deficiency symptom

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in cauliflower is whiptail where leaf-blades are not fully developed and only the midrib is present which appears as a whip (Sharma, 2002). Mo availability to the plants is strongly dependent on the soil reaction (Rutkowska *et al*., 2017), soil N levels (Elkhatib, 2009), concentration of adsorbing oxides (viz., Fe oxides), organic compounds found in the soil colloids and the extent of water drainage (Rutkowska *et al*., 2017). Molybdenum largely occurs in the soil as an oxy-complex molybdate (MoO_4^{2-}) (Mengel and Kirkby, 2001).

Mo is likely to become critical in the future for sustaining high productivity in certain areas, particularly in acidic soils. Keeping in view the future scenario, the present study was carried out with an objective to find out the appropriate method of Mo application to arrest the Mo deficiency which will have substantial effects on productivity and nutrient status. The lack of sufficient information prompted us to carry out this study in an Acid Alfisol soil of Himachal Himalaya, India. The application of Mo plays a significant role in enhancing productivity, quality, and profitability in cauliflower (Chakkal *et al.,* 2022). The present work will focus on the influence of Mo application on soil nutrient status and its uptake, which will provide major input for tackling micronutrient deficiency, particularly in areas having similar nutrient status and acidity problems.

Material and Methods

Experimental site: A field trial was carried out during *rabi* season in 2019-20 on cauliflower cv. Pusa Snowball K-1 at the experimental farm of Department of Soil Science, CSK HPKV, Palampur located at 32°09' N latitude and 76°55' E longitude at an altitude of about 1291 m above mean sea level. The study area lies in the Palam valley, district Kangra, Himachal Pradesh, India (Figure 1) representing mid-hills sub-humid agro-climatic conditions receiving an average rainfall of 2500 mm of which 25 percent is received during October to April. Taxonomically, the soil falls under order Alfisol (Typic Hapludalfs). The soils of the experimental site were silty clay loam in texture, strongly acidic with pH 5.29, organic carbon (OC) 7.11 g/kg and available nitrogen, phosphorus, potassium and molybdenum were 251, 21.2, 170 kg/ha, and 0.13 mg/kg, respectively. The respective contents of DTPA extractable iron, manganese, zinc, and copper were 16.11, 11.43, 0.71, and 0.38 mg/kg respectively.

Randomized Block Design (RBD) was used in the experiment with eleven treatments allocated randomly and replicated thrice. The treatments comprised of T_1, NPK (control); T_2, NPK + FYM (GRD); T_3, NPK+ Lime; T_4, NPK+Lime+FYM; T_5, GRD+Mo at recommended rate i.e., 1.0 kg/ha (soil); T_6, GRD+Mo at 1.5 times the recommended rate i.e., 1.5 kg/ha (soil); T_7, GRD+Mo at recommended rate of 0.1% (foliar sprays); T_8, GRD + Mo at 1.5 times the recommended rate (0.15% as foliar sprays); T_9, GRD along with Mo @1 kg/ha (soil) and @0.1% as foliar sprays; T_{10}, GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays); and T_{11}, *Subhash Palekar's Natural Farming* (SPNF).The experimental field was ploughed twice and the recommended FYM @20 t/ha was added to all treatments except in treatment NPK (control) (T_1), NPK + Lime (T_3), and SPNF (T_{11}). Lime application @ 10 t/ha was done in the treatments NPK + Lime (T_3) and NPK + Lime + FYM (T_4). In treatment SPNF (T_{11}), the cauliflower seedlings were raised by seeds soaked overnight with *beejamrit* solution @1 L/kg before sowing.

Soil application of Mo was done at the time of transplanting and its foliar sprays were applied at 45 and 60 days after transplanting (DAT). The cauliflower seedlings were transplanted in October, 2019 at row to row and plant to plant spacing of 60 and 45 cm, respectively. The N, P_2O_5, and K_2O were applied @ 115: 60: 75 kg ha^{-1} through urea (N), single super phosphate (P_2O_5) and muriate of potash (K_2O), respectively, except in treatment SPNF (T_{11}). Half dose of urea, full dose of single super phosphate (SSP), and half dose of muriate of potash (MOP) was applied at the time of transplanting. The remaining half dose of urea was applied later in two equal splits at 30 DAT and at curd initiation whereas the remaining half dose of MOP was applied at curd initiation. The *ghanjeevamrit* was applied @250 kg/ha along with FYM @250 kg/ha in the plots before transplanting. The *jeevamrit* was applied at 3-weeks interval through foliar application @50 L/ha per spray (Mahankuda and Tiwari, 2020).

Soil sampling and analysis: During layout from experimental plots three composite soil samples and individual plot samples at harvest were collected, processed and analysed for different soil properties *i.e*., available N, P, K, available Mo, and DTPA extractable micronutrient cations (Fe, Mn, Zn, and Cu) by employing standard methods (Subbiah and Asija, 1956; Olsen *et al*., 1954; Black, 1965; Lindsay and Norvell, 1978, respectively).

Plant sampling and analysis: Five plants were randomly selected at harvest to record observations for curd yield plant^{-1} and nutrient uptake i.e., nitrogen, phosphorus, and micronutrient cations by following the standard protocol (Fe, Mn, Zn, and Cu) (Jackson, 1973) and potassium (Piper, 1950) and molybdenum (Eivazi *et al.,* 1982).

Apparent nutrient recovery: It was calculated at harvest and defined as Mo accumulation in plants, divided by the total amount of Mo fertilizer (Jalpa *et al*., 2020).

Bioaccumulation factor: Bioconcentration factor (*BAF*) was calculated using standard procedure (Yashim *et al.*, 2014).

$$BAF = \frac{concentration\ of\ molybdenum\ in\ plant\ tissue\ (mg/kg)}{concentration\ of\ molybdenum\ in\ soil\ (mg/kg)}$$

Statistical analysis: One-way ANOVA (analysis of variance) for randomized complete block design was used to statistically compare (P=0.05) the effect of different treatments on yield, and quality of cauliflower as suggested by Gomez and Gomez (1984).

Results and Discussion

The results for the curd yield and the nutrient uptake are presented in the following subheadings:

Curd yield plant^{-1}: Curd yield was significantly influenced by different treatments as depicted in Figure 2(a) and varied from lowest (186.5 g/plant) in treatment SPNF (T_{11}) to highest (558.8 g/plant) in treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) which recorded a significant increase of 57.5, 29.1, 40.6, and 22.9 percent over NPK (control) (T_1), NPK + FYM (GRD) (T_2), NPK + Lime (T_3), and NPK + Lime + FYM (T_4) treatments, respectively. Similar results showing an increase in marketable yield/plant with Mo application when compared to the individual plots treated with NPK, NPK + FYM, NPK + Lime, and NPK + Lime + FYM have also been reported in pigeonpea and broccoli (Reddy *et al.,* 2007; Chowdhury and Sikdar, 2017). The higher yields in these treatments might be due to the constructive role of FYM in improving the soil health and increasing the nutrient content of soil in cauliflower (Chander and Verma, 2009) and role of lime in increasing the availability of nutrients by positively affecting the soil pH in cauliflower (Santos *et al*., 2018). Among treatments comprising of Mo application (soil or foliar), curd yield in foliar sprayed treatments (T_7 and T_8) was higher to the basal applied treatments (T_5 and T_6). The significant effect of Mo application in increasing the curd yield might be due to the role of Mo in phosphorus utilization which might have played a significant role in causing early maturity of the plant (Sahito *et al*., 2018) which prevented the curd deformation and better marketable curds compared to control. A similar experimental outcome has also been reported in cauliflower, lentil, mungbean and blackgram (Hossain *et al.,* 2018; Islam *et al.,* 2018; Khan *et al.,* 2019; Qudus *et al.,* 2020; Hossain *et al.,* 2020; Mahesh *et al.,* 2021).

Effect of treatments on nutrient uptake at harvest

Nitrogen uptake: Different treatments registered a significant effect on total nitrogen uptake (Figure 2b) and varied from 24.6 kg/ha in treatment T_{11} to 84.2 kg/ha under treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}). The treatment T_{10} registered highest nitrogen uptake when compared to the rest of the treatments, however, it remained statistically at par with treatment GRD along with Mo @1 kg/ha (soil) and @0.1% as foliar sprays (T_9). Molybdenum cofactors participate in the active site of *nitrate reductase*, which plays an important role in nitrate assimilation and might have improved the utilization rate of N fertilizer (Li *et al.,* 2017). A similar increase in the nitrogen uptake due to the Mo application was reported in many other crops *i.e*., broccoli, hairy vetch, lentil, mungbean and wheat (Ahmed *et al.,* 2011; Alam *et al.,* 2015; Pawar and Tambe, 2016; Islam *et al.,* 2018; Hossain *et al.,* 2020; Qudus *et al.,* 2020; Moussa *et al.,* 2021).

Phosphorus uptake: Significantly superior total phosphorus uptake was recorded in treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) when compared to the rest of the

Table 1: Effect of treatments on available nitrogen, phosphorus, potassium and DTPA extractable micronutrient cations.

Treatment	N	P	K	DTPA-Fe	DTPA-Mn	DTPA-Cu	DTPA-Zn
	(kg/ha)			(mg/kg)			
T_1 (NPK)	$249 \pm 1.13^{a*}$	22.2 ± 0.25^{abc}	176 ± 0.59^{a}	16.87 ± 0.13^{a}	11.58 ± 0.23^{ns}	0.47 ± 0.02^{ns}	0.79 ± 0.01^{ns}
T_2 (NPK + FYM)	245 ± 1.40^{b}	22.0 ± 0.20^{abc}	170 ± 1.48^{bc}	16.79 ± 0.17^{ab}	11.56 ± 0.10	0.45 ± 0.03	0.72 ± 0.02
T_3 (NPK + Lime)	241 ± 1.83^{cde}	22.1 ± 0.26^{abc}	167 ± 1.56^{cd}	15.81 ± 0.21^{d}	11.48 ± 0.14	0.36 ± 0.01	0.68 ± 0.03
T_4 (NPK + Lime + FYM)	244 ± 1.48^{bc}	22.7 ± 0.14^{a}	176 ± 2.09^{a}	16.09 ± 0.13^{cd}	11.54 ± 0.23	0.43 ± 0.00	0.70 ± 0.04
T_5 (T_2 + Mo @ 1.0 kg ha^{-1})	245 ± 0.70^{b}	22.4 ± 0.15^{ab}	175 ± 0.87^{a}	16.43 ± 0.15^{bc}	11.51 ± 0.22	0.45 ± 0.02	0.76 ± 0.02
T_6 (T_2 + Mo @ 1.5 kg ha^{-1})	243 ± 0.97^{bcd}	22.4 ± 0.12^{ab}	175 ± 2.40^{a}	16.41 ± 0.17^{bc}	11.49 ± 0.18	0.43 ± 0.02	0.78 ± 0.05
T_7 (T_2 + Mo @ 0.1%)	242 ± 0.99^{bcde}	22.1 ± 0.38^{abc}	172 ± 1.32^{ab}	16.37 ± 0.23^{bc}	11.47 ± 0.15	0.42 ± 0.01	0.74 ± 0.03
T_8 (T_2 + Mo @ 0.15%)	240 ± 1.63^{de}	22.0 ± 0.39^{abc}	169 ± 2.16^{bc}	16.31 ± 0.14^{c}	11.46 ± 0.13	0.41 ± 0.02	0.75 ± 0.03
T_9 (T_2 + Mo @ 1.0 kg ha^{-1} + Mo @ 0.1%)	240 ± 0.94^{de}	21.7 ± 0.16^{bcd}	167 ± 0.75^{cd}	16.31 ± 0.08^{c}	11.50 ± 0.17	0.43 ± 0.03	0.77 ± 0.01
T_{10} (T_2 + Mo @ 1.0 kg ha^{-1} + Mo @ 0.15%)	239 ± 1.28^{e}	21.6 ± 0.19^{cd}	167 ± 1.46^{cd}	16.25 ± 0.14^{c}	11.49 ± 0.11	0.41 ± 0.02	0.78 ± 0.05
T_{11} (SPNF)	232 ± 0.75^{f}	21.1 ± 0.30^{d}	163 ± 0.95^{d}	16.08 ± 0.10^{cd}	11.45 ± 0.22	0.40 ± 0.02	0.70 ± 0.03
Initial value	251	21.2	170	16.11	11.43	0.38	0.71

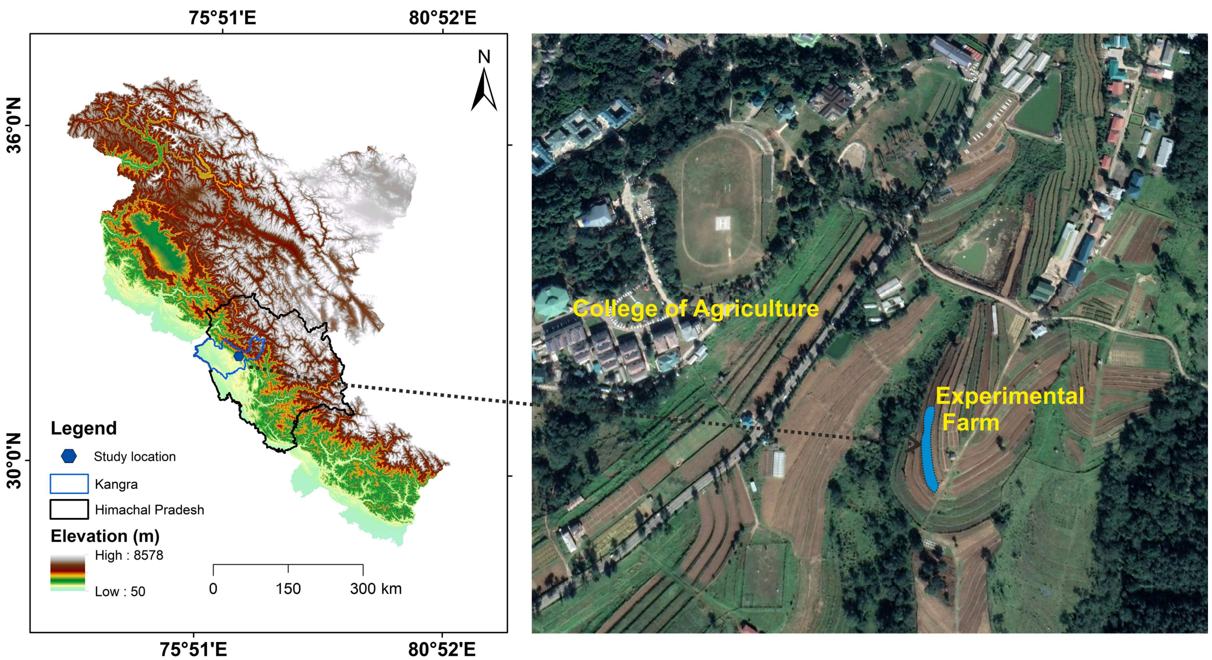

Figure 1: Location map of the study area with respect to Himachal Pradesh, India

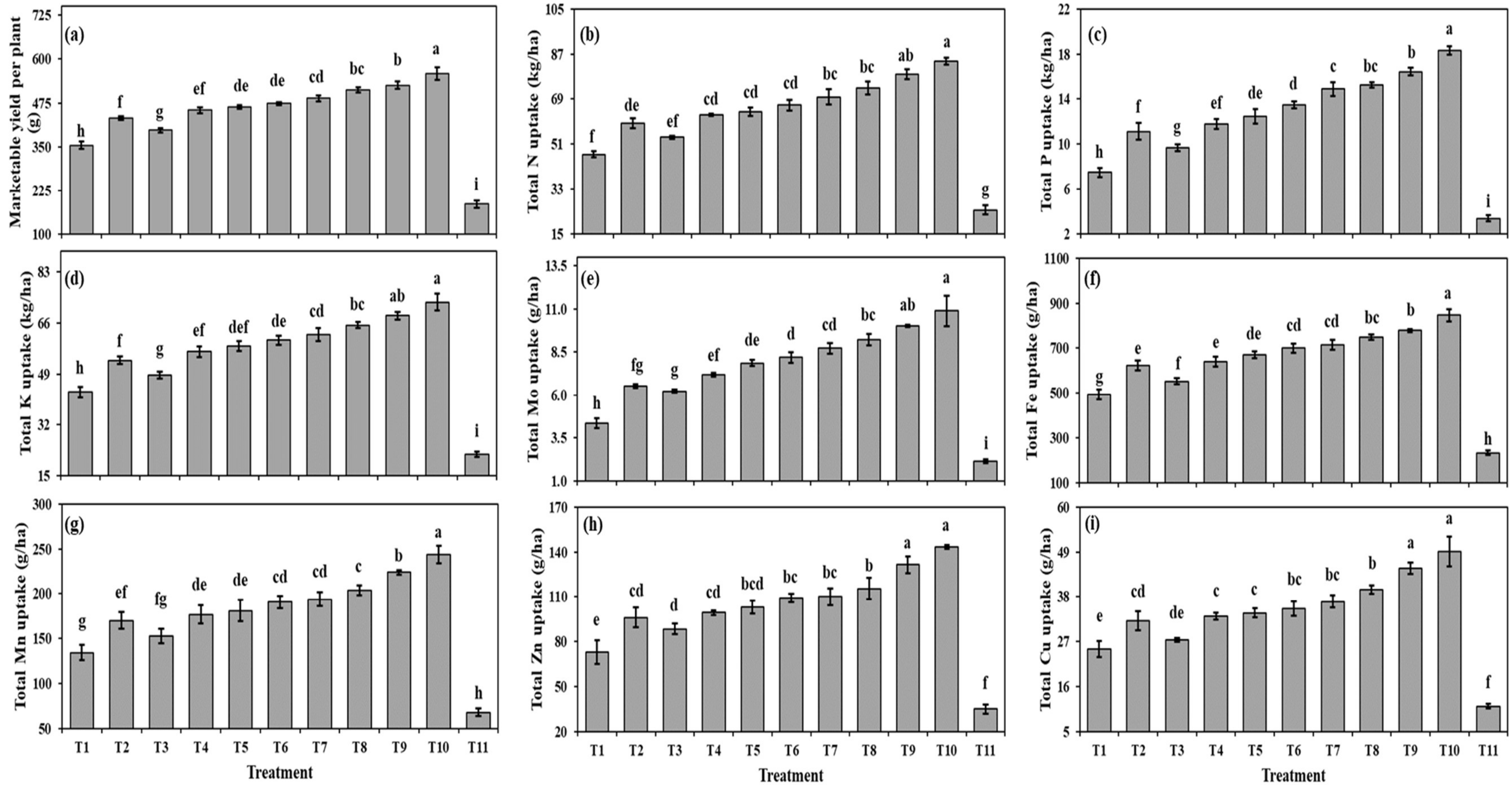

Figure 2: Effect of different treatments on (a) marketable yield plant^{-1}, (b) total nitrogen uptake, (c) total phosphorus uptake, (d) total potassium uptake, (e) total molybdenum uptake, (f) total iron uptake, (g) total manganese uptake, (h) total zinc uptake, and (i) total copper uptake.

Bars above are ± SEM, mean followed by different lower cases are significantly different by LSD (P = 0.05). Note: T_1, NPK; T_2, NPK + FYM (GRD); T_3, NPK + Lime; T_4, NPK + Lime + FYM; T_5, GRD + Mo @ 1 kg ha^{-1} (soil); T_6, GRD + Mo @ 1.5 kg ha^{-1} (soil); T_7, GRD + Mo @ 0.1% (foliar); T_8, GRD + Mo @ 0.15% (foliar); T_9, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.1% (foliar); T_{10}, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.15% (foliar); T_{11}, SPNF.

treatments (Figure 2c). However, phosphorus uptake recorded in treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) was statistically at par with the treatment GRD along with Mo @1 kg/ha (soil) and @ 0.1% as foliar sprays (T_9). The total phosphorus uptake ranged from 3.4 kg/ha in treatment SPNF (T_{11}) to 18.3 kg/ha in the treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}). A synergistic effect between phosphorus and Mo application might have led to the formation of anionic complexes between Mo and P, resulting in higher phosphorus uptake by the crop. The stimulative effect of Mo application on phosphorus uptake has also been reported by many researchers in lentil and mungbean (Islam *et al.,* 2018; Hossain *et al.,* 2020; Qudus *et al.,* 2020).

Potassium uptake: The potassium uptake varied from 22.1 kg/ha under treatment SPNF (T_{11}) to 73.0 kg/ha in the treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) (Figure 2d). Treatment T_{10} enhanced the potassium uptake followed by GRD along with Mo @1 kg/ha (soil) and @0.1% as foliar sprays (T_9) as compared to the treatments where no Mo application was applied *viz.* treatment T_1, T_2, T_3, T_4, and T_{11}. As uptake is a function of yield and higher yields were registered in the plots where Mo application was done, might have led to an increase in the potassium uptake. Similar stimulative effects of Mo application on potassium uptake were also reported by many researchers in lentil, mungbean and loquat (Islam *et al.,* 2018; Qudus *et al.,* 2020; Hossain *et al.,* 2020; Ali *et al.,* 2021).

Molybdenum uptake: The molybdenum uptake varied from 2.14 g/ha under treatment SPNF (T_{11}) to 10.89 g/ha in the treatment T_{10} as depicted in Figure 2(e). The maximum molybdenum uptake was recorded in the treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) which was significantly superior over rest of the treatments but it was statistically at par with the treatment GRD along with Mo @1 kg/ha (soil) and @0.1% as foliar sprays (T_9). As uptake is a function of yield, higher yields registered in the plots where Mo application was done, leading to an increase in the soil available Mo content, might have led to an increase in the molybdenum uptake. The results are in concordance with the finding for Mo uptake by many researchers in common bean, rice and hairy vetch (Elkhatib, 2009; Zakikhani *et al.,* 2014; Alam *et al.,* 2015). The significant increase in the molybdenum uptake in treatment NPK + Lime + FYM (T_4), over control might be due to lime's role on soil reaction and FYM creating a chelating effect, enhancing the overall uptake.

Micronutrient cations (Fe, Mn, Zn, and Cu) uptake: The lowest micronutrient cations uptake was registered in treatment SPNF (T_{11}) and highest in treatment GRD along with Mo@1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) as shown in Figure 2(f-i). The micronutrient cations uptake was found to be highest in the treatment GRD along with Mo@1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) which was significantly superior over rest of the treatments and was statistically at par with the treatment GRD along with Mo @1 kg/ha (soil) and @0.1% as foliar sprays (T_9). Mo and Fe have a similar uptake mechanism and most Mo enzymes also require Fe-containing redox groups such as Fe-sulfur clusters or hemes resulting in higher uptake of the same nutrients. The uptake is a function of yield and the increased uptake by plant indicates easy availability of Mn, Cu, and Zn in soil and higher yields were also recorded in treatments where Mo was applied. A similar finding showing an increase in Fe, Mn, Cu, and Zn uptake on Mo application were also reported by Nandi and Nayak (2008) in hybrid cabbage and Kannan *et al* (2014) in black gram.Generally, higher macronutrients and micronutrient cations uptake was recorded in all the treatments where Mo was applied along with the recommended dose of NPK as compared to the treatments devoid of Mo application *viz.,* NPK (control) (T_1), NPK + FYM (GRD) (T_2), NPK + Lime (T_3), NPK + Lime + FYM (T_4), and SPNF (T_{11}). Moreover, the incorporation of FYM was also done uniformly in all the plots where Mo was applied which improved the soil health, except in treatment NPK (control) (T_1), NPK + Lime (T_3), and SPNF (T_{11}). FYM also enhances the macronutrients and their availability by converting non-available forms into available one by its chelating action. The Mo application also improved the crop growth parameters as reported by many researchers in cauliflower and broccoli (Ningawale *et al.,* 2016; Singh *et al.,* 2018). Consequently, due to better growth parameters of cauliflower, the micronutrients present in soil were absorbed in an efficient manner which ultimately enhanced their uptake.

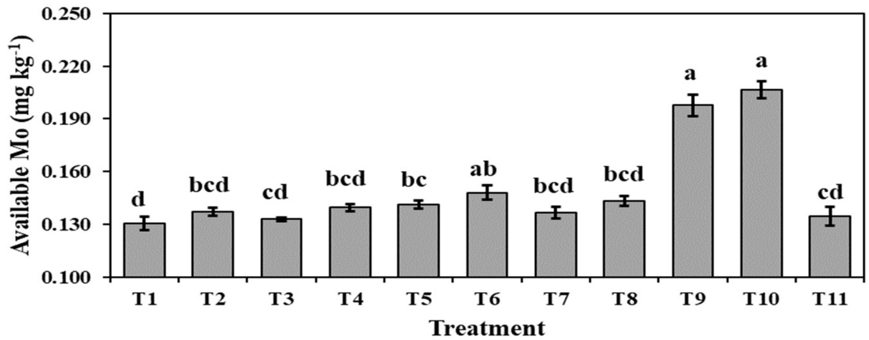

Figure 3: Effect of different treatments on available molybdenum.

Bars above are ± SEM, mean followed by different lower cases are significantly different by LSD (P = 0.05). Note: T_1, NPK; T_2, NPK + FYM (GRD); T_3, NPK + Lime; T_4, NPK + Lime + FYM; T_5, GRD + Mo @ 1 kg ha^{-1} (soil); T_6, GRD + Mo @ 1.5 kg ha^{-1} (soil); T_7, GRD + Mo @ 0.1% (foliar); T_8, GRD + Mo @ 0.15% (foliar); T_9, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.1% (foliar); T_{10}, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.15% (foliar); T_{11}, SPNF.

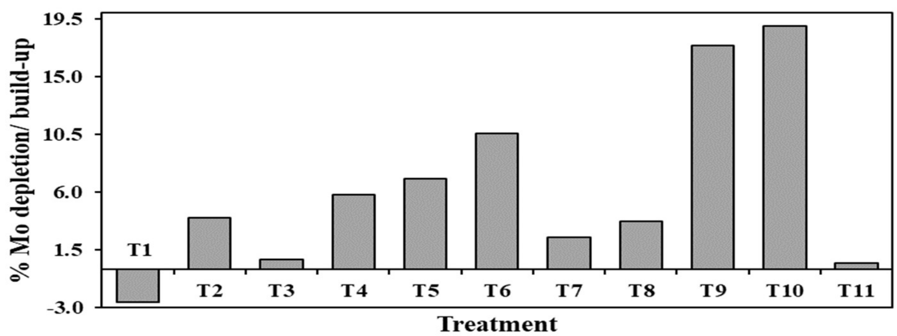

Figure 4: Effect of different treatments on build-up/depletion of soil available molybdenum over its initial status.

Bars above are ± SEM, mean followed by different lower cases are significantly different by LSD (P = 0.05). Note: T_1, NPK; T_2, NPK + FYM (GRD); T_3, NPK + Lime; T_4, NPK + Lime + FYM; T_5, GRD + Mo @ 1 kg ha^{-1} (soil); T_6, GRD + Mo @ 1.5 kg ha^{-1} (soil); T_7, GRD + Mo @ 0.1% (foliar); T_8, GRD + Mo @ 0.15% (foliar); T_9, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.1% (foliar); T_{10}, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.15% (foliar); T_{11}, SPNF.

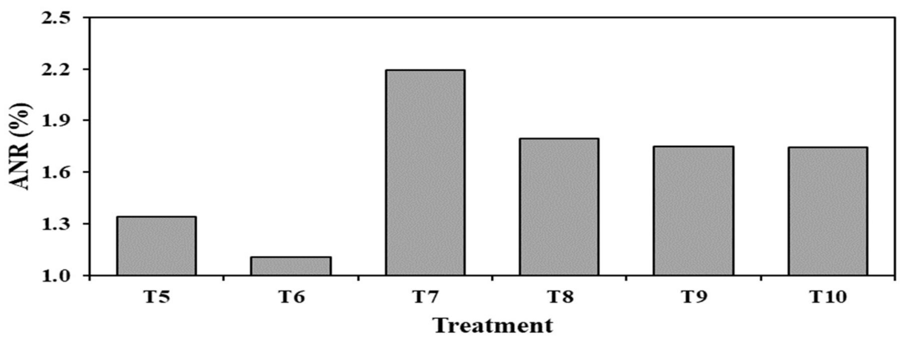

Figure 5: Effect of different rate and method of Mo application on apparent nutrient recovery (ANR).

Bars above are ± SEM, mean followed by different lower cases are significantly different by LSD (P = 0.05). Note: T_5, GRD + Mo @ 1 kg ha^{-1} (soil); T_6, GRD + Mo @ 1.5 kg ha^{-1} (soil); T_7, GRD + Mo @ 0.1% (foliar); T_8, GRD + Mo @ 0.15% (foliar); T_9, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.1% (foliar); T_{10}, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.15% (foliar).

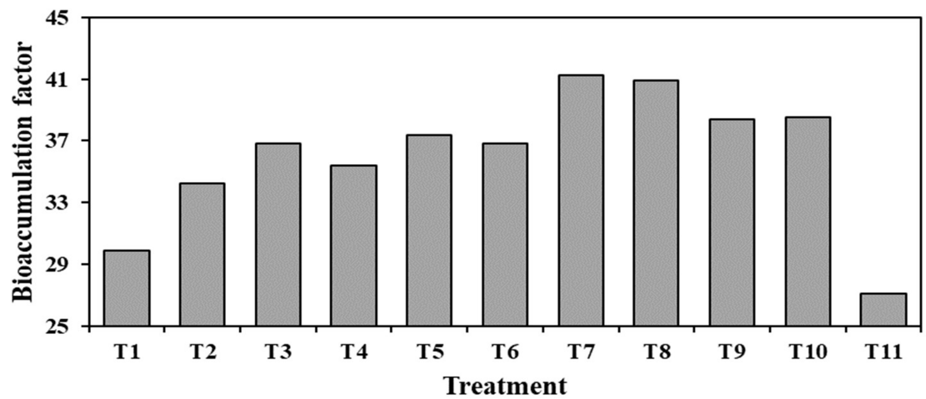

Figure 6: Effect of different treatments on bioaccumulation factor (BAF).
Bars above are ± SEM, mean followed by different lower cases are significantly different by LSD (P = 0.05). Note: T_1, NPK; T_2, NPK + FYM (GRD); T_3, NPK + Lime; T_4, NPK + Lime + FYM; T_5, GRD + Mo @ 1 kg ha^{-1} (soil); T_6, GRD + Mo @ 1.5 kg ha^{-1} (soil); T_7, GRD + Mo @ 0.1% (foliar); T_8, GRD + Mo @ 0.15% (foliar); T_9, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.1% (foliar); T_{10}, GRD + Mo @ 1 kg ha^{-1} (soil) + @ 0.15% (foliar); T_{11}, SPNF.

The higher macronutrient cations uptake which resulted from the combined (soil and foliar) application of Mo when compared to the sole foliar feeding method of Mo might be attributed to the availability of Mo in early growth stages, which was lacking in the latter method.

Effect of treatments on soil properties at harvest

Available nitrogen: There was significant difference in the nitrogen content at harvest in different treatments (Table 1) that showed a lower available nitrogen in soil, when compared with initial value (251 kg ha^{-1}). The nitrogen content at harvest in varied from 232 kg/ha under treatment SPNF (T_{11}) to 249 kg/ha in treatment NPK (control) (T_1). The treatment T_1 recorded a significant increase of available nitrogen in soil over rest of the treatments. Among the treatments receiving Mo application, recorded a depletion in available N when compared to the control. A lower N content in soil at harvest might be due to an increase in Mo application which led to an increase in growth and yield of the cauliflower and resulted in higher N uptake. Also, Mo is directly responsible for nitrogen assimilation. These similar results for the depletion in available N content with the application of Mo was also reported in pigeon pea by Reddy *et al* (2007) indicating the increased requirement of the plants.

Available phosphorus: The available phosphorus ranged from a minimum value of 21.1 kg/ha under treatment SPNF (T_{11}) to maximum value of 22.7 kg/ha in the treatment NPK + Lime + FYM (T_4) (Table 1). The highest build-up of soil phosphorus was recorded in the treatment T_4, however, it was statistically at par with treatment NPK (control) (T_1), NPK + FYM (GRD) (T_2), NPK + Lime (T_3), and the treatments where soil and foliar application of Mo was done (T_5–T_8). A higher phosphorus uptake caused due to an increase in Mo application which led to an increase in growth and yield of cauliflower might have resulted in lower phosphorus availability. These results were in conformity with the findings of Reddy *et al* (2007) in piegonpea.

DTPA extractable iron: The DTPA extractable iron was significantly affected by different treatments (Table 1) and it ranged from a minimum value of 15.81 mg/kg in treatment NPK + Lime (T_3) to the maximum value of 16.87 mg/kg in treatment NPK (control) (T_1). The highest DTPA extractable iron was registered in treatment T_1 and it was statistically at par with treatment NPK + FYM (GRD) (T_2). This increase in DTPA-Fe might be due to the effect of urea application on soil reaction and as a result of relatively lower yields registered compared to other treatments, leading to its build-up. Similar results showing an increase of DTPA extractable iron over its initial status on Mo application has also been reported earlier in piegonpea by Reddy *et al* (2007).

Available molybdenum: It ranged from a minimum value of 0.129 mg/kg in treatment NPK (control) (T_1) to the maximum value of 0.157 mg/kg (soil) in the treatment GRD along with Mo @1 kg/ha (soil) and @0.15% (foliar sprays) (T_{10}) (Figure 3). The highest soil available Mo content recorded in treatment T_{10}, was statistically at par with the treatment GRD + Mo at 1.5 times the recommended rate i.e., 1.5 kg/ha (soil) (T_6) and GRD along with Mo @1 kg/ha (soil) and @0.1% as foliar sprays (T_9). This increase in the soil available Mo content recorded in treatments where conjoint application of Mo through both, soil, and foliar application was done might be due to the addition of Mo through soil application and the drippage caused due to the foliar application. These similar results showing an increase in available Mo content on Mo application were also observed in piegonpea and hairy vetch by Reddy *et al* (2007) and Alam *et al* (2015).

Build-up/ depletion (%) of soil available molybdenum over its initial content

All the treatments registered a build-up of soil available Mo content, except for treatment NPK (control) (T_1) (Figure 4). Among different treatments, the highest build-up in soil was recorded in treatment GRD along with Mo @ 1 kg/ha (soil) and @ 0.15% (foliar sprays) (T_{10}) followed by treatment GRD along with Mo @ 1 kg/ha (soil) and @ 0.1% as foliar sprays (T_9). Furthermore, the treatment GRD + Mo at 1.5 times the recommended rate @ 0.15% (foliar sprays) (T_8), where the foliar application of Mo was done at 1.5 times the recommended rate (0.15%), registered the highest Mo use efficiency when compared to rest of the treatments. The higher build-up recorded in treatment GRD along with Mo @ 1 kg/ha (soil) and @ 0.15% (foliar sprays) (T_{10}) and GRD along with Mo @ 1 kg/ha (soil) and @ 0.1% as foliar sprays (T_9), might be due to the higher dose of Mo being applied conjointly through foliar and soil compared to its sole application.

Effect of rate and method of Mo application on apparent nutrient recovery (ANR)

Different rates and methods of Mo application influenced the ANR (Figure 5). The highest ANR was registered in treatment GRD + Mo at recommended rate @ 0.1% (foliar sprays) (T_7) (2.2%) while lowest was recorded in treatment GRD + Mo at 1.5 times the recommended rate @ 1.5 kg/ha (soil) (T_6) (1.1%). In general, the sole foliar application of Mo registered higher ANR when compared to the other methods of Mo application. This might be due to the lower rate of Mo being applied at the crucial growth and reproductive stages of cauliflower which might have led to higher uptake of fertilizer.

Bioaccumulation factor

Bioaccumulation factor ranged from the minimum value of 27.1 in the treatment SPNF (T_{11}) to the maximum value of 41.2 in the treatment GRD+ Mo at recommended rate @0.1% (foliar sprays) (T_7) (Figure 6). In general, higher bioaccumulation of Mo in plant tissue was recorded in plots treated with sole application of Mo through foliar followed by the conjoint application of Mo (soil plus foliar).

Conclusion

From the present investigation, it can be concluded that the application of Mo plays a significant role in enhancing the uptake of macro and micro-nutrients in cauliflower grown in Mo deficient soil. As a result of higher uptake, the availability of macro and micro-nutrients in soil was reduced. This demands the addition of nutrients on soil test basis for harvesting optimum crop production and subsequently maintaining soil health on a sustainable basis. The conjoint application of Mo (soil plus foliar) @1.0 kg/ha as basal and @0.15 % as foliar feeding, respectively, along with the GRD proved to be the best Mo application method to increase productivity. However, treatment with the sole application of Mo through foliar spray @0.1% recorded the highest Mo nutrient recovery and accumulation in cauliflower

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Conflict of interest

The authors declare that they have no conflict of interest.

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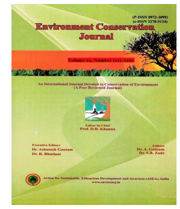

Growth, yield and economic analysis of eucalypts-barley based agroforestry system in semi-arid region of India

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ABSTRACT

The present investigation was carried out in the research area of Department of Forestry, CCS Haryana Agricultural University, Hisar during the year 2017-18 to evaluate the effect of 2.8 years old already established eucalypts plantation at 7×3 m on growth, yield attributes and yield of barley. The maximum growth increment in plant height (14.1 m) and diameter at breast height (10.3 cm) of eucalypts was recorded under agroforestry than sole eucalypts (without crop). The maximum plant height (98.5 cm), dry matter accumulation (1098.3 g/m^2), tillers/ m^2 (360.5), grain yield (3.28 t/ha), straw yield (4.32 t/ha) and biological yield (7.60 t/ha) were observed at harvesting of barley in control (devoid of eucalypts trees) than barley intercropped with eucalypts. However, maximum number of days taken for spike emergence (50 %) (97.4 days) and days to maturity (139.4 days) of barley were recorded under eucalypts plantation. The average per cent reduction of 11.33 % in effective tillers/ m^2, 15.15 % in spike length and 16.62 % in number of grains per spike in barley was recorded under eucalypts plantation over control. Maximum net return (Rs. 93347.1 ha^{-1}) was observed under eucalypts + barley cropping system than control. The overall B:C ratio was calculated higher in eucalypts based agroforestry system (1.73) over control (1.15).

Introduction

The country's total forest cover is 7,13,789 square kilometers, i.e., 21.71% of India's total geographical area (ISFR,2021). Haryana state with geographical area of 4.42 m ha is predominantly an agrarian state having 80 per cent of its area under intensive, technical and mechanical agriculture. According to ISFR (2021) report, Haryana's Forest and tree cover is 6.85 % of its total geographical area. Out of 6.85 %, the forest cover is 3.63 %, and the rest 3.22 % is the tree cover. In view of the prevailing socio-economic and agroclimatic conditions favorable for agriculture in the state, it is also not possible to divert the fertile agriculture to forest. The only option to increase area under tree

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cover is to integrate the tree species with agricultural crop on farm lands. Agroforestry system greatly contribute toward production of wood for industrial and other commercial purposes, besides maintaining ecological balance, uplifting of socio-economic status of the farmers and at the same time diversify the traditional rice-wheat crop rotation (Chauhan *et al.,* 2012). Woody perennial based production system has a great potential to combat the problem of sustainability. Historically, agroforestry in India involves two distinct pathways, *viz*; growing food crops in the forest and establishing tree crop production system on arable land (Kumar, 2006). Among mainly commercial tree species, eucalypts is considered as one of the most important agroforestry tree species in India. Brazil being the top which covers maximum area (41.17 %) of eucalypt spp. plantation followed by China (32.61 %), Chile (8.87 %), Sudan (6.54 %), Australia (6.47 %), India (2.86 %), Argentina (1.34 %) and least in Myanmar (0.09%) (Raj *et al.,* 2016). While it is considered as most water demanding due to its evergreen nature (Soare and Almeida, 2001) and also tends to show a great amount of allelopathic effect on nearby plants which causes an adverse effect on growth of nearby other plants. Eucalypts planting in India started taking shape through extension activities of the state forest departments in the late sixties and early seventies. Barley (*Hordeum vulgare*), is a nutrient rich cereal and occupies an area of 0.61 million hectare producing 1.82 million tonnes grain with productivity of 29.88 q/ha. It was cultivated on 19,400 hectares with a production of 74,000 tons in Haryana and ranked second in average productivity (38.03 q/ha) after Punjab (39.51 q/ha) during 2020-21 (ICAR-IIWBR, 2021). Eucalypts based agroforestry is also highly suitable for winter crops, such as barley, among farmers in Northern India, due to its low shading problem. Based on the tree-crop combinations, eucalypts-based agroforestry systems act as a sink and source for minerals. However, due to competition for nutrients and shading problem, generally the performance of crop grown in interspaces of eucalypts is found suppressed with lower yields (Chauhan, 2012). Hence, keeping in view the importance of agroforestry in present day context together with its importance in maintaining ecological balance and upliftment of the socio-economic status of the farmers greatly contributes toward production of wood for industries and other commercial purposes, the present investigation was planned to study the performance of barley under eucalypts based agroforestry system.

Material and Methods

The experimental site is located at 29° 10’ N latitude and 75° 43’ E longitude at an elevation of 215 m above mean sea–level in the semi-arid environment of North-Western India. The climate is subtropical-monsoonal, with an annual rainfall of 350-400 mm, 70% of which occurs between July to September. The summer months are very hot with mean maximum temperature ranging from 40 to 45°C in May and June whereas; December and January are the coldest months. The mean monthly values of weather parameters viz., temperature, evaporation and rainfall recorded at the meteorological observatory located at Research Farm, CCS Haryana Agricultural University, Hisar during the experimental period is shown in Figure 1.

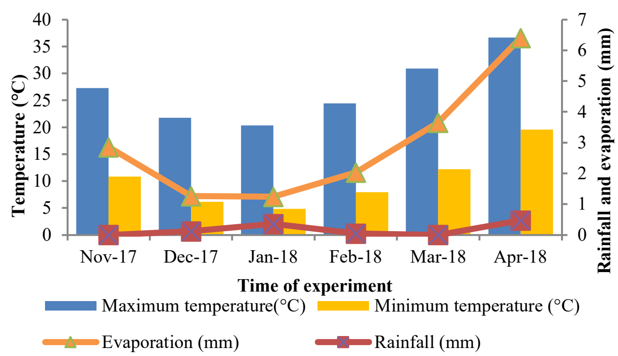

Figure 1: Monthly weather data (Temperature, Rainfall and Evaporation) of experimental site

Soil chemical properties were analyzed by following standard procedures for EC (Jackson, 1973), pH (Jackson, 1973), low organic carbon (Walkley and Black, 1934) and available nitrogen (Subbiah and Asija, 1956), medium in available P (Olsen *et al*., 1954) and available K (Jackson, 1973). The present study was conducted in 2.8 years old plantation of *Eucalyptus teriticornis* planted at a spacing of 7×3 m. During winter (*Rabi*) season, Barley (*Hordeum vulgare*) cv. BH-393 was sown under eucalypts plantation and also in control (devoid of tree) in the first week of November keeping a row to row distance of 22 cm with a seed rate of 86.45 kg/ha. In the nearby field barley was sown as control (devoid of tree). The recommended dose of fertilizers (59.28 kg N, 29.64 kg P_2O_5 and 14.82 kg K_2O ha^{-1}) were applied as per package of practices of CCSHAU, Hisar. The half amount of N and whole amount of P and K was applied at the time of sowing. The remaining dose of N through urea was top dressed at 1st irrigation. Observations on growth of barley were recorded grown under eucalypts and control (sole barley). The plant population of barley was recorded 20 days after sowing (DAS) by counting number of plants with in a running meter row length. Plant height (cm), fresh and dry matter accumulation (g) of barley was observed at 30 days interval and at harvest. For dry matter, the samples were first sun dried and then oven dried at 70°C till constant weight was attained and weighed on a digital balance. The number of days taken to 50 % spike emergence, duration of maturity, number of effective tillers, length of spike, number of grains/spike were recorded by physical appearance of plants and counting under eucalypts based agroforestry system as well as from control. Sun dried bundles of each plot were then weighed before threshing to record the biological yield and then threshed with the help of mini-plot-thresher, the clean grains obtained were weighed to record grain yield. Straw yield was obtained by subtracting the grain weight from biological yield and converted to t/ha using appropriate conversion factor. A composite sample of grains was taken from the final produce and 1000 grains were counted and weighed to record test weight in gram (g). Harvest index (%) and attraction index (%) were determined using formula:

Harvest Index (%) = [Grain yield/Biological yield] × 100

Attraction index (%) = [Grain yield/Straw yield] × 100

The height (m), diameter at breast height (cm) and crown spread (m) of ten randomly selected eucalypts under study was recorded before (October) and after harvesting of barley (April). The B: C ratio of both systems (eucalypts-barley agroforestry system and sole barley) was calculated.

Results and Discussion

Soil: The soil of experimental site is non-saline EC (0.78 dS/m), pH (7.9), low organic carbon (0.42%) and available nitrogen (140 kg/ha), medium in available P (12 kg/ha) and available K (284 kg/ha).

Growth performance of eucalypts: The overall growth pattern of eucalypts planted at 7×3 m spacing followed increasing trend with the advancement of age. The maximum growth increment in plant height (14.1 m) and dbh (10.3 cm) was recorded under eucalypts based agroforestry system after 3 year plantation. Sole eucalypts (without crops) resulted in lesser plant height (13.9 m) and dbh (10.1 cm) than planting of eucalypts with crops. However, no variation for crown spread was observed between eucalypts planted with crops and sole eucalypts (without crops). Comparatively higher growth of eucalypts with intercropping may be attributed to timely and adequate application of fertilizer, irrigation and other cultural operations. According to Pinto *et al.* (2005) the main limiting factor in agroforestry systems is the availability of solar radiation, which together with the competition for water and nutrients limits sugarcane yields in plants near to the forest species in *Eucalyptus grandis* and Sharma *et al.* (2022) observed that maximum growth of forest trees was recorded in agroforestry due to proper availability of nutrients and moisture.

Number of plants (per meter row length) and plant height (cm) :

The maximum plant population (55) of barley was recorded in control (sole crop) as compared to eucalypts based agroforestry system (44) and a reduction of 20 per cent was recorded as compared to control (Table 2). Present results are in conformity with the findings of Kumar *et al.* (2013), Chauhan *et al.* (2015) and Gawali *et al.* (2015). The maximum plant height (98.5 cm) of barley was found at harvest which is statistically at par at 120 DAS (94.8 cm) in control (sole barley). The reduction in plant height was 2.40, 11.04, 12.88, 13.29 and 15.23% at 30, 60, 90, 120 DAS and at harvest, respectively at different stages of crop growth under eucalypts plantation over control (Fig 2). The low interception of radiation under eucalypts based agroforestry system reduced the photosynthetic efficiency of barley which resulted in poor growth performance.

Table 1: Growth performance of eucalypts under agroforestry and sole eucalypts

Time	Height (m)		DBH (cm)		Crown Spread (m)	
	Agroforestry	Sole eucalypts	Agroforestry	Sole eucalypts	Agroforestry	Sole eucalypts
October,2017	12.2	12.4	9.2	9.4	2.7	2.8
April, 2018	14.1	13.9	10.3	10.1	3.1	3.1

Table 2: Number of plants per meter row length in barley at 20 DAS under eucalypts plantation and control

Treatments	Number of plants per meter row length
Eucalypts + Barley	44
Control (Sole barley)	55
t-value	7.99*

Table 3: Phenology of barley under eucalypts plantation and control

Treatments	Number of days taken	
	Spike emergence (50%)	Maturity
Eucalypts + Barley	97.4	139.4
Control (Sole barley)	82.2	123.5
t-value	12.16*	12.98

Table 4: Yield attributes of barley under eucalypts plantation and control

Treatments	Yield attributes			
	Number of effective tillers/m^2	Length of spike (cm)	No of grains/spike	Test weight (1000 grain wt) (g)
Eucalypts + Barley	312.4	11.2	32.1	36.4
Control (Sole barley)	352.3	13.2	38.5	41.2
t-value	16.76*	1.63	4.96*	3.48*

*** Significant at 0.05 per cent level of P**

Table 5: Economics of eucalypts + barley based agroforestry system and control (sole barley)

Particulars	Agroforestry	Sole crop (barley)
Cost of cultivation (Rs./ha)	127097.3	46920.5
Gross return (Rs./ha)	220444.4	53994.2
Net return (Rs./ha)	93347.1	7073.7
Cost/benefit ratio	1.73	1.15

Bhardwaj *et al.,* (2017) observed that the growth of barley crop was poor near the tree line when it intercropped with eucalypts boundary plantation and it increase with the increases of distance from tree line. The present findings are in line with the findings of Kumar *et al.* (2013) and Bisht *et al.* (2022) who reported that plant height of wheat was significantly more in sole crop than the intercropping with trees.

Fresh and dry matter accumulation (g/m^2): The maximum dry matter accumulation of barley in eucalypts plantation was found at the time of crop harvest however, lowest dry matter accumulation was recorded at 30 DAS. Barley grown in interspaces of eucalypts plantation showed a maximum reduction in fresh weight (Fig 3) and dry weight (Fig 4) 29.76%, 57.99%, 13.59%, 15.8%, 11.36% and 27.42%, 21.32%, 12.98%, 15.25% and 10.01% at 30, 60, 90, 120 DAS and at harvest, respectively than in control (devoid of tree). The lower fresh and dry matter accumulation of barley under eucalypts based agroforestry system might be due to the low availability of sunlight and more competition between tree and crop for moisture and nutrients than in control (devoid of tree). Similar findings are in close agreement with Bisht *et al.* (2022) who reported that the dry matter accumulation by different wheat varieties also

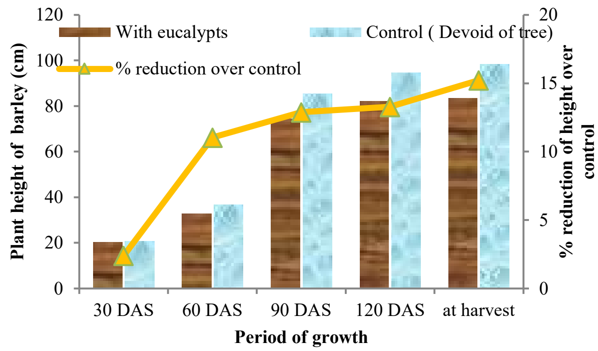

Figure 2: Plant height (cm) of barley at different time intervals under eucalypts plantation and control (sole barley)

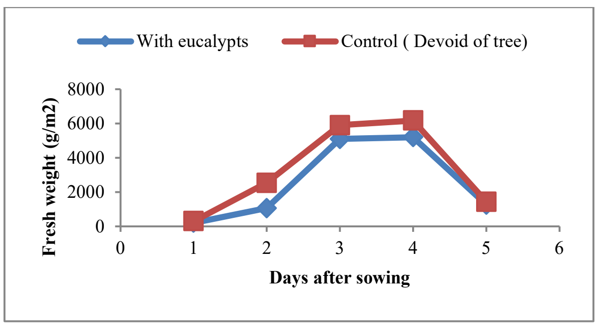

Figure 3: Fresh matter accumulation (g/m²) at 30 days interval in barley under eucalypts plantation and control (sole barley).

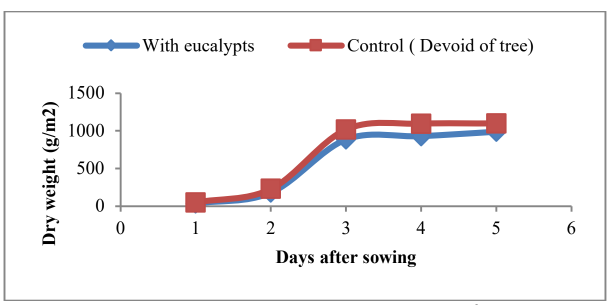

Figure 4: Dry matter accumulation (g/m²) at 30 days interval in barley under eucalypts plantation and control (sole barley).

differed significantly among different spacings of eucalypts. Kumar and Rajput (2005) also reported that total dry matter accumulation differed significantly among wheat varieties under poplar based agroforestry system and under control. They further reported that variety UP 2338 recorded significantly more dry matter over all other varieties (WH 542, Raj 3077, PBW 154, HD 2285, HD 2329, UP 2113, UP 2003, PBW 226, UP 262 and PBW 343).

Number of tillers/m² : The maximum numbers of tillers were observed at 120 DAS and at harvest in both the systems (agroforestry and control). The average increase in the number of tillers between 60 to 90 DAS was higher as compared to increase between 90 to 120 DAS under eucalypts plantation as well as in control (Fig 5). However the numbers of tillers under eucalypts based cropping system reduced upto of 10.57 per cent over control (devoid of trees). Bijalwan and Dobriyal (2014) studied different varieties of wheat under *Grewia optiva* traditional agroforestry system. Results revealed that number of effective tillers was higher in control than agroforestry system. Kohali *et al.* (1997) reported that lesser number of tillers under poplar agroforestry system due to shading effect.

Phenological characters: The maximum number of days taken for spike emergence (50%) and days to maturity in barley were higher under eucalypts plantation in comparison to control (sole crop). In eucalypts based cropping system, both the phonological characters (spike emergence and maturity) of barley were delayed by about 15 days over control (sole crop) was possibly due to deprived photosynthetic ability of crop. Kumar *et al.* (2013) conducted a field experiment on wheat and mustard under eucalypts plantations. Results showed that spike length was significantly less under eucalypts than sole cropping. Daniel and Larkin (2017) also reported that grain per spike was more in control than agroforestry system.

Effective tillers/m², length of spike (cm),number of grains per spike and test weight (g): The reduction in effective tillers of barley under eucalypts was 11.33 per cent over control. The maximum spike length (13.2 cm) was observed in control (sole crop) as compared to eucalypts based agroforestry system (Table 4). Barley exhibited 15.15 per cent reduction in spike length under eucalypts plantation over control. These results are in line with the findings of Chauhan *et al.* (2011). They reported that the rate of decrease in spike length of wheat was 33.6% in 6 year old poplar plantation than control which ultimately reflected the grain yield. In sole barley maximum numbers of grains/spike were recorded whereas, minimum under eucalypts plantation. The reduction in the number of grains per spike was 16.62 per cent under eucalypts based agroforestry system over control (sole barley).

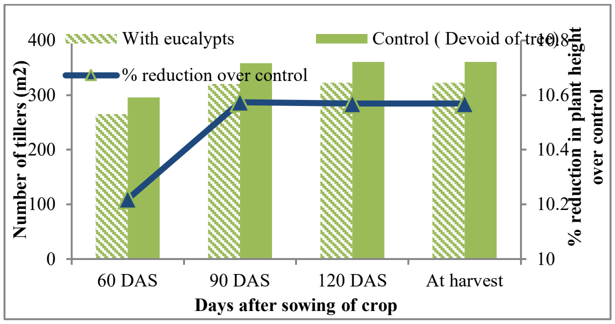

Figure 5: Number of tillers (m^2) in barley at 60, 90, 120 days after sowing and at harvest under eucalypts plantation and control (sole barley)

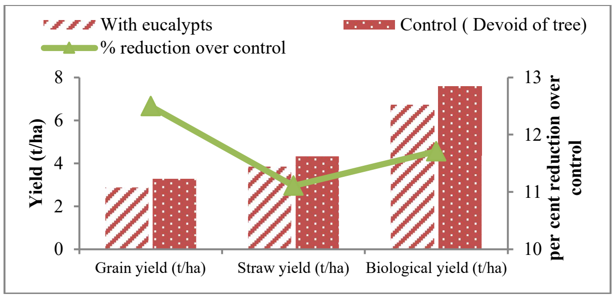

Figure 6: Grain, straw and biological yield (t/ha) of barley under eucalypts plantation and control (sole barley)

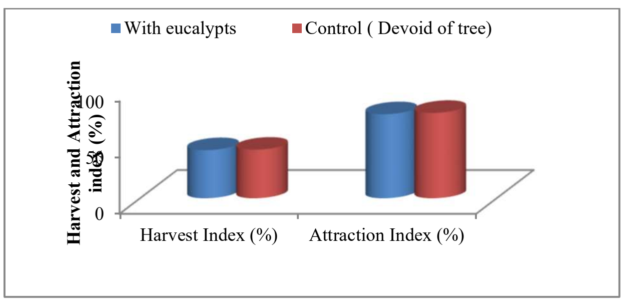

Figure 7: Harvest and attraction index (%) of barley under eucalypts plantation and control (sole barley)

Similar findings were also reported by Gandhi (2008) who found that the lower number of grains/spikes of wheat under poplar planted at 6×1.5 m, 6×3 m and 5×4 m spacing as comparison to control. Corroborative findings have also been reported earlier by Clemente *et al.* (2015) under *Eucalyptus teriticornis* based agroforestry system. In control, barley crop exhibited significantly higher test weight (41.2g) than under eucalypts based agroforestry system (36.4g). The reduction in test weight of barley was11.65 per cent under eucalypts plantation over control (devoid of tree). A significant decrease in 1000-garin weight of different agricultural crops under *Eucalyptus camaldulensis* based agroforestry system was reported by earlier Ahmed *et al.* (2008). Kumar *et al.* (2013) also reported the corroborative results which showing the reduction in test weight (26.7 g) of wheat under eucalypts based agroforestry system due to shade than in sole cropping system.

Grain, straw and biological yield (t/ha): The grain yield of barley was observed maximum (3.28 t/ha) in control (sole crop) than eucalypts. The per cent decrease in grain yield of barley under eucalypts was 12.50 % over control. The per cent reduction in straw yield of barley was 11.11% under eucalypts plantation over control (devoid of trees). However, the rate of decrease in straw yield was comparatively lower than grain yield of barley under eucalypts based agroforestry system. The maximum biological yield (7.60 t/ha) in barley was observed under control as compared to eucalypts based agroforestry system (Fig 6). Whereas, the biological yield of barley under eucalypts plantation reduced up to 11.71 % over control (sole barley). The reduction in the grain yield of barley under eucalypts based agroforestry system may be due to availability of low light and more competition for moisture and nutrients. Bhardwaj *et al.* (2017) reported that the grain yield of barley was significantly affected at different distances of eucalypts boundary plantation. Presents results are in agreement with the findings of Sharma *et al.,* (2007), Chauhan *et al.,* (2012) and Alebachew *et al.,* (2015) in different tree based agroforestry systems. Barley yield reduction under eucalypts based agroforestry system was also been recorded earlier by several research workers (Kohli and Saini (2003) and Kumar *et al.,* (2013).

Harvest and attraction index (%): The harvest and attraction index (%) of barley was significantly affected by eucalypts plantation (Fig 7). The results showed that sole barley (control) exhibited maximum harvest and attraction index (43.16 and 75.93%) than eucalypts based cropping system. The per cent reduction in harvest and attraction index of barley under eucalypts was 0.90 and 1.57 %, respectively over control. This deviation in harvest and attraction index might be due to the variation in total biomass production under agroforestry system. Bijalwan (2014) results revealed that harvest index varied from 16.42% (*Amaranthus caudatus*) to

45.01% (*Phaselolus vulgaris*) in summer season and 27.49 (*Brassica campestris*) to 47.15 (*Pisum sativum*) in winter season in northern aspect under agri-horticulture system. While the harvest index in the southern aspect varied from 26.44 (zea mays) to 47.05 (*Phaseolus vulgaris*) in summer and 24.94 (*Coriandrum sativum*) to 47.37 (*Pisum sativum*) winter season under agr-ihorticulture system. Gawali *et al.* (2015) observed that harvest index was reduced under closer spacing of poplar and highest straw yield under sole cropping.

Economic analysis of the eucalypts based agroforestry system:The maximum cost of cultivation (Rs. 127097.3/ha) and gross returns (Rs. 220444.4/ha) were found higher in barley under eucalypts based cropping system while the minimum in sole cropping. However, higher net return (Rs. 93347.1/ha) and benefit-to-cost ratio (B:C ratio) was recorded under eucalypts + barley system i.e. 1.73. The results are in line with Dhillon *et al.* (2018) who reported that higher gross return in eucalypts-barley agroforestry system over sole cropping of barley. Kaushik *et al.* (2017) also reported that horti-silvicultural systems showed maximum return in association with the field and vegetable crops. The loss in crop yield under eucalypts can be compensated by the income returns from the tree component at the end of the rotation. Satyawali *et al*, (2018) also reported that eucalypts based agroforestry system fetched higher net retruns as compared to melia.

Conclusion

In the present investigation of eucalypts-barley based cropping system, grain yield of barley was observed maximum (3.28 t/ha) in control (sole barley). However, the grain yield reduction in barley intercropped with eucalypts plantation (7x3 m) was 12.50 per cent over control**.** The maximum gross return (Rs. 220444.4/ha) as well as maximum net return (Rs. 93347.1/ha) were observed under eucalypts + barley-based agroforestry system as compared to sole cropping (control). Similarly, maximum B:C ratio (1.73) was also analyzed under eucalypts + barley cropping system. This study concludes that eucalypts-based agroforestry system will be more remunerative to the farmers than sole cropping.

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Conflict of interest

The authors declare that they have no conflict of interest.

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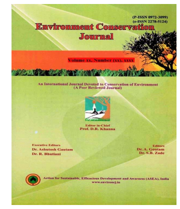

Evaluation of the fertility status of flooded soils in the Saharsa District, Bihar

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ABSTRACT

The sampling location was Saharsa, which is one of Bihar's most flood-prone area Flooding is the leading source of soil degradation in the district. The current study was carried out in the Soil Science and Agricultural Chemistry laboratory at Sam Higginbottom University of Agriculture Technology and Sciences. 27 samples were collected from several farmer's fields, and composite sampling was carried out from three depths of 0-15, 15-30, and 30-45 cm. The results revealed that the texture was sandy loam to sandy clay, bulk density ranged from 1.11 to 1.59 Mg/m^3, particle density ranged from 2.22 to 2.85 Mg/m^3, pore space ranged from 52.60 to 66.50 % and water holding capacity ranged from 61.11 to 78.12 %. The pH ranged from 6.58 to 7.65, E.C. from 0.17 to 0.39 dS/m,(Due to Flooding) Soil Organic Carbon ranged from 0.74 to 1.20 %, Soil has acceptable Bd, Pd, pore space, and water holding capacity. As a result of the beneficial electrical conductivity for plants, the pH of the soil is neutral to alkaline. Sodium is low to medium in range. Low to medium levels of macronutrients are found in nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. By employing the proper management techniques and supplying the soil with enough nourishment for plant growth, farmers must maintain the health of their soil.

Introduction

One of the planet's most dynamic and intricate natural processes is referred to as "soil." Since it provides a medium for plant growth and fulfils the bulk of organisms' nutritional demands, it is essential for the existence of many sorts of life. On the surface of the planet, soil is a natural, living substance that sustains plant development (Zaware, 2014). Both good and bad things happen as soil is developed. Rock fragments that have been eroded and weathered by mechanical, chemical, and biological processes make up soil. Numerous tasks carried out by soil benefit both people and other living things. More than just a smattering of mineral granules make up soil. In addition, it has a few more elements and a biological system with living things. Soil testing tells farmers how much and what sort of fertiliser to be used to ensure that their efforts in other better practises pay off good yield and return for their produce (Joshi *et al.*, 2013. Due to geography, climate, physical weathering processes, vegetation cover, microbiological activity, and a variety of other biotic and abiotic variables, the physico-chemical characteristics of distinct soils vary in space and

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time (Tale and Ingole 2015, Bhardwaj *et al.,* 2020). The most serious challenge facing Indian soil is soil degradation. Soil degradation can be both physical and chemical in nature. Natural factors and human activity both contribute to the degradation of soil. India is finally reaping the benefits of its decades of sowing (Supriya, 2021). The majority of soil erosion happens as a result of somewhat large and frequent rainfall events. Normal soil erosion in places with natural vegetation ranges from 0.1 to 0.2 kg/m^2 (Morgan, 1986). Because the Physico-chemical properties of soil determine food productivity and environmental quality, it is critical to have a fundamental understanding of these qualities, Soil characteristics (Tale *et al*., 2015; Ruhela *et al.,* 2022). Intensive farming can have detrimental effects on soil, including soil erosion, compaction, nitrification, acidity, desertification, loss of organic matter, contamination with heavy metals and agrochemicals, and desertification. Such degradation may be brought on by incorrect farming techniques such overfertilization, careless pesticide application, and the use of large machinery. Two significant soil attributes—nitrification and CaCO3 concentration—are employed in the current research as sub-criteria layers of the soil criterion hierarchy tree to analyse the influence on soil and the induced benefit from a switch to precision farming practises. Intensive cropping practises deplete N, P, and K in surface and subsurface soil, which can be replenished by applying manures and fertilisers together. The pH and electrical conductivity of soil are controlled by the application of manures and fertilisers (Dhaliwal *et al*., 2019). Incorporating a legume crop into a cropping system can improve soil physical and chemical qualities, especially in rice-growing regions (Kumar *et al*., 2020). Both soil nutrient availability, soil health, and crop growth may benefit from a balanced application of organic and inorganic fertilisers (Das *et al*., 2021). In order for crop and animal productivity to be sustained, environmental sustainability to be maintained or increased, and global human health to be improved, soil function must occur within ecosystem limits. Anthropogenic activities, such as favoured farming techniques and intensive land-use management, can alter the soil health in agro-ecosystems, which can further effect soil functions. The majority of previous evaluations of soil health in agriculture have been based on ecological functions of the soil that are linked with non-biological elements like soil nutrients and soil structures. Soil health is closely associated with sustainable agriculture, because soil microorganism diversity and activity are the main components of soil health. A agricultural system that "must be resource-conserving, socially supportive, commercially competitive, and environmentally sound" in order to "keep their productivity and usefulness to society for an infinite period of time."Sustainable development will require healthy soils, not only for increased agricultural production as a growing global population requires more food, but also to ensure sustainability of critical ecosystem services. (Sahu *et al*., 2021).

Material and Methods

The Gangetic Plain, the most fertile alluvial plain in the world, is where Bihar is situated. Latitude: 24°-20'-10" 27°-31'-15" N, Longitude: 83°-19'-50" 88°-17'-40" E. Soil samples were taken at depths of 0-15cm, 15-30cm, and 30-45cm from farms in nine villages using a soil auger, screw auger, and khurpi (Table 1 and Figure 1). The samples were air dried in the shade after composite sampling, and then processed for various physical and chemical analyses. The data collected throughout the inquiry was subjected to statistical analysis using the Completely Randomized Design (CRD) approach and by Opstat software. f-test, S.Ed (±) and C.D @ 5% were calculated in Mx Excel by Opstat software. In f-test Significant (S) and Non-Significant (NS) were determined by comparing the value of F(cal.) with F(tab.) at 5%. If F(cal) value is greater than F(tab.) at 5% then result is Significant and vice-versa. The Sampling site of Saharsa District are represented in Table. 1 in which all 9 villages are written and Site specification are shown in Fig 1. Method of Analysis and their Scientist name for different physical and chemical properties are respectively, Muthuaval *et al*., 1992 calculated the bulk density of soil and represented by (Mg/m^3), Muthuaval et al., 1992 calculated the particle density of soil and represented by (Mg/m^3), Jackson, 1973 used a digital pH metre to record the pH of the soil. Wilcox, 1950 used a digital conductivity metre to determine the electrical conductivity (dS/m) of the

Table 1: **Representing the Sampling site of Saharsa District**

SN	Block	Village	Latitude(^{0}N)	Longitude (^{0}E)
01	Kehra	S_1 – Kahra	25.8978	86.5866
		S_2 – Chainpur	25.8972	86.5873
		S_3 - Rohua mani	25.7246	86.6041
02	Mahishi	S_4 – Jajori	25.8395	86.4669
		S_5 – Bijwar	25.8679	86.4858
		S_6 – Gamrahu	25.8648	86.5009
03	Simri Bakhtiyarpur	S_7 – Teghra	25.4195	86.3526
		S_8 – Chapram	25.4259	86.3459
		S_9 – Baghwa	25.4208	86.3483

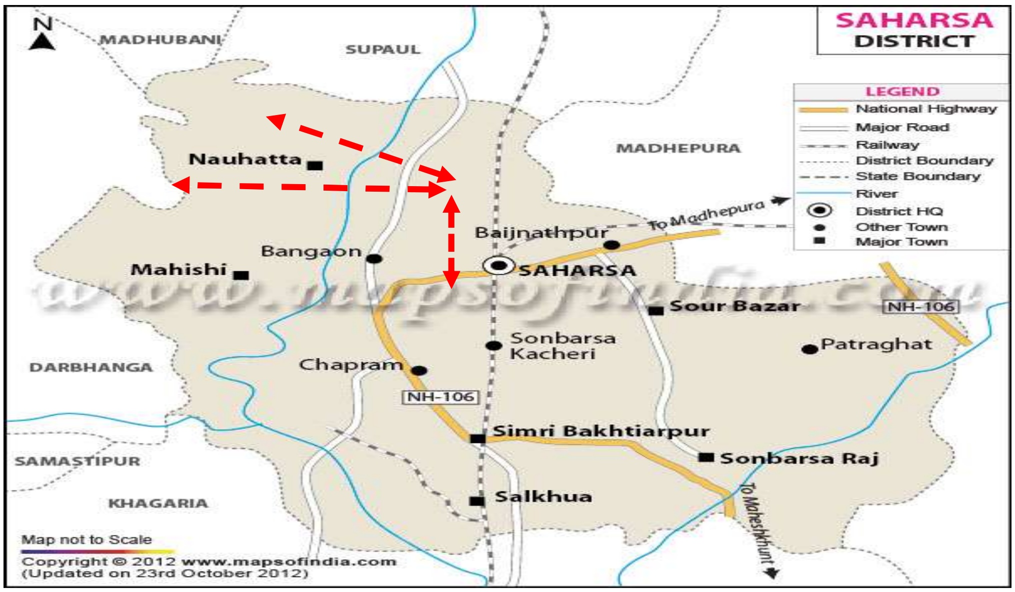

Fig.1 Saharsa map https://www.mapsofindia.com/maps/bihar/districts/saharsa.htm

soil. The organic carbon content (%) of the soil was determined using the wet oxidation method developed by Walkley and Black in 1947. Subbiah and Asija (1956) proposed a modified alkaline permanganate oxidation method for measuring available nitrogen (Kg/ha). The 0.5 M sodium bicarbonate method (Olsen's extractant) was used to assess available Phosphorus (Kg/ha) in soil. Available Potassium (Kg/ha) was determined using the neutral normal ammonium acetate (pH 7.0) method established by Jackson in 1958 with a flame photometer. Exchangeable Ca^{2+} and Mg^{2+}[cmol (p^+)/kg] was determined by EDTA method developed by Jackson, 1973. Available Sodium (mg/l) was determined using the method Flame photometer given by Richard *et al.*, 1954. Bardsley and Lancaster, 1960 used Turbidimetric method to measure the amount of Available Sulphur (ppm).

Results and Discussion

Variation in Physical Properties of Saharsa District at different depths.

In the Saharsa district, the texture ranges from sandy loam to sandy clay. The percentages of sand, silt, and clay range from 71.40-30.35 percent, 41.50-10.33 percent, and 34.08-17.20 percent, respectively observed during Experiment (Table 2), similar result was reported by (Marbaniang *et al.*, 2021). Table 3 represents physical properties of soils Saharsa district. Bulk Density varied from 1.11 and 1.59 Mg/m^3. The maximum value of 1.59 Mg/m^3 was found in S9 (30-45 cm depth) while the least value was found in S4 (0-15 cm depth) is 1.11 Mg/m^3. The Bulk Density increases with the increase in soil depth. The reason is soil compactness, which will be more at high depth, similar result was reported by (Singh *et al.*, 2020). Particle density ranged from 2.22 to 2.85 Mg/m^3. S5 has the highest value of 2.85 Mg/m^3 (30-45 cm depth). with the lowest

Table 2: Soil texture of Saharsa District. (observed during Experiment)

Farmer's site / Treatment	% Sand	% Silt	% Clay	Textural class
S_1: (Kahra)	70.00	12.8	17.2	Sandy Loam
S_2: (Chainpur)	44.5	21.6	33.6	Clay Loam
S_3: (Rohua mani)	67.2	10.4	22.40	Sandy Loam
S_4: (Jajori)	31.6	38.4	30.00	Sandy Clay
S_5: (Bijwar)	30.4	41.5	28.1	Sandy Clay
S_6: (Gamrahu)	56.6	15.4	28	Sandy Clay Loam
S_7: (Teghra)	68.2	12.6	19.2	Sandy Loam
S_8: (Chapram)	71.4	11.2	17.4	Sandy Loam
S_9: (Baghwa)	69.2	12.8	18	Sandy Loam

Table 3: Evaluation of Physical properties of soils Saharsa district

	P_b (Mg/m^3)		**D_p (Mg/m^3)**		**Pore Space (%)**		**WHC (%)**	
Treatment/ Farmer's site	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Range**
S_1: (Kahra)	1.31-1.42	1.37	2.22-2.78	2.53	66.51-61.5	63.55	65.15-61.11	63.29
S_2: (Chainpur)	1.32-1.45	1.39	2.35-2.82	2.60	61.15-57.25	58.90	65.15-64.66	64.97
S_3:(Rohua mani)	1.33-1.44	1.39	2.68-2.85	2.77	64.02-58.5	61.19	69.14-67.77	68.37
S_4: (Jajori)	1.11-1.28	1.21	2.41-2.78	2.57	54.12-52.6	53.34	78.12-72.09	75.16
S_5: (Bijwar)	1.17-1.22	1.19	2.60-2.85	2.76	54.80-53.2	53.86	76.66-64.61	70.61
S_6: (Gamrahu)	1.38-1.45	1.41	2.45-2.71	2.6	62.11-52.8	58.98	70.58-68.16	68.99
S_7: (Teghra)	1.31-1.39	1.35	2.31-2.80	2.58	56.41-55.05	55.78	64.45-63.08	63.62
S_8: (Chapram)	1.41-1.47	1.41	2.32-2.75	2.58	57.91-56.2	57.20	71.14-69.71	70.5
S_9: (Baghwa)	1.51-1.59	1.55	2.35-2.76	2.56	56.21-54.45	55.24	66.77-64.74	65.73
	Due to depth	Due to site	Due to depth	Due to site	Due to depth	Due to site	Due to depth	Due to site
F-test	S	NS	S	NS	S	NS	NS	NS
S.Ed (±)	0.019918	0.132554	0.1853	0.087704	1.326729	3.106753	2.186522	3.636299
C.D @5%	0.594333	0.000246	1.61006	0.051458	0.182575	0.016482	0.025598	0.006429

P_b= Bulk Density, D_p= Particle Density, WHC= Water Holding Capacity.

value of 2.22 Mg/m^3 reported in S1 (0-15 cm depth) Particle Density varies according to the mineral content of the soil particles similar result was reported by (Majhi *et al*., 2020). Pore Space (%) varied between 52.60 and 66.50. (%). S1 (0-15 cm depth) had the highest value of 66.50 %, while S4 (30-45 cm depth) had the lowest value of 52.60 percent (%) Pore Space was found to decrease with increase in depth attributed to increase in compaction in the sub surface. Surface soils are having high amount of macro and micro pores compared to sub surface soils due to presence of high organic matter similar result was reported by (Yuvarani *et al*., 2019). The water storage capacity (%) varied between 61.11 and 78.12 %. S4 (0-15 cm depth) had the highest value of 78.12 %, while S1 (30-45 cm depth) had the lowest value of 61.11. % WHC value decreases with the increasing depth because of soil compaction and reduction in pore space similar result was reported by (Tale *et al*., 2015).

Variation in Chemical Properties of Saharsa District at different depths (Table 4 and 5).

The pH was between 6.58 and 7.65. S1 (30-45 cm depth) had the highest value of 7.65 and S1 (0-15 cm depth) had the lowest value of 6.58, showing that the soils are moderately neutral to alkaline. pH value increases with the increasing depth because the upper horizons receive maximum leaching by rainfall and by dissolved carbonic acids and presence of high amount of exchangeable sodium ions, similar result was reported by (Marbaniang *et al*., 2021).

Table 4: Evaluation of Chemical properties of soils of Saharsa District

	pH		EC (dS/m)		O.C(%)		CEC (cmol (p+)/kg)	
Treatment/ Farmer's site	Range	Mean	Range	Mean	Range	Mean	Range	Range
S_1: (Kahra)	6.58-7.65	7.01	0.19-0.27	0.22	1.14-0.72	0.96	10.28-13.08	11.64
S_2: (Chainpur)	6.66-7.24	6.91	0.29-0.39	0.34	0.98-0.67	0.85	15.37-15.74	15.55
S_3:(Rohua mani)	6.82-7.41	7.12	0.17-0.28	0.22	1.10-0.59	0.86	11.49-11.96	11.77
S_4: (Jajori)	6.66-7.38	6.98	0.25-0.39	0.32	1.19-0.73	1.00	13.85-14.18	14.06
S_5: (Bijwar)	6.96-7.32	7.15	0.18-0.19	0.18	0.95-0.58	0.81	14.08-14.74	14.40
S_6: (Gamrahu)	7.12-7.58	7.32	0.24-0.35	0.29	0.89-0.61	0.77	14.23-14.68	14.51
S_7: (Teghra)	6.67-7.38	7.00	0.26-0.39	0.33	1.12-0.57	0.91	11.23-11.83	11.54
S_8: (Chapram)	7.08-7.48	7.29	0.21-0.24	0.23	1.17-0.77	1.02	12.34-13.12	12.74
S_9: (Baghwa)	7.14-7.62	7.10	0.28-0.37	0.33	1.20-0.74	1.02	11.33-12.88	12.16
	Due to depth	Due to site	Due to depth	Due to site	Due to depth	Due to site	Due to depth	Due to site
F-test	S	NS	S	S	S	S	S	S
S.Ed (±)	0.300605	0.139682	0.1853	0.087704	0.094086	0.059933	0.445796	1.49194
C.D @5%	0.594333	0.000246	1.61006	0.051458	6.64	3.14	0.003134	4.23628
pH-potential of hydrogen, EC- Electrical Conductivity, O.C-Organic Carbon and CEC- Cation Exchange Capacity.								

Table 5: Evaluation of Macronutrients of soils of Saharsa District.

	Avl N (Kg/ha)		Avl P (Kg/ha)		Avl K (Kg/ha)		Avl S (ppm)	
Treatment/ Farmer's site	Range	Mean	Range	Mean	Range	Mean	Range	Mean
S_1: (Kahra)	411.12--354.28	381.52	10.79-8.74	9.70	88.41-76.39	82.08	11.39--8.31	9.82
S_2: (Chainpur)	288.35--271.69	298.80	19.21-15.58	17.55	172.7-141.52	151.61	16.18-14.74	15.52
S_3:(Rohua mani)	338.24--274.66	304.78	9.97-8.89	9.42	78.3-81.44	81.95	12.08--10.96	11.59
S_4: (Jajori)	264.92--243.68	268.92	17.68--14.76	16.30	153.72-128.68	141.63	14.68--13.76	14.22
S_5: (Bijwar)	274.77--253.29	284.87	17.48--14.39	15.98	148.76-126.38	138.34	14.77--13.82	14.29
S_6: (Gamrahu)	278.66--244.77	270.33	15.45-12.14	14.09	85.23-81.49	87.00	13.88--12.59	13.17
S_7: (Teghra)	406.54--352.79	379.18	10.88-8.39	9.61	83.62-74.24	77.39	10.89--8.77	9.83
S_8: (Chapram)	384.93--323.66	354.59	9.44-7.28	8.46	76.42-64.12	71.14	9.86--6.83	8.11
S_9: (Baghwa)	424.27--356.24	380.8367	9.55-7.40	8.55	92.26-77.67	85.57	10.45--8.39	9.52
	Due to depth	Due to site	Due to depth	Due to site	Due to depth	Due to site	Due to depth	Due to site
F-test	S	S	S	S	S	S	S	S
S.Ed (±)	30.0328	87.7572	1.27816	1.2691	6.361463	32.63397	2.186522	3.636299
C.D @5%	2.081008	0.00642	5.35	6.34	0.00351	4.35011	0.025598	0.006429
Avl N = Available Nitrogen, Avl P = Available Phosphorus, Avl K = Available Potassium, Avl S= Available Sulphur.								

The electrical conductivity was measured in dS/ m and ranged from 0.17 to 0.39. S2 (30-45 cm depth) had the highest value of 0.39 dS/m, whereas S3 (0-15 cm depth) had the lowest value of 0.17 dS/m. electrical conductivity increases with depth due salt accumulation in lower depth, similar result was reported by (Mohanta *et al*., 2021). The percentage of soil organic carbon ranged from 0.74 to 1.20 %. S9 (0-15 cm depth) had the highest value of 1.20 %, while S3 (30-45 cm depth) had the lowest value of 0.74 %. The organic carbon decreases with increasing depth due to the fact that surface soil contains undecomposed and partial decomposed organic matter while subsoil contains decomposed organic matter which has undergone chemical and biological changes, similar result was reported by (Majhi *et al*., 2020). Nitrogen availability (Kg/ha) varied between 243.68 and 424.27 Kg/ha. S9 (0-15 cm depth) had the highest value of 424.27 Kg/ha, whereas S4 (30-45 cm depth) had the lowest value of 243.68 Kg/ha. The available Nitrogen decreases with the increasing depth due to the fact it is positively correlated with organic matter content which decreases with depth and might be due to higher pH to the depth, similar result was reported by (Kumar *et al*., 2020). Phosphorus availability (Kg/ha) ranged from 7.28 to 19.21 Kg/ha. S2 (0-15 cm depth) had the highest value of 19.21 Kg/ha, whereas S8 (30-45 cm depth) had the lowest value of 7.28 Kg/ha. The available Phosphorous decreases with the increasing depth. Higher level of available Phosphorous in surface soil could be attribute of favourable soil pH and organic matter content, similar result was reported by (Sarma and colleagues 2019). Potassium availability Kg/ha varied from 64.12 to 172.70 Kg/ha. S2 (0-15 cm depth) had the highest value of 172.70 Kg/ha, whereas S2 (30-45 cm depth) had the lowest value of 64.12 Kg/ha. The available Potassium decreases with the increasing depth. The high content of available Potassium on surface soil may be attributed to the release of labile K from organic residues and application of potassium fertilizers, similar result was reported by (Singh *et al*., 2020). Calcium (cmol (p+)/kg) exchangeable ranged from 1.25 to 4.14 cmol (p+)/kg. S2 (0-15 cm depth) had the highest value of 4.14 cmol (p+)/kg, whereas S8 (30-45 cm depth) had the lowest value of 1.25 cmol (p+)/kg. The exchangeable Calcium decreases with the increasing depth due to the attribute of high pH towards the depth, similar result was reported by (Mohanta *et al.,* 2021). Magnesium (cmol (p+)/kg) exchangeable ranged from 0.53 to 3.48 cmol (p+)/kg. S2 (0-15 cm depth) had the highest value of 3.48 cmol (p+)/kg, whereas S7 had the lowest value (30-45 cm depth), 0.53 cmol (p+)/kg. The exchangeable Magnesium decreases with the increasing depth due to the attribute of high pH towards the depth, similar result was reported by (Marbaniang *et al*., 2021). The sodium concentration in the soil (mg/kg) ranged from 160.5 9 to 267.53 mg/kg. S9 (30-45 cm depth) had the highest value of 267.53 mg/kg, whereas S1 (30-45 cm depth) had the lowest value of 160.59 64.12 mg/kg. Sodium decreases with the increasing depth due to the attribute of high pH towards the depth, similar result was reported by (Okolo *et al*., 2016). Sulphur concentrations (ppm) ranged from 6.83 to 16.18 ppm. S2 (0-15 cm depth) had the highest value of 16.18 ppm, while S8 (30-45 cm depth) had the lowest value of 6.83 ppm. The available Sulphur decreases with the increasing depth might be due to greater plant and microbial activities and mineralization of organic matter in surface layer, similar result was reported by (Ghodke *et al*., 2016).

Correlation Matrix between soil Physico-Chemical Properties of Saharsa District at different depths.

Table 6 shows the data on the correlation matrix between physico-chemical parameters of soil in different villages in Saharsa district. WHC (r = -0.5487), phosphorus (r = -0.60629), potassium (r = -0.58248), negatively non significantly correlated particle density (r = -0.36082), CEC (r = -0.35547), and positively significantly correlated pH (r= 0.20659), EC (r= 0.332951), organic carbon (r = 0.245996), positively non-significantly correlated nitrogen (r = 0.54888). The particle density of soil is negatively significant connected with EC (r = -0.57329), organic carbon (r = -0.57516), nitrogen (r = -0.47419), and positively significant correlated with WHC (r= 0.272781), pH (r = 0.20469), phosphorus (r= 0.177385), CEC (r = 0.125322) and potassium (r = 0.197969) have a correlation of 0.197969.

The WHC had a negative significant correlation with nitrogen (r = -0.68959), a non-significant correlation with EC (r= 0.18417), and a positive significant correlation with PH (r= 0.323876), organic carbon (r= 0.068029), phosphorus (r= 0.395382), potassium (r= 0.368893), and CEC (r = 0.403404). EC (r = -0.4332), organic carbon (r = -0.18863), nitrogen (r= -0.1401), phosphorus (r = -0.28473), and potassium (r = -0.49422) are all negatively non-significantly linked with soil pH. CEC was shown to be positively associated (r = 0.001299). The potassium (r = 0.197969) and CEC (r = 0.125322) have a correlation of 0.197969. The WHC had a negative significant correlation with nitrogen (r = -0.68959), a non-significant correlation with EC (r= 0.18417), and a positive significant correlation with PH (r= 0.323876), organic carbon (r= 0.068029), phosphorus (r= 0.395382), potassium (r= 0.368893), and CEC (r = 0.403404). The pH of the soil has a non-significant negative relationship with EC (r = -0.4332), -0.18863 for organic carbon, -0.1401 for nitrogen, -0.28473 for phosphorus, and -0.49422 for potassium. CEC was shown to be positively associated (r = 0.001299). Organic carbon (r = 0.189734), nitrogen (r = 0.062754), phosphorus (r = 0.17453), potassium (r = 0.170595), and CEC (r = 0.174683) are all positively linked with soil EC. Phosphorus (r = -0.49748), potassium (r = -0.26052), CEC (r = -0.48639), and nitrogen (r = 0.586055) are all negatively not significantly connected with soil organic carbon.

Table 6: Correlation between Different Properties of Soil

	Bd	Pd	WHC	*pH*	EC	OC	N	P	K	*CEC*
Bd	1									
Pd	-0.36082	1								
WHC	-0.5487	0.272781	1							
pH	0.20659	0.20469	0.323876	1						
EC	0.332951	-0.57329	-0.18417	-0.4332	1					
OC	0.245996	-0.57516	0.068029	-0.18863	0.189734	1				
N	0.548887	-0.47419	-0.68957	-0.14005	0.062734	0.586061	1			
P	-0.60629	0.177385	0.395382	-0.28473	0.17453	-0.49748	-0.80197	1		
K	-0.59647	0.197969	0.368893	-0.49422	0.170595	-0.25524	-0.64502	0.92261	1	
CEC	-0.35547	0.125322	0.403404	0.001299	0.174683	-0.48639	-0.77527	0.913253	0.79647	1

Phosphorus (r = 0.80195), potassium (r = 0.64502), and CEC (r = 0.77527) are all positively non-significantly linked with soil nitrogen. The soil phosphorus has a non-significant positive relationship with potassium (r = 0.922084) and CEC (r = 0.79647).

Conclusion

It is concluded from the trial that the soils of district Saharsa are sandy loam to sandy clay with adequate BD, PD, pore space and water holding capacity. Soil pH is neutral to alkaline as favourable electrical conductivity for plant growth, fertile with high organic content. Some sites showed a deficiency in secondary nutrients calcium, magnesium. Sodium is low to medium in micronutrient and low to medium of macronutrients viz. Nitrogen, Phosphorous, Potassium and Sulphur. Proper integrated soil management should be practised to increase soil health and reduce cultivation costs. Soil health can be improved by using organic fertiliser and following suitable agronomic procedures. The correlation revealed that the soil parameters differ negatively significantly, non-significantly, and favourably significantly, non-significantly.

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Conflict of interest

The authors declare that they have no conflict of interest.

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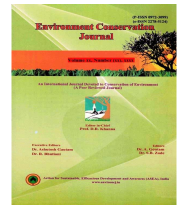

Strategies to cope with warming and reduced rainfall in green gram for northern transition zone of Karnataka, India

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ABSTRACT

South West (SW) monsoon has become more erratic and unpredictable in the northern Transition Zone (NTZ) of Karnataka and in the coming decades this will continue further with warming. To cope with change in climate, agronomic adaptation strategies (optimum sowing window and application of irrigation at critical stages) are required to maintain higher yields of greengram. As a result, the DSSAT model was used to investigate the influence of climate change on greengram. The study included a combination of two temperature (+1 and +2 °C) and two reduced rainfall (-10 and -20 %) scenarios in comparison with the baseline scenario (i.e., current climate). These scenarios were built for 32 years using historical weather data from 1985-2016. With regard to adaptation strategies, six dates of sowing; starting from June 1st week to July 2nd week at a weekly interval and four irrigation treatments each of 60 mm; one at pre-flowering stage, one at pod formation stage, one each at pre-flowering and pod formation stages, and no irrigation (rainfed) were included. Between sowing dates, the model's simulation of average grain yield across 32 years revealed that, 3rd (513 kg ha^{-1}) and 4th (508 kg ha^{-1}) week of June were found to be optimum under future climate. Irrigation at any of the critical stages increased the yield, but largest positive yield response was replicated with two irrigations: one at pre-flowering and the other during the pod formation stage (556 kg ha^{-1}). This study clearly showed that under future climates of 1 to 2 ℃ warming with reduced rainfall scenarios (-10 % & -20 %), sowing on 3rd and 4th week of June is best one, providing two irrigations (60 mm each) one at pre-flowering and the other at pod formation stage would more than compensate the loss in yield projected under changing climates in coming decades.

Introduction

Greengram (*Vigna radiata* L. Wilczek) is India's most widely produced and valuable leguminous crop after chickpea and pigeonpea. In India, it is cultivated on an area of about 34.55 lakh ha with production of 16.11 lakh tons at a productivity of 466 kg/ha. In Karnataka, it is cultivated on an area of about 3.97 lakh ha with a production of 1.28 lakh tonnes and productivity of 275 kg/ha (Anon., 2018). The average productivity of greengram at national level is much higher compared to that of Karnataka. This might be due to the fact that most of greengram area in Karnataka lies in north interior districts, which are highly vulnerable to crop failure due to low and erratic rainfall. With climate change the SW monsoon has become more erratic and unpredictable in Northern Transition Zone (NTZ) of Karnataka as well. This is exposing the *kharif* crops, including greengram, to moisture stress either due to extended dry periods or low rainfall at critical stages, thus not only affecting the productivity, but has increased the risk of crop failure. Agronomic adaptation strategies are required to cope with such situations so that higher yields are harvested even under future climates. Among them, choosing optimum sowing window and applying irrigation at critical stages are the two

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important agronomic adaptation strategies. Moisture stress during crop growth affects productivity of all crops including greengram. Therefore, critical crop growth phases must synchronize with water availability to get maximum seed yield (Monteith, 1986). Therefore, this study was taken up to optimize sowing window and irrigation timing to cope with future projected climates.

Material and Methods

Description of the Study Area

A field experiment on greengram was done to collect data for modeling during *kharif* 2016 and 2018 under AICRP on MULLaRP at Main Agricultural Research Station, Dharwad, located at 15^0 26' North latitude, 75^0 07' East longitude and at an altitude of 678 m above mean sea level (MSL). This research station falls under the Northern Transitional Zone (NTZ) No-8 of Karnataka. The average annual rainfall from 1985 to 2016 period (32 ears) was 722.80 mm. The experimental site's soil was deep black clay with pH 7.61, EC 0.51 dS m^{-1}, organic carbon content 0.59 %, available N 225.0 kg/ha, P_2O_5 19 kg/ha and K_2O 322 kg/ha, and a total profile depth of 180 cm.

Source and type of experimental data

For model calibration and evaluation, data on phenology of DGGV-2 variety *i.e*., days to flowering, physiological maturity, grain yield, total above ground biomass and seed weight were collected. The data on layer wise soil profile was us ed to build soil module, daily weather data (Tmax, Tmin, rainfall, solar radiation) for the experiment p eriod (2016 and 2018) was used to build weather m odule, crop management and resource input data for both the years was used to build experiment file (X file), and the data on phenology, yield attributes a nd yield collected during both the years of experiment were used to build time-series (T-file) and end-of-season (A-file) files within DSSAT.

Model calibration and validation

The genetic coefficients of DGGV-2 cultivar within DSSAT –CROPGRO model was calibrated with the data collected from *kharif* 2016 experiment (year-1) using GenCalc (Hunt *et al*., 1993), a semi-automated program embedded within DSSAT to optimize genetic coefficients, followed by expert calibration. Whereas, the data collected from *kharif* 2018 experiment (year-2) was used for evaluation of the model.

Seasonal analysis to study the impact of adaptation strategies on climate change

For seasonal analysis study 32 years' historical weather data (1985-2016) recorded from MARS, Dharwad weather observatory was collected and this period was considered as a 'current' or baseline scenario. To study the effect of climate change on greengram, a combination of two temperature (+1 and +2°C) and two reduced rainfall (-10 and -20 %) scenarios in comparison with the baseline scenario (i.e., current climate) were created for 32 years period from 1985 to 2016. Temperature scenarios included current (actual observed weather during 1985-2016 with no change) and +1.0ºC and +2.0ºC increase in both daily maximum and minimum temperature over current. Rainfall scenarios included no change in rainfall (actual observed weather during 1985-2016), and -10 % and -20 % reduction in daily rainfall over current scenario. A total of five scenarios were created (Table 1) and the calibrated/validated DSSAT- CROPGRO model was run for 32 years to simulate response of greengram crop for each climate scenario following standard production technology developed by the UAS, Dharwad for NTZ. The mean of 32 years, its range and standard error were calculated for model simulated outputs on grain yield and were presented here.

Results and Discussion

The most essential factor impacting a crop's adaptability and yield potential in a given place is the climate. That is why studies elsewhere have shown that more than 50 per cent of variation in the crop yield determined by climatic factors (Eghball *et al*., 1995). Temperature and rainfall are the two most essential climatic elements that determine crop growth, development and yield. Crop phenology is mainly driven by temperature; hence crop duration is affected by changes in temperature during crop growing season, whereas, changes in rainfall results in moisture stress and affects physiological processes ultimately affecting yield.

Response of greengram to warming and lower rainfall

Under current climate (Sce-1), the model simulated average grain yield of greengram over 32 years was 577 kg/ha. With increase in temperature by 1 and

Table 1: Rainfall and temperature scenarios created for seasonal analysis using 32 years historical weather data (1985-2016)

Scenario	Scenarios	Remarks
Sce-1	Control	Temperature and rainfall no change, and is the current scenario (i.e., Observed weather for the period 1985-2016)
Sce-2	+1°C T & RF -10 %	Rise in daily maximum and minimum temperature by 1.0 ºC + rainfall reduced by 10 % for 1985-2016 period
Sce-3	+2°C T & RF -10 %	Rise in daily maximum and minimum temperature by 2.0 ºC + rainfall reduced by 10 % for 1985-2016 period
Sce-4	+1°C T & RF -20 %	Rise in daily maximum and minimum temperature by 1.0 ºC + rainfall reduced by 20 % for 1985-2016 period
Sce-5	+2°C T & RF -20 %	Rise in daily maximum and minimum temperature by 2.0 ºC + rainfall reduced by 20 % for 1985-2016 period

(Sce-Scenario, T- temperature and RF- rainfall)

Table 2: Grain yield (kg ha^{-1}) of greengram as influenced by different sowing dates under different climate scenarios (Average of 32 years for the period 1985-2016)

Climate Scenarios	D1	D2	D3	D4	D5	D6	Mean
BL	538	575	577	560	545	531	554
+1°C T & RF -10 %	483	508	532	525	519	485	509
+2°C T & RF -10 %	468	498	517	515	499	465	494
+1°C T & RF -20 %	433	457	479	480	473	456	463
+2°C T & RF -20 %	422	443	461	461	451	431	445
Mean	469	496	513	508	497	473	

***BL: Baseline**

2 ℃ continued with reduction in rainfall by -10 % (Sce-2 and Sce-3, respectively), the simulated yield was reduced to 532 and 517 kg ha^{-1}. The reduction in the yield was to the extent of 8.33 and 11.62 %, respectively compared to the yield in the current climate (Sce-1; Table 2 & Fig. 1). Similarly, under Sce-4 and Sce-5, where rainfall was reduced by 20 % with 1 and 2 ℃ increase in temperature, the yield of greengram was further reduced to 478 and 460 kg ha^{-1}, respectively. The reduction in yield was to an extent of 20.55 and 25.22 % for Sce-4 and Sce-5 compared to current climate (Sce-1; Table 2 & Fig. 1). This shows that, yield response to moisture stress was much more than to temperature. On average, across temperatures, 10 % reduction in rainfall reduced the yield by 10 %, whereas 20 % reduction in rainfall resulted in 22 % reduction in the yield. Exposure to higher temperatures leads to faster accumulation of thermal units, thus the maturity of crop is hastened. This is further negatively affected if crop experiences moisture stress as well, thus affecting the yield [Aggarwal *et al*. (2004); Kumar *et al*. (2007) & Adak and Chakravarthy (2010)].

Impact of Adaptation Strategies to cope with warming and reduced rainfall

The objective of this study was to quantify changes in greengram yields under warmer climates (+1 and +2 ℃) coupled with reduced rainfall amount (-10 and -20 %) and optimize agronomic adaptation strategies to cope with this change and sustain greengram yields in NTZ of Karnataka. Two agronomic adaptation options were explored in this study to reduce the negative effects of climate change, and the details of each are discussed below.

Response to changes in sowing dates

The impact of six different sowing dates, starting from June 1st week to July 2nd week at a weekly interval was used and simulated the yields of greengram for 32 years. Under current climate scenario, the model simulated the highest yield of 577 kg ha^{-1} (average of 32 years) when crop was sown in 3rd week of June which was closely followed by the crop sown during 2nd week (575 kg

Table 3: Grain yield (kg/ha) of greengram as influenced by different sowing dates and irrigation levels under different climate scenarios (Average of 32 years for the period 1985-2016)

Climate Scenarios	Sowing dates							
	Irrigation levels	D_1	D_2	D_3	D_4	D_5	D_6	Mean
BL	I_0	538	575	577	560	545	531	554
	I_1	569	590	586	572	549	531	566
	I_2	556	599	609	590	576	587	586
	I_3	581	606	617	602	582	581	595
	Mean	561	592	597	581	563	557	
+1°C T & RF -10 %	I_0	483	508	532	525	519	485	509
	I_1	520	536	548	541	527	500	529
	I_2	508	538	583	565	558	546	550
	I_3	536	559	594	582	559	547	563
	Mean	512	535	565	553	541	519	
+2°C T & RF -10 %	I_0	468	498	517	515	499	465	493
	I_1	502	527	537	534	519	476	516
	I_2	498	531	573	563	540	525	538
	I_3	523	554	591	578	554	536	556
	Mean	498	527	554	548	528	501	
+1°C T & RF -20 %	I_0	433	457	479	480	473	456	463
	I_1	465	491	505	508	496	481	491
	I_2	472	493	537	534	522	516	512
	I_3	492	523	560	555	545	538	535
	Mean	466	491	520	519	509	498	
+2°C T & RF -20 %	I_0	422	443	461	461	451	431	445
	I_1	458	482	487	494	475	463	476
	I_2	467	487	528	523	502	490	499
	I_3	499	526	550	550	531	523	530
	Mean	461	484	506	507	490	477	

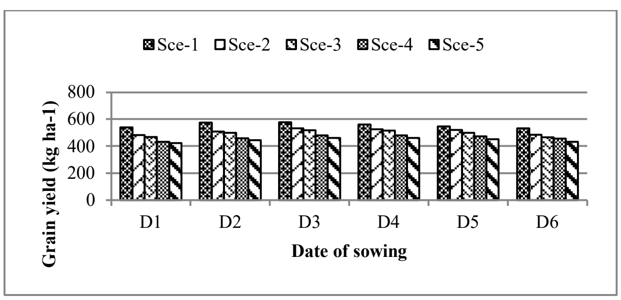

Figure 1: Simulated grain yield of greengram as influenced by different sowing dates under different climate scenarios

/ha) (Table 3 and Fig.3a). Under warmer climate (+1 and +2 °C) with reduced rainfall scenarios (-10 % and -20 %), across six dates of sowing, the highest yield was again simulated during 3rd week of June (497 kg/ha), but was closely followed by 4th week of June (495 kg/ha) (Table 3). With 10 % reduction in rainfall at +1 and +2 °C rise in temperature crop sown in 3rd week of June, yield was reduced by 45 and 61 kg/ha, respectively. Similarly, when the rainfall was reduced by 20 % with +1 and +2 °C rise in temperature, the yield was reduced by 91 and 109 kg/ha. This suggest that in coming decades of warmer climates with even more erratic rainfall pattern, the optimum sowing window for greengram in NTZ of Karnataka lies between 3rd and 4th week of June, a postponement by a weak. Weekly cumulative rainfall trend analysis for the month of June from 1985-2016 revealed that rainfall during first and second week of June showed much larger negative slope compared to third and fourth week (Fig. 2). This suggest that, reduction in rainfall in recent decades during first and second week of June has been

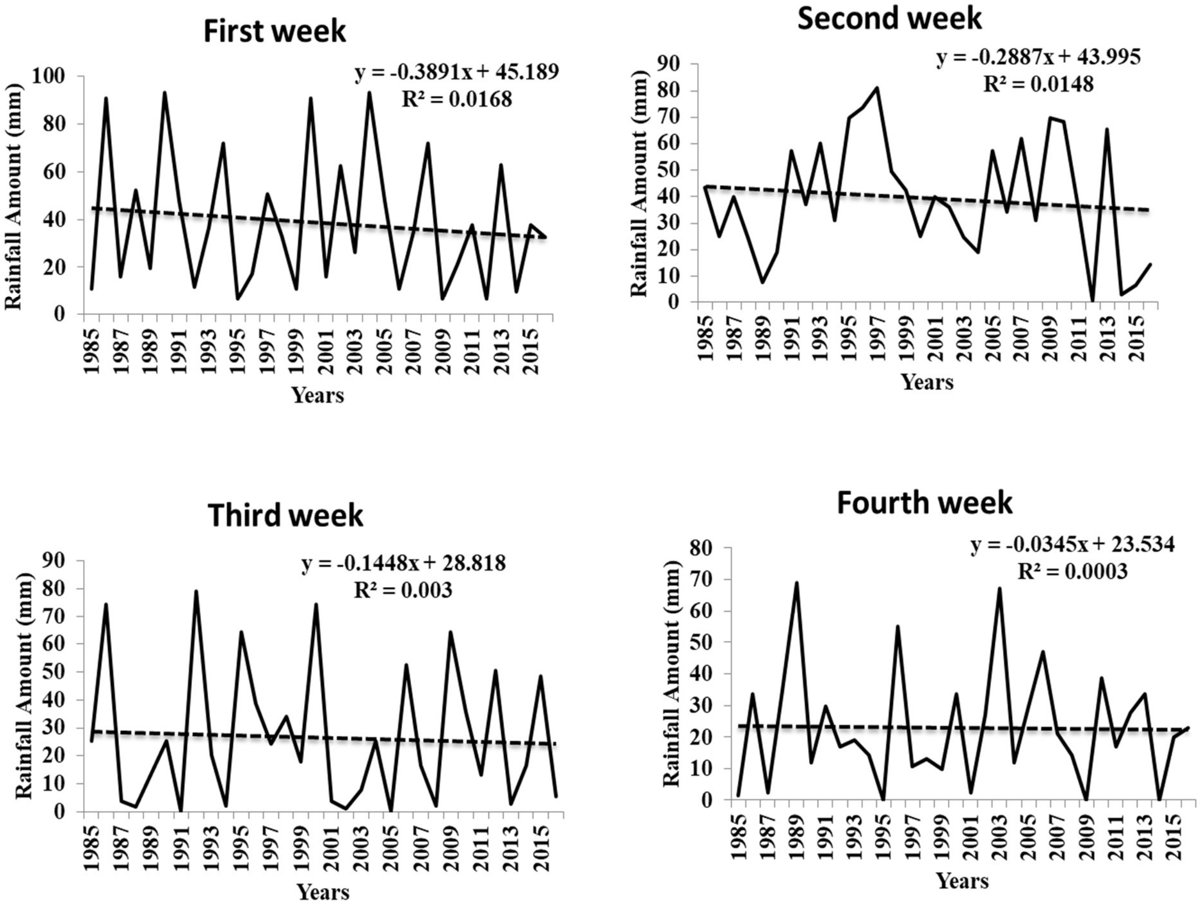

Figure 2: Annual rainfall trend analysis for June month on yearly basis (1985-2016).

