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Research Article
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EFFECT OF ZINC FERTILIZATION ON GROWTH, YIELD AND QUALITY OF FODDER MAIZE (*Zea mays* L.)

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ABSTRACT

A field experiment was conducted on sandy clay loam soil at College farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi*, 2019-20 and 2020-21 on "Effect of zinc fertilization on growth, yield and quality of fodder maize (*Zea mays* L.)". The treatment comprised of soil and foliar applications of zinc viz., Recommended dose of fertilizers (RDF) alone (120 kg N - 50 kg P_2O_5 - 40 kg K_2O ha^{-1}) without zinc application (T_1), Soil application of 15 kg $ZnSO_4$ ha^{-1} (T_2), Soil application of 25 kg $ZnSO_4$ ha^{-1} (T_3), Foliar spray of 1% $ZnSO_4$ at 20 and 45 days (T_4) and Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5). The five treatments were laid out in randomized block design with four replications. A fodder maize variety, African tall was used by adopting a spacing of 30×10 cm. The recommended dose of fertilizers was applied to all the treatments. The experimental soil was moderately alkaline in reaction, low in organic carbon, available nitrogen (N) as well as low in available zinc (Zn), medium in available phosphorous (P_2O_5) and high in available potassium (K_2O). It is concluded that among different zinc fertilization treatments studied in fodder maize, Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days with RDF (T_5) recorded significantly higher plant height, leaf to stem ratio, dry matter, green fodder yield, crude protein and other quality parameters proved better in registering higher zinc concentration in green fodder and was found economically viable with higher net returns, followed by T_4. Lowest was recorded with no Zn application (T_1) in both the years of study. Overall, our study suggest that zinc fertilization of maize through soil and/or foliar spray can enhance not only fodder productivity and also improve quality of fodder maize in Southern Telangana zone elsewhere under similar agro-climatic conditions.

Key words: Biofortification, Zn, fodder maize, quality.

Maize (*Zea mays* L.) is one of the most important cereal, next to wheat and rice in the world as well as in India. It is one of the most versatile crop and can be grown over diverse environmental conditions. It has diversified uses like human food, animal feed. Green fodder, silage and raw materials for a large number of industrial products. It is one such crop having the desirable traits and is extensively being used in animal feeding safely in summer unlike Sorghum, which contains hydrocyanic acid and sometimes proves to be toxic if fed too early so maize is the most nutritious, succulent and palatable fodder crop amongst the cereals grown for fodder purpose during the *rabi* season (Anonymous, 2015). Fodder maize is quick growing and produces high biomass. It contains sufficient quantities of protein and minerals and possesses high digestibility as compared to other non-legume fodders (Chaudhary *et al.,* 2014). The economics of milk production is also dependent upon the high quality fodder fed to the dairy animals as feeding of green forages compared to concentrates lowers the cost of milk production substantially.

Biofortification refers to increasing the availability of nutrients, such as Fe and Zn, in the staple and fodder crops without using fortificants or supplements (Waters and Sankaran, 2011; White and Broadley, 2005). Agronomic or genetic methods of producing micronutrient enriched cereals (biofortification) and improving their bioavailability are considered promising and cost-effective approaches to reduce malnutrition. Varieties of grain maize developed through the biofortification process must have the trait combinations which encourage adoption such as high yield potential, disease resistance, and consumer acceptability. Bioavailability can be defined as the proportion of the total amount of mineral element that is potentially absorbable in a metabolically active form (Simic *et al*., 2009).

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Application of Zn fertilizers may be a viable option to fulfil the crop demand for Zn and also to increase its content in edible parts. One third of the world population is reported at the risk of malnutrition due to inadequate dietary intake of zinc (Cakmak, 2010). About 50 % of Indian soils are deficient in zinc causing low level of zinc and yield losses in food and fodder crops and affecting the health of the livestock (Singh, 2011). Applying Zn to plants grown under potentially Zn-deficient soils is effective in reducing uptake and accumulation of P in plants. This agronomic side effect of Zn fertilization may result in better bio-availability of animal system. Therefore, a field study was undertaken to study the effect of zinc on growth yield and quality of fodder maize variety 'African tall' through soil and foliar applications.