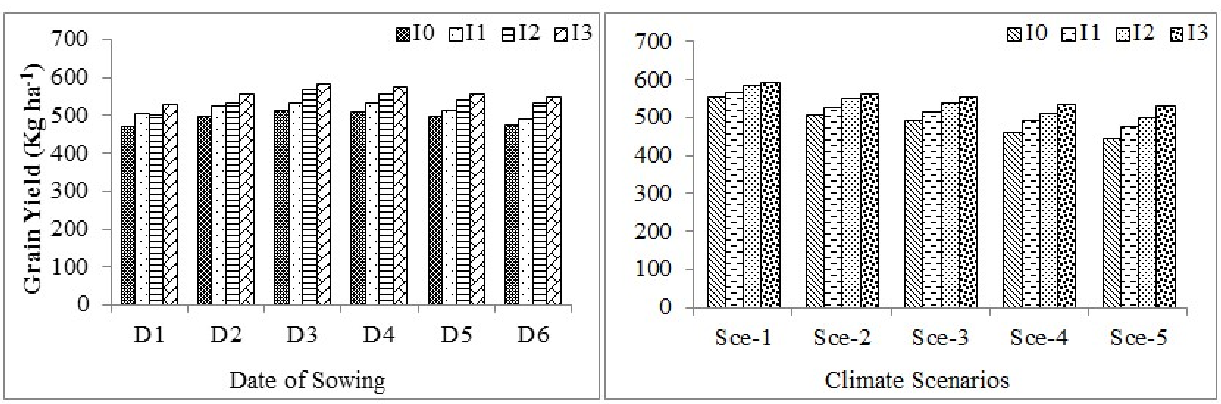

Figure 3a: Effect of irrigation levels across dates of sowing averaged over scenarios on the yield of greengram; 3b: Effect of irrigation levels across climate scenarios averaged over dates of sowing on the yield of greengram.

Irrigation levels: I0: No irrigation, I1: Irrigation at pre-flowering stage, I2: Irrigation at pod formation stage & I3: Irrigation at both pre-flowering and pod formation stage.
Dates of Sowing: D1: June 1st week, D2: June 2nd week, D3: June 3rd week, D4: June 4th week, D5: July 1st week & D6: July 2nd week.

much more, hence under future warmer climates this period becomes more risky to take up sowing. The optimum time of sowing ensures the complete synchrony between the vegetative and reproductive phases on one hand, and the climatic rhythm on the other, thus helping in realizing the potential yield (Singh and Dhingra, 1993). Bobade *et al*. (2018) studied the effect of sowing dates in kharif greengram and observed that 23rd June sowing produced maximum seed yield and which was followed by sowing on 30th June and 07th July at Parabhani, Maharashtra. This modeling study corroborates and supports these findings.

Response to application of irrigations

Supplemental irrigation at critical stages was simulated as one of the adaptation techniques to relieve moisture stress effects on greengram productivity under future climates, keeping enhanced variability and erraticity in SW monsoon in NTZ. For the optimum sowing time (June 3rd week), with 10 % reduction in rainfall at +1 and +2 °C rise in temperature with the application of single irrigation at pre-flowering stage the yield increased by 16 and 20 kg/ha, whereas, with the application of single irrigation at pod formation stage the yield increased by 51 and 56 kg/ha, respectively. However, application of two irrigation *i.e*., one at pre-flowering and other at pod formation stage enhanced the yield by 62 and 74 kg/ha, respectively compared to no irrigation in Sce-2 and Sce-3 (Table 3 and Fig. 3b). With two irrigations under Sce-2 and Sce-3 the jump in yield surpasses the yields obtained under current climate scenario (Sce-1).

For the optimum sowing time (i.e. June 3rd week), with 20 % reduction in rainfall at +1 and +2 °C rise in temperature with the application of one irrigation at pre-flowering stage the yield increased by 26 and 27 kg ha^{-1}, whereas, with the application of one irrigation at pod formation stage the yield increased by 59 and 68 kg/ha, respectively. When two irrigation were applied *i.e*., one at pre-flowering and other at pod formation stage the yield enhanced by 82 and 89 kg/ha, respectively compared to no irrigation in Sce-4 and Sce-5 (Table 3). Two irrigations at these critical stages almost compensated the loss in yield due to 20 % reduction in rainfall at +1 and +2 °C rise in temperature. Under warmer climate (+1 and +2 °C) with reduced rainfall scenarios (-10 % and -20 %), the highest yield was simulated during 3rd week of June (497 kg ha^{-1}) and was closely followed by 4th week of June (495 kg ha^{-1}), both under rainfed as well as irrigated condition. Muchow (1985) and Malik *et al*. (2006) reported that greengram is very sensitive to water stress during flowering and grain formation (Pod formation) than vegetative stage, the same is proven with this model study. This clearly showed that under future climates of +1 and +2 °C with projected lower rainfall scenarios, providing two irrigations (60 mm each) one at pre-flowering and the other at pod formation stage would more than compensate the expected loss in yield.

Conclusion

This study showed that under current climates the highest yield of 577 kg/ha was simulated when crop was sown in 3rd week of June and closely followed by 2nd week of June (575 kg/ha). Under warmer climates (+1 and +2 °C) with reduced rainfall scenarios (-10 % and -20%), the highest yield was simulated during 3rd week of June (497 kg ha^{-1}) and was closely followed by 4th week of June (495 kg ha^{-1}). However, this reduction in yield with 10 % less rainfall is more than compensated with two irrigations (563 and 556 kg ha^{-1} at +1 and +2 °C), one each at pre-flowering and other at pod formation stage. Similarly, two irrigations at these critical stages almost compensated the loss in yield due to 20 % reduction in rainfall with +1 and +2 °C rise in temperature (535 and 530 kg ha^{-1}). This study clearly showed that under future climates with +1 and +2 °C warming with lower rainfall scenarios, sowing of crop in 3rd or 4th week of June and providing two irrigations (60 mm each) i.e., one at pre-flowering and the other at pod formation stage would more than compensate the loss in yield projected under future climates.

Conflict of interest

The authors declare that they have no conflict of interest.

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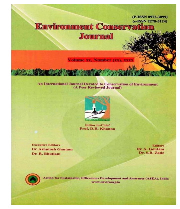

In vivo studies on anti hyperglycemic activity of sericin using rat model

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ABSTRACT

Silk protein, sericin was isolated from raw silk fabrication in reeling industry and subsequent process of silk throwing. The majority of it is thrown in the waste water from silk manufacturing. Sericin was used in antibacterial, antioxidant, wound healing, moisturising, and antiaging medications and cosmetics. Limited reports on the use of sericin in the treatment of diabetes prompted the current study on the use of sericin in the control of diabetes in rats. Thus, the present study was aimed to investigate the antihyperglycemic activity of sericin protein using rat model. The results indicated that sericin treated groups showed a noteworthy augment in body weight than the standard drug (Metformin) treatment with diabetic control. Sericin @ 400mg/kg showed 152.6 mg/dl and 141.2 mg/dl on 7th and 21st day of treatment. Similarly, Sericin @ 800mg/kg showed 126.0 mg/dl and 114.0 mg/dl on 7th and 21st day of treatment when compared to control (206.0 mg/dl and 203.6 mg/dl). SGOT of 68.4 and 50.0 units per litre of serum was observed in sericin @ 400 mg/kg and 800mg/kg treated rats when compared to control 138.6 units. SGPT 0f 26.0 and 21.6 units per litre of serum was observed in sericin @ 400 mg/kg and 800mg/kg treated rats when compared to control (75.0 units). Triglycerides of 96.4 and 81. 4 units were observed in sericin @ 400 mg/kg and 800mg/kg treated rats when compared to control (152.8 units).

Introduction

Sericin, protein produced by silkworm, *Bombyx mori* during the construction of silk (Padamwar and Pawar, 2004). Two proteins: fibroin (70–80%) and sericin (20–30%) obtained from silk is spun by mature fifth instar larvae of the silkworm *Bombyx mori* (L.). The primary core protein is fibroin, and the gum-like covering that surrounds it is sericin. Sericin is made up of 18 different amino acids, with 32 percent of the serine found as a randomised amorphous coil. Sericin can be easily transformed into a -sheet conformation in the amorphous coil by repeated moisture absorption and mechanical stretching (Mondal *et al*., 2007) (Mondal *et al*., 2007). The layers on top of the fibrin are made up of three different forms of sericin (Takusu *et al.,* 2002; Lalit Jaipura, 2015). The topmost layer, Sericin A, is insoluble in water and contains around 17 percent nitrogen, as well as amino acids like serine, threonine, aspartic acid, and glycine. Sericin B, which makes up the middle layer, is similar to

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sericin A but additionally contains tryptophan. The innermost layer, sericin C, is the layer that is nearest to and contiguous to fibroin. Sericin C, which is also insoluble in water, can be extracted from fibroin by using a hot, weak acid. Sericin C contains all of the amino acids found in Sericin B, plus proline (Aramwit *et al.,* 2012).

Around one million tonnes of fresh weight cocoons and 4,00,000 tonnes of dried cocoons are produced worldwide, yielding around 50,000 tonnes of recoverable sericin. Every year, India produces roughly 1600 tonnes of silk, leaving behind approximately 250-300 tonnes of sericin (Ghosh *et al*., 2019). The majority of silk sericin is eliminated during the reeling industry's raw silk manufacture and subsequent phases of silk tossing. Silk sericin is currently primarily thrown in waste water from silk production. Silk sericin can provide a major economic, scientific, and societal advantage if it is recovered and recycled.

Antimicrobial, antioxidant, wound healing, bioadhesive moisturising, antiwrinkle, and antiaging are only a few of the uses for sericin in pharmaceuticals and cosmetics. Because of its antibacterial and UV resistant qualities (Gupta and Agarwal, 2014), sericin is employed as a biomaterial (Chirila *et al*., 2016). Sericin from the cocoons of the mulberry silkworm, *Bombyx mori* (L.), and the non-mulberry, tropical tasar silkworm, *Antheraea mylitta* (L.), has been shown to have antioxidant properties in skin fibroblast cell lines exposed to hydrogen peroxide for 24 hours (Vittalrao, 2016; Khayade *et al*., 2016). Song *et al.* (2015) investigated the effects of sericin on the testicular growth hormone (GH)/insulin-like growth factor-1 (IGF-1) axis in rats with type 2 *Diabetes mellitus.*

Most diabetic patients manage their blood glucose levels using allopathic medications, but liver and kidney damage develops quickly, and some diabetics lose their ability to participate in routine daily activities in a short period of time (Shiyovich *et al*., 2010; Russell, 2010). As a result, diabetic patients require medications with low toxicity and side effects. Sericin is a prospective drug candidate that possesses the qualities listed above. Rare reports on the use of sericin in the treatment of diabetes inspired the current study on the use of sericin for diabetes control in rats.

Material and Methods

Procurement of animals

PSG Institutional Animal House Facility, PSG College of Pharmacy, Coimbatore provided Albino male Wistar rats aged 5 to 7 weeks with a body weight of 180-200 g for the study. The rats were fed a regular meal and given unlimited access to water for 7 days before being acclimatised to laboratory settings. All rats were housed in separate cages and fed and watered daily for up to 6 weeks before being used in the study. All of the groups were housed in a temperature-controlled environment with humidity of 55% and a temperature of 24°C 1°C. The rats' body weights and blood glucose levels were measured on a weekly basis and percent change in body weight was calculated. The experiment was carried out with the permission of the Institutional Animal Care and thic Committee at PSG College of Pharmacy in Coimbatore (Approval licence No. 442/IAEC/2019).

Induction of diabetes in rats

After acclimatization the animals were subjected to the induction of diabetes. For diabetes induction 250 mg of STZ was prepared in 0.1 M freshly prepared citrate buffer pH 4.5. The animals were kept under over night fasting. The following morning, they were injected with STZ at a dose of 30mg/kg *via* intraperitoneally route in single dose. For the first 24 hours, animals were provided with 10% sucrose solution to prevent shock due to hypoglycemic episodes. Blood glucose levels were monitored at 0, 3 and 5 hours after STZ injection by using Glucosphera blood glucose monitoring system. Subsequently, the blood glucose levels were monitored at 2 days interval after the STZ injection. On day 14, animals with fasting blood glucose level > 180 mg /dl were selected for the study and randomized to control and treatment groups.

Experimental Design

The animals were randomly divided into the four experimental groups with 6 animals per group. Group 1 received vehicle; group 2 received the standard drug Metformin (75mg/kg/day); group 3 received sericin@ 400 mg /kg/day and group 4 received sericin @ 800 mg/ kg/ day for 21 days through oral route.

Effect of sericin on body weight and fasting blood glucose and biochemical parameters

The body weight of rats of each group was measured at the day of 1, 7 and 14.The fasting blood glucose was measured at days 1,7,14 and 21. At day 21, the animals were sacrificed with a high dose of ketamine and blood was collected by carotid cutting. The plasma was isolated and stored at -20^0 C for further biochemical analysis. The fasting blood glucose level of rats in each group was measured by using Avantor blood glucose monitoring system.

Preparation of samples for biochemical assay

Plasma was extracted from blood samples centrifuged at 3000 rpm for 20 minutes. The samples were stored at –20 °C until they were tested, and any red blood cells that remained on the bottom of the tubes were washed with a phosphate buffer, pH 7.4, and the samples were kept at –20 °C until they were analysed. Coagulation was allowed on freshly obtained blood. Blood was centrifuged at 3000 rpm for 15 minutes after it coagulated, roughly 2 hours after it was collected, to extract blood serum. Serum was transferred to an Eppendorf tube and centrifuged for 10 minutes at 1000 rpm. Serum samples were transferred to new Eppendorf tubes and stored at -20°C until further analysis. Parameters *viz.,* SGOT, triglycerides, cholesterol level of rats in each group was measured by using Agappe biochemical kit.

Statistical analysis

The mean and standard error of the mean were used to express all of the data (S.E.M.). Statistics was carried out using TWO WAY ANOVA followed by Bonferroni post test.

Results and Discussion

In vitro and *in vivo* investigations of sericin's biocompatibility and antioxidant capability proved that it is immunologically inert, as well as proving its safety and opening up a wide range of biomedical applications (Sehnal, 2008 ; Lamboni *et al*., 2015). Sericin has also been shown to treat diabetes (Yang *et al*., 2002) decrease cholesterol (Limpeanchob *et al.,* 2010) and activate the immune system (Panilaitis, 2003).

Effect of sericin on body weight

Percentage change in body weight was measured for each group on day 1, 7 and 14th day when compared with day 1 for all the groups. Data were expressed as mean ± SD (n=5). There was a significant increase in the body weight of sericin treated groups at the $P< 0.05$ compared with standard treatment group and $P<0.01$ on comparison with disease control group. Sericin treated groups showed a significant increase in body weight than the standard drug (Metformin) and disease control. These findings indicated that sericin has an anabolic activity in diabetes associated weight loss.There was a significant increase in the body weight of sericin treated groups when compared with standard treatment group and when comparison with diabetic control group (Table 1).Treatment of streptozotocin-induced diabetics with sericin at a dose of 800 mg/kg body weight resulted in a substantial increase in glucose level of 114 units, followed by treatment with sericin at a dose of 400 mg/kg body weight resulted in a glucose level of 108.24 (11.786) units. In streptozotocin-induced diabetic mice, Rattana *et al.* (2017) studied the antihyperglycemic activity of silkworm powder, fibroin, and sericin isolated from three races of Thai silkworm (Nangnoi, Nanglai, and Samrong). The results showed that diabetic rats given sericin gained a significant amount of weight throughout the course of the experiment, approaching that of normal control rats, implying that sericin is effective in reducing the severity of the condition. Body weight loss may result via glycolysis, lipid, and protein metabolism in muscle to obtain sufficient energy, which is caused by insulin-mediated glucose uptake resistance in peripheral tissues, preventing glucose from being used as a major energy source (Ravi *et al*., 2004).

Effect of sericin on Fasting Blood Glucose (FBG) level

The fasting blood glucose (FBG) of each group of animals was assessed on days 1,7,14 and 21. The FBG of each group of animals was assessed. Groups treated with sericin showed a significant increase in FBG compared to standard drug (metformin) treatment and diabetic control. Change in FBG was measured for each group on day 1,7,14 and 21 and compared with day 1 for all groups. Sericin showed a significant increase in FBG compared to standard drug treatment (Fig.1).

Table 1. Effect of Sericin on body weight and FBG in diabetic induced rats

Groups	Body weight (%)			Fasting Blood Glucose (FBG)		
	1st day	7th day	14th day	1st day	7th day	14th day
Group 1	100	93.01	85.56	207.40	206.00	204.60
Group 2	100	92.54	86.59	202.00	116.40	115.60
Group 3	100	97.62	99.55	200.60	152.60	148.20
Group 4	100	96.56	103.40	200.80	126.00	111.40

Table 2. Effect of sericin on biochemical parameters of diabetic induced rats

Biochemical attributes	SGOT (units/litre of blood serum)	SGPT (units/litre of blood serum)	Cholesterol (mg/dl)	Triglycerides (mg/dl)
Group 1	138.60	75.00	170.60	152.80
Group 2	76.80	40.40	137.20	117.00
Group 3	68.40	26.00	107.00	96.40
Group 4	50.00	21.60	105.60	81.40

Sericin @ 400mg/kg showed 152.6 mg/dl and 148.2 mg/dl on 7th and 14th day of treatment. Similarly, Sericin @ 800mg/kg showed 126.0 mg/dl and 111.40 mg/dl on 7th and 14th day of treatment when compared to control (206.0 mg/dl and 204.6 mg/dl). Fasting glucose level in three Thai silkworm races were studied by Rattana *et al*. (2017. The results revealed that fibroin and sericin extracted from Nangnoi race expressed a better reduction of FPG in diabetic rats compared with diabetic control groups. Mice fed silk protein (fibroin and sericin) had lower insulin levels and higher glycogen concentrations than mice fed high fat. In mice, studies on silk protein revealed that the soluble fibroin could lower blood glucose and boost insulin levels. Okazaki *et al*. (2010) discovered that dietary administration of silk sericin reduced plasma glucose and enhanced insulin production in high fat-fed rats after an interperitoneal glucose injection. In the Brown Rat, Rattus norvegicus, Khyade and Pahade (2018) employed an aqueous solution of sericin to treat diabetes. The results showed that treating streptozotocin-induced diabetics with an aqueous solution of sericin at a dose of 250 mg / kg body weight resulted in a rise in glucose level of 142.53 (26.081) units, while a dose of 500 mg / kg body weight resulted in a glucose level of 108.24 (11.7786) units. The glucose level was lowered as the dose of sericin aqueous solution was increased. Sericin and flavonoids are two bioactive compounds that have been shown to have a therapeutic impact on diabetic nephropathy. The effect of ethanolic extract (EE) from the green cocoon of the silkworm Bombyx mori on DN in type 2 diabetes (T2D) mice generated by high-fat and streptozotocin (STZ) was examined by Wang et al. (2019). When compared to a negative control, the results showed that EE administration reduced blood glucose levels and improved body weight in diabetic mice. Oral EE could inhibit the expressions of renal tumour necrosis factor TNF-, monocyte chemoattractant protein-1 (MCP-1), fibronectin (FN), and P38 mitogen-activated protein kinase (p38 MAPK) in T2D mice. Furthermore, T2D mice treated with EE had considerably higher levels of superoxide dismutase (SOD) and glutathione peroxidase (GSH-px).

Effect of sericin on biochemical parameters

Group treated with sericin 800mg/kg showed a significant decrease in SGOT compared to standard drug treatment and disease control. SGOT of 68.4 and 50.0 units per litre of serum was observed in sericin @ 400 mg/kg and 800mg/kg treated rats when compared to control 138.6 units). Changes in SGOT level was measured for each group on day 21 and compared with day 1 for all groups (Fig 3). Changes in the SGPT levels were measured for each group on day 21 and compared with day 1 for all groups. SGPT 0f 26.0 and 21.6 units per litre of serum was observed in sericin @ 400 mg/kg and 800mg/kg treated rats when compared to control (75.0 units) (Fig 4).The sericin treated group 800mg/kg showed a significant decrease in triglycerides followed by sericin 400mg/kg treated group showed a significant decrease in triglycerides when compared to standard drug therapy and disease control groups. Triglycerides of 96.4 and 81. 4 units were observed in sericin @ 400 mg/kg and 800mg/kg treated rats when compared to control (152.8 units) (Table 2) (Fig 5). The cholesterol levels of each group of animals were assessed (Fig 6). The sericin treated group 800mg/kg showed a significant decrease in cholesterol and sericin 400mg/kg treated group showed a significant decrease in cholesterol compared to standard drug and disease control.

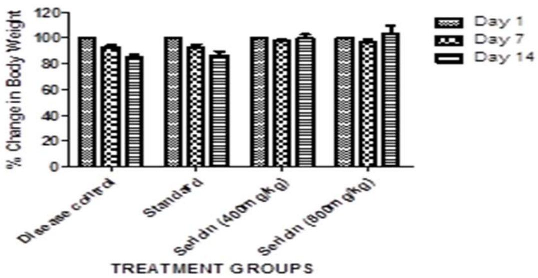

Figure 1: Effect of sericin on body weight in diabetic induced rats

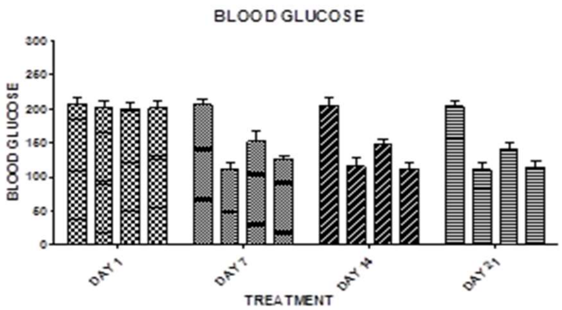

Figure 2: Effect of sericin on blood glucose level in diabetic induced rats.

Figure 3: Effect of sericin on SGOT in diabetic induced rats

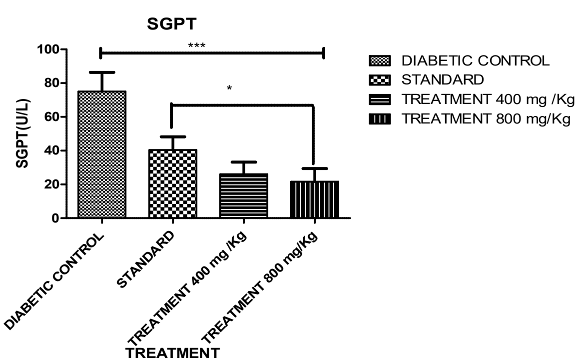

Figure 4: Effect of sericin on SGPT in diabetic induced rats

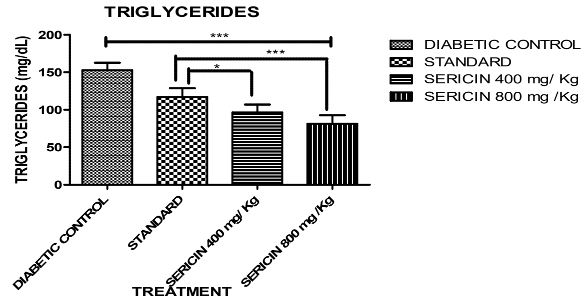

Figure 5: Effect of sericin on triglycerides in diabetic induced rats.

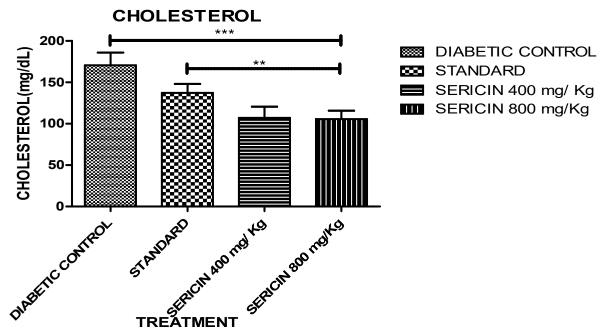

Figure 6: Effect of sericin on cholesterol in diabetic induced rats.

Changes in cholesterol levels were measured for each group on day 21 and compared with day 1 for all groups. Sericin @ 400 mg/kg and 800mg/kg treated rats showed cholesterol level of 107. 0 and 105.6 units when compared to control showed 170.6 units. Limpeanchob *et al*. (2010) studied the cholesterol-lowering impact of sericin in rats given cholesterol with and without sericin for 14 days. In rats fed a high-cholesterol diet, all three dosages of sericin lowered non-high-density lipoprotein (HDL) and total serum cholesterols (10, 100, and 1000 mg kg-1 day-1). The absorption of radiolabeled cholesterol into differentiated Caco-2 cells and cholesterol solubility in mixed lipid micelles was used to investigate the putative mechanism of action. Sericin concentrations as low as 25 and 50 g/mL prevented 30% of cholesterol uptake in Caco-2 cells, although larger concentrations had no impact. In the presence of sericin, cholesterol micellar solubility was reduced. The cholesterol-lowering action of sericin is thought to be due to its suppression of cholesterol absorption in intestinal cells and reduction of cholesterol solubility in lipid micelles, according to this study. Dietary sericin lowered serum levels of triglycerides (33%), cholesterol (16%), phospholipids (18%), and free fatty acids (18%) considerably (27 percent). The sericin intake also lowered serum VLDL-triglycerides, VLDL-cholesterol, LDL-cholesterol, and LDL-phospholipids. The decrease in serum triglycerides appeared to be due in significant part to the decrease in VLDL triglycerides (Okazaki *et al*., 2010). The decrease in blood triglycerides results in a decrease in very low-density lipoprotein (VLDL) levels without impacting serum high-density lipoprotein levels (Kato, *et al* , 2002). Because a high triglyceride and VLDL level raises the risk of atherosclerosis, sericin use can help prevent atherosclerosis. Sericin also inhibits the buildup of lipids in the liver and reduces the release of triglycerides into the bloodstream.

Conclusion

Intake of allopathic diabetic medications causes liver and renal impairments in the early stages, as well as a loss of ability to participate in normal daily activities in the later stages. Silk proteins have a variety of biological and pharmacological roles, including antioxidation, antidiabetic, anti-cancer, anti-inflammatory, and antibacterial properties. The current investigation demonstrated that sericin might be employed as a possible diabetes medication option with no toxicity or side effects. However, more research into the bioactive characteristics of sericin for the development of diabetic drugs is required.

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Conflict of interest

The authors declare that they have no conflict of interest.

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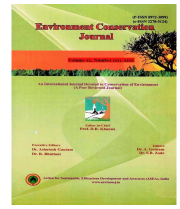

Effect of organic manures and lime on nutrient availability and soil enzyme activity under upland rice in North Eastern Himalayan Region

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ABSTRACT

A field experiment was conducted to evaluate the effect of various nutrient sources and lime on nutrient availability and soil enzymatic activities in upland rice in North Eastern Himalayan region, Meghalaya. The experiment was laid out in FRBD (Factorial Randomized Block Design), with three replications and twelve treatment combinations (Control, 100% RDN through inorganic means, 100%RDN through FYM, 50%RDN through FYM+50%RDN through Vermicompost (VC), 50%RDN though FYM+50%RDN through Poultry manures (PM), 50%RDN though FYM+50%RDN through Pig Manures (SM), each treatment alternatively supplemented with lime @ 400 kg/ha). Available N, P, K, Fe, Zn were significantly higher in 50% FYM + 50% SM followed by 50% FYM + 50% PM over control. Enzyme activities as observed for dehydrogenase, fluorescein diacetate and soil microbial biomass carbon were significantly higher by 78.6%, 47.0% and 44.5% in 50% FYM + 50% SM at harvest. Urease enzyme activity was highest in 100% inorganic at flowering. The increase in enzyme activity due to liming was not found.

Introduction

Production oriented agriculture practices contrasts modern agriculture that aims at balance input use, reduced cost of cultivation and minimal environmental impact. The type of nitrogen fertilizer used may affect the growth, yield and grain quality of rice (Chaturvedi, 2005). Rice is widely consumed staple food and India is the largest consumer and producer of rice (115.63 mt). The whole grains are rich in calorie, fibre, thiamin, magnesium, phosphorous, selenium and manganese, dietary fiber and bioactive compounds.

Livestock holds an important place in the rural farm economy giving additional income and bears risk of crop failure. Livestock population in India

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counts to 535.78 million (20th livestock census, 2019). Northeast states hold 6.7% of cattle, 1% of sheep, 5% goat, 40% pigs and 5% livestock population from the national share. The traditional practice of using organic manures has changed in recent past because of readily available cheaper chemical fertilizers. Organic manures undoubtedly enhance soil health, plant growth and are important in sustainable agriculture.The labile soil microbial biomass makes up 1–3% of total soil organic matter. Soil organic matter affects crop growth and yield by influencing the supply of available plant nutrients. Microbial biomass nitrogen makes up to 5% of total soil N, which contributes to most labile carbon and nitrogen pools in soils (Luce *et al.,* 2011). N immobilised in microbial biomass has a ten-fold faster turnover time than N obtained from plant material (Rastetter *et al.,* 2021). Organic matter, whether in the form of crop residues or farmyard manures, has been shown to improve soil structure, water retention capacity, infiltration rates, and bulk density (Bhagat and Verma, 1991). Long-term soil management is reflected in soil quality (Ramphisa and Davenport, 2020). The importance of physical, chemical, and microbiological indicators in crop production, as well as how they are affected by nutrient management strategies, are highlighted by the quality and functioning of soil in crop production. Microbial and enzyme activity are very sensitive to changes induced by fertilisation that makes them superior indicators for soil quality assessment (Ramphisa and Davenport, 2020). Microbial biomass carbon, nitrogen and extra cellular enzymes produced by soil microorganisms are the key to nutrient cycling, fertility and functionality of soil ecosystem (Sinsabaugh and Follstad Shah, 2012). As a result, the size and activity of the microbial biomass have a significant impact on nutrient cycling, availability, and production in agroecosystems (Friedel *et al.,* 1996). An index of general microbiological activity of the soil is given by soil dehydrogenases belonging to oxidoreductase class (Gu *et al.,* 2009), reflecting the rate of transformations occurring in the soil. Soil phosphatase levels regulate the biotic pathways of phosphorus, often the limited plant available nutrient (Chadwick *et al.,* 2003). Therefore, phosphatase play a fundamental role in transforming phosphorous in soil organic matter to available forms. Bacteria, fungi and plant roots produce phosphatase enzymes that cleave phosphate group from unavailable recalcitrant organic form to assimilable phosphate (Brady and Weil, 2008; Margalef. *et al.,* 2017). Urease (Urea amidohydrolase) degrades urea, is considered a good proxy of nitrogen mineralization. Lime and decomposed organic manure increases the urease enzyme activity (Adetunji *et al.,* 2020). The number of active fungus and bacteria in a soil sample is determined by fluorescein diacetate (FDA) hydrolysis, which only distinguishes between active and inactive biomasses and does not show the level of activity of the active biomass.The type and number of microorganisms are subjected to soil pH change. India being a tropical country has about 49 million ha of arable land under pH < 6.5 (Majji *et al.,* 2012). North Eastern region covers 21 million ha of acid soil both arable and non arable owing to heavy annual rainfall of > 2500mm. This leaches down and washes off tonnes of soluble nutrient from soil. Most micronutrients precipitate at low pH and become unavailable to plants, or they may be present in hazardous levels. To combat the negative effects of pH on plant growth, lime should be added to the soil prior to cultivation. Liming benefits plants in a variety of ways, including lowering the risk of Mn2+ and Al3+ toxicity. It boosts microbial activity, physical structure, symbiotic nitrogen fixation, forage palatability, and provides a low-cost supply of Ca^{2+} and Mg^{2+}. It also boosts P and Mo nutritional availability. An experiment was undertaken to evaluate the simultaneous influence of organic sources of fertilisers and lime on soil fertility in upland rice, taking into account the above available resources and limits. As a result, the focus of this experiment is on the impact of organic manure sources and lime on soil nutrition and health in an upland rice setting.

Material and Methods

Experimental site

The field trail was taken up with upland rice (Local ruling variety Bhalum 3) on the terraces at the ICAR Research Complex for North Eastern Himalayan Region (ICAR–RCNEH), Barapani, Meghalaya. The nutrient status of soil is given in Table 1.

Table 1. Nutrient status of the experiment soil

Soil chemical properties	Content	Method of analysis
Soil organic carbon (%) (0–15 cm)	1.62 %	Walkley and Black (1934)
Available N (kg/ha) ($KMnO_4$-oxidizable N)	256 kg/ha	Subbiah and Asija (1956)
Available P (kg/ha) (0.03 N NH_4F extractable P)	6.3 kg /ha	(Bray and Kurtz, 1945)
Available K (kg/ha) (0.1N NH_4OAc exchangeable K)	354 kg /ha	Hanway and Heidal (1952)
Soil pH (Initial)	3.8	0.01M $CaCl_2$

Treatment details

With three replications, the experiment was conducted in a factorial randomised block design (3 m * 4 m). Factor A: N0- Control; N1- 100% RDN inorganic; N2- 100% RDN through FYM; N3- 50% RDN through FYM + 50% RDN through Vermicompost (VC); N4- 50% RDN though FYM + 50% RDN through Poultry manures (PM); N5- 50% RDN though FYM + 50% RDN through Pig manures (SM). Factor B: L0- No Lime; L1- Lime (400kg/ha). Each of Factor A was alternated with Factor B making 12 treatment combinations. For inorganic treatment N was applied in two splits at basal and tillering stage. P and K were applied as basal @ 60–40–40 N–P_2O_5–K_2O kg/ha or @ 60–17.5–35.7 (N–P–K). Organic manure was applied at recommended dose of nitrogen (Table 2).

Soil sampling and nutrient estimation

Soil samples were collected randomly following quartering method from each plot from 0–15 cm depth using core sampler. The samples were analysed for soil organic carbon (SOC), available NPK. Micronutrients were estimated by atomic absorption spectrophotometer (AAS).

Soil microbial properties

Fresh soil samples collected from 0–15 cm depth were analysed for following parameters:

Soil microbial biomass carbon (SMBC)

Vance *et al*., (1987) described a strategy for estimating microbial biomass carbon. 17.5 g soil samples were taken in duplicate in sealed vials and fumigated with 1 ml chloroform. As non-fumigated samples, another set of 17.5g soil was stored in a 250 ml conical flask. Both sets were held at 37.5°C for 24 hours of incubation. Chloroform was evaporated for 2 hours at 37°C, after which 70 ml 0.5 M K_2SO_4 was added to both sets and shaken for 30 minutes. Whatman No. 42 filter paper was used to remove the supernatant. At 280nm, the filtrate's OD value was measured. On a soil dry weight basis, soil microbial biomass carbon (SMBC) was estimated by subtracting the titre values of non–fumigated from fumigated samples.

Dehydrogenase enzyme activity

Casida *et al*., (1964) established a technique for calculating dehydrogenase activity in soil samples. Triphenyl Tetrazolium Chloride (TTC), Methanol (AR grade), and Triphenyl Formazon (TPF-100 g/mL) were administered as reagents. In a screw-capped test tube, 6 g fresh air dried soil sample and 60 mg CaCO3 were completely mixed with 1.0 ml freshly made TTC (3 percent w/v) solution and vortexed for 1 minute. These test tubes were incubated for 24 hours at 37°C. The following day, 10 mL methanol was added and vortexed for 1 minute. TPF (pink layer) was filtered. This procedure was followed once again. At 485 nm, the absorbance of the supernatant was measured using a Spectrophotometer. TPF (0–50 g/ml) was used to create a standard curve. The standard curve was used to calculate the concentration of TPF in the sample. The activity of dehydrogenase was calculated and expressed in terms of g TPF liberated g TPF/g of soil/24 hr.

Acid phosphatase activity

The activity of acid phosphatase in soil was measured using Tabatabai and Bremner's method (1969). Toluene, p-Nitrophenyl phosphate (0.115 M), calcium chloride (0.5 M), and sodium hydroxide reagents (0.5 M) were used in a modified universal buffer (MUB; pH 6.5). 1 g of fresh soil sample was taken in triplicate in screw cap tubes and mixed thoroughly with 4 ml MUB, 0.25 ml toluene, and 1 ml p-Nitro phenyl phosphate solution. After 1 hour of incubation at 37 °C, 1 ml 0.5 M $CaCl_2$ and 4 ml 0.5 M NaOH were added to the solution. Whatman No.42 filter paper was used to filter the supernatant. The absence of p-nitrophenol phenyl phosphate was used as a control. The amount of p-nitro phenol in the sample was measured using a spectrophotometer at 420 nm, and acid phosphatase activity was calculated as g p-NP/g of soil/24 hr.

Table 2. Nutrient content of manures (manure applied w.r.t recommended dose of N given in bracket)

Manures	N (%)	P (%)	K (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)
FYM	0.5 (12t/ha)	0.3	0.5	1400	212	57
Vermicompost (VC)	3.5 (1.8t/ha)	1.2	2.0	1300	109	64
Poultry manure (PM)	3.5 (1.8t/ha)	3.0	3.0	1450	215	91
Pig manure (SM)	4.2 (1.5t/ha)	2.9	3.8	1500	110	80

Urease activity
To determine urease activity, two reagents were required. Reagent A was made with a 1:4 dilution of Phenol @50g/l and Na-nitroprusside-0.25g/l (reagent:water). Reagent B was freshly made by combining 25g/l NaOH and 2.1g/l Na-hypochlorite. In triplicate, 1 g of soil was weighed and placed in a screw-capped bottle. 500 l of 0.8M urea solution was added to it, and it was incubated for 2 hours at 37 °C. After that, 10 mL 1N KCl was added and shaken for 30 minutes. Following filtration, 1 mL of filtrate was pipetted into a test tube, followed by 5 mL of each reagent, and the OD was measured at 625 nm. It was calculated as g p-NP/g soil/24 hours.

FDA hydrolysis
A spectrofluorometer is used to measure FDA. 5mg FDA was dissolved in 10ml reagent grade acetone to make a new FDA stock solution. Dissolving 8.7g dipotassium phosphate in 400ml distil water and 1.3g potassium dihydrogen phosphate in 400ml distil water yielded a 60mM phosphate buffer (pH 7.6). Both solutions were mixed and brought to a volume of 1 litre. 5ml of 60mM potassium phosphate buffer and 10ul FDA stock solution were added to 1g of soil in triplicate. After vortexing, it was incubated at 37°C for 2 hours. The process was then abruptly stopped with the addition of 0.2ml acetone. After that, it was vortexed and filtered using Whatman No.42 filter paper, and the OD value was measured at 490nm with Fluoresein standard. It was calculated as g p-NP/g soil/24 hours. Strong enzymatic activity is indicated by a bright yellow-green glow.

Results and Discussion

Available N
The nutrient sources showed higher available N concentration over control (300 kg/ha). 100% inorganic had the lowest (247 kg/ha) and 50% FYM + 50% SM had the maximum available N (276 kg/ha). 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC were 11.7%, 10.1% and 8.0% significantly higher over 100% inorganic. Though 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC are at par with each other 50% FYM + 50% SM was 3.3% and 1.4% higher over the later two respectively. Liming had no significant effect on available N however, 4.6% increase in available N was recorded in limed treaments (Table 3).

Available P
Available P recorded was higher in soil for nutrient sources over control (5.38 kg/ha). The nutrient sources were mostly at par with each other however, 50% FYM + 50% SM had maximum available P (8.27 kg/ha) and was 5.0%, 5.7%, 12.3% and 22.3% higher over 100% inorganic. Liming did not have a significant effect but was 9.1% higher in the available P (7.48 kg/ha) over no lime (6.85 kg/ha) (Table 3).

Available K
Available K was favourable for nutrient sources over control (322 kg/ha). 50% FYM + 50% SM (370 kg/ha) was promisingly 6.6% higher over 100% inorganic (347 kg/ha). 50% FYM + 50% SM, 50% FYM + 50% PM, 50% FYM + 50% VC and 100% FYM were at par with each other however 50% FYM + 50% SM was 1.6%, 3.3% over 4.5% higher over the later three respectively. Liming increased 4.5% available K however the increase was not significant (Table 3).

Available micronutrients
Availability of Fe and Zn responded significantly to the nutrient sources and liming whereas available Mn did not. Control (207 mg/kg) and 100% inorganic (202 mg/kg) were at par with each other. 50% FYM + 50% SM (238 mg/kg) and 50% FYM + 50% PM (234 mg/kg) were similar to each other in available Fe but promisingly higher over 50% FYM + 50% VC by 8.6% and 6.8%, and 100% inorganic by 17.8% and 15.8% respectively. Similarly, control (4.65 mg/kg) and 100% inorganic (4.29 mg/kg) were at par with each other. Available

Table 3. Effect of different nutrient sources and lime on the chemical properties (available N, P, K, Fe, Mn & Zn) of soil at harvest of rice

Treatment	Available N (Kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available Fe (mg/kg)	Available Mn (mg/kg)	Available Zn (mg/kg)
Sources of Manure (A)						
Control	235	5.38	322	207	35.5	4.65
100% inorganic	247	7.82	347	202	33.2	4.29
100% FYM	264	6.56	354	228	37.8	5.32
50% FYM + 50% VC	267	7.34	358	219	36.3	5.53
50% FYM + 50% PM	272	7.57	364	234	37.2	5.60
50% FYM + 50% SM	276	8.27	370	238	36.1	5.61
SEm(±)	6.11	0.59	7.78	4.06	1.25	0.28
CD (P=0.05)	17.85	1.72	22.79	11.71	NS	0.80
Lime (B)						
No Lime	258	6.85	351	225	35.6	5.14
Lime (400 kg/ha)	270	7.48	367	234	36.5	5.50
SEm(±)	5.57	0.24	6.94	3.19	0.89	0.15
CD (P=0.05)	NS	NS	NS	8.87	NS	NS

Zn was maximum in 50% FYM + 50% SM (5.61 mg/kg). 50% FYM + 50% PM (5.60 mg/kg) was promisingly 30% high over 100% inorganic. Liming increased available Fe significantly by 4% but had no effect on Manganese and zinc availability (Table 3). 50% FYM + 50% SM and 50% FYM + 50% PM had maximum available N, P, K, Fe and Zn because pig manure and poultry manure had sufficiently higher nutrient concentration. Pig manure in Meghalaya are richer in plant essential nutrients over FYM because they make an important animal component of every household and are part of their cuisine. Hazarika *et al.,* (2020) also reported similar results. Organic manures enhance the physical, chemical, and biological qualities of the soil. Organic manures added as per recommended dose of nitrogen was sufficient to ameliorate acid soils and reduce the fixed nutrients like Fe and Mn from their higher oxide form to their lower oxide that is available to plants for uptake. Nitrogen loss as denitrification, runoff, leaching and volatilization was very meagre from the organic matter than the fertilizers where nutrients are in readily available form. The well–decomposed manures could synchronise phosphorous mineralisation with plant uptake so that fixation is minimal (Kumar *et al.,* 2021). In case of fertilizer treatment readily available phosphorous gets fixed soon in acid soil as insoluble iron and aluminium phosphates and availability is lower than organic manures (Syers *et al.,* 2008). FYM owing to its low nutrient status could supply nutrient in low concentration (Hopmans, 2019). Available Fe, Mn and Zn were slightly lower in 100% inorganic treatment over control may be because only recommended dose of N, P and K were added in former treatment. 100% inorganic treatment had better growth compared to control because of readily available plant available nutrients that might have helped in higher uptake of micronutrients from soil. Many phenolic, carboxylic, and enolic groups are found in partially decomposed organic materials, which can consume protons at their normal pH (Wong *et al.,* 1998). Their ability to neutralize acidity when added to acid soils is partly due to their buffering capacity, which is due to their ability to consume protons. Similarly, protons can be used by simple organic acid anions found in organic materials (Naramabuye and Haynes, 2007). That is, if the pH of the soil is less than the pKa of the weak acid groups on added organic matter, the pH of the soil will rise due to H^+ from the soil interacting with the organic anions (Ritchie and Dolling, 1985). This increase in pH with manure application is consistent with Ramphisa and Davenport's (2020) findings, which found that adding organic manures to soil resulted in an increase in soil pH and a decrease in Al ions in soil solution. Liming is well known for increasing soil pH by exchanging H^+ from clay complexes with Ca^{2+} ions and forming OH^-, neutralising active acidity. Liming is the process of adding mineral calcium and magnesium compounds to acidic soils, mostly carbonates, oxides, hydroxides, or a mixture of them, and, less commonly, silicates, to reduce the concentration of protons (Yadesa *et al.,* 2019). Amount of lime applied did not raise the pH of the soil to neutral but the slight increase in pH to 5.2 could show its effect faintly and without any promising result. The slight increase in available Zn due to liming may be because of high Zn concentration in manures. Zhang *et al.,* (2020) had also reported the same from Meghalaya. The meagre effect of liming may be because the quantity of lime applied was not sufficient to raise the soil pH of experimental plot to neutral.

Effect of nutrient sources and liming on the soil microbiological properties at flowering and after the harvest of rice crop

Data on the subject of, dehydrogenase activity, acid phosphatase activity, FDAase activity, urease and soil microbial biomass carbon of rice.

Dehydrogenase enzyme activity

Dehydrogenase activity was slightly higher at flowering than at harvest. In terms of nutritional sources, it outperformed the control (188 g TPF/g soil/24 hr). Among the nutrient sources highest dehydrogenase enzyme activity at harvest was observed in 50% FYM + 50% SM (377 µg TPF/g soil/24 hr) that is 16%, 28.6%, 45% and 78.6% high over 50% FYM + 50% PM, 50% FYM + 50% VC, 100% FYM and 100% inorganic respectively. There was no significant effect of lime on dehydrogenase enzyme activity just 4.4% higher activity was due to liming. The trend was also similar at flowering stage (Figure 1).

Acid phosphatase activity

Acid phosphatase activity was higher at harvest than at flowering stage. At flowering stage nutrient sources had promising enzyme activity over control (140 µg p-NP/g soil/24 hr). 50% FYM + 50% SM, 50% FYM + 50% PM, 50% FYM + 50% VC and 100% FYM were at par with each other. However, 50% FYM + 50% SM (159 µg p-NP/g soil/24 hr) had 8.9% higher activity over 100% FYM. At flowering, liming (151 µg p-NP/g soil/24 hr) favourably increased acid phosphatase activity by 6.3%. At harvest, nutrient sources and lime were at par with control and no lime respectively but had similar trend as at flowering (Figure 2).

Fluorescein diacetate activity (FDA)

Higher FDA was observed at flowering than harvest stage. 100% inorganic (1.98 µg fluorescein/g/hr) and control (1.65 µg fluorescein/g /hr) were similar to each other. Among the nutrient sources highest FDA was observed in 50% FYM + 50% SM (2.91 µg fluorescein/g/hr) that is promisingly 8.8%, 14.5% and 47% higher over 100% FYM, 50% FYM + 50% VC and 100% inorganic respectively. Liming had 12.6% significantly high FDA. Similar trend was at harvest stage for nutrient sources only (Figure 3).

Urease enzyme activity

At flowering, significantly maximum urease activity was in 100% inorganic treatment (40.4 µg NH_3/g/hr). 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC were similar in urease activity. 50% FYM + 50% SM was 37% higher over 100% FYM. 100% inorganic was 39.7% higher over 50% FYM + 50% SM. Liming raised urease activity by 13.8% at flowering. However, at harvest all the nutrient sources had a slightly higher urease enzyme activity over flowering except for control and 100% inorganic treatment. Liming slightly increased urease activity at harvest over flowering. 18.2% higher urease activity was due to liming at harvest (Figure 4).

Soil microbial biomass carbon (SMBC)

Higher SMBC was at flowering over harvest. At flowering, control (226 µg/g/dry soil) and 100% inorganic (200 µg/g/dry soil) had then lowest SMBC and were at par with each other. 50% FYM + 50% SM, 50% FYM + 50% PM and 50% FYM + 50% VC were at par with each other. 50% FYM + 50% SM (289 µg/g/dry soil) was 12.8% and 44.5% higher over 100% FYM and 100% inorganic. Liming did not have promising effect on SMBC however, 8.5% increase was seen. At harvest the trend was similar to flowering except for control (184 µg/g/dry soil) was significantly higher over 100% inorganic (136 µg/g/dry soil). Liming did not have significant effect at harvest though it gave 15% higher SMBC (Figure 5).

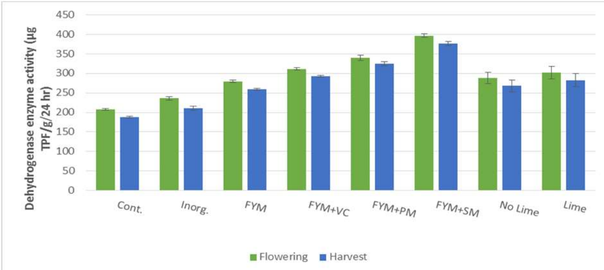

Figure 1: Effect of nutrient sources on dehydrogenase activity of soil at harvest of rice.

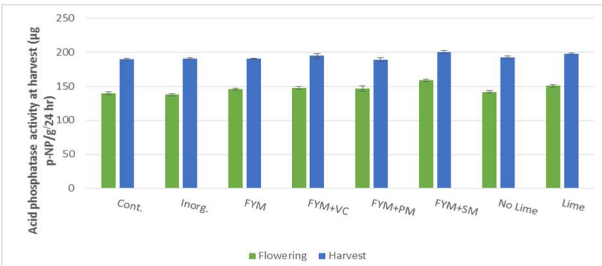

Figure 2: Effect of nutrient sources on acid phosphatase activity of soil at harvest of rice.

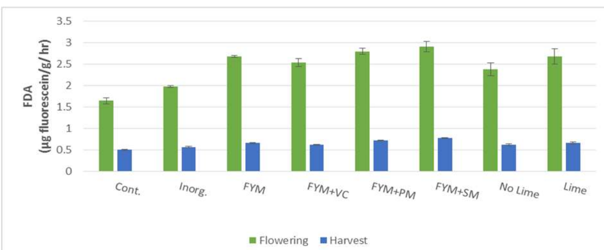

Figure 3: Effect of nutrient sources on FDA activity of soil at harvest of rice.

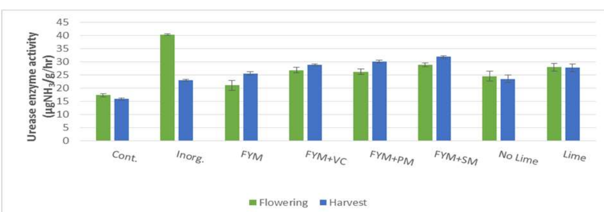

Figure 4: Effect of nutrient sources on Urease activity of soil at harvest of rice.

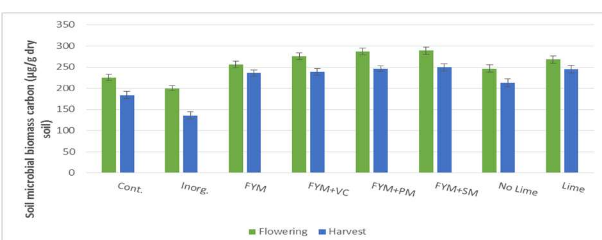

Figure 5: Effect of nutrient sources on soil microbial biomass carbon activity of soil at harvest of rice.

The physical and chemical qualities of the soil, as well as the structure of the microbial population, are affected by the application of organic manure. Wherever organic manure is used, microbial activity improves in the root rhizosphere. Soil microorganisms benefit from organic manure because it provides a suitable habitat, protects them from predation, and improves soil physicochemical qualities (Atkinson *et al.,* 2010; Lehmann and Joseph 2015; Smith *et al.,* 2010). Organic matter acts as an easily degradable substrate by increasing the soil's labile C pool, which aids soil microorganism growth (Das *et al.,* 2017; Zhen *et al.,* 2014). Increased soil microbial biomass carbon, acid phosphatase activity, urease enzyme activity, FDA activity, and dehydrogenase activity all indicate improved soil microbial characteristics. The variation in nutrient composition and indigenous microbial community in manures affect the soil microflora. Microbial community from the gut of livestock, in FYM, may not be as competitive in soil environment but the presence of beneficial and absence of harmful microorganism is favourable to improve soil fertility and productivity (Hartmann *et al.,* 2015; Sun *et al.,* 2015). Due to higher nutrient concentrations that may contribute to faster mineralization, 50% FYM + 50% SM and 50% FYM + 50% PM resulted in more biological activity than solitary application of FYM, inorganic, and control treatments. Kumawat *et al.,* (2009), reported similar observations. FDA, dehydrogenase activity values were higher at flowering over harvest because both of them are highly correlated to microbial respiration when easily degradable C sources, SMBC is high in soil (Lalande *et al.,* 2000). There was slight increase in soil microbial biomass carbon, dehydrogenase activity and FDA owing to utilization of organic substrate during the growing period of rice. Organic matter in the soil is an important predictor of microbial activity. Organic inputs promote microbial biomass carbon and organic carbon in the soil by increasing enzymatic activity (Nath *et al.,* 2012). Baishya *et al.,* (2017) showed the highest dehydrogenase and acid phosphatase enzyme activities under 50 percent FYM + 50 percent SM treatment combinations, which could be related to enhanced oxidative activity of soil microflora. Urease activity was highest for inorganic treatment because of immediate availability of urea as nitrogen substrate for hydrolysis. Acid phosphatase activity was reportedly higher at harvest stage may be due to rise in pH of acid soil which favoured the acid phosphatase activity. Bacteria, fungi, yeasts, protozoa, mycorrhizal fungi and plant roots, produce acid phosphatases. The production of acid phosphatase is optimum at 4.8 pH (Margalef *et al.,* 2017). Similar was the reason for slight higher urease activity at harvest that has optimum activity at 6.4 pH (Tabatabai and Bremner, 1972).

Conclusion

Growing upland rice on acid soils with a combination of FYM and Pig manure is a great way to maintain productivity, profitability, and soil health, according to this study. Application of 50% FYM + 50% SM or 50% FYM + 50% PM is sufficient for management of soil health and supply of essential nutrients in upland acid soils of Meghalaya in North Eastern Himalayan region of India.

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Conflict of interest

The authors declare that they have no conflict of interest.

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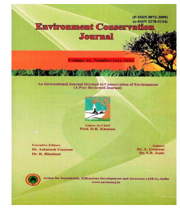

Morphological, yield and quality performance of introgression trispecies derivatives of cotton (*G. hirsutum* L. x *G. barbadense* L.) x *G. arboreum* L.)

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ABSTRACT

The experiment was carried out in CRS, Nanded, Vasantrao Naik Marathwada Agricultural University, to evaluate the effect of chromosomal ploidy level on morphological, yield and quality parameters of introgressed trispecies derivatives of cotton. Fifty introgressed trispecies derivatives of the cotton genotype obtained in the BC_1F_{21} generation of a trispecies cross of [(*G. hirsutum x G. barbadanse*) x *G. arboreum*] were used to determine the chromosomal behaviour, yield, morphology and fibre quality traits. During meiosis, variation in chromosome number ranging from 47 to 54.5 was observed against the normal chromosomal behaviour of *G. arboreum* (2n == 26) and *G. hirsutum* (2n=4x=52). Yield and morphologically, these derivatives increased significantly over the check varieties, while fibre quality traits, viz., upper half mean length (UHML) and uniformity index, were found to be inferior than the check hybrid DCH-32, however, it was followed by other checks, viz., NH-615, DHY-286 and PA-183. The fibre strength was found to be superior over all the checks. These results indicate that these developed lines had introgression character from species viz., *hirsutum, arboreum* and *barbadense.*

Introduction

Cotton is an important fibre crop of global importance. India has a pride place in the global cotton market, it has the distinction of having the largest cotton area of 12 million hectares, and production of 32.8 million bales (1 bale= 170 kg lint) (Anonymous, 2018). The cultivated amphidiploid species, *G. hirsutum* L. and *G. barbadense* L. cross readily, and the F_1 hybrid shows regular bivalent pairing and is apparently fully fertile. F_2 progenies show considerable depression in vigor, and the net effect of inbreeding is the establishment of types practically indistinguishable from the parent species. All intermediate types are at a great selective disadvantage and fail to establish themselves. A similar situation is found in the hybrid progenies of the Asiatic cultivated diploid species, *G. arboreum* L. and *G. herbaceum* L. Harland's interpretation of these phenomena is that the species differences are mainly attributable to differences in "genetic architecture." The regular bivalent pairing and full fertility of the F_1 hybrid has usually been considered to support Harland's hypothesis (Dobzhansky, 1941; Silow, 1941; Mather 1943). Almost all the species studied have been grouped into seven diploid genomes (A, B, C, D, E, F, and G) and one tetraploid genome (AD). The A subgenome of cultivated diploid cotton has been shown to be homologous to the A genome of the teraploid cotton and the D subgenome of wild

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American species to those of the D subgenome of tetraploid cotton. The hybrids between the A and D genomes are of great significance, as they will bear out the amphidiploid origin of tetraploid cotton. Such hybrids, when doubled, may prove potential in expanding the pool of new germplasm for the future improvement of tetraploid cotton.

Material and Methods

The material for the present investigation includes interspecific trispecies derivatives of the BC_1F_{21} generation, viz., IS-244/4/1 and IS-181/7/1, available at the cotton research station, Nanded. These introgressed lines were developed from a cross of DCH-32 (into a specific F_1 hybrid of *G. hirsutum x G. barbadense*) with the strain NA 80/679 of *G. arboreum* (race *bengalense*). To match the ploidy level, tetraploidy was induced by treating *G. arboreum* with colchicine. The trispecies F_1 obtained [(*G. hirsutum x G. barbadense*) x 4n *G. arboreum*)] was pollinated on the stigma of C1 plants to obtain BC_1F_{21} seeds. Plants showing distinct morphological characteristics in the BC_1F_{21} generation were isolated and advanced up to the BC_1F_{21} generation. Although the present material is presently in the BC_1F_{21} generation, segregation is still observed for morphological and economic traits. The seeds of these lines were obtained from Cotton Research Station, Nanded, VNMKV, Parbhani (Table 1). The trispecies derivatives of the BC_1F_{21} generation along with standard checks represented by two row plots of 10 plants, placed at 60 x 30 cm with two replications. All the agronomical practices and plant protection measures followed as required to raise a good crop of cotton. Observations of yield, morphological and fiber quality traits were recorded. A standard statistical procedure was followed for analyse the data according to Panse and Sukhatme (1967).

Yield contributing parameters

Number of bolls per plant

Number of bolls per plant from which seed cotton was picked during each picking was recorded and mean value for number of bolls per plant was calculated.

Boll weight (g)

At the time of second picking, seed cotton from ten well opened bolls, from each genotype was collected and weighed. Mean value was calculated and recorded.

Table 1: List of the interspecific trispecies derivatives BC_1F_{21} generation

Sr. No.	Name of the derivatives	Sr. No.	Name of the derivatives
1	IS-1-1	26	IS-32-15
2	IS-1-2	27	IS-33-1
3	IS-1-3	28	IS-33-4
4	IS-1-4	29	IS-33-5
5	IS-1-5	30	IS-34-5
6	IS-1-6	31	IS-34-9
7	IS-2-1	32	IS-35-11
8	IS-2-2	33	IS-36-12
9	IS-2-4	34	IS-39-4
10	IS-2-5	35	IS-43-2
11	IS-2-6	36	IS-43-3
12	IS-2-7	37	IS-43-5
13	IS-2-8	38	IS-43-6
14	IS-3-1	39	IS-43-7
15	IS-3-2	40	IS-43-9
16	IS-3-5	41	IS-43-10
17	IS-8-1	42	IS-43-12
18	IS-11-5	43	IS-43-13
19	IS-16-8	44	IS-43-14
20	IS-17-1	45	IS-43-15
21	IS-28-1	46	IS-44-1
22	IS-31-6	47	IS-44-3
23	IS-31-7	48	IS-44-7
24	IS-32-9	49	IS-43-4
25	IS-32-12	50	IS-43-8
Standard Checks	1) PA 183 (*G. arboreum* 2n=26) 2) DHY 286 (*G. hirsutum* 2n= 52) 3) NH 615 (*G. hirsutum* 2n= 52) 4) DCH 32 (*G. hirsutum* x *G. barbadense* interspecific hybrid 2n=52)		

Seed cotton yield per plant (g)

The seed cotton obtained from five randomly selected plants was weighed separately and mean seed cotton yield per plant was recorded.

No. of seeds per boll

Number of seeds per boll were isolated from cotton lint and recorded.

Ginning percentage (%)

Ginning percentage is the ratio of weight of lint to that of seed cotton expressed in percentage. The seed cotton was ginned by hand gin and weight of lint was recorded on the balance with 0.1 per cent sensitivity and ginning percentage was calculated by using following formula.

$$\text{Ginning percentage (\%)} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

Morphological studies

Plant height

The height of plant in cm was recorded at maturity from the base of the main stem at ground level to the tip of the fully opened leaf of main stem.

Leaf studies

Leaf characters like number of lobes, total leaf length at middle lobe and breadth as well as leaf angle were recorded.

Calyx tube

The calyx tube length was measured from the base of pedicel in centimeter.

Corolla

The colour of petals was recorded and size recorded in cm.

Staminal column

The length of staminal column was measured in cm.

Ovary

Diameter of the ovary was recorded in cm.

Bractioles

Length and breadth of bracteole were recorded in cm.

No. of locule

Number of locule / ovary.

Fibre properties

Upper half mean length (UHML) (mm)

(UHML = 0.98 x 2.5 % Staple Length + 0.1827)

Uniformity index (%)

(UI %= -0.184 x Uniformity ratio % + 91.17)

Micronaire value (µg / inch)

It is the average weight per unit length of fiber. It is used in determining the fiber fineness, linear density of fiber is expressed in micrograms per inch.

Fibre strength (g / tex)

It is the force required to break bundle of fiber of unit linear density. The fiber strength was determined by using HVI and expressed in grams per tex.

Results and Discussion

Yield contributing characters

The observations of seed cotton yield per plant, average boll weight, seeds per boll, number of bolls per plant and ginning percentage are presented in Table 2.

Seed cotton yield per plant (g)

The highest seed cotton yield per plant was recorded for derivatives IS-43-9 (48.70 g), followed by derivatives IS-1-4, IS-1-6, IS-36-12 and IS-44-3 (48.65 g, 47.75 g, 47.65 g and 46.93 g), respectively. The check varieties DHY-286, DCH-32, PA-183 and NH-615 recorded seed cotton yields of 34.90 g, 42.80 g, 43.70 g and 38.87 g respectively.

Average boll weight (g)

The highest boll weight was recorded in derivatives IS-43-7 (4.40 g), which showed a significant increase over checks varieties DHY-286, DCH-32, PA-183 and NH-615 (2.91 g, 2.78 g, 3.04 g and 3.30 g, respectively), followed by three derivatives IS-1-6, IS-2-5 and IS-2-8 (3.97 g, 4.00 g and 4.31 g, respectively).

Seeds per boll

The highest number of seeds per boll was recorded in check, NH-615 (21.06), followed by PA-183, DHY-286 and DCH-32 (21.04, 20.95 and 20.76, respectively).

Number of bolls per plant

The highest number of bolls per plant was recorded in derivatives IS-36-12 (28.33) which was significantly higher than that in the check varieties DHY-286 (12.01), DCH-32 (15.41), PA-183 (14.43) and NH-615 (11.83).

Ginning (%)

The highest ginning was recorded in derivatives IS-35-11 (39.93 %), whereas a lower ginning outturn was recorded by derivatives IS-1-3 (30.91 %), IS-1-4 (31.18 %), IS-1-5 (29.54 %), IS-2-6 (16.85 %), IS-31-6 (23.35 %), IS-33-5 (31.28 %), IS-34-9 (31.76 %), IS-43-5 (29.52 %), IS-43-7 (31.72 %), IS-43-10 (31.58 %), IS-43-4 (29.04 %) and check variety DHY-286 (25.52 %).Introgressed trispecies derivative IS-43-9 recorded the highest seed cotton yield per plant (48.70 g), which is nullisomic and has an average chromosome number of (2n=51), followed by other derivatives, viz., IS-1-4 (48.65 g), IS-1-6 (47.75 g), IS-36-12 (47.65 g) and IS-44-3 (46.93 g). However, derivative IS-32-15 (9.88 g) recorded the lowest yield per plant. Average boll weight was recorded in derivative IS-43-7 (4.40 g), which was significantly superior to all the checks viz., DHY-286 (2.91g), DCH-32 (2.78 g), PA-183 (3.04 g) and NH-615 (3.30 g), followed by three derivatives viz.,

Table 2: Mean performance for different traits studied in interspecific trispecies derivatives in BC_1F_{21} generation

SN	Character	IS-1-1	IS-1-2	IS-1-3	IS-1-4	IS-1-5	IS-1-6	IS-2-1	IS-2-2	IS-2-4	IS-2-5	IS-2-6	IS-2-7	IS-2-8	IS-3-1	IS-3-2	IS-3-5
1	Total chromosome number	42.5	54.5	49	52.5	42.5	47.5	42	36	41.25	50	44.5	47.5	47	46	46	42
2	Seed cotton yield/plant (gm)	19.21	21.05	23.33	48.65	41.75	47.75	12.76	10.73	18.25	24.95	25.65	18.54	14.78	25.67	25.51	26.8
3	Average boll weight ((gm)	2.95	3.25	3.71	3.14	2.27	3.97	2.89	3.16	3.48	4	3.94	3.51	4.31	3.63	3.48	3.64
4	Number of seeds/ boll	14.02	13.41	12.56	19.85	14.48	18.81	13.6	14.43	13.42	14.42	12.28	13.25	14.63	14.24	13.47	14.51
5	Number of bolls/ plant	6.51	6.49	6.31	15.51	18.38	12.05	4.42	3.41	5.24	6.25	6.53	5.33	3.44	7.08	7.34	7.36
6	Ginning percentage (%)	37.41	37.44	30.91	31.18	29.54	35.46	35.1	34.71	35.46	36	16.85	32.12	37.21	35.25	35.83	34.2
7	Plant height (cm)	84.5	82.67	84.75	92.11	112	116.04	95.1	77.05	90	104.26	79.21	92.25	88.95	147.76	102.34	118.26
8	Number of leaf lobes	3.43	3.68	3.79	4.62	4.5	5.41	4.85	3.76	3.84	4.46	4.61	4.5	3.25	5	4.84	4.36
9	Length of middle lobe (cm)	4.73	5.82	6.83	7.04	6.61	6.88	6.19	5.89	6.24	6.34	7.75	6.51	7.31	8.31	6.91	7.5
10	Breadth of middle lobe (cm)	2.39	3.51	3.3	3.56	2.05	3.46	3.1	3.16	2.31	3.56	4.75	4.01	4.03	3.71	3.76	3.76
11	Leaves angle 0	67.75	64.83	62.5	63.66	63.5	51.5	60.5	56.5	63.5	76.45	58.5	55.05	55.65	53.5	60.65	46.5
12	Leaf thickness (mm)	0.46	0.45	0.48	0.46	0.46	0.48	0.35	0.44	0.46	0.48	0.47	0.46	0.45	0.47	0.42	0.47
13	Calyx tube (cm)	0.45	0.61	0.68	0.73	0.59	0.64	0.56	0.45	0.55	0.61	0.54	0.46	0.65	0.66	0.78	0.74
14	Corolla length (cm)	2.33	2.14	2.22	2.29	2.15	2.15	2.05	1.69	2.44	2.45	2.54	2.25	2.17	2.15	2.65	2.74
15	Corolla breadth (cm)	1.28	1.62	1.54	1.27	1.13	1.24	1.06	1.38	1.54	1.66	1.34	1.47	0.76	1.22	1.45	2.32
16	Staminal column (cm)	0.73	0.77	0.48	0.77	1.06	1.1	0.74	0.63	0.94	1.01	1.02	0.67	0.71	1.17	1.66	1.27
17	Ovary diameter (cm)	2.21	1.82	2.15	1.95	1.87	1.97	1.84	1.68	1.56	1.91	1.91	1.82	1.76	1.67	2.14	1.78
18	Bractiole length (cm)	1.96	1.67	1.72	1.41	1.26	1.51	1.56	1.41	1.83	1.52	1.74	1.54	1.77	1.65	1.65	1.96
19	Bractiole breadth (cm)	0.93	1.38	1.6	1.49	1.35	1.35	1.52	1.32	1.84	1.89	1.53	1.51	1.27	1.45	1.53	1.47
20	Number of locules	4	3.33	3.66	4	3.5	3.5	3	4	4	4	4	3.5	4	3.5	4	4
21	Upper half mean length (mm)	28.63	29.01	26.18	25.74	28.75	29.37	29.06	27.7	28.79	28.69	29.15	29.8	25.18	27.29	27.43	27.74
22	Uniformity index (%)	82.55	83.2	80.25	84.7	83.2	84.55	87.45	86.25	85.65	80.9	83.2	82.05	84.7	84.5	85.35	84.45
23	Micronaire value (mg / inch)	3.42	3.42	3.57	4.28	3.87	3.93	3.34	3.83	3.79	3.82	3.69	4.27	4.27	3.79	3.69	4.27
24	Fibre strength (g / tex)	25.8	28.45	27.55	29.25	26.6	28.7	28.75	30.55	29.65	26.45	25.3	28.15	29	26.85	27.9	28.05

Table 2 a: Mean performance for different traits studied in interspecific trispecies derivatives in BC_1F_{21} generation

SN	Character	IS-8-1	IS-11-5	IS-16-8	IS-17-1	IS-28-1	IS-31-6	IS-31-7	IS-32-9	IS-32-12	IS-32-15	IS-33-1	IS-33-4	IS-33-5	IS-34-5	IS-34-9	IS-35-11
1	Total chromosome number	35	36.5	45.5	47	43.5	38	34	42.5	44.5	40	49	49	40.5	35	38.5	32.5
2	Seed cotton yield/plant (gm)	18.68	35.26	29.24	38.15	20.96	26.4	28.65	11.44	16.74	9.88	25.94	10.24	22.28	38.29	20.43	30.14
3	Average boll weight ((gm)	1.11	2.34	3.19	2.76	2.3	3.92	2.78	2.27	1.88	2.74	3.38	2.56	2.81	3.07	2.56	3.39
4	Number of seeds/ boll	14.35	14.52	14.57	13.2	13.3	14.28	13.37	14.88	13.15	14.67	14.37	13.47	14.55	13.25	14.36	13.48
5	Number of bolls/ plant	17.13	15.28	9.16	13.85	9.13	6.73	10.34	5.02	9.06	3.64	7.67	4	7.93	12.46	8.09	8.89
6	Ginning percentage (%)	36.3	38.42	38.23	39.24	35.57	23.35	35.09	34.71	35.11	39.17	32.96	34.51	31.28	38.5	31.76	39.93
7	Plant height (cm)	104.67	150.14	156.5	130.5	127.5	125.63	119.75	114.76	102.28	103.5	136	131.5	132.63	108	95.05	103.84
8	Number of leaf lobes	3.36	4.24	3.76	4.5	4.61	4.73	3.83	4.6	4.43	4.5	4.65	3.85	4.55	3.81	2.65	4.25
9	Length of middle lobe (cm)	6.81	8.36	8.43	6.64	8.51	7.5	8.25	7.2	6.41	8.01	6.22	6.64	7.31	8.46	7.26	6.43
10	Breadth of middle lobe (cm)	3.54	3.54	3.55	3.95	3.45	3.56	3.85	3.1	3.65	4	3.35	3.45	3.59	4.2	3.55	3.1
11	Leaves angle 0	56.5	59.5	47.5	61	67.5	62	57.5	57.5	59.5	74.5	77.5	56.5	60.8	71.85	61	69.7
12	Leaf thickness (mm)	0.49	0.48	0.45	0.45	0.45	0.45	0.44	0.44	0.45	0.43	0.43	0.46	0.5	0.51	0.48	0.45
13	Calyx tube (cm)	0.75	0.86	1.04	0.85	0.95	0.96	0.87	0.87	0.38	1.21	1.04	0.81	0.93	0.67	0.77	0.95
14	Corolla length (cm)	2.94	2.45	3.08	3.15	2.75	2.93	3.25	2.88	1.65	2.44	2.85	2.85	1.98	2.74	2.69	3.12
15	Corolla breadth (cm)	1.67	1.17	1.92	1.91	1.45	1.83	1.89	1.7	1.06	2.07	1.95	1.57	1.77	2.11	2.17	1.7
16	Staminal column (cm)	1.21	1.01	1.43	1.51	1.59	1.65	2.11	1.46	0.93	1.18	1.44	1.24	1.75	1.65	1.33	1.51
17	Ovary diameter (cm)	2.01	1.77	2.11	1.94	2.01	2.51	2.27	2.28	1.24	1.97	2.51	2.35	2.51	2.07	2.33	2.72
18	Bractiole length (cm)	2.03	1.39	2.03	1.8	1.83	2.03	2.27	1.85	1.44	1.94	2.04	1.86	2.05	3.53	2.02	2.71
19	Bractiole breadth (cm)	1.93	1.44	1.72	1.77	1.53	1.85	2.23	2.4	2.06	1.93	2.05	1.96	2.17	2.32	1.99	1.64
20	Number of locules	3.5	3.5	3.5	4	3.66	4	3.5	4	3.5	3.5	4.17	4	3.5	4	3.5	4
21	Upper half mean length (mm)	27.32	29.14	28.45	28.36	28.2	29.15	27.11	27.37	29.45	25.28	29.8	28.38	29.61	29.74	29.95	29.51
22	Uniformity index (%)	84.4	83.65	84.65	81.9	83.65	84.6	81.4	83.45	84.95	82.5	86.35	85.65	83.95	81	84.75	82.05
23	Micronaire value (mg / inch)	3.67	3.44	3.59	3.53	3.53	3.35	4.37	4.36	3.41	3.59	3.89	3.9	3.35	3.87	3.75	3.97
24	Fibre strength (g / tex)	27.9	29.15	28.1	26.4	26.8	28.6	26.4	28.05	29.25	30.7	28.65	29.35	30.05	26.25	27.75	27.6

Table 2 b: Mean performance for different traits studied in interspecific trispecies derivatives in BC_1F_{21} generation

SN	Character	IS-36-12	IS-39-4	IS-43-2	IS-43-3	IS-43-5	IS-43-6	IS-43-7	IS-43-9	IS-43-10	IS-43-12	IS-43-13	IS-43-14	IS-43-15	IS-44-1	IS-44-3	IS-44-7
1	Total chromosome number	44	44.5	44.5	39	42	38.5	32	51	42	32.5	41	54	54	45.5	45.5	42
2	Seed cotton yield/plant (gm)	47.65	12.07	21.68	25.68	33.15	44.62	28.8	48.7	25.2	15.03	38.05	24.88	31.67	17.66	46.93	22.02
3	Average boll weight ((gm)	1.71	2.23	1.98	3.36	2.41	3.49	4.4	3.46	3.16	3.13	2.8	2.85	3.62	3.07	2.93	2.92
4	Number of seeds/ boll	14.37	14.56	13.88	13.38	14.39	17.7	14.64	19.89	13.42	14.17	13.59	14.27	13.07	14.23	17.73	14.62
5	Number of bolls/ plant	28.33	5.49	11.11	7.67	13.8	12.8	6.58	14.12	8.02	4.8	13.66	8.81	8.79	5.8	16.18	7.55
6	Ginning percentage (%)	35.75	34.7	32.62	36.3	29.52	38.7	31.72	37.09	31.58	37.93	38.39	38.26	34.6	35.98	38.51	38.76
7	Plant height (cm)	128.76	60.16	63	107	102.34	96	107	109	100.5	105.83	109.34	105.67	101.5	107.67	103.5	108.16
8	Number of leaf lobes	3.77	3.45	3.55	4.85	3.5	3.45	4.5	3.85	4.51	4.27	4.61	4.41	4	3.5	3.36	4.41
9	Length of middle lobe (cm)	6.9	7.14	7.01	7.2	5.9	6.26	5.77	7.75	7.33	7.5	7.45	7.74	8	8.5	7.83	9.55
10	Breadth of middle lobe (cm)	3.25	3.76	3.55	3.15	3	3.3	3.39	3.55	3.55	3	3.76	3.65	3.85	3.55	3.55	4.21
11	Leaves angle 0	57.95	58.75	71.75	52.5	80.5	69.5	74.5	57.5	61	65.5	55.25	49.5	51.5	57.16	50.5	55.5
12	Leaf thickness (mm)	0.47	0.45	0.46	0.43	0.44	0.45	0.47	0.47	0.45	0.47	0.48	0.48	0.47	0.49	0.41	0.5
13	Calyx tube (cm)	1.01	0.99	0.67	0.82	0.87	0.8	0.74	1.03	0.78	0.62	0.71	0.97	0.87	0.91	0.95	1.04
14	Corolla length (cm)	2.96	2.12	2.26	2.56	2.43	3.08	2.27	2.94	2.32	1.95	2.35	3.12	2.84	2.58	2.54	3.07
15	Corolla breadth (cm)	1.67	1.62	1.14	1.72	1.76	1.93	1.23	1.54	3.87	1.43	1.57	1.93	1.91	1.31	1.47	1.64
16	Staminal column (cm)	1.61	1.41	0.96	1.14	0.94	1.57	0.86	3.11	1.08	0.93	1.31	1.12	1.17	0.97	0.88	1.64
17	Ovary diameter (cm)	2.26	2.17	2.01	2.02	2	2.17	1.91	3.11	2.25	2.01	2.01	2.38	2	1.85	2.21	2.02
18	Bractiole length (cm)	2.01	2.64	1.73	1.78	1.42	1.59	2.06	2.11	1.74	1.07	1.66	2.22	1.94	1.74	2.14	1.64
19	Bractiole breadth (cm)	1.77	1.81	2	1.92	1.77	2.17	1.93	2.11	1.75	1.03	1.67	2.24	1.97	1.74	2.13	1.64
20	Number of locules	3.5	4.17	3	3.5	3.83	3	4	4	3.5	3.5	3.33	3.5	3.5	3.66	3.33	4
21	Upper half mean length (mm)	26.65	27.78	27.86	28.85	27.2	28.28	29.58	28.87	27.85	29.75	26.58	28.68	26.46	27.51	26.35	27.93
22	Uniformity index (%)	83.25	84.45	82.35	83.95	85.25	83.25	84.95	81.75	84.05	82.95	81.45	83.3	81.75	81.3	81.75	83.75
23	Micronaire value (mg / inch)	3.75	3.75	3.44	3.59	3.47	3.57	3.45	3.34	3.73	3.61	3.28	3.87	3.48	3.47	3.86	3.48
24	Fibre strength (g / tex)	29.7	26.8	26.25	29.3	29.5	26.55	28.45	25.5	27.65	28.65	29.65	26.6	27.5	29.45	28.5	28.55

Table 2 c: Mean performance for different traits studied in interspecific trispecies derivatives in BC_1F_{21} generation

SN	Character	IS-43-4	IS-43-8	DHY-286	DCH-32	PA-183	NH-615	SE±	CD @ 5 %	CV
1	Total chromosome number	32.5	38.5	52	52	26	52			
2	Seed cotton yield/plant (gm)	26.06	15.97	34.9	42.8	43.7	38.87	0.97	2.76	5.05
3	Average boll weight ((gm)	2.67	2.5	2.91	2.78	3.04	3.3	0.16	0.45	7.46
4	Number of seeds/ boll	13.55	14.53	20.95	20.76	21.04	21.06	0.14	0.39	1.3
5	Number of bolls/ plant	9.78	6.4	12.01	15.41	14.43	11.83	0.98	2.79	14.65
6	Ginning percentage (%)	29.04	37.93	25.2	36.94	34.06	39.21	2.75	7.81	11.24
7	Plant height (cm)	105.67	89.25	105.85	125.15	219.15	133.9	3.14	8.1	4.07
8	Number of leaf lobes	4	4.5	4.64	5	5.26	3.36	0.2	0.56	6.69
9	Length of middle lobe (cm)	7.5	7.16	7.95	7.5	7.83	8.55	0.34	0.95	6.58
10	Breadth of middle lobe (cm)	3.55	3.15	4.65	3.25	1.2	4.35	0.05	0.15	2.11
11	Leaves angle 0	59.5	48.45	61.5	54.5	65.5	60.65	0.6	1.69	1.39
12	Leaf thickness (mm)	0.47	0.44	0.5	0.44	0.5	0.45	0	0.01	0.82
13	Calyx tube (cm)	0.78	0.87	0.87	0.81	0.61	1.06	0.02	0.06	4.02
14	Corolla length (cm)	2.3	2.22	3.08	3.15	2.98	2.93	0.05	0.13	2.61
15	Corolla breadth (cm)	1.67	1.64	1.76	1.62	1.52	1.85	0.02	0.05	1.55
16	Staminal column (cm)	1.67	1.63	1.72	1.59	1.52	1.62	0.07	0.19	7.56
17	Ovary diameter (cm)	1.92	2.01	2.08	2.21	1.79	2.04	0.03	0.07	1.76
18	Bractiole length (cm)	2.01	1.83	2.97	3.13	2.16	2.47	0.08	0.22	5.66
19	Bractiole breadth (cm)	2.01	1.81	2.97	3.11	2.12	1.53	0.01	0.04	1.17
20	Number of locules	3.5	4	4	3.66	4	4	0.19	0.55	7.44
21	Upper half mean length (mm)	28.71	26.65	26.25	32.05	25.05	26.6	0.43	1.23	2.18
22	Uniformity index (%)	83.45	84.55	83.85	87.3	81.5	84.4	0.47	1.33	0.79
23	Micronaire value (mg / inch)	3.76	3.42	3.86	2.7	4.56	3.31	0.04	0.13	1.72
24	Fibre strength (g / tex)	26.65	28.4	26.15	29.1	26.45	25.15	0.69		3.49

IS-1-6 (3.97 g), IS-2-5 (4.00 g) and IS-2-8 (4.31 g) indicating that the traits viz., yield per plant and average boll weight considerably improved over parents and checks. The numbers of bolls per plant and ginning percentage exhibited the highest heterosis over the controls. The results obtained are in accordance with earlier studies of Deshpande *et al.* (1991), Meshram and Tayyab (1991and 1994), Quian Siying (1996), Ding *et al.* (1999), Mehetre *et al.* (2003 a), Mehetre *et al.* (2003) and Kamdi *et al.* (2006). Saitwal *et al.* (2003) reported a very low possibility of improving traits viz., seeds per boll, which may be due to post fertilization barriers, lower pollen fertility and the development of bolls and seeds due to unequal pairing and irregular separation of chromosomes.

Morphological observations

Observations of fifteen following morphological traits in introgressed trispecies derivatives compared with two *G. hirsutum* varietal checks, viz., DHY-286 and NH-615, one interspecific hybrid check DCH-32 (*G. hirsutum* x *G. barbadense*) and one *arboreum* check PA-183.

Plant height (cm)

Plant height in introgressed trispecies derivative derivatives was found to be significantly more or less than that in the controls. The highest plant height was recorded in *G. arboreum* check variety PA-183 (219.15 cm), whereas the lowest plant height was recorded in strain IS-39-4 (60.16 cm).

No. of leaf lobes

Palmate types of leaf lobes were recorded in all the derivatives except IS-1-5 and the check variety, PA-183, which had a semi okra or digitate leaf shape. The highest no. of leaf lobes (5.41) was recorded in IS-1-6 and was found at par with derivatives viz., IS-2-1, IS-43-3 and the check hybrid DCH-32 and variety PA-183.

Length of middle lobe (cm)

The highest length of the middle lobe (9.55 cm) was recorded in derivatives IS-44-7. Trispecies recorded significantly more middle lobe length than all four check varieties.

Breadth of the middle lobe (cm)

The highest breadth of the middle lobe (4.75 cm) was recorded in derivatives IS-2-6 and was found at par with the check variety DHY-286. Trispecies derivatives recorded significantly higher middle lobe length compared to check varieties.

Leaf Angle

The highest leaf angle (80.50^0) was recorded in derivatives IS-43-5. Leaf angles of, 65.50^0, 61.50^0, 60.65^0 and 54.50^0 were recorded in *arboreum* check PA-183 and the *hirsutum* check varieties DHY-286, NH-615, and DCH-32, respectively. This indicates that the leaf angle in trispecies derivatives was significantly higher than that in check varieties.

Leaf thickness (mm)

The highest leaf thickness (0.51 mm) was recorded in derivatives IS-34-5 and was found at par with derivatives viz., IS-33-5, IS-44-7, check DHY-286 and PA-183. Nine derivatives, viz., IS-1-3 (0.48 mm), IS-1-6 (0.48 mm), IS-2-5 (0.48 mm), IS-8-1 (0.49 mm), IS-11-5 (0.48 mm), IS-34-9 (0.48 mm), IS-43-13 (0.48 mm), IS-43-14 (0.48 mm) and IS-44-1 (0.49 mm), significantly higher leaf thickness than check, DCH-32 and NH-615.

Flower colour

Mostly, petal colour in trispecies derivatives was observed as (white, yellow and creamy), however, six varieties and two checks recorded creamy flower colour, i.e., IS-1-1, IS-1-2, IS-1-3, IS-1-4, IS-1-5, IS-1-6, along with check varieties DHY-286 and DCH-32, however, the remaining derivatives recorded yellow color. Dark petal spot was also recorded in strain IS-1-5, which was similar to the interspecific hybrid DCH-32.

Calyx tube length (cm)

The highest calyx tube length (1.21 cm) was recorded in derivatives IS-32-15, whereas check varieties DHY-286, DCH-32, PA-183 and NH-615 recorded calyx tube lengths of 0.87 cm, 0.81 cm, 0.61 cm and 1.06 cm, respectively. These results indicated that the length of the calyx tube in trispecies derivatives was significantly higher than that in check varieties.

Corolla length (cm)

The derivatives IS-31-7 (3.25 cm) showed significantly higher corolla length than the controls, PA-183 and NH-615, followed by derivatives IS-17-1 (3.15 cm), IS-35-11 (3.12 cm), and IS-43-14 (3.12 cm) and hybrid, DCH-32 (3.15 cm).

Corolla breadth (cm)

The highest corolla breadth was recorded in derivatives IS-43-10 (3.87 cm). Trispecies derivatives, viz., IS-3-5, IS-34-5 and IS-34-9, recorded 2.32 cm, 2.11 cm and 2.17 cm, respectively. All four check varieties, viz., DHY-286, DCH-32, PA-183 and NH-615, recorded corolla breadths below 2 cm i.e. 1.76 cm, 1.62 cm, 1.52 cm and 1.85 cm, respectively. This indicates that corolla breadth in trispecies derivatives was significantly higher than that in check varieties.

Length of staminal column (cm)

The longest length of the staminal column was recorded in derivatives IS-43-9 (3.11 cm). All four check varieties, viz., DHY-286, DCH-32, PA-183 and NH-615, recorded 1.72 cm, 1.59 cm, 1.52 cm and 1.62 cm stamina column lengths, respectively.

Ovary diameter (cm)

The highest ovary diameter (3.11 cm) was recorded in derivatives IS-43-9, which was found to be significantly higher than that in the check varieties DHY-286 (2.08 cm), DCH-32 (2.21 cm), PA-183 (1.79 cm) and NH-615 (2.04 cm).

Bracteole length (cm)

The highest bracteole length (3.53 cm) was recorded in derivatives IS-34-5, which was significantly higher than that in the check varieties DHY-286 (2.97 cm), DCH-32 (3.13 cm), PA-183 (2.16 cm) and NH-615 (2.47 cm).

Bracteole breadth (cm)

The highest bracteole breadth was recorded in the check variety, DCH-32 (3.11 cm), which was significantly higher than that in the other check varieties, viz., DHY-286 (2.97 cm), PA-183 (2.12 cm) and NH-615 (1.53 cm), and the rest of the trispecies derivatives.

Number of locules per plant

The highest number of locules per ovary was recorded in derivatives IS-33-1 and IS-39-4 (4.17), which was found at par with all derivatives except the derivatives IS-1-2, IS-1-5, IS-1-6, IS-2-1, IS-2-7, IS-3-1, IS-8-1, IS-11-5, IS-16-8, IS-31-7, IS-32-12, IS-32-15, IS-33-5, IS-34-9, IS-36-12, IS-43-2, IS-43-3, IS-43-6, IS-43-10, IS-43-12, IS-43-13, IS-43-14 IS-43-15, IS-44-3 and IS-43-4.

The highest plant height (cm) was recorded in the *G. arboreum* check variety, PA-183 (219.15 cm), whereas the plant height recorded in the introgressed trispecies derivatives was more or less equal to the *hirsutum* checks, viz., DHY-286, DCH-32 and NH-615. Palmate –type leaf shape was recorded in all derivatives and checks except derivatives IS-1-5 and the check variety, PA-183, which was recorded as semiokra or digitate leaf shape. The leaf morphology of the IS-1-5 derivative was similar to that of *G. arboreum* check, PA-183. The number of leaf lobes, length of the middle lobe, breadth of the middle lobe and leaf angle were recorded to be significantly highest over the *G. arboreum* check, PA-183 and *G. hirsutum* check varieties, viz., DHY-286 and NH-615, and the interspecific hybrid check, DCH-32 (*G. hirsutum x G. barbadnese*). The results of the present investigation are in agreement with those reported by Deshpande *et al.* (1991) and Meshram and Tayyab (1994). The highest leaf thickness was recorded in derivative IS-34-5 (0.51 mm), which was higher than *G. arboreum* check, PA-183 (0.50 mm) and DHY-286 (0.50 mm). Derivatives having leaf thickness values near or above check varieties also showed resistance against sucking pests, viz., aphids, jassids, thrips and whiteflies. These findings of leaf thickness studies are in agreement with the reports of Malik and Nandal (1986), Sharma and Agarwal (1983), Butter *et al.* (1989), Raza *et al.* (1999), Bashir *et al.* (2001), Muhammad *et al.* (2004), Sarvanan *et al.* (2005), Guljar *et al.* (2005), Arif (2006) and Vanitha *et al.* (2007). The floral character petal colour in trispecies derivatives was observed as white, yellow and cream, however, six strains, viz., IS-1-1, IS-1-2, IS-1-3, IS-1-4, IS-1-5 and IS-1-6, and two checks, viz., DHY-286 and DCH-32, recorded cream flower colour, however, the rest of the derivatives recorded yellow petal colour. Dark petal spot was recorded in strain IS-1-5, which was found to be similar to the interspecific hybrid DCH-32, while other floral characters, viz., calyx tube length, corolla length, corolla breadth, length of the staminal column, ovary diameter, bracteole length, bracteole breadth, and number of locules in trispecies derivatives, were found to be comparatively higher over checks with vigorous growth. The results are in agreement with earlier reports of Deodikar (1949), Thombre and Mehtre (1981), Deshpande *et al.* (1991), Meshram and Tayyab (1991), Saitwal *et al.* (2003), Sarvanan *et al*. (2005), Kamdi *et al.* (2006) and Ramamoorthy (2006).

Fibre properties

The observations of seed cotton upper half mean length (UHML), uniformity index, Micronaire value and fiber strength are presented in Table 2.

Upper half mean length (UHML) (mm)

The highest upper half mean length (UHML) was recorded in check DCH-32 (32.05 mm), followed by derivatives IS-1-2 (29.01 mm), IS-1-6 (29.37 mm), IS-2-1 (29.06 mm), IS-2-6 (29.15 mm), IS-2-7 (29.80 mm), IS-11-5 (29.14 mm), IS-31-6 (29.15 mm), IS-32-12 (29.45 mm), IS-33-1 (29.80 mm), IS-33-5 (29.61 mm), IS-34-5 (29.74 mm), IS-34-9 (29.95 mm), IS-35-11 (29.51 mm), IS-43-7 (29.58 mm) and IS-43-12 (29.75 mm), which recorded a significant upper half mean length over the rest of the checks, viz., PA-183, DHY-286 and NH-615.

Uniformity index (%)

The highest uniformity index was recorded in check DCH-32 (87.30 %), followed by derivatives IS-2-1, IS-2-2 and IS-33-1. Derivatives IS-2-4 (85.65 %), IS-3-2 (85.35 %), IS-33-4 (85.65 %) and IS-43-5 (85.25 %).

Micronaire value (µg/inch)

The highest micronaire value was recorded in *arboreum* check variety PA-183 (4.56 µg/inch) followed by introgressed derivatives viz., IS-1-4 (4.28 µg/inch), IS-2-7 (4.27 µg/inch), IS-2-8 (4.27 µg/inch), IS-3-5 (4.27 µg/inch), IS-31-7 (4.37 µg/inch) and IS-32-9 (4.36 µg/inch).

Fibre strength (g/tex)

The highest fibre strength was recorded in derivatives IS-32-15 (30.70 g/tex), followed by derivatives IS-1-4, IS-2-1, IS-2-2, IS-2-4, IS-2-8, IS-11-5, IS-32-12, IS-33-4, IS-33-5, IS-36-12, IS-43-3, IS-43-5, IS-43-13, IS-44-1 and check DCH-32 (29.25, 28.75, 30.55, 29.65, 29.00, 29.15, 29.25, 29.35, 30.05, 29.70, 28.50, 29.50, 29.65, 29.45 and 29.10 g/tex), respectively.The hybrid check, DCH-32, recorded the highest upper half mean length (UHML) (32.05 mm), uniformity index (87.50 %) and finest micronaire (2.70 µg/inch). The highest fiber strength was recorded in trispecies derivatives IS-32-15 (30.70 g/tex) which was found superior over all the checks viz., PA-183 (26.45 g/tex), NH-615 (25.15 g/tex), DHY-286 (26.15 g/tex) and DCH-32 (29.10 g/tex) followed by introgressed trispecies derivatives viz., IS-2-1 (28.75 g/tex), IS-11-5 (29.15 g/tex), IS-32-12 (29.25 g/tex) and IS-33-5 (30.05 g/tex). Deodikar (1949) obtained similar results in their studies on introgression breeding.

Conclusion

The materials developed through introgression breeding in the present study are still showing instability for chromosomes even after 21 years. This material may be useful for students, cytologists and scientists for carrying out basic research in cotton, particularly the effect of genome interactions on total chromosome complement when two tetraploid species (*Gossypium hirsutum x Gossypium barbadense*) and one diploid species (*Gossypium arboreum*) are involved in the development of trispecies populations.

Morphological, yield contributing and fibre quality traits were found to be intermediate between *G. arboreum* and *G. hirsutum* checks, indicating introgression of traits from *G. arboreum, G. hirsutum,* and *G. barbadense*.

Four trispecies derivatives, viz., IS-2-1, IS-11-5, IS-32-12, IS-33-5 and IS-1-5, were found to be the most diverse for morphological and fiber traits, whereas IS-3-1 and IS-43-9 were found to be the most diverse and dissimilar, having a broad genetic base for the concerned fiber quality traits.

Conflict of interest

The authors declare that they have no conflict of interest.

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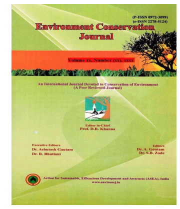

Assessment of gene action for morpho-physiological and biochemical trait in bread wheat (*Triticum aestivum* L.)

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ABSTRACT

The present study was undertaken with the objective to assess the nature and magnitude of gene action for various morpho-physiological and biochemical traits in two crosses namely cross BHU 31 × HD 2733 and cross, HPYT 485 × HD 2967 in wheat. The six basic generations (P_1, P_2, F_1, F_2, B_1 and B_2 obtained from these crosses (made in *Rabi* 2018 and 2019) were evaluated for 13 quantitative traits including yield and micronutrient traits during *Rabi* 2020 in compact family block design with 3 replications at Research farm, RPCAU, Pusa and data were recorded on randomly selected plants per replication of each cross for all the traits. The estimation of micronutrient in wheat grains was done by X-Ray Fluorescence Spectrometry at Harvest-plus Division, ICRISAT, Hyderabad. The result regarding gene effect indicated that in both the crosses dominance and dominance × dominance effect for grain Zinc content (-29.00 & 19.18 and -9.79 & 7.04 respectively in cross I and II) and grain Iron content (-18.16 & 12.37 and -20.29 & 12.31 respectively in cross I and II) has significant role in expression of these traits. Duplicate type of gene interaction was found predominant for grain Zinc and Iron content and almost for all the traits due to opposite sign of dominance (h) and dominance × dominance (l) gene effect which tends to cancel the effect of each other in hybrid combination therefore selection should be advanced in later generation.

Introduction

Bread wheat (*Triticum aestivum* L.), enjoyed the status of second most important food crop in India with a production of 107.2 million tons and average productivity of 3.51 t/ha from an acerage of 30.5 million hectares (Annual Report,2019-2020, DAC&FW). Globally, it is the preferred staple food crop for a large section of world population, fulfilling nearly 20 % of daily food requirement and ranks first at global level in terms of overall production. Additionally, it is also a rich source of protein, essential dietary micronutrient, including Zinc, Iron and Manganese and Vitamins B & E (Reynolds *et al.,* 2012; Velu *et al*., 2017). Being the most important staple crop at global level, wheat is a better alternative for bio-fortification to circumvent hidden hunger by ensuring food & nutritional security for millions of people of poorer section bio-fortification is a sustainable solution (Bouis *et al*., 2011). Wheat varieties with improved nutrition quality and high grain yield can help to overcome the micronutrient malnutrition among resource poor people (Velu *et al*., 2018). Thus, development of high yielding biofortified varieties has become the first and foremost objective of wheat breeders in the contemporary context to address the question of malnutrition. Development

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of such promising varieties require a comprehensive knowledge of prevalent gene action governing the concerned trait which will guides in choice of appropriate breeding procedure in the improvement of various morphophysio and biochemical traits. The successful breeding program for developing nutrient enriched high-yielding genotypes requires screening available germplasm to identify suitable sources of higher micronutrient content. However, improvement of these complex traits which are largely under polygenic control requires specific breeding approach which could picture a clear understanding of the inheritance, nature and magnitude of genetic variance and heritability of yield and yield attributing traits. Heritability and mode of gene action are also important genetic parameter that facilitate determination of the right stage of selection whether to start it in early generation or to advance it in later generations. Aparts, estimation of different component of genetic variance *viz*. additive, dominance and epistatic variance is helpful in deciphering the inheritance pattern of genes influencing yield and related traits. This could be achieved through Generation Mean Analysis (GMA) that helps in the estimation of different components of genetic effects namely additive effects, dominance deviations and epistatic effects in determining genotypic values of the individuals and consequently, mean genotypic values of families and generations. It is also a robust tool to determine the nature of gene interaction i.e. additive × additive, dominance × dominance and additive × dominance. Scaling test provide the information on presence and absence of epistasis while the joint scaling test enable the estimation of important genetic parameters *viz.,* mean performance, additive effects and dominance effects along with the evidence of presence and absence of epistasis. Keeping these in view, the present investigation was carried out with the objective of determining the nature and magnitude of gene action for grain yield and Zinc and Iron content in bread wheat genotypes using generation mean analysis.

Material and Methods

In this investigation, six basic generations *viz.,* P_1, , P_2, F_1, F_2, B_1 and B_2 were generated from 4 diverse parents BHU31, HPYT 485, HD2967 and HD2733 for micronutrient content which were selected & procured from department of Plant Breeding and Genetics, RPCAU, Pusa Samastipur, Bihar. The parents were crossed as following cross-I (BHU 31 × HD 2733) and cross-II (HPYT 485 × HD 2967) in which BHU31 and HPYT485 were used as female parent having high grain Zn & Fe content, while HD2733 and HD2967 were used as male parent having low grain Zn & Fe content but higher yield. The crosses were made during *Rabi* 2018 and the F_1 seeds were grown during *Rabi* 2019 to obtain F_2 seeds and backcrossed with both parents to generate B_1 and B_2 which were shown along with F_1 in Rabi 2020 for evaluation.

Statistical Analysis

The adequacy of additive × dominance model for different trait in each cross was tested using scaling test (A, B, C and D) as suggested by Mather ,1949 and elaborated by Mather and Jinks, 1982 and Joint scaling test (Cavalli 1952; Mather and Jinks 1982; Ceballos 1996). The significance of scales were tested using't' test and chi square ($\chi2$) respectively. The gene effects of various morpho-physiological and biochemical traits of each cross were estimated by generation mean analysis. Three parameter model (Jink and Jones, 1958; Manivannan, 2014) was applied to estimate gene effect of traits in absence of epistasis, whereas in the presence of non-allelic interaction test analysis was done by six parameter model (Hayman, 1958; Manivannan, 2014). The significance of the mean value of a particular parameter was tested against its corresponding standard error, via a Student's t-test, as suggested by Mather and Jinks (1982) and Uzokwe *et al.* (2017).

Results and Discussion

In any crop improvement programme, genotypic value of the lines used as parent as well as those that are selected as promising lines for a defined trait is very crucial. The relative contribution of additive, dominant and epistatic effects in governing a trait provides information on genotypic values of the individuals and, consequently, mean genotypic values of families and generations. In this research investigation, generation mean analysis was done to determine the prevalence as well as the relative contribution of different gene actions in governing expression of various morpho-physiological and biochemical trait in bread wheat. Analysis of variance and mean performance of various morpho-physiological and biochemical traits of each generation are presented in table 1 and 2. Mean sum of square showed significant difference among the generations for all traits under study indicated the presence of variability for these traits. In cross-I (BHU31 × HD2733) mean performance of F_1 was higher than both parent for days to 50% flowering(84.87 days), plant height(93.04 cm), spike length(12.35 cm) and number of tillers per plant(7.53). Mean performance of F_2 was higher than F_1 for most of traits except chlorophyll content(53.80), plant height(92.94 cm) and spike length(11.55 cm). In cross-II (HPYT485 × HD 2967), mean performance of F_1 was higher than both parent for chlorophyll content(57.24), plant height(95.60 cm), spike length (11.82 cm), number of tillers per plant(7.20) and harvest index(45.62%). Similar result was reported by Ljubicic *et al*., 2016, for spike length and by Said *et al*., 2014, for chlorophyll content, which indicate hybrid vigour of these traits. The performance of F_2 was higher than F_1 for most of traits except chlorophyll content, plant height, spike length, number of tillers per plant and harvest index. Mean performance of F_1 for grain Zinc (29.25 ppm and 29.03 ppm resp.) and Iron content (38.13 ppm and 37.80 ppm resp.) was in between the parental performances in both the crosses, while, it was lower than both parent for rest of traits under study for both the crosses.To determine the nature and magnitude of gene action of various morpho-physiological trait along with grain Zinc and Iron content, generation mean analysis was carried out using data recorded from six basic generations of cross-I (BHU 31 × HD 2733) and cross-II (HPYT 485 × HD 2967) the values of scaling and joint scaling tests and estimates of six parameters *viz.*, m, d, h, i, j and l for different traits are present in table 3,4 and 5. Information of these six parameters are essential for proper selection of breeding methodology. The scaling test showed that at least one of the scales i.e. A, B, C and D were significant for plant height(A:-11.34, D: 10.10), spike length(A:-2.10,B:-1.00,D:1.49), number of tillers per plant(A:-3.13,B:-1.66,D:1.76), number of grains per spike(A:-25.94,B:-18.88,D:21.32), 1000-grain weight(B:-12.37,D:6.45), harvest index(C:-11.79), canopy temperature(B:-3.05,C:-9.06), grain Zinc(A:-5.52, B:-3.16, D:5.24) and Iron content(A:-4.72, D: 2.70) in cross-I (BHU 31 × HD 2733) which indicate the presence of epistasis for these traits. Further $\chi 2$ value of joint scaling test was also found significant for these traits *viz.* plant height(20.09), spike length(15.58), number of tillers per plant(107.03), number of grains per spike(129.04), 1000-grain weight(29.91), harvest index(15.06), canopy temperature(34.79), grain Zinc(41.01) and Iron content(34.77) except days to maturity(7.60). In cross-II (HPYT485 × HD 2967) inter-allelic interactions were observed for number of tillers per plant, grain Zinc content and grain Iron content on the basis of scaling and joint scaling test.

Presence or absence of epistasis was sorted out by scaling and joint scaling test. Traits for which additive-dominance model was adequate three parameters *viz*. m (mean value), d (additive effect) and h (dominance effect) were estimated and estimates are presented in table 5. In cross-I (BHU31 × HD2733), three parameter model (Jink and Jones, 1958; Manivannan, 2014) was used to estimate gene effects for days to 50% flowering, chlorophyll content and grain yield per plant, while, in cross-II (HPYT485 × HD 2967), it was applicable to days to 50% flowering, chlorophyll content, plant height, spike length, days to maturity, number of grains per spike, 1000-grain weight, harvest index, canopy temperature and grain yield per plant. Estimates of gene effect from three parameter model exhibited the preponderance of additive gene effect for grain yield per plant in cross-I (BHU31 × HD2733) and for chlorophyll content, spike length, days to maturity, number of grains per spike, 1000-grain weight and grain yield per plant in cross-II (HPYT485 × HD 2967). These findings suggested that the additive gene effect plays a major role in quantitative expression of these traits. Similar findings were reported by Ljubicic *et al*., 2016 for number of grains per spike, Usman *et al*., 2013 and Kumar *et al*., 2013 for spike length. For the improvement of these traits selection would be effective in early segregating generations. In cross-I (BHU31 × HD2733) along with additive gene effect, dominance gene effect played significant role in expression of grain yield per plant with higher magnitude than that for additive effect.

Table 1: ANOVA for Morpho-physiological and biochemical traits in wheat crosses BHU 31 × HD 2733 and HPYT 485 × HD2967

Source	df	Mean sum of squares												
		Days to 50% flowering	Chlorophyll content (SPAD)	Plant height (cm)	Spike length (cm)	Number of tillers/ plant	Days to maturity	Number of grains per spike	1000-grain weight	Harvest Index (%)	Canopy temperature (˚C)	Grain Zinc content (ppm)	Grain Iron content (ppm)	Grain yield per plant (g)
BHU 31 × HD 2733														
Replication	2	0.02	0.03	0.54	0.05	0.02	0.42	0.31	0.02	0.23	0.5	0.01	0.02	0.04
Generation	5	13.39**	3.17*	18.09**	1.30**	1.36**	7.38**	135.41**	32.60**	5.09**	3.30**	32.44**	27.47**	4.60**
Error	10	0.24	0.78	0.39	0.16	0.08	0.39	0.36	0.05	0.31	0.14	0.06	0.1	0.1
HPYT 485 × HD 2967														
Replication	2	0.17	0.63	0.05	0.00	0.07	0.04	0.04	0.15	0.5	0.26	0.00	0.02	0.13
Generation	5	3.66**	3.36**	7.74**	1.42**	2.15**	6.73**	9.96**	7.22**	2.93**	1.83**	30.47**	16.09**	3.97**
Error	10	0.3	0.22	0.43	0.03	0.03	0.47	0.21	0.13	0.24	0.09	0.11	0.19	0.08

*** and ** indicate significance at 1% and 5% respectively.**

Table 2: Per se performance of six generations in two crosses of bread wheat

Cross		Generations					
		P_1	P_2	F_1	F_2	B_1	B_2
Days to 50% flowering							
BHU 31 × HD 2733	Mean	81.93	82.53	84.87	85.17	84.47	85.33
HPYT 485 × HD 2967	Mean	81.93	82.67	79.53	81.68	81.40	82.33
Chlorophyll content (SPAD)							
BHU 31 × HD 2733	Mean	54.91	56.30	54.29	53.80	54.69	53.35
HPYT 485 × HD 2967	Mean	56.47	55.47	57.24	54.95	54.86	54.51
Plant height (cm)							
BHU 31 × HD 2733	Mean	91.95	90.53	93.04	92.94	86.83	88.95
HPYT 485 × HD 2967	Mean	90.93	92.60	95.60	91.81	93.27	92.20
Spike length (cm)							
BHU 31 × HD 2733	Mean	10.95	10.68	12.35	11.55	10.60	11.01
HPYT 485 × HD 2967	Mean	10.96	11.36	11.82	11.58	10.83	11.21
Number of tillers/plant							
BHU 31 × HD 2733	Mean	6.53	6.67	7.53	6.75	5.47	6.27
HPYT 485 × HD 2967	Mean	6.67	6.73	7.20	6.50	5.13	5.27
Days to maturity							
BHU 31 × HD 2733	Mean	128.40	130.87	126.53	128.78	130.13	130.07
HPYT 485 × HD 2967	Mean	125.47	127.40	125.67	125.12	124.67	128.53
Number of grains per spike							

BHU 31 × HD 2733	Mean	59.47	51.87	51.01	52.80	42.27	42.00
HPYT 485 × HD 2967	Mean	57.27	57.93	53.67	53.58	56.40	56.07
1000-grain weight (g)							
BHU 31 × HD 2733	Mean	45.78	45.90	40.82	43.34	43.05	37.17
HPYT 485 × HD 2967	Mean	43.91	44.55	41.25	41.67	41.15	41.05
Harvest Index (%)							
BHU 31 × HD 2733	Mean	42.47	43.49	44.47	40.78	42.62	41.67
HPYT 485 × HD 2967	Mean	43.94	44.46	45.62	43.52	42.73	43.54
Canopy temperature (˚C)							
BHU 31 × HD 2733	Mean	21.37	22.83	22.49	20.03	20.83	21.13
HPYT 485 × HD 2967	Mean	23.19	22.07	24.43	23.76	23.35	23.11
Grain Zinc content (ppm)							
BHU 31 × HD 2733	Mean	33.13	24.03	29.25	29.37	28.43	25.06
HPYT 485 × HD 2967	Mean	33.73	24.70	29.03	28.65	30.05	25.96
Grain Iron content (ppm)							
BHU 31 × HD 2733	Mean	42.81	34.21	38.13	37.93	38.11	35.05
HPYT 485 × HD 2967	Mean	42.10	35.67	37.80	38.72	37.99	35.99
Grain yield per plant							
BHU 31 × HD 2733	Mean	23.65	22.01	20.71	21.64	21.25	20.06
HPYT 485 × HD 2967	Mean	21.64	23.63	20.29	22.04	20.85	21.90

Table 3: Scaling and joint scaling test for Morpho-physiological and biochemical trait in cross I (BHU 31 × HD 2733)

Traits	Scaling test				Joint Scaling test				Epistasis
	A	B	C	D	m	d	h	χ2 value (3 d.f)	
Days to 50% flowering	2.13	-2.73	0.46	0.53	85.05**	-2.89**	-0.22	3.89	-
Chlorophyll content(SPAD)	0.19	-3.89	-4.57	-0.43	54.65**	0.16	-1.27	4.40	-
Plant height (cm)	-11.34**	-5.66	3.19	10.10**	89.86**	0.19	2.71*	20.09**	Present
Spike length (cm)	-2.10**	-1.00*	-0.113	1.49**	10.66**	0.25*	1.45**	15.58**	Present
Number of tillers/plant	-3.13**	-1.66**	-1.26	1.76**	6.25**	-0.18*	0.63**	107.03**	Present
Days to maturity	5.33**	2.73	2.80	-2.63	129.87**	-1.30*	-2.36*	7.60	Present
Number of grains per spike	-25.94**	-18.88**	-2.18	21.32**	53.05**	3.89**	-3.95**	129.04**	Present
1000-grain weight (g)	-0.50	-12.37**	0.03	6.45**	44.92**	1.06	-4.48**	29.91**	Present
Harvest Index (%)	-1.70	-4.61	-11.79**	-2.73	42.18**	0.15	0.93	15.06**	Present
Canopy temperature (˚C)	-2.18*	-3.05*	-9.06**	-1.91	21.24**	-0.08	0.77*	34.79**	Present
Grain Zinc content (ppm)	-5.52**	-3.16**	1.80	5.24**	28.35**	4.53**	0.58*	41.01**	Present
Grain Iron content (ppm)	-4.72**	-2.24	-1.56	2.70**	38.27**	4.25**	-0.66*	34.77**	Present
Grain yield per plant (g)	-1.86	-2.60	-0.54	1.96	22.60**	0.91**	-2.15**	5.98	-

***and **: Significance at 5% and 1% respectively.**

Table 4: Scaling and joint scaling test for Morpho-physiological and biochemical trait in cross II (HPYT 485 × HD **2967)**

Traits	Scaling test				Joint Scaling test				Epistasis
	A	B	C	D	m	d	h	χ2 value (3 df)	
Days to 50% flowering	1.33	2.46	3.06	-0.36	82.57**	-0.46	-2.72**	2.17	-
Chlorophyll content (SPAD)	-3.98	-3.68	-6.62	0.52	55.31**	0.46	0.75	4.92	-
Plant height (cm)	0	-3.8	-7.5	-1.85	91.36**	-0.58	3.45	4.86	-
Spike length (cm)	-1.12	-0.75	0.35	1.11	11.07**	-0.23	0.65*	6.51	-
Number of tillers/plant	-3.60**	-3.40**	-1.80*	2.60**	6.35**	0.02	-0.14	81.51**	Present
Days to maturity	-1.80	4.00	-3.73	-2.96	126.33**	-1.21	-0.77	4.70	-
Number of grains per spike	1.86	0.53	-8.20	-5.30	57.38**	-0.23	-3.98**	2.94	-
1000-grain weight (g)	-2.85	-3.70	-4.27	1.14	43.48**	-0.18	-2.97**	4.41	-
Harvest Index (%)	-4.10	-2.98	-5.56	0.76	43.28**	-0.25	1.74	6.87	-
Canopy temperature (˚C)	-0.93	-0.29	0.90	1.06	22.58**	0.57*	1.81**	1.50	-
Grain Zinc content (ppm)	-2.66**	-1.81	-1.90	1.28	28.95**	4.39**	-0.06	12.83**	Present
Grain Iron content (ppm)	-3.92**	-1.48	1.49	3.45**	38.75**	3.08**	-1.12**	17.11**	Present
Grain yield per plant (g)	-0.22	-0.12	2.32	1.33	22.79**	-1.05**	-2.44**	1.46	-

***and **: Significance at 5% and 1% respectively**

Table 5: Estimates of three parameters (m, d& h) for Morpho-physiological and biochemical trait in two crosses of bread wheat cross-I (BHU 31 × HD 2733) and cross-II (HPYT 485 × HD 2967)

S. No.	Traits	Crosses	m	d	h
1	Days to 50% flowering	BHU 31 × HD 2733	86.3**	-3.3	-3.1
		HPYT 485 × HD 2967	81.57**	-0.37	2.50
2	Chlorophyll content (SPAD)	BHU 31 × HD 2733	54.73**	-0.70	-3.27
		HPYT 485 × HD 2967	57.02	0.50*	-8.50
3	Plant height (cm)	HPYT 485 × HD 2967	88.07	-0.83	7.43
4	Spike length (cm)	HPYT 485 × HD 2967	13.39**	-0.20*	-5.69
5	Days to maturity	HPYT 485 × HD 2967	120.50**	-0.97*	13.30
6	Number of grains per spike	HPYT 485 × HD 2967	47.00**	-0.33*	19.67
7	1000-grain weight (g)	HPYT 485 × HD 2967	46.51**	-0.32*	-14.11
8	Harvest Index (%)	HPYT 485 × HD 2967	45.72**	-0.26	-8.71
9	Canopy temperature ˚C	HPYT 485 × HD 2967	0.56**	-3.68	3.35
10	Grain yield per plant (g)	BHU 31 × HD 2733	26.76**	0.82**	-14.45*
		HPYT 485 × HD 2967	25.30**	-1.00*	-8.01

***and **: Significance at 5% and 1% respectively.**

Table 6. Estimates of six parameters (m, d, h, i, j & l) for Morpho-physiological and biochemical trait in two crosses of bread wheat cross-I (BHU 31 × HD 2733) and cross-II (HPYT 485 × HD 2967)

S. No.	Traits	Crosses	m	d	h	i	j	l	Epistasis
1	Days to 50% flowering	HPYT 461 × HD 2733	75.99**	-3.40**	27.40*	10.47	1.33	-23.00*	D
2	Spike length (cm)	HPYT 461 × HD 2733	14.57**	0.41**	-9.70**	-3.89**	0.22	8.44**	D
		BHU 31 × HD 2967	10.07**	-0.05	3.35	0.95	1.15*	-3.04*	_
3	Number of tillers	HPYT 461 × HD 2733	8.87**	-0.74	-10.13**	-2.34**	-1.47**	8.33**	C
		BHU 31 × HD 2967	13.53**	0.07	-20.33**	-6.47**	0.40	14.33**	D
4	Days to maturity	HPYT 461 × HD 2733	113.83**	-3.23**	33.38*	15.14*	-2.30	-22.41*	D
		BHU 31 × HD 2967	124.50**	-0.44	7.05**	4.07*	5.64	-1.33	-
5	Grains per spike	BHU 31 × HD 2967	70.37**	0.63	-45.90**	-11.40**	-0.07	-29.60**	D
6	Thousand grain weight (g)	HPYT 461 × HD 2733	37.46**	-0.94	9.49	4.40**	-2.10	-5.66	-
7	Harvest index (%)	BHU 31 × HD 2967	41.28**	-0.95	10.37	2.93	6.69*	-6.82**	-
8	Canopy temperature ˚C	BHU 31 × HD 2967	25.05**	-0.29*	-3.04	-3.38*	0.76	0.92	-
9	Grain Zinc content (ppm)	HPYT 461 × HD 2733	35.93**	6.08**	-17.05**	-5.94**	-4.40**	10.77**	D
		BHU 31 × HD 2967	32.68**	4.07**	-12.43*	-3.97	-3.02**	8.10*	D
10	Grain Iron content (ppm)	HPYT 461 × HD 2733	43.10**	4.15**	-13.51**	-4.81**	-6.14**	7.31**	D
		BHU 31 × HD 2967	43.24**	3.40**	-13.21*	-3.85	-3.81**	8.98**	D
11	Grain yield per plant (g)	BHU 31 × HD 2967	25.67**	-0.18	-7.73	-1.95	-2.94*	2.98	-

***and **: Significance at 5% and 1% respectively.**

Table 7: Estimate of heritability and genetic advance as percentage of mean for morpho-physiological and biochemical traits in four crosses of bread wheat

S.No.	Trait	Crosses	$h^2_{(bs)}$ %	$h^2_{(ns)}$ %	GAM (5%)
1	**Days to 50% flowering**	BHU 31 × HD 2733	85.90	59.70	5.54
		HPYT 485 × HD 2967	83.00	60.00	9.05
2	**Chlorophyll content (SPAD)**	BHU 31 × HD 2733	71.00	39.03	9.92
		HPYT 485 × HD 2967	70.00	55.00	10.24
3	**Plant height (cm)**	BHU 31 × HD 2733	93.00	65.17	20.13
		HPYT 485 × HD 2967	76.00	52.00	13.68
4	**Spike length(cm)**	BHU 31 × HD 2733	80.49	54.20	11.97
		HPYT 485 × HD 2967	72.00	51.00	12.13
5	**Number of tillers/plant**	BHU 31 × HD 2733	78.00	41.00	20.96
		HPYT 485 × HD 2967	51.00	40.00	15.52
6	**Days to maturity**	BHU 31 × HD 2733	75.11	36.00	3.82
		HPYT 485 × HD 2967	86.00	42.00	8.20
7	**Number of grains per spike**	BHU 31 × HD 2733	84.00	40.00	9.26
		HPYT 485 × HD 2967	82.00	60.00	18.20
8	**1000-grain weight (g)**	BHU 31 × HD 2733	91.30	50.31	11.90
		HPYT 485 × HD 2967	80.00	67.00	12.16
9	**Harvest Index (%)**	BHU 31 × HD 2733	70.00	30.00	10.03
		HPYT 485 × HD 2967	76.00	37.00	6.21
10	**Canopy temperature (°C)**	BHU 31 × HD 2733	89.00	44.00	10.58
		HPYT 485 × HD 2967	85.00	67.10	10.08
11	**Grain Zinc content (ppm)**	BHU 31 × HD 2733	94.00	72.00	13.58
		HPYT 485 × HD 2967	94.00	50.00	8.58
12	**Grain Iron content (ppm)**	BHU 31 × HD 2733	87.00	55.00	7.01
		HPYT 485 × HD 2967	78.00	36.00	5.59
13	**Grain yield per plant (g)**	BHU 31 × HD 2733	87.00	62.00	16.51
		HPYT 485 × HD 2967	89.10	40.00	11.92

role in expression of number of grains per spike with higher magnitude of dominance gene effect in cross BHU31 × HD2733. Similar findings were reported by Abedi *et al*., 2015 and Dvojkovic *et al*.,2010 for preponderance of dominance gene effect in governing number of grains per spike. Among inter-allelic interactions additive × additive and dominance × dominance gene action was observed with higher magnitude of dominance × dominance in cross BHU31 × HD2733. Similar results were reported by Erkul *et al*., 2010; Ljubicic *et al*., 2016 and Ninghot *et al*., 2016 for presence of dominance × dominance gene interaction in influencing number of grains per spike. For expression of trait 1000-grain weight dominant gene effect along with all three epistatic interactions with higher magnitude of dominance × dominance was observed in cross BHU31 × HD2733. Similar finding was reported by Mohamed *et al*., 2014 for 1000 grain weight. Additive and dominance gene effect with higher magnitude of dominance gene effect was observed in expression of Canopy temperature in cross BHU31 × HD2733 . Among the epistatic interaction only additive × additive gene effect was observed. Additive and dominance gene action played role in expression of Grain Zinc content but due to higher magnitude of dominance gene effect preponderance of dominance gene action was observed in expression of trait in both crosses, BHU31 × HD2733 and HPYT485 × HD 2967. Among the inter-allelic interactions additive × additive and dominance × dominance both interaction was found in cross BHU31 × HD2733 while in cross HPYT485 × HD 2967 only dominance × dominance was observed. Similar results were reported by Gaddameedi *et al*., 2018 and Amiri *et al*., 2020 for grain Zinc content. All the three types of gene action is found contributing in governing expression of grain Zinc content thus for improvement of this trait reciprocal recuurent selection will be very effective. In expression of grain Iron content additive and dominance gene action played role in expression of this trait but due to higher magnitude of dominance gene effect preponderance of dominance gene action was observed in both crosses, BHU31 × HD2733 and HPYT485 × HD 2967. Among epistatic interaction, higher magnitude of dominance × dominance gene effect suggests for preponderance of dominance × dominance effect in expression of grain Iron content in both crosses. Similar result was reported by Gaddameedi *et al*., 2018. Higher magnitude of non-additive gene interaction of dominant nature in expression of grain Iron content indicates that for improvement of this trait recurrent selection for specific combining ability will be more effective. Further, non-additive gene action also disfavours selection in early generations thus selection for this trait should be delayed in later generation.

Heritability and genetic advance are two important genetic parameters that guides a breeder in devising a crop improvement programme. The estimates of heritability and genetic advance are presented in table 7. In the present study broad sense heritability as well as narrow sense heritability were recoded to be high in both crosses while the genetic advance as percent of mean was low both crosses for days to 50% flowering. Thapa *et al*., (2019) reported similar findings for low genetic advance of days to 50% flowering. This indicate that days to 50% flowering is governed by genes that are predominantly non additive in nature. For chlorophyll content and harvest index broad sense heritability was high and narrow sense heritability was moderate in both crosses while the genetic advance as percent of mean was low to moderate in both crosses. For plant height broad sense heritability as well as narrow sense heritability was high in cross BHU31 × HD2733 while the genetic advance as percent of mean was moderate to high. For spike length, broad sense heritability, narrow sense heritability and genetic advance as percent of mean were moderate to high in both crosses. Similar observations were reported by Kumar *et al*., 2017 and Tilahun *et al*., 2020 for high genetic advance of plant height and spike length. These findings indicate that genes governing spike length are mostly additive in nature. Thus indirect selection for higher yield based on spike length would be rewarding and effective. For number of tillers per plant, broad sense heritability was high and narrow sense heritability was moderate and the genetic advance as percent of mean was moderate in first cross. For days to maturity broad sense heritability was high and narrow sense heritability as well as genetic advance was low. For number of grains per spike broad sense heritability and narrow sense heritability was moderate to high while the genetic advance as percent of mean was low to moderate. For 1000- grain weight and grain yield per plant, broad sense heritability was high and narrow sense heritability was moderate to high while the genetic advance as percent of mean was moderate. Kumar *et al*., 2017 reported similar results for moderate genetic advance of 1000-grain weight and grain yield per plant. These findings indicate that genes governing 1000- grain weight and grain yield per plant are mostly additive in nature. Thus these traits could be an important parameter for indirect selection for higher yield.For canopy temperature, grain Zinc content and grain Iron content broad sense heritability was high and narrow sense heritability was moderate to high while the genetic advance as percent of mean was low to moderate. Similar result was reported by Amiri *et al.,*2018 and 2020 for high broad sense heritability and moderate narrow sense heritability of grain Zinc and Iron content. These findings indicate that genes governing canopy temperature, grain Zinc content and grain Iron content are mostly non additive in nature. However, for these traits high heritability coupled with high genetic advance as percent of mean indicated for preponderance of additive gene action thus progress through selection would be rapid and rewarding. Further, the non-additive gene action in governing these traits are expected to be of additive x additive types.

High heritability coupled with low to moderate genetic advance as percent of mean indicated for slow progress through selection and preponderance of non-additive gene action or high environmental influence on trait expression, which could be exploited through selection in later generation. The findings suggested for prevalence of non-additive gene action in expression of days to 50 % flowering, chlorophyll content, number of tillers per plant, days to maturity, number of grains per spike, 1000 grain weight, harvest index, canopy temperature, grain Zinc content, grain Iron content and grain yield per plant. Thus selection for these traits should be practiced.

Conclusion

In both the crosses dominance and dominance × dominance effect played a significant role in the expression of both grain Zinc content and grain Iron content. Duplicate type of gene interaction was found predominant for grain Zinc and Iron content and almost for all the traits due to opposite sign of dominance (h) and dominance × dominance (l) gene effect which tends to cancel the effect of each other in hybrid combination therefore selection should be practiced in advance generation.

Conflict of interest

The authors declare that they have no conflict of interest.

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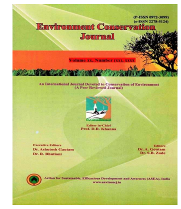

The study of morphological characteristics for best management practices over the Halayapura micro-watershed of Karnataka, India, using remote sensing and geospatial techniques

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ABSTRACT

The morphometric analysis was carried out on the Halayapura micro-watershed in Karnataka, India. Using ArcGIS 10.2.2 and applying the DEM model, the micro-watershed was subjected to quantitative investigation to determine the channel network involved and understand geo-hydrological behavior. In addition, remote sensing and geospatial techniques were used to study the micro-watershed drainage analysis and its associated parameters, such as stream order, stream length, stream frequency, drainage density, texture ratio, form factor, circulatory ratio, elongation ratio, bifurcation ratio, and compactness coefficient for the micro watershed, were evaluated. According to the findings, the stream order ranges from I to IV, with 97 streams in the micro-watershed. Streams of 72, 19, 5, and 1 are found in the I, II III, and IV order, respectively. The bifurcation values range from 3.78 to 5.00, with the average weight around 3.14. The elongation ratio and farm factor are 0.77 and 0.46, respectively. The drainage density of the micro watershed is 5.20 km/km^2. The form factor, circularity, and elongation ratio contribute to a basin with an elongated shape through decreased flood proneness, erosion, and sediment transport capacity. The results of the micro-watershed morphometric assessment are critical for evaluating and managing water resources and selecting a recharge structure for future water management in the study region.

Introduction

In today's developing world, urbanization, industrialization, and population expansion are inevitable. As a result, depleting resources such as land and water are growing increasingly scarce at an ever-increasing rate. To meet the demands for these resources, the most beneficial and time-efficient utilization is essential for long-term growth. More than half of all water sources are derived from precipitation, infiltrating soil and groundwater when it approaches the Earth's surface and flows into torrents and tributaries when it reaches the surface. The amount of water permeation is controlled by various factors, including geographic location, soil type, and the region's geologic management (Gunjan *et al.,* 2020). Therefore, morphometric drainage analysis is critical for efficient watershed planning because it gives information about the basin characteristics like the slope, topography, soil conditions, runoff, and surface water potential (Prakash *et al.,* 2019). The field of morphometry is studying both the Earth's surface layout and the overall form and size of landforms. Many attributes such as vegetation, sediment, structural elements, geology, and

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geomorphology all play a significant role in drainage systems developed over time and space. Morphometric analysis is essential in this context and maybe helps with several aspects of hydrology, such as groundwater and basins management, potential groundwater assessment, and insight into the environment.

Estimating surface runoff in a watershed could help prioritize, morphometrically assess, and predicting key micro-basins for conservative measures (Roohi *et al.,* 2020; Ghosh and Saha, 2019). At the watershed scale, the rainfall-runoff transformation process is a highly complex event; however, morphological features can be linked to a watershed's hydrological behavior and ability to produce runoff (Kumar *et al.,* 2018; Aher *et al.,* 2014). Some researchers have recently conducted drainage morphometry investigations using remote sensing technology to identify and characterize seasonal variations in the drainage basin. It also helps to comprehend groundwater potentialities, and resolves flood proneness issues (Angillieri, 2008; Kadam *et al.,* 2017; Rai *et al.,* 2017; Magesh *et al.,* 2013, 2011; Chopra *et al.,* 2005; Pankaj and Kumar, 2009). In addition, numerous studies on watershed management have been conducted, all of which used morphometry analysis as the only foundation for micro-watershed characterization for natural resources management and planning processes (Rajasekhar *et al.,* 2018; Vijith and Satheesh, 2006; Thomas *et al.,* 2010).

For morphometric analysis, Geographic Information Systems (GIS) and Remote Sensing (RS) approaches using satellite images were employed as a very convenient tool during present days in identifying the basin or sub-basin of the drainage systems (Panda *et al.,* 2019; Magesh *et al.,* 2013; Ratnam *et al.,* 2005). The most prevalent technique used in drainage basin studies involves the use of Digital Elevation Models (DEM) and Shuttle Radar Topography Missions (SRTM) (Sujatha *et al.,* 2015; Nag and Chakraborty, 2003). In addition, RS methods that employ satellite imaging and topographical maps have been used to identify morphometric parameters, such as drainage form, stream order, bifurcation ratio, drainage, and density (Zolekar and Bhagat, 2015; Mesa, 2006).

The GIS and RS techniques were used for the study enhancement to predict the drainage's attributes. When combined with previous research, the study gives critical information on researchers, decision-makers, and local communities; it contributes to micro-watershed research in integrated program design and implementation and the scaling up of effective management techniques. It also benefits academics working on related research subjects in other fields. Therefore, in the current study, efforts were made to use geo-processing tools such as the ArcGIS 10.2.2 software to investigate the various morphometric parameters of micro-watershed to plan and manage natural resources in sustainable development properly.

Material and Methods

Study area:

The study was conducted in the Halayapura micro-watershed, situated in Tumkur district of Karnataka state, India, and it has a total area of 503 hectares that falls between 77.05º05'20" to 77.07º07’20” E longitude and 13.08º30" to 13.10º10' N latitude in (Fig. 1). A micro-watershed is a portion of the Hosalaya sub-watershed located at an elevation of 845 m above mean sea level (MSL). In this micro-watershed, the annual average rainfall is 750 mm, and most of the rain received comes from the southwest monsoon (June to October). The temperature fluctuates between about 18°C (64°F) in the winter to about 37°C (99°F) in the summer. The most widely cultivated crops are coconut, areca nut, banana, mango, sorghum, ragi, jower, groundnut, and pulses are grown in the Kharif season. A micro-watershed is composed of five textural groups (loamy sand, sandy loam, sandy clay loam, sandy clay, and clay). Among these, the central part of a micro-watershed is 41.23 % sandy loam (207 ha) and 29.91 % loamy sand soils (152 ha) of the total area. (Fig. 2) show the spatial distribution of a different textural class of soil present in the Halayapura micro-watershed.

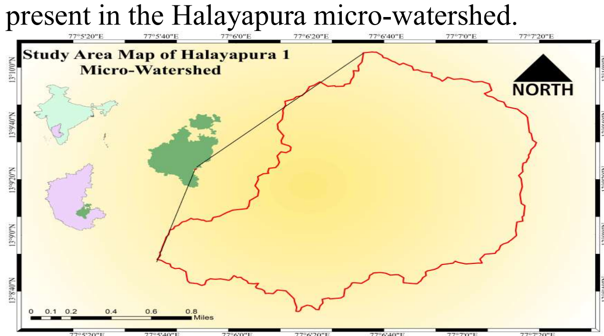

Figure1: Location map of the Halayapura micro-watershed, Tumkur district of Karnataka state, India.

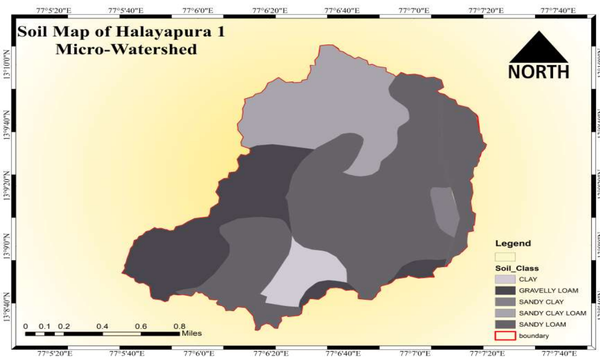

Figure 2: Soil textural map of the Halayapura micro-watershed.

Methodology:

A micro-watershed was generated using sophisticated space-borne thermal emission. A reflection radiometer (30m) resolution digital elevation model (ASTER-DEM) was utilized to create drainage networks and mark off essential areas to comprehend the hydrological and morphological features of micro-watershed using ArcGIS 10.2.2 software. A micro-watershed consisting of primary characteristics, such as the linear aspect (stream order, bifurcation ratio, mean bifurcation ratio, stream length, mean stream length, stream length ratio), the areal aspect (stream frequency, drainage density, texture ratio, form factor, circularity ratio, elongation ratio), and the relief aspect (stream frequency, drainage density, texture ratio, form factor, circularity ratio, elongation ratio) (relative relief, relief ratio, dissection index, ruggedness index). Remote sensing and GIS have successfully analyzed several morphometric characteristics (Singh *et al.,* 2013). Soil loss is proportional to linear parameters like bifurcation ratio, stream frequency, texture ratio, drainage density, length of overland flow, and relief ratio, and inversely proportional to shape parameters like form factor, compactness coefficient, circulatory ratio, and elongation ratio in a watershed (Sangma and Guru, 2020). The methodology's flow chart is shown in the diagram below (Fig. 3).

Morphometric Analysis of a micro-watershed

A combination of geoprocessing techniques available in Arc GIS 10.2.2 was used to extract and calculate the different drainage spatial distribution (linear, areal, and relief). First, the drainage network was created using Strahler's formula, which identifies portions with no tributaries as a 1^{st} order stream. When two 1^{st} order streams come together, they generate a 2^{nd}-order stream and

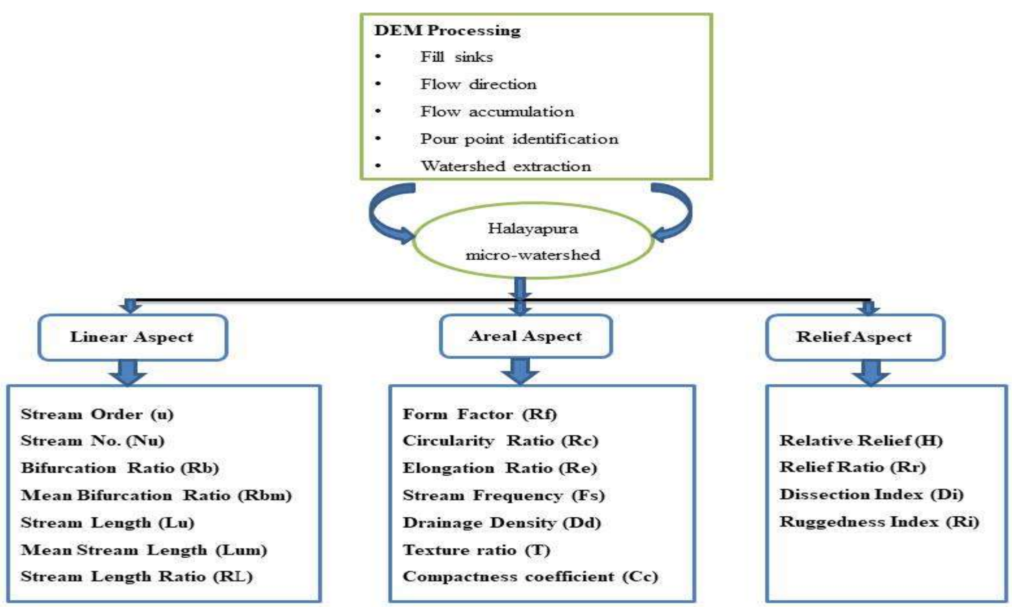

Figure 3: Flow diagram showing an approach for conducting morphometric investigation of the Halayapura micro-watershed

Table 1: Methods of calculating morphometric parameters

SN	Morphometric Characteristics	Formulae	References
1	Stream pattern (u)	Hierarchical order	Strahler (1957)
2	Stream Quantity (N_u)	Nu = amount of streams of a specific order 'u.'	Strahler (1964)
4	Mean stream length (L_u)	$L_{sm}= L_u/N_u$; L_u= average duration of a channel in a specific sequence (km), N_u= the overall the number of segmented channels.	Horton (1945)
5	Maximum length of the watershed (L_b)	The distance from the outlet of the basin from the farthest location.	Horton (1945)
6	Watershed perimeter (P_r)	The whole length of the outer catchment demarcation is manually calculated using a planimeter.	Horton (1945)
7	Stream length ratio (R_L)	$R_L= L_u/L_{u-1}$ L_u= Total stream duration of order (u), L_{u-1}=The total stream duration of its next lower rank.	Horton (1945)
8	Bifurcation ratio (R_b)	$R_b = N_u/N_{u+1}$ $R_b = N_u / N_{u+1}$ N_u= Number of stream order included in the specific order, N_{u+1}= Number of higher-order attributes in the sequence.	Schumm (1956).
9	Form factor (R_f)	$R_f = A/L^2_b$, A= basin area, L_b=length of the basin	Horton (1945)
10	Elongation ratio (R_e)	$R_e = 2/L_b\frac{\sqrt{A}}{\pi}$ A= watershed area, L_b=length of the watershed.	Strahler (1964)
11	Circulatory ratio (R_c)	$R_c = 12.57\ A/P^2r$ A= watershed area, P_r= Perimeter of the watershed.	Strahler (1964).
12	Drainage density (D_d)	$D_d = Lu/A$ L=ttotal length of the stream, A= The basin area	Horton (1945)
13	Stream frequency (F_s)	$F_s = Nu/A$ Nu= Total number of streams, A= The basin area	Horton (1945)
14	Texture ratio (T)	$T = N_1/P_r$ N_1=Total number of the first-order stream, P_r=Perimeter of the basin.	Horton (1945)
15	Maximum watershed relief (H)	H = R − r R = highest relief, r = lowest relief	Schumm (1956)
16	Compactness coefficient (R_c)	$Cc = 0.2821\ P/A^{0.5}$ P= watershed perimeter, A= equivalent a circular area circumference of the watershed	Horton (1945)
17	Ruggedness number (Rn)	Rn = Bh × Dd Where, Bh =Basin relief; Dd=Drainage density	Schumm (1956)
18	Time of concentration (Tc)	$Tc = 0.0078L^{0.77}\ S^{-0.385}$	Salimi et al. 2017

continue further on. Then, the standard formula in (Table 1) was used to calculate various aspects of drainage morphometry such as bifurcation ratio (R_b), mean bifurcation ratio (R_{bm}), mean stream length (L_{um}), stream length ratio (R_L), form factor (R_f), circularity ratio (R_c), stream frequency (F_s), drainage density (D_d), dissection index (Di), and ruggedness index (Ri), Time of concentration (Tc). The slope characteristics were also determined using Arc GIS 10.2.2 spatial analysis tool.

Results and Discussion

Morphometric studies:

The morphometric drainage characteristics will help understand the micro watersheds' hydrological and morphological features (Thomas *et al.,* 2010). Addressing the structural controls of a micro-watershed is also a very beneficial (Patel *et al.,* 2013). Basin characteristics also influence the hydro-sedimentary flow regimes (Singh *et al.,* 2020). The study aimed to understand better hydrological and morphological processes using several morphometric parameters in the Halayapura micro-watershed. Fig. 4 and Fig. 5 show the features such as the stream order and elevation of a micro-watershed. In addition, table 2 and Table 3 show the detailed morphometric study of parameters corresponding to u, N_u, L_u, L_b, D_d, F_s, R_c, R_b, R_{bm}, L_{um}, R_L, R_f, and R_i, were analyzed. Also, overland flow length, area, perimeter, the difference in elevation, length of basin, total relief, the number of streams, and full stream length for a micro-watershed were determined.

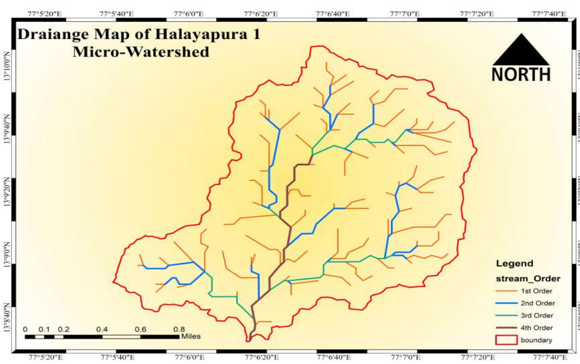

Figure 4: The stream order map for the Halayapura micro-watershed.

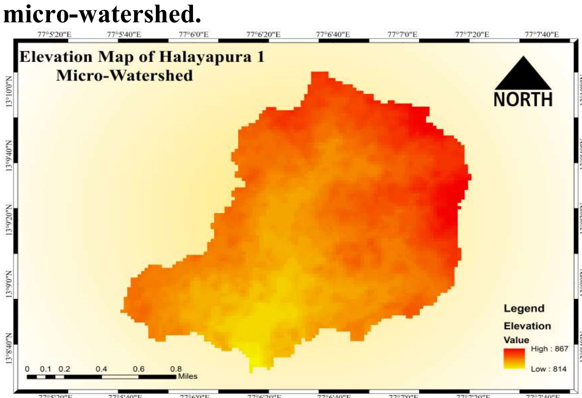

Figure 5: The digital elevation model of the Halayapura micro-watershed.

Stream Order (u):

Stream ordering refers to the process of determining a stream's hierarchical position within a drainage basin (Strahler 1964). Next, the most of the water is discharged, and the most of the water is released. Finally, the most of the water is removed from the critical channel through which the most of the water is released, recognized as the drainage basin's highest order stream. This stream order is

Table 2: Stream length measurement for the Halayapura micro-watershed.

Stream Order	Stream Number	Cumulative Stream Length (km)	Mean Stream Length (km)	Stream Length Ratio
I	72	14.71	0.2	-
II	19	5.79	0.3	0.66
III	5	3.37	0.67	0.45
IV	1	2.14	2.14	0.31

determined by the basin's form, size, and terrain features (Srinivasa vittala *et al.,* 2014). The stream pattern is essential in determining the number of exciting drainage morphometric characteristics investigated in this research. It has also been used to determine the maximum stream order within a micro-watershed. From a micro-watershed in our research, the region is identified using the highest stream order, i.e., the trunk stream, wherein all the discharge of a micro-watershed reaches its outflow. The observation made from Fig. 4 and Table 2 depicts that the Halayapura micro-watershed has up to IV order tributaries, with the I, II, III, and IV; streams are 72, 19, 5, and 1, respectively. The highest order of stream segments is the main's channel. Because of the geomorphology of a micro-watershed, all discharges, runoff, and sediments migrate and increase from upstream to downstream (Gaikwad and Bhagat, 2018). Fig. 6 show the logarithmic and arithmetic scales in the Y-axis and X-axis; the connection produces a negative linear pattern.

Stream Length (L_u):

The L_u is estimated using the law anticipated by Horton (1945). The stream length denotes each step involved in the growth of the stream section (Rai *et al.,* 2017), and the overall size of streams is often the most significant in the I order, and Lu decreases as stream order rises. Shorter stream lengths are found in areas with steeper the slopes and more delicate textures, while longer stream lengths are located on lower the slopes and coarser textures (Strahler, 1964). The determined L_u order of the Halayapura micro-watershed is 1st (14.71 km), 2nd (5.79 km), 3rd (3.37 km), and 4th (2.14 km) (Table 2). Fig. 7 show the positive relationship between stream order and length. The line grows geometrically when drawn in arithmetic scale and logarithmic scale at X and Y-axis, respectively.

Table 3. Morphometric analysis results for the Halayapura micro-watershed

SN	Morphometric Parameters	Calculated value
1	Micro-watershed Area	5 km^2
2	Micro-watershed Perimeter	11.13 km
3	Micro-watershed rank	4 th
4	Micro-watershed Length (Lb)	3.27 km
5	Mean Bifurcation ratio (Rb)	3.14
6	Stream frequency (Fs)	19.2
7	Drainage density (Dd)	5.20 km/km^2
8	Micro-watershed relief	0.01
9	Relative ratio	0.004
11	Texture ratio(T)	6.46
12	Ruggedness number (Rn)	0.28
13	Form Factor (Rf)	0.46
14	Circulatory ratio (Rc)	0.50
15	Elongation ratio (Re)	0.77
16	Length of overland flow (Lg)	0.096 km
17	Ellipticity ratio	1.68
18	Drainage texture	8.61 km^{-1}
19	Average micro-watershed width	1.57 km
20	Maximum micro-watershed relief	55 (m)
21	Compactness coefficient	0.63
22	Shape factor	2.14
23	Time of concentration (Tc)	7.58 min

Bifurcation Ratio (R_b):
A measure of the relationship between the number of streams in a particular order (Nu) and the number of net higher-order streams (Nu+1) is named as bifurcation ratio (Schumm, 1956). The mean R_b of the entire basin is 3.14, as shown in (Table 3). Rai *et al.,* 2017, reported that an R_b between 3 and 5 indicates a natural the drainage systems inside a homogeneous rock. A micro-watersheds that have flat or rolling micro-watersheds will have a lower R_b. On the other hand, higher R_b implies that the drainage pattern is well controlled structurally, and the drainage basins are well dissected. The greater the R_b, the lower the probability of floods (Eze and Efiong, 2010). The obtained results depict a natural the drainage systems having a dendritic pattern inside a homogeneous rock.

The drainage Density (D_d):
According to the study conducted by Horton (1945), the total length of streams presents per unit area is referred to as the drainage density (km/km^2). The closeness of channel spacing determines the D_d of a micro-watershed. The low D_d suggests that the

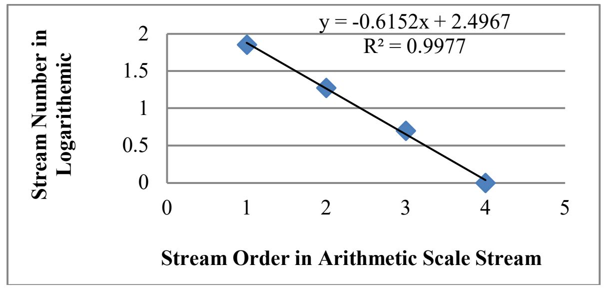

Figure 6: Plot between stream numbers versus stream order.

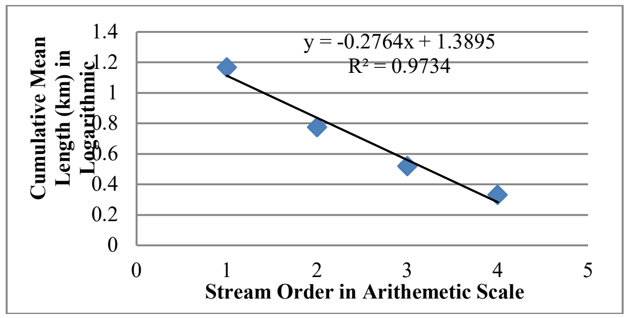

Figure 7: Plot demonstrating the relationship between stream order and cumulative mean length of streams

basin has an extremely permeable subsurface and heavy vegetation cover (Nag and Chakraborty, 2003). At the same time, high the drainage density contributes to the weak or impermeable underlying material, scarce vegetation, and hilly topography. Weather patterns, precipitation, vegetation, geology, soil properties, infiltration rate, and phase of development contribute to the drainage texture, which is a measure of the channel spacing in a topography (Smith, 1950). D_d contributes 5.21 km/km2 in the selected to the study region, suggesting an intermediate the drainage pattern to a very strongly sloping terrain with various species covering, as shown in Table 3.

Stream Frequency (F_s):
The number of streams presents per unit area is considered as stream frequency (Horton, 1945). The stream frequency correlates positively with the drainage density showing a rise in stream population because of increasing the drainage density. The weather patterns, natural vegetation, bedrock and soil characteristics, rainfall amount, hydraulic conductivity, elevation, discharge concentration, porosity, geography, and gradient all play a significant role in determining the drainage frequency along with density. The Fs for a micro-

watershed is 19.2, shown in (Table 3). The runoff will be quicker in basins at higher the drainage density and stream frequency; this may be cause many flooding chances (Solanke *et al.,* 2001).

Circulatory Ratio (R_c):

The basin area calculated is divided by the circle's circumference, which will have the same circumference as the basin's perimeter (Miller, 1953). When the fundamental shape is a perfect circle, the ratio equals one; while the basin shape is considerably elongated, indicates the percentage varies from 0.4 to 0.5 and the presence of highly permeable homogenous geologic materials. The calculated R_c may be influenced by the stream frequency, the slope, geologic structure of the relief, climate changes, and land use/land cover of the basin. As shown in Table 3, R_c value of a micro-watershed was found to be 0.5, suggesting an elongated form, modest runoff discharge, and permeability of the subsurface condition is high. Its intense, intermediate, and high values depict the tributary basins in their youth, maturity, and old age phases of their life cycle (Bisen and Kudnan, 2013).

Form Factor (R_f):

The flow intensity in a specific region is represented by the form factor (Horton, 1932). The form factor obtained is always smaller than 0.754, and the weight indicates perfectly a circular watershed (Rekha *et al.,* 2011; Gajbhiye *et al.,* 2014). The lower the value of shape factor, the longer the basin is, whereas, higher values match to a circular basin. Peak flows in basins having a high shape are more substantial, and last for a shorter time, while peak flows in elongated watersheds with low shape are flatter and last longer. Table 3 show that the R_f value for the study region is 0.46, indicating that the basin is a circular rather than elongated.

Elongation Ratio (R_e):

The maximum length of a micro-watershed basin is plotted in ArcGIS software 10.2.2, as shown in (Fig. 8) and (Table 3). Over a broad range of climatic and geologic types, Schumm's ratio exhibits values in the range of 0.6 and 1.0. The various elongation ratio indexes are classed as round, oval, less elongated, and more elongated, with values ranging from 0.9-0.10, 0.8-0.9, 0.7-0.8, 0.5-0.7, and 0.5-0.7, respectively. It is reported that the discharge of runoff is less efficient in an elongated basin compared to the circular basin (Singh and Singh, 1997). For high relief locations, the value varies in the range 0.6 to 0.8, whereas values near to 1.0 indicate shallow relief with a circular shape (Magesh *et al.,* 2013; Chopra *et al.,* 2005; Gajbhiyem *et al.,* 2014). The selected region has a R_e of 0.77, which indicates that it is less elongated, having a steep to severe the slope with a high relief.

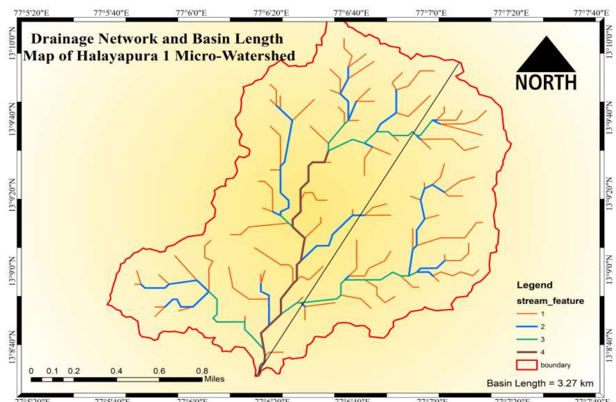

Figure 8: The basin's geometry of the Halayapura micro-watershed.

Texture Ratio (T):

The texture ratio is an essential component in the drainage morphometric analysis, since it depends on the underlying geology, infiltration rate, and relief aspect of the terrain (Schumm, 1956). The textural ratio is well defined as the proportion of I order streams to that of basin perimeter. Table 3 show that the texture ratio in the studied region is around 6.46 km^{-1}.

Relief Ratio (R_r):

R_r values over a certain threshold indicate a steep the slope with a high relief. In steeper basins, runoff is often quicker, resulting in more peaked basin discharges and increased erosive force (Palaka and Sankar, 2016; Pankaj and Kumar, 2009).

The R_r value in a micro-watershed is 0.01, indicating that values are low (0.1), implying a moderate the slope. The results are also graphically viewed and computed using a topographical map of 1:50,000 on Google Earth.

Length of Overland Flow (L_g):

The L_g is well defined as the water across the ground, before being concentrated into the mains stream, and it mainly influences the drainage basin's hydrological and physiographical progression (Horton, 1945). L_g will significantly affect when modified by soil infiltration or percolation, varying in place and time (Schmid, 1997). The higher Lg value implies that precipitation has to travel a considerable distance before condensing into stream channels (Chitra *et al.,* 2011). The overland flow length in this research area is around 0.09 km, indicating that significant structural disturbance, poor permeability, steep to extremely steep slopes, and more surface runoff will have a higher impact.

Slope

The slope in the watershed is the angular inclinations of the terrain between the peaks of the hill and valley bottoms, which is a significant morphometric attribute in studying the drainage basin landforms. Many variables contribute to its occurrence, which includes the structure of geological, absolute or relative reliefs, temperature, plant cover, and the drainage texture (Yadav *et al.,* 2014; Thakkar and Dhiman, 2007). The Halayapura micro-average watershed's the slope ranges from 0 to 14.5 percent (Fig. 9). Nearly level slope (0-1 percent), extremely gentle slope (1-3 percent), gentle slope (3-5 percent), moderate slope (5-8.5 percent), and strong slope (5-8.5 percent) are the five slope categories that vary by area (8.5-16.5 percent).

Compactness Coefficient (R_c)

A complete circle-shaped basin has an R_c of one. For a square basin, the value may be rise to 1.128, and in the case of a very long bay, it may be exceed3 (Singh *et al.,* 2013). According to Ratnam et al. (2005) and Pankaj and Kumar, (2009), the basin with a circular shape is the most detrimental because it yields the smallest concentration-time for peak flow in the basin. The C_c is unaffected by the size of the watershed and is solely influenced by the slope. (Table 3) show that the R_c for the Halayapura micro watershed is around 0.6 and indicating less influence of flood within a short duration (Table 3).

Conclusion

A micro-watershed is a significant geomorphological unit that shows topography and hydrological harmony. The Halayapura micro watershed morphometric analysis was mapped and measured with great accuracy using GIS technology. According to the research, the micro watershed has a well-developed drainage network

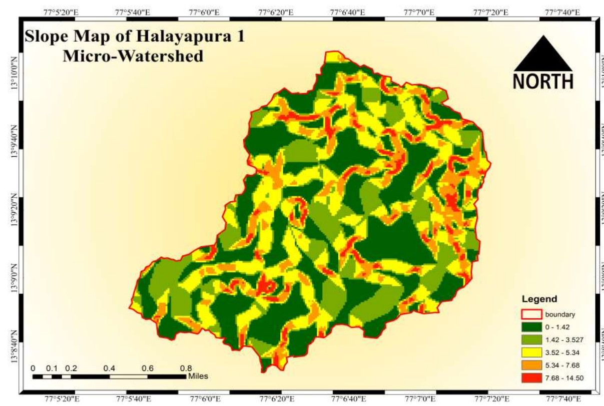

Figure 9: The slope of the Halayapura micro-watershed.

and a mature geomorphic stage. The D_d number denotes terrain with a moderate the slope, minimal to dense vegetation, a higher infiltration rate, and medium surface runoff. The micro watershed form was lengthened, making it less prone to flooding, erosion, and sediment transfer. The assessment of linear, areal, and relief characteristics using a DEM derived from contour and site altitude is extremely valuable for determining a specific micro-watershed area's physical and climatic features. The length of an overland flow indicates that the soil has good infiltration and percolation qualities. The drainage basin is less elongated, resulting in shorter-duration peak flows and shorter-distance outflow. As a result, GIS is a valuable and efficient tool for computing and analyzing the basin's many morphometric parameters.

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Conflict of interest

The authors declare that they have no conflict of interest.

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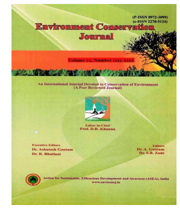

Efficacy of different agro-techniques on growth, yield and disease incidence on tomato (*Solanum lycopersicum* l.) crop of north western Himalayan region

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ABSTRACT

A field experiment was conducted during 2 consecutive years (2017-18 and 2018-19)with 12 treatment combinations at Vegetable Research Farm, Nauni, Solan with an objective to study the effects of different planting methods, mulches and training systems on flowering, fruiting, yield and incidence of diseases of tomato (*Solanum Lycopsersicum* L.) var. *Solan Lalima.* Plants grown on raised beds had minimum incidence of buckeye rot (4.19%), severity of *Alternaria* leaf blight (3.80%), incidence of bacterial leaf spot (2.38%) and incidence of *Fusarium* wilt (3.45%) and higher yield per plot (127.57 kg) and per hectare (899.96 q). Black polythene mulch responded best for lower incidence of buckeye rot (4.45%), severity of *Alternaria* leaf blight (4.01%), incidence of bacterial leaf spot (2.47%) and incidence of *Fusarium* wilt (3.62%) and higher yield per plot (129.42 kg) and per hectare (913.05 q), respectively. T_1 also recorded lower incidence of buckeye rot (4.09%), severity of *Alternaria* leaf blight (3.67%), incidence of bacterial leaf spot (2.33%) and incidence of *Fusarium* wilt (3.36%) and higher yield per plot (46.46 kg) and per hectare (327.74 q). Regarding consortium effect, the minimum incidence of buckeye rot (3.46%), severity of *Alternaria* leaf blight (2.80%), incidence of bacterial leaf spot (1.84%) and incidence of *Fusarium* wilt (2.60%) disease was recorded in $P_1M_1T_1$ treatment combination (raised bed + black polythene mulch + two stem training system). This combination was also better for all the growth and yield contributing characters.

Introduction

Tomatoes are one of the most extensively farmed crops in Himachal Pradesh, both in sheltered and open fields. Tomato fruits from open field conditions are designated for a direct consumption, as well as for processing industry (Sowinska and Turczuk, 2018). Both fresh fruits and tomato preserves have great biological value, including their antioxidant properties and popular salad vegetable which is taken with great relish (Toor *et al*., 2005). Tomato is a valuable source of nutrients, minerals, carotenoids, lycopene, vitamins particularly E and C, which prevents from cancerous and various circulatory system diseases (Pavlovic *et al*., 2017). According to Pavlovic *et al*. (2017) the biological values depends on various factors one amongst them is agro technical factor which comprises of various cultivation practices.
Inspite of wide cultivation of tomato, the average yield is rather low because little attention is paid towards scientific methods of production. The use of herbicides and other chemicals in agriculture are becoming limited, because of their expense and environment issues which have recently caused much concern. Therefore, new approaches to control weeds, insect-pests, diseases and improve yield are necessary both for assuring an adequate

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crop yield and for respecting the environment. Sustainable management practices, such as raised bed planting methods, mulching applications and suitable training systems can improve crop conditions, soil fertility and environmental conditions too. Tomato is an important off-season vegetable crop of Himachal Pradesh. The state is a key provider of fresh market tomatoes to the plains, while high temperatures and constant rains hinder output in such locations during the wet season. Thus, tomatoes from the hills find a ready market in the northern plains since they are often planted as a summer and rainy season crop, delivering lucrative returns to hill farmers. Himachal Pradesh produces 502.42 metric tonnes of tomato every year from an area of 11.75 thousand acres (Anonymous, 2018). Despite their economic importance, producers are unable to produce high-quality tomatoes with high productivity due to a variety of biotic (pests and illnesses), abiotic (rainfall, temperature, relative humidity, and light intensity) and agricultural variables that impede vegetable production. As a result, there is an urgent need to enhance tomato productivity and output in both the country and the state. Weed suppression, reduced insect pest infestation and improved yield because of useful micro-organisms activity have become suitable cause for sustainable crop production.

Raised beds are commonly used to improve soil warming and drainage and to decrease the disease incidence also (Locher *et al*., 2003). Raised bed planting for solanaceous crops in many parts of the world is gaining importance (Sayre, 2007). It can save 25-30% irrigation water, increasing water use efficiency (Hassan *et al*., 2005; Malik *et al*., 2005; Choudhary *et al*., 2008; Ahmad *et al*., 2009) and providing better opportunities to leach salts from the furrows (Bakker *et al*., 2010).

Sometimes, many of the farmers can't able to provide irrigation due to unavailability of irrigation facilities or even can't afford the expenses of irrigation. Under this situation mulching could be a good substitute means for irrigation to make soil moisture available. Mulching has been reported to be increased yield by creating favorable soil temperature and moisture regimes (Ma and Han, 1995). Plastic mulches are used in many agricultural crops to suppress weed growth, conserve soil moisture, and alter soil and air temperature (microclimatic modifications) in the rhizosphere under both protected and open conditions (Abhivyakti *et al.,* 2016), by modifying the surface's radiation budget (absorbitivity vs. reflectivity) and decreasing soil water loss, which increases crop yield and quality. According to Prakash *et al.* 2016, mulching may be utilized to tackle the problem of weed infestation, it increases microbial activity in soil by improving soil characteristics, and it reduces the need for nitrogen fertilizer. It is widely accessible and reasonably priced on the market.

Training maximizes the plant's ability to obtain the sunlight needed for growth and development (Gou *et al*., 1991). Similarly, training and pruning at later phases of plant growth minimises competitors for sunlight and photosynthetic products among fruits. Staking is another key activity that is conducted to make training more effective, especially during the wet season, for enhancing quality, yield, and protecting the crop from assault by soil-borne diseases (Ansari et al., 2017). Furthermore, the typical staking approach causes plants to become more bushy, making it difficult to accommodate a greater number of plants per unit space. Patil et al. (1973) observed that indeterminate plants have excessive leaf burden and may be aggressively trimmed without reducing output. More plants may be accommodated per unit area with correct training, trimming, and staking, improving yields.

This study was conducted to determine the effects of planting systems (raised-bed, flat-bed), mulching types (black polythene mulch, silver/grey polythene mulch and no mulch)and training systems (two stem and three stem trained plants) on flowering, fruiting, yield and incidence of diseases on tomatoes grown in open field farming system.

Material and Methods

Field experiments to determine the effect of crop management practices on growth and yield attributing characters such as, days to 50 % flowering, number of flower clusters per plant, days to marketable maturity, number of fruits per plant, weight of the fruits, yield per plant, yield per hectare, plant height and leaf area index and various soil and air borne diseases of tomato like, incidence of buckeye rot (%), severity of *Alternaria* leaf blight (%), severity of bacterial leaf spot (%), incidence of *Fusarium* wilt (%) was conducted in randomized block design (factorial) during *Khraif* seasons (April to September) of 2017-18 and 2018-19 at the Research Farm, Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP. The experiment comprised of two planting methods *viz*., P_1 (raised bed planting method) and P_2 (flat bed planting method), three levels of mulch materials *viz*., M_1 (black polythene mulch), M_2 (silver/grey polythene mulch) and M_3 (no mulch) and two training levels *viz*., T_1 (two stem training system) and T_2 (three stem training system) (Table 1). Thus, there were 12 treatment combinations which were replicated thrice.

The beds were raised to the height of 15 cm above the ground level and two beds were separated by 45 cm distance. Tomato seedlings were transplanted on well prepared plots on April, 2017 and 2018 at a spacing of 90×30 cm in a plot having dimensions of 1.8 × 6.3 m, accommodating 42 plants of tomato per plot. Mulches of 50μ (200 gauge thickness) were applied in plots according to the treatment combinations. After that holes were made on the mulch as per the recommended spacing of the plants. The mulches were spread manually and holes of 5 cm diameter were made accordingly.

Table 1: Detail of treatments used in the studies

S. No.	Treatment code	Treatment details		
1	$P_I M_1 T_I$	Raised bed	+ Black mulch	+ Two stem training
2	$P_I M_1 T_2$	Raised bed	+ Black mulch	+ Three stem training
3	$P_I M_2 T_1$	Raised bed	+ Silver/black mulch	+ Two stem training
4	$P_I M_2 T_2$	Raised bed	+ Silver/black mulch	+ Three stem training
5	$P_I M_3 T_1$	Raised bed	+ No mulch	+ Two stem training
6	$P_I M_3 T_2$	Raised bed	+ No mulch	+ Three stem training
7	$P_2 M_1 T_I$	Flat bed	+ Black mulch	+ Two stem training
8	$P_2 M_1 T_2$	Flat bed	+ Black mulch	+ Three stem training
9	$P_2 M_2 T_1$	Flat bed	+ Silver/black mulch	+ Two stem training
10	$P_2 M_2 T_2$	Flat bed	+ Silver/black mulch	+ Three stem training
11	$P_2 M_3 T_1$	Flat bed	+ No mulch	+ Two stem training
12	$P_2 M_3 T_2$	Flat bed	+ No mulch	+ Three stem training

In this study, the tomato cultivar "Solan Lalima" was employed. This cultivar was released by the Department of Vegetable Science, Dr YSP UHF Nauni, Solan. Tomato cultivar 'Solan Lalima' was used for the present study. It bears medium sized and round shaped fruits of deep red colour having TSS 4-5 ^{0}Brix. It is a self-pollinated indeterminate variety developed by selection. After transplanting, the crop is ready for the first plucking around 70-80 days. The typical fruit weight is 70-80 g, with a yield of 75-85 t/ha. This variety has received a tremendous response from the tomato growing farmers of the state being a very popular variety well suited for the mid-hills of Himachal Pradesh. All cultural activities and plant protection measures were implemented in order to maintain a homogenous plant population and optimal circumstances for plant growth and development. The seeds of 'Solan Lalima' were procured from the Seed Sale Counter of the Directorate of Extension Education, Dr YSP UHF, Nauni, Solan.

The leaf area index (LAI) was calculated after the third harvest of the fruits. The leaf area of the selected leaves on these plants was recorded using Area measurement system MK-2 (Delta-T Device Ltd. Burwell, Cambridge, England) as suggested by Redford (1967) here.

$$\mathbf{LAI} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Incidence of buckeye rot (%)

The incidence of Buckeye rot was recorded as per cent of infected fruits in ten randomly marked plants at each harvest and average incidence was worked out with the following derivation.

$$\text{Incidence of Buckeye rot (\%)} = \frac{\text{Number of infected fruits per plot}}{\text{Total number of fruits per plot}} \times 100$$

Severity of *Alternaria* leaf blight (%)
In order to record the occurrence of the disease, observations were recorded periodically. The leaf blight severity in different treatments was recorded as per the scale given by Shekhawat and Chakarvarti (1974) as shown in Table 2:
The disease severity was worked out according to Mckinney (1923) as given below:

$$\text{Disease severity (\%)} = \frac{\text{sum of all the disease ratings}}{\text{Total number of ratings} \times \text{maximum disease grade}} \times 100$$

Table 2: Scale used for recording severity of *Alternaria* leaf blight (%)

Grade	(%) Plant area infected by the disease	Category
0	0.00	Highly resistant
1	10.1-15.0	Resistant
2	15.1-30.0	Moderately resistant
3	30.1-50.0	Moderately susceptible
4	50.1-75.0	Susceptible
5	75.1 and above	Highly susceptible

Severity of bacterial leaf spot (%)
In order to record the occurrence of the disease, the observations were recorded periodically. The bacterial leaf spot severity in different treatments was recorded as per the scale given by Shekhawat and Chakarvarti (1976) mentioned in Table 3:
The disease severity was worked out according to Mckinney (1923) as given below:

$$\text{Disease severity (\%)} = \frac{\text{Sum of all the disease ratings}}{\text{Total number of ratings} \times \text{Maximum disease grade}} \times 100$$

Table 3: Scale used for recording severity of bacterial leaf spot (%)

Grade	(%) Plant area infected by the disease	Category
0	0	Highly resistant
1	0.1-5.0	Resistant
2	5.1-10	Moderately resistant
3	10.1-25	Moderately susceptible
4	25.1-50	Susceptible
5	>50	Highly susceptible

Incidence of *Fusarium* wilt (%)
The incidence of *Fusarium* wilt was recorded as per cent infected plants in ten randomly marked plants and average incidence was worked out with the following derivation.

$$\text{Disease Incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

MS-Excel and OPSTAT were used to analyze the data collected. The mean value of the data was submitted to analysis of variance using Randomized Block Design (RBD) Factorial, as defined by Panse and Sukhatme (2000).

Results and Discussion

Among the different soil and plant improvement practices, planting methods; raised bed and flat bed; mulching treatments; black polythene mulch, silver/grey polythene mulch and no mulch; training methods; two stem trained plants, three stem trained plants it was cleared that raised bed planting method, black polythene mulch and two stem trained plants were able to increase flowering, fruiting, yield and decrease incidence of disease parameter significantly as compared to other crop improvement practices. The findings in Table 4, 5, 6, 7, 8, 9, 10, 11 and 12 show that there was a substantial influence of different planting methods, mulches, and training levels on tomato illnesses, growth, yield, and yield contributing variables.

Effect on flowering, fruiting, yield attributing traits, yield and incidence of diseases on tomato

Planting methods

When compared to flat-grown plants, those grown on raised beds had a significantly lower number of days to 50% flowering (29.82 days), a higher number of flower clusters per plant (11.24), a lower number of days to marketable maturity (74.87 days), a higher number of fruits per plant (38.89), a higher fruit weight (77.98), a higher fruit yield per plot (127.57 kg), a higher fruit yield per hectare (899.96 q). Whereas, the plants raised on flat bed planting method observed higher incidence of buckeye rot (4.19 %), severity of *Alternaria* leaf blight (3.80 %), incidence of bacterial leaf spot (2.38 %) and incidence of *Fusarium* wilt (3.45 %) disease. Raised beds contributed significantly towards early flowering. This might be due to the warming up of the bed because of its bigger exposed surface and absorbance of more radiations which could create a significant difference in soil temperature especially of the root zone as compared to the flat bed mainly during day time. The current findings are consistent with those of Locher *et al.* (2003) in sweet pepper. Raised bed causes a significant difference in the root zone temperature during day time thus hastens the metabolic activities inside the plant cells and thereby approaches the reproductive phase more rapidly rather than vegetative phase (Locher *et al.,* 2003).

Table 4. Effect of planting methods, mulches and training systems on flowering, fruiting and yield contributing characters of tomato

Treatments	Days to 50 % flowering (%)	Number of flower clusters per plant	Days to marketable maturity	Number of fruits per plant	Fruit weight (g)
Planting methods (P)					
P_1^*	29.82	11.24	74.87	38.89	77.98
P_2	31.45	10.05	79.42	36.55	75.90
$CD_{0.05}$	**0.24**	**0.39**	**1.04**	**0.22**	**0.50**
Mulches (M)					
M_1^*	29.10	11.60	73.08	39.22	78.52
M_2	29.62	11.29	74.38	38.72	77.83
M_3	33.19	9.04	83.97	35.22	74.48
$CD_{0.05}$	**0.29**	**0.16**	**1.28**	**0.27**	**0.61**
Training System (T)					
T_1^*	30.32	10.83	76.29	38.31	77.64
T_2	30.95	10.46	77.99	37.13	76.24
$CD_{0.05}$	**0.24**	**0.19**	**1.04**	**0.22**	**0.50**

Table 5: Effect of planting methods, mulches and training systems on yield contributing characters, plant height and leaf area index of tomato

Treatments	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Plant height (cm)	Leaf area index
Planting methods (P)				
P_1^*	127.57	899.96	172.12	4.09
P_2	116.61	822.62	165.97	3.59
$CD_{0.05}$	**1.14**	**8.03**	**3.14**	**0.11**
Mulches (M)				
M_1^*	129.42	913.05	173.31	4.21
M_2	126.64	893.37	169.63	4.05
M_3	110.20	777.45	164.19	3.27
$CD_{0.05}$	**1.39**	**9.84**	**3.84**	**0.14**
Training System (T)				
T_1^*	125.12	882.66	174.11	4.01
T_2	119.06	839.91	163.97	3.68
$CD_{0.05}$	**1.14**	**8.03**	**3.14**	**0.11**

Raised bed facilitate the drainage in high rainfall areas, provides channels for furrow irrigation and warm the soil faster in order to take the advantage of early market (Bracy *et al.*, 1993 and Wilkes and Hobgood, 1969). It can also be attributed to better assimilation of micro and macro nutrients by the plants, prevention of soil compaction and plant damage by reduced trafficking. The benefits of raised bed planting system includes water saving combined with water use efficiency, improvement of soil physical status and nitrogen use efficiency, better utilization of sunlight, low crop weed competition and enhancement in yield and yield related attributes also (Zhang *et al.,* 2008 and

Kumar *et al.,* 2010). Other reasons for increased yield on raised beds could be longer growing period, warming up of the bed, improved drainage, better management of water, fertilizers, mulch and other soil amendments and reduced foot trafficing (Berle and Westerfield, 2013). According to Bahadur *et al.* (2013) in tomato the higher yield in the plants grown on raised bed covered with black mulch was also due to the natural drainage facility, reduced incidence of diseases and also one more important thing is favourable root zone temperature which is considerably important for flowering and fruiting. Possibly in raised bed planting system, more and larger area is exposed, therefore plants are able to facilitate more photosynthetic activity and larger leaf area is responsible for higher leaf area index (Alagoz and Ozer, 2019).

Table 6: Effect of two way interactions P × M, M × T and P × T on flowering, fruiting and yield contributing characters of tomato

Treatment combination	Days to 50 % flowering (%)	Number of flower clusters per plant	Days to marketable maturity	Number of fruits per plant	Fruit weight (g)
P_1M_1	28.06	12.30	70.63	40.76	79.69
P_1M_2	28.63	11.88	72.50	40.19	78.91
P_1M_3	32.78	9.54	81.47	35.72	75.34
P_2M_1	30.14	10.90	75.53	37.68	77.34
P_2M_2	30.60	10.70	76.26	37.25	76.74
P_2M_3	33.60	8.54	86.46	34.72	73.62
$CD_{0.05}$	**0.41**	**0.63**	**3.78**	**0.38**	**2.79**
M_1T_1	28.64	11.88	71.76	40.01	79.23
M_1T_2	29.56	11.33	74.39	38.42	77.80
M_2T_1	29.21	11.52	73.55	39.43	78.36
M_2T_2	30.02	11.07	75.21	38.00	77.29
M_3T_1	33.10	9.10	83.58	35.48	75.34
M_3T_2	33.28	8.98	84.36	34.97	73.61
$CD_{0.05}$	**0.41**	**0.53**	**3.01**	**0.38**	**3.08**
P_1T_1	29.36	11.43	73.71	39.50	78.64
P_1T_2	30.28	11.05	76.02	38.28	77.32
P_2T_1	31.27	10.24	78.88	37.12	76.64
P_2T_2	31.62	9.86	79.96	35.98	75.15
$CD_{0.05}$	**0.34**	**0.57**	**2.88**	**0.33**	**2.84**

Mulching levels

29.10 days to 50 per cent flowering were recorded when the plants were raised using black mulch (M_1). This treatment also produced significant differences with silver/black mulch i.e. M_2 (29.62 days) while maximum days (33.19) were recorded when the plants were raised without mulch (M_3). Black mulch (M_1) also produced (11.60) flower clusters which were significantly more (11.29) than in silver/black mulch (M_2), minimum (73.08) number of days to marketable maturity, more number of fruits (39.22), maximum (78.52 g) fruit weight, maximum value (129.42 kg/plot) of fruit yield per plot, maximum value (913.05 q/ha) of yield per hectare, produced maximum leaf area index (4.21), produced taller plants (173.31 cm) as well as. Whereas, the plants grown on the beds which were not applied with mulch observed higher incidence of buckeye rot (4.45 %), severity of *Alternaria* leaf blight (4.01 %), incidence of bacterial leaf spot (2.47 %) and incidence of *Fusarium* wilt (3.62 %) disease. Mulches have been demonstrated to impact tomato blossoming early. Plastic mulches have a direct impact on the microclimate around theplant by changing the surface's radiation budget (absorbitivity vs. reflection) and minimising soil water loss. The temperature of the soil beneath a plastic mulch is determined by the

Table 7: Effect of two way interactions P × M, M × T and P × T on yield contributing characters, plant height and leaf area index of tomato

Treatment combination	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Plant height (cm)	Leaf area index
P_1M_1	136.45	962.64	176.84	4.51
P_1M_2	133.20	939.71	170.42	4.38
P_1M_3	113.05	797.52	169.09	3.39
P_2M_1	122.40	863.45	169.77	3.90
P_2M_2	120.07	847.02	168.83	3.72
P_2M_3	107.36	757.38	159.29	3.15
$CD_{0.05}$	**1.97**	**13.91**	**5.43**	**0.19**
M_1T_1	133.23	939.93	180.53	4.41
M_1T_2	125.61	886.17	166.09	4.00
M_2T_1	129.85	916.02	173.66	4.23
M_2T_2	123.42	870.71	165.59	3.88
M_3T_1	112.27	792.04	168.15	3.38
M_3T_2	108.13	762.85	160.23	3.15
$CD_{0.05}$	**1.97**	**13.91**	**5.43**	**0.21**
P_1T_1	130.65	921.71	179.05	4.22
P_1T_2	124.48	878.20	165.19	3.97
P_2T_1	119.58	843.62	169.17	3.79
P_2T_2	113.63	801.62	162.76	3.39
$CD_{0.05}$	**2.01**	**13.91**	**4.44**	**0.19**

Table 8. Consortium/interaction effect on flowering, fruiting and yield contributing characters of tomato

Treatment Combinations	Days to 50 % flowering (%)	Number of flower clusters per plant	Days to marketable maturity	Number of fruits per plant	Fruit weight (g)
T_1 ($P_1M_1T_1$)*	27.52	12.64	68.86	41.64	80.47
T_2 ($P_1M_1T_2$)	28.60	11.97	72.39	39.88	78.92
T_3 ($P_1M_2T_1$)	28.10	12.07	71.22	40.80	79.47
T_4 ($P_1M_2T_2$)	29.16	11.69	73.78	39.58	78.35
T_5 ($P_1M_3T_1$)	32.46	9.58	81.06	36.06	76.00
T_6 ($P_1M_3T_2$)	33.10	9.50	81.89	35.39	74.69
T_7 ($P_2M_1T_1$)	29.76	11.12	74.66	38.39	77.99
T_8 ($P_2M_1T_2$)	30.52	10.69	76.40	36.96	76.68
T_9 ($P_2M_2T_1$)	30.33	10.97	75.87	38.07	77.25
T_{10} ($P_2M_2T_2$)	30.33	10.97	75.87	38.07	77.25
T_{11} ($P_2M_3T_1$)	30.87	10.44	76.65	36.42	76.23
T_{12} ($P_2M_3T_2$)	33.47	8.47	86.03	34.55	72.54
$CD_{0.05}$	**1.56**	**0.42**	**3.04**	**1.61**	**3.49**

thermal qualities (reflectivity, absorbtivity, or transmittancy) of the mulch material in proportion to incoming solar radiation (Abhivyakti et al., 2016). The current findings accord with those of Singh et al. (2017), Angmo *et al.* (2018), and Kumari *et al.* (2018) in tomato. The possible reason could be the modification of light environment sufficiently to enhance photosynthetic rate and/or light stimulus of morphogenic development with the use of black plastic mulches; and its effects on crop growth and development. Decoteau *et al.* (1988), Bhujbal *et al.* (2015) and Rahman *et al.*

(2016) also showed similar results and narrated that black polyethylene mulch produced the highest number of flower clusters per plant in tomato. The present findings are also in line with those of Rahman *et al.* (2016) in tomato. Black mulch applied to the planting bed prior to planting will warm up the soil and promote faster growth in early season, which generally leads to earlier harvest (Tarara, 2000 and Lamont, 2005). Because of the availability of adequate nutrients and light to the plant as a result of two stem training, which resulted in the accumulation of maximum photosynthates and the induction of early flowering and early harvest as compared to the three stem training system, which enhanced better growth and development of the tomato fruit. The results are likewise consistent with those of Singh *et al*. (2017) in tomato.

Table 9. Consortium/interaction effect on yield contributing characters, plant height and leaf area index of tomato

Treatment Combinations	Fruit yield per plot (kg)	Fruit yield per hectare (q)	Plant height (cm)	Leaf area index
T_1 ($P_1M_1T_1$)*	140.71	992.64	186.96	4.71
T_2 ($P_1M_1T_2$)	132.20	932.64	166.73	4.31
T_3 ($P_1M_2T_1$)	136.16	960.58	176.40	4.48
T_4 ($P_1M_2T_2$)	130.25	918.84	164.44	4.29
T_5 ($P_1M_3T_1$)	115.09	811.91	173.78	3.47
T_6 ($P_1M_3T_2$)	111.01	783.12	164.39	3.30
T_7 ($P_2M_1T_1$)	125.76	887.21	174.09	4.11
T_8 ($P_2M_1T_2$)	119.03	839.69	165.45	3.70
T_9 ($P_2M_2T_1$)	123.53	871.46	170.92	3.98
T_{10} ($P_2M_2T_2$)	123.53	871.46	170.92	3.98
T_{11} ($P_2M_3T_1$)	116.60	822.58	166.75	3.47
T_{12} ($P_2M_3T_2$)	105.26	742.58	156.07	3.01
$CD_{0.05}$	**10.54**	**18.78**	**14.12**	**0.79**

Table 10: Effect of planting methods, mulches and training systems on disease parameters of tomato crop.

Treatments	Incidence of buckeye rot (%)	Severity of *Alternaria* leaf blight (%)	Severity of bacterial leaf spot (%)	Incidence of *Fusarium* wilt (%)
Planting Methods (P)				
P1	14.91 (3.85)	11.40 (3.35)	4.78 (2.18)	9.57 (3.08)
P2	17.64 (4.19)	14.48 (3.80)	5.69 (2.38)	11.94 (3.45)
CD0.05	**0.02**	**0.03**	**0.03**	**0.02**
Mulches (M)				
M1	14.15 (3.76)	10.90 (3.28)	4.64 (2.15)	9.21 (3.02)
M2	14.87 (3.85)	11.83 (3.43)	4.94 (2.22)	9.96 (3.15)
M3	19.80 (4.45)	16.09 (4.01)	6.14 (2.47)	13.10 (3.62)
CD0.05	**0.03**	**0.04**	**0.04**	**0.03**
Training Systems (T)				
T1	15.68 (3.94)	12.33 (3.48)	5.02 (2.23)	10.12 (3.16)
T2	16.87 (4.09)	13.55 (3.67)	5.46 (2.33)	11.40 (3.36)
CD0.05	**0.02**	**0.03**	**0.03**	**0.02**

The results are likewise consistent with those of Singh et al. (2017) in tomato. Weed competition was minimal beneath the black polythene mulch because higher temperatures under the mulch hampered weed development, and regular moisture conservation throughout the growing season may be responsible for enhanced performance, resulting in increased blooming and fruiting (Bhujbal *et al*., 2015). As mulch films are nearly impervious to carbon dioxide which is necessary for photosynthesis, 'Chimney effect' might have been created resulting in abundant CO_2 for the plants which might have added higher plant growth, fruit weight and fruit yield grown under different plastic mulches.

Training system

As regards training systems, the plants which were trained with two stem (T_1) took least (30.32) number of days to 50 per cent flowering, produced maximum (10.83) flower clusters per plant, minimum (76.29) number of days to marketable maturity, more (38.31) number of fruits, maximum (77.64 g) fruit weight, maximum (125.12 kg/plot) yield, maximum (882.66 q/ha) fruit yield per hectare, maximum values (4.01) for leaf area index, maximum plant height (174.11 cm). Plants trained on three stem trained plants observed higher incidence of buckeye rot (4.09 %), severity of *Alternaria* leaf blight (3.67 %), incidence of bacterial leaf spot (2.33 %) and incidence of *Fusarium* wilt (3.36 %) disease. In case of two stem training techniques also had considerable impact on days to 50 per cent flowering. Early flowering might be due to the result of diversion of photosynthates towards flowering branches which could rather have been used for growth of new shoots and leaves. These plants might have completed vegetative phase much early and the photosynthates might have been shifted to the reproductive parts rather than to vegetative parts (Frank, 2000). Similar findings were also narrated by Ara *et al.* (2007), Muhammad *et al.* (2014) and Mbonihankuye *et al.* (2013) in tomato. The reason for more number of flower clusters in the plants grown on the raised bed planting system could be the availability of more nutrients because of minimum tillage (Naresh *et al*., 2012). In case of two stem training system, there would be maximum sunlight penetration and enhanced photosynthetic activity making more assimilates available for flower cluster setting (early shift from vegetative to reproductive phase) as compared to three stem training system, early and higher rate of morphogenesis (cell division, cell differentiation, cell elongation and cell maturation) and also good aeration through the canopy which might be a valid reason to increase the number of flower clusters per plant and ultimately increased fruit set (Ara *et al.,* 2007; Mbonihankuye *et al.,* 2013 and Ansari *et al.,* 2017). Yadav et al. (2017) also observed the highest number of fruits per plant (86.59) with a twin stem training technique due to greater levels of carbohydrates and soluble chemicals in the fruits. Plants clipped to two stems produced considerably more big fruits than plants treated to three stems, four stems, or no pruning. The results of increased average fruit weight by cutting side branches were consistent with Cebula's (1995) findings that fewer shoots per plant generated heavier pepper fruits. In the present case also, less soil compaction and increased oxygen intake from the atmosphere might have helped the plant to perform better resulting into conditions that favors better growth and higher yield. The increased yield in two stem training system might be attributed to availability of more space for individual plant growth, more leaf area for better photosynthesis, ample sunlight and aeration. These results are consistent with the findings of Bhattarai et al. (2015) and Singh and Kumar (2005) in cherry tomato. Earlier plant growth as a result of mulching allows for higher solar radiation interception and a rapid increase in leaf area assimilation (Kumar and Lal, 2012). Two stem trained plants produced the tallest plants compared to the other treatments which could be the possible reason for the larger leaf area of the two stem plants because of less competition for space and light which consequently lead to higher leaf area index (Razzak *et al.* 2013). Taller plants were observed in two-stem pruned plants which could be due to reduced competition for photosynthates among the branches (Frank, 2000).

Consortium/interaction effect

The interaction of P, M and T was found to be significant for all the flowering, fruiting, yield contributing factors, yield and disease parameters. The treatment combination including raised bed planting method, black polythene mulch and plants trained to two stem training system ($P_1M_1T_1$) took minimum (27.52 days) number of days to 50 % flowering, produced maximum number of flower clusters per plant (12.64), lesser number of days to marketable maturity (68.86 days), maximum number of fruits per plant (41.64), maximum fruit weight (80.47), excellent fruit yield per plot (140.41 kg), per hectare (992.64 q), maximum plant height (186.96 cm) and leaf area index (4.71) compared to other treatment combinations. The minimum incidence of buckeye rot (3.46 %), severity of *Alternaria* leaf blight (2.80 %), incidence of bacterial leaf spot (1.84 %) and incidence of *Fusarium* wilt (2.60 %) disease was recorded in $P_1M_1T_1$ treatment combination (raised bed + black polythene mulch + two stem training system).

Table 11: Effect of two way interactions P × M, M × T and on P × T on incidence of buckeye rot and severity of *Alternaria* leaf blight in tomato crop

Treatment combination	Incidence of buckeye rot (%)	Severity of *Alternaria* leaf blight (%)	Severity of bacterial leaf spot (%)	Incidence of *Fusarium* wilt (%)
P_1M_1	12.85 (3.58)	8.79 (2.96)	4.10 (2.02)	7.83 (2.79)
P_1M_2	13.38 (3.66)	10.19 (3.18)	4.61 (2.15)	8.74 (2.95)
P_1M_3	18.50 (4.30)	15.23 (3.90)	5.64 (2.37)	12.16 (3.49)
P_2M_1	15.46 (3.93)	13.01 (3.61)	5.19 (2.28)	10.58 (3.25)
P_2M_2	16.35 (4.04)	13.47 (3.67)	5.26 (2.29)	11.18 (3.34)
P_2M_3	21.10 (4.59)	16.96 (4.12)	6.63 (2.57)	14.05 (3.75)
$CD_{0.05}$	**0.04**	**0.06**	**0.05**	**0.04**
M_1T_1	13.26 (3.64)	10.15 (3.16)	4.23 (2.04)	8.43 (2.89)
M_1T_2	15.05 (3.87)	11.64 (3.40)	5.06 (2.55)	9.98 (3.15)
M_2T_1	14.19 (3.76)	10.82 (3.27)	4.77 (2.18)	9.34 (3.05)
M_2T_2	15.55 (3.94)	12.84 (3.58)	5.11 (2.26)	10.58 (3.25)
M_3T_1	19.59 (4.42)	16.02 (4.00)	6.07 (2.46)	12.58 (3.54)
M_3T_2	20.01 (4.47)	16.17 (4.02)	6.20 (2.49)	13.63 (3.69)
$CD_{0.05}$	**0.04**	**0.06**	**0.05**	**0.04**
P_1T_1	14.33 (3.77)	10.58 (3.22)	4.44 (2.09)	8.80 (2.95)
P_1T_2	15.49 (3.92)	12.23 (3.48)	5.13 (2.26)	10.35 (3.21)
P_2T_1	17.03 (4.11)	14.08 (3.74)	5.61 (2.36)	11.43 (3.70)
P_2T_2	18.24 (4.26)	14.87 (3.85)	5.78 (2.40)	12.45 (3.52)
$CD_{0.05}$	**NS**	**0.05**	**0.04**	**0.03**

Table 12: Effect of P × M × T interaction on incidence of diseases in tomato crop

Treatment combination	Incidence of buckeye rot (%)	Severity of *Alternaria* leaf blight (%)	Severity of bacterial leaf spot (%)	Incidence of *Fusarium* wilt (%)
$P_1M_1T_1$*	11.99 (3.46)	7.84 (2.80)	3.38 (1.84)	6.76 (2.60)
$P_1M_1T_2$	13.71 (3.70)	9.74 (3.12)	4.36 (2.19)	8.91 (2.98)
$P_1M_2T_1$	12.87 (3.59)	8.81 (2.97)	4.36 (2.09)	7.90 (2.81)
$P_1M_2T_2$	13.89 (3.73)	11.58 (3.40)	4.86 (2.20)	9.57 (3.09)
$P_1M_3T_1$	18.12 (4.26)	15.09 (3.88)	5.57 (2.36)	11.76 (3.43)
$P_1M_3T_2$	18.88 (4.35)	15.37 (3.92)	5.71 (2.39)	12.56 (3.54)
$P_2M_1T_1$	14.54 (3.81)	12.47 (3.53)	5.08 (2.25)	10.11 (3.18)
$P_2M_1T_2$	16.38 (4.05)	13.55 (3.68)	5.30 (2.30)	11.05 (3.32)
$P_2M_2T_1$	15.50 (3.94)	12.83 (3.58)	5.17 (2.27)	10.79 (3.28)
$P_2M_2T_2$	15.50 (4.15)	12.83 (3.58)	5.17 (2.27)	10.79 (3.28)
$P_2M_3T_1$	17.21 (4.15)	14.10 (3.75)	5.36 (2.31)	11.58 (3.40)
$P_2M_3T_2$	21.13 (4.60)	16.97 (4.12)	6.69 (2.59)	14.71 (3.83)
$CD_{0.05}$	**0.06**	**0.04**	**0.07**	**0.05**

*The figures in parentheses represent square root transformed values

P: Planting methods, **M:** Mulching treatments, **T:** Training systems; **P_1:** Raised bed planting method, **P_2:** Flat bed planting method, **M_1:** Black polythene mulch, **M_2:** Silver/black polythene mulch, **M_3:** No mulch, **T_1:** Two stem training system, **T_2:** Three stem training system

Buckeye rot appears on tomato under mid-hill conditions any time after May, when the warm and rainy season begins and continues till September or late fall. The disease is caused by *Phytophthora nicotianae* var. *parasitica*. The fungus overwinters in the soil in the form of oospores or chlamydospores and can remain active in soil for at least one year without the support of a susceptible host. With the onset of monsoon rains, in the presence of high soil moisture and moderate temperatures (20-25°C), the chlamydospores and oospores start germinating by producing mycelium and sporangia. The disease is caused by three different species of *Alternaria viz., Alternaria solani Alternaria alternata* and *Alternaria alternata* f.sp. *lycopersici*. *Alternaria* species survive in diseased plants debris and can persist for one to two years. Primary infection of lower leaves first takes place through conidia formed on crop debris in soil. Secondary spread of the disease occurs through conidia developed on primary spots. These conidia are blown by wind, water and insects to the neighbouring leaves of plants. Leaf spot is caused by *Xanthomonas campestris* pv. *vesicatoria.* The *Fusarium* wilt caused by the fungus *Fusarium oxysporum* Schlechtend f.sp. *lycopersici* (Sacc.) Snyder and Hans. The pathogen is soil borne in nature and overwinters in the infected plant debris and in the soil as mycelium and spore forms especially as chlamydospores. It spreads over small distances by means of water and contaminated farm. Raised bed method of planting offer better conditions for the plant to grow since they warm up more quickly and drain better. In the present case, better drainage conditions coupled with quick warming of the upper layer as well as beneath of the soil might have created conditions which are not suitable for the development of various disease causing organisms. This might have resulted into less growth of the germinating spores and insufficient disease causing inoculum. Similar are the findings of Sharma *et al.* (2016) who observed that the disease incidence in the bell pepper plants grown on raised beds and ridges were low as compared to the flat beds. The results of present study also revealed low incidence of buckeye rot in different treatments may be due to the prevalence of non-congenial environmental conditions. However, the incidence was comparatively less in the black polythene as compared to the others. The reduced buckeye rot incidence with black polythene mulch may be due to the fact that mulches mitigate the harmful effect of soil borne fungi and create a barrier to the pathogen which causes the disease (Mukherjee *et al*. 2010). The findings are consistent with those of Mehta et al. (2010) in tomato. The lowest incidence of early blight was recorded with black polythene mulch, which might be attributed to the fact that plastic mulching works as a barrier between soil and plant, keeping foliage and fruits away from soil contact (Suresh *et al*. 2014). Mulch also prevents soil splash on lower canopy as soil often consist disease causing conidial spores (Bhujbal *et al.,* 2015). Mulching (black polythene or other) resulted in increased temperature in soil ecosystem which proves to be lethal to tomato wilt pathogen (Mahadeen, 2014). Mulching is basically an addition of a thick layer of mulch on the soil surface to help control weeds, optimise soil moisture and keep the soil cooler which influence plant response to *Fusarium* wilt incidence. It helps in disease control by standing as a barrier between the plant parts above the ground and plant pathogen in the soil. Since it helps to control weeds, it also helps in altering the environment for these pathogens thereby creating unfavourable conditions for them and controlling diseases (Seyfi and Rashidi, 2007). In order to avoid splashing soil borne diseases on tomato leaves during watering, mulching of the plant is advised. The findings are consistent with those of Caroline et al. (2013) in tomato. The unmulched plots stayed more saturated for a long period without any improvement in the drainage system, which might have resulted in increased disease incidence/severity (Khurshid *et al*. 2006). In our opinion, improved soil drainage through black plastic mulching could be the reason for less disease incidence/severity. Bala (2012) also observed that the black polyethylene mulch proved to be most effective to lowest incidence of buckeye rot and minimum *Alternaria* blight severity Lyimo et al. (1998) also investigated the effects of mulching and staking on the development of tomato leaf blight caused by Alternaria solani and Phytophthora infestans, respectively. Mulching and staking were found to reduce the incidence of early and late blight by 5 to 20% when compared to unmulched and unstaked controls. The apparent rate of infection of the two pathogen was also significantly lower in mulched and staked tomato.

Mulching was more effective than staking in suppressing early and late blight diseases in tomato. In two stem training system, incidence of the disease was low because the plants were more erect as compared to three stem training system and foliage and fruits up to a height of 15-20 cm were removed which could avoid the moist and stagnant air conditions for the pathogen to perpetuate. This might be the suitable reason for less buckeye rot incidence in two stem trained plants. More incidence/severity of different diseases in three stem training system might be due to more number of branches/laterals which could have created suffocative conditions which are desirable for the development of the disease. On the other hand, less number of branches will provides more passage of air and sunlight towards the soil and less suffocative conditions might have resulted into less disease spread. Mehta et al. (2010) revealed similar findings on several illnesses in the tomato crop.

Conclusion

In the present study, various aspects of plant growth, yield and diseases were assessed for tomato cultivation. The importance of raised-bed planting systems for sustainability of soils suitable for cultural practices was revealed by this study. It was also proved that due to the improved soil physical and chemical properties with raised-bed planting systems the production and productivity of tomato could be enhanced in mid hills conditions of Himachal Pradesh. In addition, it was determined that fruit yield did not increase in flat planting method in short term even though the same agro-techniques were followed. Such a case was probably because the soils were not able to create suitable conditions for microorganism's activity due to reduced mineralization which could add organic matter in the soil probably. In unsuitable soil conditions, enzymatic activity of microorganisms decreases and nutrient quantities mineralized from the organic matter decreases as well. In the study, the highest values for all parameters were obtained from raised-bed planting systems, black mulch application along with two stem training system. Therefore, from the present findings it was revealed that raised-bed planting system improved mainly the plant growth and yield parameters. Therefore, raised-bed planting system was found to be superior over the flat planting system. Planting on raised beds when used singly and in combination with other cultural methods produced good disease control and higher yield that compared favorably to the conventional methods. Based upon present results, it can also be concluded that use of black and silver/black shaded color synthetic mulch significantly increased the growth, yield and yield contributing characters as compared to the un mulched treatments in tomato in the open field conditions. Results of this study showed that different training levels influence plant developmental characteristics and yield of the indeterminate tomato variety. Therefore, taking into consideration all the aspects it is concluded that plants trained to double stem performed best for all the plant growth and yield characters as well as. Based upon the present results it could be revealed that raised bed planting method along with black polythene mulch produced the significantly higher yield due to the favorable soil temperature conditions achieved in that particular treatment.

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Conflict of interest

The authors declare that they have no conflict of interest.

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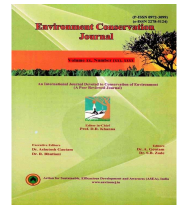

Performance of heat resilient maize hybrids to different levels of fertilizers in Tungabhadra Project command area

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ABSTRACT

The high temperature and heat stress are the main factors that limit the optimum yield of maize in tropical countries. Improvement in the agronomic practices is need of the hour to overcome heat stress in maize hence the experiment was conducted to study the response of heat resilient maize hybrids to different fertilizer levels on nutrient uptake, dry matter production and yield. It was laid out in split plot design and replicated thrice. Main plot includes genotypes (*viz*., RCRMH-2, RCRMH-3, RCRMH-11 and Cargill 900M Gold) and sub plots with three fertilizer levels (*viz*., 75 % Recommended Dose of Fertilizer (RDF), 100 % RDF and 125 % RDF. The 100 % RDF was 187.5:75:37.5 kg NPK ha^{-1}). Results revealed that significantly higher grain yield was recorded by genotype, RCRMH-3 (5841 kg / ha) and RCRMH-2 (5627 kg / ha) and suitable for summer seasons as compared to RCRMH-11 (5139 kg / ha) and Cargill 900M Gold (4695 kg / ha). Among the fertilizer levels, increase in fertilizer levels from 75 (4922 kg / ha) to 100 % (5365 kg / ha) increased the grain yield significantly and further increase to 125 % RDF (5689 kg / ha), there is no significant differences among the treatments. These treatments also showed similar effects with respect to growth and yield parameters contributing for the higher yield and monetary benefits.

Introduction

Maize is the major crop grown under diverse environment conditions. Due to its greater degree of adaptability and higher productivity maize is grown in commercial scale. It is mainly consumed by humans, serves as fodder to livestock and raw material in many processing industries (Hearn, 2014) and hence it stands as third most important food grain in India after wheat and rice. In India scenario, 28% of maize produced is used for food purpose, 11% for livestock feed, 48% as feed for birds, 12% in wet milling industry (e.g. starch and oil production) and only 1% for seed purpose (Anon., 2017). In tropical areas, where temperature rise has become a major problem, the heat stress conditions is the limiting factor affecting yield and productivity of maize (Sultan and Gaetani, 2016). Reduction in crop production and yield will be due to change in microclimate due to high temperatures which have adverse effect on the plant physiology. The heat stress caused due to rise in temperature above 30 ^{0}C have adverse effect on the physiological processes (Jagadish *et al*., 2011), such as higher respiration rate, shortening of plant life cycle, reduced light interception, hampered photosynthesis and higher pollen sterility (Vani *et al*., 2001). Increase in heat stress two weeks before flowering have adverse effect on yield due to leaf firing by premature damage to the leaf tissue (Jagadish *et al.,* 2011), accelerated leaf senescence rate (Lobell *et al.,* 2012) and early lodging of plants. The heat stress will cause tassel blasting which reduces the production of pollen, reduced

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pollen viability and pollination rate when high temperature occurs at the on-set of flowering (Meseka *et al.,* 2018). Heat stress during grain-filling stage leads to reduced grain-filling period, lower kernel set and reduced grain weight (Pradhan *et al*., 2012), causing reduction in 10% grain yield. For every increase in temperature over 30 ^{0}C, 1 per cent reduction in yield of the crop and by 1.7 per cent grain yield under drought stress conditions (IPCC, 2007). The combination of both drought and heat stress will affect 40 per cent yield reduction (Lobell *et al.,* 2011; Lobell and Schlenker, 2011). The climate change impacts will be more for the less resilient impoverished countries. This change in environmental conditions will reduce 10 to 20 per cent yield reduction in maize until and unless new agronomic practices will come to help in food security (Lobell, 2008; Pye-smith, 2011). The genotypic response to heat stress during reproductive stage reduced the grain yield to an extent of 50% (Saifi *et al*., 2018). This was owing to a stronger inhibitory effect during vegetative development on physiological variables such as crop growth rate, average net assimilation rate, and harvest index of the three cultivars. The sterility will increase with the increase in temperature. Under high temperature conditions, there will be decrease in chlorophyll content and it will have adverse effect on photosynthesis (Abdel-Rasoul *et al.,* 2009; Chaves *et al*., 2013). The agronomic impacts of climate change will depend principally on how well the agriculture crops can adapt to these conditions. Sowing hybrid maize after January or when the tasseling coincides with high temperature during March induce male sterility and yield will be drastically reduced (Muneeb *et al*., 2017).

The use of adequate and balanced level of fertilizer will help for the increased and profitable crop production (Dejene Getahun *et al*., 2020). The availability of nutrients at right time during the crop requirement will help for higher yield and crop productivity. The precise release of nutrients to the crop without wastage causing environmental problem is necessary for sustainable development (Wu and Liu, 2008). The environmental factors and plant genetic capacity influence on the nutrient uptake and yield functions (Koocheki and Khajehosseini, 2008). The fertilizer level and uptake influence the grain yield and protein in maize. The fertilizer use has met the nutrient demand of the crops but over long run the use of chemical fertilizer has led to environmental pollution and ecological instability (Iqbal *et al.*, 2013; Dibaba *et al*., 2013). The amount of nitrogen, phosphorous ad potassium has positive effect on the protein content of maize (Cai *et al*., 2012). The nitrogen has increased effect on number of grains per cob, weight of grain and yield in different maize hybrids. Muhammad *et al*. (2018) observed that application of potassium had significantly ($P \leq 0.05$) affected on the crop phenology growth (plant height) and yield traits, biological and yield of maize. The physiological traits like leaves number, length of leaf and width, and dry matter production of the plant increases with increased fertilizer levels (Mousavi *et al*., 2019; Barker, 2012; Gao *et al.,* 2020; Pepó and Karancsi, 2017; Hejazi *et al.,* 2013). Jadhav (2018) reported that increase in fertilizer dose from 120 kg of nitogen ha^{-1}, 60 kg of phosphorous ha^{-1} and 60 kg of potassium ha^{-1} to 180:90:90 kg / ha of Nitrogen, Phosphorous and potassium had significantly increased the grain yield of maize sown during summer.The systematic effort to develop maize cultivars with heat tolerance was initiated in 2012 under Heat Stress Tolerant Maize for Asia (HTMA) project implemented by International Maize and Wheat Improvement Centre (CIMMYT)-Asia team. In the project, biomarkers and bioassays for heat tolerance as well as genomic regions associated with heat tolerance traits were identified and validated. Using rapid-cycle genomic section (RC-GS) and breeding informatics coupled with DH technology, new heat tolerant germplasms were developed and new generation of heat stress tolerant maize hybrids *viz*., RCRMH-2, RCRMH-3 and RCRMH-11 were developed. Under low input and heat stress conditions the heat resilient maize yield up to 20 to 25 per cent higher than the commercial varieties (Setimela *et al*., 2017). There will be yield advantage of 10 to 25 percent with use of climate-resilient varieties in many maize growing areas of Eastern and Southern Africa (Tesfaye *et al*., 2016; Setimela *et al.,* 2017). The heat tolerant inbreds either resisted or exhibited very little drop in chlorophyll content. Under high temperatures, the chlorophyll content of vulnerable inbreds decreased dramatically. (San *et al.,* 2015).

The tolerance of maize to temperature varies with the genotypes. The mid-day leaf water potential was higher in heat tolerant maize cultivars (3358, FFR-915c and K-8388) than in heat susceptible cultivars (Choko, P-3424 and JX-77). The degree of leaf rolling in heat tolerant cultivars was lower than in heat susceptible cultivars in Japan (Ogata *et al*., 2016). However, these genotypes need to be evaluated for agronomic managements. The present study was to develop better agronomic management practices for heat resilient maize using different levels of fertilizer dose to increase the yield and profitability.