MATERIAL AND METHODS

A field experiment was carried out during *rabi* 2019-20 and 2020-21 at College Farm College of Agriculture, PJTSAU, Hyderabad. The soil characteristics of the experimental site was sandy clay loam in texture, near neutral in reaction, medium in organic carbon, low in available nitrogen (160.5 kg N ha^{-1}) and zinc (0.48 ppm), and medium in available phosphorus and potassium. The experiment was laid out in a randomized block design with five treatments and four replications. The treatments comprised of soil and foliar applications of zinc *viz.,* Recommended dose of fertilizers (RDF) alone (120 kg N - 50 kg P_2O_5 - 40 kg K_2O ha^{-1}) without zinc application (T_1), Soil application of 15 kg $ZnSO_4$ ha^{-1} (T_2), Soil application of 25 kg $ZnSO_4$ ha^{-1} (T_3), Foliar spray of 1% $ZnSO_4$ at 20 and 45 days (T_4) and Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days after sowing (T_5).

Fodder maize was sown on 7th November 2019 and 5th November 2020 and harvested on 3rd February 2020 and 4th February 2021 at the age of 85 days for green fodder purpose. The fodder maize variety of African tall was sown with a seed rate of 40 kg ha^{-1} and spacing of 30 x 10 cm. The recommended dose of fertilizer 120:50:40 kg N, P_2O_5, K_2O ha^{-1} was applied to all treatments in which full dose of Muriate of potash, Single Super Phosphate and half dose of Nitrogen was applied as basal dose while the remaining half of the N was supplied at the knee-high stage by band placement. Zinc sulphate was applied as per the treatments i.e. soil application of $ZnSO_4$ at two days after basal application of N, P , K and foliar application of 1% $ZnSO_4$ at 20, 45 and 60 DAS as per the treatments. Other cultural operations and plant protection measures were followed as per the recommendations. Crop received 116 mm (12 rainy days) and 176 mm (9 rainy days) rainfall during the crop growth period in 2019-20 and 2020-21, respectively.

Green fodder, dry matter yield and growth parameters i.e plant height, number of leaves, stem girth and leaf to stem ratio were measured. To check out the quality of the fodder crop, representative samples were oven dried at 60°C to constant weight to determine dry matter (DM) content, sample was ground using a Wiley mill to pass through a 1 mm sieve and were stored into an airtight polythene bags till further analysis. Proximate principles namely crude protein (CP), crude fiber (CF), ether extract (EE) and total ash was determined according to *AOAC* (2000). Neutral detergent fibre (NDF) was measured by following methods of Van Soest *et al.,* 1991. The data emanating from the present investigation is tabulated after statistical analysis following the randomized block design technique, functional analysis (comparison means of ZnSO4 soil vs foliar application) suggested by LeClarg *et al.* (1962) and those sampled over periods to measurement over time analysis suggested by Gomez and Gomez (1984). Statistical significance was tested by F- value at 0.05 % level of probability and critical difference (CD) was worked out where ever the effects were significant inferences are drawn and critically discussed. Treatment differences that were non-significant were denoted as "NS".