Material and Methods

During the cropping season, 36.2 mm of rainfall (from January to May) was received. As the crop was grown in irrigated condition, water is not the main constraints but the temperature may be the main factor affected maize genotypes. The maximum temperature was 42 ^{0}C noticed in first forth night of May during which crop was at harvesting stage.

During the 2018 Kharif, field research was carried out at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, Karnataka, India, located between 16^o 12 ' North latitude and 77^o 20' East. longitude at an altitude of 389 meters above sea level and falls within Karnataka's North Eastern Dry Zone. The data on weather parameters such as rainfall (mm), mean maximum and minimum temperatures (^{0}C) recorded at the meteorological observatory of the Agricultural Research Station; Siruguppa during the experimental year 2018-19 and the mean of the last 11 years are presented in Table 2. The normal annual rainfall for the past 11 years was 555.9 mm. The highest normal rainfall was received in the month of June (72.2 mm) followed by January (90.1 mm). The total rainfall during 2018-19 was 309.3 mm. The highest monthly rainfall of 76.5 mm was received in September followed by 60.9 mm in June, 56.8 mm in August and 55.4mm in October. The monthly mean maximum temperature ranged from 42 ^{0}C in May to 31^{0}C in December during 2018-19. The months of May, April, March and June were more warmer . The monthly mean minimum temperature ranged from 23^{0}C in November and December to 29^{0}C in May during 2018-19. Experimental site with medium deep black soil and clayey in soil texture. Composite soil sample (0-30 cm) was collected from the experimental site before initiation of the experiment. The soil was air-dried, powdered and allowed to pass through 2 mm sieve and was analyzed for physical and chemical properties. Initial properties of the soil are presented in Table 1.

The heat resilient maize hybrids used are RCRMH-2, RCRMH-3 and RCRMH-11, which are developed in collaboration with CIMMYT-Asia, Hyderabad under HTMA project funded by United States Agency for International Development (USAID). Cargill 900M Gold is medium duration variety released by Syngenta and Monsanto. The experiment was conducted in split plot design having main plot for 4 Genotypes and 1 Check (G_1: RCRMH-2, G_2: RCRMH-3, G_3: RCRMH-11, G_4: CHECK (Cargill 900M Gold)) and subplot containing 3 fertilizer levels F_1: 75% RDF, F_2: 100% RDF, F_3: 125% RDF (RDF: 187.5:75:37.5 NPK kg / ha). Total 12 treatment combinations and 3 replications were followed (table 3).

The recommended doses of fertilizers are applied through application of urea, di-ammonium phosphate and muriate of potash. Complete dose of phosphorus, potassium and half of recommended nitrogen was applied at the time of sowing in seed lines. Remaining half of nitrogen was split in two doses *viz*., 25% applied at 30 DAS and another 25% applied at tasseling stage, respectively.

Observations on the various growth parameters were recorded at 30, 60, 90 DAS and at harvest. The average leaf area was expressed in cm^2 /plant (Stickler *et al*., 1961). Leaf area index (LAI) was calculated by using below mentioned formula given by Watson (1952).

$$\textbf{Leaf area index (LAI)} = \frac{\textbf{Leaf area (cm}^2\textbf{)}}{\textbf{Ground area (cm}^2\textbf{)}}$$

Total N, P and K uptake was calculated for each treatment separately using the following formula and uptake of N, P and K were expressed in kg / ha.

$$\textbf{Nutrient uptake} = \frac{\textbf{Per cent of nutrient concentration}}{\textbf{100}} \textbf{ x Biomass (kg/ha)}$$

Statistical analysis of data

The experimental data collected on various growth and yield components of plant were subjected to Fisher’s method of “Analysis of variance”

(ANOVA). Data collected for one season; effect of treatment were statistically analyzed. Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation NS (Non-Significant) was indicated.

Results and Discussion

The main objective of the experiment is to develop and evaluate the efficiency of heat resilient maize under varied fertilizer rate. Heat resilient varieties have low yield potential due to heat stress than other regional varieties. The growth parameters were significantly higher in heat resilient maize varieties. RCRMH-3 is heat stress tolerant and drought tolerant medium maturing, single cross maize hybrid which is a multiple disease resistant medium maturing single cross maize hybrid**.**

Table 1: Physico-chemical properties of soil from the experimental site before experiment

SN	Particulars	Value
	Particle size distribution	
1	Sand (%)	21.62
	Silt (%)	23.51
	Clay (%)	54.44
2	Textural class	Clay soil
3	Soil pH (1:2.5)	8.01
4	EC (dSm^{-1})	0.39
5	Organic carbon (%)	0.43
	Available nutrients (kg / ha)	
1	Available nitrogen (N kg / ha)	231.0
2	Available phosphorous (P_2O_5 kg / ha)	24.0
3	Available potassium (K_2O kg / ha)	364.1

Growth components

Leaf area

Leaf area is very important aspect with respect to photosynthesis. Among the genotypes, RCRMH-3 found to significantly higher leaf area (84.22 dm^2/plant) (Table 4) and was significantly superior over Cargill 900M Gold (67.67 dm^2/plant). Among the fertilizer levels, the highest leaf area was recorded in 125 % RDF (82.00 dm2/plant) and was significantly superior over 75 % RDF (71.00 dm^2/plant) (Table 4). Non-significant interaction was observed in leaf area $plant^{-1}$ due to the effect of genotypes and fertilizer levels at all the stages of crop growth.

The increased leaf area may be due to high photosynthetic rate leading to improved plant growth. The heat tolerance in hybrids is due to increased chlorophyll content in leaves with lower MDA content and electrolyte leakage (Kumar *et al*., 2012). Increase in antioxidative capacity in maize will help for the heat tolerance and improved growth (Almeselmani *et al*., 2006; Babu and Devaraj, 2008). Lower production of Reactive Oxygen Species due to enhanced synthesis of ascorbate (asa) and glutathione (GSH) will help the plant for higher adaptation and growth under heat stress (Xu *et al*., 2006).Higher leaf area per plant at higher fertilizer level may be due to increased in cell division, assimilation rate and metabolic activities in plant (Jat, 2006; Kumar and Thakur, 2004; Massey and Gaur, 2006). The leaves number and leave length and breadth will be increased due to application of NPK fertilizers (Arpad *et al*., 2020). The different plant growth stages have different tolerance to heat stress due to number of genes regulating the effect leading to complex mechanisms (Maestri *et al.,* 2002).

Leaf area index (LAI)

The LAI increased progressively with the increase in age and maximum at 90 DAS and declined thereafter upto harvest. The variations in LAI due to genotypes and fertilizer levels were significant at all the growth stages. Among the genotypes RCRMH-3 recorded significantly higher LAI (7.11) (Table 4) and was closely followed by RCRMH-2 (6.78) and these two treatments were on par with each other but significantly superior over Cargill 900M Gold (5.67) (Table 4). RCRMH-11 was on par with RCRMH-3.The highest LAI was recorded in 125 % RDF (6.92) (Table 4) and was significantly superior over 75 % RDF (6.00) but on par when compared to 100% RDF (6.42) (Table 4). The interaction were non-significant.Due to higher leaf area, LAI was higher in hybrids. The genotypes, RCRMH-2 and RCRMH-3 showed higher LAI, indicating the efficiency of these hybrids in covering the land area in short time as compared to Cargill 900M Gold. LAI was higher due to higher rate of nitrogen (Bindhani *et al*., 2007; Meena *et al*., 2007; Oscar and Tollenaar, 2006; Sharar *et al*., 2003). This in turn increases the efficiency of the hybrids in tapping the solar radiation. The higher values of LAI might be associated with increased nutrition, which played an important role in increased cell division and elongation in meristematic tissues. This might be due to increase in leaf number and size of leaves due to higher nitrogen dosage (Zothanmawi *et al.*, 2018).

Dry matter accumulation

RCRMH-3 and RCRMH-2 were on par with each other but recorded significantly higher dry matter accumulation in leaves over RCRMH-11 and Cargill 900M Gold (Table 4). Dry matter accumulation in leaves increased with the advancement in age till 90 DAS and declined thereafter and the data was significant due to different treatments. Among the fertilizer levels, 125 % RDF was recorded highest dry matter accumulation in leaves plant^{-1} and significantly superior over 75 % RDF but on par when compared to 100% RDF (Table 4). The dry matter

Table 2: Monthly meteorological data for the year 2018-19 and the average of 11 years (2007-2018) at Agricultural Research Station, Dhadesugur

Months	Temperature (°C)		Rainfall (mm) 2018-19	Relative humidity (%)	Average rainfall (mm) 2007-2018
	Maximum	Minimum			
June-2018	38	26	60.9	76.10	72.2
July-2018	34	25	22.1	72.26	41.6
August-2018	34	26	56.8	84.52	53.0
September-2018	34	24	76.5	85.97	48.8
October-2018	34	25	55.4	81.16	48.4
November-2018	33	23	1.4	76.80	54.5
December-2018	31	23	0.0	76.55	67.8
January-2019	33	24	0.0	75.10	90.1
February-2019	36	25	0.0	71.21	27.0
March-2019	38	25	0.0	54.74	5.9
April-2019	41	28	19.0	45.73	16.6
May-2019	42	29	17.2	44.26	30.0
Total			309.3		555.9

accumulation in stem followed similar trend with that of leaves. RCRMH-3 (61.87) and RCRMH-2 (59.58) were on par with each other, but recorded significantly higher dry matter accumulation in leaves over RCRMH-11 (54.39) and Cargill 900M Gold (49.73) (Table 4). The difference between RCRMH-11 and Cargill 900M Gold was non-significant. Among the fertilizer levels, highest dry matter accumulation in stem plant^{-1} was recorded in 125 % RDF (60.23) and was significantly superior over 75 % RDF (52.13) but on par with 100% RDF (56.81) (Table 4). The interaction effect between genotypes and fertilizer levels was non-significant at all the crop growth stages. Among the genotypes, RCRMH-3 recorded significantly higher dry matter accumulation in tassel plant^{-1} (4.59) and was closely followed by RCRMH-2 (4.42 and) and these two treatments were on par with each other,but significantly superior over RCRMH-11 (4.03) and Cargill 900M Gold (3.69) (Table 4). Application of 125% RDF recorded significantly higher dry matter accumulation in tassel plant^{-1} (4.47) over 75 % RDF (3.87) but on par with 100% RDF (4.21) (Table 4). Among the genotypes, RCRMH-3 recorded significantly higher dry matter accumulation in cob plant^{-1} (224.83 g) and was closely followed by RCRMH-2 (216.54 g) and these two treatments were on par with each other, but significantly superior over Cargill 900M Gold (180.71 g) (Table 4). The significantly highest dry matter accumulation in cob plant^{-1} was recorded in 125 % RDF (218.90 g) over 75 % RDF (189.46 g) but on par with 100% RDF (206.45 g) (Table 4).

Among the genotypes, RCRMH-3 recorded significantly higher total dry matter production plant^{-1} (325.44 g) and was closely followed by RCRMH-2 (313.42 g) and these two treatments

Table 3: Treatment combinations

Treatments	Genotype	Fertilizer level
T_1: G_1 F_1	RCRMH-2	75% RDF
T_2: G_1 F_2	RCRMH-2	100% RDF
T_3: G_1 F_3	RCRMH-2	125% RDF
T_4: G_2 F_1	RCRMH-3	75% RDF
T_5: G_2 F_2	RCRMH-3	100% RDF
T_6: G_2 F_3	RCRMH-3	125% RDF
T_7: G_3 F_1	RCRMH-11	75% RDF
T_8: G_3 F_2	RCRMH-11	100% RDF
T_9: G_3 F_3	RCRMH-11	125% RDF
T_{10}: G_4 F_1	Cargill 900M Gold	75% RDF
T_{11}: G_4 F_2	Cargill 900M Gold	100% RDF
T_{12}: G_4 F_3	Cargill 900M Gold	125% RDF

were on par with each other, but significantly superior over Cargill 900M Gold (261.57 g) (Table 4). The difference between RCRMH-11 (286.10 g) and Cargill 900M Gold was non-significant. Among the fertilizer levels, the highest total dry matter production plant^{-1} was recorded in 125 % RDF (316.84 g) and was significantly superior over 75 % RDF (274.23 g) but on par when compared to 100% RDF (298.83 g) (Table 4).The number of green leaves plant^{-1} and leaf area were directly proportional to the dry matter accumulation in leaves. The highest dry matter accumulation in leaves of RCRMH-3 and RCRMH-2 was mainly due to their genetic makeup. Further, increase in fertilizer level from 75 % to 125 % RDF increases the dry matter accumulation in leaves due to increase in cell division, assimilation rate and metabolic activities in plant (Mohamed *et al*., 2010). The genotypes, RCRMH-3 and RCRMH-2 were recorded higher dry matter accumulation in stem due to their genetic ability to grow taller and produce thicker stem. Increase in fertilizer level from 75 % to 125 % RDF also recorded higher dry matter accumulation in stem due to increased net assimilation and photosynthetic rate in plants with higher levels of NPK. Variation in dry matter production in different parts of plant and total dry matter accumulation in genotypes may be attributed to better growth and development of genotypes *viz*., RCRMH-3 and RCRMH-2. In the present investigation, these genotypes attained higher plant height and produced more number of leaves compared to other genotypes. With respect to fertilizer levels, maximum dry matter accumulation was obtained under higher fertilizer level (125% RDF) which may be due to more availability of nutrients from inorganic fertilizers. The 125 % RDF may have supplied better nutrient (NPK) throughout the growing period of the crop. This helped in production of growth promoters like auxin, an important growth promoter that enhanced cell division and elongation that in turn produced the higher dry matter of maize crop (Kumar, 2008; Kurne *et al.,* 2017; Siam *et al.,* 2008). Raju *et al.* (1997) reported that higher doses of nitrogen applied to maize increased its availability and uptake, resulting in production of more photosynthates in terms of dry matter. Likewise, Tomar *et al*. (2017) also observed 100% NPK along with 5 t FYM+ Azotobacter + PSB application recorded significantly higher growth attributes *viz*., plant height (203.6 and 198.9 cm) and dry matter accumulation (265.1 and 269.4 g) during 2010 and 2011 respectively.

Yield components

Significantly higher cob length was recorded in RCRMH-3 (15.19 cm) followed by RCRMH-2 (14.63 cm), RCRMH-11 (13.35 cm) and Cargill 900M Gold (12.21 cm) and they were significant with each other. Application of 125 % RDF recoded significantly higher cob length (14.79 cm) over 75 % RDF (13.94 cm) and was on par with 100% RDF (12.80 cm). The genotype, RCRMH-3 recorded significantly higher number of grains cob^{-1} (451.1) over Cargill 900M Gold (362.5) and RCRMH-11 (396.6), but on par with RCRMH-2 (434.4). 125 % RDF application recorded significantly higher number of grains cob^{-1} (439.2) over 75 % RDF (380.1) and was on par with 100 % RDF (414.2).Among the genotypes, RCRMH-3 recorded significantly higher test weight (30.1 g) and was closely followed by RCRMH-2 (29.0 g) and these treatments were found on par with each other but significantly superior over Cargill 900M Gold (24.2 g). The differences between RCRMH-11 (26.4 g) and Cargill 900M Gold was non-significant. Among the fertilizer levels, application of 125 % RDF recorded significantly higher test weight (29.3 g) and superior over 75 % RDF (25.3 g). However, there is no significance difference between 100% (27.6 g) and 125 % RDF.

Table 4: Growth indices of heat resilient maize hybrids at different growth stages as influenced by fertilizer levels

Treatments	Leaf area (dm^2 /plant)	Leaf area index	DMA in leaves (g /plant)	DMA in stem (g /plant)	DMA in tassel (g /plant)	DMA in cob (g /plant)	TDMA of plant (g /plant)
Genotype (V)							
V_1: RCRMH-2	81.11	6.78	38.89	59.58	4.42	216.54	313.42
V_2: RCRMH-3	84.22	7.11	40.38	61.87	4.59	224.83	325.44
V_3: RCRMH-11	74.22	6.22	35.50	54.39	4.03	197.66	286.10
V_4: Cargill 900M Gold	67.67	5.67	32.46	49.73	3.69	180.71	261.57
Mean	76.80	6.44	36.80	56.39	4.18	204.93	296.63
S.Em. ± C.D. at 5 %	2.42 8.37	0.19 0.66	1.15 3.96	1.16 3.27	0.13 0.45	6.38 22.07	9.23 31.97
Fertilizer levels (F)							
F_1: 75 % RDF	71.00	6.00	34.03	52.13	3.87	189.46	274.23
F_2: 100 % RDF	77.42	6.42	37.08	56.81	4.21	206.45	298.83
F_3: 125 % RDF	82.00	6.92	39.31	60.23	4.47	218.90	316.84
Mean	76.80	6.44	36.80	56.39	4.18	204.93	296.63
S.Em. ± C.D. at 5 %	1.62 4.86	0.18 0.53	0.78 2.34	1.19 2.38	0.09 0.26	4.34 13.0	6.28 18.8
Interaction (V X F)							
a) V x F (V at same level of F) S.Em. ± C.D. at 5 %	3.23 NS	0.45 NS	1.62 NS	2.45 NS	0.25 NS	8.72 NS	12.64 NS
b) V x F (overall) S.Em. ± C.D. at 5 %	3.58 NS	0.35 NS	1.71 NS	2.62 NS	0.19 NS	9.53 NS	13.80 NS

RDF - 187.5:75:37.5 kg NPK ha^{-1} **DAS -** Days after sowing **DMA**-Dry matter accumulation

Among the genotypes, RCRMH-3 (5841 kg / ha) recorded significantly higher grain yield (5841 kg / ha) and was closely followed by RCRMH-2 (5627 kg / ha) and these treatments were on par with each other, but found significantly superior over Cargill 900M Gold (5695 kg / ha) (Table 5). There is no significant difference between RCRMH-11 (5139 kg / ha) and Cargill 900M Gold (5695 kg / ha). With respect to fertilizer levels, significantly higher grain yield (5689 kg / ha) was observed with application of 125 % RDF over 75 % RDF (4922 kg / ha), but on par with 100 % RDF (5365 kg / ha) (Table 5).Significantly higher stover yield was recorded with RCRMH-3 (7497 kg / ha) and RCRMH-2 (7220 kg / ha). These two treatments were on par with each other, but significantly superior over Cargill 900M Gold (6026 kg / ha) (Table 5). The stover yield between RCRMH-11 (6591 kg / ha) and Cargill 900M Gold was on par. Increase in fertilizer dose from 75 % RDF (6317 kg / ha) to 125 % RDF (7299 kg / ha) recorded significantly higher stover yield (Table 5). The difference between to 100 % RDF (6884 kg / ha) and 125 % was on par with each other. Among the interaction effect, there is due to genotypes and fertilizer levels with respect to stover yield was not significant.The improved plant architecture, plant could able to intercept more solar radiation and thus, plant could synthesize more photosynthates and accumulate them in different plant parts (leaves, stem, tassel and cob). This ultimately as a result increase in stover and grain yield. Similar to cob length, the cob girth was also influenced by genotypes and enhanced by nutrients. Hence, the maize hybrids *viz.,* RCRMH-3 and RCRMH-2 showed higher girth at high level of RDF (Saruhan and Sireli, 2005). Genetic character of maize hybrids (RCRMH-3 and RCRMH-2) was the main factor attributed for increase in cob length. Further, application of 125 % or 100 % NPK increased cob length indicated that these hybrids respond for high level of nutrients. Results are in line with the findings of Majid *et al.* (2017) and Patil *et al*. (2018). Application of different nitrogen doses had significant influence the girth of cob in BARI hybrid maize-7 and BARI hybrid maize-9. The cob girth increased with increasing nitrogen levels. BARI hybrid maize-9 produced the highest cob girth (16.67 cm) with application of 345 kg N ha^{-1}, which hasn't significant difference with 230 kg N ha^{-1} (Majid *et al.,* 2017).Patil *et al.* (2018) observed that, application of 200 kg N ha^{-1} recorded significantly higher number of cobs $plant^{-1}$, cob length and cob girth without husk as compared to rest of nitrogen levels (100 and 150 kg N ha^{-1}). Likewise, application of 50 kg P_2O_5 and K_2O recorded significantly higher number of cobs $plant^{-1}$, cob length and cob girth without husk as compared to other treatment. The main factor attributed for increased grains cob^{-1} was the genotypic characters and it further enhanced with the increase in fertilizer levels. During this study, increase in fertilizer dose from 75 % to 125 % increases the uptake of nutrients and its assimilation in plant. This increased the cob length and girth, in turn accommodated more number of grains cob^{-1}. Among the genotypes tried, RCRMH-3 was found to be more efficient genotype followed by RCRMH-2 and RCRMH-11. Similar results were reported by Karasu (2012). The test weight is mainly influenced by the genetic character. Among the genotypes tried RCRMH-3 and RCRMH-2 showed the highest test weight indicating their genetic superiority. Further, they responded to high dose of fertilizers and produced higher cob length and girth. This in turn produced bold and good filled seeds. Thus there was increase in test weight. Similar results were reported by Majid *et al.* (2017).Higher yield of maize hybrids *viz*., RCRMH-3 and RCRMH-2 was due to significantly superior growth and yield parameters *viz.*, plant height, number of green leaves per plant, leaf area per plant, leaf area index, leaf area duration, total dry matter accumulation, cob length, cob girth, no. Of grains cob^{-1} and test weight. Application of 100 and 125% RDF has produced higher yield. This might be due to optimum supply of nutrients that enhanced the growth (plant height, number of green leaves per plant, leaf area per plant, leaf area index, leaf area duration, total dry matter accumulation, cob length, cob girth) and yield parameters (number of grains cob^{-1} and 100 seed weight) of maize.The stover yield was closely related to growth attributes such as plant height, number of leaves, leaf area, leaf area index, leaf area duration and total dry matter production. In the present investigation, RCRMH-3 and RCRMH-2 showed higher growth attributes (plant height, number of

Table 5: Grain yield (kg / ha), stover yield (kg / ha) and harvest index (%) of heat resilient maize hybrids as influenced by fertilizer levels

Treatments	Cob length (cm)	Number of grains cob^{-1}	Test weight (g)	Grain yield (kg / ha)	Stover yield (kg / ha)	Harvest index (%)
Genotype (V)						
V_1: RCRMH-2	14.63	434.4	29.0	5627	7220	43.8
V_2: RCRMH-3	15.19	451.1	30.1	5841	7497	43.7
V_3: RCRMH-11	13.35	396.6	26.4	5139	6591	43.8
V_4: Cargill 900M Gold	12.21	362.5	24.2	4695	6026	43.7
Mean	13.84	411.1	27.4	5325	6833	43.8
S.Em. ± C.D. at 5 %	0.43 1.49	12.8 44.2	0.8 2.9	166 574	213 736	0.0 NS
Fertilizer levels (F)						
F_1: 75 % RDF	12.80	380.1	25.3	4922	6317	43.7
F_2: 100 % RDF	13.94	414.2	27.6	5365	6884	43.8
F_3: 125 % RDF	14.79	439.2	29.3	5689	7299	43.8
Mean	13.84	411.1	27.4	5325	6833	43.8
S.Em. ± C.D. at 5 %	0.29 0.88	8.7 26.0	0.5 1.7	113 338	145 434	0.0 NS
Interaction						
a) V x F (V at same level of F) S.Em. ± C.D. at 5 %	0.61 NS	17.4 NS	1.2 NS	225 NS	289 NS	0.5 NS
b) V x F (overall) S.Em. ± C.D. at 5 %	0.61 NS	19.1 NS	1.3 NS	248 NS	318 NS	0.8 NS

RDF - 187.5:75:37.5 kg NPK ha^{-1} **DAS -** Days after sowing

green leaves per plant, leaf area per plant, leaf area index and total dry matter accumulation) at all the stages and finally it was exhibited in the stover yield. On the other hand Cargill 900M Gold recorded the lowest growth attributes, thus recoded lower stover yield.

Harvest index

Among the different genotypes with fertilizer levels. There is no significant difference between harvest index but the values ranged from 0.42 to 0.43 (Table 5).

$$\text{Harvest Index} = \frac{\text{Grain yield (kg/ ha)}}{\text{Biological yield (kg/ ha)}}$$

Nutrient uptake and retention

Significant variations were observed with respect to nitrogen uptake by maize due to different genotypes and fertilizer levels.Among the genotypes, RCRMH-3 (213.70 kg / ha) and RCRMH-2 (205.80 kg / ha) were on par with each other but significantly superior over Cargill 900M Gold (171.76 kg / ha) (Table 6). There is no significant difference in nitrogen uptake among the RCRMH-11 (187.86 kg / ha) and Cargill 900M Gold. Among the fertilizer levels, 125 % RDF recorded significantly higher nitrogen uptake (208 kg / ha) over 75 % RDF (180 kg / ha) and was on par with 100% RDF (196.08 kg / ha) (Table 6). The interaction effect due to genotypes and fertilizer levels on nitrogen uptake was non-significant.

The data on phosphorus uptake by maize due to different genotypes and fertilizer levels was significant. Among the genotypes, RCRMH-3 (34.20 kg / ha) and RCRMH-2 (32.9 kg / ha) were on par with each other but significantly superior over Cargill 900M Gold (27.5 kg / ha) (Table 6).

Table 6: Nutrient uptake (kg / ha) of heat resilient maize hybrids as influenced by fertilizer levels

Treatments	N uptake (kg / ha)	P uptake (kg / ha)	K uptake (kg / ha)	Available nutrients after harvest (kg / ha)		
				N	P_2O_5	K_2O
Genotype (V)						
V_1: RCRMH-2	205.80	32.90	155.02	213.02	19.11	330.01
V_2: RCRMH-3	213.70	34.20	161.05	207.00	18.49	321.03
V_3: RCRMH-11	187.86	30.11	142.01	216.12	19.63	341.02
V_4: Cargill 900M Gold	171.76	27.50	130.01	220.25	20.60	358.11
Mean	194.78	31.21	147.11	213.67	19.43	337.47
S.Em. ± C.D. at 5 %	6.06 20.97	0.97 3.36	4.58 15.84	6.42 NS	0.58 NS	10.10 NS
Fertilizer levels (F)						
F_1: 75 % RDF	180.02	28.82	136.03	205.00	18.10	323.71
F_2: 100 % RDF	196.08	31.42	148.03	213.02	19.52	336.60
F_3: 125 % RDF	208.02	33.31	157.05	223.01	20.71	352.21
Mean	194.78	31.21	147.11	213.67	19.43	337.47
S.Em. ± C.D. at 5 %	4.12 12.36	0.66 1.98	3.11 9.33	4.47 13.41	0.41 1.22	7.05 21.14
Interaction						
a) V x F (V at same level of F) S.Em. ± C.D. at 5 %	8.24 NS	1.34 NS	6.25 NS	8.91 NS	0.82 NS	14.10 NS
b) V x F (overall) S.Em. ± C.D. at 5 %	9.12 NS	1.50 NS	6.88 NS	9.72 NS	0.88 NS	15.32 NS

RDF - 187.5:75:37.5 kg NPK ha^{-1} **DAS -** Days after sowing

The differences between RCRMH-2 (32.9 kg / ha) and Cargill 900M Gold (27.5 kg / ha) was non-significant. With respect to fertilizer levels, increase in the fertilizer dose from 75 % RDF (28.8 kg / ha) to 100 % RDF (31.4 kg / ha) recorded significantly higher P uptake and further increase to 125 % RDF (33.3 kg / ha) was non-significant (Table 6). The interaction effect due to genotypes and fertilizer levels on phosphorus uptake was non-significant. Potassium uptake by maize differs significantly by maize genotypes and fertilizer levels. Similar to N and P uptake, the genotypes, RCRMH-3 (161 kg / ha) and RCRMH-2 (155 kg / ha) recorded significantly higher K uptake over Cargill 900M Gold (130 kg / ha) (Table 6). The differences in K uptake between RCRMH-11(142.01 kg / ha) and Cargill 900M Gold was non-significant. Among the fertilizer levels, 125 % RDF (157 kg / ha) recorded on par P uptake with 100 % RDF (148 kg / ha) but significantly higher over 75 % RDF (136 kg / ha) Table 6).The interaction between genotypes and fertilizer levels was found non-significant. The data concerned to available soil nitrogen as influenced by genotypes is non-significant and it varied significantly with fertilizer levels. With respect to fertilizer levels, application of 125 % RDF recorded significantly higher available N in soil (223 kg / ha) over 75 % RDF (205 kg / ha) (Table 6). The difference between available N in soil at 100 % RDF and 125 % RDF was non-significant. Interaction effects between genotypes and fertilizer levels with respect to available N in soil not significant. Significant differences in available soil phosphorus were recorded among fertilizer levels but it was non-significant with genotypes. Application of 125 % RDF (20.7 kg / ha) recorded on par P_2O_5 in soil with 100 % RDF (19.52 kg / ha) but significantly higher over 75 % RDF (18.1 kg / ha) (Table 6). Non-significant interaction was observed with respect to available soil phosphorus due to genotypes and fertilizer levels. Significant differences in available soil potassium were recorded among fertilizer levels but it was non-significant with genotypes. Among fertilizer levels, 125 % RDF recorded significantly higher available K in soil after harvest (352.2 kg / ha) over 75 % RDF (323.71 kg / ha) but on par with 100 % RDF (336.60 kg / ha) (Table 6). Non-significant interaction was observed with respect to the available soil potassium due to genotypes and fertilizer levels. The present investigation revealed that the uptake of nutrients was directly proportional to the fertilizer levels applied to the soil. The amount of nutrients taken up by the crops was affected by the mass of vegetative and reproductive organs and their NPK content. Increase in the uptake of nitrogen, phosphorus and potassium by maize genotypes indicates the efficiency of the genotypes in absorption. Further, increase in growth, yield attributes and yield, indicates its ability to utilize these absorbed nutrients. Application of 250 N kg / ha recorded higher nutrient uptake. Increased N uptake at higher doses resulted in an early development of strong growth and a greater photosynthetic rate, resulting in improved nutrient uptake throughout the crop growth cycle. P uptake was significantly influenced by fertilizer levels. The P uptake was high under 250:125:125 NPK kg / ha. This could be attributed to increased growth and dry matter production, as well as enhanced N uptake, as a result of the application of N. The uptake of K was improved with a higher dose of NPK. This could be owing to the synergistic action of N and K, as well as improved root foraging ability as a result of greater NP application, resulting in higher dry matter production (Srikanth *et al.,* 2009). Significantly higher removal of NPK in 100% NPK + 5 t FYM+ Azotobactor + PSB which was superior to rest of its treatments. Application of 75% NPK along with other parts showed lowest removal of NPK as against 100% NPK with either FYM or biofertilizer. Higher uptake of N, P, and K could be owing to the beneficial effect of combining organic and inorganic nutrients (Tomar *et al.,* 2017). Post-harvest soil available N, P and K were favorably influenced by NPK levels. Increased NPK levels recorded higher soil available N, P and K. Patil *et al.* (2018) opined that the higher nitrogen, phosphorous and potassium levels increased nutrients availability to plants, which resulted into higher values of yield attributes and yield under higher levels of NPK. Nagy (2010) revealed that the NPK fertilizer effects indicate that the fertilizers are different on yield of genotype. Altogether, the findings of this study revealed that different maize cultivars produce differently in response to nitrogen fertiliser treatments (Szeles *et al.,* 2019).

Conclusion

RCRMH-3 and RCRMH-2 maize hybrids are resistant to high temperatures and produce more grain, stover, and economic returns. Thus, they are suitable for summer sowing. The fertilizer dose of 100 % RDF (187.5:75:37.5 kg NPK ha^{-1}) found optimum for both the genotypes. Due to higher dry matter accumulation during the crop's growth stages, resistant genotypes had higher nutrient uptake. For climate change scenarios, heat resistant genotypes are the best option.

Conflict of interest

The authors declare that they have no conflict of interest.

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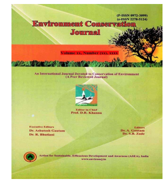

Extent of livelihood opportunity of the sericulture farmers in Kamrup district of Assam

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ABSTRACT

The study was conducted with a sample of 120 sericulture farmers in Kamrup district of Assam in three development blocks *viz.* Bongaon, Boko and Chayani Borduwa. The study revealed that majority (43.33%) of the respondents belonged to middle age group, 36.67% were illiterate, 45.83% belonged to small size family and 69.17% had pucca house. In case of operational land holding majority (34.17%) of the respondents possessed small size of land holding, 33.95% had annual income ranging from Rs.75,001-1,00,000, 75.00% had medium level of extension contact, 61.67% had moderate level of risk bearing ability, 59.17% had moderate level of decision-making ability and only 23.33% had received training. Most of the respondents (35.00%) practiced "Sericulture +paddy+plantation crops" followed by "Sericulture+paddy+piggery" (15.83%) and "Sericulture+paddy+fruits" (12.50%) as their livelihood options. Education, family size, house type, operational land holding risk bearing ability and decision-making ability have significant relationship on livelihood options.

Introduction

Sericulture is an economically feasible and commercially viable agro-based labour-intensive industry comprised of food plant cultivation, silkworm rearing, reeling and spinning, yarn making and weaving. The economic advantages of sericulture industry lie in its high employment potential with low investment. Sustainable livelihood creation is a major role played by sericulture industry. Sericulture provides stable income to many rural agricultural families and a livelihood to scores of landless farm and non-farm women labourers giving much economic strength (Sarkar *et al.,* 2017). In the global textile parlance, India has the unique identity for production of all the four commercial types of silk *viz.*, mulberry, muga, eri and tasar. It is the second largest producer of silk among all the silk producing countries and contributes about 36.76 per cent to the total world raw silk production during the year 2020 (Anonymous, 2021a). Sericulture in India provides livelihood to about 9.4 million population of the country indicating a growth rate of 2.74% per cent during 2019-20 (Anonymous, 2021b). Sericulture industry plays indispensable role in the economy of Assam. With the richest tradition of silkworm rearing, the state contributes almost 82.29 per cent of muga silk and 70.09 per cent of eri silk production in India and shares about 14.17 per cent of total silk production of the country (Anonymous, 2020). The Kamrup district of Assam plays a major role in silk production and is an emerging 'Textile Hub' of Northeast India. About 477 seri-villages and 17,074

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families of the district is associated with sericulture practice and area under eri, muga and mulberry food plant cultivation is 2915.16 hectare (Anonymous,, 2019a). It is playing an important role in mitigating the problem of unemployment and also in uplifting the socio-economic status of sericulture farmers of Kamrup district. The present study is aimed to know how sericulture fulfils the opportunities of livelihood for the sericulture farmers, its diversification and impact in the livelihood security.

Material and Methods

The study was carried out purposively in 3(three) Development Blocks of Kamrup Sadar Sub-division under Kamrup district *viz*. Boko Development Block, Bongaon Development Block and Chayani Borduwar Development Block. Two villages were selected from each block *viz.,* Nowapara village and Thangkhula village from Boko development block; Batakuchi village and Makhandal village from Bongaon development block and Rani Khamar village and Baregaon village from Chayani Borduwa block. A total of 120 respondents were selected for the present study selecting 20 respondents randomly from each of the 6 villages under the 3 surveyed Blocks. The primary data was collected by following the personal interview method using standardized structured interview schedule. Data was analyzed using statistical tool *viz.,* frequency, percentage, Karl Pearson's correlation of coefficient, Chi-Square and multiple regression (Sahu, 2010).

Results and Discussion

Profile characteristics of the sericulture farmers

A total of ten socio-personal, socio-economic and psychological variables were examined (Table 1) for the present study. Majority (43.33%) of the respondents belonged to middle age group and they could better utilize their skill as well as resources for income generation and sustaining their livelihoods. The data pertaining to education level of the farmers revealed that majority of the respondents (36.67%) were illiterate and no respondents found to have educational qualification up to graduate or post graduate level although the literacy rate of Kamrup district is 75.55% (Anonymous, 2019b).

Majority (45.83%) of the respondents belonged to small size family and 69.17% of them had pucca house. In case of operational land holding, majority (34.17%) of the respondents possessed small size of land holding. It was found that 33.95% had income ranging from Rs. 75001-100000. Rabha and Saikia (2021) reported that majority of the women (62.50%) involved in eri culture belong to the income level upto Rs. 15,000 followed by 23.33 per cent women in the range of Rs. 15,001- Rs. 25,000 and 10.83 per cent in the range of Rs. 25,001- Rs. 35,000. Sericulture can be a major booster which may be taken by the small and marginal farmers to earn extra income to their livelihood option. Present study revealed that majority (75.00%) of the farmers had medium level of extension contact, moderate level of risk bearing ability (61.67%) and moderate level of decision-making ability (59.17%). As regards to training exposure, only 23.33 % of the respondents received training. Yadav and Dahiya (2020) revealed that training of women farmers was important to overcome the constraints during marigold cultivation in Gurugram district of Haryana.

Distribution of Sericulture farmers of Kamrup district according to different types of livelihood opportunities

Almost all the respondents in the study area were involved in different types of livelihood opportunities (Table 2) in addition to sericulture such as plantation crops, paddy, piggery, dairy, goatery, poultry, fruits and others. Most of the respondents practiced paddy and plantation crops in addition to sericulture, followed by paddy and piggery, paddy and fruits, poultry and goatery. In this regard, it is to be stated that the study area was protected under tribal belt and block due to which the respondents could utilize the forest reserve land for cultivation of plantation crops which provide heavy income within short duration of time. Piggery was practiced as livelihood options due to the reason that pork has a high market demand in the locality. Hotels and restaurants of Guwahati city mainly collect pork from the study area due to its quality and affordable price. Dairy is adopted by the respondents as it provides daily income through production of milk and milk products and considered as a livelihood opportunity due to its relative advantage in terms of economic viability through production of farmyard manure to be used

Table 1: Profile characteristics of the sericulture farmers in Kamup district of Assam (N = 120)

SN	Profile characteristics of the Sericulture Farmers		Frequency	Percentage
1.	Age	18-35 (Young)	18	15.00
		36-50 (Middle)	52	43.33
		51 and above (Old)	50	41.67
2.	Education	Illiterate	44	36.67
		Primary School Passed	29	24.17
		Middle School Passed	24	20.00
		High School Passed	15	12.50
		Higher secondary passed	8	6.67
		Graduate	0	0
		Post graduate and above	0	0
3.	Family Size	Small Family (2-4)	55	45.83
		Medium Family (5-7)	33	27.50
		Large Family (More than 8)	32	26.67
4.	Type of House	RCC	10	8.33
		Kutcha	27	22.50
		Pucca	83	69.17
5.	Type of land holding	Marginal (Below 1 ha)	29	24.17
		Small (1-2 ha)	41	34.17
		Semi medium (2-4ha)	36	30.00
		Medium (4-10 ha)	14	11.67
		Large (More than 10 ha)	0	0
6.	Annual Income	Up to Rs.35000	12	10.00
		Rs 35001 to 75000	34	28.33
		Rs. 75001 to 100000	41	33.95
		Rs. 100001 and above	33	27.50
7.	Extension Contact	Low	16	13.33
		Medium	90	75.00
		High	14	11.67
8.	Risk Bearing Ability	Low	32	26.67
		Moderate	74	61.67
		High	14	11.67
9.	Decision Making Ability	Low	28	23.33
		Moderate	71	59.17
		High	21	17.50
10.	Training Exposure	Yes	28	23.33
		No	92	76.67

in the plantation crops. Poultry was utilized for the production of eggs and meat for their household consumption and extra income earned help in their livelihood security. The respondents practiced goatery with the growing market demand of mutton amongst consumers and considered as a quick source of income and require less monitoring. Vegetables and fruits cultivation along with sericulture was also adopted as it helps in continuity of income from year-round production. The other types of livelihood opportunities such as business, agro-tourism, handicrafts, weaving, input dealer and custom hiring were also some of the livelihood opportunities of the respondents in the studied area. Nagaraju and Raghavendra (2016) in his study reported that crop, dairy, sheep, piggery and sericulture were practiced as an important integrated farming system by the scheduled caste farm families in CB Pura district of Karnataka. Kumar *et al.* (2020) in their study reported that the integrated approaches can provide sustainable livelihood for the rural people particularly small and marginal farmers.

Table 2: Distribution of Sericulture farmers of Kamrup district according to different types of livelihood opportunities

Livelihood Opportunities	Frequency	%
Sericulture+Paddy+Plantation Crops	42	35.00
Sericulture+Paddy+Piggery	19	15.83
Sericulture+Paddy+Fruits	15	12.50
Sericulture+Poultry+Goatery+ Others	11	9.17
Sericulture+Plantation Crops+Fruits	7	5.83
Sericulture+Dairy+Poultry	5	4.17
Sericulture+Vegetables+Dairy+Othe	4	3.33
Sericulture+Goatery+Fruits	4	3.33
Sericulture+Piggery+Others	4	3.33
Sericulture+Paddy+Dairy	3	2.50
Sericulture+Others	2	1.67
Sericulture+Plantation crops+Others	1	0.83
Sericulture+Poultry	1	0.83
Sericulture+Vegetables+Fruits	1	0.83
Sericulture+Dairy+Poultry+Goatery	1	0.83

Table 3: Factors affecting the livelihood opportunities of the sericulture farmers

Variables	'r' value	χ^2 value
Age	-0.241*	-
Education	-	420.667[a]
Family size	0.218*	-
House type		216.588[a]
Operational land holding	0.325*	-
Extension contact	-	2825.688[a]*
Risk bearing ability	0.303*	-
Decision making ability	-0.159	-
Training exposure	-0.129	-

***Significant at 5%, [a] Association**

Factors affecting the livelihood opportunities of the sericulture farmers

The data on correlation coefficient values between extent of livelihood opportunity and the various independent variables presented in Table 3 revealed that age of the respondents found to have negative and significant (-0.241) relationship with the livelihood opportunities. This indicates that less is the age of the respondents more would be the chances of gaining extent of livelihood opportunities. The young and middle age respondents were more energetic and efficient in carrying out livelihood activities as compared to old aged respondents. Education (420.667[a]) and house type (216.588[a]) had no association with the extent of livelihood opportunities of the respondents. Operational land holding (0.325*) had positive and significant relationship with the livelihood opportunities of the respondents. Extension contracts (2825.688[a]*) had association with the extent of livelihood opportunities of the respondents. Family size (0.218) and risk bearing ability (0.303) of the respondents had positive and significant relationship with the extent of livelihood opportunities. Decision making ability (-0.159) and training exposure (-0.129) of the respondents had no relationship with the extent of livelihood opportunities.

Ifeanyi-obi and Matthews-Njoku (2014) in their study on socio-economic factors affecting choice of livelihood activities among rural dwellers in Southeast Nigeria reported that age was positively significant while education and monthly income correlated negatively with livelihood activity. Binkadakatti (2013) found that family size had positive and significant relationship with livelihood security of rehabilitant farmers in Upper Krishna Project (UKP) area of Bagalkot district of Karnataka state. Islam *et al.* (2015) revealed that socio-economic characteristics of the indigenous households, education, family composition, main occupation, housing status and gross annual income had positively significant correlation with the livelihood dependency on forest; age and size of land holding had non-significant association with the livelihood dependency of indigenous people of forest in Jharkhand district.

Multiple regression analysis of factors affecting the livelihood opportunities of the sericulture farmers

Data presented in table 4 revealed that education and risk bearing ability were found to have significant relationship with livelihood opportunities of the sericulture farmers at 0.01 level of significance while family size, house type, operational land holding and decision-making ability have significant relationship with livelihood opportunities of the sericulture farmers at 0.05 level of significance. Age, extension contact and training exposure did not have significant relationship with the livelihood opportunities of the sericulture farmers. This indicated that the education and risk bearing ability has high impact whereas family size, house type, operational land holding and decision-making ability were also found to have impact on the livelihood opportunities of the sericulture farmers in Kamrup district.

Table 4: Multiple regression analysis of factors affecting the livelihood opportunities of the sericulture farmers

Variables	't' value	'sig' value
(Constant)	0.613	0.540
Age	-1.700	0.091
Education	3.018**	0.003
Family size	2.249*	0.026
House type	2.726*	0.007
Operational land holding	2.591*	0.010
Extension contact	0.062	0.950
Risk bearing ability	3.174**	0.001
Decision making ability	-2.156*	0.033
Training exposure	-1.838	0.068

****Significant at 1%, *Significant at 5%**

The R-square value 0.400 implies that the independent variables considered for the study are 40% responsible for the variability in the model also to determine the livelihood opportunities of sericulture farmers. Soini (2005) found that land size and age of farmers in the slopes of Mt. Kilimanjaro, Tanzania had significant influence in varying patterns of assets and strategies of livelihood. Ramya *et al.* (2017) revealed that education, land holding, annual income, extension contact, mass media exposure, social participation, economic orientation, risk orientation and level of aspiration had shown positively significant relationship and fatalism had shown negatively significant relationship with livelihood security of tribal farmers in high altitude tribal zone of Karnataka state.

Conclusion

The findings of the study concerning the livelihood of the sericulture farmers would help in drawing relevant policy decision to facilitate, upscale and secure their livelihood. In the area of study, mostly middle age group were engaged in sericulture than the young age group. Young people are energetic and dynamic. Therefore, they may be encouraged by providing necessary facilities to take this venture as their livelihood option. Since majority of the respondents in the study area do not have any training exposure on sericulture, training on different sericulture related activities may be organized for the upliftment and encouragement of new generation towards the sector. Most of the sericulture farmers practice paddy cultivation for livelihood along with sericulture. Therefore, sericulture can be regarded as one of the most propitious avocations for the development of socio-economic condition of the rural population in Assam. Based on the results obtained regarding the livelihood options of the sericulture farmers, occupations can be categorized and depending upon their priority, developmental initiatives can be planned by the government and development organizations. Government can consider the factors like education, family size, house type, operational land holding and decision-making ability which were found to have significant effect on livelihood opportunities. Government may give more emphasis on these factors while selecting beneficiaries for projects or programmes and trainees for trainings. Thus, the findings of the present study are imperative to conclude that sericulture has immense potential in generating livelihood for every section of the society. Though sericulture has always been remained as a subsidiary cottage industry it would be a good option for livelihood opportunity in Assam.

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Conflict of interest

The authors declare that they have no conflict of interest.

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A research study on creation of seed hubs for increasing indigenous production of pulses in India

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ABSTRACT

KVK, Palem, Nagarkurnool district Telangana state was allotted with the seed hub project entitled with Creation of seed hubs for increasing indigenous production of pulses in India. With the project buy back policy KVK was procured 284 quintals of Greengram (WGG 42), 571 quintals of Redgram (PRG 176), 234 quintals of Blackgram (PU 31) and 2.2 quintals of Horsegram (CHRG 19) from the farmers and INR 13, 49,989 was earned by the 51 farmers as additional income from seed production. Total 1,091 quintals of pulses seed was procured by KVK, Palem, during 2016 to 2020. (4years).Seed production was implemented on farmers' fields across different villages of Nagarkurnool and Jogulamba Gadwal districts based on farmers experience in pulse seed production through bye back agreement. These quality seeds covered through our intervention nearly 7,690 hectares, contributing 16 to 18 per cent of total cropped area under cultivation of pulses in Nagarkurnool district. The total gross amount realized from pulses seed production programme in the four years (2016-17, 2017-18, 2018-19 and 2019-20) was INR 1.24 crores. The net profit to KVK, Palem, is INR 41, 92,086. The profit generated out of seed sale has been utilized by Seed-Hub for development of additional facilities/workforce as needed for scaling quality seed production of pulses. It is noteworthy that this programme generated employment opportunities for rural youth, farm workers and farm women as seed production is a skill oriented work. Regular and timely management practices reduce additional expenditure while producing seeds, so that no additional labour and special input costs were incurred. Socio-economic status of the farmers has improved due to generation of additional income through seed production as compared to general cultivation.

Introduction

Between 1965 green revolution period and 2001, the production of pulses has increased negligibly whereas the production of wheat increased greatly. Thus, we can say that the Green Revolution was more successful in increasing the production of wheat as compared to pulses.

Quality seed production is one of the most critical components for ensuring quality seed supply of

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pulses at the doorstep of farmers. Provision of quality seeds is an important step in enhancing the yield and production of pulses. Replacing old varieties from seed chain and farmers' fields remains a major concern among research managers, extension workers and other stakeholders. Realizing importance of quality seed in enhancing productivity of pulses, Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW), Government of India (GOI), approved a special project "Creation of seed hubs for increasing indigenous production of pulses in India" worth INR 225.31 crores during 2016 involving eight ICAR Institutes, 47 centers of All India Coordinated Research Projects (AICRPs) located in State Agricultural Universities (SAUs) and 95 KrishiVigyanKendras (KVKs). The main objective of this project was to ensure supply of quality seed and maintain sustainability with profitability to the farmers locally by developing suitable infrastructure for seed quality enhancement, safe storage and seeds development.

India holds the 1st position in means of production of pulses (it shares the ¼ of world production) (FAOSTAT 2010). Majorly six states are contributing 80 percent of Indian pulses production as well as Area and they are M.P, Maharashtra, U.P, A.P, Karnataka and finally Rajasthan (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2010). In India all vegetarians are meeting their required proteins in diet through pulses only and cereals will compliments the proteins in daily diets, 22-24 percent of proteins holds with vitamins, minerals and amino acids, when we compare this with rice it is three times and two times with wheat, creates the noticeable difference in point of health and pulses are also reduce many diseases like non communicable vize., cardiovascular and cancers related to colon (Yude *et al.,* 1993; (Jukanti *et al.,* 2012).Chickpea has 40 percent production in total pulses than Redgram 18-20 percent, 11%with Greengram, 10-12 percent with Blackgram, and lentil with 8-9 percent and 20 percent with other pulses. According to the advanced estimates population may reach nearly 1.68 billion by 2030 and at present we have 1.21 billion populations. We need to produce 32 million tonnes pulse production by the 2030 with 4.2 percent expected growth rate (IIPR Vision 2030).Good quality seed availability is the fundamental problem to increase the productivity. Actual needed quality seed for pulse production is 33 lakh quintals but 28 lakh quintals only available for replacing rate (Ali *et al.,* 2016). Generally 20-25 percent protein content withholds by pulses and they have the ability to atmospheric nitrogen fixation like ca 30-150 kg/ha creates minimum guaranteed returns and man days for work this is how pulses are making best place in world agriculture (Ali andGupta2012). By the initiation of AICPIP all India coordinated pulse improvement project in the year 1966. With these pulses improvement was intensified (SinghandSingh2016). Many number of high yielders in pulses with all resistance or tolerance to many diseases (Chauhan *et al.,* 2016).

Material and Methods

The seed hub project (12-11/2016-NFSM- Seed Hubs/1492) was allotted to KVK, Palem, during 2016-17 and a one-time grant of INR 50 lakhs was sanctioned in the first year for creating infrastructure such as seed processing plant and storage facility. In addition to this, INR 1 crore has been allocated to the seed hub as revolving fund to meet expenses for production, procurement and processing of seeds. At KVK Palem, the seed production was implemented on farmers' fields across different villages of Nagarkurnool and Jogulamba Gadwal districts.

Farmer Selection

Farmers were selected based on prior experience in pulse seed production and availability of adequate irrigation. The selected farmers were already a part of the seed production programme of Telangana State Seed Development Corporation (TSSDC) and had good knowledge and skills for undertaking quality seed production. Their fields were equipped with appropriate irrigation, infrastructure and assured irrigation.

Farmer Training

Farmers were trained by KVK staff in seed certification procedures *viz.,* online registration, rouging, isolation distance, field inspection, seed processing and geo-tagging. The KVK conducted four on-campus trainings with 110 farmers and training was divided into two sessions for four batches. Two off-campus trainings were conducted with 45 farmers and training was divided into two sessions for two batches in farmers' fields.

Seed Distribution

Subsequently, breeder seeds of different varieties of red gram, green gram and black gram were distributed by the KVK to seed producing farmers for producing foundation seed in farmers' fields. During the last four years (2016-2020), with the support of KVK, Palem, 51 farmers have produced seed.

Field Inspections

Inspections and field visits were organised by scientific staff of KVK, Palem, certification officers and NFSM (National Food Security Mission) consultants during cropping period to create awareness of production technologies of pulses.

Buy Back Policy

Under the buy-back policy, farmers and KVK entered into a Memorandum of Understanding (MoU). The farmers agreed to follow suggestions the KVK makes with respect to seed production including quality, purity, other management practices and sell seeds to the KVK based on the price offered by the University.

Promoting appropriate varieties

Seed production of newly released and high yielding/farmer preferred varieties were taken up as per fixed targets. In Pigeonpea (red gram) production, there has been a consistent demand for wilt resistant, short and medium duration varieties owing to terminal moisture stress usually experienced by the mid-late and late cultivars that were hitherto grown. The recently released Pigeonpea variety, PRG-176 (Ujwala), is a short duration (140 days) variety that suits well in areas where the crop is grown on light red soils under rainfed conditions. Green gram is an important pulse crop predominantly grown in Khammam and Warangal districts of Telangana. With concerted breeding efforts of scientists, the variety WGG- 42 was recently released by PJTSAU, Hyderabad. The variety WGG-42 is an extra early duration (60 days), resistant to yellow mosaic virus, uniform maturity with long pods and shiny bold seeds. Black gram variety PU-31 is highly suitable and popular in the farming communities of Khammam and Mahabubnagar districts.

Results and Discussion

Economic Benefits to the Farmer due to Best Integrated Crop Management Technology

KVK, Palem, procured 284 quintals of green gram (WGG 42), 571 quintals of red gram (PRG 176), 234 quintals of black gram (PU 31) and 2.2 quintals of horse gram (CHRG 19) from the farmers. The details of seeds procured during the four years, 2016-17 to 2019-20, and their procurement price are given below in Table 1. INR 13, 49,989 was earned by the 51 farmers as additional income from seed production. It might be because of good seed bed, soil position and ideal tillage for crop stand establishment it will help in root and shoots development initially. Pulses need deep plough in Kharif then harrowing twice and then planking. Similarly in Rabi season plough, harrowing and planking. One time irrigation may be given if water is available. In zaid season Greengram Crop refuge may be incorporated with the help of deep plough to improve cereal based cropping system it may increases the succeeding crop productivity, income and status of soil (Pooniya *et al.,*2014). Sowing time will play major role in crop development and reduce the biotic and abiotic factors these are all leads to increase in unit area production (Ali *et al.,* 1998). Crop spacing may vary with season, variety, planting method. Narrow spacing will be convenient for early duration pulses while the broad spacing needs the crops which are long in duration for spreading the stature.(Choudhary *et al.,*2014b). According to the weather conditions and crop duration seed requirement may differs. Initially, per meter population decides the seed requirement (Prasad. 2012). Ridge and furrow method of planting gives 25- 30 percent more yields when we compare with flat bed plantings in case pulses in Kharif season (Singh and Singh. 2008 *et al.,* Das *et al.,* 2014). Use of fertilizer in right time, method, and dose will increase use efficiency of fertilizers and mean while it maintains the soil health (Das *et al.,* 2014). India's most pulse crops are under rainfed condition in Kharif season. Pulses needs good drainage facilities they are highly sensitive to the excessive water conditions (Sharma *et al.,* 2005). Fluchloralin used as pre plant incorporation and pendimithalin used as pre emergence herbicide followed by one hand weeding at 30 days after sowing results higher yields in pea at Jabalpur (Madhya Pradesh) (Mishra and Bhan*.,* 1997*).*

Table 1: Details of seeds procured by the KVK from 2016-2020

SN	Crop	Local Market Rate of the seed (Rs./Q)	KVK Procurement Rate (Rs./Q)	Additional Amount by ICM technology (Rs./Q)	Quantity Procured (Q)	Total Additional amount (Rs.) over local rate
2016-17						
1.	Greengram	6,310	7,500	1190	26.4	31,416
2.	Redgram	5,600	6,515	915	216.9	1,98,463
3.	Blackgram	9,100	11,000	1900	28.8	54,720
4	Horsegram	4500	5500	1000	2.2	2200
Total						**2,86,799**
2017-18						
1.	Greengram	5,310	6,515	1205	32	38,560
2.	Redgram	5,700	7,500	1800	129	2,32,200
3.	Blackgram	9,200	11,000	1800	64.76	1,16,568
Total						**3,87,328**
2018-19						
1.	Greengram	6,200	7,500	1300	88.79	1,15,427
2.	Redgram	5,800	7,000	1200	182.70	2,19,240
3.	Blackgram	6,800	7,500	700	133.11	93,177
Total						**4,27,844**
2019-20						
1.	Greengram	7,050	8,300	1250	136.82	1,71,025
2.	Redgram	5,800	7,500	1700	42.14	71,638
3.	Blackgram	6,800	7,500	700	7.65	5,355
Total						**2,48,018**

(Ahmad *et al.,* 1999*)* integrated pest management protocols proved that for controlling the gram pod borer NPV 250 LE per hectare then cypermithrin 0.02 percent with 10 days gap was recorded the significant change in yield when we compared to nuclear poly hydrosis virus then cypermithrin second place. Integrated disease management vize. Crop rotation, solarisation of soil, cultivation of resistant varieties and summer deep plough, fungicide seed treatments like captan, vapam, and use of neem cake 150 kg per hectare to minimize the root rot disease. Arbuscularmycorhyzae will also do the same in pulses disease management. (Kumar *et al.,*2014).As per the (FAO), holistic approach like ICM was developed in recent years to reduce all problems like weed, water, fertilizer, pest and disease management (Varatharajan *et al.,*2019).Proper growth and yield both efficient irrigation and moisture management are essential in pulses. In case of less water availability for legumes, the irrigation water must be applied at critical growth stages using simple irrigation scheduling approaches like IW/CPE ratio as mentioned (Rana *et al,.* 2014).Very recently integrated crop management practices were generated and it was created the good difference as well as relation when we compare to single practice like weed irrigation, soil and biotic factors. Researchers kept many efforts to improve the crop productivity and are also included the soil condition improvement. (Das *et al.,* 2013). It is noteworthy that this programme generated employment opportunities for rural youth, farm workers and farm women as seed production is a skill oriented work. Regular and timely management practices reduce additional expenditure while producing seeds, so that no additional labour

Table 2: Economic benefit to KVK Palem from pulse seed sale.

SN	Material sold	Quantity sold (quintals)	KVK sale Price (Rs/Q)	Gross amount earned (Rs)	Procurement price paid to farmers	Net profit to KVK, Palem
2016-17						
1.	Greengram	26.4	11,000	2,90,400	1,98,000	92,400
2.	Redgram	216.9	11,000	23,85,900	14,13,103	9,72,797
3.	Blackgram	28.8	13,000	3,74,400	3,16,800	57,600
4	Horsegram	2.2	11,000	24,200	12,100	12,100
Total		**274.3**	**-**	**30,74,900**	**19,40,003**	**11,34,897**
2017-18						
1.	Greengram	32	11,000	3,52,000	2,08,480	1,43,520
2.	Redgram	129	11,000	14,19,000	9,67,500	4,51,500
3.	Blackgram	64.76	13,000	8,41,880	7,12,360	1,29,520
Total		**225.76**	**-**	**26,12,880**	**18,88,340**	**7,24,540**
2018-19						
1.	Greengram	88.79	11,000	9,76,690	6,65,925	3,10,765
2.	Redgram	182.70	11,000	20,09,700	12,78,900	7,30,800
3.	Blackgram	133.11	13,000	17,30,430	9,98,325	7,32,105
Total		**404.6**	**-**	**47,16,820**	**15,09,031**	**17,73,670**
2019-20						
1.	Greengram	136.82	11,000	15,05,020.00	11,35,606	3,69,414
2.	Redgram	42.14	11,000	4,63,540.00	3,16,050	1,47,490
3.	Blackgram	7.65	13,000	99,450.00	57,375	42,075
Total		**186.61**	**-**	**20,68,010.00**	**15,09,031**	**5,58,979**

and special input costs were incurred. The buy-back policy of KVK, Palem, has been quite satisfactory for the farmers and 12-18 per cent higher procurement price was paid over prevailing minimum support prices of the government. The additional income earned from seed production helped farmers start other enterprises, thus opening newer avenues for further development for them.

Economic benefit to the KVK, Palem (Institution) due to technology

The quantity of pulse seed produced at KVK, Palem, sold to farmers during the period 2016-2020 and the amount earned by the KVK is given below in table 2. 1091 quintals of seeds of pulses were produced by KVK, Palem during 2016-20. Accordingly, these quality seeds covered acreage of 7,690 ha which is contributing 16 to 18 per cent of total cropped area under cultivation of pulses in Nagarkurnool District. The total gross amount realized from pulse seed production programme in the four years (2016-17,2017-18, 2018-9 and 2019-20) was INR 1.24 crores. The net profit realized to the KVK, Palem is INR 41, 92,086. The profit generated out of seed sale has been utilized by Seed-Hub for development of additional facilities/workforce as needed for scaling quality seed production of pulses.

Impact of the Project from 2016-17 to 2019-20

We have covered almost 7,690 ha area of Nagarkurnool, Mahabubnagar, Narayanpet, Wanaparthy and Jogulamba Gadwal, parts of Nalgonda and Ranga Reddy districts. The total number of farmer beneficiaries is 9,481 (Table 3) who are getting 25-30 per cent higher profits than before. Cultivation of long duration crops like cotton and red gram in rainfed conditions without technical knowledge leads to increased cost of cultivation and reduction in net income. This is a recurring problem faced by farmers of erstwhile Mahabubnagar district, parts of Nalgonda and Ranga Reddy districts. Even in pulses crops (red gram, black gram and green gram) farmers are getting low yields (an average of 4-6 quintals/acre) .

Table 3: Area coverage and number of farmers seed during 2016-17 to 2019-20.

Crop	2016-17		2017-18		2018-19		2019-20		Total Impact	
	Area Covered (Acres)	No. of farmers	Area Covered (Acres)	No of farmers	Area Covered (Acres)	No. of farmers	Area Covered (Acres)	No. of farmers	Area Covered (ha)	No of farmers
Redgram	3615	1807	2150	1075	3045	1523	1456	743	4106	5148
Blackgram	480	240	1079	540	2218	1109	-	-	1511	1889
Greengram	440	220	536	268	1479	740	2313	1202	1907	2430
Horse gram	27	14	0	0	0	0	-	-	11	14
Total	4562	2281	3765	1883	6742	3372	3769	1945	7535	9481

due to lack of availability of quality seeds. Therefore, we introduced our good quality varieties like PRG-176 (Ujwala) in red gram, PU-31 in black gram and WGG-42 (Yadadri) in green gram. In addition, we also provided technical guidance for integrated crop management for these crops. As a result, with all these practices, farmers are now able to produce 7-8 quintals/acre with minimum cost of cultivation.

Conclusion

This programme has attracted several farmers of the district to pulses seed production in a farmer participatory mode not only in their main field but in the marginal land as well, resulting in additional expansion of pulses cultivation over 7,690 ha during last three years (2016-2019). Additionally, productivity of Blackgram (Vigna mungo (L.) Hepper) or urd, Greengram (Vigna radiata (L.) Wilczek) or mung, and Redgram (Cajanus cajan (L.) has increased around 200-300 kg/ha with the implementation of the seed hub project. It has generated year-round two-three fold more income for farmers.

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Conflict of interest

The authors declare that they have no conflict of interest.

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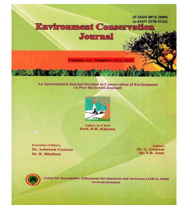

Effectiveness of social media agricultural information on farmer's knowledge

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ABSTRACT

The agriculture research and extension institutes are a major source of agricultural information and they are making full use of all information dissemination methods to bridge the information gap among farmers. Social media platforms are dominating agricultural information dissemination platforms in field level. The present study was conducted to assess the effect of agricultural information disseminated through social media on farmer's knowledge level. The Ex-post facto research design was adopted for the study with a sample of 120 respondents, covering all three erstwhile districts form the Southern Telangana Zone of Telangana state. majority of the respondents had low (75.20%) level of knowledge on agricultural technologies followed by medium (26.67%) and high (0.83%) before intervention to social media. after intervention to social media the respondents had low (51.70%) level of knowledge on agriculture technologies followed medium (42.50%) and high (5.80%). It was found that significant difference existed between the extent of knowledge of respondents before and after use of social media (Z value 8.76). The variables digital literacy, social media usage, information processing, mode of access and preference, and social media participation found to be positive and significant relation with knowledge levels on agriculture technologies at one per cent level of significance. Further variables farm size, social media network and readiness to accept information found to positive and significant at five per cent level of significance.

Introduction

The present age is termed as Information Age, where information is treated as a vital and powerful tool of socio-economic development, no less important than land, labour and capital towards the empowerment of people towards attaining sustainable development. Sustainable development depends on attitude towards information, adjustment for sharing information, and proper consumption of information by the people (Sinha, 2018). ICAR institutes, SAU's, Ministry of Agriculture and Cooperation; GOI, State Departments of Agriculture, Ministry of Rural Development, State Development Departments and Voluntary Organisations are the institutes carrying first line extension work in India. The extension worker to farmer ratio is low in India, which may be one of the main reasons for the delay in reaching the latest farm information to farmers. The gap between information haves and information have-nots is increasing day by day. Not all the information can be delivered to each farmer, because there is a requirement of need-based information. So, the information delivered by extension agents should be need based and it is not

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possible with traditional extension system, as farmers are spread in large areas and are located in distant locations. Traditionally, agricultural information dissemination was dominated by mass media channels *i.e.,* newspapers, radio, television and farm magazines to reach a large number of farmers. The way of communication is changing day by day and the advancement in Information Communication Technologies (ICTs) revolutionised the system of communication. ICTs has potential to facilitate the creation, management, storage, retrieval and dissemination of any relevant data, knowledge and information that may have already been processed and adapted (Batchelor, 2002; Champan and Slaymaker 2002; Heeks, 2002; Rao, 2007). Recent innovations in information technology can deliver agricultural information with high speed to a largenumber of people and with more accuracy (Goyal, 2011). In recent years, however, technology awareness and digital literacy are increasing among farming community in all demographics and various forms of social media are being used more and more by farmers searching for news, education, and other information in day-to-day life for agricultural development.

Social media is one of the latest ICT technologies that revolutionized the way of communication in 21st century. Its usage is inevitable in current decade and the field of agriculture is not an exception. The usage of social media made communication faster, cheaper and imparts timely information to receivers. WhatsApp, Facebook, and YouTube are more familiar at field level among all social media platforms, extension personnel should develop content accordingly in such a way that reach farmers more effectively through these social media platforms (Sandeep *et al.* 2020). The social media platforms like WhatsApp were familiar in field level to connect farmers with other farmers and local extension personnel, the networking platforms like Facebook are familiar in connecting farmers networks and YouTube channels are disseminating large amount the farm information in video format to benefit farm community. Social networking was found effective in creating knowledge (Nain *et al.,* 2019). Farmers perceived that the information available or received through social media platforms as effective and useful to them in adopting best agricultural practices (Sandeep *et al.* 2022). With this brief background the research study is taken with objective to study the effectiveness of agricultural information disseminated through social media platforms in terms of extent of knowledge on agricultural technologies disseminated through selective social media platforms.

Material and Methods

Ex-post-facto research design was adopted for the investigation and the Southern Telangana Zone (STZ) was selected purposively based on the teledensity and pre-research visit. All three districts of the Southern Telangana Zone were selected purposively for the study. All three viz., Mahaboobnagar, Nalgonda and Rangareddy (Erstwhile districts) were selected for the study. Two mandals form each district were selected randomly and two villages from each mandal selected by using simple random sampling procedure. From each village, ten farmers were selected purposively based on status of having active accounts in selected social media platforms (YouTube, Facebook and WhatsApp) for last three years. Thus, total sample constitutes the sample size of one hundred and twenty (120) farmers. Knowledge is generally understood as an intimate acquittance of an individual with facts. Knowledge is a body of understood information possessed by an individual or by culture. Knowledge is one that plays an important role in the covert and overt behavior of an individual. (English and English). In the present study, extent of knowledge was operationalised as the degree of production technologies of agriculture (crop production, crop protection, agriculture marketing, climate resilient agriculture, post-harvest management and government policies) known to respondents using social media as a source for agriculture information source. The extent of knowledge level data was collected with help of personnel interview. The respondents were categorized into three categories as low, medium and high by their respective percentage of the score. Based on the scores obtained on 35 items of five different categories of agricultural production, technologies knowledge percentages (Obtained score / Total score X 100) were calculated and ranks were given accordingly. The primary data was collected from the farmers using social media as source of agricultural information and appropriate statistical methods like data classification, frequency, and correlation used for data analysis.

Results and Discussion

Distribution of respondents based on their extent of knowledge on agriculture technologies: From the table 1 and figure 1 it can be observed that the majority of the respondent's level of extent of knowledge before intervention to social media was found to be low (72.50%) followed by medium (26.67%) and high (0.83). Whereas the majority (51.70%) of the respondents had low level of extent of knowledge followed by medium (42.50%) and high (5.80%) after intervention to social media.

Difference between extent of knowledge of respondents before and after intervention to social media:
It was evident form the table 2 that calculated 'Z' value (8.76) was greater that the table 'Z' value at 0.01 level of probability. Hence it could be concluded that there exists a difference between extent of knowledge on agriculture technologies before and after intervention to social media platforms. It can be depicted that farmers using social media gained knowledge on agriculture technologies by using social media. Approximately similar trend were observed by Kumar and Padmaiah (2012), Kumar (2014) and Madan (2017).

Table 1: Distribution of respondents according to their extent of knowledge

SN	Extent of knowledge	Before intervention (n = 120)		After intervention (n = 120)	
		F	%	F	%
1.	Low (Up to 33.33%)	87	72.50	62	51.70
2.	Medium (33.33 - 66.66%)	32	26.67	51	42.50
3.	High (Above 66.66%)	1	0.83	7	5.80
Total		120	100.00	120	100.00

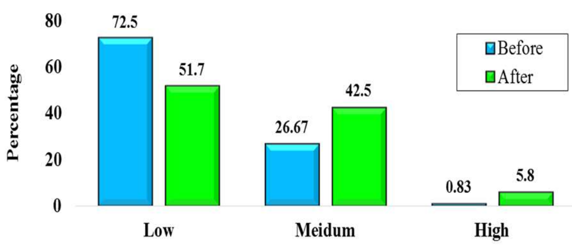

Figure 1: Distribution of respondents according to their extent of knowledge

Table 2: Difference between extent of knowledge of respondents before and after intervention to social media (n = 120)

SN	Category	Size of sample	Mean	S.D.	'Z' Value
1.	After intervention	120	60.39	9.05	8.76**
2.	Before intervention	120	49.96	9.40	

****Significant at 0.01 level of probability.**

Distribution of respondents according to their extent of knowledge in each category before intervention to social media: To ascertain the extent of knowledge possessed by respondents' extent of knowledge is divided into five categories.In each category the respondents were grouped into low, medium and high levels of extent of knowledge groups based on the percentages in each group by using class interval technique. The analyzed data contained in table 3 and figure 2 revealed that, (50.84%) of the respondents had medium level knowledge on production technologies and practices followed by low level (48.33%) and high (0.83%). Knowledge percentage attained was 35.21, hence this category was accorded first position in order. The results further indicates that (65.00%) of the respondents had low level knowledge on post-harvest, schemes and modern concepts followed by medium

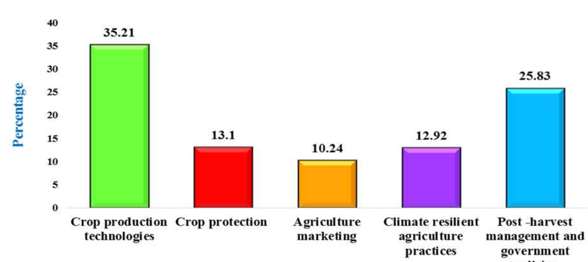

Figure 2 : Knowledge percentages on agricultural technologies of respondents before intervention to social media

Table 3: Distribution of respondents according to their extent of knowledge before intervention to social media (n = 120)

SN	Categories	Groups	C.I.	F	%	Knowledge percentage	Rank
1.	Crop Production technologies (Items-10)	Low	< 33.33%	58	48.33	35.21	I
		Medium	33.33-66.66%	61	50.84		
		High	>66.66%	1	00.83		
2.	Crop protection (Items-7)	Low	<33.33%	96	80.00	13.10	III
		Medium	33.33-66.66%	24	20.00		
		High	> 66.66%	00	00.00		
3.	Agriculture marketing (Items-7)	Low	<33.33%	101	84.20	10.24	V
		Medium	33.33-66.66%	19	15.80		
		High	>66.66%	00	00.00		
4.	Climate resilient agriculture practices (Items-4)	Low	<33.33%	103	85.84	12.92	IV
		Medium	33.33-66.66%	16	13.33		
		High	>66.66%	1	00.83		
5.	Post-harvest management and government policies (Items-7)	Low	<33.33%	78	65.00	25.83	II
		Medium	33.33-66.66%	41	34.17		
		High	>66.66%	1	00.83		

(34.17%) and high (0.83%). The knowledge percentage attained was 25.83, hence this category was accorded second position. Regarding the protection technologies and practices, it was observed that (80.00%) of respondents have low level of extent of knowledge followed by medium (20.00%). Knowledge percentage obtained was 13.10 and hence this category was ranked third position in order. Regarding the extent of knowledge on climate resilient agriculture technologies and practices, it was observed that majority (85.84%) of respondents had low level of knowledge followed by medium (13.33%) and high (0.83%) The obtained knowledge percentage was 12.92, hence this category was accorded with fourth position. The study further indicated that (84.20%) of the respondents had low knowledge on agriculture market followed by medium (15.80%). The knowledge percentage obtained was 10.24, hence this category was accorded fifth position in order. It can therefore, be concluded that nearly three by fourth of the respondents had low level of the extent of knowledge and one by fourth had medium level before intervention to social media. The possible reason could be that majority of the respondents were young and had low farming experience.

Distribution of respondents according to their extent of knowledge in each category after intervention to social media: The analyzed data contained in table 4 and figure 3 indicates that 72.50 per cent of the respondents had medium level knowledge on post-harvest, schemes and modern concepts followed by low (25.00%) and high (2.50%). The more or less similar medium level knowledge category with majority of respondents were reported by Azad *et al.* (2014). The knowledge percentage attained was 43.69, hence this category was accorded first position. The study further revealed that, 85.00 per cent of the respondents has medium level knowledge on production technologies and practices followed by low level (11.70%) and high (3.30%). Knowledge percentage attained was 42.50, hence this category was accorded second position in order. Regarding the protection technologies and practices, it was observed that 58.40 per cent of respondents have low level of extent of knowledge followed by medium (35.80%) and high (5.80%). A more or less similar kind of trend was observe by Oztas *et al.* (2018). Knowledge percentage obtained was (35.24%) and hence this category was ranked third position in order. Regarding the extent of knowledge on climate resilient agriculture technologies and practices, it was observed that majority (67.50%) of respondents had low level of knowledge followed by medium (29.20%) and high (3.30%). Similar tend of results were observed by Niranjan *et al.* (2018). The obtained knowledge percentage was 26.98, hence this category was accorded with fourth position. The study further indicated that 70.00 per cent of the respondents had low knowledge on agriculture market followed by medium (28.30%) and high (1.70%).

Table 4: Distribution of respondents according to their extent of knowledge after intervention to social media (n=120)

SN	Categories	Groups	C.I.	F	%	Knowledge percentage	Rank
1.	Crop Production technologies (Items-10)	Low	< 33.33%	14	11.70	42.50%	II
		Medium	33.33-66.66%	99	85.00		
		High	>66.66%	4	3.30		
2.	Crop protection (Items-7)	Low	Below 33.33%	70	58.40	35.24%	III
		Medium	33.33-66.66%	43	35.80		
		High	> 66.66%	7	5.80		
3.	Agriculture marketing (Items-7)	Low	<33.33%	84	70.00	26.31%	V
		Medium	33.33-66.66%	34	28.30		
		High	>66.66%	2	1.70		
4.	Climate resilient agriculture practices (Items-4)	Low	<33.33%	81	67.50	26.98%	IV
		Medium	33.33-66.66%	35	29.20		
		High	>66.66%	4	3.30		
5.	Post-harvest management and government policies (Items-7)	Low	<33.33%	30	25.00	43.69%	I
		Medium	33.33-66.66%	87	72.50		
		High	>66.66%	3	2.50		

The knowledge percentage obtained was 26.31, hence this category was accorded fifth position in order. It can be therefore, concluded that nearly half of the respondents had medium to high level knowledge and rest half had low extent of knowledge after intervention to social media.

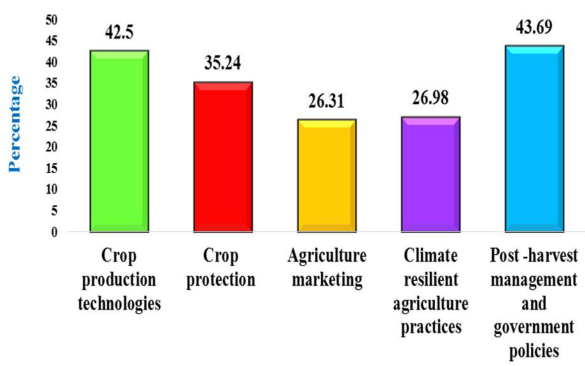

Figure 3 : Knowledge percentages on agricultural technologies of respondents after intervention to social media.

Relationship between the profile characteristics of farmers and extent of knowledge

It is revealed from the Table 5. that calculated 'r' values between digital literacy, social media usage, information processing, mode of access and preference, social media participation and the extent of knowledge were greater than table 'r' value at 0.01 level of significance. Whereas, the calculated 'r' value of the variables farm size, social media network and readiness to accept information was greater than 'r' value at 0.05 level of significance.

Therefore, it can be concluded that there is a positive and significant difference between extent of knowledge of farmers using social media and the independent variables like digital literacy, farm size, social media network, social media usage, information processing, mode of access and preference, readiness to accept information and social media participation. On other hand calculated 'r' values between age, farming experience and extent of knowledge of farmers using social media were less than the 'r' table value. Therefore, it can be concluded that there is non-significant relationship between age, farming experience and extent of knowledge of farmers using social media. The observed relationship of age with extent of knowledge might be due to the experience gained by the middle and old age people over the years and on other side it could not acquire significant knowledge due to their decreasing recalling ability as individual getting old. The probable reason for this kind of result for variable farming experience may be due to knowledge increase with experience and but not at significant level due to usage of social media is equal among all groups of farmers irrespective of their experience in farming.

Table 5: Relationship between the profile characteristics of farmers and extent of knowledge (n = 120)

SN	Profile characteristics	Correlation coefficient (r)
1	Age	0.027 NS
2	Digital literacy	0.408**
3	Farming experience	0.037 NS
4	Farm size	0.211*
5	Social media network	0.187*
6	Social media usage	0.300**
7	Information processing	0.367**
8	Mode of access and preference	0.345**
9	Readiness to accept information	0.210*
10	Social media participation	0.315**

Significant at 0.0l level ***Significant at 0.05 level***
NS = non-significant

A more or less similar trend was observed by Singh (2017). Regarding the variable digital literacy, it enhances extent of knowledge of the farmers as this helps to acquire latest information on new technologies form different digital platforms. Positive and significant relation was found between the variable farm size and extent of knowledge of farmers using social media. Similar observation was reported by Singha and Devi (2013) and Rahman *et al.* (2016). This can be justified based on fact larger land holding will have more opportunities and potentialities to gain more information and learn about a greater number of technologies related to agriculture. The probable reason for positive and significant relation between social media network and extent of knowledge, may be based on reason that the farmer with high social media network connectivity have more chances of getting information from different sources, which in turn help in acquiring knowledge on different agriculture practices. The variable social media usage has showed positive and significant relation with extent of knowledge, the probable reason for this result is based on fact that more usage of social media acts as a driving force to acquire new formation from different sources from social media platforms. The results are in agreement with Adejo *et al.* (2013). Information processing showed positive and significant relationship with extent of knowledge. The probable reason for this result is based on fact that better information preservation and evaluation result in better knowledge acquisition. Better access towards social media platforms and preference helps in getting access to agricultural information available on social media and which influence the knowledge level of individuals. The same phenomenon was reflected in the study and positive significant relation was found. The variable readiness to accept information was found significant and positive with extent of knowledge. It is quite obvious that an individual who is willing to accept information has better chances to explore and receive more information through different channels, which directly influences the knowledge acquisition. The participation of an individual will help him or her in better learning. Similar phenomenon was observed in this study, social media participation had positive and significant relationship with knowledge of respondents.

Conclusion

The research result proved that there is a significant difference (Z value 8.76**) in knowledge levels among farmers when compared before and after intervention to social media. Hence it can be recommended that extension system can consider social media platforms as potential tools in disseminating the agricultural information. It also suggested that there is a need of research in content analysis of videos, text, image and audio format of information and to suggest optimum guidelines in developing content in social media platforms. The results also showed a trend of low and medium level among farmers in overall agricultural production technologies. The knowledge levels among farmers on agricultural marketing (26.31 per cent), climate resilient agricultural practices (26.98 per cent) and crop protection (35.24 per cent) were found to be ranked low. From these results it is recommended that more focus should be given on disseminating MSP of different agricultural crops, availability of agriculture inputs and market news for better fetching of price for the produce. Provision of more local weather information in relation to pest and disease incidence, selective plant protection practices with accurate dosage of application, and information on the advantage of soil test-based application to farmers will help in better overall management so as to produce optimum yield from the field. It also recommended that social media platforms should also be used to collect feedback and to identify the knowledge gaps among the farmers. With the results of above research, it is recommended that the social media tools can be used as the medium in disseminating the agricultural information to farming community.

Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of various soil health indicators on rice productivity in old alluvium of Bihar: A correlation study

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ABSTRACT

Conventional method of rice-wheat cropping system leads to deteriorate soil health drastically day by day. An appropriate idea of particular soil health indicator that effects soil health directly should be known to make the crop productivity high. In order to determine the direct and indirect associations among various soil health properties with rice yield in rice-wheat cropping system a survey was done in farmer's field. Overall 100 soil samples were collected randomly from 100 farmer's field and studied to find out the soil health. Soil chemical properties (pH, EC, SOC, Avl. N, Avl. P_2O_5, Avl. K_20), Soil physical properties (sand, silt, clay and Available water capacity) and soil biological properties (active carbon, soil respiration and autoclaved citrate extractable protein) were studied to find out the principal indicator for soil health that effects directly to rice yield. The study revealed that mainly soil organic carbon effects rice yield directly along with clay content of soil and soil respiration. Soil microbial activity is also very important in order to achieve good rice yield and positive correlated soil respiration value is evidence of it. Thus the results suggest that farmers should focus on enhancing soil organic carbon and microbial activity by means of soil respiration with best sustainable management practices in order to achieve higher productivity of rice.

Introduction

Unbalanced fertiliser application causes yield stagnation and soil health degradation (Surekha *et al.,* 2013). The soil system regulates plant growth in terrestrial ecosystem (Nath *et al.,* 2021; 2022) Nutrient balance is one of the most critical variables in enhancing crop yield. Nutrient mining from the soil has come from excessive and imbalanced fertiliser use. Organics, as well as organic and inorganic mixes, replenish vital nutrients, which has a direct impact on soil health and crop productivity (Kumar *et al.,* 2015). On the other hand, due to various current production system practises, such as the indiscriminate use of chemical fertilisers and pesticides, the rotational farming of rice and wheat is facing a sustainability challenge (Prasad *et al.,* 2010). The impacts of agrochemicals on soil structure, microbiota, food, and fodder are all plainly detrimental. The current rice-wheat farming method has raised concerns about lower factor productivity, soil organic carbon depletion, and mineral nutrient depletion (Yadav, 2008). Long-term fertiliser trials are essential for determining changes in crop physical, chemical, and microbiological features, as well as crop production. Continuous application of manures and fertilisers for a long time causes quantifiable changes in soil properties. Rice nutrient management is crucial for long-term crop viability.

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Following the 1960s, Indian agriculture made significant progress. The success of agricultural output has been attributed to the widespread use of high yielding cultivars. The cornerstone in the change of Indian agriculture from subsistence to excess has been fertiliser, among other inputs. Rice yield is a complex trait that is influenced by a number of soil parameter variables. A effective selection requires knowledge of genetic diversity and the relationship between soil parameters variables and grain production. At the moment, agriculture's top objective is to prevent future crop output and soil health decreases (Bhatt *et al.,* 2019). In agriculture, the phrase soil quality refers to the soil's ability to sustain crop development without degrading. It is a vital component of sustainable agriculture and consists of a combination of physical, chemical, and biological properties that allow the soil to perform a variety of functions (Dwivedi and Thakur, 2000). Using Pearson's correlation coefficient analysis, this study attempted to investigate the influence of various soil properties on rice yield and some physical, chemical, and biological aspects of soil.

Material and Methods

Brief description about study area

A total of 100 GPS based soil samples were collected from Rohtas. The latitude and longitude of the district is 24˚30' - 25 ˚ 25' (N) and 83˚45' - 84˚22' (E) respectively. Agro-climatic zone is South Bihar Alluvial Plain Zone (III-B). Soils are old alluvium with slight reddish to yellow in colour. Net sown area is 231.8 thousands ha along with 155.7 thousands ha area sown more than once.The electrical conductivity and soil pH was tested in 1:2 soil-water extract (Jackson, 1967)." Soil texture was determined using the Comprehensive Assessment of Soil Health (Kettler *et al.,* 2001) and available water capacity (Reynolds *et al*., 2008). Soil Organic C was determined using Rapid titration method (Walkley and Black; 1934). Available N was Alkaline permanganate method (Subbiah and Asija, 1956) used to determine Available N. Available P was determined following Watanabe and Olsen's method (1965). Available Potassium was determined using Jackson (1958) described using a flame photometer to assess the potassium content of the extract. Available S was determined turbidimetrically (Chesnin and Yien, 1950).Available micronutrient cations (Cu, Zn, Fe, Mn) determined using DTPA (Diethylene triamine penta-acetic acid) extracting solution (Lindsay and Norvell, 1978). Soluble B method (Berger and Troug,1939) was used to know the bio-availability of B in soil. Among soil biological properties, Active C was determined following Comprehensive Assessment of Soil Health (Stiles *et al.,* 2011); ACE protein were extracted using a method modified from Wright and Upadhyaya (1998) and soil respiration following Haney and Haney (2010).

Statistical analysis

For the statistical analysis of the data, SPSS Windows version 20.0 (SPSS Inc., Chicago, IL, USA) was used (Pearson's correlations and coefficient of determination (R^2).

Results and Discussion

Table 1 shows the relationship between soil chemical parameters and rice yield, indicating that SOC (0.853**), Avl. N (0.050), Avl. P_2O_5 (0.056), Avl. K_2O (0.022) were positively and significantly associated with rice yield, whereas pH (-0.245*), EC(-0.013) were negatively associated with rice yield. The highest value was recorded in SOC (0.853**) for rice yield (Table 1) while the minimum value was shown in pH and EC (-0.245** and - 0.013**). However, SOC had a positive correlation with P_2O_5 (0.217). SOC improves soil organic matter in soil as a result it makes chelation with P_2O_5, hence availability increases. Soil organic carbon and rice yield (t/ha) shows a positive trend (R^2=0.93) along with soil organic matter too (Fig. 1). Also as Organic acids were formed during the degradation of organic matters, reducing the pH of the soil. Similarly, the decrease in electrical conductivity might be due to the creation of different organic acids during the breakdown process, which solubilized the salt and allowed it to be leached down by irrigation. The increase in soil SOC was due to the crop residue incorporation along with application of organic manure and a greater amount of crop waste (Bellakki *et al.,* 1998). The soil system regulates plant growth in terrestrial ecosystem (Nath *et al.,* 2021; 2022). Kumar *et al.,* 2015 observed that organic carbon and agricultural yield had a positive association. This might be attributed to a change in the physical

Table 1. Correlation studies of rice yield with physico-chemical properties of soil

	pH	EC	SOC	Avl. N	Avl. P_2O_5	Avl. K_2O	Rice yield (t/ha)
pH	1						
EC	0.492**	1					
SOC	-0.078	0.233*	1				
Avl. N	0.236*	-0.093	0.630**	1			
Avl. P_2O_5	0.025	-0.099	0.217	0.100	1		
Avl. K_2O	0.360**	0.343**	0.407**	0.111	0.011	1	
Rice yield	-0.245*	-0.013	0.853**	0.750**	0.256*	0.322*	1

****. Correlation is significant at the 0.01 level (2-tailed).**
***. Correlation is significant at the 0.05 level (2-tailed).**

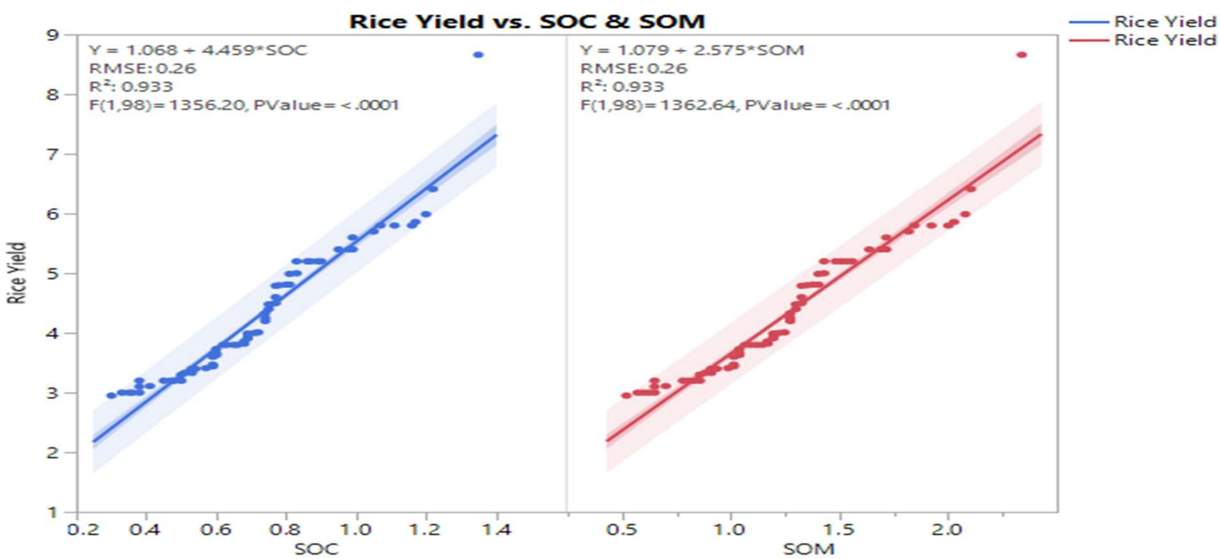

Figure 1: Variation of rice yield (t/ha) with soil organic carbon (SOC) and soil organic matter (SOM).

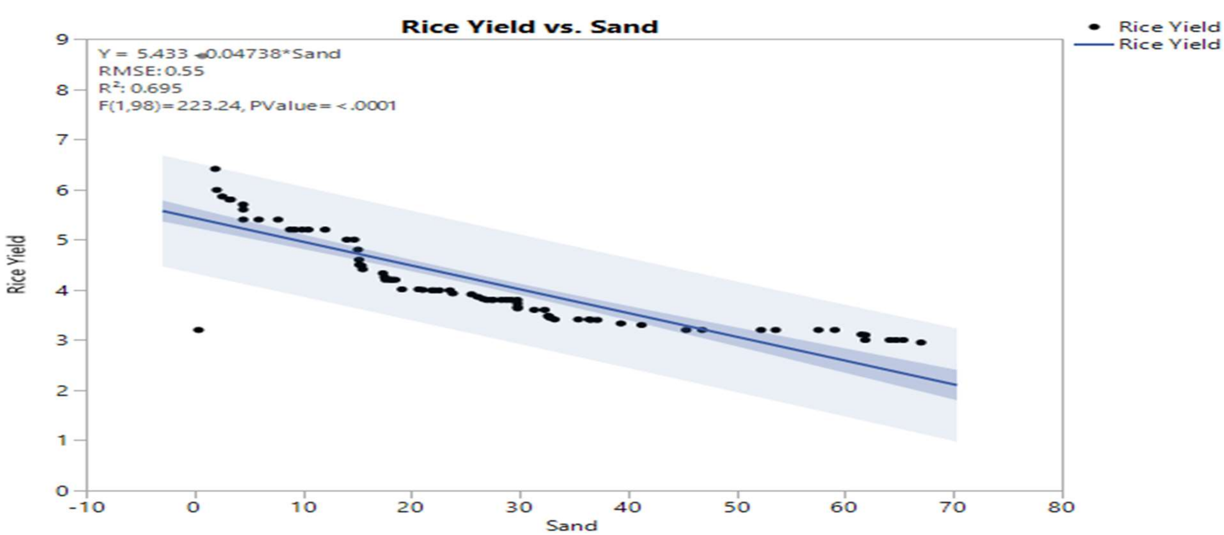

Figure 2: Variation of rice yield (t/ha) with sand (%) in old alluvium.

environment of the soil as a result of the combined application of compost, crop debris, and chemical fertiliser, which increased productivity (Chaudhary and Thakur, 2007). Kumari *et al.,* 2022 also observed that SOCstock can be tremendously increased with water aggregate stability and clay content of alluvial soils of Bihar as a result productivity of crop is in increasing trend. Except for sand content, which had a negative relationship with yields, the findings showed that other physical properties of soil were positively and substantially linked to rice yield (Table 2 and Fig.2.) Sand content in soil results in less water holding capacity and also less nutrient content along with less soil organic matter content leads to less rice yield. Also the R^2 value in the correlation graph is 0.69 which shows that there is a positive trend with sand and reducing yield. Sand (-0.219*) had the lowest value whereas silt (0.201*) had the highest value in rice yield. Clay and available water capacity (AWC) had also positive correlation with yield.

Table 2 also shows the correlation coefficients of several biological properties associated with rice productivity. All biological metrics, namely active carbon, soil respiration, and protein, were shown to be positively and strongly linked with rice yield. Under rice yield, the ACE protein (autoclaved citrate extractable protein) content had the highest value (0.107) while the soil respiration and active carbon had the lowest value (0.099 and 0.019) (Table. 3). The crop residue incorporation along with use of organic manure may enriched microbial proliferation (Singh *et al.,* 2019). As a consequence, integrated fertilisation modifies the soil's organic material content, resulting in increased crop yield. Because of improvements in soil physical, chemical, and biological properties, the combined use of chemical fertilisers and organic manure may have increased SOC apart from soil organic matter enrichment, which increased rice yield (Thakur *et al.,* 2011).

Table 2: Correlation studies of Rice yield with soil physical properties

	Sand (%)	**Silt (%)**	**Clay (%)**	**AWC (%)**	**Rice yield (t/ha)**
Sand (%)	1				
Silt (%)	-0.878**	1			
Clay (%)	-0.130	0.360**	1		
AWC (%)	-0.147	0.205**	0.138	1	
Rice yield (t/ha)	-0.219**	0.201*	0.219*	0.212*	1

****. Correlation is significant at the 0.01 level (2-tailed).**
***. Correlation is significant at the 0.05 level (2-tailed).**

Table 3: Correlation studies of Rice yield with soil biological properties

	Active C (mg/kg)	**Soil Respiration ($mgCO_2/g$)**	**ACE Protein (g/kg)**	**Rice yield (t/ha)**
Active Carbon (mg/kg)	1			
Soil Respiration ($mgCO_2/g$)	0.254**	1		
ACE Protein (g/kg)	0.200*	0.810**	1	
Rice yield (t/ha)	0.019	0.299**	0.107	1

****. Correlation is significant at the 0.01 level (2-tailed).**
***. Correlation is significant at the 0.05 level (2-tailed).**

Conclusion

The study revealed that soil organic carbon (SOC) is the principal component that effects rice yield directly along with clay content of soil and soil respiration. SOC was much higher in soils with the sand (%). The main influential factors on rice yield were SOC, clay (%) and soil respiration in the soil, according to correlation analysis. Soil microbial activity is also very important in order to achieve good rice yield and positive correlated soil respiration value is evidence of it. Thus, the results suggest that farmers should focus on enhancing soil organic carbon (SOC) along with soil organic matter (SOM) with various sustainable management practices, as SOC coupled with SOM will leads to higher productivity of rice. Future studies should focus on the primary reasons of SOC sequestration in old alluvium of Bihar 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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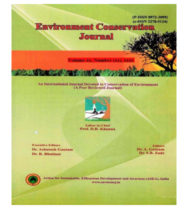

Effects of different aqueous extraction techniques on physicochemical quality and oil recovery of sesame oil

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ABSTRACT

Sesame is the oldest oilseed crop in agriculture, and it produces more oil than any other crop on the planet. This research aimed to investigate the impact of different oil extraction procedures on sesame seed oil physicochemical quality and oil recovery. The oil was extracted from the clean and healthy seeds using four extraction methods: aqueous, enzyme-assisted aqueous, ultrasound-assisted aqueous and solvent extraction using the Soxhlet apparatus. It was observed that ultrasound-assisted aqueous extracted oil had maximum saponification value and minimum acid value, refractive index, and lower free fatty acid value, compared with aqueous extracted oil and enzyme-assisted aqueous extracted oil. Ultrasound-assisted aqueous extraction method also yielded maximum oil, retrieval followed by enzyme-assisted aqueous extraction and aqueous extraction.

Introduction

Food and bio-fuel industries rely on oil extraction from oil-bearing crops and materials. The vegetable oil industry's most common oil extraction process is solvent extraction. Vegetable oil producers have been seeking new ways to improve the efficiency of their extraction operations to reduce production costs and waste. Sesame oil extraction using ultrasound-assisted aqueous which has the calibre to exchange the solvent extraction. The findings demonstrate that the physicochemical quality of sesame oil extracted using an ultrasound-assisted aqueous technique was equivalent to that of oil extracted using an enzyme-assisted aqueous method. Annual flower plant sesame is the oldest oilseed crop in agriculture and the most geriatric crop known to mankind. Sesame (*Sesamum indicum*) is a widespread and famous crop which is known by the local names as til or gingely or sim sim or ellu. Sesame is cultivated in tropical and subtropical areas of 3 different continents like Asia, Africa, and South America in the summer Kharif and semi-rabi seasons (Berhe Gebremedhn *et al.*, 2017). Sesame seed is available in different color like white, black, and yellow vary with the variety of seeds that grows for cultivation. Sesame is a premium oil known for its high nutritional value, economical value, and medicinal properties due to its oil composition and oil content in sesame seeds vary between 45-60% (Pathak *et al.*, 2014),which is high amount than the other oil-producing crops in the world. In 2019, Sudan, Myanmar, India, Tanzania, and China were the leading producers of sesame crops, harvesting over 5.0 million metric tonnes of sesame seeds from an aggregate of 9.6

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million hectares (Anonymous, 2021a). India is the world's third-largest producer of sesame oilseeds, and the industry plays a significant role in the agricultural economy. India's total sesame acreage was 1.6 million hectares in 2019-20, with a total output of 0.69 million metric tonnes (Anonymous, 2021a). In India, the sesame crop is majorly cultivated in West Bengal, Andhra Pradesh, Gujrat, Tamil Nadu, Telangana, Punjab, Madhya Pradesh, and Maharashtra. In Punjab, the total area under sesame was 2.6 thousand hectares and total production was 0.1 million metric tons (Anonymous, 2021b). Sesame seeds are a chain of nutritional benefits such as fibre, minerals, protein, vitamins, carbohydrates, fats, fatty acids, etc. With these several health benefits, sesame is used in making pharmaceuticals, cosmetics, perfumes, bath oil, snacks, and beverages. Sesame seeds are used to prepare and garnish various Indian sweets, baking products, and dishes that act as a flavouring agent. In north India, it is used in different forms like seeds, oil, paste, flour, and so on. Oil extraction from seeds is a crucial component in the commercialization of these products. The extraction technique directly influences the amount and quality of protein and oils produced. Cold pressing, mechanical screw pressing, solvent, supercritical fluid, and aqueous extraction are all ways of extracting oilseeds (Çakaloğlu *et al.*, 2018). The most frequently used method of extracting oil from oilseeds is mechanical screw pressing. About 90% of the total oilseeds produced in India are crushed using this method. The use of heat and pressure to extract oil from seeds is known as mechanical extraction. In India, however, mechanical screw presses (oil expellers) are inefficient, leaving 8 to 14 percent of the remaining oil in the cake. Several scholars have undertaken research on increasing oilseed oil recovery (Boutin & Badens, 2009). Solvents for oil recovery have numerous downsides, including significant safety risk, high energy input, low-quality oil, environmental danger, toxicological consequences, and low-quality food (Chemat *et al.*, 2019).

The growing trend of avoiding hazardous organic solvents has rekindled interest in alternate extraction methods. Although the oil yield was poor, aqueous oil extraction has emerged as a viable approach for oil extraction. This procedure is determined to be the most acceptable option for solvent extraction. Enzymatic pre-treatment has recently developed as a unique and effective method of improving oil recovery. Several scientists have investigated the use of enzymes in oil extraction (Abdulkarim *et al.*, 2005). In the oil extraction process, enzymes are primarily used to hydrolyze the structured polysaccharides present in the cell wall. When compared to hexane extracted oils, the quality of the oil produced by enzyme treatment is rather excellent (Jeevan Kumar *et al.*, 2017). Considering the use of benefits of alternative extraction techniques for extraction of oils. The study aimed to evaluate the effect of different extraction methods on the oil recovery and the physicochemical quality of sesame seed oil.

Material and Methods

The sesame seeds were procured from a local farmer from Jalandhar, Punjab, India. The cleaning was done with the help of a sieve shaker. Clean and healthy seeds were selected for the extraction of oil. The experimentation was conducted in the various laboratories of the SGTB Khalsa College, Shri Anandpur Sahib, Punjab, India. Figure 1 shows the flowchart of extraction of oil from sesame seeds.

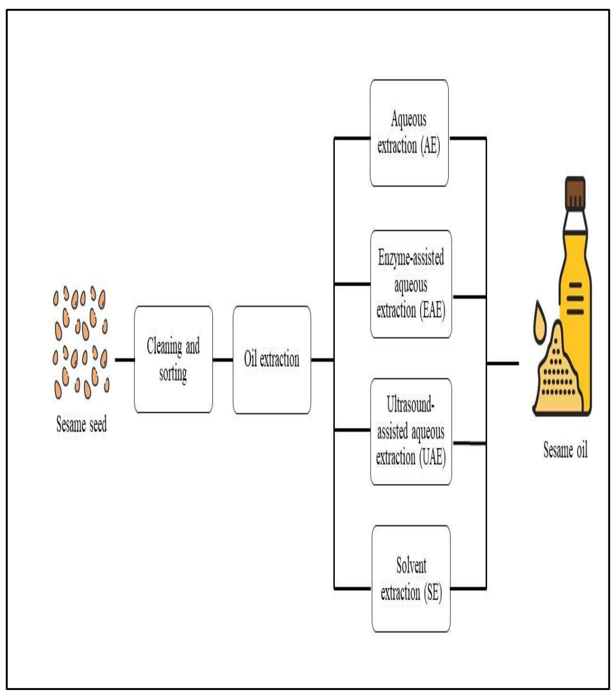

Figure 1: Process flowchart for extraction of sesame oil using different aqueous methods

Oil extraction methods

Aqueous extraction (AE)

240 ml of distilled water was combined with 40 g of seed sample. 0.5 N NaOH and 0.5 N HCl were used to adjust the pH of the mixture to 5. Grind the mixture with a high-speed grinder (Tandem 10 W) for 20 minutes in a hot water bath. “Churn” the mix in a rotating water bath at 65ºC for 20 hours, with tubes shaking horizontally at 160 rpm. Allow tubes to cool for 30-60 minutes at room temperature. In a centrifuge, spin for 15 minutes. Using a pipette, remove the top oil layer. To eliminate the remaining water, the oil was put in a 70ºC oven for 30 minutes (Moreau *et al.*, 2004).