RESULTS AND DISCUSSION

Growth parameters

Growth parameters like plant height (297.6 cm), No of leaves (13.98) stem girth (8.10 cm) leaf to stem ratio (0.218) were recorded highest with RDF +Foliar spray of 1% $ZnSO_4$ at 15, 30, 45 and 60 days after sowing (T_5) which was differed significantly over soil and foliar application of Zn at various stages compared to Recommended dose of fertilizer No Zn application (T_1) (Table 1). Foliar application of Zn at 1% considerably increased the plant height and other growth attributes. This may be due to the positive effect of foliar application Zn at different growth stages and

Table 1: Plant height (cm) No of leaves, leaf to stem ratio (%) and stem girth (cm) of fodder maize in response to fortification with soil and foliar spray of zinc (Pooled mean of two years)

Treatments	Plant height (cm)	No of leaves $plant^{-1}$	Leaf to stem ratio	Stem girth (cm)
T_1- No Zn (control)	264.4	11.87	0.153	6.75
T_2-$ZnSO_4$ @ 15 kg ha^{-1}	274.6	12.66	0.173	7.20
T_3-$ZnSO_4$ @ 25 kg ha^{-1}	284.4	13.13	0.19	7.59
T_4- Foliar spray of 1% $ZnSO_4$ at 20 and 45 days	291.6	13.64	0.185	7.81
T_5-Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days	297.6	13.98	0.218	8.10
SE.d ±	3.1	0.13	0.007	0.08
CD (p=0.05)	6.4	0.27	0.014	0.16
Mean of $ZnSO_4$ ~ soil	279.5*	12.90*	0.182*	7.40*
Mean of $ZnSO_4$ ~ foliar spray	294.6*	13.81*	0.201*	7.95*
Significance for mean of soil vsfoliar spray †	†	†	†	†

Note: Recommended dose of fertilizers Applied for all the treatments,
Asterisks at different growth stages for mean of ZnSO4 ~ soil and foliar sprays represent their effect vs no zinc application.
† shows the level of significance for mean effect of soil vs foliar spray
NS= Not significant; *=Significant at 1% and **= Significant at 5%

absorbed directly in to plant tissues. Zn aids in the synthesis of growth hormones and plays a vital role in cell elongation. Increase in plant height with respect to increased Zn application rate indicates maximum vegetative growth of plant under higher Zn availability. These finding are in relevance with the findings of Yasin *et al.,* 2018

Dry matter yield (q ha^{-1})

The data on improvement of dry matter production of maize in response to the method and level of fortification with $ZnSO_4$ is shown in table 2. The crop raised without the fortification treatment of $ZnSO_4$ produced dry matter of 74.8 q ha^{-1} in 2019-20 and 73.3q ha^{-1} in 2020-21. The production increased significantly to 82.2 q ha^{-1} by the addition of 15 kg ha^{-1} $ZnSO_4$ through the soil in the first year and to 84.3 q ha^{-1} in the second year. The response improved to 88.6 and 99.1 q ha^{-1} in the respective years by increasing the level of this nutrient to 25 kg ha^{-1}. The crop turned out more dry matter by foliar spray than through the soil application. Maximum dry matter production of 102.8 and 104.7 q ha^{-1} was realized in the corresponding years by foliar feeding of 1% $ZnSO_4$ sprayed thrice at 20, 45 and 60 DAS.

Both the methods of feeding the crop with $ZnSO_4$ through soil and foliar sprays significantly enhanced the dry matter production. But foliar feeding was consistently superior to soil application. The pooled analysis of variance for dry matter production over the two years also portrayed similar response as in the individual years. This might be due to involvement of zinc in biosynthesis of plant hormones by activating tryptophan, which is a precursor of Indole acetic acid (auxin). IAA is a component of various enzymes, such as carbonic anhydrase and alcoholic dehydrogenase, which have a suggestive role in chlorophyll formation, photosynthesis and metabolic reactions in plants. It also involves in protein synthesis, cell division and cell elongation, which in turn promotes the vertical growth of the plant, photosynthates accumulation and thereby improving the plant biomass production. The results are in accordance with those of Mahdi *et al.* (2012), Mohan and Singh (2014), Kumar *et al.* (2018).

Green fodder yield (q ha^{-1})

Response on green fodder yield of fodder maize for silage due to the fortification with soil and foliar fed $ZnSO_4$ is furnished in Table 2. The fodder variety of maize African tall nurtured with the optimal dose of 120 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5 and 40 kg K_2O ha^{-1} (T_1) produced 333 kg ha^{-1} green fodder in 2019-20 and 334 kg ha^{-1} in the following year. Fortification of the crop by the application of 15 kg ha^{-1} $ZnSO_4$ incorporated in the soil at the time of sowing significantly increased the forage yield to 364 kg ha^{-1} in the first year and to 368 kg ha^{-1} in the second year. Relatively higher level of 25 kg ha^{-1} further increased the production significantly to 388 and 390 kg ha^{-1} during the corresponding years. The foliar feeding of 1% $ZnSO_4$ twice at 20 and 45 days were significantly superior to the application of 15 kg ha^{-1} $ZnSO_4$ applied through the soil. But spraying of this micronutrient at 1% thrice at 20, 45 and 60 days maximized the green fodder yield to 417 q ha^{-1} in 2019 -20 and to 421 q ha^{-1} in 2020-21. The pooled analysis of variance also exhibited similar trends. The mean green fodder yield was 333 q ha^{-1} in control without the application of zinc. The addition of $ZnSO_4$ significantly increased the mean production. Highest mean production of 419 q ha^{-1} was realized by the foliar application of 1% $ZnSO_4$ thrice at 20, 45 and 60 days providing additional yield of 86 q ha^{-1} over control.

Table 2: Dry matter yield and Green fodder yield of fodder maize in response to fortification with soil and foliar spray of zinc.

Treatments	Dry matter yield (q ha^{-1})			Green fodder yield (q ha^{-1})		
	2019-2020	2020-2021	Pooled mean	2019-2020	2020-2021	Pooled mean
T_1-No Zn	74.8	73.3	74.0	333	334	333
T_2-$ZnSO_4$ @ 15 kg ha^{-1}	82.2	84.3	83.3	364	368	366
T_3-$ZnSO_4$ @ 25 kg ha^{-1}	88.6	90.1	89.3	388	390	389
T_4-Foliar spray of 1% $ZnSO_4$ at 20 and 45 days	92.7	93.1	92.9	391	394	392
T_5-Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days	102.8	104.7	103.7	417	421	419
S.Ed.±	2.1	2.0	1.6	5.0	4.0	3.0
CD (*p*=0.05)	4.5	4.5	3.6	12.0	10.0	7.0
Mean of $ZnSO_4$ ~ soil	85.4 *	87.2 *	86.3 *	376 *	379 *	378 *
Mean of $ZnSO_4$ ~ foliar spray	97.8 **	98.9 **	98.3 **	404 **	408 **	406 **
Significance for mean of soil vs foliar spray †	††	††	††	††	††	††

Note: Recommended dose of fertilizers Applied for all the treatments,
Asterisks at different growth stages for mean of $ZnSO_4$ ~ soil and foliar sprays represent their effect vs no zinc application.
† shows the level of significance for mean effect of soil vs foliar spray
NS= Not significant; *=Significant at 1% and **= Significant at 5%

The maize variety African tall on an average yielded significantly more green fodder by the application of ZnSO4 through the soil or foliar spray. Nonetheless, spraying was more productive than soil application consistently in the two years of experimentation. Similar results of significantly higher fodder yield with Zn application was reported by Kumar *et al.* (2021) Increase in green fodder yield might be due to the enhanced translocation of photosynthates with applied zinc, which resulted in higher production of green fodder in the respective levels of nutrient. Similar results were also reported by Mahdi *et al.* (2012).