Enzyme-assisted aqueous extraction (EAE)

40 g dry seed samples and 240 ml buffer were placed in Borosil tubes with a capacity of 300 ml (0.05 M Na acetate, pH 4.0). In a food processor, the ingredients were ground for a minute at high speed (make Tandem 10 W). Cellulase enzyme was added at a dosage of 0.025 percent (w/w). Churning was done in a shaking water bath for 4 hours at 50 degrees Celsius, with tubes shaking horizontally at 160 rotations per minute. Churning for another 16 hours at 65°C in a revolving water bath with tubes rotating horizontally at 160 rpm. Tubes were allowed to cool for 30-60 minutes at room temperature. After that, the samples were centrifuged for 15 minutes in a hot centrifuge. The top oil layer was scraped with a pipette to remove any remaining water, and the oil was then baked for 30 minutes at 70°C (Moreau *et al.*, 2004).

Ultrasound-assisted aqueous extraction (UAE)

For ultrasound preparation, an ultrasonic cleaning bath was employed. 40 g crushed dry material was combined with 240 ml distilled water. The pretreatment with ultrasound lasted 60 minutes. 0.5 N NaOH and 0.5 N HCl were used to adjust the pH of the solution to 5. The mixture was incubated at 60°C for 2 hours. After incubation, the mixture was spun in a hot centrifuge for 15 minutes at 3000 rpm using centrifuge equipment. In a hot water bath, mill the mixture for 20 minutes using a high-speed grinder (Tandem 10 W). "Churn" the mixture for 20 hours at 65°C with tubes shaking horizontally at 160 rpm in a spinning water bat. Allow tubes to cool at room temperature for 30-60 minutes. Spin for 15 minutes in a centrifuge. A pipette was used to remove the top oil layer. The oil was kept in the oven for 30 minutes at 70°C to remove any leftover water (Khoei & Chekin, 2016).

Solvent extraction (SE)

In the soxhlet extractor, the 40 g powdered seed sample was placed in a thimble composed of thick filter paper and fed into the main chamber. The Soxhlet extractor was placed on top with the extraction solvent in a distillation flask. The apparatus was then fitted with a condenser. The solvent was then heated to boiling point. A distillation arm raised solvent vapour, which rose into the solid thimble chamber. In the condenser, the solvent vapour cooled and fell back into the chamber containing the solid substance. The solid material was gradually poured into the compartment containing the warm solvent. The heated solvent caused some of the desired chemicals to dissolve. A syphon side arm automatically emptied the Soxhlet chamber when it was nearly full, returning the solvent to the distillation flask. In this way, the thimble ensured that no solid materials were carried into the still pot by the quick velocity of the solvent. The cycle was repeated several times over the course of several hours. A portion of the nonvolatile component is dissolved in the solvent during each process**.** Many cycles of distillation were required to concentrate the required component in the flask. A liquid or solid phase is extracted by transferring its components to another liquid phase. The extraction process takes advantage of differences in the solubility of components. Extracting a solute from a liquid solution involves contacting it with another liquid solvent that is somewhat miscible with the solution (liquid-liquid extraction or solvent extraction). Solvents are liquids that are added to a solution to allow it to be extracted. A solvent layer is called extract, and a raffinate layer is called raffinate.

Physico-chemical properties of sesame oil

Different physicochemical properties of extracted sesame oil viz., refractive index, acid value, saponification value, and free fatty acid were determined using standard methods as discussed below:

Refractive index

For the determination of the Refractive Index, Abbe's Refractometer was used (AOAC, 2000).

Saponification value

The saponification value is defined as the amount of potassium hydroxide needed to saponify one gram of oil (AOAC, 2000). 1.5 g of oil was placed in a flask. The mixture was then refluxed at 50ºC for 1 hour with 25 ml of alcoholic potassium hydroxide solution added. It was then allowed to cool. Using approximately 1.0 mL of phenolphthalein indicator solution, 2 to 3 drops of phenolphthalein were added. The excess potassium hydroxide was titrated with 0.5 N hydrochloric acid until a pink colour appeared. A burette measurement was made at the beginning and end to determine the amount of HCl solution. The saponification value is calculated using Equation 1:

$$\textbf{Saponification value (mg KOH/g oil)} = 56.1 \times \frac{(B-S)N}{W} \quad (1)$$

Where,
B = Volume of HCl required in ml for titration of a blank sample
S = Volume of HCl required in ml for titration of oil sample
N = Normality of HCl solution
W = Weight of oil taken in grams

Free fatty acid

The oil was placed in a conical flask along with 50 ml of freshly neutralized ethyl alcohol and 1 ml of phenolphthalein indicator solution in a 250 ml flask. Titration was performed with N/10 potassium hydroxide after boiling for roughly five minutes and continuing until a slight pink colour appeared. To determine the amount of potassium hydroxide solution, the initial and final burette measurements were recorded (AOAC, 2000).

$$\textbf{Free fatty acid (mg KOH/g oil)} = \frac{28.2\ VN}{W} \quad (2)$$

Where,
V = Volume in ml of potassium hydroxide solution used
N = Normality of the potassium hydroxide solution used
W = Weight of sample in g

Acid value

According to AOCS (1996), the acid value was calculated. Two and a half grams of oil were placed in a 250 ml conical flask, 50 ml of freshly neutralized hot ethyl alcohol and about 1 ml of phenolphthalein indicator solution. It was then titrated with N/10 potassium hydroxide for approximately five minutes until a slight pink colour was obtained. Calculation of the amount of potassium hydroxide solution was done using equation 3 based on the initial and final burette measurements.

$$\textbf{Acid Value (mg KOH/goil)} = \frac{56.1\ V \times N}{W} \quad (3)$$

Where,
V = Volume in ml of potassium hydroxide solution used
N = Normality of the potassium hydroxide solution used
W = Weight of sample in g

Oil recovery

The oil recovery was calculated using the equation 4 (Olaniyan & Oje, 2011)

$$\textbf{The oil yield (Y)} = \frac{W_{OE}}{W_S} \times 100 \quad (4)$$

Where,
W_{OE} = weight of oil expressed (g)
W_S = weight of the sample before expression (g)

Statistical analysis

The statistical programme R version 4.0.5 was used for the analysis of variance (ANOVA) and mean comparisons at a 5% level of significance.

Results and Discussion

Physico-chemical properties of sesame oil using different extraction techniques

Refractive index

The refractive index is a physical parameter during oil processing from various oil extraction methods. The refractive index indicates the transparency or amount of impurities present in the oil and method described by Pearson in 1976. The Refractive index with the lowest value indicated the highest transparency and fewer impurities. Hence, it should not exceed 1.4559 for edible oil (FAO/WHO, 2009). The refractive index of sesame oil under different extraction methods was found to be 1.46 ± 0.02 for the AE sample, 1.45 ± 0.01 for the UAE sample, 1.46 ± 0.01 for the EAE sample, and 1.47 ± 0.02 for the SE sample. The refractive index was found minimum in UA extracted oil and maximum in aqueous, solvent and EA extracted oil as shown in Figure 2. As the refractive index is affected by the wavelength of light, hence it can be increased due to the presence of impurities in the oil (Katkade *et al.*, 2018). Therefore, it was concluded that the UAE sample had fewer impurities causing it to have a lower refractive index value.

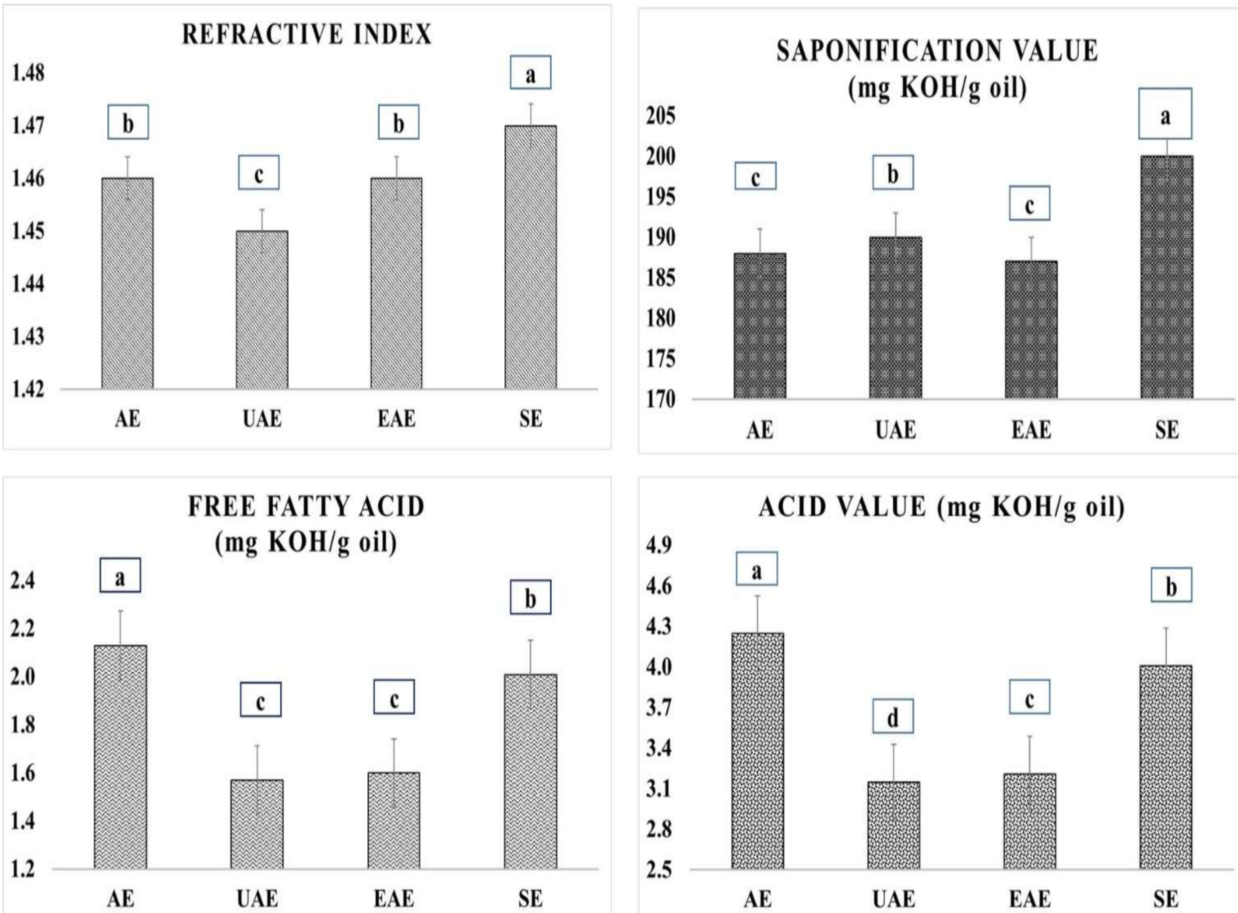

Figure 2: Effect of different extraction methods on the physicochemical quality of sesame oil (AE- Aqueous extraction, UAE- Ultrasound-assisted aqueous extraction, EAE-Enzyme-assisted aqueous extraction and SE-Solvent extraction) Note: Similar letters have no significant difference

Saponification value

The saponification value of sesame oil under different extraction methods was found to be 190 ± 3.15 mg KOH/g oil for the AE sample, 186 ± 3.01 mg KOH/g oil for the UAE sample, 189 ± 3.33 mg KOH/g oil for the EAE sample whereas it was 200 ± 3.89 KOH/g oil for solvent extracted oil. It was significantly (p<0.05) affected by different extraction methods. The maximum value was found for SE oil, followed by AE oil and minimum in EAE oil (Figure 2). The lower saponification value shows this might be due to the high amount of impurities present. Similar results were found for a refractive index of coconut oil (Odoom & Edusei, 2015).

Free Fatty Acids

The free fatty acid value in sesame oil varied from 1.57 to 2.13 mg KOH/g oil. The maximum free fatty acid value was found for AE oil (2.13 ± 0.62 KOH/g oil), followed by SE oil (2.01 ± 0.22 mg KOH/g oil) and minimum in UAE oil (1.57 ± 0.41 mg KOH/g oil) as shown in Figure 2. The higher value of the free fatty acid in oil makes it more susceptible to oxidative ageing, hence quicker the oil becomes rancid. Therefore, a higher level of free fatty acids decreases the overall quality of oil (Katkade *et al.*, 2018).

Acid Value

The acid value is a chemical parameter carried out on the oil of sesame seeds. The Acid value is a measurement of the free fatty acids in oil which is directly connected to the superiority of the oil. According to AOAC (1990), the acid value does not exceed the 5.0386 mg KOH/g. Therefore, the acid value of sesame oil extracted using different methods was lower value than prescribed by AOAC (1990) viz. 4.25±0.6mg KOH/g oil for the AE sample, 3.21±0.25 mg KOH/g oil for the EAE sample, 3.15±0.13 mg KOH/g oil for the UAE sample, and 4.01 ± 0.22 mg KOH/g oil for the SE sample. It examined that the acid value was significantly ($p < 0.05$) pretentious by the method used for oil extraction from sesame seeds. The acid value of the oil sample extracted using the AE method had maximum value, followed by SE then EAE method, and minimum in UAE method as shown in Figure 2. It can be attributed that oil had a lower free fatty acid value in the oil, causing a lower acid value (Negash *et al.*, 2019).

Oil recovery and extraction time

The sesame oil recovery and extraction time using various methods i.e., AE, SE, UAE, and EAE are presented in Table 1. Although Controlled sample oil extracted by SE had a higher extraction time as compared to the other three methods, the oil recovery was found to be maximum in SE followed by UAE and minimum in AE. This finding suggested that the compression and rarefaction of the elastic mechanical vibration wave of ultrasonic can drive the medium, resulting in changes in liquid pressure and a significant number of vacuum bubbles. When bubbles rupture and produce high immediate pressure, this is known as the "cavitation effect". Cells from sesame seeds were sheared and crushed. This activity aided sesame oil extraction, increasing the rate of oil production (Khoei & Chekin, 2016).

Table 1: Extraction of oil by various methods

Method of extraction	Total time taken (h)	Oil yield (%)
Aqueous extraction	22.5	27±0.02
Ultrasound assisted aqueous extraction	23.5	41±0.04
Enzyme assisted aqueous extraction	21.5	37±0.08
Solvent extraction	12	45±0.03

Note: Readings were taken in triplicate and readings represent in the form of Mean ± SD

Conclusion

The influence of four distinct oil extraction procedures on the physicochemical quality of sesame oil was investigated in this study: solvent extraction, aqueous extraction, ultrasound-assisted aqueous extraction, and enzyme-assisted aqueous extraction. When compared to oil extracted by AE, EAE, and SE, UA extracted oil had a lower refractive index, acid value, and free fatty acid value, maximal saponification value, extraction time, and oil recovery. It was concluded that oil extracted from sesame seeds using UAE method had better quality retention than other methods.

Conflict of interest

The authors declare that they have no conflict of interest.

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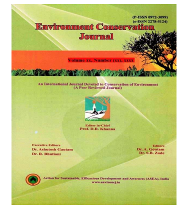

Influence of integrated nutrient management on growth and yield of cowpea (*Vigna unguiculata* L.) in Prayagraj region

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ABSTRACT

A field study was conducted at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, during the zaid season of 2021. (U.P.). This study was carried out with the objective to study the interaction effect of different levels of NPK, FYM, Vermicompost and Panchagavya on growth and yield of cowpea. The experiment used a randomized block design (RBD) with nine treatments which were replicated three times. The soil texture of the experimental plot was sandy loam, with a pH of 7.2, low organic carbon (0.48 percent), available N (171.48 kg/ha), available P (13.6 kg/ha), and available K (215.4 kg/ha). The results showed significantly increase in growth parameters *i.e.* plant height (69.48 cm), number of nodules/plant (24.37), plant dry weight (22.22 g/plant), crop growth rate (3.0 g/m^2/plant) and yield attributing parameters i.e. number of pods/plant (15.45), length of pods (27.02cm), number of seeds/pod (13.57), test weight (85.6 g), seed yield (2.68 t/ha), stover yield (6.09 t/ha). The harvest index (30.56) was recorded with vermicompost 1.5t/ha + RDF 100% kg/ha.

Introduction

Cowpea is a major leguminous crop among the pulse crops. It is a drought tolerant and hardy crop which can survive in most of the stressful environments. It also improves soil fertility by fixing atmospheric nitrogen, especially in small-holder agricultural farming systems where almost no or little fertilizer is applied and requires low input for its production. The green pods and leaves of cowpea are consumed as vegetable while the grainsare used for culinary purposes.Cowpea is a cheap and major source of quality protein since its leaves have a protein content ranging from 27 to 43 percent, while the dry grain has a protein content ranging from 21 to 33 percent (Ahenkora *et al.,* 1998; Ddamulira *et al.,* 2015).Cowpea is also used as fodder for livestock and as a green manure crop. Worldwide, Cowpea is grown in an area of 12.5 million ha with a total grain production of 3 million tonnes. Nigeria is the leading producer of the crop followed by Brazil. Other African countries like Senegal, Ghana, Mali and Burkina Faso are its significant producers. In Asia, only India and Myanmar are significant producers. In India, Cowpea is grown in an area of 3.9 million hectares in India, with a yield of 2.21 million tones and a productivity of 567 kg/ha (Singh *et al.,* 2012). With these and other crop-related challenges in mind, a growing focus is needed on the integrated nutrient management (INM) system, which is necessary for maintaining soil health and crop yield. The basic tenet of integrated nutrient management (INM) is to maintain or modify soil fertility and provide nutrients to plants to an optimum level in order to maintain desirable crop yield by maximizing benefits from all potential sources of plant nutrient in an integrated manner (Tondon, 1992). Uses of

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Organic manure becomes an unavoidable practice in the foreseeable future to meet crop nutrient requirements for sustainable agriculture, as these manures enhance the physical, chemical, and biological properties of the soil while retaining and enhancing the soil water content and nutrient holding capacity, leading to higher crop productivity as well as maintaining the crop produce quality (Jangir *et al.,* 2021).

Inorganic fertilizer to use for pulses crops such as Nitrogen plays an important role in plant metabolism.It promotes the growth and development of all living tissues while also increasing the crop's protein content and yield. The phosphorous helps in root proliferation and development. So, there is efficient biological nitrogen fixation by the roots. It is also essential for meristematic growth, seed development and protein synthesis (Malhotra *et al.,* 2018). Further, potassium plays an important role in photosynthesis and respiration. It plays an important role in osmoregulation, stomatal movement and disease resistance(Prajapati andModi, 2012).

Therefore, it is to know about the integrated nutrient management, because with this technique, soil fertility can be managed and regulated besides the maintained of the organic matter in the soil for further generation. It also gets more production or yields with low input or cost.

Material and Methods

Location of Experimental Site

The experiment was conducted at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.), which is located at 25°39"42" N latitude, 81°67"56" E longitude, and 98 m altitude above mean sea level (MSL) during the *zaid* season of 2021. This area is around 12 kilometres from the city, on the right bank of the Yamuna river, along the Prayagraj-Rewa route.

Climate and Weather

Prayagraj has a subtropical and semi-arid climate, whereas the south-eastern section of Uttar Pradesh experiences both winter and summer temperatures. This sub-tropical climate has a humid sub-tropical climate. In the winter, temperatures can drop as low as 3°C in December and January, while the weather turns extremely hot in the summer, with temperatures reaching above 48°C in May and June. Cold waves in the winter and hot desiccating winds in the summer are both typical in the region. The average rainfall in this area is over 90.0 cm, with the majority of it falling between July and September during monsoon season with a few showers thrown in throughout the winter months.

The field experiment to assess the effect of integrated nutrient management on growth and yield of cowpea. The soil of experimental plot was sandy loam in texture, nearly natural in soil reaction (pH 7.2), low in organic carbon (0.48 %), available nitrogen (171.48 kg/ha), available phosphorus (13.6 kg/ha) and available potassium (215.4 kg/ha). The experiment was conducted in Randomized Block Design consisting of nine treatment combinations with three replications and was laid out with the different treatments allocated randomly in each replication. The treatment combinations are T_1 – vermicompost 1.5t/ha + RDF 100%, T_2 - vermicompost 1.5t/ha + RDF 75%, T_3 - vermicompost 1.5t/ha + RDF 50%, T_4 – FYM 5 t/ha + RDF 100%, T_5 – FYM 5 t/ha + RDF 75%, T_6 - FYM 5 t/ha + RDF 50%, T_7 – Panchagavya 6% + RDF 100%, T_8 - Panchagavya 6% + RDF 75%, T_9 - Panchagavya 6% + RDF 50%. Kashikanchan is the dwarf variety of cowpea which was sown @ 25 kg/ha with the spacing of 45 cm x 15 cm in net plot area of 3m x 3m was carried on 12 April 2021 for seed production. Full dose of nitrogen was applied through Urea, phosphorus was applied through SSP and potash through MOP. Cowpea seeds were treated with 2 g/kg of seed with thiram before sowing. An observation of growth parameters, such as plant height (cm), number of nodules/plant, plant dry weight (g), crop growth rate and relative growth rate of data were collected from five randomly selected tagged plants. At the time of harvesting, yield-attributing parameters such as the number of pods/plant, number of seeds/pod, length of pods, test weight, seed yield was recorded from each treatment. The data was analysed statistically by ANOVA technique (Gomez and Gomez, 1984). There was a significant difference between the mean of treatments when compared to the critical value at five percent level of significance.

Results and Discussion

A. Growth Attributes:

Plant height (cm)

The result at 75 DAS shows that the effect of T_1 *i.e.*, Vermicompost at 1.5 t/ha along with RDF 100% over plant height was found to be highest (69.48 cm) and significantly superior over other treatment combinations except with T_2 *i.e.,*Vermicompost at 1.5 t/ha along with RDF 75% which was found statistically (69.22 cm) at par with treatment T_1 (69.48 cm). However, effect of T_6 *i.e.,* Farm Yard Manure at 5 t/ha along with RDF 50% over plant height was found to be significantly lowest (55.74 cm) at 5% level of significant.

Vermicompost and NPK application may have regulated oxidation- reduction enzyme reaction of the metabolism in plants which have resulted in cell elongation and multiplication. Organic and inorganic source of nutrients which play major role in cell devision and cell elongation. Then it leads plant height Sabarad *et al.* (2004).

Plant dry weight (g)

The data pertaining to 75 DAS shows that the effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over plant dry weight per plant was found to be highest (22.22 g/plant) and significantly superior over other treatment combinations except with T_2 i.e., Vermicompost at 1.5 t/ha along with RDF 75% Treatment T_2 (21.95g) was shown to be statistically equivalent to treatment T_1 (22.22g). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over plant dry weight per plant was found to be significantly lowest (15.92 g/plant) at 5% level of significant.

Higher dry matter due to the availability of widely accessible nitrogen for rapid growth stage and cumulative improved performance in most growth characters as a result of prolonged availability of macro and micronutrients and improved soil physical conditions throughout the season from vermicompost. Prakash *et al.* (2018).

Numbers of nodules per plant

The data pertaining to 60 DAS shows that the effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over number of nodules per plant was discovered to be the highest (39.2) and significantly superior over other treatment combinations except with T_2 (38.54) i.e., Vermicompost at 1.5 t/ha along with RDF 75% it was discovered to be statistically equivalent to the treatment T_1 (39.2). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Number of nodules per plant was found to be significantly lowest (25.76) at 5% level of significant.

The above result might be due to the effect of Vermicompost which might have enhanced increased plant growth and yield through lowering pH and particle density while boosting porosity, water holding capacity, cation exchange capacity, and macronutrients in the soil. The presence of humic chemicals in the vermicompost might be the reason of the pH reduction, according to many previous observations (Mahaly *et al.,* 2018). The humic acid concentration of the vermi-compost is high, which aids root development by increasing the effectiveness of the root system and so stimulating plant growth and production. It was done by enhancing food absorption by increasing the permeability of the cell membrane. Humic acid also assisted the development of soil microbial characteristics, leading in higher synthesis of organic aids and, as a consequence, an improvement in soil quality. The bacteria in the vermicompost may create auxin, cytokinins, gibberellins, and other plant growth regulators, as well as a variety of metabolites that the plants can use (Gholami *et al.,* 2018).

Crop growth rate

The result at 45-60 DAS shows that the effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over CGR was found to be highest (4.11 $g/m^2/day$) and significantly superior over other treatment combinations except with T_2 (4.05 $g/m^2/day$) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which, statistically, was determined to be comparable to treatment T_1 (4.11 $g/m^2/day$). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over CGR was found to be significantly lowest (2.21 $g/m^2/day$) at 5% level of significant.

Relative Growth Rate (RGR) (g/g/day)

Shows the mean data for germination percentage recorded at 15-30 DAS, 30-45 DAS, 45-60 DAS, and 60-75 DAS, as well as a graphic representation of the data. The data pertaining to Relative Growth Rate and Integrated Nutrient Management (RGR) (g/g/day) of Cowpea (*Vignaunguiculata* L.) shows that the relative growth rate was found to be non-

Table 1: Effect of integrated nutrient management on growth parameters of Cowpea

Treatment symbols	Treatments	At Harvest		At 60 DAS	During 60 – 75 DAS	
		Plant height (cm)	Dry weight (g)	Nodules/ Plant (No.)	CGR ($g/m^2/day$)	RGR (g/g/day)s
T_1	Vermicompost at 1.5 t/ha + RDF 100%	69.48	22.22	39.2	3.01	0.0213
T_2	Vermicompost at 1.5 t/ha + RDF 75%	69.22	21.95	38.54	2.97	0.0213
T_3	Vermicompost at 1.5 t/ha + RDF 50%	58.61	16.59	28.86	2.19	0.0207
T_4	Farm Yard Manure at 5 t/ha + RDF 100%	62.2	18.46	32.52	2.37	0.0201
T_5	Farm Yard Manure at 5 t/ha + RDF 75%	60.68	17.57	30.62	2.29	0.0205
T_6	Farm Yard Manure at 5 t/ha + RDF 50%	55.74	14.95	25.76	2.15	0.0229
T_7	Panchagavya at 6% + RDF 100%	66.53	20.36	35.5	2.58	0.0198
T_8	Panchagavya at 6% + RDF 75%	64.63	19.36	33.98	2.44	0.0197
T_9	Panchagavya at 6% + RDF 50%	57.07	15.92	27.19	2.16	0.0215
SE(m)±		0.12	0.12	0.25	0.01	0.0002
CD (P=0.05)		0.36	0.36	0.75	0.04	NS

Table 2: Effect of integrated nutrient management on yield attributes and yield of Cowpea

Treatment symbols	Treatment combinations	Pods/ plant (No)	Length of pod/ plant	Seeds/ pod (No)	Test Weight (g)	Seed yield (t/ha)	Stover Yield (t/ha)	Harvest Index (%)
T_1	Vermicompost at 1.5 t/ha + RDF 100%	15.45	27.02	13.57	85.6	2.68	6.09	30.56
T_2	Vermicompost at 1.5 t/ha + RDF 75%	15.13	26.87	13.35	85.19	2.54	6.07	29.5
T_3	Vermicompost at 1.5 t/ha + RDF 50%	12.15	23.22	11.14	81.38	1.64	5.74	22.22
T_4	Farm Yard Manure at 5 t/ha + RDF 100%	13.29	24.65	11.93	82.69	1.95	5.87	24.91
T_5	Farm Yard Manure at 5 t/ha + RDF 75%	12.72	23.81	11.64	81.65	1.76	5.80	23.29
T_6	Farm Yard Manure at 5 t/ha + RDF 50%	10.85	21.31	10.44	80.06	1.34	5.55	19.52
T_7	Panchagavya at 6% + RDF 100%	14.45	26.06	12.81	84.86	2.33	5.99	28.02
T_8	Panchagavya at 6% + RDF 75%	13.85	25.43	12.12	84.25	2.08	5.91	26.03
T_9	Panchagavya at 6% + RDF 50%	11.49	22.24	10.56	80.73	1.45	5.63	25.63
S.EM=		0.11	0.11	0.21	0.19	0.50	0.09	0.49
CD (5%) =		0.32	0.32	0.63	0.57	1.49	0.28	1.48

significant with 5 % confidence level during the entire cropping period. Also, it was found that relative growth rate was higher during vegetative stage and decreased gradually up to maturity stage. However, the effect of treatments on RGR values was more or less similar throughout the crop growth stages.

Yield attributes and yield

Number of pods/plant

The data regarding to Number of pods/plants depicts that the effect of integrated nutrient management on Number of pods/plant of Cowpea (*Vigna unguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Number of pods/plants was found to be highest (15.45) and significantly superior over other treatment combinations except with T_2 (15.13) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which was found to be statistically at par with treatment T_1 (15.45). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Number of pods/plants was found to be significantly lowest (10.85) at 5% level of significant.

The beneficial response of vermicompost to Number of pods/plant might also be attributed to the availability of sufficient amounts of readily usable form of plant nutrient throughout the growth period and specially at critical growth periods of crop resulting in better uptake, plant vigour and superior yield attributes (Brar and Pasrich, 1998; Bansal *et al.,* 2000 and Surender Rao and Sita Ramayya, 2000). These finding corroborates with the results of several other workers (Ghanshyam *et al.,* 2010; Singh *et al.,* 2010; Singh *et al.,* 2008; Ramawter *et al.,* 2013).

Length of pod/plant (cm)

The data in relation to Length of pod/plant depicts that the effect of Integrated Nutrient Management on Length of pod/plant of Cowpea (*Vigna unguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Length of pod/plant was found to be highest (27.02 cm) and significantly superior over other treatment combinations except with T_2 (26.87 cm) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which was found to be statistically at par with treatment T_1 (27.02 cm). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Length of pod/plant was found to be significantly lowest (21.31 cm) at 5% level of significant. Application of vermicompost significantly increased length of pod. The beneficial effect of vermicompost on yield attribute like length of pod may probably due to enhanced supply of macro as well as micronutrients during entire growing season led to higher assimilation of food and its subsequent partitionary in sink (Mahaly *et al.,* 2018).

Number of seeds/pod

The data on Number of seeds/pod shows how Integrated Nutrient Management affects the number of seeds/pod of Cowpea (*Vignaunguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Number of seeds/pod was found to be highest (13.57) and significantly superior over other treatment combinations except with T_2 (13.35) i.e., Vermicompost at 1.5 t/ha along with RDF 75% it was discovered to be statistically equivalent to the treatment T_1 (13.57). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Number of seeds/pod was found to be significantly lowest (10.44) at 5% level of significant. Vermicompost and NPK could be attributed to improve photosynthetic translocation to the sink, which increased the amount of photosynthetic in the system thus it helps in increased number of seeds/pod. Similar results were also reported by (Jat and Ahlawat, 2004).

Test Weight (g)

The data as it relates to Test Weight depicts that the impact of Integrated Nutrient Management on Test Weight of Cowpea (*Vignaunguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Test Weight was found to be highest (85.6 g) and significantly superior over other treatment combinations except with T_2 (85.19 g) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which was observed to be statistically tat par with treatment T_1 (85.6 g). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Test Weight was found to be significantly lowest (80.73) at 5% level of significant.

The above result might be attributed due to the fact that the vermicompost acts as slow-release source of N which is expected to match more closely with supply of N and other nutrient with crop demand and provides all essential nutrient along with growth promoting substances, like enzymes, hormones, growth regulators etc. Hence, Test weight as affected by different organic sources of nutrient varied significantly, being higher with vermicompost with 100% RDF. These results are in conformity with the findings of Devi and Singh (2006) and Reddy *et al.* (1998).

Seed yield (t/ha)

The data concerning to Seed yield (t/ha) depicts that the impact of Integrated Nutrient Management (INM) on Seed yield (t/ha) of Cowpea (*Vigna unguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Seed yield (t/ha) was found to be highest (2.68 t/ha) and significantly superior over other treatment combinations except with T_2 (2.54 t/ha) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which was found at par with treatment T_1 (2.68 t/ha).

However, effect of T_6 i.e.,Farm Yard Manure at 5 t/ha along with RDF 50% over Seed yield (t/ha) was found to be significantly lowest (1.34 t/ha) at 5% level of significant. The increase in seed output following the application of 1.5 tonnes of vermicompost and 100 percent RDF could be due to higher vegetative growth in the crop, which means more light interception and hence more assimilated production, resulting in higher pod and seed yield. These findings are consistent with those of (Babaji *et al.,* 2011).

Figure 1: General view of experimental site

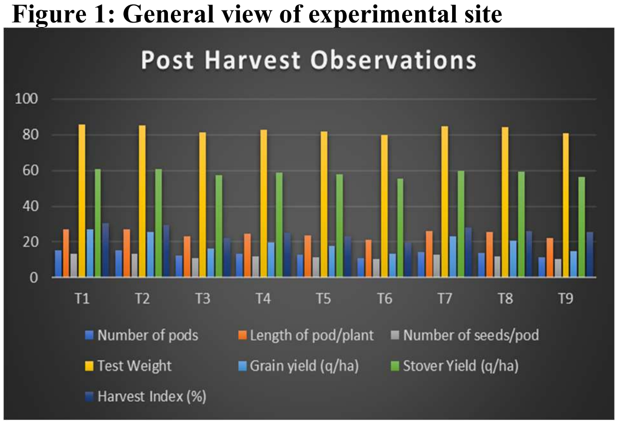

Figure 2: Graphical presentation of post-harvest observation

Stover yield (t/ha)

The data pertaining to Stover yield (t/ha) depicts that the effect of Integrated Nutrient Management on Stover yield (t/ha) of Cowpea (*Vigna unguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Stover yield (t/ha) was found to be highest (6.09 t/ha) and significantly superior over other treatment combinations except with T_2 (6.07 t/ha) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which was found at par with treatment T_1 (6.09 t/ha). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Stover yield (t/ha) was found to be significantly lowest (5.55 t/ha) at 5% level of significant. The application of 1.5 tonnes of vermicompost and 100 percent RDF could be due to higher vegetative growth of the crop i.e plant height, number of branches, leaf area etc. these positively affect biomass production. Which means more light interception and hence more assimilated production, resulting in higher straw yield.

Harvest Index (%)

The data pertaining to Harvest Index (%) depicts that the effect of Integrated Nutrient Managemnt on Harvest Index (%) of Cowpea (*Vigna unguiculata* L.) was found to be significant. The effect of T_1 i.e., Vermicompost at 1.5 t/ha along with RDF 100% over Harvest Index (%) was found to be highest (30.56%) and significantly superior over other treatment combinations except with T_2 (29.5%) i.e., Vermicompost at 1.5 t/ha along with RDF 75% which was found to be statistically at par with treatment T_1 (30.56%). However, effect of T_6 i.e., Farm Yard Manure at 5 t/ha along with RDF 50% over Harvest Index (%) was found to be significantly lowest (19.52%) at 5% level of significant.

Conclusion

The current inquiry has led to the conclusion that Treatment (T_1) with the application of Vermicompost 1.5 tones along with RDF 100% was found to be significant higher at Pre and post-harvest parameters whereas Treatment (T_2) application of Vermicompost at 1.5 t/ha + RDF 75% was found to be statistically at par with Treatment (T_1). It may be concluded that influence of integrated nutrient management will not only reduces the cost of cultivation also enhances the productivity, quality of crop and maintaining the soil fertility for next generation. Continuous usage of organic manure will not only enrich the nutrients in the soil but also increases the soil water holding capacity, porosity, and other physical qualities density and infiltration of soil as well as protects the crop from pest and diseases. Since this is based on one season trail therefore, further evaluation trails are needed to substantiate the findings.

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Conflict of interest

The authors declare that they have no conflict of interest.

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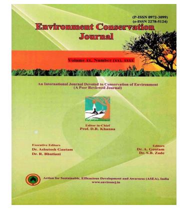

Variability and divergence studies on rice genotypes for micronutrient potential and its utility in biofortification

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ABSTRACT

Rice is the staple food crop for more than half of the world population. Thus, rice varieties enriched with various micronutrients qualifies as a better alternative to combat micronutrient deficiency. The present investigation was undertaken to study the variability, heritability and genetic divergence for grain characters especially grain Zinc (Zn) content and grain Iron (Fe) content in 30 genotypes of rice. Among the 30 genotypes that were under investigation, the Phenotypic Coefficient of Variation (PCV) values were found to be higher than that of Genotypic Coefficient of Variation (GCV) values for all the traits. High heritability (>60%) was observed for all the studied traits. Days to 50% flowering showed highest heritability (99.1%) followed by test weight (94.8%) and grain Fe content (94.8%). The genetic advance as percent of mean ranged between medium (10%-20%) to high (>20%) with grain yield per plant showing the highest GAM (40.84%) followed by test weight (38.56%) and grain Zn content (33.73%). These 30 genotypes were assigned into groups of 11 clusters using Tocher's method. Cluster I comprised of the most number of genotypes with 18 genotypes followed by Cluster V with 3 genotypes while the remaining 9 clusters were monogenotypic. Days to 50% flowering was found to have the highest contribution towards genetic divergence. These findings indicated that the genotypes under study have sufficient trait variability and varietal diversity which could be exploited in crop improvement programmes aimed at developing Zinc (Zn) and Iron (Fe) biofortified varieties.

Introduction

Rice (*Oryza sativa L.*) is the single most important staple crop of the world. Asia is second to none in terms of production and constitutes 90% of the global rice cultivation area (Singh *et al.*, 2018).India produced an estimated 117.94 Mt of grain with a productivity of 2.7 t/ha during the 2019-2020 season. Although rice production is high in India, productivity is meagre compared to other major producers such as China (6.5 t/ha) and Indonesia (5.2 t/ha) (MoA and FW, 2019-2020).Though the progress in rice production has moved forward by leaps and bounds, there is still a necessity to increase production and productivity to meet the needs of the growing population. However, feeding the ever growing population is not the only concern; we should also ensure the

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nutritional security especially with respect to essential micronutrients, vitamins and proteins as micronutrient deficiency is a major issue plaguing developing countries like India (Bain *et al.*, 2013). According to a survey by the WHO (2002), more than two billion people are afflicted with micronutrient deficiencies. Development of rice cultivars that possess substantial yield with ample amount of micronutrients could create an avenue for solving two problems with a single solution. In view of these various hurdles and predicaments, this present research was undertaken to study variability, heritability and genetic divergence in 30 genotypes of rice to explore their potential for utility in crop improvement programmes aimed at yield increments along with biofortification.

Material and Methods

The present investigation was undertaken at Research farm, RPCAU, Pusa, Bihar during *Kharif* 2019-2020. The experimental materials comprised of 30 rice genotypes, of which 29 were test entries and one check entry. The test entries were acquired from Harvest Plus programme, ICRISAT, Hyderabad while the local check entry was taken from Rice breeding section, Department of Plant Breeding and Genetics, RPCAU, Pusa, Samastipur, Bihar. 21 days old seedlings were transplanted in an experimental unit of 5m^{2}atspacing of 20cm apart between rows and 15cm apart between plants. Randomized Complete Block Design was followed with three replications. Standard agronomic practices along with plant protection measures were followed to raise healthy crop stand. Eleven quantitative traits were taken into consideration for the present study. The observations on traits like plant height, number of panicles per plants, panicle length and grain yield per plant were taken by selecting 5 random plants from each plot while number of days to 50% flowering was recorded on a plot basis. Observation on test weight, kernel length, kernel breadth, kernel L/B ratio, grain Iron content and grain Zinc content was recorded from seeds taken from bulk harvest of individual plot. An instrument known as Energy Dispersive X-Ray Fluorescence(ED-XRF) was used for estimation of the grain Iron and Zinc content. The computed mean data for each character was subjected to analysis for variance following methods illustrated by Panse and Sukhatme (1985), genotypic (GCV) and Phenotypic (PCV) coefficients of variation according to the formula as illustrated by Burton (1952), Broad sense heritability as per the formula given by Lush (1940) and Genetic Advance as per cent of mean according to Johnson *et al.* (1955). Genetic Divergence among the thirty genotypes was estimated using D^2 analysis proposed by Mahalanobis (1936). The genotypes were grouped into several clusters in accordance with Tocher's method (Rao**,** 1952).

Results and Discussion

The results obtained from the analysis of variance (Table 1) indicated that the genotypes under investigation varied significantly for all 11 quantitative traits that were studied ($p < 0.01$). Similar findings were reported by Singh *et al.* (2017) for traits like kernel length and kernel breadth. The perusal of the data on coefficients of variation revealed that for all of the traits examined, GCV and PCV estimates were greater than their corresponding GCV estimates in the current study. GCV and PCV values for kernel breadth (6.82%and 8.41%), kernel length (7.06%and 7.32%), kernel L/B ratio (8.26%and 9.48%), plant height (9.41% and 9.7%) and panicle length (9.66%and 10.63%) were found to be low, ranging from 10% to 20%. Similar findings were reported by Singh *et al.* (2020). Moderate values of GCV and PCV were observed for test weight (19.22% and 19.74%), number of panicles per plant (15% and 18.94%), days to 50% flowering (12.39 and 12.45%), grain Fe content (15.80% and 16.22%) and grain Zn content (17.52% and 18.76%). A similar finding for panicle length, test weight and days to 50% flowering was documented by Khan *et al.* (2009). These findings were also in concordance with the findings of Raza *et al.* (2019) as they reported ample amount of variability in grain Iron and Zinc content.The resultant GCV and PCV value for grain yield per plant (20.71% and 21. 65%) was determined to be high with a value greater than 20%. Similar findings of high GCV and PCV values had been previously reported by Bekele *et al.* (2013) for grain yield. It was observed that the values of PCV and GCV were in a close range for almost all of the traits studied during the investigation inferring that environment had little impact on the expression of these traits. The greatest ECV value was observed in number of panicles suggesting that of all the traits studied, it is the most influenced by the environment.

Table 1: Analysis of variance (ANOVA) for 11 quantitative traits in Rice

Traits	Mean sum of squares		
	Replication (df=1)	Treatment (df=29)	Error (df=29)
Plant height (cm)	16.69	161.44**	4.74
Days to 50% flowering	4.81	285.56**	1.26
Number of panicles per plant	0.41	7.08**	1.62
Panicle length (cm)	1.32	12.13**	1.16
Test weight (g.)	0.50	25.53**	0.68
Kernel length (mm)	0.03	0.36**	0.01
Kernel breadth (mm)	0.00	0.05**	0.01
Kernel L/B ratio	0.012	0.11**	0.01
Grain Fe content (ppm)	0.59	12.81**	0.33
Grain Zn content (ppm)	1.10	30.42**	2.06
Grain yield per plant (g.)	0.73	30.13**	1.32

Table 2: Genetic parameters for 11 quantitative traits in Rice.

Traits	Mean	Min	Max	GCV (%)	PCV (%)	h^2 (%)	GA as % of Mean
Plant height (cm)	93.97	79.36	124.80	9.41	9.70	94.3	18.42
Days to 50% flowering	96.18	80.50	124.	12.39	12.45	99.1	25.42
Number of panicles per plant	11.01	9.00	17.50	15.00	18.94	62.7	24.47
Panicle length (cm)	24.24	20.00	30.93	9.66	10.63	82.5	18.07
Test weight ((g.)	18.33	11.91	24.59	19.22	19.74	94.8	38.56
Kernel length(mm)	5.95	5.22	6.79	7.06	7.32	93.2	14.04
Kernel breadth(mm)	2.18	1.80	2.45	6.82	8.41	65.7	11.38
Kernel L/B ratio	2.74	2.25	3.14	8.26	9.48	75.9	14.83
Grain Fe content (ppm)	15.80	10.85	19.5	15.80	16.22	94.8	31.70
Grain Zn content (ppm)	21.48	11.15	30.61	17.52	18.76	87.3	33.73
Grain yield per plant (g.)	18.31	14.05	28.75	20.71	21.65	91.6	40.84

Table 3: Clustering pattern of 30 genotypes of Rice for 11 quantitative traits.

Cluster number	No. of genotypes	Genotypes in cluster
I	**18**	R-RHZ-MB-119, DRR Dhan 48, R-RHZ-IR-142, RRHP-MI 30, IR 64, R-RGY-IS-110, R-RHZ-SM-14, DRR Dhan 49, CGZR-1, R-RHZ-IB-80, R-RHZ-IR-132, DRR Dhan 45, IET 25470, R-56, R-RH2-M1-93, R-RHZ-IR-131, R-RHZ-SK-128, R-RHZ-IH-82, R-RHZ-IR-140
II	**1**	RajendraBhagwati
III	**1**	R-RGY-MH-113
IV	**1**	CGZR-2
V	**3**	CR Dhan 310, CR 2818-1-11-1-B-1-1-2-B-1, MI 127
VI	**1**	Zinco Rice
VII	**1**	CR Dhan48
VIII	**1**	Samba Mahsuri
IX	**1**	CR 2819-1-5-3-2B-12-1
X	**1**	IET 26383
XI	**1**	MI 156

Table 4: **Intra and Inter cluster distance between 30 genotypes of Rice for 11 quantitative traits.**

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	146.14										
II	189.56	0.00									
III	211.57	68.24	0.00								
IV	255.93	149.73	128.68	0.00							
V	530.75	199.34	164.16	404.66	138.20						
VI	309.14	77.09	94.48	123.99	226.94	0.00					
VII	232.69	153.69	173.31	198.71	318.47	231.87	0.00				
VIII	212.87	332.92	423.84	277.73	856.62	534.53	318.37	0.00			
IX	194.37	183.78	154.20	204.11	433.99	224.85	344.15	315.10	0.00		
X	265.32	418.25	406.15	607.16	791.68	613.60	595.54	393.92	191.52	0.00	
XI	405.72	256.69	220.24	564.19	256.98	492.95	372.56	635.02	390.06	441.94	0.00

Table 5: **Cluster mean and per cent contribution of 11 quantitative traits of Rice.**

Traits / Clusters	PH	DFF	NPP	PL	1000-GW	KL	KB	L/B	FeC	ZnC	YPP
I	94.12	90.67	10.56	24.33	18.83	5.86	2.14	2.76	15.71	21.05	17.04
II	94.42	105.00	10.00	24.50	20.24	5.80	2.22	2.62	18.65	26.60	17.06
III	91.01	105.50	13.50	25.00	15.29	5.80	2.28	2.54	14.25	19.20	18.39
IV	79.37	100.00	13.00	25.50	13.47	6.35	2.27	2.81	18.40	21.45	17.34
V	92.15	120.67	14.17	23.66	19.95	6.04	2.30	2.64	14.77	19.98	22.34
VI	90.01	110.00	9.00	20.00	14.84	5.99	2.23	2.69	18.10	22.10	14.05
VII	79.45	101.50	13.50	20.10	21.10	6.30	2.22	2.84	17.10	11.85	28.75
VIII	86.71	80.50	11.50	26.24	18.09	6.14	2.10	2.93	19.55	30.61	22.85
IX	103.96	98.00	9.50	22.80	11.91	6.80	2.17	3.14	14.65	26.45	14.99
X	124.83	84.50	9.00	23.24	14.14	5.98	2.25	2.66	13.90	23.90	14.10
XI	98.91	106.50	9.00	30.94	22.23	5.95	2.40	2.50	12.45	23.45	28.27
% contribution towards divergence	6.21	51.03	0.00	0.00	6.90	9.66	2.53	0.23	15.40	1.15	6.90
No. of times ranked 1st	27	222	0	0	30	42	11	1	67	5	30

Most of the traits in the current study had high heritability of *i.e.* > 60% which was coupled with large values of Genetic Advance as per cent of mean (Table 2), suggesting that selection for enhancement of these traits could be performed with relative ease. Grain Fe content (94.8% and 31.70%), test weight (94.8% and38.56%), grain yield per plant (91.6% and 40.84%), grain Zn content (87.3% and 33.73%), days to 50% flowering (99.1% and 25.42%) and number of panicles per plant (62.7% and 24.47%) demonstrated high heritability percent in tandem with high values for Genetic Advance as per cent of mean. Agrawal (2003) and Girma *et al.* (2018) documented similar findings for these traits. However, non-additive gene action in the traits *viz.,* panicle length (82.5% and 18.07%), kernel length (93.2% and 14.04%), plant height (94.3 % and 18.42%), kernel breadth (65.7% and 11.38%) and kernel L/B ratio (75.9% and 14.83%) is likely to be present due high heritability coupled with poor genetic advance as a percent of mean exhibited by these traits. These results were similar with the findings of Parihar *et al.* (2017).

The existence of significant variation in the collection of thirty genotypes was shown by D^2 analysis in the current study. The genotypes were divided into eleven groups based on their degree of divergence (Table 3). Clusters II, III, IV, VI, VII, VIII, IX, X, and XI had 0 intra cluster distance since each cluster had just one genotype. Cluster I (146.14), with 18 genotypes, demonstrated largest intra cluster distance closely followed by Cluster V (138.20) which had three genotypes. Cluster V and Cluster VIII (856.62)exhibited the largest inter cluster distance between each other followed by Cluster V and Cluster IX (433.99) suggesting that crosses between these different clusters would produce desirable segregates with the accumulation of beneficial genes in successive generations (Table 4). Days to 50% flowering, grain Fe content, kernel length, test weight, grain yield per plant, plant height, kernel breadth, grain Zn content, and kernel L/B ratio, all made contribution towards total divergence (Table 5). These findings are similar to those of Nachimuthu *et al.* (2014), Ranjith *et al.* (2018) and Rathan *et al.* (2020) who also reported that days to 50% contributed greatly towards total divergence. Based on the results obtained from D^2 statistics, the genotypes located at more diverse clusters with high mean values for desirable traits could be used in breeding programmes to accumulate favourable alleles and desirable traits into a single background, and thus could be effectively used in developing improved cultivars. Furthermore, since 9 out of the 11 clusters were monogenotypic, the cluster mean of the 9 clusters could be used to find genotypes appropriate for crossing.

Conclusion

The Analysis of Variance (ANOVA) revealed that significant variation exists among the genotypes for all the traits. The traits like days to 50% flowering, panicle length, number of panicles per plant, test weight, grain Fe content, grain Zn content and grain yield per plant exhibited high values of GCV and PCV and high heritability in conjunction with high Genetic advance as percent of mean inferring the possibility for efficient selection of these traits and their modification towards the desired direction of selection. Clustering of genotypes grouped all the 30 genotypes into eleven clusters. Inter cluster distances showed high values suggesting the genotypes possessed a lot of variability indicating that selection of diverse parents for hybrid production could be done in the genotypes that were under investigation.

Conflict of interest

The authors declare that they have no conflict of interest.

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Harnessing conventional wisdom for rain water harvesting to mitigate the risks of climate change

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ABSTRACT

Rain water harvesting is the process of collection and storage of rain for various purposes. Rainwater harvesting continues to be the main source of water supply for potable and non-potable uses. Located in a hot and semi-arid region with water scarcity, the National Innovation Foundation - India (NIF) identified a need to conserve water for office use. Building upon the expertise and experience of Lok Mitra Trust in this field, NIF got built traditional, but unique type of rain water harvesting tanks also known as "Matka tank" at its headquarters in Gandhinagar, Gujarat. The unique features of the tank are its hemispherical shaped upper dome and saucer shaped bottom surface, which is being reported for the first time.The Matka tank for rain water harvesting may be considered as a sustainable technique to mitigate the water scarcity in the context of climate change.

Introduction

Linked to spiritualty and mythology in India, water is one of the most vital components for all life forms. It is impossible to imagine life on earth without water. But, indiscriminate use and inadequate water management has resulted in depletion of ground water resources, decline of ground water table and an ever increasing water stress. NITI Aayog (2018) has stated that India is facing the worst water crisis and about 600 million of India's population is already facing "high to extreme water stress". The report also observed that due to this water crisis, India may also witness a decline of 6% in the total GDP by 2030. Further, taking a call on the current scenario, on July 1, 2019, the Government of India launched the "Jal Shakti Abhiyan" identifying 1,592 blocks (1,186 over-exploited, 313 critical and 93 semi-critical) in 256 districts, facing acute water crisis with an aim of ensuring water conservation in these water stressed blocks with five interventions viz. a) water conservation and rainwater harvesting b) renovation of traditional and other water bodies/tanks c) reuse and recharge structures d) watershed development and e) intensive afforestation. Among all the interventions, rainwater harvesting is the simplest and cost effective technique to save water (Pala *et al.*, 2021). Rain Water Harvesting (RWH) is the process of collecting natural precipitation from prepared watersheds for beneficial use (Patil, 2019). It is pure in nature and a substantial source of income in many regions of the world. RWH can be used for agriculture and other utilities such as washing, toilet flushing, gardening, and so on.

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Water harvesting system is deep rooted in the science of ancient India. Archaeological evidence suggests that water harvesting systems have been use in the country for over 4000 years. Researchers have identified a total of 37 types of water conservation systems (figure 1) used in different parts of the country (Borthakur, 2009; Bhattacharya, 2015; Pradhan and Sahoo, 2019). Such local traditional practices are not found just in India, but also in other parts of the world as well. Every such practice has an associated knowledge system (about local geography, climate, soil, rainfall, flora etc.) and requires a specific skill set to assimilate this knowledge to reproduce the conservation systems. But in this era of increasing urbanization and technological development, we are consciously or unwittingly, not utilizing the traditional skills of non-craft artisans. The absence of demand for such and other traditional systems has made survival difficult for non-craft artisans, resulting in their abandoning of traditional skills in resulting in their abandoning of traditional skills in favor of more lucrative pursuits for a living. As a result, not only such skills are gradually vanishing but the associated knowledge systems are also getting depleted rapidly. Therefore, in order to conserve traditional skills and techniques, it is necessary to combine modern technological approaches with traditional knowledge to ensure the livelihood of grassroots innovators and traditional knowledge practitioners. The aim of this study is to disseminate information about an innovative rainwater management practice implemented by National Innovation Foundation-India (NIF), an autonomous body of the Department of Science and Technology, Government of India by leveraging the expertise and knowledge of people at the grassroots. NIF was looking at implementing a rain water harvesting system in its campus to meet part of its water requirements.

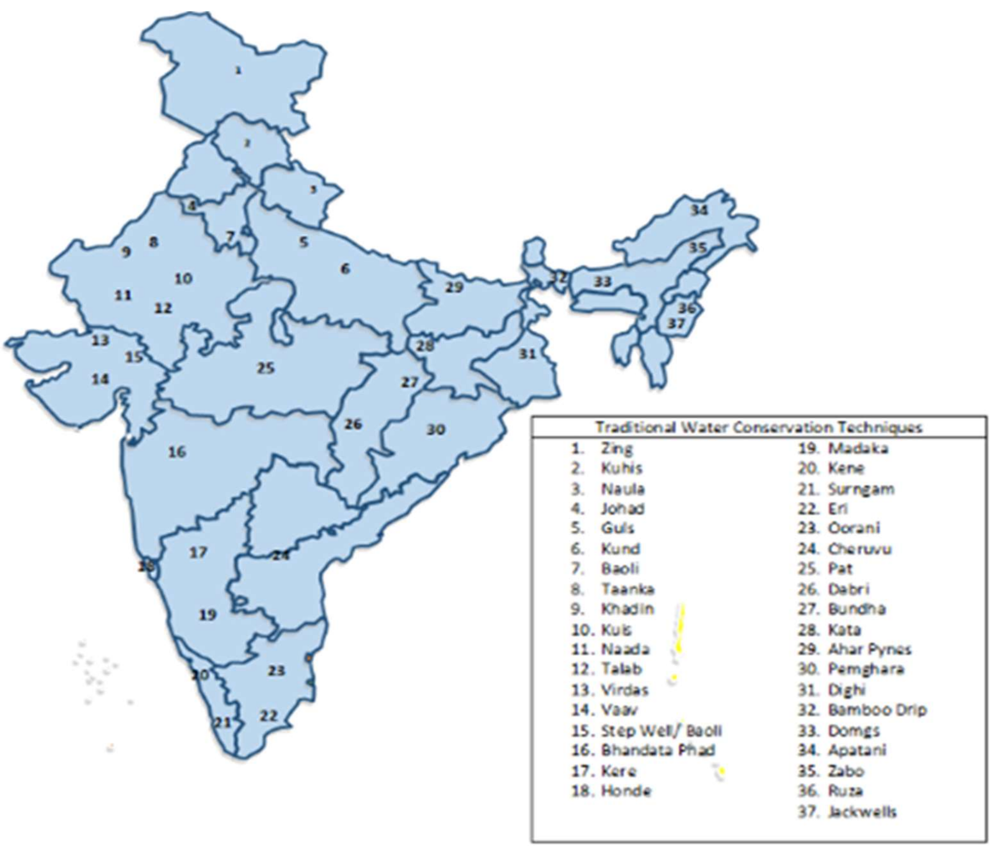

Figure 1: Traditional water conservation systems in India

After studying all available traditional techniques, the design, maintenance and cost aspects of rainwater harvesting, it was decided that the construction of an underground tank with brick masonry would be the most cost effective and practical design as compared to other existing designs (Harvesting, 2001). During this period, NIF came across Lok Mitra Trust and its founder Chaitanyabhai Bhatt who were the first in the country to design and build water tanks with saucer shape bottoms and hemisphere top domes, locally known as “matka tank” using bricks. The concept was originally based on the Deenbandhu Biogas plant and modified for use as an underground water storage system. Chaitanyabhai had not only standardized the technique but also trained more than 30 artisans in the construction of the design independently. More than 550 water tanks have been built by him and his team all over India. He has taken a pioneering approach with both methodological and practical viewpoints, providing hands on training and creating a team of practitioners to replicate the design for further advancement of technology.

Material and Methods

Study area

The campus of National Innovation Foundation (NIF) - India is situated in Gandhinagar, Gujarat (23.2156 ^{0}N, 72.6369 ^{0}E). Located in hot and semi-arid climate, the region is basically a flat region with sandy loam soil. The summers are hot to very hot (35 ^{0}C to 45^0 C) and winters are pleasant (15 ^{0}C to 30 ^{0}C). The average annual rainfall is about 803.4 mm mostly during the monsoon season, with the rest of the year remaining dry. Much of the precipitation percolates deep in the ground, due to the nature of soil, resulting in a very low ground water table in the region (Verma, 2014).

NIF has implemented the project of developing four underground rainwater harvesting tank of capacity 24,990 liters each. The depth of tank is 3.13 m, radius (R1) is taken as 2.09 m for making saucer shaped bottom surface and a radius (R2) is taken as 2.93 m for making hemispherical shape top dome (figure 2) with the following objectives: a) documenting knowledge, traditional elements, and skills, as well as preserving the practices of traditional masonry art of making underground water storage tanks out of bricks, b) developing a training manual and creating a unique resource material in the form of a guidebook and study material for development professionals and artisans who follow sustainable practices, c) disseminating traditional knowledge and ancient masonry techniques of a group of practitioners who have this information and want to improve their skill set, d) raising awareness and developing new prospects about this traditional heritage on a local and worldwide level.

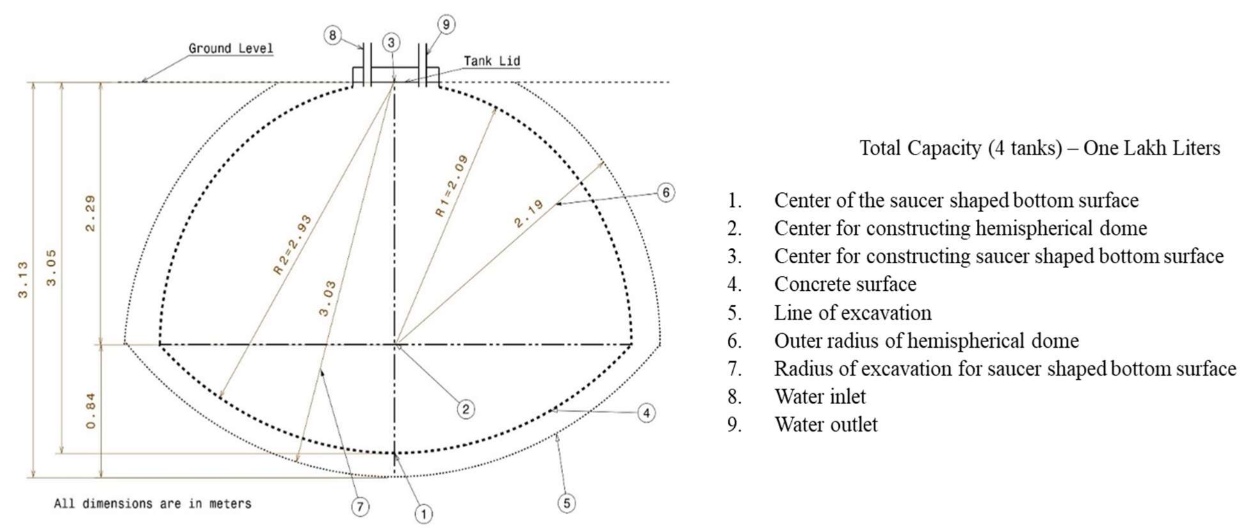

Figure 2: Blueprint of the rainwater harvesting tank

Determination of Catchment Area:
The catchment area of the NIF building-2, which is L shaped (figure 3), is calculated as:

Catchment Area = (length X breadth) + (length X breadth)
= (37.40 m X 9.80 m) + (19.50 m X 13.30 m)
= 366.52 m^2 + 259.35 m^2
= 625.87 m

Determination of volume of water that can be harvested in a year:
(i) Rainwater endowment: The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area (Kumar, 2015).

Rain water endowment = Catchment area (m^2) X Mean annual rainfall (m)
= 625.87 X 0.8034
= 502.823958 m^3 or 502823.958 L

(ii) Runoff coefficient: Runoff coefficient is a dimensionless factor that is used to convert the total rainfall amounts to runoff amount. In this case as the catchment area is a well-constructed roof, the run off coefficient is taken as 0.9 (Goel, 2011).

(ii) Water Harvesting Potential: The amount of water that can be effectively harvested is called rainwater potentiality (Kumar, 2015).

Rainwater Harvesting Potential= Mean annual rainfall (m) x X Area of roof top (m^2) X Runoff coefficient
= 0.8034 X 625.87 X 0.9
= 452.5415622 m^3 or 452541.5622 L

Determination of Total Volume of tank
(i) Volume of Hemisphere at Top (Hemispherical dome)

Volume (V1) = (2/3) X π X R1^3
= (2/3) X (22/7) X (2.09 X 2.09 X 2.09)
= 19.11 m^3

where, R1 = Radius for Hemispherical dome = 2.09 m
(ii) Volume of Spherical Cap at bottom (Saucer shaped bottom surface)
Volume formula (V2) = (1/3) X π X h^2 (3R2 - h)
= (1/3) X (3.14) X (0.84 X 0.84) X (3 X 2.93 - 0.84)
= 0.3333 X 3.14 X 0.7056 X (8.79-0.84)
= 0.3333 X 3.14 X 0.7056 X 7.95
= 5.88 m^3
where, R2 = Radius for Saucer shaped bottom surface =2.93 m &, h = Height for Saucer shaped bottom surface = 0.84 m

(iii) Total Volume of tank = V1 + V2
=19.11+5.88
= 24.99 m^3 or =24990 L ≈ 25000 L

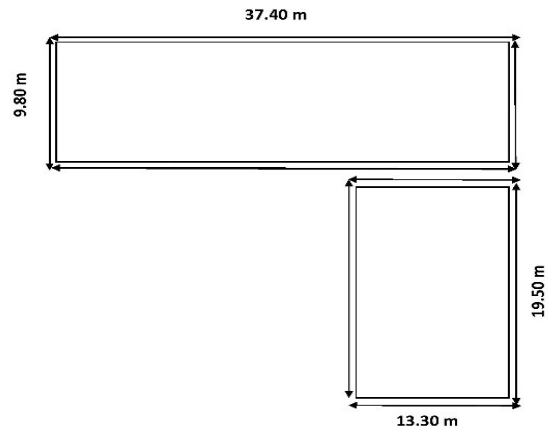

Figure 3: Rooftop/ Terrace area of NIF building-2

Construction Procedure
A blueprint was prepared initially, based on the tank's capacity and location. This was followed by an excavation exercise, which was carried out aligned with the measurements of the tank's size. A vertical rod/pipe was placed in the excavation pit to mark an arch, taking ground level as reference point and 2.93 m as the radius for constructing saucer shaped bottom surface. Similarly, the vertical pipe/rod was marked at 0.84 m from the bottom to build the hemispheric top of the tank, with a radius of 2.09 (figure 2). The soil was then dressed in the shape of a saucer at the bottom. To lay the Plain Cement Concrete (PCC), the dressed surface was slightly moistened and compacted. The bottom inverted dome "saucer" was then built at a thickness of 150 mm. Plumbing pipes were installed concurrently while constructing the water tank to minimize the need for subsequent correction on later stages. Then the PCC was poured on top of the soil and completed according to the blueprint. The hemispherical dome was half brick thick (110 mm) and built from the bottom of the lower inverted dome (however, if the groundwater table is

high and the surrounding soil is loose/black cotton, the dome is built one brick thick). The exterior was plastered concurrently with every 0.75 to 1 m of brickwork to counter balance the weight of the bricks. The dome was completed by the manhole in the center. To prevent water leakage, the inner surface was scraped with a steel bowl to fill the spaces between the bricks, followed by a second layer of plaster and a smooth finish. Finally, on the manhole, the inlet and outlet pipe connections were made, and the entire construction was plastered with cement mortar (figure 4 & 5).

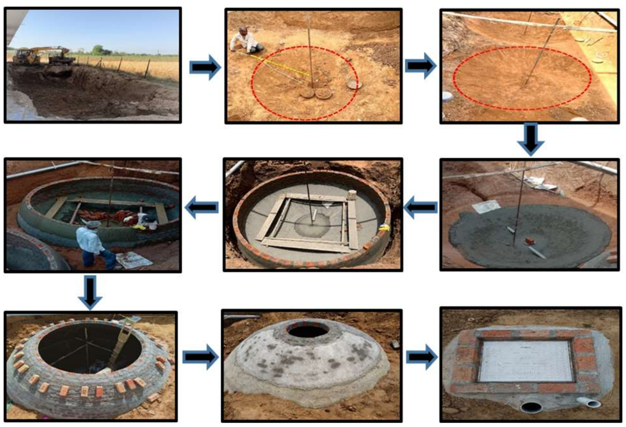

Figure 4: Stepwise construction of Rainwater Harvesting Tank at NIF building.

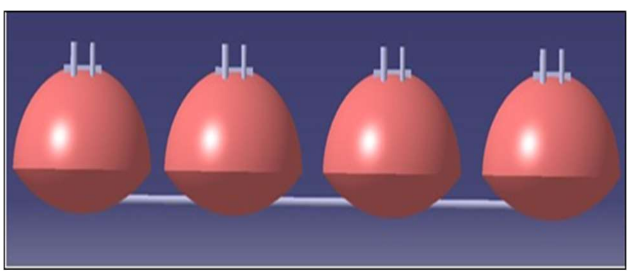

Figure 5: Isometric front view of the rainwater harvesting tank.

Precautions
After construction, there are a few things to be kept in mind, viz. i) avoid planting large trees nearby as their roots might damage underground construction, ii) driving a heavy vehicle over a tank or other heavy object may cause damage to the structure, iii) cleaning and checking the tank for any seepage or cracks on a regular basis has to be undertaken iv) marking the area around the tank for safety has to be undertaken. The absence of appropriate skills to design and construct such subterranean tanks is a key limitation in this approach when compared to conventional ground storage systems. It needs specialized training due to its more difficult construction.

Results and Discussion
Underground dome shaped tanks are considered to be much more cost effective than other types of tanks (Harvesting, 2001). Such underground tanks are larger in size than surface tanks and are appropriate in places where space above ground is limited (Mati, 2012). This brick tank which has a hemisphere shaped top dome and saucer shaped bottom, constructed at NIF, is uniquely conceptualized and takes advantage of geometry when compared to square and rectangle RCC tanks, as it provides better strength and durability to the tank along with its cost effectiveness (5 Rs. / litre). The whole design is derived empirically, the thickness of saucer shaped bottom dome and hemisphere shaped top dome is constructed based on the experience of the artisan. Before laying bottom concrete, the artisan dresses the soil as per the exact profile of the saucer. This is very crucial for effectively transferring the load to prevent the possible damage which may be caused either by load of water or by the negative pressure created from the ground. The least surface area to volume ratio is the main advantage of this dome/sphere shape water tank when compared to the cuboidal tank. So, whenever there is negative pressure due to a higher water table, the same will dissipate due to dome shape, decreasing the chances of leakage and hence adding more life to the tank (Lema et al., 2009). Furthermore, when compared to other expensive water harvesting containers built of masonry, plastic, or RCC, it is a low-cost alternative approach. It is less expensive to build than surface tanks since it does not require reinforcement during construction (Mati, 2012). As subterranean tanks are supported by the earth, the spherical / arch shape design probably provides the necessary strength to hold the water and is safer in earthquakes.

Conclusion
The conservation of heritage, cultural, social or technological, has multiple facets and necessitates a multidisciplinary approach. In these days of

scarcity of potable drinking water, one cannot overlook traditional water conservation techniques of our ancestors. To preserve such traditions, it is imperative to protect and promote artisans' skills through adoption of their work. The work of Chaitanyabhai has set an example for professionals, researchers, students, academics, and others to promote sustainable and inclusive development. The next stage for preserving historical legacy and human cultural values is collaboration between stake holders involving multidisciplinary and multi-level approaches. The NIF's effort to build traditional underground water harvesting tanks, is a small step and is expected to go a long way in promoting this innovative masonry technique by keeping this practicing skills of mason alive. This will also evoke the institutional accountability and leadership to adopt such an approach of sustainable development to mitigate the water scarcity and also in the context of climate change. This opensource design can also be replicated by following the guidelines in the manual and the video that is being prepared by NIF. The design can be replicated anywhere by making minor local adaptations depending on the soil type of the region.

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

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Impact of soil temperature, pH and carbon dioxide on the population and efficiency of fluorescent pseudomonad in the rhizosphere soil of *Pokkali* rice

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ABSTRACT

The present study was aimed at the evaluation of soil temperature, pH and carbon dioxide evolution on the number and efficiency of fluorescent pseudomonads around the root system of *Pokkali* rice at Vytilla in Ernakulam district of Kerala. Two plots (40 m^2) comprising control (without application of *Pseudomonas fluorescens*) and *P. fluorescens* treated plants were used for the field experiment. The isolates of fluorescent *Pseudomonads* or *Pseudomonas fluorescence* were counted and their efficiency was assessed for IAA, ammonia, HCN and siderophore production. Simultaneously, soil temperature, pH, and carbon dioxide evolution were also recorded. A total of 6 fluorescent pseudomonads (VPJU, VPJL, VPAU1, VPAU2, VPAU3 and VPAU4) were found during the crop period. All the isolates produced IAA and ammonia with varying degrees of intensity. Three isolates (VPAU1, VPAU3 and VPAU4) produced HCN, and no microbial isolates produced siderophore. The effect of soil temperature, pH, EC and carbon dioxide evolution was correlated with the number of fluorescent pseudomonads in the soil. The bacteria were significantly afflicted by pH and EC, whereas soil temperature and CO_2 evolution did not show any effect on the number of fluorescent pseudomonads. There was no significant influence of soil temperature, pH, EC and carbon dioxide evolution on indole acetic acid production, ammonia, and HCN production. Inoculated *Pseudomonas fluorescence* did not survive in *Pokkali* rice fields. However, further studies are needed for at least three seasons in Pokkali soils to confirm the results of the present study.

Introduction

Upadhyay *et al.* (2011) reported that saline-tolerant PGPR can alleviate soil salinity stress during plant growth and exopolysaccharide (EPS) secreted by the bacteria. Different bacterial genera have been proposed to alleviate salt stress in plants, such as *Agrobacterium*, *Arthrobacter, Azotobacter, Azospirillum, Bacillus, Burkholderia, Klebsiella, Pseudomonas* (Costa-Gutierrez *et.al.*,2020; Lami, *et.al*.2020), *Rhizobium*, *and Serratia*. Earlier studies have reported that the potential PGPR with plant growth-promoting traits should be able to efficiently colonize the rhizosphere and survive under field conditions for effective use as bioinoculants (Amaya-Gómez *et al.,* 2020). Fluorescent Pseudomonads are the most promising plant growth-promoting rhizobacteria involved in the biocontrol of plant diseases, produce phytohormones, hydrogen cyanide (HCN), siderophores,indole-3-acetic acid (IAA), and antibiotics. Matsuguchi and Sakai (1995) reported that the total bacteria and gram-negative bacterial population did not change significantly but total

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fluorescent pseudomonads increased in saline soils. Few species of *Pseudomonas* can survive under saline condition and improves the plant growth in maize, cotton seedling, and *Cicer arietinum* L. (Mishra *et al.,* 2010). Thus, traits related to bacterial fitness in the environmental settings in which they will be applied must be considered an intrinsic part of the selection process for PGPBs.

Pokkali rice cultivation in Kerala state is considered a sustainable system which is one of the most eco-friendly farming practices in the world. The term '*Pokkali*' refers to a saline-resistant rice variety that is cultivated once a year. The *Pokkali* fields are in low-lying areas which are waterlogged with saline conditions due to the influence of tidal action. Normally, a single-season crop is cultivated during the low salinity phase and it is followed by prawn farming throughout the high saline conditions. Since *Pokkali* cultivation is organic, the use of agrochemicals for plant growth promotion and disease management is not desirable. One of the alternatives for plant protection is the use of Plant Growth Promoting Rhizobacteria (PGPR). However, the population and functional efficiency of the Plant Growth Promoting Rhizobacteria are influenced by both abiotic and biotic factors which affect the performance. Among the abiotic stress factors, climatic, microclimatic and soil parameters could adversely affect the performance of the PGPR. The purpose of this study was to see how soil temperature and soil factors affected the number and efficiency of fluorescent pseudomonads in the rhizosphere of Pokkali rice.

Material and Methods

The present study was aimed at the evaluation of soil temperature, pH and carbon dioxide evolution on the number and efficiency of fluorescent pseudomonads around the root system of *Pokkali* rice at Vytilla in Ernakulam district of Kerala. One plot was maintained as a control (without *P. fluorescens*), while another was treated by the most widely used *P. fluorescens* as PGPR. Pokkali rice was cultivated during thevirippu virip pu season, which spans from May to October (201 7). A talcbased formulation of *Pseudomonas fluor escens* (KAU reference culture) was applied as a seed treatment (10g/kg) and also soil application (2.5 kg/ha).From June to October (2017), the rhizo sphere soils of Pokkali rice were sampled at periodic intervals.The fluorescent Pseudomonads were enumerated by Vidhyasekaran and Rabindran (1996) using King's B and King's A media and in vitro analysis for IAA, ammonia, HCN (Bakker and Schipper,1987), and siderophore synthesis was done at periodic intervals.Soil temperature, pH, EC and CO_2 (Chonnkar *et al.,* 2007) evolution were all recorded simultaneously. The number of bacterial isolates, microclimatic and soil parameters were recorded and CD values were calculated using the software OP STAT. The square root transformations of soil temperature were carried out using one-factor analysis through OP STAT. Correlation studies were conducted to study the effect of soil parameters on the population of fluorescent pseudomonads. To study the effects of soil temperature and soil parameters on the functional efficiency of fluorescent pseudomonads, the software WASP 2.0 was used to cross-aggregate the data through the significance of chi-square statistics.

Results and Discussion

The number of fluorescent pseudomonads around the root systems of *Pokkali* rice before the start of the experiment was absent in both treated and control plots (Table 1). However, one isolate (VPJU) was obtained from an untreated plot in June 2017(30 DAS). Fluorescent pseudomonads were absent in June 2017, September 2017 and October 2017 in the treated plot. The highest population (3×10^3cfu g^{-1}) was recorded in August 2017 (90 DAS) and was absent from July 2017 to October 2017 in the control plot. Characterization of bacterial isolates for identification was studied on Kings' B agar medium. Based on the morphological, cultural and biochemical characteristics, all the isolates were tentatively assigned to the fluorescent pseudomonads. The isolates of fluorescent pseudomonads were screened for their functional efficiency at a monthly interval(Table 2). Among the six isolates (*Pseudomonas* sp (VPJU), *P. aeruginosa* (VPJL), *Pseudomonas* sp (VPAU1), *Pseudomonas* sp (VPAU2), *P.aeruginosa* (VPAU3) and *P.aeruginosa* (VPAU4) of fluorescent pseudomonads, all the isolates produced Indole acetic acid (IAA) and ammonia with varied intensity. Three isolates (VPAU1, VPAU3 and VPAU4) produced hydrogen cyanide (HCN) and

Table 1: Total population of fluorescent pseudomonads in the *Pokkali* soils

Month	Fluorescent pseudomonads (cfu/g)	
	T_1 (Control)	T_2(PF)
Initial population of *P. fluorescens*in main field (May,2017)	ND	ND
June, 2017(30 DAS)	3.3×10^2(2.5)	ND
July, 2017 (60 DAS) (Second inoculation of *P.fluorescens*as soil application)	ND	3.3×10^2(2.5)
August, 2017 (90 DAS and 30 DASI of *P. fluorescens*)	ND	3×10^3(3.5)
September, 2017 (120 DAS and 60 DASI of *P.fluorescens*)	ND	ND
October 2017 (150 DAS and 90 DASI of *P. fluorescens*)	ND	ND

( ): Logarithmic transformed values are given in the parenthesis
ND: Not detected
DAS: Days After Sowing
DASI: Days After Second Inoculation

Table 2: Growth promotion and antagonistic traits of fluorescent pseudomonads.

Month	Isolate code	Indole Acetic Acid (IAA)		Ammonia		Hydrogen Cyanide (HCN)		Siderophore	
		T_1 (Control)	T_2 (PF)	T_1 (Control)	T_2 (PF)	T_1 (Control)	T_2 (PF)	T_1 (Control)	T_2 (PF)
June,2017	*Pseudomonas* sp. (VPJU)	+	a	++	a	++	a	-	a
July,2017	*P. aeruginosa* (VPJL)	a	+++	a	+++	a	-	a	-
August, 2017	*Pseudomonas* sp. (VPAU1)	a	++	a	+++	a	+++	a	-
	Pseudomonas sp. (VPAU2)	a	++	a	++	a	-	a	-
	P.aeruginosa(VPAU3)	a	+++	a	+++	a	++	a	-
	P.aeruginosa (VPAU4)	a	++	a	++	a	++	a	-
September 2017	ND	a	a	a	a	a	a	a	a
October 2017	ND	a	a	a	a	a	a	a	a

ND: Not Detected, PF: *P.fluorescens*
a: No isolate obtained, - Negative, + Low, ++ Medium, +++, High

no isolates exhibited siderophore production. Isolate VPAU3 in August 2017 (90 SAR) followed by isolate VPJL in July 2017 (60 SAR) was the largest producer of IAA. The highest ammonia production was in the case of VPAU1 and VPAU3 isolate in August 2017 (90 DAS-Days after sowing) followed by VPJL isolate in July 2017 (60 DAS-Days after sowing) whereas, VPAU1 isolate in August 2017 (90 DAS) was the highest producer of hydrogen cyanide.

The mean monthly soil temperature recorded at two depths (5 cm and 10 cm) ranged from 27.3 to 33.3°C (Table 3). In the case of the treated plot, at 5 cm, the highest soil temperature (32.8°C) was in October 2017 (150 DAS) and the lowest (27.9°C) in September 2017(120 DAS). However, at 10 cm depth, the highest soil temperature (32.0°C) was in July 2017 (60 DAS) and the lowest (27.3°C) in October 2017 (150 DAS). In the case of the control plot at 5 cm, the highest soil temperature (33.3°C) in July 2017 (60 DAS) and the lowest (27.6°C) in June 2017 (30 DAS). Whereas in the case of 10 cm depth, the highest soil temperature (32.1°C) in July 2017 (60 DAS) and the lowest (27.9°C) in September 2017 (120 DAS). Soil temperature was found to be significantly different in different months. But, soil temperature did not show any significant differences between the treated and control plot. Soil pH and EC and soil respiration were recorded in the rhizosphere at a monthly

Table 3: Mean monthly soil temperature in *Pokkali* rice field at monthly intervals

Treatment	Depth (cm)	Mean soil temperature (ºC)									
		June'17		July'17		Aug'17		Sep'17		Oct'17	
		8:30AM	2:30 PM	8:30AM	2:30 PM	8:30 AM	2:30 PM	8:30 AM	2:30 PM	8:30 AM	2:30 PM
T_1 (Control)	5	27.6	29	29.6	33.3	30.5	31.6	27.9	31.1	28	32.5
	10	30	28.2	29.8	32.1	30.9	31.3	28	29.7	27.9	30.4
T_2(*P. fluorescens*)	5	28	29.6	30.3	32.6	29.2	31.3	27.9	30.8	27.4	32.8
	10	28.6	28.7	30	32	29.6	30.8	28	29.2	27.3	29.3
CD value (Treatment effect)	0.098										
CD value (Effect of soil temperature)	0.139										
CD value (Interaction effect)	0.196										
$T_1 \times T_2$	Probability of t statistic										
5cm (AM)	0.678^{NS}										
5cm (PM)	0.749^{NS}										
10cm (AM)	0.130^{NS}										
10cm (PM)	0.267^{NS}										

NS: Non-Significant

interval (Table 4, 5). The highest soil pH (7.45) in the treated plot was during October 2017 (150 DAS) and the lowest (6.28) was during August 2017 (90 DAS). The highest soil pH (7.23) was during October 2017 (150 DAS) and the lowest (6.17) was in August 2017 (90 DAS) in the case of the control plot. The highest soil EC (3.43 dS/ m) in the treated plot was recorded in July 2017(60 DAS) and the lowest (1.37dS /m) was in August 2017 (90 DAS) whereas, the highest soil EC (3.02dS/ m) during July 2017 (60 DAS) and lowest (1.17dS/m) was in August 2017 (90 DAS) in case of control plot. The soil pH and EC were significantly different in different months and also between the treated and control plot. The highest soil respiration (16.28 mg CO_2/g) in the treated plot was recorded in August 2017 and the lowest (1.54 mg $CO_{2/}$ g) was in July 2017 whereas, the highest soil respiration (15.31mg $CO_{2/}$ g) during September 2017 (120 DAS) and lowest (2.42mg CO_2/g^-) in July 2017 (60 DAS) in the case of control plot. Carbon dioxide evolution was significantly different in different months and did not show any significant differences between the treated and control plot. The optimum growth of microorganisms is enhanced by a set of optimum environmental conditions (Petterson, 2004). Correlation studies of soil temperature, pH, EC and carbon dioxide production with the number of fluorescent pseudomonads revealed that the population was negatively correlated with EC and pH (Table 6). Other parameters did not show any effect on the number of fluorescent *Pseudomonas* sp. In a similar study, Gamliel and Katan (1990) found an inverse relationship between soil pH and the population of fluorescent pseudomonads. The effect of soil temperature, soil pH, soil EC and carbon dioxide evolution was correlated with the functional efficiency of fluorescent pseudomonads. The effect of soil temperature on IAA, ammonia, and HCN production did not show any significant differences. Maximum growth promotion activities of fluorescent pseudomonads were observed in a soil temperature range of 29.2 to 32.6°C. These results conform to the findings reported by Koche (2012) and Sarwar*et al*. (1992). The effect of soil pH on IAA, ammonia and IAA production did not show any significant differences. The soil pH ranged from 6.72 to 7.45. Earlier studies reported that maximum proliferation of the *Pseudomonas fluorescence* occurred at 30ºC and 7.5 pH, whereas the growth of bacteria at lower pH was slower than in soils with neutral pH (Ambardar and Sood, 2010; Baath, 1998) which is contradictory to the present studies, in which maximum growth and growth promotion activities of fluorescent pseudomonads were in a soil pH of 6.28 to 6.89. In a similar study, Baath and Arnebrant (1995) reported that when pH changes from pH 4 to 7, a five-fold increase in bacterial growth were observed. In the present study, soil pH was almost neutral ranging from 6.17 to 7.45, which is favorable for the growth of fluorescent pseudomonads. *Pokkali* soils are acidic saline and the salinity of the soil might be the

Table 4: Soil pH and soil EC in the rhizosphere of *Pokkali*rice at monthly intervals

Month	Soil pH		Soil EC (dS/ m)	
	T_1 (Control)	T_2(*P. fluorescens*)	T_1 (Control)	T_2(*P. fluorescens*)
June,2017	**6.72**	**6.86**	**2.8**	**3.24**
July,2017	**6.75**	**6.89**	**3.02**	**3.43**
August, 2017	**6.17**	**6.28**	**1.17**	**1.37**
September, 2017	**7.22**	**7.28**	**1.51**	**1.67**
October, 2017	**7.23**	**7.45**	**1.62**	**1.72**
Probability of t statistic	**2.486***		**2.489***	
CD value	**0.096**		**0.204**	

***Significant at 5% level**

Table 5: Carbon dioxide evolution in the rhizosphere of *Pokkali* rice

Month	Soil respiration (mg CO_2/g)	
	T_1 (Control)	T_2(*P. fluorescens*)
June,2017	3.34	1.76
July,2017	2.42	1.54
August, 2017	12.70	16.28
September, 2017	15.31	15.79
October, 2017	12.72	10.53
Probability of t statistic	0.837^{NS}	
CD value	1.347	

Table 6: Correlation of micro-climatic and soil parameters with the number of fluorescent pseudomonads

SN	Parameter	Correlation coefficient
1.	**Microclimatic parameter**	
a.	Soil temperature at 5cm (FN)	0.229^{NS}
b.	Soil temperature at 5cm (AN)	0.028^{NS}
c.	Soil temperature at 10cm (FN)	0.358^{NS}
d.	Soil temperature at 10cm (AN)	0.147^{NS}
2.	**Soil parameters**	
a.	Soil pH	-0.486*
b.	Soil EC	-0.223^{NS}
3.	**Microbial activity**	
a.	Carbon dioxide evolution	0.294^{NS}

Table 7: Effect of fluorescent pseudomonads on plant height (cm) at monthly intervals

Treatment	Plant height (cm)				
	June, 2017	**July, 2017**	**August, 2017**	**September, 2017**	**October, 2017**
T_1 (Control)	29.73	53.3	92.5	126.2	127.0
T_2 (*P. fluorescens*)	30.58	55.5	92.7	134.6	135.1
CD value (Treatment effect)	14.243				
CD value (Plant height effect)	14.243				
CD value (Interaction effect)	28.486				
Probability of t statistic	0.868^{NS}				

Mean of 10 replication

Table 8: Effect of fluorescent pseudomonads on the number of tillers in *Pokkali* rice

Treatment	Number of tillers				
	June, 2017	July, 2017	August, 2017	September, 2017	October, 2017
T_1 (Control)	3	23	47	37	31
T_2 (*P. fluorescens*)	4	24	50	38	35
CD value (Treatment effect)	60.154				
CD value (Number of tillers)	85.071				
CD value (Interaction effect)	120.308				
Probability of t statistic	0.348^{NS}				

Table 9: Effect of fluorescent pseudomonads on yield attributes of *Pokkali* rice at harvest

Treatment	Number of panicles/ hill (mean of 10 replication)	Number of grains/panicle (mean of 10 replication)	Chaff (%)	Yield (kg/ha)	1000 grain weight (g)
T_1 (Control)	34	77	18.5	2560	30.4
T_2 (*P. fluorescens*)	47	78	18.1	3230	34.2
Probability of t statistic	0.121 NS	0.952 NS	0.95NS	-	-

reason for the absence of fluorescent pseudomonads under neutral pH. The soil EC ranged from 1.17 to 3.43 in the present studies which were in agreement with earlier studies of the low saline phase in the *Pokkali* field (Shylaraj*et al.,* 2013). The EC fluctuates in *Pokkali* soils depending upon tidal action and the dilution effects of rainfall. The impact of soil EC on IAA, ammonia, and HCN production did not show any significant differences. Rangarajan *et al*. (2001) reported that soil salinity affects the rhizosphere *pseudomonads* population which might be the reason for the non-survivability of *Pseudomonas aeruginosa*. The carbon dioxide production ranged from 1.54 mg /g/day to 16.28 mg g/ day^{-}. The effect of CO_2 evolution on IAA, ammonia, and HCN production did not show any significant differences in the present studies. The effect of fluorescent pseudomonads on the height of the plant and height of the plant and tillers were non-significant (Table 7, 8). However, the highest plant height (135.4) was noticed in October 2017 (150 DAS) in the treated plot. Whereas, the highest number of tillers (50) was in August 2017 (90 DAS) in the treated plot. In a similar study, Deshwal and Kumar (2013) found that all the *Pseudomonas* strains enhanced plant growth in rice plants. *P. fluorescens*(PW-5) produced maximum shoot, root and dry weight. The treatment of *Pseudomonas fluorescens* contributed to the growth of the plant in terms of height and number of tillers. Seenivasan, (2011) also described the positive influence of *Pseudomonas fluorescens* on growth parameters of rice such as plant height, base length, shoot weight, root weight and the number of tillers per hill. Similarly, Salamone*et al.* (2012) reported an increase in the number of tillers in rice plants treated with rhizobacteria that promote plant growth, which is in line with the present studies.Yield parameters such as panicles per hill, number of grain per unit of panicle, chaff percent, thousand-grain weight, nd grain yield were recorded at the time of harvest and grain yield were recorded at the time of harvest (Table 9). It was found that all these parameters were non-significant in both plots. However, panicles per hill, number of grains per panicle, thousand-grain weight and grain yield were higher in the treated plot. Elekhtyarthe (2015) reported that *Pseudomonas fluorescence* (PGPR *Pf*) enhanced the grain yield and its attributes such as number of panicles m^{-2}, number of grains panicle, percentage of filled grains, 1000 grain weight, and grain yield.Using 16S rDNA sequencing, VPAJU, VPAU1, and VPAU2 isolates were identified as *Pseudomonas* sp. and VPAJL, VPAU3 and VPAU4 isolates were identified as *Pseudomonas aeruginosa.* The inoculated *Pseudomonas fluorescence* did not survive during the crop period.

Conclusion

In the present studies, inoculated *Pseudomonas fluorescens* was not found during the entire period of rice growth in Pokkali rice fields. However, the population of other fluorescent pseudomonads was found instead of *Pseudomonas fluorescens* in the rhizosphere soil of Pokkali rice. The population of other fluorescent pseudomonads found in the Pokkali soil was negatively correlated with pH and EC where as, soil temperature and carbon dioxide did not affect the population of fluorescent pseudomonads. The efficiency of fluorescent pseudomonads was not affected by soil temperature, pH, EC and carbon dioxide evolution. Hence, the fluorescent pseudomonads could be a potential PGPR in the Pokkali rice. However, further studies are needed to confirm why *Pseudomonas fluorescens* did not survive in Pokkali soils.

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Conflict of interest

The authors declare that they have no conflict of interest.

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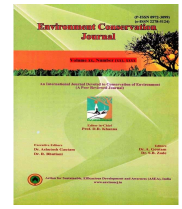

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Efficacy of eco-friendly treatments on yield attributes in Indian mustard (*Brassica juncea* L.) against alternaria blight

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ABSTRACT

Indian Mustard that is emerged as the core oilseed crop is cultivated in the northern regions of India during *Rabi* season. Alternaria blight is one of the most destructive pathogens for Indian Mustard resulting in huge losses in quality and quantity of the produce. A research study was taken up to control the alternaria blight in Indian Mustard with selected eco-friendly treatments by monitoring disease intensity and yield attributes. It is noted that T_2 – *Trichoderma viride* has shown significant results on disease intensity and yield attributes, where disease intensity has significantly minimised in T_2 may be due to the mycoparasitic nature and ability to generate volatile and non-volatile compounds against pathogen with great anti-microbial activity. The results showed that maximum plant height (56.10 cm), test weight (4.11 g) and seed yield (1.21 t/ha) of Indian Mustard with minimum disease intensity (40.21 %) were recorded in the treatment T_2 and followed by T_6 – neem leaf extract @15% that has shown significant results on Alternaria blight.

Introduction

Indian Mustard that belongs to the Brassicaceae family is considered as the "Miracle for the Mankind" due to its wide gamut of benefits. It is also grown under wide agroclimatic conditions across the globe. Its oil is used as the main cooking medium in the northern regions of India which is irreplaceable by any other edible oil and the seeds are of high energy content, having 28-32% oil and relatively high protein content of 28-36% (Fahad, 2012). It also has a versatile use in the medical and tanning industry. Its oilcake is used as cattle feed. The sustainable cultivation of Rapeseed Indian Mustard is ravaged by several destructive fungal pathogens among which the diseases like downy mildew (*Peronospora parasitica*), Alternaria blight (*Alternaria brassicae*), white rust (*Albugo candida*) and powdery mildew (*Erysiphe polygoni*) are of major importance. Alternaria blight caused by *Alternaria brassicae* (Berk.) Sacc. and *Alternaria brassicicola* is one among the important diseases of Indian Mustard with severe losses up to 70% in Rapeseed (*Brassica campestris*) (Kolte 2002); (Kolte *et al.,* 1987), which had reported from across the globe causing 10-70% yield losses in which 15 to 71% losses were reported from India (Kadian and Saharan, 1983; Ram and Chauhan, 1998) depending on the crop species, being high in *Brassica rapa* with 35-40% in Indian Mustard (Chattopadhyay, 2008). These fungal pathogens chase the crops in every stage of the crop growth ultimately resulting in huge losses in the quality of the produce. Several management strategies have merged in recent times which relied primely on chemicals resulting in hazardous effects on mankind and the environment. Considering the above mentioned facts, a research study was planned to study the efficacy of selected eco-friendly treatments on Indian Mustard against Alternaria blight.

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Material and Methods

The present study was conducted at Central Research Field of Naini Agricultural Institute, U.P. The study was conducted with selected treatments mentioned in (table 1) during *Rabi* season in 2021. The field was laid out in random block design with three replications (Fig 4). Infected plant parts with typical disease symptoms are fetched from standing field of Indian Mustard and brought to the laboratory for further studies. Identification of the pathogen based on characteristics was done through microscopic examination. Though, the damage due to *Alternaria brassicae* at initial stages may not be prominent but at later stages, the incidence of the disease becomes very high resulting in great losses. However, in severe cases, the plant may die Jay *et al.* (2019). Pre-post-harvest observations such as disease intensity (%), plant height (cm) at regular intervals, seed yield (t/ha) and test weight (1000 seeds) are recorded from randomly selected plants from each plot.

Table 1: Details of the selected eco-friendly treatments against *Alternaria brassicae*

Treatments		Mode of application
T_1	Control	-
T_2	*Trichoderma viride* @10g/kg	Seed treatment
T_3	Nativo @0.05%	Foliar spray
T_4	Garlic bulb extract @1%	Foliar spray
T_5	*Pseudomonas fluorescens* @1%	Foliar spray
T_6	Neem leaf extract @15%	Foliar spray

Preparation of botanical extracts

The fresh parts from healthy, disease plants were collected and carefully washed in clean water. Thus, obtained plant parts were grounded with the help of mortar and pestled by adding similar amount (100 ml) of sterile distilled water (1:1 w/v). This solution was boiled at 800°C for 10 minutes in hot water bath. Later, the grounded matter was filtered with the help of muslin cloth and followed by filtering with the help of Whatman No.1 filter paper. Thus, obtained plant extract was considered as 100%. Then the extract was diluted by adding required amounts of sterile distilled water as suggested by (Kavita and Dalbeer, 2013).

Morphology of pathogen

The mycelium of *Alternaria brassicae* is septate, brown to brownish-grey, and the conidiophores are dark, septate and arise in fascicles, measuring about 14-74×4-8µm. Conidia are brownish-black, obclavate, borne singly in chains of 2-4, muriform with a long beak. Initially, symptoms were noticed as black spots with yellow hallow, later these enlarge and developed into prominent round spots with concentric rings giving a target board appearance (Fig 3). As the infestation increases, these spots coalesce to form large patches and cause blighting of leaves later defoliate Dharmendra *et al.* (2014). The beak of the pathogen is usually pale brown coloured, short, cylindrical and measures about 9-131µm in length and 3-8 microns in width (Fig 2).

Disease intensity (%)

Assessment of disease was done with the grading method following a grade chart of 0-9 (table 4). Disease intensity (%) is calculated by using the formula given by Wheeler (1969).

$$\text{Disease intensity} = \frac{\text{Sum of all disease rating}}{\text{Total number of rating} \times \text{Maximum disease grade}} \times 100$$

Its disease intensity (%) was recorded at 45, 60 and 75 days after the incidence of *Alternaria brassicae*.

Results and Discussion

Disease intensity (%)

The statistical analysis of the data exhibited (table 2 and figure 3) reveals that disease intensity was notably reduced in treatment T_2 – *Trichoderma viride* @10g/kg (40.21%) followed by T_6 – neem leaf extract @15% (42.58%), T_5 – *Pseudomonas fluorescens* @1% (44.83%) and T_4 – garlic bulb @1% (45.69%) as compared to treated check T_3 – Nativo @0.05% (38.61%) and untreated control T_1 – 48.50%. All the treatments were found to be significant over control but among the treatments, T_5 and T_4 are found to be non-significant to each other. The practice of bio-agents principally *Trichoderma* species has been stated as quite effective against a broad range of pathogens (Chattopadhyay *et al.,* 2002), predominantly as a seed treatment. Similar results with *Trichoderma viride* were reported by Yogita *et al.* (2017) as the most effective bio-agent in reducing the disease intensity. Hence, from the present study, the bio-agent *Trichoderma viride* has proved to be potential enough in restricting the pathogen growth and can

Table 2: Effect of treatments on disease intensity (%) and test weight (g)

Treatments	Disease intensity (%)			Test weight (1000 seeds) - g
	45 DAS	60 DAS	75 DAS	
T_1 – Control	38.60	42.85	48.50	2.52
T_2 – *Trichoderma viride* @10g/kg	31.83	36.76	40.21	4.11
T_3 – Nativo @ 0.05%	29.30	34.52	38.61	4.33
T_4 – Garlic bulb extract @1%	35.90	39.71	45.69	2.87
T_5 – *Pseudomonas fluorescens* @1%	34.74	38.64	44.83	3.15
T_6 – Neem leaf extract @15%	33.40	37.27	42.58	3.92
C.D @ (5%)	1.11	1.12	1.25	1.02
S.Em (±)	0.34	0.35	0.39	0.32

Table 3: Effect of treatments on plant height (cm) and seed yield (t/ha)

Treatments	Plant height (cm)			Seed yield (t/ha)
	45 DAS	60 DAS	75 DAS	
T_1 – Control	38.26	43.75	51.05	0.62
T_2 – *Trichoderma viride* @10g/kg	42.23	46.82	56.10	1.21
T_3 – Nativo @0.05%	43.14	47.28	58.74	1.61
T_4 – Garlic bulb extract @1%	38.82	44.10	52.45	0.92
T_5 – *Pseudomonas fluorescens* @1%	39.22	44.91	53.95	1.09
T_6 – Neem leaf extract @15%	40.44	46.12	55.24	1.11
C.D. @ (5%)	1.34	1.21	1.23	0.42
S.Em (±)	0.42	0.38	0.38	0.54

Table 4: Disease rating scale (Ram Singh Dhaliwal and Bahaderjeet Singh 2020)

Grade	Leaf area covered	Reaction
0	0	Immune
1	Small spots covering 1% or >1% leaf area	Highly resistant
3	Small spots (5mm) covering 1-10% leaf area	Resistant
5	Spots covering 11-25% of leaf area	Moderately resistant
7	Big patches covering 26-50% of leaf area	Moderately susceptible
9	Large spots covering <51% of leaf area	Highly susceptible

be used to manage the Alternaria leaf blight in mustard.

Plant height (cm):

The statistical data presented (table 3) reveal that maximum plant height (cm) observed in treatment T_2 – *Trichoderma viride* @10g/kg (56.10 cm) followed by T_6 – neem leaf extract @15% (55.24 cm), T_5 – *Pseudomonas fluorescens* @1% (53.95 cm) and T_4 – garlic bulb extract @1% (52.45 cm) as compared to treated check T_3 – Nativo @0.05% (58.74 cm) and untreated control T_1 – 51.05 cm. All t the treatments were found to be significant over control and among the treatments, T_6 and T_2 are found non-significant to each other. The results obtained from the present study could be correlated with the studies made by Rini and Sulochana (2006) who evaluated the efficacy of bio-control agents against Alternaria blight when applied alone or in combination. The height of the plant increased greatly in *Trichoderma viride*, may be due to the inhibitory effect of bioagents related to the bio-control agent's hyper parasitism/mycoparasitism feature.

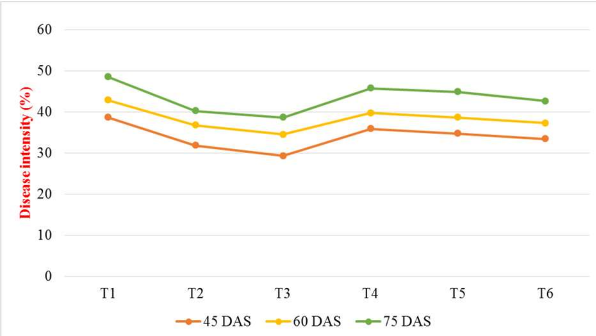

Figure 1: Effect of different treatments on disease intensity (%) of Indian Mustard

Figure 2: Pure culture and microscopic view of *Alternaria brassicae*

Figure 3: Symptoms caused by the pathogen

Figure 4: Experimental trial of Indian Mustard

Seed yield (t/ha):

The analysed data depicted in the table 3 discloses that seed yield considerably increased in treatment *Trichoderma viride* @10g/kg (1.21) followed by T_6 – neem leaf extract @15% (1.11), T_5 – *Pseudomonas fluorescens* @1% (1.09) and T_4 – garlic bulb extract @1% (0.92) as compared to treated check T_3 – Nativo @0.05% (1.61) and untreated control T_1 – 0.62. All treatments found to be merely equal to control but the treatments (T_1 and T_4), (T_4, T_5, T_6 and T_2), (T_5, T_6 and T_2), (T_6 and T_2) and (T_2 and T_3) are found non-significant among themselves.

Test weight (g):

The analysed data and presented in the (table 2) explain that test weight considerably increased in treatment T_2 – *Trichoderma viride* @10g/kg @ (4.11) followed by T_6 – neem leaf extract @15% (3.92), T_5 – *Pseudomonas fluorescens* @1% (3.15) and T_4 – garlic bulb extract @1% (2.87) as compared to treated check T_3 – Nativo @0.05% (4.33) and untreated control T_1 – 2.52. All the treatments were found to be significant over control and the treatments (T_1, T_2 and T_5), (T_4 and T_5), (T_5, T_6 and T_2), (T_6, T_2 and T_3) and (T_2 and T_3) were found not significant themselves.

Similar discoveries were also reported by Yogita *et al.* (2017) *Trichoderma viride* was proven as the most effective bio-agent recorded maximum yield (t/ha). *T. Viride* seems to possess an antagonistic effect on fungal plant pathogens due to its parasitic nature, competition for space, nutritional supply and antagonistic chemical produced. It has been involved in the production of antibiotics like Trichodermin, extracellular enzymes such as chitinase, cellulase and unsaturated monobasic acids like dermadine and peptides that can harm the plant pathogens Mamgain *et al.* (2013) and Rehman *et al.* (2013).

Conclusion

The results revealed that minimum disease intensity with maximum plant height (cm), test weight (g) and seed yield (t/ha) are observed in treatment T_2 – *Trichoderma viride* @10g/kg. In a view to cutdown the indiscriminate use of the chemical fungicides and their uncertainties on the environment and mankind, such an attempt was made to evaluate the efficacy of the bio-control agents and botanicals on the Alternaria blight of rapeseed. Thus, it is evident from the present study that the application of bio-control agents and botanicals is more efficient in defeating pathogen growth and it is eco-friendly to utilise. These can provide a way better and effective management practice for the pathogen. However, further freedom is there for more research trials for better results in a broader view.

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

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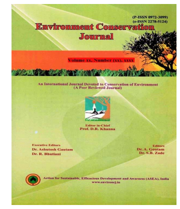

Irrigation scheduling and soil moisture use on growth and yield of late sown wheat (*Triticum aestivum* L.) varieties

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ABSTRACT

The present investigation was intended to determine the growth , yield capacity and soil moisture use of different late sown varieties of wheat (*Triticum aestivum* L.) under different irrigation schedules. is the present study was undertaken with an objective to evaluate the varietal performance under less moisture availability. To fulfil the aim the field experiment was conducted during winter (*Rabi*) season of 2019-20 with the combination of three irrigation schedules as main plot, and five late sown wheat varieties as sub plot factor, with three replication. Significant impact of three irrigations on crop growth, yield and total soil moisture use was observed over two and one irrigation schedule. Among varieties, WR-544 reported superior growth and yield attributes, where the grain yield was 11.5–15.0% more over MACS-6222, HS-562 and HD-3086, and was at par with HI-1544. Better establishment and tillering capacity of the varieties HI-1544 and WR-544 resulted in efficient moisture utilisation starting from CRI to harvest stage compared to the variety MACS-6222. Irrigation scheduling at the critical moisture stages resulted in efficient soil moisture use by the late-sown varieties HI-1544, WR-544, HS-562 and HD-3086.

Introduction

Wheat (*Triticum aestivum* L.) is the most important crop among all the cereal food grains used for consumption in the world. The production potential of the world was 760.9 million tonnes (M t) from an area of 219.0 million hectares (M ha) and with a productivity of 34.7 q/ha (FAOSTAT, 2020). On the other hand, the wheat area in India was 31.4 M ha, with a production of 107.9 M t and a productivity of 34.4 q/ha (Indiastat, 2020). Green revolution has paved the way for evolution of high yielding wheat varieties which improved the production levels of wheat exponentially. Despite the fact that wheat is second most produced crop besides rice in India, the production is plagued by many factors, of which the most important are inadequate irrigation and poor and imbalanced crop nutrition. Water is essential at every developmental phase starting from seed germination, crop maturity to the harvesting of wheat, and also shares a positive correlation between grain yield and irrigation frequency (Kumar *et al.*, 2015). Efficient water management, being one of the good agronomic management practices, leads to improved crop production and higher yield (Singh *et al.*, 2018). Deficit irrigation considerably reduced agronomic traits as well as grain yield of the wheat cultivars (Moghaddam *et al.*, 2012). Varietal selection is also the most important factor apart from irrigation scheduling to be decided by the farmers before taking up the crop. Improved performance of the newly developed wheat varieties under various management practices can maximize the economic returns under local growing conditions (Sapkota *et al.*, 2007). The shortened growing period adversely affects all growth stages in late sown wheat, such as tillering,

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flowering and grain filling. The reduced optimum growth coupled with an increase in temperature leads to leaf senescence and force maturity, resulting in a low photosynthetic rate that is insufficient to satisfy the carbon economy of plants (Sharma *et al.*, 2006). Combination of irrigation scheduling and varietal relation help in selecting best variety under late sown condition of eastern Uttar Pradesh, wherein wheat sowing gets delayed due to late harvest of long duration rice varieties sown in the prior rainy season.

Material and Methods

A field experiment was conducted at the Agricultural Research Farm, BHU, Varanasi, U.P., India during *Rabi* season of 2019-20, under neutral sandy clay loam soil. Total rainfall received during the crop growing period was 32.4 mm. The maximum rainfall (13.0 mm) obtained during the 4th standard week (22-28 of January 2019) and it didn't coincide with irrigation schedules. United States Weather Bureau (USWB) open pan evaporimeter recorded average evaporation (during the crop growing period) wide-ranging from 1.2 to 10.0 mm per day and it was recorded lowest 1.2 mm in 52th week of December 2018. The experiment was laid out in a split plot design having 15 treatment combinations. Three irrigation schedules viz., I_1; one irrigation (CRI stage), I_2; two irrigations (CRI and late jointing stages) and I_3; three irrigations (CRI, late jointing and milking stages) were assigned to main plot and five wheat varieties (viz., MACS-6222, HS-562, HD-3086, WR-544 and HI-1544) were kept in sub plots. The treatments were allocated to main plot and subplot randomly and replicated three times. Soil of the experimental field was low in available N and P, and high in available K. The growth attributes of plant were recorded at 30, 60, 90 DAS and at harvest and yield attributes at harvest. Soil moisture studies were started right from sowing and continued up to maturity of wheat crop. The soil moisture content under all the treatments of three replications was determined before irrigation and 24 hours after irrigation from 0-15, 15-30, 30-60 and 60-90 cm. The soil samples for soil moisture studies were taken with the help of screw auger. The water use efficiency was calculated by using formulae

$$\text{WUE (kg/ha-mm)} = \frac{Y}{CU}$$

Where,

WUE = water use efficiency (kg/ha-mm)
Y = grain yield (kg/ha)
CU = Consumptive use of water (mm)

$$\text{CU} = \frac{M_{1i} - M_{2i}}{100} \times \text{B.Di} \times \text{depth of soil (mm)}$$

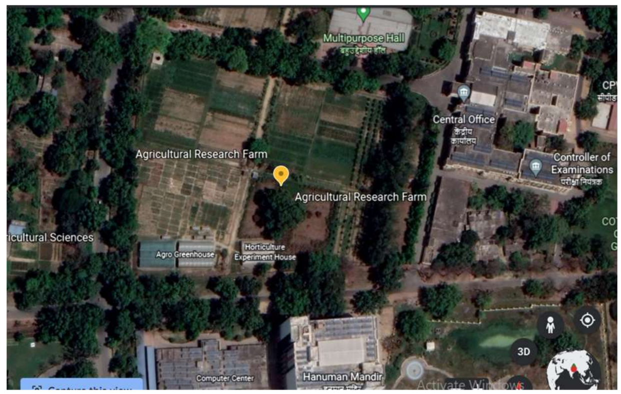

Figure 1: Geotagged image of Agricultural Research Farm IAS, BHU, Varanasi.

Results and Discussion

(A) Growth attributes

The observations showed three irrigations scheduled at CRI, late jointing and milking stages, recorded significantly taller plants (102.01 cm), LAI (4.51) and shoot biomass (605.56 g) over two irrigations (97.64 cm, 4.17 and 555.65g) scheduled at both CRI and late jointing stages and one irrigation scheduled at CRI (88.88 cm, 3.26 and 446.13 g), respectively (table 1). This might be due to more availability of water at three irrigations which enhanced nutrient uptake and metabolic activities translocation and assimilation of plant (Mubeen *et al.,* 2013; Mitra *et al.,* 2015; Kumar *et al.*, 2015).WR-544 was significantly taller than rest of varieties except HI-1544. In terms of LAI, HI-1544 was significantly superior over rest of the varieties except WR-544 and HD-3086 (table 1). WR-544 recorded (563.92g) significantly higher shoot biomass over rest of the varieties except HI-1544 (557.25 g). The differences in plant height, LAI and shoot biomass among various varieties may be due to dry matter accumulation and their genetic constitution. These results are in line with those of (Moghaddam *et al.*, 2012; Abdrabbo *et al.*, 2016).

(B) Yield attributes

(i) Effective tillers and spike length

The higher number of effective tillers (280.43 m^{-2}) and spike length (15.05 cm) were recorded with three irrigations while at par with two irrigations (270.13 m^{-2} and 14.38 cm) and significantly superior over one irrigation (250.33 m^{-2} and 12.22 cm). This might be due to better growth attributes and nutrient uptake consequently less or no tiller mortality with optimum moisture supply when three irrigations were applied (Abdelraouf, *et al.,* 2013; Ali *et al.*, 2014; Kumar *et al.*, 2015). WR-544 recorded effective tillers (277.00 m^{-2}) and spike length (14.78 cm) significantly higher over rest of varieties except with HI-1544 (276.56 m^{-2} and 14.57 cm). Variation in effective tillers and spike length were might be due to better growth attributes and genetic potential of the variety (Abdelraouf *et al.,* 2013; Nayak *et al.*, 2015).

Table 1: Effect of irrigation schedules on growth, yield attributes, straw yield and harvest index of late-sown varieties.

Treatments		Plant height at harvest (cm)	LAI (90DAS)	Shoot biomass at harvest (g m^{-1})	Effective tillers (m^{-2})	Grains $spike^{-1}$	Spike length (cm)	Test Weight (g)	Straw yield (q/ha)	Harvest index (%)
Irrigation	I_1	88.88	3.26	446.13	259.33	38.10	12.22	34.89	44.60	36.78
	I_2	97.64	4.17	555.65	270.13	42.28	14.38	35.38	48.77	37.86
	I_3	102.01	4.51	605.56	280.43	44.66	15.05	39.60	52.61	39.40
	SEm±	1.03	0.08	8.97	2.98	0.66	0.29	0.88	1.25	0.79
	CD ($P \leq 0.05$)	4.04	0.32	35.21	11.69	2.61	1.13	3.44	4.92	3.15
Varieties	V_1	91.94	3.95	519.45	264.22	40.93	13.04	34.49	47.74	36.72
	V_2	94.14	3.75	520.98	266.56	40.41	13.44	36.75	46.67	37.26
	V_3	99.23	4.20	557.25	276.17	43.17	14.57	38.11	50.96	38.97
	V_4	94.95	3.98	517.30	265.89	40.07	13.58	35.68	46.93	38.10
	V_5	101.07	4.04	563.92	277.00	43.82	14.78	38.08	50.99	39.02
	SEm±	1.63	0.08	10.58	3.28	0.98	0.35	0.84	1.11	0.90
	CD ($P \leq 0.05$)	4.74	0.24	30.88	9.57	2.85	1.03	2.45	3.25	2.66

I_1; one irrigation (CRI stage), I_2; two irrigations (CRI and late jointing stages) and I_3; three irrigations (CRI, late jointing and milking stages). Five wheat varieties V_1: MACS-6222, V_2: HS-562, V_3: HD-3086, V_4: WR-544 and V_5: HI-1544

(ii) Grains $spike^{-1}$ and 1000 grain weight

The significant highest numbers of grains $spike^{-1}$ and 1000 grain weight were recorded under three irrigation schedules (44.66 and 39.60 g) over two irrigations (42.28 and 35.38 g) and one irrigation (38.10 and 34.89 g), respectively. This might be due to better growth attributes, (like LAI) and nutrient uptake with optimum moisture supply. The lowest number of grains $spike^{-1}$ recorded with one irrigation. It might be due to inadequate moisture at the time of jointing and grain filling stages, caused forced maturity and poor, and shrivelled light weighted grains $spike^{-1}$ (Wang *et al.*, 2016; Abdrabbo *et al.*, 2016). WR-544 (43.83 and 38.08 g) and HD-3086 (40.07 and 38.11 g) were at par with each other and significantly superior over rest of varieties in response of grains $spike^{-1}$ and 1000 grain weight, respectively. It might be due to genetic potential and environmental conditions under late sown condition. Such explanations were also reported by Verma *et al.* (2016); Bachhao *et al.* (2018).

(B) Yield

(i) Grain yield

The significant highest grain yield was recorded with three irrigations (34.20 q/ha) which was 13.19% and 23.95% more over two irrigations and one irrigation, respectively (table 2). The increase in grain yield was to be due to cumulative effect of vegetative growth and yield attributes (Hwary *et al.*, 2011; Abdrabbo *et al.*, 2016; Sharma *et al.*, 2017). WR-544 (32.70 q/ha), recorded significantly higher (15.0, 14.5, and 11.5 %) grain yield over HS-562, MACS-6222, and HD-3086, respectively except HI-1544 (32.43 q/ha). The maximum yield of WR-544 and HI-1544 was attributed due to their higher biomass accumulation, higher number of tillers and better yield attributes. These conclusions were similar to that of Ahmad and Kumar (2015).

Critical assessment of data revealed that interaction effect (I × V) between irrigation schedules and varieties on grain yield was found to be significant and presented in table 2.The grain yield recorded significantly highest in combination of WR-544 (36.93 q/ha) with three irrigations over all other treatment combinations, except combination of HI-1544 (33.88 q/ha) × three irrigations and MACS-6222 × three irrigations. However, treatment combination at two irrigations; HI-1544 (33.88 q/ha) with two irrigations and WR-544 (32.55 q/ha) with two irrigations being at par with each other and found to be significantly higher over rest of treatment combinations. Treatment combination at one irrigation; MACS-6222 × one irrigation recorded significantly lowest grain yield (23.53 q/ha) than HI-1544 × one irrigation, but remained at par with rest of combinations. (Aslam *et al.*, 2014; Abdelkhalek *et al.*, 2015)

Table 2: Interaction effect of irrigation schedules and varieties on grain yield (q/ha)

Treatments (I × V)	I_1	I_2	I_3	**Varietal Mean**
MACS-6222	23.53	25.33	34.95	27.94
HS-562	23.90	26.66	32.83	27.80
HI-1544	30.11	33.30	33.88	32.43
HD-3086	23.89	30.59	32.38	28.95
WR-544	28.63	32.55	36.93	32.70
Irrigation schedule mean	26.01	29.69	34.20	

	SEm±	**CD ($P \leq 0.05$)**
Two varieties at the same irrigation schedules	1.17	2.41
Two irrigation schedules at the same or different varieties	1.76	4.06
Irrigation schedules (I)	0.68	2.65
Varieties (V)	0.68	1.97

I_1; one irrigation (CRI stage), I_2; two irrigations (CRI and late jointing stages) and I_3; three irrigations (CRI, late jointing and milking stages).

(ii) Straw yield and harvest index

The maximum straw yield was recorded with the three irrigations (52.61 q/ha) which was significantly superior over two irrigations and one irrigation (table 1). This might be due to combined effect of vegetative growth attributes viz., plant height, shoot dry matter and tillers production. WR-544 (50.99 q/ha) being at par with HI-1544 (50.96 q/ha), and significantly higher than rest of varieties. Varieties WR-544 and HI-1544 were efficient in utilizing biomass towards grain formation as evident from its highest harvest index (39.1%). These findings are in line with those of Tomar *et al.* (2014) and Verma *et al.* (2016). Recorded data clearly indicated that the irrigation schedules had no significant effects on the harvest index. Variety WR-544 (39.02%) being at par with HI-1544 (38.97%), HD-3086 (38.10%), and HS-562 (37.26%) and MACS-6222 (36.72%), respectively (table 1).

(C) Stage wise soil moisture use and water use efficiency

The total soil moisture use due to three irrigations scheduled was found to be significantly higher than two irrigations and one irrigation schedule (table 3). It was due to more demand of water by crop and optimum supply of water through irrigation. Similar results were found by Shivani *et al.* (2003); Mishra and Kushwaha (2016). Stage wise moisture use between CRI - late jointing and milking- harvest by HI-1544 was found significantly higher than MACS-6222 only. However, stage wise moisture use between late jointing - milking stage was found significantly higher in variety WR-544 over rest of varieties. In case of total moisture use, variety WR-544 recorded significantly higher in total moisture use over other varieties except HI-1544.

Table 3: Effect of irrigation schedules on stage wise soil moisture use (mm) and water use efficiency (kg/ha-mm) by wheat varieties

Treatment	Moisture use(mm) and water use efficiency (kg/ha-mm)					
	Sowing to CRI	CRI to late jointing	Late jointing to milking	Milking to harvesting	Total moisture use	WUE
Irrigation schedules (I)						
CRI	44.55	74.38	66.92	42.12	230.98	11.26
CRI and late jointing	44.11	76.81	81.61	62.98	268.51	11.54
CRI, late jointing and milking stage	45.00	81.40	95.87	81.25	306.52	11.62
SEm±	0.42	1.05	1.69	0.97	2.47	0.18
CD ($P \leq 0.05$)	NS	4.11	6.63	3.79	9.69	NS
Varieties (V)						
MACS-6222	44.12	72.09	77.96	56.25	255.22	11.11
HS-562	44.76	77.63	73.94	63.19	264.31	10.97
HI-1544	44.68	80.49	81.91	64.62	276.50	12.06
HD-3086	44.85	79.40	79.27	61.98	270.30	11.19
WR-544	44.35	78.04	85.24	64.57	277.00	12.04
SEm±	0.50	1.34	1.33	1.32	2.17	0.26
CD ($P \leq 0.05$)	NS	3.92	3.88	3.87	6.34	0.76

The maximum WUE was recorded in HI-1544 (12.06 kg/ha-mm) which was at par with WR-544 (12.04 kg/ha-mm) and significant higher over rest of varieties. This might be due to proportionate increase in grain yield per unit consumptive use of water from the soil by the varieties during growing period. (Bikrmaditya *et al.*, 2011; Singh *et al.,* 2012). Regression analysis between grain yield and total soil moisture use resulted in strongly positive correlation. There is an increase of 0.119 q/ha in wheat grain yield per unit total soil moisture utilization at harvesting stage (figure 2).

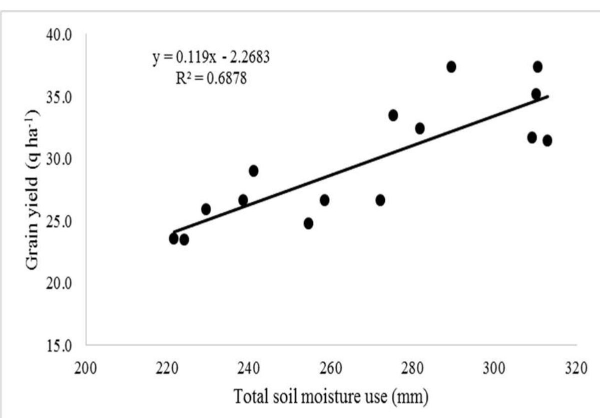

Figure 2: Relationship between total soil moisture use and grain yield of wheat.

Conclusion

Irrigation scheduling resulted in significant variation among the growth parameters as well as yield parameters. Application of three irrigations at CRI stage, late jointing and milking stage resulted in significant increase in growth attributes *viz*. plant height, tillers m^{-1}, LAI and shoot biomass than two irrigations and one irrigation treatments during crop growth period. Also, the yield attributes, yield and total soil moisture use recorded were reportedly had a marked difference with three irrigation schedules. Among the varieties used, WR-544 being at par with HI-1544 recorded higher growth attributes *viz*. plant height, LAI, tillers m^{-1}, 1000 grain weight and shoot biomass. WR-544 being at par with HI-1544 also exhibited significant effect on yield attributes, but also recorded higher grain yield which was followed by "HI-1544". Cultivation of wheat varieties WR-544 and HI-1544 with assured irrigation thrice at CRI stage, late jointing and milking stage can be beneficial with efficient soil moisture use and higher yields under late-sown conditions.

Conflict of interest

The authors declare that they have no conflict of interest.

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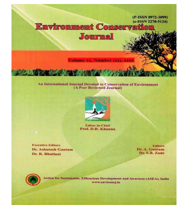

Analysis of changes in land use and land cover in Central Kashmir of the Great Himalayas using geospatial technologies

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ABSTRACT

Remote sensing data may identify changes in land use and land cover (LU/LC). Land cover changes include changing from one land cover category to another and changing conditions within a category. LU/LC change is an essential aspect of current environmental management techniques. It is vital for land conservation, sustainable development, and water resource management. The study's goal is to investigate changes in land use and land cover in Central Kashmir of the Great Himalayas. This study used LISS III 23.5 m resolution images between 2000 and 2017 to detect land cover change. Changes were identified using Arc GIS 10.4.1. This method identified seven land use/cover classes: water bodies, glaciers/snow; forests; agriculture; horticulture; wasteland/barren; and built-up/utility. Ground truthing was done to test the accuracy of the preprocessing and categorization of the images. This study found that in the previous 17 years, all land use classes in Central Kashmir have changed significantly. Remote sensing and Geographic Information Systems (GIS) have been used to better comprehend the consequences of physical changes. The study's findings can be used to design resource conservation measures. To protect unwanted LU/LC change in Central Kashmir, proper land management methods, integrated watershed management, and community engagement should be encouraged.

Introduction

Land use refers to the employment and management approaches that human agents or land managers envision for the land cover in order to exploit it. It reflects anthropogenic accomplishments such as industrial zones, residential zones, agricultural fields, grazing, logging ,and mining Land cover, on the other hand, refers to the characteristics of the earth's land surface captured in the distribution of vegetation, water, desert, and ice, as well as the immediate subsurface, which includes biota, soil, topography, surface and groundwater, and structures created solely by human activities like mine exposures and settlements (Lambin *et al*., 2003; Ahamad *et al.,* 2022). Land use connects the land cover to anthropogenic activities that alter the land. Land cover changes take two forms: conversion from one category of land cover to another and modification of condition within a category (Meyer and Turner-II 1991). Land cover change stemming from human land uses represents a major source and a major element of global environment change (William *et al*., 1994; Houghton *et al.,* 2012). The most potent contemporary forces that drive LU/LC change are

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increasing human activities and climatic change (Xu 2008). However, the same land cover change can have different sources in different areas (Meyer and Turner-II 1991; Salazar *et al*., 2015). LU/LC change is a key component of current systems for managing natural resources and monitoring environmental changes. Conventional ground survey methods were time-consuming, arduous, costly, and manpower-intensive, making them unsuitable for monitoring dynamic changes over a short period of time because of time constraints. However, the exorbitant costs of such surveys led to their downfall in the late 1960s. Change detection based on remote sensing data has become an essential technique for providing appropriate and wide-ranging information to various decision support systems for environmental sustainability and management of natural resources. Advances in the ability of geographic information systems to incorporate social, physical, and remote sensing information have also been significant. This is often done to understand how processes at local scales are nested in regional, national, and global dimensions. Collecting accurate and timely information on LU/LC is crucial for LU/LC change research (Giri *et al*., 2005). Repeated satellite images can allow for timely and consistent estimates of changes in LU/LC trends over large areas and have the additional advantage of ease of data capture into GIS, which can facilitate the analysis and presentation of such data (Shalaby and Tateishi 2007) greatly. In the Himalayan region, use of this tool was introduced in the mid-eighties (Singh *et al*., 1985) to identify landscape/land-use patterns, mapping, monitoring and change detection (Joshi *et al*., 2003).

Material and Methods

This study emphasizes land use/land cover change detection in the Central Kashmir Himalayas. The LU/LC analysis was studied using a comprehensive methodological framework that included the generation of various data sets. Remote sensing data, satellite imageries (LISS III 23.5 meters), and image processing techniques were used between 2000 and 2017 to ascertain LU/LC change detection. The changes were determined using the Arc GIS 10.4.1 software. Employing Supervised Classification, it was possible to categorize land use and land cover into seven distinct classes. Figures 1 and 2 offer a general overview of the various methodological steps described in detail below.

The Central Kashmir Valley's boundaries were determined using ASTER DEM, which comprises three districts and six watersheds. The details of the datasets used were downloaded from the various websites given in table 1. In order to generate the LU/LC map using satellite images, a LU/LC classification technique has been used. The appropriate number of LU/LC classes depends on the requirements of a specific project for a specific application (Saha *et al*., 2005). Seven major LU/LC classes were chosen for mapping the entire study area viz; waterbodies/wetlands, glacier/snow, forests, agriculture, horticulture/plantation, wasteland/barren, and built-up/utility. Following the development of the classification scheme, one of the most extensively used image classification techniques supervised classification, was used to map all of the land use/land cover classes to assess the land use pattern and its geographic variation using widely available satellite data. Prior to choosing training samples, the empirical approach of satellite data, Google Earth photographs, and toposheet of the subject region were thoroughly explored. The minimum number of training samples for most of the classes was 100. Before being utilized as an input for any applications, the classified images were further checked for accuracy. Individual accuracy evaluation parameters can be used in the study to evaluate the model performance of a specific category or class of interest. The accuracy of this study was assessed using an error matrix.

Table 1: Datasets used for the present study

S#	Data Set	Source
1.	ASTER DEM (30 m)	https://search.earthdata.nasa.gov/search
2.	LISS III (23.5 m)	https://bhuvan.nrsc.gov.in/
3.	SOI (Toposheets) Scale 1:50,000	https://www.surveyofindia.gov.in/

Results and Discussion

Land use/land cover analysis – 2000

The study's LU/LC analysis included a period of nearly 17 years, spanning from the year 2000 to

2017. The time spans have been chosen based on the temporal representation and the availability of relevant remote sensing data. It was found that the research region in 2000 had seven different LU/LC classes as given belowin figure 3. In the study area, forest was the most prominent category of land cover with 1339.20 km^2, constituting more than 40 % of the total Central Kashmir Himalayan area. The area under Snow/Glacier was 784.83 km^2 (23.85 %), while Agriculture accounts for 515.72 km^2 (15.67 %). Horticulture covered 293.81 km^2 (8.93 %), and Wasteland/Barren is spread over an area of 215.31 km^2 (6.54 %) of the total area as shown in table 2 and figure 4. The area under Waterbody/Wetland/Water and Built-up/Utility constituted 2.40 % and 1.90 %, respectively of the total area of Central Kashmir Himalayas (Figure-3 & 4) (Table-2). A kappa value of 0.721 and an overall classification accuracy of 82.3 % were observed in the analysis. In light of the substantial kappa coefficient, the classified image is considered suitable for further investigation.

Table 2: Land Use/Land Cover statistics from 2000 to 2017

LU/LC	2000		2017		Relative Change	
	km^2	%	km^2	%	km^2	%
Waterbody/Wetland	79.00	2.40	69.66	2.12	9.34	-0.28
Snow/Glacier	784.83	23.85	799.98	24.31	-15.15	0.46
Built Up/Utility	62.64	1.90	170.01	5.17	-107.38	3.26
Forest	1339.20	40.70	1099.02	33.40	240.18	-7.30
Horticulture/Plantation	293.81	8.93	463.19	14.08	-169.39	5.15
Agriculture	515.72	15.67	357.15	10.85	158.58	-4.82
Wasteland/Barren	215.31	6.54	331.48	10.07	-116.17	3.53

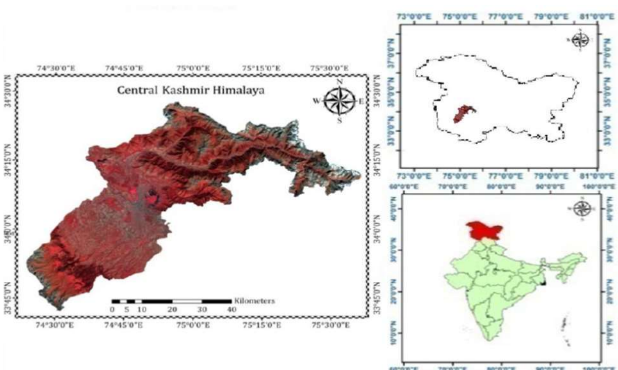

Figure 1: Location map of the study area

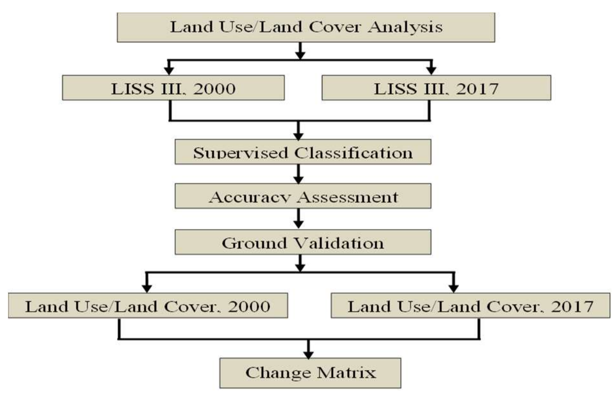

Figure 2: LU/LC change matrix methodology

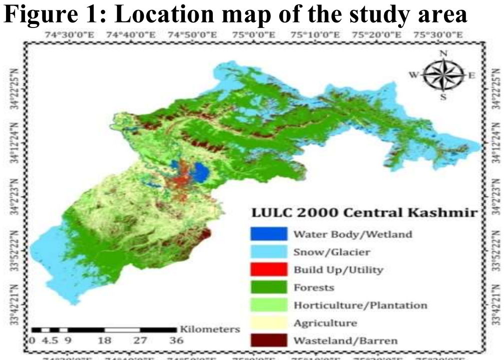

Figure 3: LU/LC of Central Kashmir generated from LISS III 2000

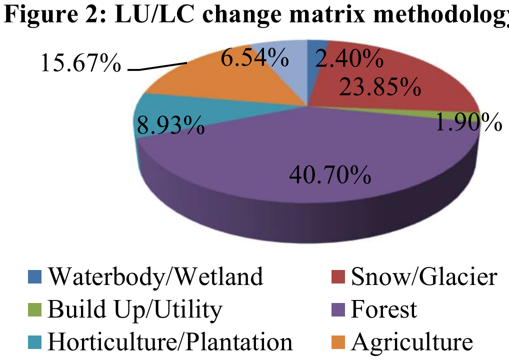

Figure 4: Percentage area of LU/LC categories, 2000

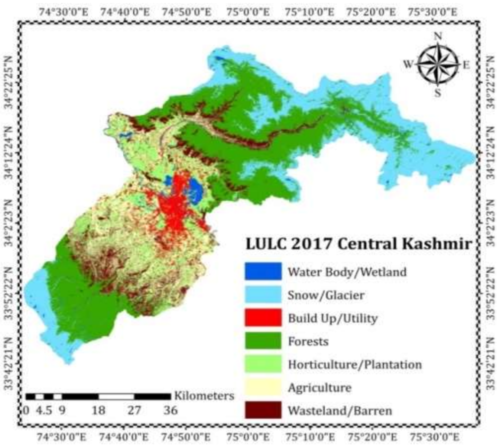

Figure 5: LU/LC of Central Kashmir generated from LISS III 2017

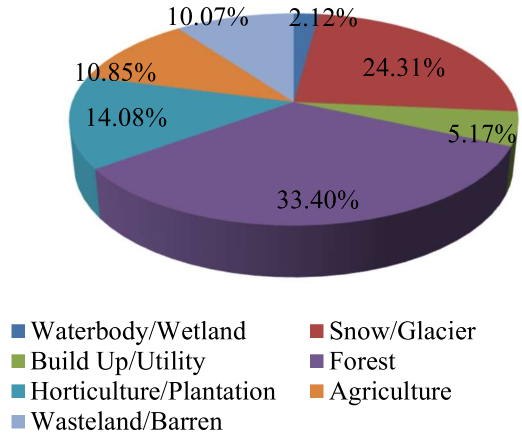

Figure 6: Percentage area of LU/LC categories, 2017

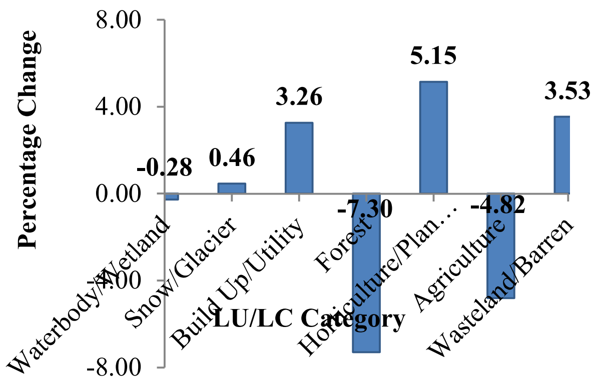

Figure 7: Percentage change of LU/LC categories, 2000 & 2017

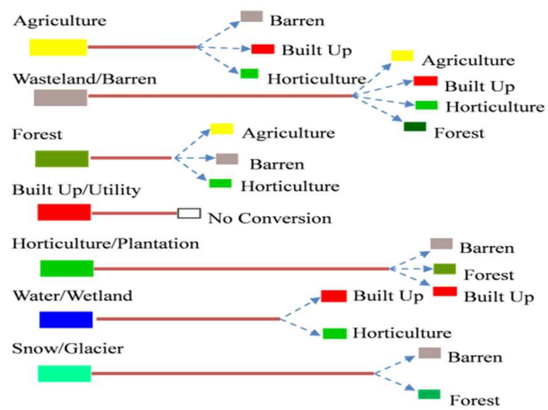

Figure 8: Analysis of conversion of different LU/LC categories of Central Kashmir

Land use/land cover analysis – 2017

It was revealed in 2017 that there were seven distinct classes of land use and land cover (LU/LC) in the Central Kashmir as shown in figure 5. Forests were again the most prevalent land cover category, covering 1099.02 km^2 (33.40 %). Snow/Glaciers occupied about 799.98 km^2(24.31 %). Horticulture constituted 463.19 km^2(14.08 %) while Agriculture covered an area of 357.15 km^2(10.85 %), followed by Wasteland/Barren as 331.48 km^2 (10.07 %). However, Built-up covered an area of 170.01 km^2 (5.17 %) while the Waterbody/Wetland was 69.66 km^2(2.12 %) to the total area of the Kashmir Himalayas (Figure-5 & 6) (Table-2). The image categorized with an accuracy of 84.7% and a kappa value of 0.742. The kappa coefficient is substantial, indicating that the categorized imagery is appropriate for further analysis.

Change detection analysis of land use/land cover for Central Kashmir Himalayas

Comparisons of post-classification LU/LC change have showed significant changes in several LU/LC categories. The area under Horticulture/Plantation, Built-up/Utility, and Wasteland/Barren has continuously increased while the area under Forest and Agriculture has constantly shown a decreasing trend from 2000 to 2017. Table 2 shows that the forest area has decreased from 1339.20 km^2 in 2000 to 1099.02 km^2 in 2017, thus registering a decline rate of 7.30 % as reflected in figure 7. The agricultural class has also shown a decreasing trend from 2000 to 2017. The area has decreased from 515.72 km^2 to 357.15 km^2,with an area loss of 158.58 km^2 (4.82 %) (Table-2). Similarly, the Built-up category increased from 118.98 km^2 in 2000 to 186.73 km^2 in 2017 (Table-2), indicating a 3.26 % increase (Figure-7). From 2000 to 2017, there had been an increase in horticulture class as well. 169.39 km^2 have been increased to the area, from 293.81 km^2 to 463.19 km^2 (Table-2) (5.15 %). The area under Water in 2000 was 79.00 km^2 and got reduced to 69.66 km^2 in 2017 with a decrease of 9.34 km^2 (-0.28 %) (Figure-7, Table-2).Glaciershave also shown a decreasing trend from 2000 to 2017. The area in 2000 was 784.83 km^{2}while it got reduced to 799.98km^2 in 2017 with a decrease of 118.48 km^2 (-0.89 %) (Figure-7, Table-2).

Conversion of land use/land cover for Central Kashmir Himalayas

The analysis of the study has revealed that different LU/LC classes have shown conversion into different LU/LC categories. Agriculture showed conversion into three LU/LC categories: Barren, Built-up, and Horticulture. Barren category got changed into four LU/LC classes Agriculture, Built-up, Horticulture, and Forest. The land cover category of the forest showed the conversion into three LU/LC categories, viz. Agriculture, Barren, and Horticulture, while the Built-up category led no conversion. Horticulture showed the conversion into three Barren, Forest, and Built-up categories. Water bodies/wetlands got changed into Built-up, Agriculture, and Horticulture, while Glacier/Snow showed the conversion into two categories of Barren and Forest can be observed in figure 8.

Conclusion

It can be concluded from the initial results that the Central Kashmir Himalaya has indeed changed to LU/LC from the year 2000-2017. Out of all seven LU/LC classes, significant changes have occurred in forest areas, which showed a continuous decrease, and at the same time, Horticulture/Plantation land showed an increase of 5.15%. All these results infer and establish the apprehensions of the locals that the area is turning more into horticulture and arable area. This investigation was prompted by the local community's concerns about the changing landscape. This study illustrates how remotely sensed data combined with ground truth data might help to solve LU/LC management problems in the Central Kashmir Himalaya. A protective strategy should lead to several land use strategies. Local government should come up with planning and conservation groups to protect these valuable natural resources.

Conflict of interest

The authors declare that they have no conflict of interest.

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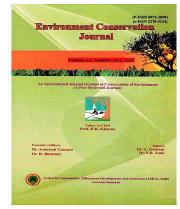

Evaluation of some genetic variability associated traits of 32 rice (*Oryza sativa* L.) genotypes in three different planting spacing by path coefficient analysis

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ABSTRACT

The study was taken up to estimate 32 advance breeding lines of rice for grain yield and the related traits in three different planting techniques, *viz.* direct seeded condition (E-I), transplanting with spacing of 15 x 15 cm (E-II) and 25 x 15 cm (E-III). The experimentation was carried out to explore the parameters of hereditary & variability for yield along-with yield components, to study the extent of association and direct and indirect special effects of different yield components on grain yield in rice. The analysis of variance from the experimental results documented significant changes amongst various genotypes for all studied traits with respect to the three-planting spacing. High GCV, high magnitude of broad sense heritability coupled with genetic advance as percentage of mean was detected for grain yield/plant and harvest index. These above-mentioned traits displayed considerable contribution of different additive gene action for their phenotypic appearance. The characters harvest index (%), biological yield/plant, flag leaf angle and no. of productive tillers/plant showed positive correlation & direct effect on grain yield per plant on pooled analysis. It indicated that these traits might be included in formulating criteria of selection for enhancement of the grain yield per plant in rice.

Introduction

Rice (*Oryza sativa* L.) is the supreme cereal crop belonging to the genus of *Oryza*. Rice is the world second largest producing crop after wheat. Asia accounts for more than 90% rice production of world (FAO STAT, 2020). Rice designated as "Global Grain" (Pillai and Tulasi, 2008) for its usage as foremost essential food supplements in various developed and developing nations around the globe. Rice overfills the nutritious necessities of more than 50% of world's population. Genetic parameters such as genetic coefficient of variation (GCV), phenotypic coefficient of variance (PCV), heritability, genetic advance are important biometrical tools that are advantageous for measuring genetic variability. The achievement of any breeding improvement programme greatly be determined by the extent of variations available in that individual population and the assortment to which the appropriate traits were transferred. The significances of heritability will give advantage to the plant scientist to identify promising accessions for desired attributes and further efficaciously using that in our plant improvement programme. Direct selection through grain yield is not operative as it is governed by several polygenes and greatly affected by environmental fluctuations. To minimalize the

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environmental effects, it is needed to comprise qualitative traits which have significant positive correlation and direct effect on yield. The relative contribution of individual traits may be accomplished by correlation studies, Path coefficient analysis utilized to find out the direct and indirect causes of association governing the traits.

Material and Methods

The trial was performed at the area of Instructional Farm, College of Agriculture, Rewa (M.P.) during the season of *Kharif* in the year of 2018. The material contains of 32 advance breeding lines of rice. These lines were implanted in Randomized Block Design (RBD) with three replications with three planting spacing, *viz*. direct sowing: 4th July, 2018 (E- I), transplanting with spacing of 15 x 15 cm: 24th July, 2018 (E- II) and transplanting with spacing of 25 x 15 cm: 24th July, 2018 (E- III), (Katkani *et al.* 2021). Ten plants selected randomly from each replication and further observations documented for the traits *like,* plant height (cm), no. of tillers/plant, no. of productive tillers/plant, panicle length (cm), no. of grains per panicle, angle of flag leaf (^{0}), test weight (gm), biological yield/plant (gm), harvest index (%) and yield of grain/plant (gm) except for the trait days to 50% flowering and days taken to maturity. These two characters were noted on individual plot basis when more than half plants of one plot

Statistical analysis

Analysis of variance (ANOVA), Different genetic parameter of variation *like,* genotypic & phenotypic coefficient of variation, heritability, genetic advance as percentage of mean, Correlation coefficient and Path analysis were analyzed by using Windostat Version 9.2.

Results and Discussion

The analysis of variance discovered that significant differences were recorded amongst the lines for all the traits in three planting spacing. It directed that among the considered advance lines satisfactory extent of genetic variability is existing for all the traits. Similar findings were also reported by Ajmera *et al.* (2017), Bhardwaj *et al.* (2017) and Katkani *et al.* (2021). The days to 50% flowering ranged from 65-106.3 days (91.0 mean) in E I, 66-86.0 days (73.2 mean) in E II, 59.6-83.6 days (72.5 days) in E III (table-1), days to maturity varied from 95.6-149.3 days (mean 124.1) in E I, 96.6-128.0 days (mean 112.8) in E II, 99-123.0 days (mean 111.6) in E III, the observed range of plant height was 61.6-120.40 cm (mean 82.2) in E I, 66.9-128.2 cm (mean 93.4) in E II, 68.6-128.2 cm (mean 92.8) in E III, number of tillers per plant found between 3.5-7.4 (mean 5.2) in E I, 5.3-12.0 (mean 8.3) in E II, 6.2-12.3 (mean 9.6) in E III, number of productive tillers per plant ranged from 1.4-7.1 (mean 3.5) in E I, 4.5-10.6 (mean 7.3) in E II, 5.7-10.9 (mean 8.7) in EIII, panicles length from 18.1-24.9 cm (mean 22.5) in E I, 19.4-28.7 cm (24.4 mean) in E II, 19.7-28.7 cm (mean 24.9) in E III, number of grains/panicle from 26-152.8 (86.3 mean) in E I, 117.1-200.5 (mean 147.6) in E II, 87.8-222.7 (mean 161.1) in E III, flag leaf angle ranged from 33.4-76.3^0 (57.5^0) in E I, 37.7-83.0^0 (mean 63.4^0) in E II, 39.4-83.8^0 (mean 63.3^0) in E III, test weight ranged from 7.7-32.8 gm (17.8 mean) in E I, 13.6-24.1 gm (mean 18.8) in E II, 13.9-31.8 gm (mean 18.6) in E III, biological yield per plant from 9-27.6 gm (mean 16.9) in E I, 19.3-34.0 gm (mean 26.9) in E II, 17.5-38.0 gm (mean 31.0) in E III, harvest index ranged from 10.4-58.0 % (mean 22.7) in E I, 33-73.6 % (mean 49.0) in E II, 33.2-85.0 % (mean 60.2) in E III and grain yield per plant varied from 1.4-13.9 gm (mean 4.1) in E I, 6.8-20.0 gm (13.1 mean) in E II, 6-28.2 gm (mean 18.6) in E III. The genetic changeability that measures the distinctions existing in the population, subsequently it is an outcome of additive-fixable and non-additive genetic factor effects. These results were agreement with the findings of Rolando *et al.* (2016), Rashmi *et al.* (2017), Bharadwaj *et al.* (2017), Kumar *et al.* (2018), Sadimantara *et al.* (2018), Katkani *et al.* (2021).

Genetic parameter of variation:

The extent of genotypic and phenotypic coefficient of variation, heritability and genetic advance as percentage of mean were recorded for all studied characters are presented environment wise *like,* E-I, E-II and E-III in table 1 respectively. The genotypic coefficient of variation (GCV%) provides the information about the amount to genotypic variability standing in polygenic traits. The values of phenotypic coefficient of variation (PCV%) was slightly higher than genotypic coefficient of variation (GCV%) for all the traits in three planting spacing. It shown that environment does not play

Table 1: Parameters of genetic variability of morphological traits of E-I, E-II & E-III

Character	ENV	Range Lowest	Range Highest	Mean	GCV (%)	PCV (%)	h^2 (bs) %	GA as % of mean
Days to 50% flowering	E I	65.0	106.3	91.1	11.6	12.0	93.9	23.2
	E II	66.0	86.0	73.3	7.4	7.9	86.4	14.1
	E III	59.7	83.7	72.5	7.4	7.9	87.4	14.2
Days to maturity	E I	95.7	149.3	124.2	10.6	10.8	95.4	21.2
	E II	96.7	128.0	112.9	6.2	6.6	88.9	12.1
	E III	99.0	123.0	111.6	5.4	5.8	89.4	10.6
Plant height	E I	61.6	120.4	82.2	20.0	20.3	97.3	40.6
	E II	66.9	128.2	93.5	18.3	18.7	96.8	37.2
	E III	68.6	128.6	92.9	18.3	18.8	95.2	36.8
Number of tillers per plant	E I	3.5	7.4	5.2	20.5	22.2	85.0	38.9
	E II	5.3	12.0	8.3	17.7	19.7	80.9	32.9
	E III	6.2	12.3	9.6	15.5	18.3	71.5	27.0
Number of productive tillers per plant	E I	1.4	7.1	3.5	45.5	47.5	91.7	35.9
	E II	4.5	10.6	7.3	18.1	21.7	69.5	31.0
	E III	5.7	10.9	8.7	14.4	20.8	47.6	20.5
Panicle length	E I	18.1	24.9	22.5	7.4	8.1	85.4	14.2
	E II	19.4	28.7	24.4	7.6	8.3	84.4	14.5
	E III	19.7	28.7	24.9	8.3	9.2	81.4	15.4
Number of grains per panicle	E I	26.0	152.8	86.3	38.9	39.1	99.3	46.9
	E II	117.1	200.5	147.6	14.5	15.1	93.2	28.9
	E III	87.8	222.7	161.1	17.8	18.0	97.8	36.3
Flag leaf angle	E I	33.4	76.3	57.5	20.4	21.0	94.4	40.8
	E II	37.7	83.0	63.4	19.2	20.3	89.6	37.4
	E III	39.4	83.8	63.3	19.0	20.2	89.0	37.0
Test weight	E I	7.7	32.8	17.8	28.7	29.0	98.3	39.7
	E II	13.6	24.1	18.8	11.4	12.9	78.7	20.9
	E III	13.9	31.8	18.6	16.2	16.5	97.0	33.0
Biological yield per plant	E I	9.0	27.6	16.9	22.0	22.4	96.3	44.4
	E II	19.3	34.0	26.9	16.9	17.4	94.4	33.9
	E III	17.5	38.0	31.0	16.1	16.4	96.2	32.5
Harvest index	E I	10.4	58.0	22.7	58.8	59.5	97.9	52.7
	E II	33.0	73.6	49.0	20.0	20.6	94.1	40.0
	E III	33.2	85.0	60.2	26.0	26.5	96.6	52.7
Grain yield per plant	E I	1.4	13.9	4.1	77.3	77.9	98.4	61.7
	E II	6.8	20.0	13.1	22.0	22.5	95.5	44.2
	E III	6.0	28.2	18.6	28.6	29.0	97.2	58.0

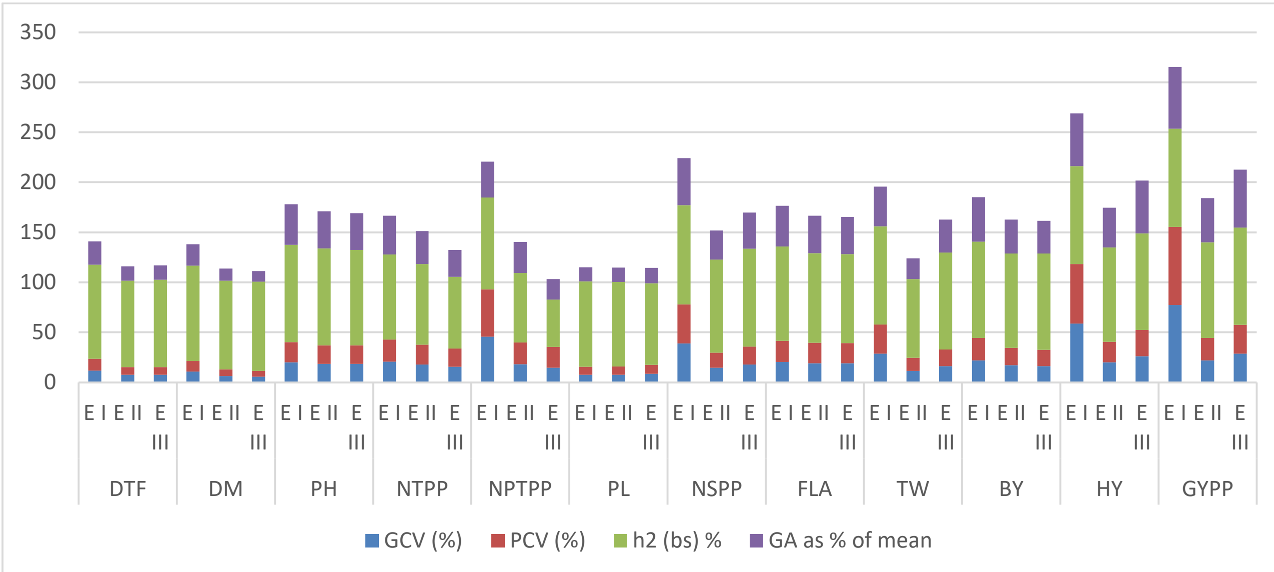

Figure 1: Genetic variability of quantitative traits in E I, E II & E III

significant role on the expression of these traits. The high degree of genotypic coefficient of variation (GCV%) and PCV% was detected for grain yield/plant (77.3%, 77.9%) followed by harvest index (58.8%, 59.4%), number of productive tillers per plant (45.4%, 47.5%), number of grains per panicle (38.9%, 39.0%), test weight (28.7%, 29.0%), biological yield/plant (22.0%, 22.4%), no. of tillers per plant (20.4%, 22.2%) and flag leaf angle (20.3%, 21.0%) in E I, whereas the high magnitude of GCV% and PCV% was detected for grain yield/plant (22.0%, 22.5%) followed by harvest index (20.0%, 20.6%) in E II and high value of GCV and PCV (%) were recorded for grain yield/plant (28.5%, 29.0%) followed by harvest index (26.0%, 26.4%) in E III. On pooled analysis grain yield/plant and harvest index exhibited high amount of GCV % and PCV% (table-1, Figure 1). The presence of large amount of variability might be due to diversified source of materials as well as environmental fluctuations affecting the phenotypes (Ovung *et al.,* 2012) is an important element for selection and improvement of the crop. Similar kind of result's were also reported by Sritama *et al.* (2015), Sameera *et al.* (2016), Prasad *et al*. (2017), Manjunatha *et al.* (2017), Abebe *et al*. (2018).

The high range of heritability was detected for all the studied traits in E I, E II and E III, except for number of productive tillers per plant (47.1%) in E III. The high amount of genetic advance as percentage of mean were detected in E I, E II and E III for grain yield per plant (61.7%, 44.2%, 58.0%, respectively) followed by harvest index (52.7%, 40.0%, 52.7%), number of grains per panicle (46.9%, 28.9%,36.3%), biological yield per plant (44.4%, 33.9%, 32.5%), flag leaf angle (40.8%,37.4%,37.0%), plant height (40.6%,37.2%, 36.8%), test weight (39.7%, 20.9%,33.0%), number of tillers per plant (38.9%, 32.9%, 27.0%), number of productive tillers per plant (35.9%, 31.0%,20.5%). The above-mentioned outcomes were also supported by Chowdary *et al*. (2016) for grain yield per plant, Prasad *et al*. (2017) for number of grains per panicle, test weight, plant height, number of productive tillers per plant and number of tillers per plant, Rahman *et al*. (2015) for harvest index, Abebe *et al*. (2018) for biological yield per plant, Sameera *et al*. (2016) for flag leaf angle. These above discussed traits were disclosed extensive influence of additive & fixable special gene inter-action for their phenotypic countenance and via direct selection improvement in these traits might be possible. Heritability is the ratio of variation which is transmissible from one to next generation and results of heritability is helpful for breeder to select promising advance lines for desirable traits. Selection will be effective for the traits having high heritability coupled with high genetic advance. High GCV, high magnitude of broad heritability along-with GA were documented for the trait grain yield/plant and harvest index.

Table 2: Phenotypic correlation coefficient analysis of E-I, E-II & E-III

Character	ENV	DTF	DM	PH	NTPP	NPTPP	PL	NGPP	FLA	TW	BYPP	HI	GYPP
DTF	E I	**1**	0.960***	0.541***	-0.169	-0.446 ***	-0.274**	-0.317 **	-0.333 ***	-0.610 ***	-0.009	-0.593 ***	-0.510 ***
	E II	**1**	0.911 ***	0.096	0.061	0.083	-0.107	0.179	0.157	-0.141	0.150	-0.351***	-0.193
	E III	**1**	0.871***	-0.111	-0.167	-0.193	-0.249 *	-0.100	0.098	-0.191	-0.318 **	0.151	-0.005
DM	E I		**1**	0.499***	-0.165	-0.381***	-0.293**	-0.272 **	-0.313 **	-0.576 ***	0.008	-0.556 ***	-0.463 ***
	E II		**1**	0.152	0.013	0.024	-0.102	0.266 **	0.138	-0.045	0.153	-0.376 ***	-0.228*
	E III		**1**	-0.276**	-0.057	-0.091	-0.200 *	-0.224 *	-0.032	-0.134	-0.302 **	0.090	-0.049
PH	E I			**1**	-0.077	-0.155	0.061	0.239 *	-0.269 **	-0.579 ***	0.437***	-0.212 *	0.541***
	E II			**1**	0.123	0.177	-0.011	0.101	-0.134	0.061	0.110	-0.018	0.009
	E III			**1**	0.013	0.024	0.074	0.075	-0.236 *	0.016	0.381***	-0.055	-0.111
NTPP	E I				**1**	0.758***	-0.221 *	-0.010	-0.018	0.025	0.429***	0.366 ***	0.457***
	E II				**1**	0.951 ***	-0.152	-0.290 **	-0.013	-0.159	0.278**	0.077	0.277
	E III				**1**	0.927	0.375 ***	-0.199	-0.178	0.087	0.428***	-0.020	0.178
NPTPP	E I					**1**	0.085	0.305**	0.171	0.368 ***	0.430***	0.619***	0.658***
	E II					**1**	-0.074	-0.312 **	-0.028	-0.095	0.313**	0.086	0.313
	E III					**1**	0.361***	-0.103	-0.168	0.202 *	0.442 ***	0.108	0.306
PL	E I						**1**	0.263**	-0.071	0.217*	0.003	0.120	0.110
	E II						**1**	-0.258 *	0.131	0.254 *	-0.022	0.2833**	0.236*
	E III						**1**	0.111	0.095	0.156	0.180	0.222 *	0.306 **
NGPP	E I							**1**	0.075	-0.138	0.378***	0.426***	0.440 ***
	E II							**1**	-0.013	0.0002	0.223 *	-0.320 **	-0.123
	E III							**1**	0.162	-0.079	0.292 **	0.412***	0.512***
FLA	E I								**1**	0.389 ***	0.122	0.295**	0.331 ***
	E II								**1**	0.300**	-0.047	0.063	0.052
	E III								**1**	0.276**	-0.255 *	0.326 **	0.177
TW	E I									**1**	-0.191	0.412***	0.297**
	E II									**1**	0.174	0.070	0.197
	E III									**1**	0.152	0.422 ***	0.476***
BYPP	E I										**1**	0.429 ***	0.673***
	E II										**1**	-0.261**	0.515***
	E III										**1**	-0.052	0.448***
HI	E I											**1**	0.939 ***
	E II											**1**	0.677 ***
	E III											**1**	0.857 ***

Where *, and *** significant at 5%, 1% and 0.1% level of probability, respectively**

DTF= Days to 50% flowering, DM= days to maturity, PH= plant height (cm), NTPP= number of tillers per plant, NPTPP= number of productive tillers per plant, PL= panicle length (cm), NGPP= number of grains per panicle, FLA= flag leaf angle (^{0}), TW= test weight (gm), BYPP= biological yield per plant (gm), HI= harvest index (%) and GYPP= grain yield per plant (gm)

Table 3: Phenotypic path analysis of E-I, E-II & E-III

Character	ENV	DTF	DM	PH	NTPP	NPTPP	PL	NGPP	FLA	TW	BYPP	HI	GYPP
DTF	E I	**-0.1701**	-0.1634	-0.0922	0.0289	0.0759	0.0467	0.0539	0.0567	0.1038	0.0015	0.1009	-0.5102
	E II	**0.0671**	0.0611	0.0065	0.0042	0.0056	-0.0072	0.0120	0.0106	-0.0095	0.0101	-0.0236	-0.1937
	E III	**0.0354**	0.0308	-0.0039	-0.0059	-0.0068	-0.0088	-0.0035	0.0035	-0.0068	-0.0113	0.0054	-0.0057
DM	E I	0.1498	**0.1560**	0.0779	-0.0258	-0.0595	-0.0458	-0.0426	-0.0488	-0.0899	0.0014	-0.0867	-0.4638
	E II	-0.0681	**-0.0748**	-0.0114	-0.0010	-0.0019	0.0077	-0.0199	-0.0103	0.0034	-0.0115	0.0282	-0.2284
	E III	0.0099	0.0114	-0.0031	-0.0007	-0.0010	-0.0023	-0.0025	-0.0004	-0.0015	-0.0034	0.0010	-0.0499
PH	E I	-0.0275	-0.0253	**-0.0507**	0.0039	0.0079	-0.0031	-0.0121	0.0137	0.0294	-0.0222	0.0108	-0.0781
	E II	-0.0052	-0.0083	**-0.0544**	-0.0067	-0.0097	0.0006	-0.0055	0.0073	-0.0033	-0.0060	0.0010	0.0091
	E III	0.0014	0.0035	**-0.0128**	-0.0002	-0.0003	-0.0010	-0.0010	0.0030	-0.0002	-0.0049	0.0007	0.1295
NTPP	E I	-0.0097	-0.0094	-0.0044	**0.0571**	0.0434	-0.0127	-0.0006	-0.0011	0.0014	0.0245	0.0209	0.4579
	E II	-0.0021	-0.0005	-0.0041	**-0.0331**	-0.0315	0.0051	0.0096	0.0004	0.0053	-0.0092	-0.0026	0.2776
	E III	0.0103	0.0035	-0.0008	**-0.0613**	-0.0569	-0.0231	0.0122	0.0109	-0.0054	-0.0263	0.0013	0.1789
NPTPP	E I	0.0130	0.0111	0.0045	-0.0221	**0.0291**	-0.0025	-0.0089	-0.0050	-0.0107	-0.0125	-0.0180	0.6584
	E II	0.0040	0.0012	0.0084	0.0451	**0.0475**	-0.0035	-0.0148	-0.0013	-0.0045	0.0149	0.0041	0.3139
	E III	-0.0071	-0.0033	0.0009	0.0339	**0.0365**	0.0132	-0.0038	-0.0062	0.0074	0.0161	0.0040	0.3062
PL	E I	-0.0141	-0.0151	0.0032	-0.0114	0.0044	**0.0513**	0.0135	-0.0037	0.0111	0.0002	0.0062	0.1109
	E II	-0.0003	-0.0002	0.0000	-0.0004	-0.0002	**0.0024**	-0.0006	0.0003	0.0006	-0.0001	0.0007	0.2363
	E III	-0.0107	-0.0086	0.0032	0.0161	0.0155	**0.0429**	0.0048	0.0041	0.0067	0.0077	0.0095	0.3067
NGPP	E I	0.0079	0.0068	-0.0059	0.0003	-0.0076	-0.0065	**0.0249**	-0.0019	0.0035	-0.0094	-0.0106	0.4408
	E II	0.0013	0.0019	0.0007	-0.0021	-0.0023	-0.0019	**0.0073**	-0.0001	0.0000	0.0016	-0.0023	-0.1231
	E III	-0.0020	-0.0045	0.0015	-0.0040	-0.0021	0.0023	**0.0202**	0.0033	-0.0016	0.0059	0.0084	0.5123
FLA	E I	-0.0212	-0.0199	-0.0171	-0.0012	0.0109	-0.0045	0.0048	**0.0636**	0.0248	0.0078	0.0188	0.3319
	E II	0.0037	0.0032	-0.0031	-0.0003	-0.0007	0.0031	-0.0003	**0.0232**	0.0070	-0.0011	0.0015	0.0520
	E III	0.0002	-0.0001	-0.0005	-0.0003	-0.0003	0.0002	0.0003	**0.0019**	0.0005	-0.0005	0.0006	0.1775
TW	E I	0.0114	0.0108	0.0108	-0.0005	-0.0069	-0.0041	0.0026	-0.0073	**-0.0187**	0.0036	-0.0077	0.2974
	E II	-0.0011	-0.0004	0.0005	-0.0013	-0.0008	0.0021	0.0000	0.0024	**0.0081**	0.0014	0.0006	0.1974
	E III	-0.0094	-0.0066	0.0008	0.0043	0.0100	0.0077	-0.0039	0.0136	**0.0492**	0.0075	0.0208	0.4760
BYPP	E I	-0.0032	0.0031	0.1555	0.1527	0.1529	0.0013	0.1345	0.0434	-0.0680	**0.3555**	0.1528	0.6738
	E II	0.1113	0.1141	0.0818	0.2064	0.2326	-0.0170	0.1659	-0.0352	0.1296	**0.7421**	-0.1943	0.5158
	E III	-0.1595	-0.1513	0.1906	0.2142	0.2211	0.0903	0.1461	-0.1278	0.0761	**0.5002**	-0.0260	0.4480
HI	E I	-0.4465	-0.4185	-0.1596	0.2759	0.4662	0.0908	0.3206	0.2223	0.3107	0.3234	**0.7527**	0.9399
	E II	-0.3041	-0.3258	-0.0158	0.0668	0.0751	0.2450	-0.2767	0.0547	0.0609	-0.2264	**0.8646**	0.6778
	E III	0.1259	0.0753	-0.0463	-0.0172	0.0906	0.1852	0.3433	0.2716	0.3515	-0.0432	**0.8318**	0.8574

E I R square = 0.9827, Residual effect = 0.1316, E II R square = 0.9806, Residual effect = 0.1394, E III R square = 0.9824, Residual effect = 0.1328

These traits can be additionally enriched by direct selection and considered for formulating selection criteria for further rice improvement programme.
Correlation coefficient represented the nature of association amid the characters. Grain yield/plant showed positive and significant relationship with harvest index (0.939) followed by biological yield per plant (0.673), no. of productive tillers per plant (0.658), plant height (0.541), no. of tillers per plant (0.457), no. of grains per panicle (0.440), flag leaf angle (0.331) and test weight (0.297) in E I, whereas grain yield per plant showed significant positive correlation with harvest index (0.677) followed *via.* Biological yield/plant (0.515) and length of panicle (0.236) in E II and harvest index (0.857) followed by no. of grains per panicle (0.512), biological yield/plant (0.448), test weight (0.476) and panicle length (0.306) in E III.
Based on pooled performance of all the environments, the yield of grains from individual plant depicted significant and positive association with the harvest index, biological yield/plant, no. of productive tillers per plant, plant height, no. of tillers/plant, no. of grains/panicle, flag leaf angle and test weight. Similar findings were also reported by Kumar *et al.* (2018) for biological yield per plant, Pandey *et al.* (2017) for number of tillers per plant and number of productive tillers per plant, Rashid *et al.* (2017) for plant height and number of grains per panicle, flag leaf angle and Archana *et al.* (2018) for test weight and harvest index. Hence, it can be concluded from this study that these traits should be considered as the selection criteria for improvement of grain yield per plant in rice.
Path coefficient analysis is a standard regression coefficient which split the measures of correlation into direct and indirect effect. Among twelve, eight traits presented positive direct effect (table-3) on grain yield/plant *viz.,* harvest index (0.752) followed by biological yield per plant (0.355), days to maturity (0.156), flag leaf angle (0.063), no. of tillers per plant (0.057), length of the panicle (0.051), no. of productive tillers per plant (0.029) and grains no./panicle (0.024) in E I, while harvest index (0.864) followed by biomass yield/ plant (0.742), days to 50% flowering (0.067), productive no. of tillers/plant (0.047), angle of flag leaf (0.023), test weight (0.008), grains no./panicle (0.007) and length of the panicle (0.002) in E II and the traits *viz.,* harvest index (0.831) followed by per plant biological yield (0.500), test weight (0.049), panicle length (0.042), productive no. of tillers/plant (0.036), no. of grains per panicle (0.020), days to mature (0.011) and flag leaf angle (0.001) in E III. Similar findings were also reported by previous scientists *like,* Bhujell *et al.* (2018) for test weight, harvest index, Kumar *et al.* (2018) for biological yield per plant, Rashid *et al.* (2017) for number of productive tillers per plant, Menaka *et al.* (2016) for number of grains per panicle, Dhurai *et al.* (2016) for days to maturity and flag leaf angle. The traits harvest index, biological yield per plant, flag leaf angle, panicle length and no. of productive tillers/plant had positive direct effect on grain yield/plant at in pooled analysis. Thus, these characters appeared as most imperative direct contributor in the direction of the grain yield of rice. The traits depicting significant positive correlation and positive direct effect on grain yield per plant on pooled basis are harvest index, biological yield per plant, flag leaf angle, panicle length, test weight and number of productive tillers per plant. These diverse traits must be included in constructing plant architecture in different plant spacing environments.

Conclusion

The major goal of a plant breeder is to boost the genetic yield potential of the crop with high economic returns. In succeeding this objective, it is important to collect information based on genetic parameters of variability. The results depicted that wide-ranging variability were available for all the studied traits in three planting spacing. High range of GCV%, high heritability coupled with genetic advance was documented only for the trait harvest index and grain yield per plant. It indicated that direct selection for these traits might be effective since the heritability is most likely due to additive gene effect. Significant positive correction along with direct effects was recorded for harvest index (%), per plant biological yield, angle of flag leaf, and productive no. of tillers/ plant on pooled analysis. These discussed traits might be taken in the expansion of selection criteria for genetic enhancement of per plant grain yield in advance breeding lines of rice under different planting spacing conditions.

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

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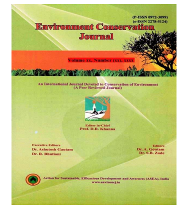

Evaluation of genotypes and correlation studies in Marigold (*Tagetes spp.*) for growth and yield attributes

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ABSTRACT

The study was conducted to evaluate 23 genotypes of marigold (*Tagetes spp.)* collected from different and diverse sources and correlation studies were performed for various growth and yield characters. The results shows that the maximum plant height (92.60 cm) is recorded in the genotype AMS-15, whereas maximum plant spread (52.80 cm), flower weight (8.93 g) and largest flower size (7.63 cm) was recorded in the genotype 'AMS-16'. The highest number of branches (11.13), flowers per plant (509.93), flower yield per plant (622.27 gm), flower yield per m^2 (4635.83 gm) and duration of flowering (88.47 days) was recorded in genotype 'AMS-3'. The genotype 'AMS-4' showed earliest bud initiation (38.20 days) and flower opening (47.53 days). Plant spread is positively correlated with number of branches, flower stalk length, flower diameter, days to bud initiation, first flower opening, flower yield per plant and per m^2, whereas, plant height has positive correlation with plant spread, number of branches per plant, flower stalk length and flower diameter. The study concludes that the genotype AMS-3 is the best amongst all the genotype with respect to flower yield and flowering duration. The various growth parameters *viz.* plant spread, number of branches, flower diameter, days to bud initiation, days to first flower opening and number of flowers per plant has positive correlation with flower yield, hence, these characters may be considered as selection indices in improving yield attributes in marigold.

Introduction

Marigold (*Tagetes* spp.) belonging to family Asteraceae is traditional ornamental crop commercially grown for loose flower in different parts of the world. It has gained massive trend and popularity due to its wider versatility and adjustability to various soil and atmospheric conditions, short duration, free and longer flowering durations. It can be used as bedding plant, pot plant or in rock gardens and floral arrangements for interior decoration. The essential oil and carotenoids extracted from petals are used in perfumery, textile and pharmaceutical industry. In order to enhance chicken skin colour and egg yolk pigmentation the petals are used as dietary supplement in poultry industry (Hojnik *et al.*, 2008). Marigold is grown as intercrop or trap crop as it is beneficial to control nematode population (Soule, 1993). The demand for varieties with uniform, medium size and compact growth with bright colour flowers having more shelf life are very high and development of such varieties requires genetically stable genotypes with more flower yield (Bharathi *et al.*, 2014). Variation with respect to character is an essential requirement for selection of superior variety and successful breeding programme. To enhance variation in heterozygous crop like marigold, the open pollinated crops are utilized and are gaining considerable importance (Singh and Misra, 2008).
Correlation coefficient is considered as principal device for the selection of advantageous traits for genetic improvement of particular character, it can measures relationship between various plant characters and this can be utilized to magnify the

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productivity of marigold. Character association of marigold revealed that quantitative traits had a significant genotypic and phenotypic correlation coefficient with flower yield (Karuppaiah *et al*., 2010). Singh *et al*. (2008) reported that flower yield per plant exhibited positive correlation with number of primary and secondary branches and flowers per plant. The selection based on the component traits can be easier and smoother if plant breeder knows the degree of relationship between yield and its various components (Prasad *et al*., 2011). Hence, due to the ever-changing scenario and rapid advancement in floriculture sector, evaluation of marigold germplasm is essential to bring the suitable genotypes with desirable quality parameters and recommended to farmers for exploitation of their potential. It is of great importance to employ correlation studies in marigold to discover the traits having interrelationship with flower yield and quality parameters.

Material and Methods

The study was conducted in the Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana during 2019-20. The experimental material comprised of 23 genotypes of marigold (*Tagetes spp.)* which were collected from distinct and diverse sources. The genotypes Pusa Narangi Gainda, Pusa Basanti Gainda, Summer Saugat were collected from IARI, New Delhi, whereas, other all genotypes were local selections. The seeds were sown in nursery beds and then transplanted at 40x40 cm as per Randomized Block Design (RBD) with three replications. Five randomly selected plants from each replication were marked for recording observations on plant height, plant spread, number of branches per plant, bud initiation, days to first flower opening, flower stalk length, flower diameter, average flower weight, number of flowers per plant, duration of flowering, flower yield per plant, flower yield per unit area. The following formula suggested by Al -Jibouri *et al*. (1958) was used to compute correlation coefficients-

$$rp = \frac{pcov\ x\cdot y}{\sqrt{\delta^2 px\cdot\delta^2 py}}$$

$$rg = \frac{gcov\ x\cdot y}{\sqrt{\delta^2 gx\cdot\delta^2 gy}}$$

√Where: rp and rg are phenotypic and genotypic correlation coefficients, respectively; pcov x·y and gcov x·y are phenotypic and genotypic covariances between variables x and y, respectively; δ^2px and δ^2gx are phenotypic and genotypic variances, respectively, for variable x; and δ^2py and δ^2gy are phenotypic and genotypic variances, respectively, for variable y.

Results and Discussion

Evaluation of genotypes

The 23 genotypes of marigold exhibited pronounced variation and significant differences for growth and yield attributes as presented in Table 1 and 2.

Table 1: Genetic variability in 23 marigold genotypes for growth and yield attributes

Cultivars	Plant height (cm)	Plant spread (cm)	Number of branches per plant	Days to bud initiation	Days to first flower opening	Duration of flowering (days)
Pusa Narangi	63.27	33.87	7.80	65.27	78.93	48.67
Pusa Basanti	67.20	31.93	5.33	58.07	71.00	56.53
Jafri	59.27	43.40	7.93	75.40	87.73	56.20
Summer Saugat	80.40	41.40	10.80	51.27	68.40	41.00
AMS -1	68.53	34.00	8.93	81.20	92.47	60.67
AMS-2	83.53	49.60	10.87	74.20	89.67	42.73
AMS-3	68.00	45.47	11.13	147.07	167.67	88.47
AMS-4	48.27	30.33	6.60	38.20	47.53	50.80
AMS-5	48.53	28.40	6.60	42.33	50.33	75.93

AMS-6	41.80	24.07	4.40	60.33	68.40	52.60
AMS-7	88.53	52.73	8.93	49.87	72.60	47.07
AMS-8	63.33	36.27	5.47	72.67	85.00	43.80
AMS-9	56.73	32.20	5.60	69.00	82.13	45.07
AMS-10	46.87	27.03	8.93	58.47	68.43	32.03
AMS-11	54.60	34.40	9.73	73.67	82.07	62.33
AMS-12	44.60	27.20	7.47	62.20	74.40	54.27
AMS-13	70.67	33.00	7.20	75.00	81.13	67.53
AMS-14	90.83	34.00	7.83	77.00	83.50	46.50
AMS-15	92.60	45.67	5.20	78.53	85.73	42.33
AMS-16	82.26	52.80	7.80	79.87	89.60	38.27
AMS-17	57.00	31.40	5.60	70.20	79.97	47.93
AMS-18	56.80	35.20	9.67	88.87	95.03	62.27
AMS-19	41.87	24.00	4.27	78.93	89.20	52.40
C.D. (P=0.05)	5.02	6.93	1.68	4.30	4.71	7.61

Table 2: Genetic variability in 23 marigold genotypes for growth and yield attributes

Cultivars	**Flower diameter (cm)**	**Stalk length (cm)**	**Average flower weight (g)**	**Number of flowers per plant**	**Flower yield per plant (g)**	**Flower yield per m^2 (g)**
Pusa Narangi	4.93	2.73	6.50	25.93	160.20	1193.47
Pusa Basanti	4.37	3.30	4.77	29.87	143.13	1066.33
Jafri	4.43	3.00	4.83	37.07	182.80	1361.83
Summer Saugat	6.37	2.57	3.40	151.73	409.73	3052.47
AMS -1	4.37	2.90	5.47	24.93	129.07	961.50
AMS-2	4.20	2.73	4.37	31.67	133.07	991.33
AMS-3	3.80	4.23	1.20	509.93	622.27	4635.83
AMS-4	4.57	3.53	6.50	29.07	161.93	1206.40
AMS-5	3.90	3.63	6.30	35.93	190.53	1419.47
AMS-6	3.43	1.93	4.10	41.87	141.00	1050.40
AMS-7	4.47	3.30	3.23	101.53	285.00	2122.70
AMS-8	5.17	3.57	5.33	22.00	102.53	760.83
AMS-9	4.50	3.33	4.77	23.47	132.13	984.33
AMS-10	3.67	3.30	4.97	54.07	252.67	1882.33
AMS-11	2.47	2.17	1.07	244.73	260.47	1944.93
AMS-12	2.83	2.63	1.43	111.47	140.33	1045.47
AMS-13	2.63	3.60	1.70	132.67	214.47	1597.73
AMS-14	5.57	4.67	5.07	39.93	184.80	1376.70
AMS-15	7.17	3.33	4.53	88.07	409.00	2931.17
AMS-16	7.63	3.83	8.93	45.93	457.13	3405.57
AMS-17	5.60	3.27	4.17	83.53	308.27	2296.53
AMS-18	3.77	2.17	2.30	237.00	444.20	3309.23
AMS-19	6.63	2.13	6.13	74.87	411.07	3062.37
C.D. (P=0.05)	0.56	0.54	1.11	28.77	72.49	554.29

P= 0.05., Significant at 5%

The maximum plant height (92.60 cm) was recorded in genotype 'AMS-15' followed by genotype 'AMS-14' (90.83 cm) and minimum (41.80 cm) was observed in genotype 'AMS-6'. The maximum plant spread (52.80 cm) was observed in genotype 'AMS-16' followed by genotype 'AMS-7' (52.73 cm) and minimum (24.00 cm) was observed in genotype 'AMS-19'. The highest number of branches (11.13) was recorded in genotype 'AMS-3' and lowest (4.40) was observed in genotype 'AMS-19'. Similar findings were reported previously by Bharathi and Jawaharlal (2014), Shivakumar *et al*. (2014) and Singh *et al*. (2014) while determining the variability among African marigold genotypes. It was observed that the genotypes with more plant height recorded greater plant spread and those with short height recorded less spread thus, exhibiting the direct relationship between these characters. These results were true for genotypes 'AMS-15' and 'AMS-16'. The plant height, spread and branch count vary are among genotypes due to genomic sequence of the plants as these are varietal traits. The accessibility of compatible environment to express the dominant gene in the genotypes may be the reason for variation (Maynard and David, 1987).The highest number of flowers per plant (509.93), flower yield per plant (622.27 g), flower yield per m^2 (4635.83 g) and duration of flowering (88.47 days) were recorded in genotype 'AMS-3'. The greater number of branches resulted in building and accumulation of maximum photosynthates which directly resulted in greater number of flowers with bigger size and this might be the reason for variation in flowers number within genotypes. The largest flower size (7.63 cm) and maximum flower weight (8.93 g) was recorded in genotype 'AMS-16' and smallest flower size (2.47 cm) and minimum flower weight (1.07 g) was observed in genotype 'AMS-11'. The weight of flowers was observed more in genotypes whose flower size was found larger. This variation in flower weight among different genotypes might be attributed to the higher water and carbohydrates level in the flower that helps to maintain flower turgidity, freshness and petal orientation. The ultimate effect of all these factors resulted in long flower stalks, large sized flower and finally increases flower weight. Similar results were reported by Panwar *et al*. (2013). The longest flower stalk length (4.67 cm) was recorded in genotype 'AMS-14', whereas shortest stalk length was observed in genotype 'AMS-6'. The variation in number of flowers per plant, flower diameter, stalks length, fresh flower weight, flower yield per plant and duration of flowering is due to genetic makeup of genotypes and environmental variation. The earliest bud initiation (38.20 days) and first flower opening (47.53 days) were recorded in genotype 'AMS-4'. The days taken to bud initiation and flower opening signifies the availability of flowers in the market (Behera *et al*., 2002). Singh *et al*. (2008) reported that variation in days taken to flowering is attributed to genetic makeup of various germplasm lines. Moreover, due to favorable climatic conditions there is more dry matter accumulation which favors early flowering in marigold (Rao and Reddy, 2002).

Correlation Coefficient

The correlation coefficient between various yield components and interrelationship among the traits were computed and presented in Tables 3. The results indicate a strong association between plant morphological characters with yield. The plant height revealed a significant and positive correlation with plant spread, number of branches per plant, flower stalk length and flower diameter. Plant spread is positively correlated with number of branches, flower stalk length, flower diameter, days to bud initiation, days to first flower opening, flower yield per plant and flower yield per m^2. Number of branches per plant is positively and significantly associated with number of flowers per plant, flower yield per plant and flower yield per m^2. The days to bud initiation exhibited significant positive correlation with days to first flower opening, duration of flowering. Flower diameter is positively and significantly associated with average flower weight, flower yield per plant and flower yield per m^2. Flower yield per plant has shown positive and significant association with flower yield per m^2. Thus, the increase in plant spread, number of branches, flower diameter, days to bud initiation, days to first flower opening and number of flowers per plant can enhance the flower yield per plant and flower yield per m^2. These results are in conformity with the finding of Anuja and Jahnavi (2012), Vishnupriya *et al*. (2015) in marigold.

Table 3: Phenotypic (rp) and Genotypic (rg) correlation co-efficient between different pairs of characters in marigold

Characters `	rp rg	Plant height	Plant spread	Number of branches per plant	Flower stalk length	Flower diameter	Average flower weight	Days to bud initiation	Days to first flower opening	Number of flowers per plant	Flower yield per plant	Flower yield per m^2	Duration of flowering
Plant height	rp												
	rg	1.000											
Plant spread	rp	0.759**											
	rg	0.815	1.000										
Number of branches per plant	rp	0.314**	0.465**										
	rg	0.359	0.533	1.000									
Flower stalk length	rp	0.418**	0.250*	0.048									
	rg	0.476	0.318	0.017	1.000								
Flower diameter	rp	0.434**	0.315**	-0.243*	0.180								
	rg	0.458	0.381	-0.252	0.226	1.000							
Average flower weight	rp	0.030	0.017	-0.345**	0.195	0.603**							
	rg	0.049	0,024	-0.415	0.233	0.660	1.000						
Days to bud initiation	rp	0.175	0.270*	0.291*	0.192	0.008	-0.313**						
	rg	0.186	0.317	0.344	0.217	0.007	-0.344	1.000					
Days to first flower opening	rp	0.218	0.347**	0.351**	0.190	0.013	-0.328**	0.979**					
	rg	0.232	0.408	0.417	0.224	0.011	-0.362	0.982	1.000				
Number of flowers per plant	rp	0.031	0.203	0.501**	0.044	-0.262*	-0.660**	0.716**	0.735**				
	rg	0.030	0.228	0.550	0.043	-0.270	-0.698	0.731	0.751	1.000			
Flower yield per plant	rp	0.204	0.357**	0.308*	0.085	0.353**	-0.155	0.574**	0.575**	0.709**			
	rg	0.229	0.406	0.325	0.079	0.392	-0.188	0.602	0.607	0.728	1.000		
Flower yield per m^2	rp	0.194	0.353**	0.315**	0.084	0.345**	-0.154	0.574**	0.576**	0.713**	0.999**		
	rg	0.221	0.403	0.333	0.077	0.385	-0.191	0.604	0.670	0.733	0.999	1.000	
Duration of flowering	rp	-0.214	-0.102	0.169	0.088	-0.474**	-0.428**	0.429**	0.407**	0.598**	0.204	0.209	
	rg	-0.242	-0.132	0.181	0.087	-0.519	-0.456	0.492	0.476	0.644	0.238	0.244	1.000

Conclusion

It was concluded that genotype AMS-3 was best amongst all with respect to highest number of branches, flowers per plant, flower yield per plant, flower yield per m^2 and duration of flowering. Plant spread is positively correlated with number of branches, flower stalk length, flower diameter, days to bud initiation, first flower opening, flower yield per plant and per m^2, whereas, plant height has positive correlation with plant spread, number of branches per plant, flower stalk length and flower diameter. The various growth parameters *viz.* plant spread, number of branches, flower diameter, days to bud initiation, days to first flower opening and number of flowers per plant has positive correlation with flower yield, hence, these characters may be considered as selection indices in improving yield attributes in marigold.

Conflict of interest

The authors declare that they have no conflict of interest.

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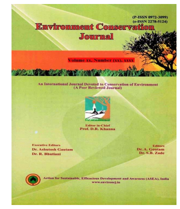

Development of laboratory model of fluidized bed gasifier for low density leafy biomass

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ABSTRACT

Crops can also be grown for energy could be produced in large quantities, and likely to become the most popular in the future. One of the most widely used renewable energy source for heating is biomass in the form of fuel wood, charcoal, agriculture residues etc. A lab model of Fluidized Bed Gasifier (FBG) for handling low density and leafy biomass materials like rice husk, saw dust, bagasse, tree leaves etc. was developed. The performance study of the gasifier was determined by different parameters such as air factor, gas yield, calorific value and hot gas efficiency. The average gas yield of 2.5 m^3/kg and a maximum possible feed rate 10 kg/h with the existing feeding system the capacity of the unit was worked out as 20kW.

Introduction

Crops can also be grown for energy could be produced in large quantities, and likely to become the most popular in the future. One of the most widely used renewable energy source for heating is biomass in the form of fuel wood, charcoal, agriculture residues etc.Agricultural residues are available in almost every country around the world while municipal waste is available in every city. India produces about 320 million tones of agricultural residues comprising of mainly rice husks, paddy straw, sugarcane leaves and wheat residues (Jorapur and Rajvanshi, 1997;). It is guesstimated that about one third of this or 100 million tons of residues are not being utilized and are disposed of by burning them in the open fields (NPCMR, 2014). Unsustainable management practices of biomass waste would create high adverse environmental impacts (Ross, 2018; ruhela *et al.,* 2020; Bhardwaj *et al.,* 2019).

Energy can be harvested from a biomass, a significant renewable energy source forever. Biomass energy can be produced from plants and agricultural wastes, crops, trees, and crop residues to manure. Gasification is a promising route to harness the source of biomass energy. In India, gasifiers being used for thermal applications (Mukunda *et al.* (1994)). Jorapur and Rajvanshi (1997) developed a commercial-scale (1080 MJ h^{-1}) model of a gasifier, which can handle low density and leafy biomass materials like sugarcane leaves and bagasse and also analyzed the techno-economic feasibility. Fluidized bed gasification is one of the major processes to reach a high gas product yield from a large panel of carbonaceous resources (biomass, wastes). Some advantages of implementing fluidized bed for gasification have been reported in several studies (Basu, (2006) and Bain (2004). Alauddin *et al.* (2010) presented the merits of gasification of lignocellulosic biomass in fluidized beds for renewable energy development. Ramjani *et al.* (2020) showed the characterization of Coir pith for fluidized bed gasification. This

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paper reports the development of a lab model Fluidized Bed Gasifier (FBG), which can handle low density and leafy biomass materials like rice husk, saw dust, bagasse, tree leaves etc. The performance study of the gasifier was determined by different parameters such as air factor, gas yield, calorific value and hot gas efficiency.

Material and Methods

The study was conducted at Agricultural Engineering College and Research Institute, Kumulur, Tamil Nadu, India which has Leafy biomass potential around 30 tonnes per annum. The major leafy biomass of Teak leaves, mango leaves, and rice husk are taken for the development of FBG and for gasification studies.

Development of a fluidized bed gasifier

Development of Fluidized Bed Gasifier includes reactor dimension, estimation of bed dimensions, distributor plate, fuel feeding and air supply system, and producer gas burner. The reactor was made of M.S. Pipe of 12" diameter and 10' length. The reactor was covered at the top and bottom with an air tight detachable lid. The reactor consists of provision for fuel inlet, producer gas outlet, air supply, temperature measurement and heat source inlet. The feed point was kept at height of 30" from the bottom of the reactor. The distributor plate was fixed at a level of 17" from the bottom the reactor. Cr/Al thermocouples were inserted to measure the bed temperature and gas temperature.A simple perforated air distributor is used for the uniform supply of air. Orifices that are too small are liable to become clogged and that are too large may cause uneven distribution of fluidizing air. According to Howard (1987), the orifice diameter has to be in the range of 2 to 3 mm. Hence orifice of 2.5 mm diameter and 300 numbers were adopted, giving fractional open area of 2.0%. The feeding system consists of a screw auger with hopper run by a one horse power single phase AC motor. The length, diameter and pitch of the screw are 45.0cm, 7.5cm and 5.0 cm respectively. The feeding rate was adjusted by adjusting the speed of the motor through a variable frequency drive. The air required for fluidization and gasification was supplied by a one horse power blower. An orifice meter with water manometer was fixed in the air supply line to measure the volume of air supplied. The air flow rate was controlled by a gate valve in the air supply line. The experimental set up is shown in Figure 1.

Figure 1: Fluidized bed gasifier for leafy biomass

Estimation of bed dimensions

Sand (Silica sand) was used as a bed material in fluidized bed gasifier. Sand is an inert material and has high heat retention capacity makes it suitable for use as bed material in a fluidized bed Gasification system. The physical properties of bed materials are furnished in Table 1. As leafy biomass can cause intensive elutriations, hence a low static bed height of 5 cm was maintained. The fluidization parameters of the sand bed are given in Table 2.

Table. 1 Physical properties of sand

S. No.	Properties	Value
1	Bulk density, kg/m^3	1355.0
2	Porosity, %	38.2
3	Particle density, kg/m^3	2193.0
4	Mean Particle size, mm	0.672

Table.2 Fluidization parameters of the sand bed

S. No.	Parameters	Value
1.	Bed height at minimum fluidizing velocity , L_{mfs} (Kunii and Levenspiel, 1969)	8.1 cm
2.	Minimum Fluidization velocity (Kunii and Levenspiel, 1969)	0.1 m/s
3.	Quality of fluidization (Product of four dimensional groups - {Fr, Re, $(\rho_{ps} - \rho_{f})/ \rho_f$, L_{mfs} / d}(Howard, 1987)	> 100, Smooth or Particulate fluidization

Biomass feeding system

The biomass feeding system consists of a screw feeder with a hopper. A variable frequency drive is connected to the 1 horse power three phase motor that controls the biomass feed rate. The feed was calibrated with various frequency of the drive motor. The feeding point is fixed at the height of 0.125 m above the distributor plate, to avoid pyrolysis of biomass inside the screw feeder. The screw feeder pushes the biomass materials instantaneously into the bottom dense region of the fluidized bed. The mass flow rate of biomass fuels was maintained at the desired operating conditions.

Air and gas flow measurement system

An orifice plate was positioned on the duct between blower delivery end and the air supply point in the plenum chamber to measure the air flow rate into the fluidized bed gasifier. Another orifice plat was fixed between producer gas outlet and burner to measure the product gas flow rate. The pressure drop across this plate was measured using a differential pressure manometer (water column) and this pressure drop was then used to estimate the flow rate of the gases through the orifice. Air required for complete combustion of a biomass is calculated based on the composition of leafy biomass and by using the given empirical formula:

Air requirement for complete combustion = 100/23 $[8/3\ C + 8H_2{+}S) - O_2]$

Where, C, H_2, and S mass of carbon, Hydrogen and Sulphur in 1 kg of fuel.

Performance study of the gasifier

The performance study of the gasifier was determined by different parameters such as air factor, gas yield, calorific value and hot gas efficiency. The proximate analysis of selected leafy biomass are determined by using ASTM standards E 871, E 1755 and E872; for moisture, ash and volatile matter, respectively and fixed carbon content was calculated by difference. Thermogravimetric analysis of selected leafy biomass was carried out in a TGA Q50 V20.13 Build 39 model instrument.

Results and Discussion

Characterization of selected biomass

For gasification process teak leaves, rice husk and mango leaves were selected. The raw materials are collected in the college campus premises are sundried for a week. The Proximate and ultimate analysis, Thermo gravimetric analysis and Higher Heating Value of biomass samples were analyzed and presented. The proximate and ultimate analysis are given in the Table 3 and 4 respectively.

Table 3: Proximate composition of selected leafy biomass.

Biomass	Moisture content, %	Volatiles, %	Ash %	Fixed Carbon ,%
Teak leaves	7.2	65.8	10.9	16.1
Mango leaves	7.5	47.0	10.5	35.0
Rice husk	8.1	53.2	24.1	14.0

Table 4: Ultimate analysis of Leafy biomass.

Elements	Teak leaves	Mango leaves	Rice husk
Carbon , %	56.97	44.12	50.45
Hydrogen, %	6.79	6.1	06.57
Oxygen, %	35.01	47	41.26
Nitrogen, %	1.22	2.66	01.49
Sulfur, %	-	0.12	0.23
Heating value (MJ/ kg)	22.73	15.24	19.10

Thermogravimetric analysis of selected leafy biomass.

The most common technique used to investigate the thermal behaviour and kinetics of fuels is TGA. TGA was conducted in the temperature range of 50 °C to 1000 °C with the heating rate 40 °C/min with suitable cooling attachment with thermocouple sensor Pt-Pt/Rh. The thermograms of selected leafy biomass materials are divided into four distinct stages (A to E). The percentage and rate of mass loss are shown in Table 5. The thermograms are divided into four distinct stages as shown in Fig. 2. The rate of mass loss in the first stage varies from 5.00 to 11.17 % which occurs upto the temperature range of 100 to 150°C. The mass loss indicates the removal moisture from the biomass. The mass loss in the second stage is slow and varies from 3.29 to 8.00 % which may be due to the volatilization of

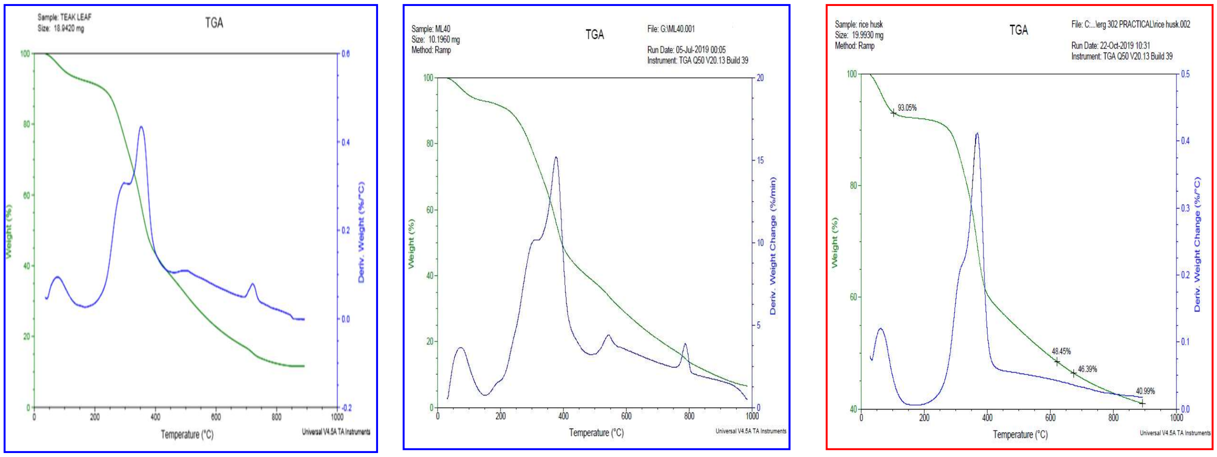

Figure 2: Thermogram of Teak leaves, Mango leaves and Rice husk

Table.5. Percent and rate of mass loss (mg/min) in different stages

Biomass	Stage A – B		Stage B – C		Stage C – D		Stage D – E	
	%	Rate (mg/min)	%	Rate (mg/min)	%	Rate (mg/min)	%	Rate (mg/min)
Teak leaf	5.22	0.45	7.83	0.53	45.24	1.85	23.49	0.53
Mango leaf	6.58	0.21	3.29	0.14	44.08	0.97	38.16	0.31
Rice husk	11.17	0.83	5.26	0.15	50.00	0.95	22.32	0.85

simple volatile matters. The steep fall in the third stage contributes maximum mass loss (44 to 50%) for each biomass and it is due to the removal of remaining volatile matters. The fourth stage which starts at the temperature range of 450 to 700°C may considered as the start of ignition of fixed carbon in the biomass. After reaching the temperature level of 800 °C, the mass loss is constant which indicates the ash content of the biomass.

Air required for gasification leafy biomass

For gasification 25 to 40% of stoichiometric has to be supplied (Reed, 1984). Air required for complete combustion of the biomass is given in Table 6.

Table 6. Air requirement for complete combustion

Biomass	Air requirement, m^3/ kg of fuel
Teak leaves	9.08
Mango leaves	6.34
Rice husk	7.75

Hot run of the gasifier

To start up the system known quantity of red hot charcoal was fed into the charcoal chamber. From the Table 7, it is observed that the fluidizing bed temperature ranges from 400 to 750°C for all the leafy biomass taken for the study. When the temperature of the bed exceeds 600°C, feeding of raw biomass was started. The results of gasification of leafy biomass are presented in the Table.8. The product gas flow rate for the leafy biomass varies from 2.8 to 3.1 m^3 per kilo gram of biomass feed. The calorific value of producer gas from the gasification varies from 3.0 to 3.6 MJ/m^3.

Table 7: Temperature Profile in the fluidized bed gasifier for leafy biomass

Time, min	Bed Temperature °C		
	Teak leaves	Mango leaves	Rice husk
10	443	496	532
20	490	507	537
30	535	505	563
40	550	534	595
50	576	554	605
60	614	600	640
70	635	625	655
80	621	554	528
90	590	560	522
100	551	510	510
110	523	485	515

Table 8: Performance of Fluidized bed gasifer for selected leafy biomass

Parameters	Biomass		
	Teak leaves	Mango leaves	Rice husk
Feed rate, kg/h	2.0	2.0	3.0
Air factor	0.3	0.3	0.3
Bed temperature, °C	700	680	700
Gas yield, m^3/kg	2.9	2.8	3.1
Average Gas Composition of Producer gas, %			
CO	13.5	13.7	14.2
H_2	12.3	11.4	15.4
CO_2	18.4	16.5	13.1
Calorific value of Producer gas, MJ/ m^3	3.1	3.02	3.56
Hot gas efficiency, %	40.0	55.0	54.0

Fluidized bed gasifier capacity

Average capacity of the gasifier is arrived based on the assumption that the average gas calorific value of producer gas obtained from leafy biomass is 3.0 MJ/m^3, average gas yield of 2.5m^3 /kg and a maximum possible feed rate 10 kg/h with the existing feeding system the capacity of the unit was worked out as 20kW.

Conclusion

Fluidized bed is one of the major platforms of biomass gasification. A fluidized bed biomass gasifier of 20kW capacity was developed for leafy biomass gasifier with all sub systems. The gasifier runs smoothly with the selected leafy biomass and in few runs the fluidizing air escapes through biomass feed port when the airflow rate is more than 0.4. The thermograms showed that after reaching the temperature level of 800 °C, the mass loss is constant which indicates the ash content of the biomass. Average capacity of the gasifier is arrived based on the assumption that the average gas calorific value of producer gas obtained from leafy biomass is 3.0MJ/m^3 and average gas yield is 2.5m^3/kg.

Conflict of interest

The authors declare that they have no conflict of interest.

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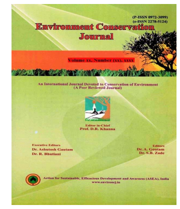

Incidence of stem rot disease of groundnut in relation to weather parameters in major groundnut growing areas of Telangana

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop and the economic production of groundnut is constrained by soil-borne diseases. Stem rot, caused by the necrotrophic fungus *Sclerotium rolfsii*, was the most common soil-borne disease in groundnut. A roving survey was conducted in major groundnut growing areas of Telangana during *kharif* 2019 and *rabi* 2019-20 to collect a preliminary data of the incidence level and pattern of prevalence of the stem rot disease. The district of Warangal has the highest incidence of stem rot. The lowest incidence of stem rot was found in Telangana's Wanaparthy and Nagarkurnool districts. Disease incidence was correlated with weather parameters, during *Kharif*-2019, temperature, relative humidity and rainfall showed positive correlation, whereas evaporation showed negative correlation, during *Rabi*-2019-20, temperature, relative humidity and evaporation showed positive correlation and rainfall showed negative correlation. This study provided an elementary idea about the per cent disease incidence as well as paved the path for developing ecosystem specific management strategy to reduce impact of soil borne diseases of groundnut in different districts of Telangana.

Introduction

Groundnut (*Arachis hypogaea* L.) is one of the most significant oilseeds and food crops grown in the semi-arid tropics, originated in South America.

Groundnut is grown on 29.59 (mha) over the world, with a total production of 48.75 million tonnes (FAOSTAT, 2019). The crop is grown on 4.8 million ha in India, with a yield of 9.2 million tonnes (INDIASTAT, 2019). It is grown to an extent of 0.13 mha in Telangana, with a production of 0.30 mt and a productivity of 2364 kg/ha (Directorate of Economics and Statistics, 2019).

Soil-borne diseases have been identified as one of the key limiting factors for groundnut production. *Aspergillus niger*, *Sclerotium rolfsii*, and *Rhizoctonia bataticola* are identified as major soil-borne pathogens (Ghewande *et al*., 2002). Pre-emergence rotting in seeds, soft rot in emerging seedlings, collar rot, stem rot and dry root rot in mature plants are the symptoms of these pathogens.

Stem rot has been found in regions where moisture and temperature levels are high enough for *Sclerotium rolfsii* to develop and survive. *Sclerotium rolfsii* infect groundnut plants at all stages of growth, including the seed germination stage, causing pre-emergence rot and young plant stem rot. The time it has taken for the plants to wilt ranged from 8 to 15 days. Because the infection was more widespread and quick, the younger plants

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were found to be more vulnerable. (Patil and Rane, 1983). *S. rolfsii* mycelia survives in sandy soils, whereas the sclerotia survive in moist, aerobic conditions near the soil surface. (Punja, 1985).

Material and Methods

During *kharif* 2019 and *rabi* 2019-20, roving surveys were conducted in main groundnut growing areas of Telangana's Warangal, Wanaparthy, and Nagarkurnool districts (Figure-1) when the crop was at the peg and pod development stage and 45-90 days old. In addition, key growing mandals and villages were chosen for the study within each groundnut-producing area. Visual symptoms and signs such as white mycelial development, sclerotia, lesions on the stem, wilting, and/or dead plants were used to determine the incidence of groundnut stem rot. Five plots, each measuring 5x5 m2, were chosen in each field. One of the five plots was placed in the field's central, while the other four were placed at random.

The following formula was used to determine the percent disease incidence in these areas.

$$P = N/T \times 100$$

Where,

P = % disease incidence

N = Number of infected plants

T = Total number of plants

Kadiri-6 (K-6) and local are the prominent variety's grown by the farmers. Majority of farmers applied fungicides like Thiram and Carbendazim as seed treatment.

Figure 1: Telangana map showing the sampling locations of *S.rolfsii* disease during *Kharif* 2019 and *Rabi* 2019-20 with sampling locations

The impact of weather variables on the disease's occurrence

A study of the effect of weather conditions (Temperature, Relative Humidity, Evaporation, and Rainfall) on percent disease incidence was performed. The weather data of three districts (Warangal, Wanaparthy, and Nagarkurnool) were obtained from meteorological stations and correlated to the disease's periodic occurrence at the same locations using the Karl Pearson's correlation coefficient, respectively (r).

Results and Discussion

During the seasons of *kharif* 2019 and *rabi* 2019-2020, a roving survey was undertaken in Telangana's major groundnut-growing districts, namely Warangal, Wanaparthy, and Nagarkurnool. Thirty villages were surveyed across three districts in seven mandals (Fig.1). Data on percent disease incidence, variety grown, soil type, crop stage at the time of survey, and crop protection measures used were gathered, and the results are presented in (Table 1, Table 2).During the *kharif* season of 2019, stem rot disease was detected in all of the surveyed villages, with disease incidence ranging from 31.24 to 12.1%. (Table 1). The highest disease incidence was found in Kadarigudem village in Wardannapet mandal of Warangal district, as well as Yedutla and Polikapadu villages in Gopalpet mandal of Wanaparthy district (31.24%) and the lowest in Bopally village in Talakpally mandal of Nagarkurnool district (12.1 %). In Warangal district, Kadarigudem (31.24) exhibited the highest disease incidence, while the least disease incidence was observed in Muchimpla village (14.21). Polikapadu village (31.24) had the highest disease incidence in Wanaparthy district and the lowest disease incidence was observed in Apparaala village (13.56). In Nagarkurnool district maximum disease incidence was observed in Thummanpet (23.55), Jinkunta (23.40), Gattunallykuduru (21.40), Gattuthummen (20.15), Zamisthapur (19.80), Pedduru (19.50) and Godal (13.56), while least disease incidence was observed in Bopally village (12.10). The average disease incidence of stem rot in Telangana's major growing areas ranging from 16.93 to 21.80 %. (Table 3). In fact, the Warangal district had the highest mean disease incidence rate of 20.31 %, followed by Wanaparthy (19.86 percent) and Nagarkurnool (19.18 %). In Warangal district stem rot incidence varied from 18.45 % (Narsampet mandal) to 21.80 % (Wardannapet mandal) in 16 villages spread over in four mandals of the district. Majority of the farmers have grown groundnut variety K6 except in 9 villages *viz*., Rangapur, Kadarigudem, Kammapally, Malakpally, Polikapadu, Apparaala, Gattunally kuduru, Zamisthapur and Godal villages where a local variety was grown. The sowings were done in June-July except in Chennur and Apparaala villages where the sowings were taken up in May, 2019. The soil type is red loamy and the crop was at peg to pod formation at the time of survey. However, it was observed that seed treatment with fungicides was not done by majority of the farmers.