Quality parameters of green fodder

Significantly higher organic matter (OM) content (94.5%) was recorded in the control (T_1 no zinc) treatment followed by other treatments (T_2, T_3 T_4) and (T_5). The lowest organic matter (92.7%) content was recorded with the treatment where 100 % RDF and 1% Zn foliar spray at 20, 45 and 60 days was applied (Table 3). Under different treatments, organic matter content decreased with increasing nutrient application. This might be due to the inverse relation of OM with total ash content in the fodder sample. On the other hand, significantly higher DM (%) was attained from treatment of T_5 -Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days with RDF application, which was significantly superior over all other treatments. Similar result with the application of zinc were earlier reported by other research workers (Chand *et al.,* 2017). The data on total ash content (%) of fodder maize (Table 3) indicates that different zinc nutrient application has significantly (*P=0.05*) improved the ash content (%) over the control. Higher ash content (%) was obtained with application of RDF with Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5). This might be due to the favourable effect of balanced nutrition on growth and development of plants which further increases the nutrient demand leading to higher assimilation of nutrients within the plant system. Again; synergistic effect of zinc with nitrogen, potassium, and some other micronutrient to also contribute the ash content of the fodder crop (Jamil *et al.*, 2015). Significantly higher crude protein (8.9) content and Ether extract (2.4) was recorded with the treatment of Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days after sowing with application of RDF. Nitrogen and Potassium plays an important role in the activation of nitrate reductase enzyme that involves in the protein synthesis process, thus increase Crude Protein, Ash and Ether Extract (Hasanuzzaman *et al.,* 2018). Zn is essential for the activity of RNA polymerase, protects ribosome and is also involved in function and stability of genetic material that plays a direct role in amino acid synthesis resulting in improved protein content (Panda *et al.,* 2020).

Table 3: Effect of soil and foliar zinc nutrition on Quality parameters of fodder maize (%) (Pooled mean of two years)

Treatments	DM	CP	OM	CF	EE	T. Ash	NDF
T_1- No Zn (control)	21.9	7.6	94.5	38.2	1.5	5.5	66.9
T_2 -$ZnSO_4$ @ 15 kg ha^{-1}	22.9	8.1	94.1	36.6	1.8	5.9	65.7
T_3 -$ZnSO_4$ @ 25 kg ha^{-1}	23.1	8.4	93.3	36.2	2.2	6.7	65.1
T_4 - Foliar spray of 1% $ZnSO_4$ at 20 and 45 days	23.6	8.6	93.2	35.7	2.2	6.8	64.8
T_5 -Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days	24.9	8.9	92.7	34.1	2.4	7.3	63.3
S.Ed$\pm$	0.3	0.1	0.2	0.5	0.1	0.2	0.9
CD (*p*=0.05)	0.7	0.2	0.4	1.1	0.1	0.4	1.8

Note: Recommended dose of fertilizers Applied for all the treatments, DM: Dry matter,
EE: Ether extract, T. Ash: Total ash content, CP: Crude protein, CF: Crude fiber and NDF: Neutral Detergent fibre.

In general, lower values of fiber fractions (Crude fiber and NDF) are considered to be better. The data obtained from the experiment recorded significantly (p=0.05) lower value on application of 100% RDF with Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5) over the control (T_1 No Zn). The reduction of fibre fraction indicates an improvement in fodder quality which could be due to the combined application of RDF and zinc spray at vegetative and reproductive stage which reduces the soluble carbohydrate content in plant tissue and promotes protein synthesis these results are in conformity with (Chand *et al.,* 2017, Kumar *et al.,* 2019).

CONCLUSION

Biofortification with micronutrients is becoming regular practice and zinc and iron are the front liner in maize biofortification. Hence, there is a possibility of enriching nutrient content of grain and green fodder by biofortification. It is considered to be potentially more cost-effective than other methods to deliver the benefits of micronutrient enhancement to the rural populations in developing countries. Maize crop responded widely to Zn fertilization and the crop is very sensitive for Zn deficient soil. Based on the research results, it can be concluded that among soil and foliar zinc fertilization treatments studied in fodder maize, application of 100% RDF+ Foliar spray of 1% $ZnSO_4$ at 20, 45 and 60 days (T_5) recorded significantly higher vegetative growth parameters, yield and crude protein content over control (T_1 no zinc application). Similarly, superior quality of neutral detergent fibre (NDF) was also reported with (T_5). However, agronomically bio fortified maize will enhance the nutritional security and also maintain the environmental sustainability.