The stem rot disease was observed in all of the villages surveyed during *Rabi* 2019-20, with disease incidence ranging from 25.66 to 10.11 percent (Table 2). Maximum disease incidence was observed in Yedutla village of Gopalpet mandal of Wanaparthy district (25.66%), while the least disease incidence was noticed in Muchmpla village of Nallabelli mandal of Warangal district (10.11%) and Godal village of Balmoor mandal of Nagarkurnool district (10.11%). In Warangal district maximum disease incidence was observed in Kadarigudem (25.33) village and least disease incidence was observed in Muchimpla village (10.11). In Wanaparthy district maximum disease incidence was observed in Yedutla (25.66) village, while least disease incidence was noticed in Buddaram (10.44) village. In Nagarkurnool district highest disease incidence was noticed in Thummanpet (20.13) while least disease incidence was observed in Godal (10.11). In Telangana's major groundnut growing areas, the average disease incidence of stem rot ranged from 14.23 to 18.88 % (Table 3). In addition, the Warangal district had the highest mean disease incidence rate of 17.53 %, followed by Wanaparthy (17.03 %) and Nagarkurnool (17.03 percent) (14.82 %).In 16 villages spread over four mandals in Warangal district, stem rot incidence varied from 16.61 % (Nallabelli mandal) to 18.88 % (Wardannapet mandal).Majority of the farmers have grown groundnut variety K6 except in 12 villages *viz*., Rangapur, Kadarigudem, Kammapally, Malakpally, Dharmapur, Polikapadu, Palem, Apparaala, Sankireddypally, Kanimetta, Bopally and Godal villages where a local variety was grown. The sowings were done in November except in Madannapet, Dasaripally, Gattunallykuduru, Zamisthapur and Pedduru villages where the sowings were taken up in October, 2019. The soil type is red loamy and the crop was at peg to pod formation at the time of survey. However, it was observed that seed treatment with fungicides was not done by majority of the farmers.The varied incidence of groundnut stem rot from one locality to the next in this study could be related to the

Table 1: Prevalence of stem rot disease in major groundnut growing areas of Telangana during *Kharif*-2019

State	District	Mandal/Taluka	Village	Variety	Soil type	Planting date	Crop Stage	Crop density	Crop protection	Disease incidence *Kharif* 2019
Telangana	Warangal	Nallabelli	Nandigama	K 6	Red	June	Pod	High	-	16.44
			Muchimpla	K 6	Red	June	Pod	Medium	-	14.21
			Lenkalapalli	K 6	Red	July	Peg	High	Thiram ST	21.33
			Rangapur	Local	Red	June	Pod	High	-	26.55
		Wardannapet	Ramojikummarigudem	K 6	Red	June	Pod	Medium	-	14.50
			Ellanda	K 6	Red	July	Peg	High	-	21.33
			Kadarigudem	Local	Red	June	Pod	High	-	31.24
			Nashkal	K 6	Red	June	Pod	Medium	Thiram ST	20.15
		Narsampet	Madannapet	K 6	Red	July	Peg	Medium	Carbendazim ST	16.40
			Dasaripally	K 6	Red	July	Peg	Medium	Carbendazim ST	15.40
			Chandrayappally	K 6	Red	June	Pod	Medium	-	15.45
			Kammapally	Local	Red	July	Peg	High	-	26.55
		Dharmasagar	Malakpally	Local	Red	June	Pod	Medium	-	21.33
			Dharmapur	K 6	Red	June	Pod	Medium	-	21.44
	Wanaparthy	Gopalpet	Chennur	K 6	Red	May	Pod	Medium	-	14.21
			Buddaram	K 6	Red	June	Pod	Medium	Carbendazim ST	14.55
			Polikapadu	Local	Red	June	Pod	Medium	-	31.24
			Yedutla	K 6	Red	July	Peg	High	-	31.20
		Kothakota	Palem	K 6	Red	July	Peg	Medium	-	14.21
			Apparaala	Local	Red	May	Pod	High	-	13.56
			Sankireddy pally	K 6	Red	June	Pod	Medium	-	24.51
			Kanimetta	K 6	Red	June	Pod	Medium	Carbendazim ST	15.45
	Nagarkurnool	Talkapally	Gattunallykuduru	Local	Red	June	Pod	High	Carbendazim ST	21.40
			Zamisthapur	Local	Red	June	Pod	Medium	Carbendazim ST	19.80
			Bopally	K 6	Red	June	Pod	Medium	-	12.10
			Pedduru	K 6	Red	June	Pod	Medium	-	19.50
		Balmoor	Gattuthummen	K 6	Red	July	Peg	Medium	-	20.15
			Thummanpet	K 6	Red	June	Pod	Medium	-	23.55
			Godal	Local	Red	June	Pod	High	-	13.56
			Jinkunta	K 6	Red	June	Pod	High	Carbendazim ST	23.40

Table 2: Prevalence of stem rot disease in major groundnut growing areas of Telangana during *Rabi*-2020

State	District	Mandal/Taluka	Village	Variety	Soil type	Planting date	Crop Stage	Crop density	Crop protection	Disease i
										Rabi 2020
Telangana	Warangal	Nallabelli	Nandigama	K 6	Red	November	Pod	High	-	15.24
			Muchimpla	K 6	Red	November	Pod	Medium	-	10.11
			Lenkalapalli	K 6	Red	November	Pod	High	Thiram ST	19.56
			Rangapur	Local	Red	November	Pod	High	-	21.54
		Wardannapet	Ramojikummarigudem	K 6	Red	November	Pod	Medium	-	10.12
			Ellanda	K 6	Red	November	Pod	High	-	24.11
			Kadarigudem	Local	Red	November	Pod	High	-	25.33
			Nashkal	K 6	Red	November	Pod	Medium	Thiram ST	15.99
		Narsampet	Madannapet	K 6	Red	October	Peg	Medium	Carbendazim ST	16.33
			Dasaripally	K 6	Red	October	Peg	Medium	Carbendazim ST	15.11
			Chandrayappally	K 6	Red	November	Pod	Medium	-	16.44
			Kammapally	Local	Red	November	Peg	High	-	20.11
		Dharmasagar	Malakpally	Local	Red	November	Pod	Medium	-	15.21
			Dharmapur	Local	Red	November	Pod	Medium	-	20.14
	Wanaparthy	Gopalpet	Chennur	K 6	Red	November	Pod	Medium	-	15.66
			Buddaram	K 6	Red	November	Pod	Medium	Carbendazim ST	10.44
			Polikapadu	Local	Red	November	Pod	Medium	-	23.77
			Yedutla	K 6	Red	November	Peg	High	-	25.66
		Kothakota	Palem	Local	Red	November	Peg	Medium	-	15.12
			Apparaala	Local	Red	November	Pod	High	-	11.23
			Sankireddypally	Local	Red	November	Pod	Medium	-	20.11
			Kanimetta	Local	Red	November	Pod	Medium	Carbendazim ST	12.33
	Nagarkurnool	Talkapally	Gattunallykuduru	K 6	Red	October	Pod	High	Carbendazim ST	16.22
			Zamisthapur	K 6	Red	October	Pod	Medium	Carbendazim ST	15.23
			Bopally	Local	Red	November	Pod	Medium	-	10.25
			Pedduru	K 6	Red	October	Pod	Medium	-	15.22
		Balmoor	Gattuthummen	K 6	Red	November	Peg	Medium	-	15.99
			Thummanpet	K 6	Red	November	Pod	Medium	-	20.13
			Godal	Local	Red	November	Pod	High	-	10.11
			Jinkunta	K 6	Red	November	Pod	High	Carbendazim ST	15.45

Table 3. Stem rot disease incidence in major groundnut growing areas of Telangana state during *kharif*-2019 and *rabi* 2019-20

District	Mandal	% disease incidence	
		***Kharif* 2019**	***Rabi* 2019-20**
Warangal	Nallabelli	19.63	16.61
	Wardannapet	21.80	18.88
	Narsampet	18.45	16.99
	Darmasagar	21.38	17.67
	Mean	**20.31 (highest)**	**17.53 (highest)**
Wanaparthy	Gopalpet	22.80	19.38
	Kothakota	16.93	14.69
	Mean	**19.86**	**17.03**
Nagarkurnool	Talkapally	18.20	14.23
	Balmoor	20.16	15.42
	Mean	**19.18**	**14.82**

Table 4: Weather data of major groundnut growing areas of Telangana during *Kharif* 2019 and *Rabi* 2019-20

District	***Kharif***				***Rabi***			
	Temperature	**Relative humidity**	**Evaporation**	**Rainfall**	**Temperature**	**Relative humidity**	**Evaporation**	**Rain fall**
Warangal	27.29	75.43	2.62	8.17	23.63	69.91	4.35	0.40
Wanaparthy	26.33	74.06	5.31	4.00	22.75	67.52	4.26	0.47
Nagarkurnool	26.33	74.06	5.31	4.00	22.75	67.52	4.26	0.47

cultivation of different groundnut types (K 6 and local cultivars) and the presence of diverse soil conditions (temperature and soil moisture content). It could also be attributable to the fungus's pathogenic variability. The findings are consistent with those of (Kulkarni, 2007), who observed different levels of stem rot incidence in various groundnut growing villages in the Dharwad district of Karnataka, and Siddaramaiah *et al*. (1979), who observed varying levels of stem rot incidence in various groundnut growing villages in the Dharwad district of Karnataka. Similarly, Ramakrishna and Kolte (1988) reported varying levels of stem rot incidence in India's major crop-growing areas, ranging from 15 to 30 %.

Amrutha Veena *et al*. (2019) reported highest stem rot incidence in Nellore and Chittoor districts of Andhra Pradesh. Palaiah *et al*. (2019) noticed 22.72 % stem rot incidence in Chitradurga district of Karnataka. Divya Rani *et al.* (2016) noticed the varied levels of incidence of stem rot of groundnut in different villages of Andhra Pradesh during *kharif,* 2012 and *kharif,* 2013. Further, Kadam *et al.* (2011) recorded higher incidence of stem rot in cultivar JL 24 (17.3%) among various cultivars grown in marathwada region of Maharashtra. Additionally, Ghewande *et al.* (2002) reported the average incidence of 27 % in major groundnut growing areas of India. They also noticed higher incidence of stem rot in Maharashtra, Saurashtra region of Gujarat compared to other areas surveyed. The present findings are also in agreement with Okabe and Matsumoto (2000) who reported 10 to 40 % incidence of stem rot in different groundnut growing areas of Japan. During the investigation, it was found that the incidence of stem rot was higher in pod-stage than in mature crops (Table 1 and Table 2). The findings support Pande and Rao's (2000) hypothesis that stem rot occurs in seedlings but becomes more common as the crop matures.

Correlation of weather parameters with stem rot disease incidence caused by *Sclerotium rolfsii*

Variations in meteorological conditions (temperature, relative humidity, evaporation, and rainfall) in each area could explain the variations in disease incidence (Table: 4). Significant relationships between mean per cent disease incidence, mean temperature, mean relative humidity, evaporation and mean rainfall were

Table 5: Correlation of weather parameters with incidence of stem rot disease

S.No.	Correlation coefficient (r)		
	Weather parameters	***Kharif*-2019**	***Rabi*-2020**
1	Temperature	0.80	0.64
2	Relative humidity	0.83	0.69
3	Evaporation	-0.79	0.65
4	Rainfall	0.81	-0.72

found. Temperature, relative humidity, and rainfall were shown to have positive correlations with disease incidence in *kharif* 2019, however evaporation was found to have a negative correlation. In *rabi*, 2020 temperature, relative humidity, and evaporation were found to have positive correlations with disease incidence, but rainfall was found to have a negative correlation., (Table: 5). The prevalence of *S. rolfsii* in warm regions of the world, according to Punja, Z. K. (1985), is a reflection of the high temperature required for its growth and sclerotial formation. The hyphal extension and dry weight production temperature range is 8-40°C, with maximum growth and sclerotial formation occurring at 27-30°C. *S. rolfsii* mycelia survives in sandy soils, whereas the sclerotia survive in moist, aerobic conditions near the soil surface.

Conclusion

The roving survey conducted during *kharif,* 2019 and *rabi,* 2019-20 revealed the incidence of stem rot in major groundnut growing areas of Telangana and was ranged from 12.1 to 31.24 % and 10.11 to 25.66 % respectively. In Warangal district highest disease incidence was observed in both *kharif* and *rabi*.Temperature, relative humidity, and rainfall were shown to have positive correlations with disease incidence in *kharif* 2019, however evaporation was found to have a negative correlation. In *rabi*, 2020 temperature, relative humidity, and evaporation were found to have positive correlations with disease incidence, but rainfall was found to have a negative correlation. In the present study, the varied incidence of stem rot of groundnut from one locality to another was might be due to cultivation of different groundnut varieties, prevalence of different weather conditions (temperature, relative humidity, evaporation and rainfall) and adoption of different cropping patterns.

Conflict of interest

The authors declare that they have no conflict of interest.

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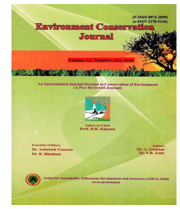

Occurrence of *Phytophthora nicotianae* causing collar and root rot disease of Chrysanthemum in India

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ABSTRACT

Chrysanthemum is an important flower crop grown in different parts of the world. Apparently there are new reports of chrysanthemum collar rot and root rot caused by *Phytophthora* sp. around the world. In recent years there has been increase in incidence of *Phytophthora* root and collar rot in chrysanthemum and no information is available about this disease in India. Therefore the aim of the present study is to isolate and characterize the pathogen causing collar rot and root rot disease of chrysanthemum. During year 2021, the plants exhibiting collar rot and root rot disease symptoms were received from the local farmers. Based on initial micro-morphological observation it was identified as *Phytophthora* sp. Further the pure culture of pathogen was isolated and confirmed its identity through cultural, morphological and amplification of the three regions/genes (ITS, *tef-1α* and *β-tubulin*) of *Phytophthora* sp. Phylogenetic analysis of concatenated sequence derived from ITS, *tef-1* and *β-tubulin* sequences of five *Phytophthora* isolates (PhN1, PhN2, PhN3, PhN4 and PhN5) showed close clustering of these isolates with *Phytophthora nicotianae* isolates infecting different crops. This is first detailed characterization of *Phytophthora nicotianae* causing collar rot and root rot in chrysanthemum in India.

Introduction

Ornamental flower plants are primarily cultivated for beautification and also to increase aesthetic value of public places, gardens and landscaping. Growing of flower crops is one of the prime businesses throughout the worldwide due to increase in demands for flowers at national and international market. In India, the area under flower crops production was 324 thousand hectares and the production of 1962.03 MT during 2017-18 (www.agricoop.nic.in). Among the flower crops, chrysanthemum (*Chrysanthemum indicum* L.) is one of the oldest flowering plant commercially grown in different parts of the world including India. Chrysanthemum belongs to the family Asteraceae and is cultivated globally for its cut as well as loose flowers and also used for herbal tea and preparation of pesticides (Bhattacharya and Silva, 2006). In India the crop is being cultivated commercially in Karnataka, Maharashtra, Rajasthan, Gujarat, Haryana, West Bengal, Delhi, Uttar Pradesh and Tamil Nadu. The crop is more popular due to wide range of colours, size and shape. So far, around 200 species of chrysanthemum comprising 20,000 varieties are reported around the world (Joshi *et al.,* 2010) of which nearly 200 varieties are grown in India (Singh and Kumar, 2014). The intensive cultivation of chrysanthemum is hampered by different disease caused by numerous pathogens such as bacterial, fungal and viral diseases (Bhattacharya and Silva,

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2006; Cook, 2001; Luong *et al.,* 2010; Nishi *et al.,* 2009). Among them collar and root rot is one of the major limiting factor for commercial cultivation of chrysanthemum in other countries. So far, different *Phytophthora* species has been well documented around the world causing disease on chrysanthemum that includes *Phytophthora chrysanthemi* from Japan (Naher *et al.,* 2011), Croatia (Tomic and Ivic, 2015), Germany (Götz *et al.,* 2017), United States (Lin *et al.,* 2017); Randall-Schadel, 2016), *Phytophthora drechsleri* and *Phytophthora nicotianae* from United States (Krasnow *et al.,* 2021; Mullen *et al.,* 2001). In India *Phytophthora* species causing flower blight of chrysanthemum has been identified in 1997, but no report of collar and root rot disease caused by *Phytophthora* in chrysanthemum. Since there is no much information available about *Phytophthora* species causing collar and root rot disease in chrysanthemum in India, Present study was attempted to characterize the collar and root rot disease of chrysanthemum based on morphological and molecular method for accurate identification of incite of the disease.

Material and Methods

Collection of Chrysanthemum collar rot and root rot disease samples

In September 2021, chrysanthemum plants (variety: Scent white and Scent yellow) exhibiting collar rot and root rot were submitted by the local chrysanthemum growing farmers from the two different locations (Shivakote and Bylakere) to the Division of Crop Protection, ICAR-Indian Institute of Horticultural Research, Bengaluru.

Since the disease appeared to be new and based on initial observation the pathogen was tentatively confirmed as *Phytophthora* sp. based on the microscopic observation. So, far there were no reports of *Phytophthora* causing collar and root rot disease in chrysanthemum, therefore field visit was undertaken in chrysanthemum growing areas to collect more number of samples in different farmers field in Bengaluru rural Area *i.e.* Shivakote (13°08'00.3"N,77°30'33.1"E), Madappanahalli (13°08'50.2"N,77°31'38.9"E), Linganahalli (13°09'19.2"N, 77°31'14.5"E) and Bylakere (13°06'16.9"N,77°30'43.5"E), Karnataka (India). From each location one infected chrysanthemum plants showing the collar and root rot disease samples were collected and transported to Division of Crop Protection, ICAR-Indian Institute of Horticultural Research, Bengaluru. For isolation of causal agent standard pathological procedure was followed as mentioned above.

Isolation of causal agents

The infected leaf, flower, stem segments of chrysanthemum plants collected during field visit were observed under the microscope to check for any sporulation. Further the infected root and collar region of the stem of chrysanthemum samples were washed in running water to remove soil and air-dried on blotting paper. The infected stem and root region were cut into 5 mm segments and surface sterilized using 1% sodium hypochloride followed by rinsing in distilled water for three times. The procedure for isolation of *Phytophthora* fungi was followed as mentioned by Sonavane and Venkataravanappa (2017). Then stem and root segments were dried on blotting paper and then inoculated aseptically on plates containing Potato Dextrose Agar with 100mg/L streptomycin. After 2 days of incubation at room temperature, a mycelia disc of 5 mm were cut using cork borer and transferred to petriplates containing sterile distil water for sporangia formation and incubated for 2 days. The isolated pure cultures were further maintained on PDA slants for further use. Infected samples were also surface sterilized and incubation at 25°C in sterile distill water for sporulation.

Morphological identification

The pure culture of *Phytophthora* isolates were used for morphological identification (colony growth, sporangia, oospore formation) using microscope at 100X magnification based on morphological keys (Waterhouse, 1963; Santos *et al.,* 2005). To study sporangia and oospore formation, mycelia disc from pure culture of each isolate was cut into 5mm disc using cork borer and dispersed in petriplates containing sterile distill water. After 48 hours of incubation at room temperature, abundant sporangia were observed at terminal end of mycelia. Sporangia from each isolate were collected and observed under 100X magnification. Colony characteristic (colour and texture) was observed after 5 days and colony diameter was measured at 2, 4, 8 and 10 days after inoculation.

Pathogenicity test:
For pathogenicity test two cultivars of Chrysanthemum (Scent white and Scent yellow) grown locally were used. For sporangia production procedure mentioned earlier in morphological identification was carried out. Produced sporangia were incubated at 8°C for 10 minutes for zoospore release which was confirmed under microscope. Chrysanthemum plants were maintained in polyhouse and zoospore suspension (1 x 10^6 zoospores/ml) of the pathogen was inoculated to the root zone. In control distil water was inoculated. The plants were kept in growth chamber at 28°C. Collar rot symptoms were visible 3 days after inoculation. The pathogen was re-isolated from infected roots.

Genomic DNA extraction, PCR amplification and sequencing
The pure culture of the fungus was grown on Potato Dextrose Broth and incubated for 7 days at 28°C. The mycelia mat was harvested by filtration through whatman filter paper no. 1 and washed with sterile distilled water and dried. Two grams of mycelia mat was used for total DNA isolation using CTAB method (Doyle and Doyle, 1990). The quality and concentration of the DNA was assessed using NanoDrop™ 1000 Spectrophotometer (Thermo Fisher Scientific). For molecular identification, the total genomic DNA extracted from the *Phytophthora* fungi was subjected to the PCR amplification using universal primer pairs of ITS rDNA, Translational elongation factor one alpha gene and *β-tubulin* gene regions of rDNA (Table 1).

Table 1: Primers used in this study for DNA amplification and sequencing

Locus	Primer name	Primer sequence (5'- 3')	Annealing temperature (°C)	References
ITS	ITS-1	TCCGTAGGTGAACCTGCGG	55°C	White et al., 1990
	ITS-4	TCCTCCGCTTATTGATATGC		
Beta-tubulin	T1	AACATGCGTGAGATTGTAAGT	60°C	O'Donnell & Cigelnik, 1997
	T2	TAGTGACCCTTGGCCCAGTTG		
Elongation Factor1 alpha	EF1	ATGGGTAAGGAAGACAAGAC	60°C	O'Donnell et al., 1998
	EF2	GGA(G/A)GTACCAGT(G/C)ATCATGT		

The PCR reactions were carried out in a GeneAmp PCR system 9700 (PE Applied Biosystems, Foster City, CA) thermocycler. All amplifications were performed in volumes of 25 µL PCR mix containing 2 µL DNA templates, 1.5 U Taq DNA polymerase, 25mM MgCl2, 2 mM dNTPs and 20 pmol of each primer. The PCR was programmed with the initial denaturation at 94ºC for 2 min, followed by 35 cycles of denaturation at 94ºC for 45 seconds, annealing temperature for ITS, tef-1α, and β-tubulin is mentioned in table 1 and the final extension of 72ºC for 90 seconds. PCR products were electrophoresised (1 h at 80 V) in 0.8% agarose gels in Tris-Borate-EDTA buffer, pH 8. Gels were stained with ethidium bromide (10 mg/mL) and viewed in a gel documentation system (Alpha Innotech, USA). The amplified PCR products of Internal transcribed spacer, Translational elongation factor one alpha gene and β-tubulin gene of *Phytophthora* isolates was purified from agarose gels using the QIA quick gel extraction kit (Qiagen, Hilder, Germany) and sequenced using automated DNA sequencing facility at Eurofins Genomics India Pvt. Ltd., Bangalore, India.

Sequence analysis
The sequences of ITS rDNA, Translational elongation factor one alpha gene and *β-tubulin* gene of the *Phytophthora* isolates were subjected to NCBI BLASTn to search for similar sequences in the database. The related sequences retrieved from the database belong to different *Phytophthora* species infecting diverse hosts were used for phylogenetic analysis. The ITS, Translational elongation factor one alpha gene and *β-tubulin* gene nucleotide sequences were concatenated with Mesquite version 3.61 (Maddison and Maddison, 2019). Sequences were aligned using clustalW method implemented in SEAVIEW program. A phylogenetic tree of the ITS, Translational elongation factor one alpha gene and *β-tubulin* gene

was constructed by maximum likelihood method using MEGA X version software (Kumar *et al.,* 2018) with 1,000 bootstrapped replications to estimate evolutionary distances between all pairs of sequences simultaneously.

Results and Discussion

Survey and collection of diseased chrysanthemum samples

During survey five fields were surveyed in diverse location of Bengaluru rural area for the incidence of collar rot and root rot disease of chrysanthemum. Typical symptoms of collar rot and root rot, yellowing, defoliation, leaf blight, blossom blight and complete dead of the plants was observed on two predominately grown local chrysanthemum varieties scent white and scent yellow in different farmer's field (Figure1). The infection appeared to be isolated in different areas of the field rather than complete loss at one place. The disease incidence in different location of Bengaluru rural Area ranged from 19.5 - 32.2 percent. Based on initial observations the pathogen was identified as *Phytophthora* sp. During field visit infected flowers, leaves, stem, roots and soil was collected (Figure 1).

There was no mycelia growth or sporulation on infected samples. Infected leaf, flower, stem and roots were used for isolation after surface sterilization. Among these only from roots the pathogen could be isolated. There was no sporulation on any of the infected material even after incubation in moist chamber.

Morphological characterization

The isolated pathogen was characterized as *Phytophthora nicotianae* on the basis of morphological and cultural characteristics. Mycelia growth of *Phytophthora nicotianae* on potato dextrose agar can be described as dense cottony mycelium with slightly petaloid pattern and growth was found to be abundant at 30°C (Figure 1). Intercalary hyphal swelling was abundant in solid culture.

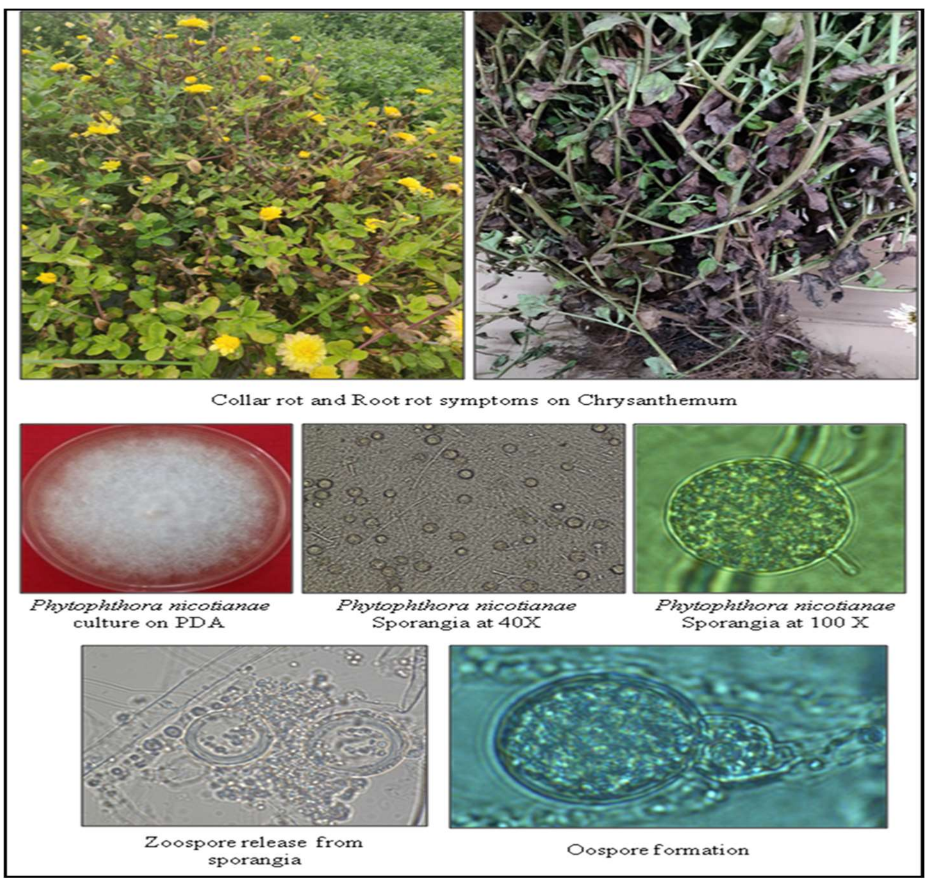

Figure 1: Symptoms, cultural and morphological characterisation of *Phytophthora nicotianae*

There was no sporangia formation on PDA agar but abundant sporangia was observed when disc were immersed in sterile distill water after 48h of incubation. The sporangia were mainly terminal, papillate, spherical, ovoid, 50-60μm in length, non-caducous. Zoospores are discharged through an exit pore 10-15μm wide (Figure 1). Isolates are homothallic, amphigyous based on oospores formation in 4 days after incubation. Oogonia are abundantly produced after 4 days. Oogonium is terminal, spherical. Anthridium is terminal and amphiygnous (Waterhouse, 1963 ; Santos *et al.,* 2005) (Figure 1).Pathogenicity test was conducted to determine the collected isolates of *P. nicotianae* were capable of causing similar observed symptoms under field conditions. The test was conducted on two popular chrysanthemum varieties i.e. Scent white and Scent yellow mentioned earlier. Plants were inoculated with zoospore suspension (10^6 spores per ml) of sterile water and control plants were left un-inoculated. In inoculated plants collar rot symptoms were visible 3 days after inoculation in both the varieties of chrysanthemum.

Molecular characterization

PCR amplification of different genomic regions of *Phytophthora* isolates

Total genomic DNA of the five *Phytophthora* isolates (PhN1, PhN2, PhN3, PhN4 and PhN5) causing collar and root rot disease of chrysanthemum were subjected to PCR for the amplification using universal primers pairs specific to ITS, *tef-1* and *β-tubulin* gene (Table 1). It resulted in the amplicons size of 550bp, 871bp and 799 bp respectively. The amplified PCR products of ITS, *tef-1* and *β-tubulin* was cloned and subjected to sequencing. The sequence analysis of three regions of five *Phytophthora* isolates (PhN1, PhN2, PhN3, PhN4 and PhN5) showed they belongs to *Phytophthora nicotianae* having nucleotide identity of 98-100 % with the respective from NCB. The consensus nucleotide sequence data of ITS, *tef-1* and *β-tubulin* was deposited in the GenBank under the following accession numbers listed in Table 2.

Table 2: List of the isolates sequenced for molecular phylogenetic analysis in this study

Species	Isolate no.	DNA database accession		
		ITS rDNA	β-tubulin	Elongation factor 1α
Phytophthora nicotianae	1	MZ396857	MZ502251	MZ447850
Phytophthora nicotianae	2	MZ396871	MZ502252	MZ447851
Phytophthora nicotianae	3	MZ411440	MZ502253	MZ447852
Phytophthora nicotianae	4	MZ411441	MZ502254	MZ447853
Phytophthora nicotianae	5	MZ411443	MZ502255	MZ447854

The nucleotide sequences of ITS, *tef-1* and *β-tubulin* regions of five *Phytophthora nicotianae* isolates infecting chrysanthemum in the present study were compared with the different *Phytophthora* species. The concatenated sequence derived from ITS, *tef-1* and *β-tubulin* sequences analysis indicated that, five *Phytophthora* isolates (PhN1, PhN2, PhN3, PhN4 and PhN5) in the current study shared nucleotide identity between 99.8-100% similarity per cent, among themselves. There were no sequences of *Phytophthora nicotianae* infecting chrysanthemum in the database, therefore other *Phytophthora* species identified in different parts of the world infecting chrysanthemum were used for phylogenetic analysis. Further, ITS sequence of these isolates shared maximum nucleotide (nt) identity of 99.74% per cent with the *Phytophthora nicotianae* infecting pomegranate from Turkey. While translation elongation factor shared highest nt identity with *Phytophthora nicotianae* infecting Nagpur orange from India. In case of *β-tubulin* showed more identical to *P. nicotianae* infecting ornamental crops in Italy. The phylogenetic analysis also showed close clustering of these isolates with *Phytophthora nicotianae* isolates infecting different crops (Figure 2). Phylogeny studies based on single locus DNA sequence was the common practice in fungi. This may not always elucidate the taxonomic status of the organisms (Berbee, 2001) and also give wrong conclusion about the relationship of a fungus within the same members of the same species or even the same genus (Lang *et al.,* 1999). The nuclear rDNA is the most popular and highly conserved genes, 18S (SSU), 5.8S (ITS), and 28S (LSU) for molecular phylogenetic studies (Kroon *et* *al.,* 2004). Therefore, analysis of concatenated sequences derived from multi-gene loci is becoming more acceptable in taxonomic positioning of fungi in the recent days (Kroon *et al.,* 2004). In the present study the analysis of concatenated sequence derived from ITS, *tef-1* and *β-tubulin* regions of five *Phytophtho*ra isolates infecting chrysanthemum with reference sequences

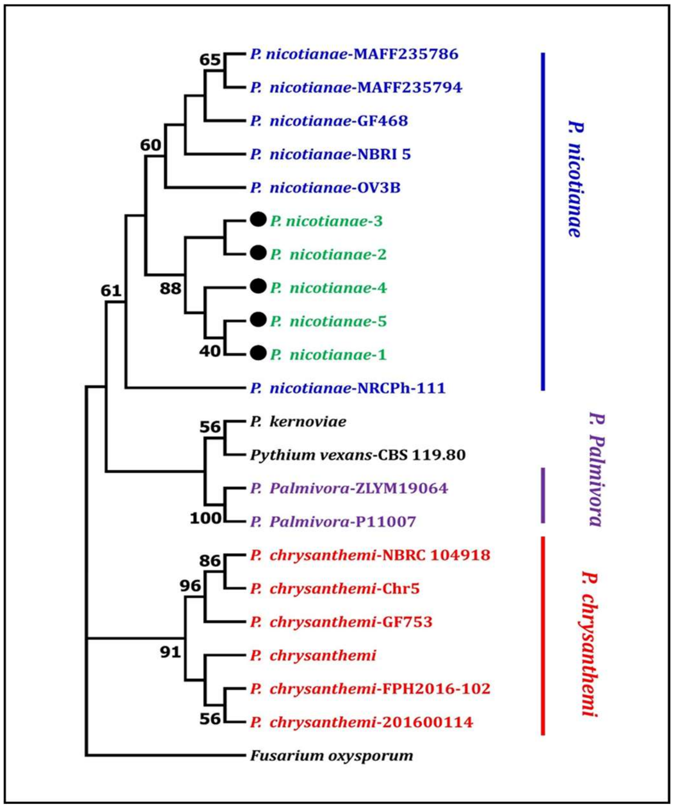

Figure 2: Phylogenetic tree showing the relationship of *Phytophthora nicotianae* within the genus *Phytophthora* based on gene sequences of (ITS, translation elongation factor 1α and β-tubulin) inferred by Bayesian analysis.

of *Phytophthora chrysanthemi, Phytophthora nicotianae* and *Phytophthora drechsleri* and different *Phytophthora* sequences available in the NCBI database revealed that all the five *Phytophthora* isolates infecting chrysanthemum along with several isolates of *Phytophthora nicotianae* formed monophyletic clade in the phylogentic analysis. Literature surveyed also showed similar conacatenated sequences derived from multi-gene loci analysis was carried out in fungi infecting different crops (Blair *et al.,* 2008; Camacho, 2009; Cook *et al.,* 2000; Donahoo *et al.,* 2006; Frezzi, 1950; Ivors et al., 2004; Lang *et al.,* 1999; Martin and Tooley, 2003ab; Molnar *et al.,* 2020). So, far three different species of *Phytophthora* has been identified around the world in chrysanthemum that includes *Phytophthora chrysanthemi* from Japan (Naher *et al.,* 2011) and United States (Lin *et al.,* 2017) and *Phytophthora drechsleri* from United States causing stem and blight of chrysanthemum (Krasnow *et al.,* 2021). However, this is first attempt of using concatenated sequence for identification of *Phytophtho*ra *nicotianae* infecting chrysanthemum as per our knowledge. In conclusion, the morphological and molecular analysis of five *Phytophthora* isolates infecting chrysanthemum from Karnataka State, India are identified as *Phytophtho*ra *nicotianae.* More sampling may provide insights into its population structure pathogen and better information for resistance breeding programmes and designing management strategies to contain the disease.The collar rot and root rot disease of chrysanthemum caused by *Phytophtho*ra *nicotianae* is becoming major threat for the production of chrysanthemum in recent years in different parts of the world. Collar and root rot disease of chrysanthemum initially starts with yellowing, dwarfing, no flower bud initiation, partial or complete wilting of plants and finally death plants. Under humid environmental conditions, the disease develops around the stem and root region of chrysanthemum plant later spreading over the soil. *Phytophthora nicotianae* infects several horticultural crops causing huge loss to the growers. In the present study, field visit was undertaken in different chrysanthemum growing areas of Bengaluru rural of Karnataka State to collect more number of infected chrysanthemum samples. During surveys, it was observed that the Collar and root rot disease of chrysanthemum was prevelling in almost all surveyed areas. The infected plants are exhibiting collar and root rot and complete dead of the plants. The incidence collar and root rot disease of chrysanthemum is ranged from 19.5 - 32.2 percent per cent different surveyed areas of Bengaluru rural. The higher disease incidence might be due to growing of local chrysanthemum scent white and scent yellow variety continuously every year in the same land and location which is considered as susceptible to collar rot and root rot disease of chrysanthemum (RF).

Conclusion

Chrysanthemum is an important flower crop cultivated in different parts of the country attacked by different biotic stress leads to huge loss to the growers. In past few years there have been several reports of *Phytophthora* species infecting chrysanthemum from all over the world, but very limited information is available in India. Therefore In the present study of *Phytophthora nicotianae* was identified for cause of collar rot and root rot disease of chrysanthemum in India Further, survey and research work needs to be carry out to estimate disease severity, pathogen diversity and management practices to tackle the losses in chrysanthemum flower production.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Historical pattern of rice productivity in India

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ABSTRACT

Forecast of productivity (yield) has an importance over production and area separately because it depends on both. Trend of the same reveals the necessity of the resources to be managed, for increasing yield in future. The forecast values of the series are obtained using autoregressive integrated moving average (ARIMA) model and the trend is determined by the means of Mann Kendall's trend test. In the present work we have found that the productivity of rice for overall country shows an increasing trend. Mann Kendal's trend analysis reported that the productivity has a steadily increasing trend which was also evident from the Sen's slope coefficient (*Q*). ARIMA (1,1,1) model with constant was found to be appropriate model for forecasting the productivity of rice. The forecast values were obtained for the subsequent four years starting from 2018 to 2021. Forecast error was also calculated and it was found to be less than 2 per cent i.e., 1.36 per cent.

Introduction

Rice is one among the most essential crops for human consumption which is grown and consumed by almost each and every part of India. India itself has an area of 43.79 million hectare with a rate of production of 168.50 million tonnes and average productivity of 3.85 tonnes per hectare (FAOSTAT, 2017). Rice has a potential to grow in different diversified climates so it is considered to be an important crop which also provide the food security to the country. A proper trend analysis and forecast for such a crucial crop has potential significance on many accounts as food securities and the management of storage and transportation facilities (Tripathi *et al.*, 2014). To know the maximum possible potential of yield as well an area and production for the optimum harvest of a crop, there should be a proper knowledge of ecology, appropriate advancements in that region.

In the present investigation we have taken productivity of rice as a variable under study. Why "productivity" rather than "production"? The answer is that the productivity is the result of relationship between area and production. At present almost all the possible resources (i.e., area, technologies) are being used in their optimum levels, then there is no further scope of increment in them. The only option is to fulfil the food requirements of the increasing population is increase the yield per unit of land. Keeping the above views in mind, the present study deals with the following objectives: (*i*) to determine the trend (*ii*) to forecast and validate the rice productivity.

An upward rise in price can be seen with the decrease in production which reduces marketable surplus. The adverse effect of income on farmers can also be seen with the increase in production i.e., as production increases the price decreases or *vice-versa*. To determine the inflation rate, salaries, wages and various policies related decisions, price plays an important role. The managements like surplus and deficit, which would stabilize the price in long term, can be achieved roughly by proper forecast of the production and also ensures the profit to the farmer. The latest trend in yield as well as production and area should be well studied for getting an idea about the future requirements of storability and transportation. Sometimes the actual series does not hold the assumptions imposed on

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error term. In that case, a transformation of the data set or the different techniques from the class of non-parametric approaches can be used (Nath *et al.*, 2020). Mann Kendal's trend test is a non-parametric procedure which is considered here for estimation of possible trend (Tripathi *et al.*, 2014). Trend analysis of productivity as well as area and production of garlic in Dindigul district of Tamil Nadu, India has been attempted by Manoharan and Ramalakshmi (2015). They have used Mann Kendal's trend test, Sen's slope coefficient, simultaneously for determination of magnitude of trend in productivity of rice. In the present work trend has been obtained by using Mann Kendal's trend test.

Now a day's modelling like remote sensing and simulation are being used widely for forecasting of the crop acreage and production. Sometimes, forecast for the same is needed much before the planting or harvesting of the crop. In that situation, ARIMA model which is based on the historical data (time series) can be used for forecasting the acreage, production and yield of crop. Contreras *et al.* (2003) used ARIMA methodology and obtained the forecast values for next-day electricity prices in the market of California and central Spain for daily markets namely, spot market and long-term market. Forecast values of productivity, production and yield of rice for the state of Odisha were attempted by Tripathi *et al.* (2014) by using ARIMA models for time series data starting from 1950-51 to 2008-09. Box-Jenkins' ARIMA model for forecasting the production of wheat for India was used by Nath *et al.* (2019). They selected the best appropriate ARIMA model by using minimum value of the AIC and MAPE. By using the selected model, forecast values for subsequent years can be obtained. Many studies available in the literature to justify that the vigilant and detailed selection of ARIMA model can produce a precise forecast to univariate time series. So, for forecasting the productivity of rice can be done by using ARIMA (p, d, q) model.

Data Collection

The data on productivity of rice for India were collected from the secondary source i.e., Data Net India Pvt. Ltd. Dataset comprise of time series data on annual productivity of rice (tonnes per hectare) starting from 1963 to 2017.The whole data set is divided in two parts viz., training set and validation set. The training data set has the observations starting from 1963 to 2014 and the remaining observations were retained for model verification under validation data set.

Trend Analysis

Mann Kendall trend test

Initially, this test was developed by Mann and Kendall separately and subsequently they derived the distribution of the test statistic also. The possible trend in a particular time series can be tested by using Mann-Kendall trend test which is a rank-based non-parametric method (Kolliesuah *et al.*, 2020).

The test statistic can be defined as,

$$s=\sum_{i=1}^{n-1}\sum_{j=(i+1)}^{n}\operatorname{sgn}(x_j - x_i) \quad (1)$$

where, x_i and x_j are the sequential data values, n is the total number of observations and

$$\operatorname{sgn}(\theta)=\begin{cases}+1, & \text{if } \theta>0\\ 0, & \text{if } \theta=1\\ -1, & \text{if } \theta<1\end{cases} \quad (2)$$

Significance level and the estimate of slope magnitude are the two parameters of this test. Significance level shows the strength of trend whereas the estimate of slope magnitude reflects the magnitude as well as the magnitude of the trend. For a random variable having *i.i.d.* $N(0,1)$ without any tie in data values, $E(S) = 0$ and

$$\sigma_S^2=\frac{n(n-1)(2n+5)}{18} \quad (3)$$

If some data values are tied, then the correction to $\sqrt{\sigma_S^2}$ can be done as,

$$\sigma_S^2 = \frac{n(n-1)(2n+5)-\sum_{i=1}^{n} t_i(i)(i-1)(2i+5)}{18} \quad (4)$$

Where, t_i denotes the number of ties of extent i. For n larger than 10, the test statistic can be modified as,

$$Z_s=\begin{cases}\frac{S-1}{\sqrt{\sigma_S^2}}, & \text{for } S>0\\ 0, & \text{for } S=0\\ \frac{S+1}{\sqrt{\sigma_S^2}}, & \text{for } S<0\end{cases} \quad (5)$$

where, Z_s is the standard normal variate.

Sen's slope coefficient

The magnitude of slope of trend can also be obtained by applying the Sen's slope coefficient (Ghimire *et al.*, 2018). Sen's estimate for slope is associated with the Mann-Kendall test as,

$$\beta=\text{median}\left(\frac{x_j-x_i}{j-i}\right), \quad \text{for all } j>i, \quad (6)$$

The median of these N values of β_i is represented as Sen's estimator of slope which is defined as,

$$Q_i = \begin{cases} \beta_{(N+1)/2}, & \text{if } N \text{ is odd} \\ \frac{1}{2}\left(\beta_{\frac{N}{2}} + \beta_{\frac{N+2}{2}}\right), & \text{if } N \text{ is even} \end{cases} \quad (7)$$

The positive and negative values of Q indicate an upward and downward trend, respectively.

ARIMA Modelling

To obtain the forecast values of equally distant time series, the well-known ARIMA modelling approach can be used. An ARIMA model forecasts the value of a dependent series by considering the linear combination of its own past values. Suppose the model is ARIMA(1,1,1), then it can be written mathematically as,

$$Y_t = \mu + \phi_1 Y_{t-1} + \theta_1 \varepsilon_{t-1}, \quad (8)$$

where, μ= the mean term, Y_t= the response variable observed at time t, ϕ_1= coefficient of the AR component, θ_1= coefficient of the MA component and ϵ_t= error term. The model given in (8) can be extended for, p number of AR components, q number of MA components and d, difference taken to make the series stationary, respectively and can be expressed as the model given in (9).

$$Y_t = \mu + \phi_i Y_{t-i} + \theta_i \varepsilon_{t-i}, \quad (9)$$

(***i***) ***Identification stage:*** The ARIMA model needs a stationary time series which can be performed using Augmented Dickey-Fuller (ADF) test. Then, the tentative values of the number of parameters "*p*"and "*q*" are to be decided. These values can be decided by looking at the significant spikes in autocorrelation function (ACF) and partial autocorrelation function (PACF). At this stage, one or more tentative models can be chosen for the available data.

(***ii***) ***Estimation stage:*** The tentative orders of the ARIMA models are needed to be estimated. These estimates can be obtained by using different packages like, SPSS, R etc. Presently, R is considered in this study.

(***iii***) ***Diagnostic checking:*** The best fit model can be obtained by considering the following information criteria:

(a) Significance of the parameters: Significance test forall the estimates of the parameters in the model should be obtained.

(b) Akaike Information Criteria (AIC): AIC can be estimated as,AIC = $(-2 \log L + 2m)$, where $m = p + q$ and L is the likelihood function.

(c)Model evaluation: Candidate models can be further evaluated by using mean absolute percent error(MAPE) which is defined in (10).

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n} \frac{|\hat{Y}-Y|}{Y} \times 100, \quad (10)$$

where, $\hat{Y}$ is the forecast value, Y is actual value of response variable and n is the total number of observations.

(d) Residual diagnosis: The residuals are to be diagnosed for autocorrelation and normal distribution. These can be done by ACF, PACF and normal Q-Q plot, respectively.

Empirical Findings

Mann Kendall's trend analysis

As has already been discussed that the it is a nonparametric test, then it becomes an important task to test the normality of the residuals of the concerned series. The normality of the error distribution of the series has been tested by using Shapiro-Wilk's test and Normal Q-Q plot (Nath *et al.*, 2020). Shapiro Wilk's test and normal Q-Q plot suggested that the series does not follow the normality of the error distribution (Table-1 and Figure-1). Under this test, the null hypothesis about normal distribution is rejected because p-value is less than 0.05 also the observations are deviating much from the normal line in normal Q-Q plot.

It is evident from Table-2 that the time series data under study possess an upward trend as Q is found to be positive and further it can be checked by forecasting the actual series using ARIMA model.

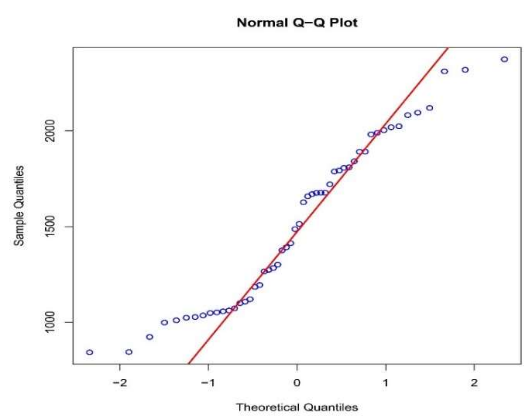

Figure 1: Normal Q-Q plot for the actual time series data

Table1: Descriptive measures for the actual time series

Variable	Mean	Median	Skewness	Kurtosis
Productivity	1516.71	1500.50	0.1963	-1.2467

Shapiro-Wilk's test	
Test statistic (*W*) value	Significance (*p*-value)
0.9405	0.011*

*significant at 5% level of significance.

Table 2: Mann Kendall's trend and Sen's slope coefficient summary

Test Statistic (*Z*) value	Observations (*n*)	*p*-value
8.538	52	0.001
S	σ_S^2	τ
1083	16058.33	0.817
Sen's slope coefficient (*Q*)		
Q	Lower limit	Upper limit
27.528	25.667	29.500

Table 3: Augmented Dickey Fuller test summary

	Statistic value	Lag order	*p*-value
Actual series	-2.8314	3	0.24
Series with $d = 1$	-5.9535	3	0.01**

**Significant at 1% level of significance.

Table 4: List of candidate ARIMA models.

Model	Coefficient	Estimate (se)	AIC
ARIMA (1,1,0)	*AR(1)*	-0.5633 (0.1131)	682.63
ARIMA (1,1,0) with Constant	*AR(1)*	-0.5855 (0.1107)	681.88
	Constant	27.3948 (16.1793)	
ARIMA (1,1,1)	*AR(1)*	-0.3275 (0.2163)	682.97
	MA(1)	-0.3535 (0.2176)	
ARIMA (1,1,1) with Constant	***AR(1)***	**-0.1397 (0.2395)**	**677.56**
	MA(1)	**-0.7132 (0.2319)**	
	Constant	**26.9253 (6.3578)**	

Table 5: MAPE for cross validation of fitted model

Year	Forecast	Actual	APE
2015	2305.28	2295.00	0.4459
2016	2337.88	2305.00	1.4066
2017	2364.02	2417.00	2.2413
MAPE (%)		**1.3646**	

Table 6: Box-Ljung test summary.

Test	χ^2 statistic value	*df*	*p*-value
Box-Ljung	1.3522	19	1

Table 7: Forecast summary obtained from ARIMA (1,1,1) with constant model

Year	Forecast	90% (C.I.)		95% (C.I.)		99% (C.I.)	
		Low	High	Low	High	Low	High
2018	2391.05	2081.14	2700.97	2021.76	2760.34	1905.73	2876.38
2019	2417.96	2099.65	2736.28	2038.66	2797.26	1919.48	2916.44
2020	2444.89	2118.41	2771.37	2055.86	2833.91	1933.62	2956.15
2021	2471.81	2137.37	2806.26	2073.30	2870.33	1948.07	2995.56

Note- C. I. stand for Confidence Intervals.

Fitting of ARIMA model

Model identification

ADF Test: Under ADF test the construction of the hypotheses is done as,

H_0: the series is not stationary against H_1: the series is stationary

Then this hypothesis was tested for the actual time series and it was found that the actual time series was not a stationary time series. So, the first order difference (i.e., $d = 1$) of the actual time series was taken and ADF test was applied to that series and it was found that the differenced time series was stationary. First order difference ($d = 1$) means we have generated a differenced time series of current year (Y_t) and immediate previous year values [i.e., $Y = Y_t - Y_{t-1}$]. The test result, is given in Table-3.

ACF and PACF

Approximate ARIMA models can be decided by the deciding the values of (p, d, q) As we have discussed earlier that choosing the order of ARIMA(p, d, q) is the way to get approximate ARIMA models. The actual series was not stationary, then first order differenced time series was tried for stationarity check and it produced significant result. That produces the value of "*d*" as "1" for the present time series. Now, the AR (p) and MA(q) orders are needed to be defined and it would be possible only by looking at the significant spikes of the ACF and PACF plots for the differenced time series.

Figure-2 produces the MA(q) order of 1 to 13, as all the 13 lags have significant spikes and AR(q) order of 1 and 2 as lags 1 and 2 are having significant spikes. It becomes difficult to identify an appropriated ARIMA (p, d, q) model from the ACF and PACF plots of actual time series because the actual time series was non-stationary. Therefore, the ACF and PACF plots of first differenced time series (Figure-3) was considered for determination of the orders and MA(q) order i.e., q = 0, 1 and AR(p) order i.e., $p = 1$. These values were found to be the approximate values of the parameters to be considered for building the model for concerned time series.

Model identification

The four approximate ARIMA (p, d, q) models were found to be the appropriate models based on the looking at the ACF and PACF plots. The detailed list of the expected models with their respective AIC values are given in the Table-4. Table-4 reveals that ARIMA (1,1,1) with constant was found to have the minimum AIC (677.56) value among four candidate ARIMA models. So, ARIMA (1,1,1) with constant model was found to be the appropriate ARIMA model for the present time series data. Then this said model has been checked for error diagnostics and diagnostic check summary is given in the Table-5.

Further, forecast values have been obtained by using ARIMA (1,1,1) model with constant after the cross validation of the model based on MAPE (Table-5). The MAPE is found to be less than 2 per cent (i.e., 1.36%).

Test for the autocorrelation in Residuals

Now in next step we would check presence of autocorrelation among the residuals obtained from the fitted ARIMA(1,1,1) model with constant by using "Box-Ljung" test (Table-6). The large p-values (more than the α=0.05)of the test suggests that H_0could not be rejected and it may lead to the conclusion that the autocorrelation functions were found to be non-significant among lags 1 to 20. Here the degrees of freedom are 19 because 20 lags have been used under ACF and PACF plot. Thus, it can be concluded the assumption of presence of serial correlation is rejected in the fitted ARIMA(1,1,1) model with constant.Residuals were further checked for the normal distribution by plotting histogram (Figure-4) and normal Q-Q plots (Figure-5).From figures 4 and 5, it can be clearly said that residuals are normally distributed. On the basis of normal Q-Q plot of standard residuals (Figure-5) in the fitted ARIMA (1,1,1) model, it can be concluded that standard errors are roughly constant with respect to mean and variance overtime.To check whether there is any auto correlation present in forecast errors, the plots of ACF and PACF are obtained. It can easily be seen that there is no any lag with significant spike in both the plots i.e., ACF and PACF plots (Figure-6).

Forecast using fitted ARIMA (1,1,1) model with constant

The forecast has been obtained from the selected ARIMA (1, 1, 1) with constant model, which was found to be the appropriate ARIMA model for the present time series data. Forecast values (Table-7) with the lowest and highest values for the confidence intervals of 90, 95 and 99 percent are

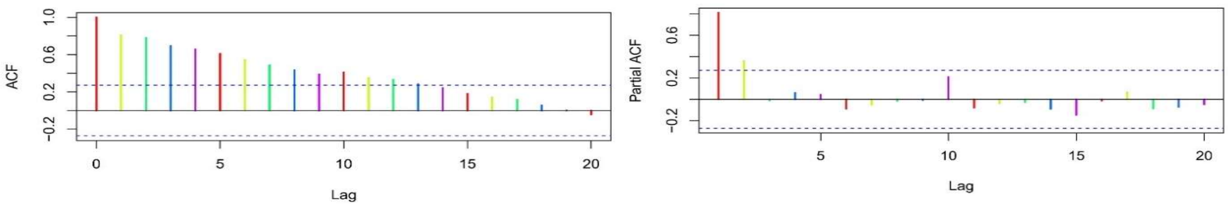

Figure 2: ACF and PACF plot for the actual series

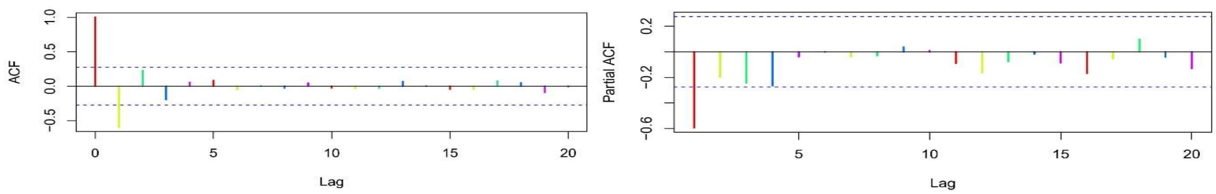

Figure 3: ACF and PACF plots of the differenced time series

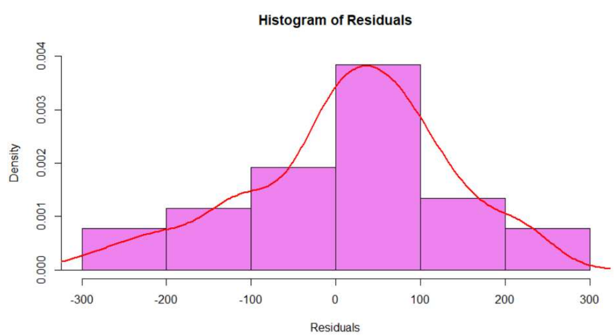

Figure 4: Histogram of residuals obtained in fitted ARIMA (1,1,1) model with constant

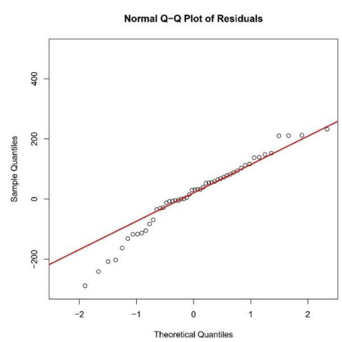

Figure 5: Normal Q-Q plot of residuals obtained in ARIMA (1, 1, 1) model with constant

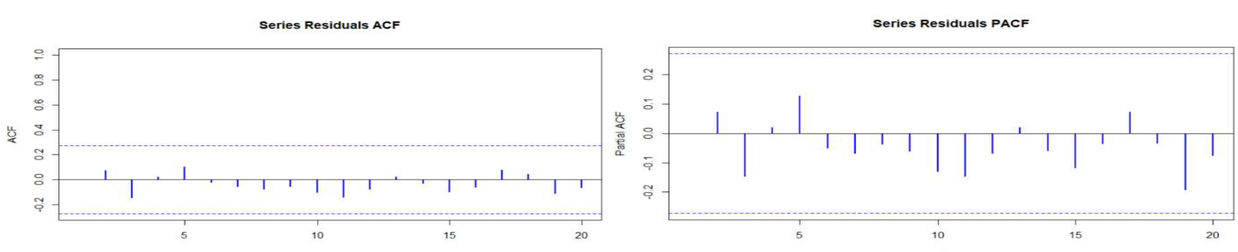

Figure 6: ACF and PACF plots of residuals obtained in ARIMA (1,1,1)

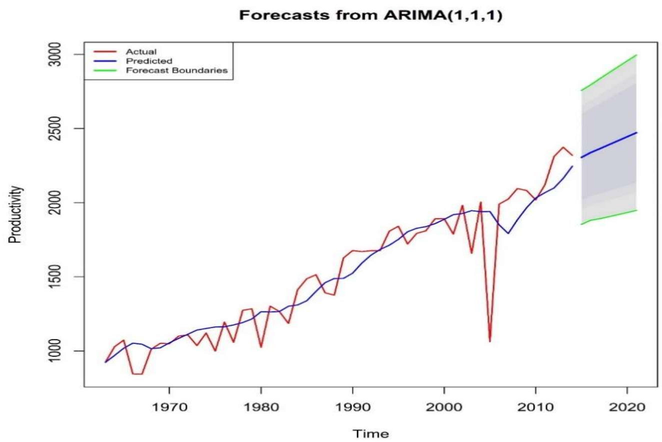

Figure 7: Plot of forecast with ARIMA (1,1,1) model with constant

obtained. The plot of actual and forecast values are also obtained which shows steadily increasing trend during the period of forecast (Figure-7).

Conclusion

Mann Kendal's trend test shows a significant presence of trend in the data on productivity of rice which is also evident from Sen's *Q* statistic. The positive value of *Q* indicates the presence of increasing trend. Upward trend can also be seen in the plot of forecast provided in the Figure-7 which has been obtained by using ARIMA (1,1,1) model with constant. The forecast values are showing the average growth rate of approximately 1.11 percent indicating the estimate of productivity of 2471.81 quintals per hectare for the year of 2021. To increase the potential productivity of rice suitable varieties according to the different ecological conditions can be introduced in farmer's field along with the nutrient requirement and agronomic management practices. Based on the forecast and validation results, it may be concluded that ARIMA (1,1,1) model with constant captures the real behaviour of the data.

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Conflict of interest

The authors declare that they have no conflict of interest.

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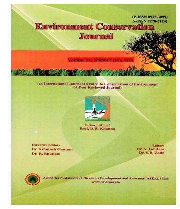

Standardization of post-harvest practices for best quality essential oil production of *Mentha arvensis* L.

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ABSTRACT

***Mentha* species belongs to Lamiaceae family is an important industrial crop, cultivated commercially on large scale. In this study, a common cultivar of M. arvensis with a high essential oil content (Cim Kranti) was investigated to determine the impact of drying techniques for 10 days immediately following harvest on the essential oil content and its chemical profile under three conditions: open field (S1), shade (S2), and ventilated chamber (S3). According to results, significantly higher essential oil (0.723%) with 77.58 % of menthol content was observed in freshly harvested crop on same /1st day of harvest (T_1) than any other conditions. *M. arvensis* was harvested and drying in open field condition (S_1) has showed 0.68% of essential oil having rich amount of menthol (76.86 %) content on fresh sample (T_1) which decline to 0.51% essential oil content with menthol content 76.88% at 10th days after harvest. *M. arvensis* dying in ventilated room (S_3) showed essential oil (0.71%) and menthol content 76.58 % on same day of harvest, which later decreases upto 0.6% essential oil with menthol content 74.32% on 10th day after harvest. Results concluded that the best quality and high yield of essential oil of *M. arvensis* should willingly be distilled fresh just after harvest. It also indicates that postharvest processes should immediately followed harvesting with appropriate drying method to minimize the loss of high quality essential oil.**

Introduction

Aromatic compound especially essential oil is one of the volatile compond in nature. In recent years, farming of aromatic plants have become more popular with increasing demands of essential oil in cosmatic, aromatherapy and other industries. This demand of aromatic crop had created pressure on farmers to supply the high quality raw material or essential oil. In present experiment *Mentha arvensis* crop was seleted to study the post harvest effects because of its high demand of essential oil and large scale farming. *Mentha arvensis* L. known as mints or Japanese mint have total 42 species, 100

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subspecies and cultivars (Salehi *et al*. 2018). It is a perennial aromatic crop and cultivated commercially in different parts of the world. *M. arvensis* with rich amount of menthol are cultivated in countries like America, Europe, China, Brazil, and India. India produce larger amount of essential oil of *M. arvensis* and export in all over the world (Gupta *et al*. 2016). Mentha is a natural sources of menthol and other chemical constituents like menthone, methyl acetate, isomenthol and terpenes. About 70 to 80% menthol content were recorded in an essential oil extracted through hydro-distillation of herb. *M. arvensis* L. possess a fresh cooling and soothing effect on the skin and mucous membranes of the human body, making it a useful ingredient in pharmaceuticals, food and cosmetics preparations as well as beverages (Rawashdeh, 2011). Its also widely used in mouth washes, as flavouring agent in confectionaries and dental creams (Singh and Khanuja, 2007).

Essential oil of mentha has large market with growing demand through out the world. To fulfill the requeriments, farmers needed to cultivate *M. arvensis* on larger field area. These cultivated fields create difficulty for farmers at the time of harvesting and during its transportation and distillation due to limited manpower and facility (distillation units). Maximum farmers having small or medium size field distilled essential oil of their harvested crop on rent basis. They harvested their crops and kept in field for days for later oil extraction. Post harvest storage of aromatic crops are usaully common in rural areas (Rahimi and Farrokhi, 2019). Post harvest losses due to inappropriate handling, drying and storage of mentha crop after harvest, results in damaging the raw material and decreases the quality and quantity of essential oil which effect the product price in market. Poor drying process of aromatic crops after harvest has also affected the essential oil content and biochemical compound. To conquer the challenges, different drying methods were used on harvested crops which can influences the essential oil content without disturbing the quality and yield of oil. Postharvest processes applied immediately after the harvest to protect from the deterioration of crop product. Drying is an important primary process which involves the removal of moisture content with minimum damage. Correct drying of raw material, protect the herb from contamination and preserve the unwanted change in essential oil content and composition quality. Therefore, current trial were performed to study the effects of drying methods on the essential oil yield, oil content and composition of *M. arvensis* and to identify the best storage methods with respect to mainitaing the quality of essential oil and to minimize the loss of essential oil during post-harvest.

Material and Methods

Site description

The experiment was conducted at CSIR-Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP) Centre, Pantnagar located at coordinates of 29°N, 79.38°E and an altitude of 243.84 m, Uttarakhand, India.

Experimental set up and treatments

The fresh *Mentha arvensis* was harvested and collected in 2019 from the field of CIMAP, research center. A random sampling of 200 g fresh harvested mentha crop was divided in to 3 batches (10 samples each) as treatments with three replicates. 3 batches were divided in open field storage condition (S_1), shade condition (S_2), and ventilated room condition. One sample from each batch was distilled on the same day of harvesting. The observations of essential oil and menthol content were recorded from 1st to 10th day after harvest of mentha and stored under three different conditions.

Extraction of essential oil

The essential oils of fresh and stored samples were isolated by hydro-distillation in a Clevenger type apparatus for 3 hours. The distilled essential oil was dehydrated by adding pinch of anhydrous sodium sulphate and kept in a refrigerator until analysis.

Chemical components of Mentha

Essential oils compounds were characterize by Gas Chromatography carried out on Nucon model 5765 equipped with flame ionization detector (FID) and DB-5 (30 m × 0.32 mm; 0.25 µm film thickness) fused silica capillary columns. Carrier gas was used as hydrogen at 1.0 mL/min. Temperature programming was range from 60-230 °C at 3 °C/min. The injector and detector temperatures were 220 °C and 230 °C, respectively. The injection volume was 0.03 µL neat with a split ratio of 1:40. GC-MS analysis of essential oil was carried out on a Perkin-Elmer Turbo mass Quadrupole Mass spectrometer fitted with PE-5 (Perkin-Elmer) fused silica capillary column (60 m × 0.32 mm; 0.25 µm film thickness). The column temperature was programmed 70 °C, initial hold time of 2 min, to 250 °C at 3 °C/min with final hold time of 3 min, using helium as carrier gas at a flow rate of 1.0 mL/min. The injector and ion source temperatures were 250 °C. The injection volume was 0.06 µL neat with a split ratio of 1:30. 2.5.

Statistical analysis

The numerical data of all the components were subjected to analysis of variance (ANOVA) using randomized block design. Statistical analyses of data were done using statistical calculator.

Results and Discussion

Essential oil percent (%) and oil yield (kg/ha)

The obtained results of essential oil percent (%) and yield (kg/ha) of mentha crop were varied under different storage conditions (S_1, S_2, and S_3) are presented in Table 1 and 2. Storage method has affected the essential oil % of *M. arvensis* from 0.70% to 0.51%, 0.723% to 0.51%, and 0.71% to 0.6% in the S_1, S_2 and S_3 conditions, respectively after 10 days of continuous drying. Significantly higher essential oil (0.723%) on first day after harvest (T_1) showed significant decrease upto 0.51% after 10th day of harvest under S_2 condition. However, the storage methods for 10 days was significantly affected the essential oil yield (kg/ha) and content of mentha with lowest essential oil content S_1T_{10}. Study showed the significant relation of drying storage method in respect to essential oil content and yield of the crop. The literature indicates that alteration in essential oil content and bioactive compound was not entirely depends on drying process but can also be species specific, time duration, temperature, and method of drying (Dehghani *et al*. 2018). In previous study of postharvest method, drying *Lippia citriodora* under high temperature above 30ºC, damage the volatile compound and reduced the essential oil content (Yadegri *et al*. 2013; Ebadi *et al*. 2015). Similar results were observed in *Origanum vulgare* and *Origanum onites*, when herb was dried under 60ºC (Ozdemir *et al*. 2017). Ozdemir found negative impact of high temperature on the essential oil content, yield and its chemical composition of these two crops.

Table 1: Influence of post-harvest storage condition on essential oil (%) and quality of *Mentha arvensis*

Parameters	Essential oil content (%)				Menthol (%)			
Treatments	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
T_1	0.68	0.72	0.71	0.71	76.86	77.58	76.58	77.01
T_2	0.70	0.71	0.70	0.70	74.61	77.58	75.21	75.80
T_3	0.69	0.69	0.69	0.70	71.4	75.28	75.39	74.02
T_4	0.69	0.69	0.68	0.70	75.3	74.57	74.39	74.75
T_5	0.66	0.67	0.66	0.66	74.98	75.18	75.77	75.31
T_6	0.65	0.65	0.65	0.65	76.7	72.87	73.98	74.52
T_7	0.58	0.59	0.59	0.59	76.36	72.81	74.72	74.63
T_8	0.58	0.55	0.57	0.57	71.75	74.01	74.2	73.32
T_9	0.55	0.54	0.56	0.56	75.4	73.99	74.4	74.60
T_{10}	0.51	0.52	0.54	0.54	76.88	73.80	74.32	75.00
Mean	0.63	0.63	0.65		75.02	74.77	74.90	
Analysis	T	S	T ×S		T	S	T ×S	
SEm$_{\pm}$	0.004	0.001	0.0112		0.098	0.026	0.294	
LSD$_{(0.05)}$	0.011	0.003	0.0315		0.277	0.075	0.833	

T_1: same or first day of harvest; T_2: second day of harvest; T_3: third day of harvest; T_4: fourth day of harvest; T_5: fifth day of harvest; T_6: sixth day of harvest; T_7: seventh day of harvest; T_8: eighth day of harvest; T_9: ninth day of harvest; T_{10}: tenth day of harvest

S_1: open field condition; S_2: under shade; S_3: ventilated room. Treatments with the same superscript letter are not significantly different at alpha=5%.

Table 2: Influence of post-harvest storage on essential oil yield of *Mentha arvensis.**

Storage → Treatment ↓	S1	S2	S3	Mean
T1	170.83	180.83	179.16	176.94
T2	175.00	177.50	175.83	176.11
T3	172.50	172.50	172.50	172.50
T4	172.50	168.30	172.50	171.11
T5	165.80	168.30	164.16	166.11
T6	164.16	162.50	162.50	163.05
T7	145.83	146.66	155.83	149.44
T8	145.83	138.33	150.00	144.72
T9	137.50	134.16	150.00	140.55
T10	129.91	130.00	150.00	136.38
Mean	157.91	157.91	163.25	
Analysis	**T**	**S**	**T*S**	
SEm$_{\pm}$	0.929	0.253	2.787	
LSD$_{(0.05)}$	2.628	0.716	7.880	

****On the basis of estimated herb yield 250 quintal/ha of menthol-mint***

Oil yield (kg/ha)

Maximum oil yield of mentha 180.83 kg/ha and 179.16 kg/ha were observed on the first day of harvest (T_1) in S_2 (shade condition storage) and S_3 condition, respectively (Table 2). 2nd day of storage T_2S_1 oil yield showed essential oil yield 175 kg/ha, which is almost equal to oil yield observed in T_2S_2 (177.5kg/ ha) and T_2S_3 (175.83 kg/ha). Yield of *M. arvensis* essential oil start to decrease continuously till the plant loses its moisture content completely. In S_3 storage condition, essential oil yield decline from 5th day T_5 (164.16 kg/ha) to 7th day T_7 (150 kg/ha) was still higher than the other two conditions. 10th of storage (T_{10}), lowest essential oil yield recorded was 129.16 kg/ha, 130 kg/ha and 150 kg/ha in S_1, S_2 and S_3 condition, respectively. Significant relation was found between different drying days and essential oil yield in T_1S_2 with highest oil yield 180.83 kg/ha and in $T_{10}S_1$ with lowest oil yield 129.91 kg/ha. Out results were match with previous records that essential oil yield of aromatic crops (in this case mentha) dried in open field condition (sun) was affected with decrease in bioactive compounds. Rebey, carried out an experiment which shows increased essential oil content when the sample was dried under shade (Rebey *et al*. 2020). Similar finding were observed in *C. flexuosus* (lemongrass) where essential oil percentage was higher in shade condition than the other conditions (Upadhyay *et al*. 2019). Drying mentha herb in open field condition (S_1) has directly affected the essential oil content from 1st day (T_1) to 10th day of harvest (T_{10}), was due to direct exposure to sunlight and temperature. Present result has recorded maximum essential oil content and oil yield in drying material under ventilated room than any other methods. Drying process under shade was found more suitable than open field condition because of the lower temperature which preserves the damage of trichomes and protects the loss of essential oil content (Thamkaew *et al*. 2020).

Bioactive content (%)

Significantly highest Menthol content 76.86 %, 77.58%, 76.58% were recorded on same or 1st day of harvest (T_1) stored under different post-harvest methods viz., open field (T_1S_1) condition, shade (T_1S_2) condition and ventilated room (T_1S_3) conditions, respectively. The lowest menthol content 71.75%, 72.81% and 73.98% were recorded in different days of harvest stored under open field (T_8S_1), shade (T_7S_2) and ventilated room (T_8S_3) condition, respectively. Menthol content decreases up to 76.88% in ($T_{10}S_1$), 73.8% in ($T_{10}S_2$) and 74.32% ($T_{10}S_3$) on 10th day of harvest (Table 1). Although, there is less consistency in decreasing order of menthol content (76.86 to 76.88%) recorded from 1st day to 10th day of harvest in open field condition (S_1) may be due to uneven exposer of sunlight in each sample as compared other drying condition. Different studies evaluate the influence of drying condition on the essential oil yield and major compounds of *Melissa officinalis L.*, *Mentha piperita*, *Thymus vulgaris*, *Thymus daenensis*, *Salvia hydrangea* and *Pogostemon cablin* and found that dying in high temperature or under direct sunlight involves in evaporating the oil content and volatile compounds in it, which lower the oil yield after distillation (Çalişkan *et al*. 2017; Khanuja *et al*. 2004; Ambrose and Naik, 2013; Mashkani *et al*. 2018; Mahdiyan and Pirbalouti, 2017; Pluha *et al*. 2016). Menthol was the major compound found in essential oil of fresh and dried leaves of *M. arvensis*. High menthol content (77.58%) was found in fresh mentha distilled immediately after harvest. Our results were similar with previous reported data of essential oil composition of *M. piperita*, *Ocimum basilicum* and *L. thymoides* (Gasparin *et al*. 2014; Alves *et al*. 2015; Silva *et al*. 2016). There results showed a change in the percentage of major compound menthol, linalool, methyl chavicol and thymol in sample dried under different condition with temperature above 30°C. Therefore, correct drying method is very important step of postharvest process to minimize the loss of essential oil content and change in chemical profile. Drying under ventilated room or shade can be an appropriate method to obtained better quality essential oil. Numerous studies in past few years have been focused on post harvested management of aromatic plants to increase their shelf-life and maintain the quality of essential oil (Mahmoudi *et al*. 2020).

Conclusion

According to the results, storage at different condition for long period of time has affected the essential oil content of *Mentha arvensis*. Significantly highest essential oil content (0.723%) was collected from first day of harvest as compared to other days of treatments (days after harvest). High menthol content (77.58%) was identified in essential oil collected from fresh leaves of *M. arvensis*. However, Mentha crop stored in ventilated room (S_3) have good impact with minimum loss of essential oil and menthol content as compared to other drying methods. Perhaps this drying process is right in preserving the quality of essential oil and preventing from contamination but still needed more study. Results do not suggest the postharvest drying of crop in open field under direct sunlight. Thus, the results of present study suggest that distillation of *M. arvensis* crop should be done fresh after harvest for better quality and quantity of essential oil.

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Conflict of interest

The authors declare that they have no conflict of interest.

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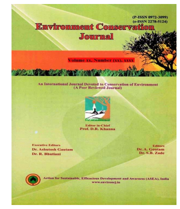

Arsenic acquisition pattern in different plant parts of aromatic rice cultivars

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ABSTRACT

A field trial was conducted in Gontra village under Chakdaha block of Nadia district, West Bengal during rainy (*kharif*) season of 2020 to assess arsenic (As) accumulation in different plant parts of aromatic rice cultivars. The field trial was laid out in Randomized Block Design (RBD) with 15 treatments (aromatic rice cultivars) and three replications. Results revealed that the aromatic rice cultivar 'Poreiton' (collected from Manipur) showed maximum arsenic accumulation in grain (0.93 mg/kg) and husk (1.68 mg/kg); being statistically at par with cultivars 'Wairi-Chakhao' (0.87 and 1.55 mg/kg grain and husk, respectively) and ''Lalbadshabhog' (0.74 and 1.52 mg/kg grain and husk, respectively). Least arsenic accumulation was found in the cultivar 'Tulaipanji' (0.17 and 0.71 mg/kg grain and husk, respectively). Hence, the cultivar 'Tulaipanji' grain was found to be safe for human consumption, as the grain As content within the safe limit as per WHO's guideline (maximum 0.2 mg/kg of white rice). But other cultivars need some mitigation strategies with respect to water and nutrient management so that grain As content is kept within the safe limit.

Introduction

Rice is a staple food for more than 70% of global population and is produced in about 120 countries worldwide. India is the second-largest producer, with a total production of 177.64 million tonnes in 2019 (Banerjee *et al.,* 2022).West Bengal, the rice bowl of the country, is the richest reservoir of rice bio-diversity (Banerjee *et al.,* 2018).Aromatic rice (basmati type and non-basmati type) occupies a unique position among rice varieties on account of its excellent quality characters and thereby having a great potential in its export. This group of rice is popular and highly priced because of its aroma and cooking characteristics. The rice has its uniqueness in the fact that it releases aroma both on the field (during flowering and harvesting,) and off the field (during, milling, storing and cooking) (Heisnam *et al*., 2020). Many aromatic varieties are grown in restricted areas of West Bengal and hence, there is need to promote its cultivation in non-traditional areas also. Now-a-days, people give more interest on quality of the food rather than quantity. However, due to the presence of some contaminant like heavy metals, its quality has decreased by tenth fold and this might have great impact on its export potentiality. Arsenic is a metalloid that is found in the environment through natural events like volcanic eruption, weathering of rocks etc. and anthropogenic activities like mining, application

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pesticides etc. This heavy metal enters into human body and plant system through consumption of contaminated drinking and irrigation water respectively (Moulick *et al*.,2021). In July 2014, the World Health Organization set worldwide guidelines for safe levels of arsenic in rice, maximum being 0.2 mg/kg for white rice and 0.4 mg/kg for brown rice (Sohn, 2014). So, the present experiment was conducted to find out arsenic acquisition pattern of various aromatic rice cultivars in vegetative (root, stalk and husk) and economic part (grain).

Material and Methods

The field trial was laid out in Gontra village under Chakdaha block of Nadia district, West Bengal during *kharif* season of 2020. The experiment was laid out in Randomized Block Design (RBD) with 15 treatments (T_1-Poreiton, T_2-Chakhao-amubi, T_3-NC365, T_4-Tulaipanji, T_5-Wairi-chakhao, T_6-Lalbadshabhog, T_7-Kaminibhog, T_8-Gopalbhog, T_9-Monibhog, T_{10}-Radhunipagol, T_{11}-Kataribhog, T_{12}-Radhatilak, T_{13}-Kalonunia, T_{14}-NC324 and T_{15}-Gobindobhog) and three replications. These 15 aromatic cultivars were collected from different parts of Manipur and West Bengal. The seedlings were raised in separate plots and 28 days old seedlings were used for transplanting in the main field. Standard agronomic management practices were followed in the main field with recommended fertilizer dose of 40-20-20 kg N-P-K/ha.After harvesting, plants were digested and arsenic content of the digested sample was measured by using ASS (Analyst 200) coupled with FIAS 400 (a hydride generator) (Sparks *et al*., 2006).The collected data were analyzed statistically by the analysis of variance (ANOVA) technique using the SPSS ver. 20 software. The significant difference between treatments means was tested at $p \leq 0.05$. Linear regression-enter method was intervened to establish the relationshipbetween As content in economic (grain) and vegetative (root, stalk and husk) parts. To predict the presence of auto-correlation in the residuals of such regression models, Durbin-Watson statistics were used (Ghasemi *et al.,*2010).Agglomerative Hierarchical Clustering was done using XLSTAT 2017.

Results and Discussion

Arsenic accumulation in different plant parts

Different chemical properties of soil were determined before initiation of the present study. Results revealed that the soil of the experimental site had pH 6.84, organic carbon 0.72, 218 kg/ha available nitrogen, 48 kg/ha available phosphorus, 178 kg/ha available potassium and available arsenic of 5.77 mg/kg. In West Bengal and Bangladesh, during the dry wintery season, As contaminated ground water is used for rice production (Duxbury and Pnaullah, 2007; Roberts *et al*., 2007) thereby increasing As content in agricultural soil (Ahmad and Bhattacharya, 2019). Moreover the capability to transfer heavy metals from soil to crop differs for different crops and ultimately affects their bioaccumulation pattern (Sekara *et al*., 2005) which is in conformity with the present findings. The results revealed that aromatic rice cultivar 'Lalbadshabhog' showed maximum arsenic accumulation in root (8.55 mg/ kg) and this was found to be statistically at par with the cultivars 'Poreiton' (8.39 mg /kg) and 'Wairi-Chakhao' (8.09 mg/ kg) collected from Manipur (Table 1). The least root As accumulation was recorded in 'Tulaipanji' (5.92mg/ kg). It was also observed that the maximum As content in stalk was found in 'Wairi-Chakhao' (3.35mg /kg); being statistically at par with stalk As content of the cultivars Poreiton; (3.20 mg /kg) and 'Lalbadshabhog' (3.08 mg /kg). While the least stalk As content was recorded in 'Gopalbhog' (2.11 mg/ kg). Greater arsenic content in husk was assessed in the cultivar 'Poreiton' (1.68 mg /kg); and it was statistically at par with husk As content of the cultivars 'Wairi-Chakhao' (1.55 mg /kg) and 'Lalbadshabhog' (1.52 mg /kg). However, the least As accumulation in husk was recorded with 'Tulaipanji' (0.71 mg /kg). From the results of the experiment, the accumulated arsenic followed the order root>stem>leaf>grain which was in conformity with the findings of Abedin *et al*., 2002. There was significant difference in grain As content of different tested aromatic rice cultivars which was in accordance with the findings of the Meharg and Rehman (2003) and Duxbury and Zavala (2005). The build up As in the paddy soil from continuous using of contaminated water eventually augmented the rice grain arsenic accumulation (Upadhyay *et al*., 2019).

Table 1: Arsenic content in different plant parts of tested aromatic rice cultivars grown during *kharif* 2020

Treatment	Arsenic content (mg /kg)			
	Root	Stalk	Husk	Grain
T_1-Poreiton	8.39	3.20	1.68	0.93
T_2-Chakhao-amubi	7.22	2.45	0.94	0.28
T_3-NC 365	7.11	2.25	1.08	0.47
T_4-Tulaipanji	5.92	2.34	0.71	0.17
T_5-Wairi-chakhao	8.09	3.35	1.55	0.87
T_6-Lalbadshabhog	8.55	3.08	1.52	0.74
T_7-Kaminibhog	7.48	2.16	1.01	0.39
T_8-Gopalbhog	7.57	2.11	0.97	0.54
T_9-Monibhog	6.84	2.57	1.10	0.23
T_{10}-Radhunipagol	6.76	2.30	0.93	0.21
T_{11}-Kataribhog	6.49	2.61	0.91	0.25
T_{12}-Radhatilak	7.15	2.20	0.97	0.61
T_{13}-Kalonunia	7.19	2.50	0.92	0.47
T_{14}-NC 324	6.45	3.05	0.94	0.23
T_{15}-Gobindobhog	6.23	2.79	0.91	0.21
S.Em±	0.37	0.21	0.14	0.05
CD (P=0.05)	0.75	0.43	0.28	0.11

Table 2: Relationship between As content in economic (grain) and vegetative (root, stalk and husk) parts of tested rice cultivars

Relationship	R^2	Adj. R^2	SE_{est}	Durbin-Watson
Grain Arsenic = 0.178root arsenic** -.0.027stalk arsenic + 0.387husk arsenic-1.181	0.835	0.791	0.115	1.724

***Significant at $p_{0.05}$ and **Significant at $p_{0.01}$**

Table 3: Class statistics of Agglomerative Hierarchical Clustering (AHC) along with cluster-wise mean values of As accumulation of different plant parts

Cluster	Size	Member of cluster	Mean As content (mg /kg)± SD			
			Grain	Root	Stalk	Husk
1	3	Poreiton, Wairi-Chakhao and Lalbadshabhog	0.85 ± 0.0971	8.34 ± 0.2335	3.21 ± 0.1353	1.58 ± 0.0850
2	12	Chakhao-Amubi, NC-365, Tulaipanji, Kaminibhog, Gopalbhog, Monibhog, Radhunipagol, Kataribhog, Radhatilak, Kalonunia, NC-324 and Gobindobhog	0.34 ± 0.1501	6.87 ± 0.5107	2.44 ± 0.2787	0.95 ± 0.0982

SD=standard deviation

The highest grain As content was recorded for the cultivar ‘Poreiton’ (0.93 mg /kg); being statistically at par with cultivar ‘Wairi-Chakhao’. In contrary to that, the least grain As accumulation was found in the cultivar ‘Tulaipanji’ (0.17mg /kg) and the amount of As is very much within the safe limit of human consumption (≤ 2 mg /kg). Multiple linear regression analysis of grain As content as a dependent variable showed that root As content and husk As content had positive significant and non-significant relationship with grain As content, respectively (Table 2). Therefore, contribution of root As content could only bring significant increase in grain As content. While grain As content had a synchrony with husk As content, but not in a significant way.

Hierarchical clustering

Agglomerative Hierarchical Clustering (AHC) was performed for clustering the different homogeneous groups of aromatic rice cultivars on the basis of As accumulation in different plant parts (Banerjee *et* *al*., 2018). Based on AHC analysis, a dendrogram is illustrated in Figure 1 which reveals that 15 different types of rice cultivar (aromatic) were grouped into two clusters - Cluster I included three cultivars (Poreiton, Wairi-Chakhao and Lalbadshabhog) and Cluster II was comprised of twelve cultivars (Chakhao-Amubi, NC-365, Tulaipanji, Kaminibhog, Gopalbhog, Monibhog, Radhunipagol, Kataribhog, Radhatilak, Kalonunia, NC-324 and Gobindobhog). The class and descriptive statistics of different rice cultivar obtained from AHC analysis has been presented in Table 3. Based on the results of Agglomerative Hierarchical Clustering (AHC) of tested rice cultivars, it can be concluded that three rice cultivars under Cluster I namely Poreiton, Wairi-Chakhao and Lalbadshabhog showed greater tendency of As accumulation in different plant parts than other tested cultivars. Contrarily, twelve cultivars (Chakhao-Amubi NC-365, Tulaipanji, Kaminibhog, Gopalbhog, Monibhog, Radhunipagol, Kataribhog, Radhatilak, Kalonunia, NC-324 and Gobindobhog) had lower As accumulation in different plant parts. Moreover, the least As acquisition was exhibited by 'Tulaipanji'.

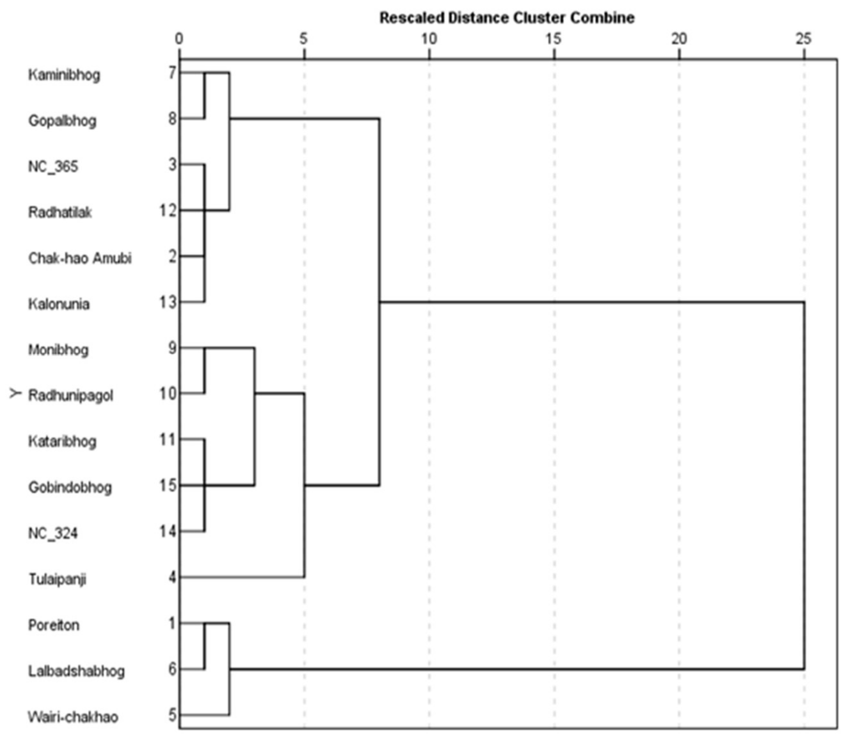

Figure 1: Clustering of tested aromatic rice cultivars based on their As acquisition pattern in different plant parts by agglomerative Hierarchical clustering using Euclidean dissimilarity distance

Conclusion

Based on the above findings, it is concluded that grains of 'Tulaipanji' was found to be safe for consumption. However, the cultivars 'Radhunipagol' and 'Gobindobhog' were found to produce grains with threshold limit of As. So they can be consumed as it is by taking up some remedial measures while cooking or processing. But other cultivars need some mitigation strategies in crop cultivation with respect to water and nutrient management so that grain As acquisition is kept within the safe limit. It further concluded that the people living in the arsenic affected area need to be taken into account the differences between rice types and cultivars in assessing the dietary intake of arsenic.

Conflict of interest

The authors declare that they have no conflict of interest.

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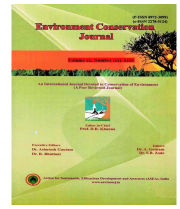

Stability analysis of short duration rice genotypes in Telangana using AMMI and GGE Bi-plot models

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ABSTRACT

In order to identify stable short duration rice genotypes across different agro-climatic zones in Telangana state, Additive Main Effects and Multiplicative Interaction Models (AMMI) and GGE Bi-plot analyses was performed. Analysis of variance clearly revealed that genotypes contributed highest (34.57 %) followed by environments (32.31 %) and genotype environment interaction (17.10 %) in total sum of squares indicating very greater role played by genotypes, environments and their interactions in realizing final grain yield. AMMI analysis revealed that rice genotypes *viz.*, KNM 2305 (G12), KNM 2307 (G16) and JGL 20776 (G9) were recorded higher mean grain yield with positive interactive principal component analysis 1 (IPCA1) scores whereas, KNM 2307 (G16) and RNR 23595 (G5) were plotted near to zero IPCA1 axis indicating relatively more stable performance across locations. However, the GGE Bi-plot genotype view depicts that the genotypes *viz.*, RDR 1188 (G6) and KNM 2305 (G12) were known as highly unsteady across locations. Among environments, Rudrur (E4), Kunaram (E2) and Rajendranagar (E5) locations were identified as relatively ideal to realize good yields whereas Jagtial (E1), Kampasagar (E3) and Warangal (E6) locations were poor and most discriminating. Among the six locations, the performance of genotypes was relatively similar in Kunaram (E2), Kampasagar (E3) and Rudrur (E4), Warangal (E6) though they belong to different agro-climatic zones of Telangana state, whereas Jagtial (E1) location seems to be little divergent. Further, KNM 2305 (G12) and US 314 (G17) were performed better at Jagtial (E1) and Rajendranagar (E5) while MTU 1010 (G8) was found to have good performance in Rudrur (E4) and Warangal (E6) locations. The results conclude that KNM 2305 was high yielder but found to be unstable across locations whereas KNM 2307 (G16) and KPS 6251 (G15) were identified as good with reasonably higher grain yield and stable performance over locations.

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Introduction

Rice (*Oryza sativa* L.) is a staple crop for more than half of the world's population, supplying roughly 20% of dietary energy requirements. Rice is grown on roughly 116 million hectares throughout the world every year, yielding over 700 million tons (Anonymous, 2019). Rice is one of the most predominantly grown crops in Telangana state during rainy and post rainy seasons. Rice is being grown in an area of 41.89 lakh hectares with the production and productivity of 218 lakh tons and 5215 kg/ha, respectively (Anonymous, 2021). In view of delayed release of canal irrigation water, existence of mostly light textures soils and varied temperatures, short duration varieties (115 to 125 days) suits well in the region. Rice productivity must be increased to address the problems of higher cost of cultivation, population expansion, climate change and limited arable land (Cordero, 2020). Rice is grown in a range of environments, including temperate, subtropical and tropical climates. Several yield-related parameters influence rice yield, including panicle number, spikelet number per panicle and grain weight. Previous research has shown that, in addition to genotypic effect, environmental effects and genotype environment interaction (GEI) have a significant impact on rice production (Balakrishnan *et al*., 2016). The adaptation response of various genotypes to each environmental condition is represented by GEI (Olivoto *et al*., 2019). To correctly evaluate the yield performance of different rice genotypes, GEI must be identified in specific or broad environments (Kempton *et al*., 2012). Wide adaptation is defined as the ability to produce stable high yields across diverse environments (Gauch *et al.,* 2008; Yan, 2016) and a major goal in rice breeding programs is to achieve stability of yield performance in different agricultural environments (Xu *et al*., 2020).

The AMMI model has recently been popular for interpreting the G × E interaction, with a biplot often used to interpret the AMMI result, with yield on one axis and principal component analysis (PCA) scores on the other, or two PCA axes scores on two axes (Crossa *et al*., 1990). Regular analysis of variance for additive effects is combined with PCA for multiplicative structure within the interaction in the AMMI model. AMMI also provides a visual representation of trends in the data through a biplot that makes use of the first interaction principal component axis (IPCA1) and the mean yields of both the genotypes and environments (Nachit *et al*., 1992). To enhance the selection method, it is important to take advantage of the possibility of finding genotypes that are less influenced by G × E interaction (GEI). Genotypic main effect plus GEI (GGE) biplot analysis is a statistical method that has been widely employed to detect the GEI of target traits in multiple environments. GGE biplots graphically indicate the GEI of multiple environmental trials in a way that facilitates the evaluation of varieties. GGE biplots are constructed using first and second symmetrically scaled principal components derived from singular value decomposition of environment-centered multiple environment trial data, facilitating genotype evaluation and mega-environment delineation (Yan *et al*., 2000). Under this context, present investigation was carried out to identify stable short duration genotypes suitable for Telangana state through AMMI and GGE biplot models.

Material and Methods

The investigation was carried out on eighteen short duration genotypes of rice (Table 1). The experiment was conducted at six locations of Telangana comprising different agro-climatic zones as detailed in Table 2 during *kharif* 2017. Crop was raised by sowing the nursery during first fortnight of July and 25-30 days age seedlings were planted in main field under irrigated farming system at all the six locations. The spacing adopted was 15 × 15 cm between rows and hills with plot size of 10-15 m^2 replicated thrice in Randomized Complete Block Design. Crop was well managed by adopting recommended agronomic package and suitable plant protection measures to realize potential yields. Grain yield was recorded in each plot and expressed in kg/ha. Statistical analyses like, combined ANOVA and AMMI analysis were conducted to understand the pattern of genotypic performance across the locations. ANOVA was used to partition genotypic deviations, environmental deviations and G × E deviations from the total variation.

Table 1: Details of 18 rice genotypes used in the study along with parentage

Code	Genotypes	Parentage	Source	Duration (Days)	Grain Type
G1	JGL 24497	JGL 17004 × NLR 3042	RARS, Jagtial, PJTSAU	115	Long Slender
G2	RDR 1162	JGL 11727 x JGL 17004	RS&RRS, Rudrur, PJTSAU	115	Medium Slender
G3	RNR 15048	MTU 1010 x JGL 3855	RRC, Rajendranagar, PJTSAU	125	Short Slender
G4	JGLH 169	CMS 64A × JMBR2	RARS, Jagtial, PJTSAU	120	Long Slender
G5	RNR 23595	Yamini × BM 71	RRC, Rajendranagar, PJTSAU	120	Medium Slender
G6	RDR 1188	JGL 17653 × RP 2421	RS&RRS, Rudrur, PJTSAU	110	Long Slender
G7	IBT R9	MTU 1010 × 2/GPP2	RRC, Rajendranagar, PJTSAU	120	Long Slender
G8	MTU 1010	Varietal Check	RARS, Maruteru, ANGRAU	115	Long Slender
G9	JGL 20776	MTU 1010 × JGL 13595	RARS, Jagtial, PJTSAU	120	Long Bold
G10	WGL 1119	WGL 32100 × RP-1 (B 95-1 × Abhaya)	RARS, Warangal, PJTSAU,	120	Medium Slender
G11	RNR 26241	WGL 505 × RNR 15048	RRC, Rajendranagar, PJTSAU	125	Medium Slender
G12	KNM 2305	JGL 11470 × Himalaya 741	ARS, Kunaram, PJTSAU	120	Long Bold
G13	IBT R4	Tellahamsa × 2/GPP2	IBT, Rajendranagar, PJTSAU	115	Long Slender
G14	WGL 962	BPT 5204 × GEB 24// BPT 5204 × Shatabdi	RARS, Warangal, PJTSAU,	125	Medium Slender
G15	KPS 6251	MTU 1010 × Chittimutyalu	ARS, Kampasagar, PJTSAU	115	Medium Slender
G16	KNM 2307	JGL 11727 × JGL 17004	ARS, Kunaram, PJTSAU	115	Long Bold
G17	US 314	Hybrid check	US Agriseeds Pvt. Ltd	115	Medium Bold
G18	IBT R8	Tellahamsa × 2/GPP2// Tellahamsa × 2/NLR145	IBT, Rajendranagar, PJTSAU	115	Long Slender

Further, multiplication effect analysis (AMMI) was used to partition GE deviations into different interaction principal component axes (IPCA). Genstat 15th Edition (GenStat, 2012) and P B Tools (IRRI, 2014) were used to analyze the AMMI and GGE biplot for eighteen genotypes.
The AMMI model used in the stability analysis is as follows:

$$Y_{ij} = \mu + g_i + e_j + \sum \lambda_k a_{ik} \gamma_{jk} + \varepsilon_{ij}$$

where
Yij = mean of a trait of i^{th} genotype in j^{th} environment;
μ = the grand mean;
g_i = genotypic effect;
e_j = environmental effect;
λ_k = eigen value of Interaction Principal Components Axes (IPCA) k;
a_{ik} = eigen vector of genotype i for PC k;
γ_{jk} = eigen vector for environment j for PC k;
ε_{ij} = error associated with genotype *i* in environment *j*.

The GGE biplots were generated to predict the which-won-where pattern and to identify the genotypes best suited across environments as well as for specific environment.

Results and Discussion

An experiment was formulated to identify stable rice genotypes across different agro-climatic zones of Telangana state through Bi-plot analyses. The mean grain yield ranged varyingly from 2121 kg/ha to 9140 kg/ha (Table 3). Mean grain yield across locations showed that the KNM 2305 (6803 kg/ha) was recoded highest mean grain yield followed by MTU 1010 (6443 kg/ha) and KNM 2307 (6393 kg/ha), whereas RDR 1188 (3744 kg/ha) was the poorest yielder. Likewise, among locations, Jagtial (E1) was found to be ideal location with highest mean grain yield (6451 kg/ha) across genotypes followed by Kampasagar (E3) (6262 kg/ha), whereas Warangal (E6) was poorest location with least mean grain yield (4324 kg/ha). Genotypic performance of rice and other crops in relation to different environments has been estimated by worker like Xing *et al*. (2021), Amiri *et al*. (2015), Rakshit *et al*. (2012) and Mohammadi *et al*. (2012) all of them identified varieties suitable for a defined production system.

Analysis of variance

Analysis of variance elucidated that significant difference existed among genotypes, environments and genotypes × environment interactions and witnessed the considerable influence of environments and interaction of genotypes with environments in expression of the grain yield (Table 4). Further, genotypes contributed highest (34.57 %) in total sum of squares followed by environments (32.31%) and genotype environment interaction (17.10 %) revealing that genetic architecture of the genotypes play greater role apart from environment and their interaction in manifestation of the trait. Xing *et al*. (2021) reported similar finding that the grain yield was more influenced by genotype, genotype × environment interactions and environment with contribution of 35.6, 37.1 and 16.5 percent of total variance, respectively.

AMMI analysis

The significant G × E interactions were further partitioned into five significant principal component axes explaining 34.4, 31.3, 18.1, 12.2 and 4.0 of GEI variation, respectively (Table 5). The first two interaction PCAs accounted for maximum of 65.7 %. Similarly, Das *et al*. (2010) and Umma *et al.* (2013) earlier reported that first two PCAs explained the maximum GEI. Zewdu *et al.* (2020) had similar findings that the two IPCA axes together accounted for 69.17% of the genotype by environment interaction mean squares. The IPCA score of a genotype in the AMMI analysis is a signal of the adaptability over environments and relationship between genotypes and environments (Gauch *et al*., 1996 and Mahalingam *et al*., 2006).

The mean grain yield and IPCA1 (interaction effects) were plotted on x and y axes, respectively for the construction of AMMI1 Bi-plot (Fig. 1). A genotype with IPCA1 score near to zero is considered to be steadier across environments. In opposition, a genotype with high IPCA1 score is highly variable among environments (Rao *et al.,* 2020). The genotypes, KNM 2305 (G12), KNM 2307 (G16) and JGL 20776 (G9) were recorded higher mean grain yield with positive IPCA1 scores (Fig. 1). The genotypes, MTU 1010 (G8), KPS 6251 (G15) and JGL 24497 (G1) had high mean grain yield and found more adaptable to Kampasagar (E3) location. However, KNM 2307 (G16) and RNR 23595 (G5) were plotted near to zero IPCA1 axis indicating that these genotypes are relatively more stable across locations. The remaining genotypes had less than the mean grain yield and found specific adaptation to few tested environments. Similarly, Balakrishnan *et al*. (2016) exhibited G8, G2, G3, G14, G11 and check Swarna (G15) had high yield with high main (additive) effects showing positive PC1 score.

GGE Bi-plot analysis

GGE Bi-plot offers effective assessment of genotypes and allow for complete understanding of the target and test atmospheres through various IPCAs. The genotype x environment interactions were partitioned into six significant interaction PCAs and 81.2% variance was explained by first two IPCAs together (Table 6). Similarly, Zewdu *et al.* (2020) partitioned the genotype × environment interactions into six rays which divided the biplot into seven sections.

GGE Bi-plot genotype view depicts that the genotype WGL 1119 (G10) was inside the first concentric circle and found to be more stable across environments (Fig. 2). However, the genotype RDR 1188 (G6) and KNM 2305 (G12) were known as highly unsteady across locations with longest

Table 2: Details of six locations in Telangana state used for evaluation of genotypes

Code	Location name	District	Agroclimatic Zone	Latitude (N)	Longitude (E)	Altitude (m)	Normal cultivated area (ha)
E1	Regional Agricultural Research Station, Polasa, Jagtial	Jagtial	Northern Telangana	18.49°	78.56°	243.4	85584
E2	Agricultural Research Station, Kunaram	Peddapally	Northern Telangana	18.32°	79.32°	231.0	78969
E3	Agricultural Research Station, Kampasagar	Nalgonda	Southern Telangana	16.59°	79.28°	152.0	139410
E4	Regional Sugarcane and Rice Research Station, Rudrur	Nizamabad	Northern Telangana	18.01°	85.01°	404.0	143778
E5	Rice Research Center, ARI, Rajendranagar	Rangareddy	Southern Telangana	17.33°	78.40°	586.6	21773
E6	Regional Agricultural Research Station, Warangal	Warangal	Central Telangana	15.50°	79.28°	268.5	47237

Table 3: Mean grain yield (kg/ha) of 18 rice genotypes across six locations

Code	Details of Genotype/ Environment	Environments						
		E1	E2	E3	E4	E5	E6	Mean across locations
G1	JGL 24497	7269	5096	7318	7052	5725	5181	6274
G2	RDR 1162	5153	5565	5761	6012	5461	5378	5555
G3	RNR 15048	6164	3903	5865	5110	4851	3575	4911
G4	JGLH 169	6568	3093	5134	4568	6144	3760	4878
G5	RNR 23595	6283	4003	6538	5617	6719	4553	5619
G6	RDR 1188	4551	3608	3587	4294	4301	2121	3744
G7	IBT R9	4332	3942	6242	5511	4792	3821	4773
G8	MTU 1010	6958	5004	7511	6362	6554	6267	6443
G9	JGL 20776	7824	5434	7668	5044	6424	5649	6340
G10	WGL 1119	6257	4870	6691	4921	5755	5035	5588
G11	RNR 26241	7269	3868	6087	5454	4655	2868	5033
G12	KNM 2305	9140	6378	7842	6082	6479	4895	6803
G13	IBT R4	5668	3522	5118	4951	3285	2894	4240
G14	WGL 962	5834	3847	5764	5670	5336	3592	5007
G15	KPS 6251	6998	5040	7893	6287	6729	5128	6346
G16	KNM 2307	7454	5223	7754	6541	6313	5074	6393
G17	US 314	7097	4528	5096	5343	7442	4179	5614
G18	IBT R8	5298	3924	4845	4303	5575	3864	4635
	Mean across genotypes	6451	4492	6262	5507	5697	4324	
	SE (m)±	**CD (0.05)**						
Genotypes	204.02	568.18						
Environments	122.07	340.12						

Table 4: Analysis of variance for grain yield over 18 rice genotypes and 6 locations

Source of variation	df	SS	MMS	P Value	% Explained
Treatments	107	548843832	5129382**	0.0000	
Block	12	17040747	1420062*	0.0017	
Genotypes	17	225912375	13288963**	0.0000	34.57
Environments	5	211160152	42232030**	0.0000	32.31
Genotypes x Environments	85	111771306	1314957**	0.0000	17.10
Residuals	45	38302099	851158**	0.0099	
Error	204	104742731	513445		
Total	323	670627310	2076246		

***Significant at P≤0.05, **Significant at P≤0.01**

Table 5: Partitioning of genotype x environment interaction with AMMI model for grain yield in rice

Source of variation	df	SS	MMS	% Explained
Varieties x Environments	85	111771306	1314957**	
IPCA1	21	25652925	1221568**	34.4
IPCA2	19	23326828	1227728**	31.3
IPCA3	17	13478753	792868**	18.1
IPCA4	15	9101972	606798**	12.2
IPCA5	13	2954188	227245**	4

****Significant at P≤0.01**

Table 6: Partitioning of genotype x environment interaction with GGE model for grain yield in rice

Source of variation	df	SS	MMS	% Explained
IPCA1	21	157418863	7496136**	69.9
IPCA2	19	25446919	1339312**	11.3
IPCA3	17	22943248	1349603**	10.2
IPCA4	15	9109878	607325**	4
IPCA5	13	7251639	557818**	3.2
IPCA6	11	2953691	268517**	1.3

****Significant at P≤0.01**

vector from origin. GGE Bi-plot environment view depicted that Rudrur (E4), Kunaram (E2) and Rajendranagar (E5) locations were relatively ideal indicating that they were poor and most discriminating. The lengths of environment vectors from the biplot origin are proportional to the standard deviation within each environment and thus represent the discriminating ability of the environments (Yan and Tinkler, 2006). Similarly, Zewdu *et al.* (2020) revealed that E6, E1, E3 and E2 with short environmental vectors, did not exert strong interactive forces and had a strong contribution to the stability of the genotype, while those with long spokes (E4 and E5) indicate the high discriminating ability of these environments.

The angle between the environment line and the average-environment axis (AEA), which passes through the average environments and biplot origin, (Fig. 3) with less vector length from origin. Conversely, Jagtial (E1), Kampasagar (E3) and Warangal (E6) locations had longest vectors and indicates the representativeness of each environment. Depending on direction of environments dispersion, more similarities were noticed among Kunaram (E2), Kampasagar (E3) and Rudrur (E4), Warangal (E6) whereas Jagtial (E1) location seems to be little divergent. Yan and Kang (2003) reported that the distances from the biplot origin were indicative of the amount of interaction exhibited by genotypes over environments or environments over genotypes.

Mean performance and stability of genotypes

The genotype KNM 2307 (G16) was identified as ideal genotype followed by KPS 6251 (G15) and

Table 7: Mean grain yield and principal component scores of AMMI and GGE for rice genotypes

Genotype/ Environment code	Details of Genotype/ Environment	Mean Grain yield (kg/ha)	Interaction Principal Component Scores			
			AMMI		GGE	
			IPCA1	IPCA2	IPCA1	IPCA2
G1	JGL 24497	6274	-5.36	-15.25	-1941.49	464.22
G2	RDR 1162	5555	-30.55	4.99	-37.31	1748.46
G3	RNR 15048	4911	3.54	-7.34	1282.78	-203.52
G4	JGLH 169	4878	16.49	18.99	1367.74	-1140.52
G5	RNR 23595	5619	-1.27	13.00	-399.70	17.04
G6	RDR 1188	3744	-1.50	8.25	4385.11	-185.79
G7	IBT R9	4773	-26.19	-6.54	1698.61	1544.45
G8	MTU 1010	6443	-12.32	1.79	-2469.68	843.33
G9	JGL 20776	6340	8.75	-1.22	-2416.91	-348.56
G10	WGL 1119	5588	-6.47	1.98	-453.31	437.48
G11	RNR 26241	5033	21.54	-18.90	973.95	-1208.47
G12	KNM 2305	6803	24.76	-13.86	-3383.38	-1259.27
G13	IBT R4	4240	0.88	-21.85	2938.26	-25.48
G14	WGL 962	5007	-2.42	-1.02	1176.14	82.22
G15	KPS 6251	6346	-3.43	-2.63	-2235.62	324.95
G16	KNM 2307	6393	0.80	-9.94	-2325.29	105.94
G17	US 314	5614	16.32	31.63	-196.06	-1222.04
G18	IBT R8	4635	-3.55	17.91	2036.17	25.54
E1	Jagtial	6451	49.36	-10.49	-0.45	-0.78
E2	Kunaram	4492	-9.38	-4.48	-0.34	0.16
E3	Kampasagar	6262	-5.15	-28.69	-0.53	0.20
E4	Rudrur	5507	-17.15	-13.81	-0.27	0.28
E5	Hyderabad	5697	8.19	46.34	-0.36	-0.22
E6	Warangal	4324	-25.87	11.14	-0.45	0.45

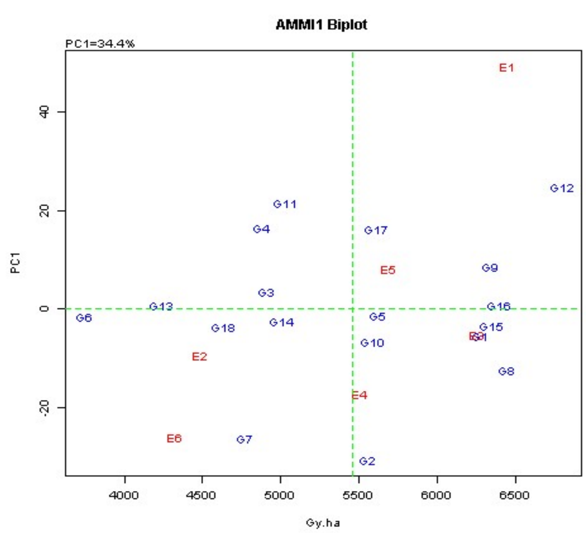

Figure 1: Means of genotypes (G) and environments (E) against their respective IPCA1 scores for grain yield in rice using AMMI-1 model.

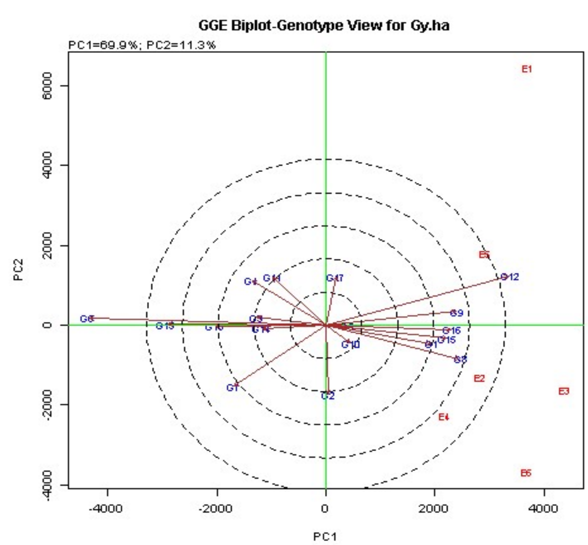

Figure 2: GGE biplot genotype view for grain yield in rice.

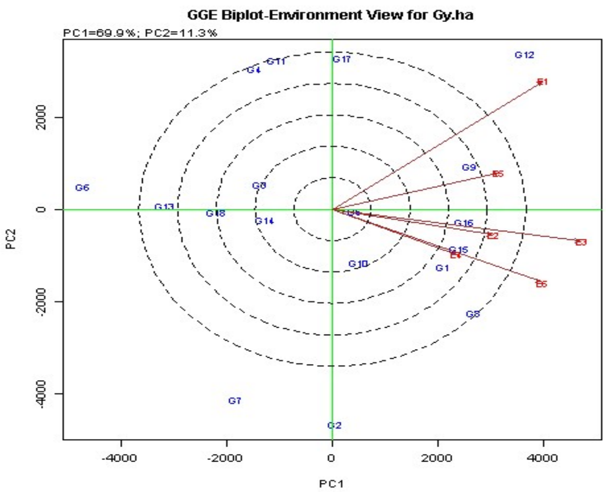

Figure 3: GGE biplot environment view for grain yield in rice.

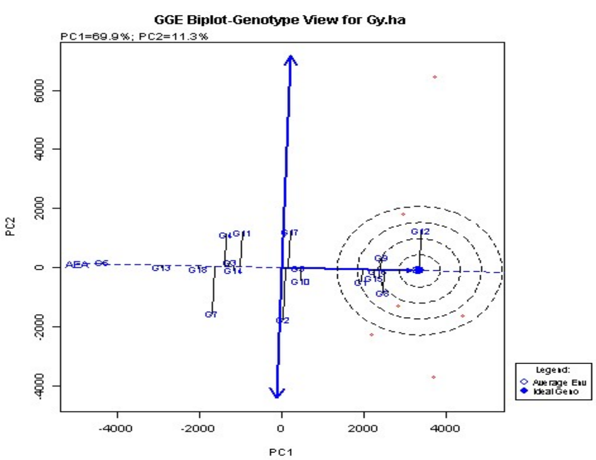

Figure 4: GGE biplot genotype view with AEA axis for grain yield in rice.

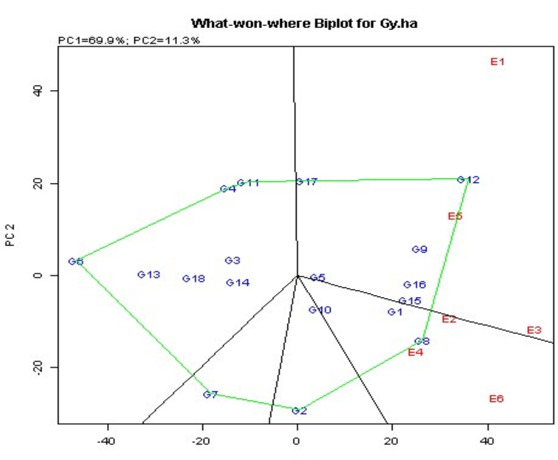

Figure 5: What-won-where biplot for 18 genotypes and six locations in rice.

JGL 20776 (G9) with relatively higher mean yield and good stability. Though the genotype, KNM 2305 (G12) had highest mean grain yield, found to be relatively not stable across locations falling out of the 2nd concentric circle (Table 7 & Fig. 4).

Further, the genotypes RDR 1162 (G2) and US 314 (G17) were found to be unstable across locations with more dispersion from AEA axis and also recorded relatively less mean grain yield. Xing *et al*. (2021) reported that Suwon-2010 (temperate) and IRRI-2010 (tropical) locations were the most representative for thousand grain weight and grain yield, respectively.

What-won-where Bi-plot

What-won-where view of the GGE Bi-plot is the best model for multi-environment data for classifying the environments and also to select best performing genotype in each (Yan *et al*., 2000). Genotypes located on the vertices of the polygon performs either the best or the poorest in one or more environments. The biplot view classified that KNM 2305 (G12) and US 314 (G17) were the best performing genotypes in Jagtial (E1) and Rajendranagar (E5) locations (Fig. 5). Similarly, the genotypes MTU 1010 (G8) was found to have good performance in Rudrur (E4) and Warangal (E6) locations. Earlier Chandramohan *et al*. (2021) found that the hybrids, JGLH 337 (G3), JGLH 275 (G11) at Jagtial (E1) whereas RNRH 98 (G7), JGLH 373 (G12) at Warangal (E6) locations were performed well while the hybrids, RNRH 99 (G4) and Bio 799 (G5) fall in separate group with poor performance in many of the locations. Comparably, Mary *et al.* (2019) reported that the biplot for yield during the wet season showed that G10 was the winner genotype in E4 and G7 in E8 and E9.

Conclusion

The results clearly conclude that expression of the grain yield was affected significantly by environments and interaction of genotypes with environments. The genotypes, KNM 2305 (G12), KNM 2307 (G16) and JGL 20776 (G9) were recorded higher mean grain yield with positive IPCA1 scores whereas KNM 2307 (G16) and RNR 23595 (G5) were plotted near to zero IPCA1 axis indicating that these genotypes were relatively more stable across locations. However, GGE Bi-plot genotype view depicts that the genotypes *viz*., RDR 1188 (G6) and KNM 2305 (G12) were known as highly unsteady across locations with longest vector from origin. Further, among environments Rudrur (E4), Kunaram (E2) and Rajendranagar (E5) locations were relatively identified as ideal to realize good yield whereas Jagtial (E1), Kampasagar (E3) and Warangal (E6) locations were poor and most discriminating. Among the six locations, more similarities were depicted among Kunaram (E2), Kampasagar (E3) and Rudrur (E4), Warangal (E6) though they belong to different agro-climatic zones of Telangana state and hence among them, two locations could be eliminated as testing centres to save resources. What-won-where Bi-plot clearly demonstrated that the genotypes, KNM 2305 (G12) and US 314 (G17) were performed better at Jagtial (E1) and Rajendranagar (E5) while MTU 1010 (G8) was found to have good performance in Rudrur (E4) and Warangal (E6) locations. Considering grain yield and stability over locations, KNM 2307 (G16) and KPS 6251 (G15) were identified as promising and need to be advanced for testing at farmers' fields to enable for commercial release.

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Conflict of interest

The authors declare that they have no conflict of interest.

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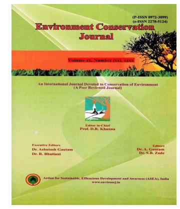

Necessity of genetic diversity study and conservation practices in chironji (*Buchanania cochinchinensis* (Lour.) M.R. Almedia)

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ABSTRACT

Chironji (*Buchanania cochinchinensis*) is an indigenous tree species of Indian subcontinent which belongs to the Anacardiaceae family. It has tremendous potential to uplift the socio-economic status of village dwellers and tribal people. It is used for various purposes including fruits, fuel, fodder and medicines. The species is facing severe ecological and anthropogenic pressures due to indiscriminate harvesting and illicit felling. IUCN has designated Chironji as a vulnerable species indicating that it may be on the verge of extinction if proper conservation measures are not taken very soon. The reports on its conservation and genetic improvement are very less. Hence, it is needed to devise the strategies to conserve its germplasm and genetically improve the species for higher fruit yield. The genetic diversity present in the species is also needed to be studied for effective conservation. Eco-distribution mapping and Molecular characterization using modern tools like molecular markers can give an accurate idea about the genetic diversity in lesser time and will also help in devising the breeding strategies and conservation of its diverse genotype. This review encompasses the researches done on Chironji till date detailing the importance of its genetic diversity and tries to indicate the future conservation and improvement strategies to be taken to fill up the remaining gaps.

Introduction

Buchanania cochinchinensis (Lour.) M.R. Almedia [Syn: *Buchanania lanzan* (Spreng.)] belongs to the family Anacardiaceae and originated in Indian sub-continent (Avani *et al.*, 2019). The tree is globally known as 'Almondette' or 'Little gooseberry tree' in English (Janick and Paull, 2006), but is most commonly called as 'Chironji' in its native regions like India, Nepal and Burma. The natural distribution of Chironji ranges from the foothills of western Himalayas, Sri Lanka, Bangladesh, China to Myanmar, Thailand, Laos and Vietnam. In India, it is known by several names varying with different regions and languages. In Hindi it is called as Achar, Char, Baruda, Priyala, Piyar; in Bengali it is known as Piyal, Chironji; in Gujarati & Marathi, Charoli, Pyalchar; in Tamil, Morala; in Telegu, Saarachettu, Morichettu; in Kannada, Charpoppu; in Malyalam, Mungapper; in Oriya, Charu; and in Sanskrit it is described as, Priyalam, Char, Rajadana, Dhanu etc. It is presumed that the foremost description of the tree Chironji was done by Francis Hamilton in 1798 as a small to medium-sized tree with a height up to 18 m (~ 55 ft) and girth up to 1.5 m (~ 5 ft). It is endemic to the tropical dry deciduous forests of India (Siddiqui *et al.*, 2014) and naturally found in the forests of central, north and west India along with hills of the peninsula, encompassing the states of Madhya

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Pradesh, Maharashtra, Gujrat, Rajasthan, Uttar Pradesh, Orissa, Jharkhand, Bihar, Chhattisgarh and parts of Andhra Pradesh and Karnataka up to an elevation of 1200 m from mean sea level (Singh *et al.*, 2010a). It is a very common associate of Sal (*Shorea robusta*), Kaldhi (*Anogeissus pendula*), Teak (*Tectona grandis*), Salai (*Boswellia serrata*) (Sharma, 2012) and Mahua (*Madhuca longifolia*).

Buchanania cochinchinesis is one of the neglected tree species in India, which may be at the verge of extinction very soon. The species is facing severe ecological and anthropogenic pressures due to indiscriminate harvesting and illicit felling. Poor attention and sheer negligence, degeneration of indigenous knowledge, high biotic and anthropogenic pressures, and over-exploitation by the natives are some of the major causes for the fast rate of depletion of the species. IUCN has already designated Chironji as a vulnerable (VU) species in its Red Data List (Prasad, 2020). It possesses medicinal properties and has tremendous potential to uplift the socio-economic status of village dwellers and tribal people. Hence, it is required to devise the proper conservation strategies to maintain the natural diversity and population distribution of this species, conserve its germplasm and genetically improve the species for higher fruit yield and kernel oil.

Morphological and Phenological characters of the species:

Chironji is naturally a dicot deciduous woody tree having a straight, cylindrical trunk and tomentose branches. The trunk has rough fissured bark which is dark grey or black in colour. The tree can be characterized by its signature dark-grey crocodile bark (Figure 1) (Siddiqui *et al.*, 2014). The trunk is reddish inside and gives a unique identifiable red blaze. The oblong or elliptic-oblong leaves are coriaceous or leathery in upper texture and tomentose beneath with entire margin, obtuse apex and 1.5 – 2 cm long pubescent petioles (Figure 2). The flowers typically adhere to the characteristics of the family Anacardiaceae. Flowering starts with small, sessile greenish-white flowers on well-developed terminal and axillary pyramidal panicles in the month of January-February (Singh *et al.*, 2019). A single panicle can hold up to 5000 flowers (Figure 3). The flowers are hermaphrodite in nature. The flowers take around 16-20 days for complete development from when the buds start external growth. Singh *et al.* (2010b) conducted a detailed floral biology study in Chironji with 15 elite genotypes. They recorded the peak period of anthesis between 6 – 11 AM of the day. Chironji fruits are drupe by nature (Figure 4) and become perfectly ripe for harvesting in the month of April – June and the ripe fruits may remain on the tree for a long time (Singh *et al.*, 2010a). Fruits are alternate bearing in nature. Singh *et al.* (2006a) indicated that the immature fruits are green, but darken to black when ripe and moderately sweet in taste with juicy, acidic pulp. Interestingly, the fruit set and panicle length of the flowers were found to be positively and significantly correlated by the same authors.

Figure 1: *Buchanania cochinchinensis* in natural wild population with the signature crocodile bark

Economic importance of the species:

Chironji is a species that is less known in the global market for its economical uses, but it is uncontrollably exploited by the natives for the local markets. Its fruits are one of the most delicious wild fruits available in forests due to its pleasant sub-acidic flavour. Its seeds are crushed to powder to be used as a spice or flavouring substance in many local dishes. The nuts are often used in home-made sauces and stews to thicken the dish. Seeds can be

Figure 2: Juvenile leaves of *Buchanania cochinchinensis*

Figure 3: Flowering of *Buchanania cochinchinensis*

Figure 4: Fruiting of *Buchanania cochinchinensis*

used for making a traditional sweet dish known as "*Chironji ki burfi*" along with other sweets like *halwa* and *kheer* (Rajput *et al.*, 2018). Its kernels contain oil and can also be eaten raw or roasted. The kernels are the most economically valuable produce of Chironji. Kernels are used for preparation of puddings, and the juicy mesocarp is cherished by local children (Munde *et al.*, 2003). Sweet highly nutritious edible oil can be extracted from the kernels which can be used in cooking as a cheap substitute for almond or olive oil. Juices and beverages can be prepared from the pulp of Chironji fruits. In summer seasons, leaves of Chironji are used as a substitute to green fodder for the cattle. It produces a moderate quality of timber which have some natural resistance to termites. The timber is mainly utilized for making light furniture, boxes and crates, desks, match boxes, packing cases etc. The wood is very much cheap and hence can be utilized in timber industries after some treatments and modifications. Dried branches are generally used as fuel wood by local inhabitants. The bark consists good amount of tannin (around 14%) and can be used in tanning. Tewari (1995) reported that the gum exudates may also be used in textile industries as a colouring substance. The gum is also used in incense industries for adulteration of *Commiphora wightii* (Rajput *et al.*, 2018). The gum with good quality after treatments and refinements, may be used in soft drinks and making food colourings. It proves to be a good source of income and backbone of the daily economy for local dwellers and tribal people in many states like Chhattisgarh, Jharkhand, Bihar etc. (Avani *et al.*, 2019). Apart from these tangible economical values, it is a very suitable species for the reclamation of wastelands and has a high potential for commercial dryland horticulture. It can tolerate adverse climatic stresses and hence the cultivation can be established in any arid, semi-arid, resource-poor areas.

Ethno-medicinal uses of the species:

Indigenous and traditional knowledge (ITK) is very much important for proper and sustainable use of any resource. The plant species are not different from this. The livelihoods of native and tribal people are often dependent on Chironji. ITK reveals the immense medicinal value of almost every part of Chironji like leaves, roots, fruits, seeds, gum etc. In Ayurveda and Unani systems of medicine, it is described as a plant from which various drugs and medicines can be prepared. The roots of Chironji are astringent, depurative, acrid, constipating and have cooling properties. They are used in the treatment of Diarrhoea. Extract of roots may also be used as an expectorant for curing several blood diseases and biliousness. The leaf juice contains 2.64% tannins, saponins, triterpenoids, flavonoids and different reducing sugars and can be used as an aphrodisiac, purgative, expectorant, blood purifier, thirst quencher (Rajput *et al.*, 2018). Leaf extract is used to cure digestive disorders. The leaves themselves have properties to heal minor wounds (Kala, 2009). Its seeds and kernels are very much palatable, nutritional and used in confectioneries as a substitute of almonds. The kernels are used by several tribal groups of Gujarat as brain tonic (Singh *et al.*, 2018). The seeds are also used as an expectorant tonic. The seed contains 34 – 47% of fatty oil which can be used for cooking. The oil extracted from seed kernels is natively known as '*Char*' and known to have medicinal values for curing skin diseases and removing spots and blemishes from the skin. The oil is non-toxic and safe for human consumption and also has non-repellent properties (Avani *et al.*, 2019). An ointment is made from this oil which is locally used to cure glandular swellings on several parts of the body (Dai *et al.*, 2002). The whole fruits of Chironji are also edible. They have some laxative properties and are used to relieve high body temperature, fever, cough, asthma etc. Even the bark of Chironji trunk have certain medicinal properties. Powder of Chironji bark and Malabar Plum (*Syzygium cumini*) bark is mixed together and used as a treatment of infantile diarrhea by the tribes of Southern Bihar (Rajput *et al.*, 2018). The bark and leaf paste of Chironji mixed with East Indian Ebony (*Diospyros melanoxylon*) dissolved in a glass of water at a dose of twice daily is reported to treat poisonous snakebite by Shukla *et al.* (2001). Chironji oozes water soluble gum from any cut on the bark or stem. The gum has tremendous medicinal values. It is an analgesic and is used to treat intercostals pain and diarrhea upon mixing with goat's milk (Shende and Rai, 2005). In some tribal areas of Andhra Pradesh, the gum dissolved in cow's milk is used as a cure to rheumatic pains.

Phytochemical importance of the species:

The genus *Buchanania* was always a species of interest for the chemists due to the varied range of phytochemicals available. Probably, the first and foremost phytochemical studies for Chironji was reported by Sengupta and Choudhary in 1977. They investigated the fatty acid composition in Chironji seed oil through gas liquid chromatography (GLC) and concluded that the seed oil contains 0.6% myristic acid, 33.4% palmitic acid, 6.3% stearic acid, 53.7% oleic acid and 6% linoleic acid. Triglyceride compositions were also determined and the oil is reported to be composed of 3.2% tri-saturated, 35.8% monosaturated – disaturated, 45.5% disaturated – monosaturated and 15.5% tri-unsaturated glycerides. Interestingly, the Chironji seed oil contains 22.7% di-palmitoolein, 31% di-oleopalmitin and 11.3% tri-olein which may be denoted as a unique characteristic of Chironji seed oil (Mishra and Tiwari, 2018). The chemical compositions make Chironji seed oil as a promising commercial source of palmitic and oleic acids. Also, the oil yields a product with a slip point of 41.5°C upon directed inter-esterification, which has the potential to be used as a coating material for delayed action tablets (Sengupta and Choudhary, 1977). The lipid compositions of seed oil were determined by Hemavathy and Prabhakar (1988) and they reported the total lipids contain neutral lipids (90.4%), glycolipids (3.4%) and phospholipids (6.2%). Tri-acylglycerols (82.2%), free fatty acids (7.8%), small amounts of di-acylglycerols, mono-acylglycerols and sterols mainly formulate the neutral lipids. In this study, the researchers identified and reported three glycolipids and six phospholipids.

Potential anti-inflammatory and anti-oxidant activities of methanolic extract of Chironji kernel extract (BLK-ME) were evaluated by Warokar (2010) and total polyphenolic content was reported to be 16.82 ± 23 mg of GAE/100. The author concluded that the presence of several phytochemicals like saponins, tannins and triterpenoids probably be the cause for BLK-ME to show such anti-inflammatory and antioxidant activities. Simultaneously, Mishra *et al.* (2010), investigated the antioxidant activities of dried fruits of Chironji along with other edible fruit species through different biochemical assays. The total phenolic content was estimated using Folin-

Ciocalteu reagent assay. In this method, EC_{50} values were calculated to evaluate the antioxidant activities and it was concluded that Chironji fruits also have significant antioxidant properties. Khatoon *et al.* (2015) have evaluated the nutraceutical potential of Chironji and reported that there are huge opportunities to develop value-added products, dietary supplements and phototherapeutic compounds from Chironji. Tripathi *et al.* (2016) have tried to standardize the methods of phytochemical investigation and pharmacogenetic studies on Chironji seeds. Recently, there have been a lot of investigations on the phytochemistry of Chironji as the evaluation equipment and scientific methods have advanced at a rapid pace. Siddiqui *et al.* (2016) evaluated phytochemicals, physio-chemical properties and antioxidant activities in gum exudates of Chironji. Pawar and Singh (2020) investigated for antioxidant and anti-cancerous potential of Chironji through an *in-vitro* study of antioxidant activity of various extracts from Chironji leaves and concluded that chemicals extracted from Chironji have tremendous potential to be used as a cure for cancer in near future. Niratker and Sailaja (2014) evaluated antimicrobial activities of Chironji leaf-extract and reported that it has high potential antimicrobial activities against three bacterial species namely *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* and two fungal species namely *Aspergillus Niger* and *Penicillium* sp.

Species variation and genetic diversity:

Chironji is a highly heterozygous, cross-pollinated tree which resulted in high variation in a natural population (Singh *et al.*, 2010a). Around 20 species under the genus *Buchanania* have been identified so far, among which seven species are reported to be found in India. *B. cochinchinensis* (Syn: *B. lanzan* / *B. latifolia*) and *B. axillaries* are the two main species producing edible fruits in India. *B. axillaries* (Syn: *B. angustifolia*) is a dwarf species that is reported to produce good quality edible kernels. *B. lanceolata* is found in the evergreen forests of Kerala and is marked as an endangered species. *B. Platyneura* is also reported to be edible, but found only in the islands of Andaman (Chauhan *et al.*, 2012). The other minor species reported in India are *B. lucida*, *B. accuminata* and *B. glabra*. Among all the Chironji species, *B. cochinchinesis* is the most widely distributed and found throughout the country (Kirtikar and Basu, 1918). Cytogenetic studies of the genus *Buchanania* is very much scarce and at a very nascent state. Very recently, cytogenetic analysis on root cells of *Buchanania cochinchinensis* through the chromosome splash technique revealed that the species is diploid in nature with chromosome number 2n = 18 (Singh *et al.*, 2019).

Being a highly heterozygous and cross-pollinated tree species, Chironji exhibits a high degree of genetic diversity and variation in its natural population. However, only a handful of works have been done till date to exploit the genetic variation and resources of Chironji in India. Chironji is still not cultivated for commercial purposes and hence the importance of releasing superior high-yielding variety is not felt at a large scale. Although researchers are now engaged in studying the genetic diversity of the species and a few improved cultivars are available. A detailed study is required including germplasm collection from the range of its distribution, genetic diversity assessment and genetic improvement through the breeding programs are needed for the commercial utilization of the species.

One of the foremost surveys was carried out by Rai (1982) in Uttar Pradesh for investigating the extent of variability in terms of morphological characters and yield attributes present in the species. They reported a high degree of variability in seed size, fruit yield and chemical compositions of fruits in the study area. Later several surveys were carried out for assessing the genetic diversity present in its growing areas throughout the country by several researchers like Singh and Chaturvedi (1983) and Chadhar and Sharma (1997). Singh *et al.* (2006b) conducted an extensive survey during 2004 – 2005 in Gujarat for exploring its genetic diversity under semi-arid conditions. They identified thirty (30) candidate plus trees (CPTs) of the species which were propagated vegetatively and utilized under tree improvement programs (Singh *et al.*, 2016). Out of identified CPTs, CPT1, CPT5, CPT10, CPT15, CPT17, CPT19 and CPT22 showed early flowering (first week of February) while CPT13 showed late flowering (last week of February). Variation in the panicle lengths was also observed as the longest length (35.11 cm) in CPT1 and the shortest length (14.20 cm) in CPT18. The highest fruit yield recorded was 28 kg / plant in CPT7 whereas the highest protein content of 30.70% was observed in CPT2. All these data indicated the presence of wide variation and diversity in natural population. National Bureau of Plant Genetic Resources (NBPGR), New Delhi also conducted a survey in the states of Rajasthan, Chhattisgarh, Madhya Pradesh and Gujarat and collected 74 different accessions (Malik *et al.*, 2010). Another important landmark survey for the exploration of genetic diversity and germplasm collection of Chironji was carried out by Malik *et al.* (2012) in the states of Gujarat, Madhya Pradesh and Rajasthan. They collected 72 diverse accessions of Chironji with a wide range of genetic variations and preserved them.

Conservation approaches:

Chironji is a wild tree that is facing high biotic and anthropogenic pressure leading to severe genetic erosion. Abrupt deforestation in the areas where a wide range of genetic variations of Chironji could be found, is one of the major causes. As a counter measure, both *in-situ* and *ex-situ* conservation strategies should be taken up for maintaining the genetic diversity of Chironji in India. Due to the rapid depletion of genetic diversity, immediate *ex-situ* conservation accompanied by proper *in-situ* conservation is to be considered the most appropriate measure for germplasm conservation (Rajput *et al.*, 2018). Moreover, presence of a hard seed coat and association of several pathogen fungi like *Curvularia, Trichothecium, Fusarium, Alternaria, Aspergillus, Mucor, Penicillium* etc. poses a problem in the regeneration of Chironji (Sharma *et al.*, 1998) which greatly contraints the conservation and area expansion procedures for this species. To overcome such problems, *ex-situ* field gene banks for Chironji are established at Godhra, Gujarat and Lucknow, Uttar Pradesh by the Indian Council of Agricultural Research (ICAR) for the conservation and development of advanced propagation practices of superior cultivars. Moreover, the germplasms collected from all over India, consisting of 127 accessions of Chironji, representing the genetic diversity and variation explored so far are cryopreserved as a base collection at NBPGR, New Delhi (Malik *et al.*, 2012). For enhancing the conservation of Chironji, modern biotechnological and tissue culture tools are being used recently. Rapid clonal techniques for multiplication through profuse shooting and rooting to supplement the establishment of *in vitro* gene banks for Chironji have been developed by Shende and Rai (2005).

Future Prospects in conserving the genetic diversity of the species:

Chironji is mainly multiplied through seed propagation which ensures variability within the population. Hence, selection can prove to be a very useful tool for the improvement of the species. Selecting the desirable traits like good quality seeds, kernels, high yield will help in developing improved cultivars. A detailed survey in the areas with rich diversity to select the promising elite genotypes is a must for this. These elite genotypes may be evaluated and propagated to produce true to the type cultivars as a preliminary step in developing improved varieties. Hybridization may be another approach for the improvement programmes. Crossing with elite genotypes may become useful for producing improved cultivars with high yield, good resistance and short height in near future. Some future prospects and thrusts may be enumerated as:

- Research on the genetic resources across the country should be undertaken for studying the genetic diversity.
- The proper genetic structure of Chironji is yet to be discovered, detailed study can be done for exploring the genome of the species.
- The selection of promising genotypes with good tolerance to several abiotic and biotic stresses can lay a path to the release of improved cultivars.
- Model nurseries for preservation and propagation for the species may be established.
- A standardized package of practices for commercial cultivation of Chironji is yet to be published.
- Other aspects like maturity indices, harvesting time, grading and preservation of produce are also to be standardized throughout the country.
- Research on integrated pest and pathogen management for Chironji is also a need for the hour.
- Proper dispersal of information about new improved varieties, processing and value addition techniques, demand and supply in

local as well as international markets about Chironji is very much necessary to improve and popularize the species throughout the country.

Conclusion

Buchanania cochinchinensis or Chironji has a high potential for being used as a commercial horticultural crop which can uplift the socio-economic status of the native inhabitants and tribal people. Over-exploitation and unscientific harvesting practices hinder the sustainability of the species which is leading the species to extinction. Urgent conservation measures and scientific researches are in dire need for the species to prevent these threats. Standardization of proper cultivation practiced along with modern molecular and biotechnological approaches should be taken for conservation and improvement of the species, unless we can lose this native species of India in the very near future.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Effect of exogenously administered thyroid hormones on gonadotropin, thyrotropin and deiodinases encoding genes in the catfish, *Heteropneustes fossilis*

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ABSTRACT

Thyroid hormones are known to regulate the basal metabolism rate of an organism. They are also known to regulate the seasonal reproduction of long-day breeding vertebrates in response to thyrotropin induced deiodinase enzymes switching in the brain. The current study attempted to investigate the effect of intraperitoneal administration of thyroxine (T4) and tri-iodothyronine (T3) hormones at various doses on gonadal recrudescence, plasma estradiol-17β and quantitative expression analysis of genes encoding for gonadotropin, thyrotropin, and deiodinases. The estradiol-17β levels were not affected by either thyroid hormone; however, the gonado-somatic index (GSI) and ovarian histology were varying. The gonadotropin releasing hormone 2 (*gnrh2*) and follicle stimulating hormone-β subunit (*fsh-b*) gene expressions correspond to the fish GSI and ovarian histology. The gene expressions show that T4 inhibits the expression of thyroid stimulating hormone-β subunit (*tsh-b*) and type 3 deiodinase (*dio3*), though it enhances the expression of type 2 deiodinase (*dio2*). T3, on the other hand, inhibits *tsh-b* and *dio2* expression while increasing *dio3* expression. In summary, the T4 appears to regulate gonadal recrudescence in *Heteropneustes fossilis* in a dose-dependent manner, whereas the T3 appears to have no effect on gonadal activity.

Introduction

Thyroid hormones, such as thyroxine (T4) and tri-iodothyronine (T3), are secreted from vertebrate thyroid follicles in response to thyroid stimulating hormone (TSH), released from pars distalis region of pituitary gland. Thyroid hormones are synthesized as a less potent pro-hormone T4, which undergoes an outer ring deiodination catalyzed by the DIO1 or DIO2 enzymes to get converted into active hormone T3. Thyroid hormones play an important role in physiology; their primary function is to maintain the basal metabolic rate in vertebrates it is also, involved in amphibian metamorphosis (Furlow and Neff, 2006) and fish metamorphosis (Power *et al.,* 2001). It has been reported in fish that thyroid hormone promotes gametogenesis and gonadal steroidogenesis (Cyr and Eales, 1996; Swapna *et al.,* 2006; Flood *et al.,* 2013; Tovo-Neto *et al.,* 2018). The thiourea (an antagonist of thyroid receptors), treatment depletes thyroid hormones; additionally, it reduces gonadal size, gonadal steroids, *gnrh2,* and *lh-b* expression in walking catfish (Swapna *et al.,* 2006). Hyperthyroidism, a condition of increased plasma thyroid level, stimulates the early gonadal recrudescence in pink salmon (Leatherland *et al.,* 1989), goldfish (Sohn *et al.,* 1999), cod (Norberg *et al.,* 2004) and stinging catfish (Biswas *et al.,* 2006). *Heteropneustes fossilis* is an annual breeding catfish, its annual ovarian cycle is divisible into four phases, *viz*., preparatory phase (February to April), pre-spawning phase (May-June), spawning phase (July-August) and post-spawning phase (September to January) (Sehgal and Sundararaj, 1970). The present

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study aims to identify the existence of the thyroid hormone-regulating genes, viz., thyroid stimulating hormone beta subunit (*tsh-b*), thyroid stimulating hormone receptor (*tsh-r*), type 2 deiodinase (*dio2*), type 3 deiodinase (*dio3*), along with gonadotropin releasing hormone 2 (*gnrh2*), follicle stimulating hormone-β subunit (*fsh-b*), and luteinizing hormone-β subunit (*lh-b*) and gonadal recrudescence after intraperitoneal administration of the thyroid hormones (T3 and T4), in the *H. fossilis*.

Material and Methods

Ethical clearance: All experimental procedures were performed in conformity with animal care and use guidelines approved by the Institutional Animal Ethics Committee (IAEC), at Department of Zoology, University of Delhi, Delhi, under recommendation by the Committee for the Purpose of Control and Supervision of Experiments for Animals (CPCSEA), New Delhi, India (file no. DU/ZOOL/IAEC-A/01/2019).

Specimen collection and maintenance: *H. fossilis*, were procured from backwaters of the river Yamuna and its tributaries near Delhi region (Lat. 28°35'N and Long. 77°12'E) in February month. The fish were acclimatized to laboratory conditions at a temperature of 25±1°C and a photoperiod regimen of 12L: 12D for seven days prior to the initiation of experiments.

Thyroid dose preparation: 0.5 mg/mL stock solution of thyroid hormone (T4 and T3 separately) was prepared in 5% ethanol. The fish were divided into nine groups, group injected with vehicle served as control, four groups were administered with T3 (5 ng, 50 ng, 250 ng, and 500 ng) and four groups were administered with T4 (5 ng, 50 ng, 250 ng, and 500 ng) intraperitoneally on alternate days. Thereafter, fish were maintained under laboratory conditions with 25±1°C of water temperature and a photoperiod regime of (L:D::12:12) for 60 days.

Sample collection and evaluation: Fish from each experimental group were sampled at the onset of experiment to serve as initial control and again on 60th day, sample was collected. Fish were anesthetized with 2-phenoxyethanol (0.001%) and weighed. Blood was collected from the caudal artery with the help of a heparinized syringe for estradiol-17β estimation using the Cayman estradiol kit (Cat no. 501890), according to the manufacturer's protocol. Following that, fish were decapitated, ovaries were excised, and the GSI was calculated. A small piece of ovarian tissue was fixed in Bouin's fixative and processed for histological examination using hematoxylin-eosin staining. The brain with pituitary was excised and processed for total RNA isolation, followed by cDNA preparation as per our laboratory standard protocol (Kumari *et al.,* 2020) . The primer pairs for the genes *tsh-b*, *tsh-r*, *dio2*, *dio3*, *gnrh2*, *fsh-b* and *lh-b* used for the quantitative analysis are mentioned in the table 1. The *β-actin* gene was taken as an endogenous control and the relative gene expression ($2^{-\Delta\Delta Ct}$) was calculated, the RNA from initial control was used for calibration.

Table 1: The sequence of the primer pairs employed for qRT-PCR in the present study are as follows.

S.no.	Gene	Primer	Primer sequence for qPCR	Product size
1	*β-actin*	Forward	5'- CGA AGA CGA CAG GAT TTG CT -3'	105bp
		Reverse	5'- GTT TGA AGC GCT CGT CTC TC -3'	
2	*tsh-β*	Forward	5'- GCT GTA CCT ATC AGG ACG TG -3'	141bp
		Reverse	5'- TGT GGG CAC ACT CAT CAC TG -3'	
3	*tsh-r*	Forward	5'- TGC TGT AAT GCT CGG GGG TT -3'	74bp
		Reverse	5'- GGT AAC TGC TCA CCC CTA ACG -3'	
4	*dio2*	Forward	5'- GTT CCC GTT CGA GGT GAA GAA -3'	125bp
		Reverse	5'- CAT TGT TGT CCA TGC AGT CGG CC -3'	
5	*dio3*	Forward	5' GTA CCA GAT CCC GCG CC -3'	110bp
		Reverse	5' ACG AGT TGT CCA TGG TGT CC -3'	
6	*gnrh 2*	Forward	5'- TGT GAG GCA GGA GAA TGC TG -3'	132bp
		Reverse	5'- GCT ATG GTG CCG GGA TAT GT-3'	
7	*fsh-β*	Forward	5'- CAC ACA CGC CTA CTA CTG AAC-3'	128bp
		Reverse	5'-AAC CTG ATG GTA CGC AGT ATT T-3'	
8	*lh-β*	Forward	5'-AGC CCG TTC TCT TCC ATC TA-3'	125bp
		Reverse	5'-CAG CTT AGT GCG ACA GGA TAT G-3'	

Statistical analysis: The statistical analysis one way ANOVA (P<0.05) was performed using IBM®SPSS 25.0 software. The results in bar and line graph were plotted as mean ± SEM. The significant difference was marked by using different superscripts.

Results and Discussion

Gonado-somatic index and estradiol-17β: The T3 treatment did not exhibit significant variation in GSI, nor did the plasma estradiol-17β levels. The GSI was significantly higher in the 50-ng and 250-ng T4-treated groups than in the two remaining T4-treated groups. However, the plasma estradiol-17β level among the T4 treated groups did not exhibit significant variation (Figure 1).

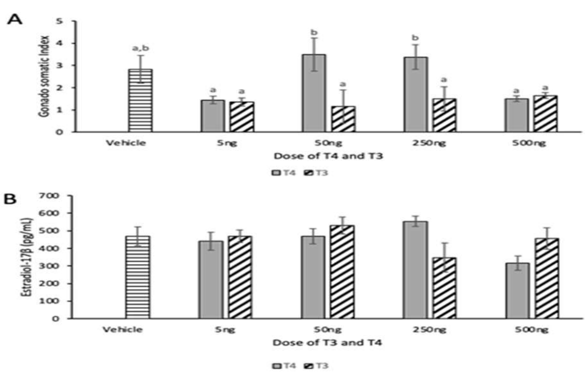

Figure 1: (A) Gonado-somatic index (GSI) and (B) Plasma estradiol-17β (pg/mL) estimation of intra-peritoneally T3 and T4 administered female *H. fossilis*. Values are presented as mean ± SEM (n=6). Bars with different superscripts indicate statistically significant differences and bars without superscript shows no variation (One way ANOVA followed by Tuckey test, p<0.05).

Gene expression analysis: The vehicle treated fish show the maximum expressions of *tsh-b* gene with significantly higher gene expression than 5 ng, 50 ng and 500 ng T3 and 5 ng and 250 ng T4 treated group, suggesting the inhibitory regulation of intraperitoneally administered T3 and T4 on brain *tsh-b* expressions (Figure 2a). The *dio2* expressions were increasing with the increasing dose of T4 with significant variation in expression between 500 ng T4 and 5 ng T4 treated group, suggesting the enhancement of expression of *dio2* by T4 administration in a dose dependent manner. On the contrary the T3 treatment reduces the *dio2* expression with increasing T3 dose, showing inhibitory effect (Figure 2c).

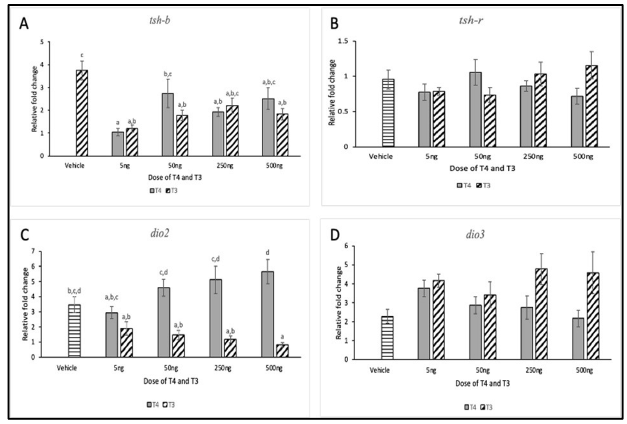

Figure 2: Quantitative expression analysis of (A) *tsh-b*, (B) *tsh-r*, (C) *dio-2*, (D) *dio-3* in the brain of intra-peritoneally T3 and T4 administered female *H. fossilis*. Values are presented as mean ± SEM (n=6). Bars with different superscripts indicate statistically significant differences and bars without superscript shows no variation (One way ANOVA followed by Tuckey test, p<0.05).

The expression of both *gnrh2* and *fsh-b* were significantly higher in the vehicle administered fish than all doses of T3 and 5 ng, 250 ng and 500 ng dose T4 treated groups. The expressions of both *gnrh2* and *fsh-b* are significantly lowest in T3 treated group, suggesting both T3 and T4 inhibits the expressions of *gnrh2* and *fsh-b* of which T3 is a potent inhibitor than T4 of these two genes (Figure 3a and 3b). The *tsh-r*, *dio3* and *lh-b* gene expression in the brain did not exhibit significant variation by intraperitoneal administration of T3 and T4 hormones (Figure 2b, 2d and 3c).

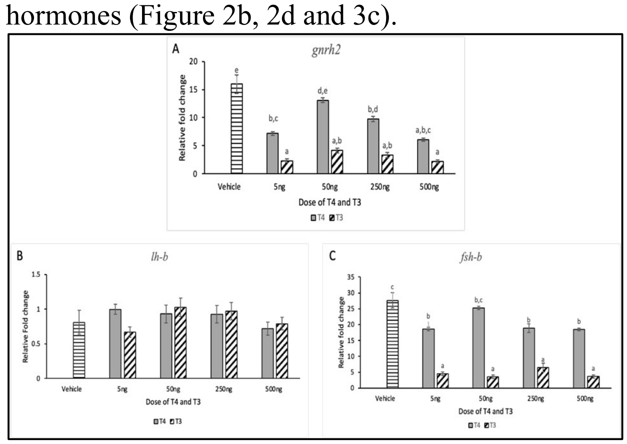

Figure 3: Quantitative expression analysis of (A) *gnrh2*, (B) *lh-b*, (C) *fsh-b* in the brain of intra-peritoneally T3 and T4 administered female *H. fossilis*. Values are presented as mean ± SEM (n=6). Bars with different superscripts indicate statistically significant differences and bars without superscript shows no variation (One way ANOVA followed by Tuckey test, p<0.05).

Ovarian histology: The catfish sacrificed at the commencement of the experiment had a regressed ovary (GSI ~0.7) containing stage 1 (non-yolky oocytes) and stage 2 (showing cortical alveoli) oocytes in equal proportions (Figs. 4a. At the end of the experiment, after 60 days, the ovarian histology showed the presence of vitellogenic oocytes in group injected with 50 ng dose of T4 followed by 250 ng dose of T4 (Figure 4).

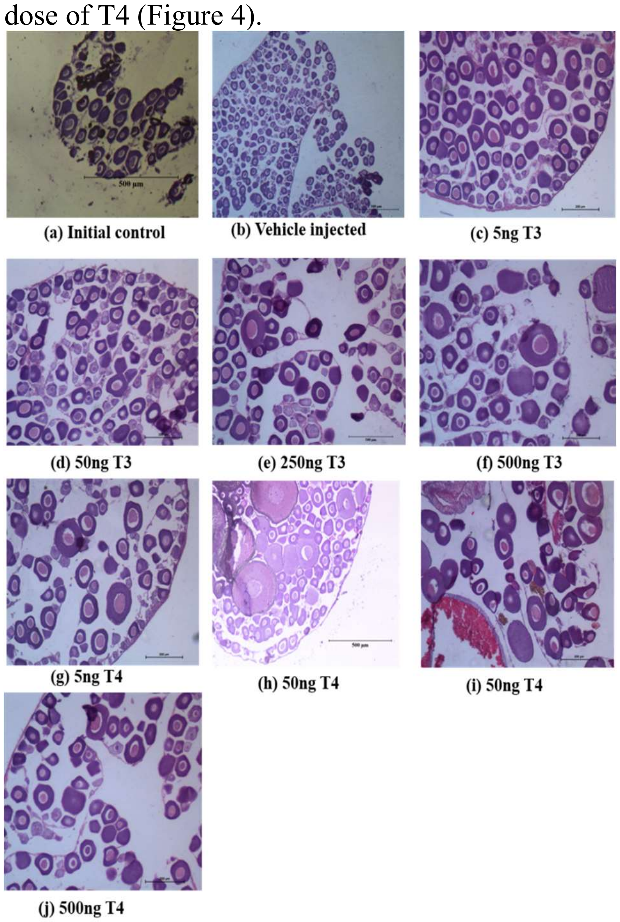

Figure 4: Transverse section of *H. fossilis* ovary, stained with hematoxylin-eosin; at the commencement of the experiment (a); vehicle administered (b); Tri-iodothyronine (T3) administered (c-f); Thyroxine (T4) administered (g-j).

The intra-peritoneal administration of thyroid hormones (T3 or T4) during the preparatory phase was studied in *H. fossilis*. The vehicle administered fish have highest *tsh-b* expression, followed by T4, and least in T3 administered in a dose dependent manner. The varying expression of *tsh-b* suggests that thyroid hormone downregulates *tsh-b* expression via a negative feedback loop. The *tsh-r*, *dio3* and *lh-b* gene expression in *H. fossilis* does not exhibit significant variation in gene expression after intra-peritoneal thyroid administration. The thyroid hormone is well known to be metabolized by deiodinases, and we found that T4 administration results in *dio*2 upregulation and *dio3* inhibition with increasing doses. On the contrary, T3 administration upregulates the *dio3* expression and inhibits the *dio2* expression in a dose dependent manner, however, both supporting and contradicting scenario have appeared in the existing literature (Coimbra *et al.,* 2005; Yamamura *et al.,* 2006; Gereben *et al.,* 2008; Hernandez *et al.,* 2010; Sabatino *et al.,* 2020). In a previous study, we found that the expression of *tsh-b*, *dio2*, and *dio3* in the brain varies seasonally and has a positive correlation with the GSI of *H. fossilis* (Pant *et al.,* 2023). The *gnrh2*, and *fsh-b* genes express maximally in the vehicle administered group, low expression in T4-administered fish and least in T3 administered group, suggesting an anti-gonadal effect of the thyroid hormone (T4 or T3).

The T3 treatment is also known to alter the glycoprotein alpha subunit (*cg-a*) expression based on sex and reproductive phase in *Carassius auratus* (Sohn *et al.,* 1999; Yoshiura *et al.,* 1999). The alteration in *cg-a* expression may further affect the hormone levels of TSH, LH, and FSH. The *tsh-b* gene expression and thyroid hormone have been shown to have an inverse relationship in several studies; *tsh-b* expression is inhibited by a high dose of T3 in *Oncorhynchus kisutch* (Larsen *et al.,* 1997) and *Carassius auratus* (Sohn *et al.,* 1999, Ma *et al.,* 2020) and T4 in *Carassius auratus* (Yoshiura *et al.,* 1999). T3 inhibits the *tsh-b* expressions in the goldfish pituitary under *in-vitro* conditions, though its impact can be altered by other factors *in-vivo* (Allan and Habibi, 2012). T3 is also known to reduce circulating LH level which implies gonadotropin inhibition by thyroid hormone in *Carassius auratus* (Allan and Habibi, 2012). In histological studies, T4 exposure reduces the size of gonadotropes and enhances the gonadotropin effect on ovarian development in *Carassius auratus* (Hurlburt, 1977). The thyroid hormone enhances Sertoli cells proliferation and spermatogonial cell maturation in *Danio rerio* (Morais *et al.,* 2013). Circulating T3 is known to induce vitellogenesis *via* upregulation of estrogen receptors in liver of *Carassius auratus* (Nelson and Habibi, 2016; Hur *et al.,* 2020).

In summary, the intra-peritoneal administration of T3 and T4 hormone inhibits the expressions of *tsh-b*, *gnrh2* and *fsh-b* genes in the brain. The *dio2* expressions were enhanced by T4 and inhibited by the T3 administration may infer the enhancement by substrate and inhibition by product. However, *tsh-r*, *dio3*, and *lh-b* expressions were not altered by either T3 or T4 treatment.

Conclusion

The *tsh-b, dio2,* and *dio3* expressions in the brain exhibit variation with thyroid hormone administration. The above-discussed results suggest thyroid hormones affect deiodinase expression via a negative feedback loop. The expression of *gnrh2*, *fsh-b,* and *lh-b* genes can be altered by the administration of thyroid hormones in a dose-dependent manner. The results of the experiment support the involvement of the thyroid hormones in altering the seasonal reproductive cycle in the female *H. fossilis*.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Status of particulate matter in the indoor air of residential units of Sunderbani area of Rajouri district (J&K), India

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ABSTRACT

Air pollution is currently the greatest environmental threat to human health and one of the fastest growing issues on the global health agenda. The extremely fine particulate matter (aerodynamic diameter < 2.5 microns) is of greatest concern because the particles can penetrate deep into human lungs and enter the bloodstream. The elderly, asthmatics and immune-deficient population are the most vulnerable with the increasing levels of particulate matter. The present study was conducted to assess the concentration of size-segregated Indoor Particulate Matter ($PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$, $PM_{0.25}$) in Sunderbani, Rajouri, J&K. The average values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$, and $PM_{0.25}$ were reported as 110.36µg/m^3, 180.50µg/m^3, 276.99µg/m^3 and 445.93µg/m^3 respectively in the sampled households of the study area. The average value of $PM_{2.5}$ in the study area was found to be above the permissible limits of 60µg/m^3 given by central pollution control board (CPCB). This was the first study on concentration of size-segregated particulate matter in the indoor environment of study area and the data obtained from the study will serve as baseline data for future studies in the area.

Introduction

Air pollution is one of the greatest threats among the various other type of pollution. Indoor air pollution is more harmful than outdoor air pollution as most of the people spend their maximum time in indoor environment such as schools, offices, malls etc. (Karakas *et al.,* 2013; Gautam *et al.,* 2018; Ruhela *et al.,* 2022a & b). Indoor air pollution refers to the deterioration of indoor quality of air which is caused by the presence of various toxic chemicals and materials in the indoor environment. Indoor air pollution from sources like solid fuels was responsible for 3.5 million deaths and 4.5 percent of global daily-adjusted life year (DALY) in 2010, as well as 16 percent of particulate matter pollution. Though household air pollution from solid fuels has decreased in Southeast Asia, it still ranks third among risk factors in the Global Burden of Disease report. Combustion, construction materials, and bioaerosols are the main causes of indoor air pollution (Bhutiani *et al.,* 2021; Ruhela *et al.,* 2022b). Although radon, heavy metals, volatile organic matter, pesticides, asbestos and tobacco smoke are regarded as the major indoor contaminants in developed countries, biomass fuel combustion products are the most polluting in developing countries. These indoor air pollutants may be categorised as organic, inorganic, biological, or radioactive in general (Tran *et al.,* 2020). In India, 49 percent of the 0.2 billion people who use firewood, 28.6% liquefied petroleum gas, 8.9% cow dung cakes, 2.9 percent kerosene, 1.5 percent coal, lignite, or charcoal, 0.4 percent biogas, 0.1 percent electricity, and 0.5 percent some other means for cooking. The incomplete combustion of biomass fuels releases some products such as suspended particulate matter (SPM), carbon monoxide (CO), polyaromatic hydrocarbons (PAHs), formaldehyde (HCHO), etc., all of which are harmful to human health. Sulfur, arsenic, and fluorine oxides are generated during

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the combustion of coal (Kankaria *et al.,* 2014).According to World Health Organization (WHO), 3.8 million people die each year as a result of exposure to indoor air pollution. Gases, chemicals, and other pollutants that come from various sources contribute to household air pollution. Fine particles, which can penetrate deep into the lungs, infiltrate the bloodstream, and migrate to the organs, are an excellent indicator of health risks (Viana *et al.,* 2013). Particulate matter concentrations can surpass the levels recommended by WHO by a factor of 100 in various poorly ventilated places. It has been found that concentrations of indoor PM were reported to be higher during domestic activities (Jones *et al.,* 2000). There is currently a lack of data on the pollutant load by different sizes of particulate matter ($PM_{2.5-1.0}$ and $PM_{1.0-0.5}$) (Masih *et al.,* 2019). In the present study, attempt has been made to assess the status of Indoor Particulate Matter ($PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$, $PM_{0.25}$) in the households of Sunderbani area, Rajouri (J&K).

Material and Methods

Study area and Sampling sites description:

The study area, Sunderbani, is a town and a notified area in Rajouri district in Jammu and Kashmir (UT) in the coordinates of $33^0 4'$ north, $74^0 49'$ east at an altitude of 633 metres (2077 feet) above sea level. The study was carried out during February, 2020 to December, 2020. The study area was divided into two zones viz. residential zone and commercial zone. Each zone was further divided into following sites on the basis of type of cooking fuel and ventilation in the kitchen. The study area is shown in figure 1 and table 1.

Table 1: Showing the description of sampling sites.

Category	Site Code	Description
Residential Sites	**RLE**	Households with LPG as type of cooking fuel and exhaust in the kitchen
	RLWE	Households with LPG as type of cooking fuel and without exhaust in the kitchen
	RLIE	Households with LPG-Induction as type of cooking fuel and exhaust in the kitchen
	RLIWE	Households with LPG & Induction as type of cooking fuel and without exhaust in the kitchen
	RLIM	Households with LPG & Induction as type of cooking fuel and modular kitchen
	RTC	Households with traditional cooking stove (mud stove/chullah) and wood as type of cooking fuel
Commercial Sites	**CLE**	Households with LPG as type of cooking fuel and exhaust in the kitchen
	CLWE	Households with LPG as type of cooking fuel and without exhaust in the kitchen
	CLIE	Households with LPG-Induction as type of cooking fuel and exhaust in the kitchen
	CLIWE	Households with LPG & Induction as type of cooking fuel and without exhaust in the kitchen
	CLIM	Households with LPG & Induction as type of cooking fuel and modular kitchen
	CTC	Households with traditional cooking stove (mud stove/chullah) and wood as type of cooking fuel

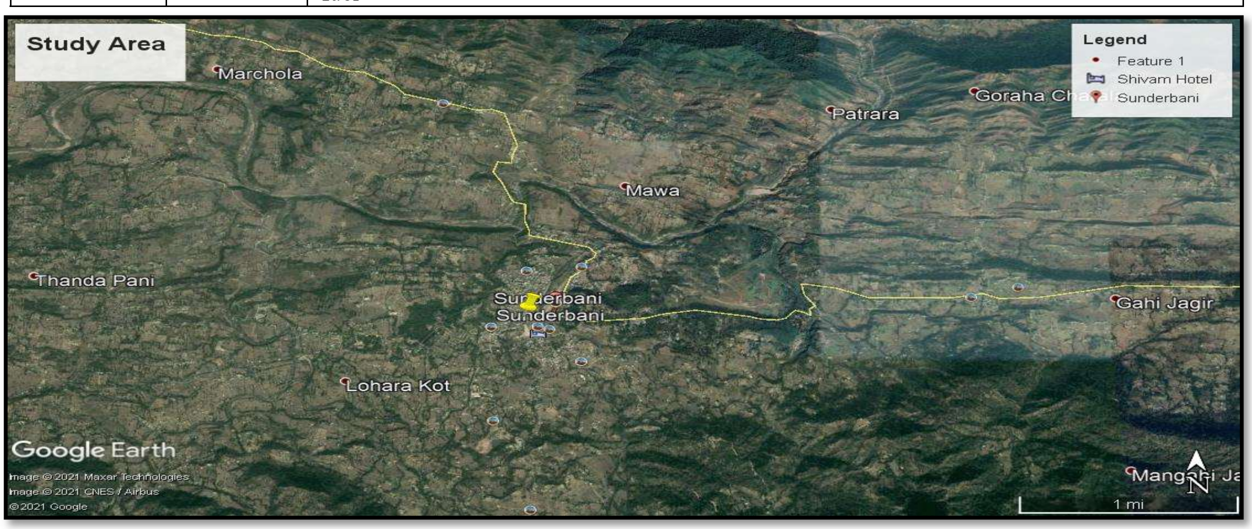

Figure 1: Satellite image showing the study area

Sampling of indoor air and data collection:
At each site sampling of indoor air was done thrice (once each in Kitchen, bedroom, and drawing room on three consecutive days) by CPCB Gravimetric method given by CPCB (2014) using Leland Legacy Sample Pump (at selected air flow rate of 9 L/min) in combination with a five-stage Sioutas Personal Cascade Impactor provided with particle size cut points of 2.5 µm, 1 µm, 0.5 µm and 0.25 µm on Zefluor[TM] supported PTFE filter paper of pore size 0.5 µm (micrometre) and 25 mm diameter for 24 h. All the filter papers before and after sampling were weighed thrice using Mettler Toledo micro balance with sensitivity of 0.01 mg. The concentration of PM ($PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$, $PM_{0.25}$)
$PM_{0.25}$) was calculated by the formula:

$$\boldsymbol{Conc. of\ PM}\ (\mu g/m^3) = (W_2 - W_1) \times \frac{10^6}{\boldsymbol{Volume\ of\ air}}$$

where,
W_1 - initial weight of filter paper (mg).
W_2 - final weight of filter paper (mg).

Results and Discussion

The results are tabulated in table 2, 3, 4, 5, 6 and 7 and figure 2, 3 and 4. The critical analysis of data at Residential area revealed that values of $PM_{2.5}$ were highest in RTC followed by RLWE and least in RLIM whereas the values of $PM_{1.0}$, $PM_{0.50}$ and $PM_{0.25}$ were found highest in RTC followed by RLIM and least by RLIE households (Figure 4). Highest values of indoor particulate matter were reported in households with traditional chullah (TC) which supports the finding that indoor $PM_{2.5}$ concentration were higher for Traditional Cooking Stoves (TCS) and lower for Improved Cooking Stove (ICS) reported by Parajuli *et al.* (2016). The critical analysis of data at Commercial area revealed that values of $PM_{2.5}$ were highest in CTC followed by CLWE and least in CLIM whereas the values of $PM_{1.0}$ were highest in CTC followed by CLE and least by CLIM, $PM_{0.50}$ were highest in CTC followed by CLIE and least by CLE and $PM_{0.25}$ were found highest in CTC followed by CLWE and least by CLIE households (figure 4).
These results support the findings of Nishu and Rampal (2019) that in comparison to residences even without exhaust, Chulha-using households showed higher levels of indoor $PM_{2.5}$ at all the study sites. Further, the analysis of the data of particulate matter in the households with traditional chullah revealed that kitchens of residential area exhibited insignificantly ($p>0.05$) higher values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and $PM_{0.25}$ as compared with that of commercial area.
The overall comparison of particulate matter in the non-wood burning fuel households with exhaust and households without exhaust at residential and commercial areas revealed that households without exhaust exhibited higher values of particulate matter as compared with that of households with exhaust and even households with modular kitchen exhibited lowest values of particulate matter which validates the claim of Parajuli *et al*. (2016) that in order to enhance the indoor air quality of rural homes, greater attention should be paid to ventilation and chimney location. It was also reported that UFP concentrations during cooking were highest when kitchen exhaust fan was turned off and gas stove was utilised at a higher temperature by Zhang *et al*. (2010). The analysis of particulate matter in the households with LPG as cooking fuel and exhaust at study area revealed indoor $PM_{2.5}$, $PM_{1.0}$, and $PM_{0.25}$ exhibited highest values in the Kitchen followed by Drawing room and lowest in the Bedroom whereas indoor $PM_{0.50}$ exhibited the trend Kitchen followed by Bedroom and lowest in the Drawing room (Table 2). Households with LPG as cooking fuel and without exhaust exhibited highest values of indoor $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and $PM_{0.25}$ in the Kitchen and lowest in the Bedroom (Table 3).
Households with LPG-induction as cooking fuel and exhaust exhibited highest values of indoor $PM_{2.5}$ and $PM_{0.50}$ in the Kitchen followed by Drawing room and lowest in the Bedroom whereas $PM_{0.25}$ exhibited the trend Kitchen followed by Bedroom and lowest in the Drawing room and $PM_{1.0}$ exhibited the trend Drawing room followed by Kitchen and lowest in the Drawing room in the overall study area (Table 4). Households with LPG-induction as cooking fuel and without exhaust in the study area exhibited highest values of indoor $PM_{2.5}$ and $PM_{0.50}$ in the Kitchen followed by Drawing room and lowest in the Bedroom whereas $PM_{1.0}$ and $PM_{0.25}$ exhibited the trend Kitchen followed by Bedroom and lowest in the Drawing room (Table 5).

Table 2: Indoor PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ concentrations in household with LPG and Exhaust in overall Study area

PM Size	PM Average (µg/m^3)			
	Kitchen	Bedroom	Drawing room	Study Area
$PM_{2.5}$	41.66	18.51	20.82	26.99±12.75
$PM_{1.0}$	28.93	12.72	17.35	19.66±8.34
$PM_{0.50}$	17.35	15.04	5.78	12.72±6.12
$PM_{0.25}$	41.66	15.04	19.67	25.45±14.22

Table 3: Indoor PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ concentrations in household with LPG and Without Exhaust in overall Study area

PM Size	PM Average (µg/m^3)		
	Kitchen	Bedroom	Study Area
$PM_{2.5}$	56.71	26.62	41.66±21.27
$PM_{1.0}$	20.83	16.20	18.51±3.27
$PM_{0.50}$	15.02	10.41	12.71±3.25
$PM_{0.25}$	38.19	24.30	31.24±9.82

Table 4: Indoor PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ concentrations in household with LPG-Induction and Exhaust in overall Study area

PM Size	PM Average (µg/m^3)			
	Kitchen	Bedroom	Drawing room	Study Area
$PM_{2.5}$	32.40	26.61	31.24	30.08±3.06
$PM_{1.0}$	17.35	15.04	19.67	17.35±2.31
$PM_{0.50}$	19.67	12.72	16.20	16.19±3.47
$PM_{0.25}$	30.08	11.57	10.41	17.35±11.03

Table 5: Indoor PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ concentrations in household with LPG-Induction and Without Exhaust in overall Study area

PM Size	PM Average (µg/m^3)			
	Kitchen	Bedroom	Drawing room	Study Area
$PM_{2.5}$	47.45	20.82	26.61	31.62±14.00
$PM_{1.0}$	28.93	12.72	11.57	17.74±9.70
$PM_{0.50}$	27.77	10.41	16.19	18.12±8.84
$PM_{0.25}$	34.71	23.14	20.83	26.22±7.43

Table 6: Indoor PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ concentrations in household with LPG-Induction and Modular Kitchen in overall Study area

PM Size	PM Average (µg/m^3)			
	Kitchen	Bedroom	Drawing room	Study Area
$PM_{2.5}$	16.20	25.45	19.67	20.44±4.67
$PM_{1.0}$	11.57	17.35	27.77	18.89±8.21
$PM_{0.50}$	11.56	16.20	35.87	21.21±12.90
$PM_{0.25}$	20.82	18.51	52.08	30.47±18.75

Table 7: Indoor PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ concentrations in household with Traditional Chullah in overall Study area

PM Size	PM (µg/m^3)
	Kitchen Average (Study Area)
$PM_{2.5}$	190.58
$PM_{1.0}$	342.58
$PM_{0.50}$	537.80
$PM_{0.25}$	865.73

Figure 2: Filter papers showing accumulation of different types of PM $_{(2.5\text{-}0.25)}$ in the Household with Traditional Chullah at the Residential area

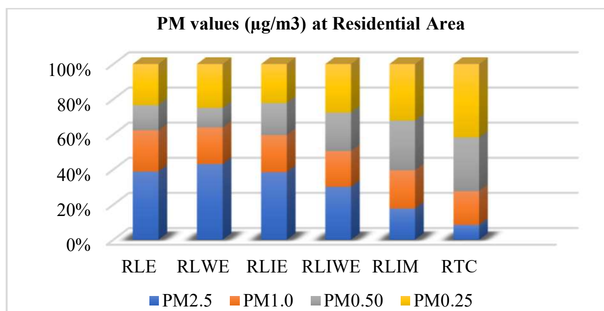

Figure 3: PM concentrations (µg/m^3) at Residential area with different fuel and ventilation conditions

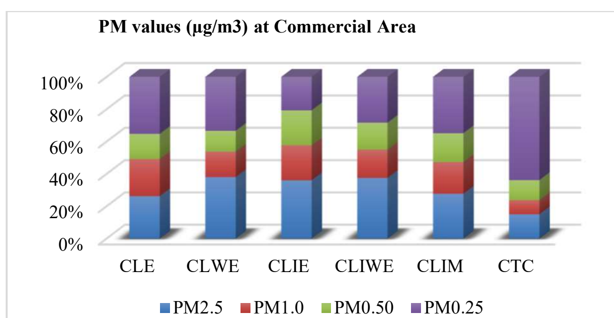

Figure 4: PM concentrations (µg/m^3) at Commercial area with different fuel and ventilation conditions

Households with LPG-induction as cooking fuel and without exhaust in the study area exhibited highest values of indoor $PM_{2.5}$ and $PM_{0.50}$ in the Kitchen followed by Drawing room and lowest in the Bedroom whereas $PM_{1.0}$ and $PM_{0.25}$ exhibited the trend Kitchen followed by Bedroom and lowest in the Drawing room (Table 5). Households with LPG-induction as cooking fuel and Modular Kitchen revealed $PM_{1.0}$ and $PM_{0.50}$ exhibited the trend Drawing room followed by Bedroom and lowest in the Kitchen whereas $PM_{2.5}$ exhibited the trend Bedroom followed by Drawing room and lowest in the Kitchen and $PM_{0.25}$ exhibited the trend Drawing room followed by Kitchen and lowest in the Bedroom in the overall study area (Table 6). Rampal and Chib (2013) while studying indoor suspended particulate matter (SPM) levels in kitchens of households using various cooking methods noticed that SPM levels were higher than the levels prescribed by CPCB (200 $\mu g/m^3$) in all households. They also found that fuelwood using kitchens had the highest SPM (1435.54 ± 849.47$\mu g/m^3$), followed by kitchens using kerosene oil (710.06 ± 180.37$\mu g/m^3$), kitchens using LPG (376.79 ±140.98$\mu g/m^3$) and kitchens using electric heater (262.08 ± 95.90$\mu g/m^3$) as their mode of cooking. Households with Traditional chullah in the overall study area on the basis of compilation of data showed the average value of $PM_{2.5}$ as 190.58$\mu g/m^3$, $PM_{1.0}$ as 342.58$\mu g/m^3$, $PM_{0.50}$ as 537.80$\mu g/m^3$, $PM_{0.25}$ as 865.73$\mu g/m^3$. The value of average indoor $PM_{2.5}$ was found to be 3.1 times above the CPCB prescribed 24 hrs. limit of 60 $\mu g/m^3$ in the study area (Table-7 and Figure-4). This observation was supported in one study which reported that wood users were subjected to much more particle pollution (1200 $\mu g/m^3$) than charcoal users (540$\mu g/m^3$) or modern fuel users like LPG and electricity (200-380 $\mu g/m^3$) during the cooking process in Mozambique conducted by Ellegard (1996). Vicente *et al*. (2020) also observed that the levels of PM_{10} were about 12 times higher during the usage of wood burning devices in uninhabited rural households.

Generally, kitchens in the households of study area exhibited higher values of all types of particulate matter, PM $_{(2.5,\ 1.0,\ 0.50,\ 0.25)}$ except in the household with LPG-Induction and Modular Kitchen when compared with the average values recorded in the bedrooms and drawing rooms. This was due to the higher fuel emissions and less space in the kitchen as indoor air pollutants accumulate more quickly in the enclosed spaces rather than in the open spaces.

The average values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and $PM_{0.25}$ in the Wood fuel burning Households were observed to be significantly ($p<0.05$) higher than the average values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and, $PM_{0.25}$ in the non-wood fuel burning households of the study area. This observation find supports from the findings of Mukkannawar *et al.* (2014) who also observed higher particulate matter concentrations in homes using chullah as compared to kerosene stove and LPG stove respectively. And the values obtained were found to be 81.8% and 97% times more than NAAQS values of $PM_{2.5}$ and PM_{10} respectively thereby concluding that people residing in households using traditional chullah and kerosene stove were exposed to greater risk of disastrous respiratory health impacts. Kurmi *et al.* (2014) also reported both men and women who were exposed to biomass smoke had greater respiratory issues than those who were exposed to cleaner fuel found in a study in Nepal.

Conclusion

The average values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and $PM_{0.25}$ in all types of wood and non-wood fuel burning households of the study area were observed to be 110.36$\mu g/m^3$, 180.50$\mu g/m^3$, 276.9$\mu g/m^3$ and 445.93$\mu g/m^3$ respectively. The value of average indoor $PM_{2.5}$ was observed to be 1.8 times above the CPCB prescribed 24 hrs. limit of 60 $\mu g/m^3$ in the study area. The average values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and, $PM_{0.25}$ in the wood fuel burning households were observed to be significantly ($p<0.05$) higher than the average values of $PM_{2.5}$, $PM_{1.0}$, $PM_{0.50}$ and, $PM_{0.25}$ in the non-wood fuel burning households of the study area. The information gathered in the current study will serve as a baseline for further research to identify the presence of toxic metals and ions, their sources that contribute to ambient air and have an impact on the environment and human health. Moreover, study of more size segregated particulate matter in indoor and outdoor environment is expected that will enable the researchers to effectively address the effects of these on health in the future.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Phytoremediation potential of macrophytes against heavy metals, nitrates and phosphates: A review

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ABSTRACT

Natural waters are degraded either by contaminants or pollutants. Contaminants are synthetic compounds which cause degradation of water quality, even when present in minute residues. They include pesticides, heavy metals, Poly Chlorinated Biphenyl's, Poly Aromatic Hydrocarbons, plastics etc. On the other hand, pollution precisely refers to the increase in nitrates and phosphates in water body. Aquatic macrophytes, besides their role in the food chains, play significant part in mitigating both pollutant and contaminant levels. Their uptake and sequestration of nitrates, phosphates and heavy metals is well documented and published in worldwide. This paper reviews the efficacy of different macrophytes in freshwater ecosystems for uptake of pollutants and contaminants. It will provide an insight for policy makers in efficient mitigation of pollution levels in the water body.

Introduction

Water being employed in many industrial processes, as well as the release of discharges originating from industry and urban growths, exposes aquatic habitats to additional contamination than other environments (Fernandesa *et al*., 2007). Although most aquatic ecosystems have a natural inclination to dilute pollution to some level, significant contamination causes changes in the community's fauna and flora (Mateo-Sagasta *et al*., 2017). Sewage is the most common waste dumped into aquatic habitats. Sewage is made up of industrial, municipal, and domestic wastes, such as waste from baths, washing machines, kitchens, and faeces (Bhutiani *et al.,* 2016). The ideal sinks for the disposal of these contaminants are fresh water sources (Tukura *et al*., 2009; Bhutiani and Ahamad, 2021). Contamination of water bodies by heavy metal ions, which has damaging consequences on the environment and human health, is one of the most serious environmental challenges related to water pollution around the world (Akpor and Muchie, 2010; Bhutiani *et al*., 2022). Chemical elements with a specific gravity greater than five times that of water are known as heavy metals (Charan *et al*., 2014). The build-up of heavy metals in marine ecosystems is a global concern among contaminants. The strong association between metals, metal pollution, and human history was developed due to ancient breakthroughs in mining and metal-working techniques. The burning of fossil fuels, mining and smelting of metalliferous ores, municipal wastes, sewage, pesticides, and fertilisers are the principal causes of metal pollution (Pendias and Pendias, 1989). In terms of metal pollution in the aquatic ecosystem, it is low in open oceans and rises dramatically as it approaches coastal areas and estuaries. Heavy metal pollution is known to cause a variety of ailments around the world, including minamata sickness (organic mercury poisoning), itai-itai disease (cadmium poisoning), arsenic acid poisoning, and asthma caused by air pollution (Matsuo, 2003). Metal pollutants in aquatic systems are normally in soluble or suspension form, and they eventually settle to the bottom or are taken up by organisms. Because of their toxicity, the cumulative and irreversible accumulation of heavy metals in various organs of marine species leads to

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metal-related disorders in the long run, putting the aquatic biota and other organisms at risk. Heavy metals are hazardous due to their proclivity for bioaccumulation. In comparison to the chemical's concentration in the environment, bioaccumulation refers to an increase in the concentration of a chemical in a biological organism over time.

Phytoremediation is a type of bioremediation in which plants are used to remove, transport, stabilise, and/or eliminate pollutants from the soil and groundwater. As a result, phytoremediation is a plant-based technique that entails using plants to extract and eliminate elemental contaminants from the environment or reduce their bioavailability in soil (Berti and Cunningham, 2000; Bhutiani *et al.,* 2019a&b; Ruhela *et al.,* 2021). Plants extend their root systems into the soil matrix, forming a rhizosphere ecosystem, which accumulates heavy metals and modulates their bioavailability, reclaiming damaged soil and restoring soil fertility (Dal-Corso *et al*., 2019). Phytoremediation has a number of advantages (Yan *et al*., 2020), including:

- Phytoremediation is an autotrophic system fuelled by solar energy, making it easy to run and maintain, and the cost of installation and maintenance is inexpensive.
- It can reduce pollutant exposure to the environment and ecosystem.
- It can be applied over a large-scale field and easily disposed of.
- It prevents erosion and metal leaching by stabilising heavy metals, reducing the risk of contaminants spreading.
- It can also improve soil fertility by releasing various organic matter to the soil.

Plants have faster growth rate, high biomass production and ingest significant amounts of heavy metals. Additionally, they transport metals in above-ground sections and have a mechanism to withstand metal toxicity and thus they are utilised in phytoremediation (Burges *et al*., 2018). In aquatic ecosystems absorbing industrial effluents and municipal wastewater, macrophytes are effective instruments for reducing heavy metal contamination. Because of their inexpensive cost, frequent abundance in aquatic habitats, and ease of handling, they are favoured over other bio-agents. Heavy metal removal requires the extraction and transport of contaminants to aerial parts, or the inactivation of hazardous metals in a system, hence aquatic macrophytes are significant tools. Heavy metals are sequestered by aquatic macrophytes, whether free-floating, submerged, or emergent. The rate of metal absorption, accumulation, and translocation in plants is influenced by plant species and environmental conditions such as the metal's chemical speciation, temperature, pH, redox potential, and salinity (Dhir *et al*., 2009). The availability of metals to macrophytes is regulated by pH, which is critical for metal speciation. Various macrophytes are known for their ability to remove metals from contaminated environments (Burges *et al*., 2018) (Table 1).

Heavy metal removal by water hyacinth (*Eichhornia crassipes*)

Water hyacinth is a prominent freshwater weed in most of the world's frost-free zones, and is widely considered to be the most bothersome aquatic plant. Despite its negative consequences, it is commonly used as water ornamental around the world due to its lovely, stunning blossoms. Aquatic plants such as water hyacinth (*Eichhornia crassipes*) are a sensible and practical technique to absorb toxic substances and enhance water quality. Water hyacinth could effectively phytoremediate contaminated water including metals like cadmium (Cd), arsenic (Ar), and mercury (Hg), reducing the risk of untreated waste water entering the environment (Nazir *et al*., 2020). According to their research, the largest quantity of metal absorbed per dry weight of water hyacinth was 166.25ppm for cadmium and the lowest was 0.032ppm for mercury. The water hyacinth (*Eichhornia crasssipes*) was found to absorb the most cadmium (Cd) metal from sewage water, compared to arsenic and mercury. After 11 days of exposure, water hyacinth accumulated up to 3.542 and 2.412 $mg^{-1}$of Zn and Cr, respectively, at a metal concentration of 10 mg/l (Mishra and Tripathi, 2009). This plant has removed up to 84% of Cr and 94% of Zn from the environment. During the treatment process, the root of the water hyacinth was the most successful portion of all the plant tissues in accumulating Zn. Under field conditions, water hyacinth removed 600 mg arsenic/ha/d, and under laboratory conditions, it recovered 18% of the arsenic (Alvarado *et al*., 2008).

Table 1: Phytoremidiation potential of aquatic macrophytes

SN	Heavy Metal	Phytoremediatormacrophyte	Reference
1	Cr	*Eichhornia crassipes* *Wolffia globosa* *Pistia stratiotes* *Salvinia minima*	Muramoto and Oki, 1983 Upatham *et al*., 2002 Sen *et al*., 1987 Srivastav *et al*., 1994
2	Cu	*Eichhornia crassipes* *Pistia stratiotes* *Lemna minor* *Vallisneria spiralis*	Delgado *et al*., 1993 Miretzky *et al*., 2004 Kara, 2005 Sinha *et al*., 1994
3	Fe	*Pistia stratiotes* *Potamogeton pectinatus* Myriophyllum spicatum	Zayed *et al*., 1998 Tripathi *et al*., 1991 Brankoviˊc *et al*., 2012
4	Ni	*Eichhornia crassipes* *Lemna gibba* *Lemna minor*	Fargo and Parsons, 1994 Zayed *et al*., 1998 Axtell *et al*., 2003
5	Zn	*Eichhornia crassipes* *Pistia stratiotes* *Azolla pinnata*	Low *et al*., 1994 Odjegba and Fasidi, 2004 Jain *et al*., 1990
6	Cd	*Wolffia globosa* *Eichhornia crassipes* *Lemna trisulca* *Salvinia minima* Ceratophyllum demersum	Boonyapookana *et al*., 2002 Zhu *et al*., 1999 Huebert and Shay, 1993 Hoffman *et al*., 2004 Bunluesin*et al*., 2004
7	Mn	*Pistia stratiotes* Typha latifolia	Maine *et al*., 2004 Hejna *et al*., 2020
8	Hg	*Eichhornia crassipes* *Spartina alterniflora* *Scirpus robustus*	Vesk *et al*., 1999 Carbonell *et al*., 1998 DeSouza *et al*., 1999
9	Ag	*Eichhornia crassipes*	Olguin *et al*., 2002
10	Pb	*Eichhornia crassipes* *Lemna minor* *Typha latifolia* Myriophyllum spicatum	Molisani *et al*., 2006 Rahmani and Sternberg, 1999 Qian *et al*., 1999 Sivaci *et al*., 2004
11	Pt	*Eichhornia crassipes*	Hu *et al*., 2003

Heavy metal removal by *Lemna*

The Lemnaceae family includes duckweed, which is a tiny, free-floating aquatic plant. Duckweed species have been recommended for wastewater treatment and have been used in water quality studies for monitoring heavy metals (Radic *et al*., 2010). They are regarded a better option and have been used in water quality studies for monitoring heavy metals. All metals (cadmium, copper, lead and nickel) were removed with higher than 80% efficiency by *Lemna*, with nickel (Ni) removing the most (99%) from sewage mixed industrial effluent. Lead accumulation and absorption were substantially higher in dry biomass than for other metals (Bokhari *et al*., 2016). The plant's bioconcentration factors were less than 1000, with the highest values for copper (558) and lead (523.1), indicating that it is a moderate accumulator of both metals.

Heavy metal removal by *Azolla*

Azolla has a great potential for heavy metal removal from water resources and can be employed in heavy metal phytoremediation. *Azolla filiculoides* has the ability to absorb Cr, Pb, Zn, Hg, Cu, Cd, Ag, and Ti, making it a valuable plant for bioremediation and heavy metal removal from wetlands (Hassanzadeh *et al*., 2021).

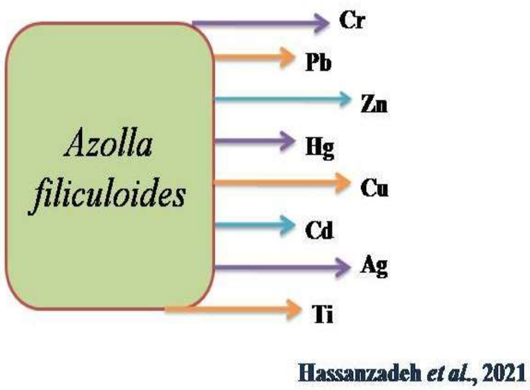

Figure1: Phytoremediation efficiency of *Azolla filiculoides*

Another study (Shafi *et al*., 2015) found that *A. filiculoides* can accumulate the most Zn in its tissues when compared to Cu, Pb, and Cd, which could be related to Zn's importance in the fern's vital functions. Metal accumulation in the roots of *A. filiculoides* is higher than in the leaf tissue, indicating inadequate ion transport in this water fern. In another study, *Azolla caroliniana* was revealed to show phytoremediation against metals (Bennicelli *et al*., 2004). More lead than cadmium has been taken up by *A. caroliniana*. Lead levels were 53-416 mg/kgd.m., while cadmium levels were 23-259 mg/kgd.m. According to these findings, *A. caroliniana* is more tolerant of lead than cadmium. The presence of lead and cadmium ions inhibited the growth of *A. caroliniana* by 30–37% and 24–47%, respectively (Stepniewska *et al*., 2005). *Azolla pinnata* is a promising candidate for the removal of Cd^{+2} from wastewater. As a result, *A. pinnata* could play a key role in the rehabilitation of anthropogenic-stressed aquatic ecosystems and wastewater treatment (Tantawy *et al*., 2017).

Heavy metal removal by *Potamogeton*

Potamogeton spp, a globally distributed submerged macrophyte, produces vast amounts of biomass and may remove hazardous metals like Cd and Hg from effluent (Demirezen and Aksoyo, 2007). Heavy metals (Cr, Fe, Mn, Zn, Cd, and Pb) are accumulated by *Potamogeton pectinatus* at concentrations of 300.86, 1782.31, 1777, 146.79, 0.38, and 6.85 ppm, respectively. *Potamogeton pectinatus* gathered heavy metals of Cr, Zn, Cd, Pb in its roots (lower portions), Cr, Mn, Zn in its stem, Cr, Zn, Cd in its leaves, and all tends to accumulate considerable amounts of Cu, Cr, Pb, As, and Cd (Ibrahim *et al*., 2016). *Potamogeton pectinatus* accumulates large amounts of metals in its tissues, resulting in a reduction in heavy metals (Fe, Cu, Zn, and Pb) in waste water. The plants were able to remove 70-85% of Fe, Cu, Zn, and Pb from waste water, demonstrating their metal phytoremediation capability (Singh *et al*., 2014).

Heavy metal removal by *Salvinia*

Salvinia molesta is a free-floating perennial weed that can be utilised to remediate blackwater effluent in environmentally friendly sewage systems. The study clearly shows that *Salvinia molesta* consumes heavy elements like as chromium, cadmium, copper, and lead (Table 2), yet the growth regulation process remains unchanged (Donatus, 2016). *Salvinia biloba* was shown to be highly successful in the removal of Cu and Pb (>95%) from water samples, but less so in the removal of Zn (77–70%) and Cd (79–54%). The buildup of Cd, Cu, Pb, and Zn in plant tissue caused visible visual changes in leaves, indicating that this aquatic fern can be used as an ecological indicator of heavy metal contamination in contaminated waters (Emiliani *et al*., 2020).

Table 2: Uptake of heavy metals by *Salvinia molesta*

SN	Heavy metal	Concentration (ppm)	
		Before treatment	After treatment
1	Copper	1.092	2.035
2	Chromium	2.021	1.052
3	Lead	2.974	1.924
4	Cadmium	0.251	0.018

(Donatus, 2016)

Heavy metal removal by *Pistia*

Cu, Zn, Fe, Cr, and Cd uptake have no negative effects on the plant, making *Pistia stratiotes* a viable candidate for use as a hyper-accumulator plant for the broad-scale mitigation of organic pollutants and heavy metals from wastewater (Eloy *et al*., 2019). During the experiment, the biomass of *P. stratiotes* removed more than 70% of the zinc and cadmium from the contaminated fluid.

Eutrophication of water bodies:

Eutrophication is the process of an overabundance of nutrients in a water body, resulting in abundant growth of basic plant life. This process is indicated by the excessive development (or bloom) of algae and plankton in a water body. Plant development in an ecosystem is limited by the availability of nutrients such as nitrogen and phosphorus. The growth of algae, plankton, and other simple plant life is favoured over the growth of more sophisticated plant life when water bodies are too loaded with these nutrients. All water bodies are vulnerable to a slow and natural eutrophication process, which has accelerated in recent decades due to cultural eutrophication. The structural changes in the water body are triggered by the constant increase in the input of nutrients, mostly nitrogen and phosphorus (organic load), until it surpasses the capacity of the water body.

Phytoremediation potential of aquatic macrophytes against nitrates:

The contamination of water caused by high amounts of nitrates present in various bodies of water is referred to as nitrate water pollution. Nitrate pollution occurs in surface and groundwater as a result of numerous sources of nitrate leaking into the soil and then into the water supply. The roots of aquatic plants create a range of micro-environments surrounding them that can support the growth of nitrifying or denitrifying bacteria (Wu *et al*., 2003). The elimination of nitrate by aquatic plants was found to entail both plant absorption and the impact of microbes (Chong *et al*., 2003). In terms of nitrate removal, some emergent macrophytes produce significant purification effects (with nitrate removal percentages surpassing 50%). In terms of nitrate removal percentage, there was a highly significant difference between the three species of aquatic plants (Table 3, $P < 0.01$). The nitrate removal percentage of *Acoruscalamus* was the highest, at 86.16 percent, and the nitrate removal percentage of *Phragmitesaustralis* was much lower, at only 62.34 percent, than the other two species (Li *et al*., 2016).

Phytoremediation potential of aquatic macrophytes against phosphates:

The ability of *Eichhornia crassipes* and *Pistia stratiotes* to sequester phosphorus was calculated. After 48 hours of equilibrium time, the phosphate removal efficiencies of *P. stratiote s*and *E crassipes* were 71.6% and 76.8%, respectively. At pH 7, *P. stratiotes*and *E. crassipes* had maximum removal efficiencies of 77.7% and 83.7 percent, respectively. *Pistia stratiotes* had the greatest uptake of 47 mg/l at 250 mg/l, despite having the highest removal efficiency of 89.5 percent at 25 mg/l. *E. crassipes* had the highest uptake of 47 mg/l at 250 mg/l, despite having the highest removal efficiency of 89.5 percent at 25 mg/l. After five days, *P. stratiotes*and *E. crassipes* had 35.4 percent and 41.6 percent phosphorus sequestration potential from a eutrophied water body, respectively, showing higher phytoremediation efficacy (Dayarathne *et al*., 2020). The sequestration of phosphates is exhibited in table 4.

Table 3: The nitrate removal percentages of plants

SN	Final nitrate removal	Plant	Final nitrate removal
1	0.6473	*Scirpus validus*	0.6234
2	0.7118	*Phragmites australis*	0.6874
3	0.8162	*Acorus calamus*	0.8616

(Li *et al*., 2016)

Table 4: Sequestration percentage of phosphates

SN	Plant	Days	Sequestration percentage
1	***Eichhornia crassipes***	5	41.6
		10	23.5
		15	29.3
2	***Pistia stratiotes***	5	35.4
		10	10.9
		15	16.2

(Dayarathne *et al*., 2020)

Conclusion

Phytoremediation is an efficient technique by which we can eliminate the contaminants from the water body. Macrophytes such as *Eicchornia, Lemna, Azolla, Potamogeton, Salvinia and Pistia* can effectively remove the heavy metals. Besides, they can be helpful in the removal of nitrates and phosphates enabling lake reclamation. Therefore, they can be used for the control of eutrophication in the lakes.

Conflict of interest

The authors declare that they have no conflict of interest.

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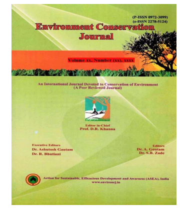

Reflective mulch films a boon for enhancing crop production: A review

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ABSTRACT

Mulches are materials that are put to the surface of the soil for a variety of reasons. Plastic mulches of various colours have been developed and employed in a variety of agricultural production methods. Colored plastic mulches are used to modify the radiation budget and prevent soil water loss. It also helps with weed and insect infestation, as well as soil temperature regulation, water efficiency, plant development, yield, and quality. This paper reviews and discusses the understanding and prospective application of coloured plastic mulches to improve soil physical attributes growth, yield, and crop quality. Colored plastic mulches' effectiveness in minimising the detrimental impacts of environmental stress on crops is also explored. The impact of coloured plastic mulches on soil temperature has been documented by several researchers to vary from area to area and crop to crop. Various physicochemical mechanisms have also described that result in increased crop productivity when coloured plastic mulches are employed. Colored plastic mulches have a significant impact on soil temperature, moisture, and water holding capacity, according to the study. Clear and white plastics lower the temperature of the soil, but black and blue plastics raise it. A higher number of fruits, roots, tubers, and bulbs were produced when coloured plastic mulches were used. TSS, Vitamin C, and the proportion of liquid in diverse plants all improved significantly. Infestation of weeds and viral diseases has also been found to be significantly reduced. Reduced plant growth and yield, increased pest infestation, microplastic pollution, soil puddling, soil structural loss, and reduced soil-microorganism activity are some of the disadvantages of coloured plastic mulches. As a result, using coloured plastic mulches demands a detailed investigation of interactions with factors such as cropping season, root zone temperature, crop type, insect pest infestation, and water use efficiency.

Introduction

Farmers all around the world are using various types of including, both organic and inorganic, which are used not only to conserve water but also to reap other benefits such as reducing weed and pest infestations. Inorganic mulches, such as plastic mulch films, have become more popular among farmers due to their ease of transport and installation. The research work done on several types of reflective plastic mulch films is examined in this paper, and distinct case studies based on the colour of the mulch films used in their studies are described.

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Black coloured plastic mulch film

In India, black colour reflective plastic mulch films are the most widely available and used films. The black colour mulches, like other plastic films, inhibit weed development and decrease soil temperature during hard winters. UV (ultraviolet), visible, and infrared wavelengths of solar light are all efficiently absorbed by it. By absorbing a large amount of radiation, it had a considerable impact on increasing soil heat. Black plastic mulches recorded greater temperatures than olive, silver, white, and blue colour films, according to a study (Shah *et al.,* 2018). According to reports, black plastic mulch films are more effective than white, aluminum/black plastic mulch films in boosting minimum, maximum, and mean soil temperature (Claudio *et al*., 2017). Many crops yielded more under black-colored mulch films than in bare fields (Rashidi *et al*., 2010; Berihun 2011; Bhatt *et al.,* 2011; Hatami *et al*., 2012; Kumar and Lal 2012). The effects of black polyethylene plastic mulch on okra and squash growth and yield under rain-fed conditions revealed that plants with polyethylene mulch produce larger fruits and higher fruit yield per plant. This is due to better plant growth caused by a favourable hydro-thermal regime of soil and a completely weed-free environment (Mahadeen, 2014). In comparison to control, the study found that extended moisture retention and availability resulted in higher nutrient uptake for optimum plant growth and development. The goal of the study (Mohammad *et al.,* 2018) was to create ways for reducing salt impact in maize crops using three different coloured plastic mulches (blue, black, and white), rice straw mulch, and a non-mulch control (bare soil). In 2016 and 2017, the black plastic mulch had 0.2 and 1.0 °C lower temperatures than the control, whereas the rice straw mulch had 2.0 and 1.5 °C lower temperatures than the control. At 5 and 10 cm depth, (Deshmukh *et al*., 2013) discovered the highest soil temperature under black plastic mulch, followed by no mulch and paddy straw mulch. They discovered a strong correlation between soil temperature and 1000-grain weight in the experiment. Studies on influence of mulch film removal date on potato indicated that the water use efficiency (WUE) was highest under black plastic mulch that was removed on the 60th day (50 kg tuber/ha mm) after sowing, over no mulch condition (34 kg tuber/ha mm) (Gangwar *et al.,* 2017) (Fig 1). The treatment of black mulch film removed on the 60th day after sowing produced the maximum yield (30.2 t/ha), followed by silver mulch removed on the same day (29.3 t/ha), and no mulch (20.8 t/ha).

Figure 1: Black coloured plastic mulch film

Silver coloured plastic mulch film

In comparison to black and white plastic mulches, silver plastic mulches reflect more radiation. The root zone temperature and water loss are reduced as a result of the increased refection of radiations (Rylander *et al*., 2020). This plastic mulch's fundamental qualities make it effective at conserving water and preventing water loss (Díaz-Pérez 2010; Rylander *et al*., 2020). The mean soil temperature has influence on plant growth characteristics such as stem diameter, plant height, leaf length, leaf dry weight, stem dry weight, and plant dry weight. In the hot season, silver plastic film mulching produced better yields than black plastic film mulching, but in the cold season, the opposite is true. Under silver plastic mulch, the maximum weight of fruit per plant (1 kilogram) was reported by Sarkar *et al*., 2019. Total soluble solids, reducing sugar, non-reducing sugar, vitamin C, and pyruvates were all higher in onion crops cultivated beneath silver polyethylene film. The explanation for this is that the reflective aspect of the film increases microbial activity in photosynthesis by increasing S and K activity (Helaly *et al*., 2017; Sarkar *et al*., 2019). Aphids (and the viral illnesses they carry), whiteflies, cucumber beetles, and other pests are deterred by the reflective aspect of film (Rao *et al*., 2018; Saxena 2018). Crops grown under silver plastic films had a higher leaf area than those grown on bare soil (Fig 2). Experiments on a Chickpea crop in the winter season showed that silver plastic mulch films (17.21 kg/ha mm) provided superior water use efficiency than a crop without mulch (Rao *et al*., 2021). A study on the effect of different mulching materials and mulch colour on watermelon growth and yield found similar trends. The efficiency of water and fertilizer consumption in a crop grown under a silver-colored mulch film was found to be 60% greater than in a crop grown without one (Rao *et al*., 2017).

Figure 2: Silver coloured plastic mulch film

White coloured plastic mulch film

White mulches are generally used for reflecting incident solar radiation so as to moderate micro climate near the vicinity of plant environment. When white plastic mulch films are placed on the soil top, they chill the soil and are commonly employed in crops that do not require much heat (Lament, 2017; Agrawal, 2010). According to the findings, crops farmed beneath plastic mulch films have earlier branching and are lower in height than crops cultivated using traditional methods. White and clear plastic mulches are more successful in reducing the incidence of viral illnesses, whitefly population, and aphid population, according to studies (Brown *et al*., 2019). White plastic films keep the soil cool longer than black, dark, or transparent plastic films (Snyder *et al*., 2015) (Fig 3). The warming effects of mulch films are advantageous in the spring when soil temperatures are below ideal, but they could be detrimental to plant growth later in the season (Snyder *et al*., 2015).

Red coloured plastic mulch film

Red plastic mulch is more efficient than black, blue, green, and yellow plastic mulches at absorbing global sun radiation. According to some studies, the energy balance is described in the following order: red>transparent>green>blue> yellow>black (Díaz-Pérez, 2010; Deshmukh *et al*., 2013; Claudio *et al*., 2017). When compared to other coloured films, certain crops perform better when planted in red mulch. Tomatoes, for example, produce 20% more fruit; basil leaves have a higher surface area, succulence, and fresh weight; and strawberries smell better, taste sweeter, and produce a larger harvest. Researchers discovered that red mulch increased tomato and eggplant yields when compared to black mulch. Tomatoes grown in red mulch produced more mature fruit and set fruit earlier than those cultivated in black plastic (Fig 4). Phytochromes are pigments found in tomato plants that contain color-sensitive proteins and react differently to different light spectra. When far-red light wavelengths from the plastic reflect back up to tomato plants, phytochromes help the fruit grow quicker (Rao *et al*., 2016; Trivedi and Nandeha, 2020). Plants planted in red mulch are taller than those cultivated in other coloured mulch treatments in red bell pepper. The lettuce (Lactuca sativa) with the most leaves was planted on red mulch.

Figure 3: White coloured plastic mulch film

Fig 4: Red coloured plastic mulch film

Other colour mulches

Other coloured mulch films have been studied in other crops; however, the results are very subjective to a specific crop or disease. When crops were covered with yellow mulch films, they did not perform well when aphids attacked because the colour of the film attracts them. Blue mulch is used in the Cantaloupe crop. This resulted in a 35% increase in yield over black plastic films. Under blue mulch films, there was a 30% rise in cucumber and a 20% increase in summer squash when compared to black mulch films. However, because the blue colour attracts thrips, it's best to avoid using it in thrips-prone crops like bell peppers and tomatoes. Brown Infrared Transmitting (IRT) plastic mulch films are a relatively new crop protection technology. IRT is a technology that combines the weed-suppressing features of black plastic with the heat-absorbing qualities of clear plastic. It warms garden soil better than black plastic early in the growth season and reduces weeds. Brown mulch can help naturally repel insects like termites, cockroaches and crickets. Brown mulch is beneficial to soil because it adds nutrients and moisture. Various mulches are depicted in Fig.5.

Figure 5: Other colour mulch films

The crop specific recommendations of colour of the mulch film to based on the studies conducted across the country in different seasons are presented in Table1.Plastic mulches alter plant microclimate by adjusting the reflectivity and absorptivity of the topsoil around the plant, according to research. The table below shows the impact of different polymers on soil temperature, radiation, and weed control (Maughanand and Drost, 2016) (Table 2).

Table 1: Crop specific recommendations of colour of the mulch film

Name of the crop	Colour of the mulch film recommended	Season	Reported by
Watermelon	Silver	Summer	Parmar *et al*. (2013); Rao *et al*. (2017); Dadheech *et al*. (2018)
Tomato	Red	Winter	Agrawal *et al*. (2010); Rao *et al*. (2016)
Potato	Black	Winter	Karam *et al*. (2016); Gangwar *et al*. (2017); Li *et al*. (2018); Qiang *et al*. (2018); Kader *et al*. (2021)
Chickpea	Silver	Winter	Rao *et al*. (2021)
Capsicum	Black	Winter	Ashrafuzzaman *et al*. (2011); Claudio *et al*. (2017)
Pea	Black	Winter	Awal *et al*. (2016); Khan *et al*. (2018)
Cauliflower	Black	Winter	Mintu *et al*. (2018); Kumar *et al*. (2020); Tawfeeq and Abdulrhman (2021)
Strawberry	Black	Winter	Bakshi *et al*. (2014); Adnan *et al*. (2017); Sharma and Goel (2017); Rannu *et al*. (2018)
	Red		Posada *et al*. (2011)

Table 2: Effect of various plastic colours on light and weed control (Reddy *et al*. 2020)

Plastic color	Soil Temp. (2-4" depth)	Light Reflectivity	Light Absorptivity	Weed Suppression
Black	Increases (3 to 5 ℉)	Low	High	Excellent
Clear	Increases (6 to 14 ℉)	Low	Low	Poor
White/silver	Decreases(-2 to 0.7 ℉)	High	Low	Excellent

Conclusion

These findings could have a lot of implications for farmers. Mulch films may provide improved flexibility and the ability to develop with better assurance due to the numerous types of microclimate management that can be achieved. These investigations found that these films give insulation against temperature extremes, and that choosing different colours of films can result in effects ranging from higher to lower average temperatures. Mulch films also reduced the need for irrigation and other methods of water management by covering the soil bed with these films, which prevented both extreme wet and dry conditions. Root zone temperature, microbial life, soil properties, and moisture levels have all been proven to be influenced by coloured plastic sheets. By improving the plant microenvironment, these mulch films boosted plant growth, fruit quality, and yield. Black and silver-colored plastic mulches were found to benefit the majority of the crops. However, choosing the right film colour for a specific crop in a specific season of the year will assist farmers boost their economic returns by increasing agricultural yield.

Conflict of interest

The authors declare that they have no conflict of interest.

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