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Research Article
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BENEFICIAL EFFECT OF LIMING TO GREEN GRAM AND SPINACH IN ACID SOILS OF ZAHEERABAD DIVISION IN SANGAREDDY DISTRICT OF TELANGANA

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ABSTRACT

An investigation entitled "**Beneficial effect of liming to green gram and spinach in acid soil of Zaheerabad division in Sangareddy district of Telangana**" was carried out at Agricultural Research Institute (ARI), Rajendranagar to study the beneficial effect of liming and FYM as well as suitable combination of nutrients with and without lime and FYM in acid soils and it's beneficial effect to green gram and spinach. Incubation of acid soils with lime and FYM for 15 days, 30 days, 45 days and 60 days influenced soil pH and nutrient availability. It was observed that soil pH increases with increasing a period of incubation from 15 to 60 days, where highest (pH 7.01) in 60 days of incubation with T3 -lime. Available nitrogen increases with a period of incubation, available phosphorus increases with a period of incubation and gradually decrease in 45 days, available potassium increased till 30 days and gradually decreased at 45 days of incubation with application of lime and FYM. Exchangeable calcium is highly at 15 days of incubation and gradually decreased with increasing a period of incubation, and the highest is observed in 15 days (2.30 cmol kg^{-1}) with application of lime.A pot culture experiment was conducted employing six treatments, T1- RDF, T2 - FYM @10 t $ha^{-1,}$ T3 - Lime, T4 - RDF+FYM, T5 - RDF+ lime and T6 - RDF + FYM+ lime. Applications of RDF+ FYM+ lime resulted in highest grain yield of green gram (5.11 g pot^{-1}) and dry matter of spinach (12.23 g pot^{-1}). Acid soils treated with lime and FYM alone observed to significantly increased yield of green gram and spinach. The best results were obtained in combined application of lime along with FYM @10 t ha^{-1} and RDF. Application of lime and FYM resulted in significant increase in nutrient content as well as uptake in both green gram and spinach. Nitrogen, Phosphorus and Potassium content and uptake increases with applications of lime and FYM. The highest content and uptake were resulted in RDF + FYM@ 10 t ha^{-1}+ lime. Among the micronutrients, manganese content and its uptake by green gram and spinach decreased where zinc and copper gradually increase with applications of lime and FYM, respectively. Applications of lime increased the soil pH in acid soils, with the highest from 4.98 to 7.01 and 5.32 to 6.93. It was observed that acid soil treated with lime significantly effect the nutrients availability. A vailable nitrogen, phosphorus, potassium, sulphur and exchangeable calcium & magnesium increased whereas, available manganese and iron decreased with application of lime in acid soils. Application of lime significantly increased exchangeable calcium from 0.87 to 2.15 cmol kg^{-1} and exchangeable magnesium from 0.12 to 1.61 cmol kg^{-1}. Available manganese decreased from 26.6 to 22.7 mg kg^{-1} and available iron from 11.76 to 8.05 mg kg^{-1}, respectively. From the results obtained, it is concluded that liming and FYM significantly increased yield of green gram and spinach in acid soils. Application of lime along with FYM and RDF increased the availability of essential nutrients.

Keywords: Acid Soils, Liming, FYM, Incubation, nutrients, uptake.

Soil acidification is a natural, slowly occurring phenomenon that results from geological evolution through the pedogenic process. Soils can also become acidic due to parent material being acidic or containing base cations in small quantities (Fageria & Baligar., 2008). Soil acidity and elemental toxicities or deficiencies associated with it, affects crops growth and restricts yields throughout the world (Eswaran *et al*., 1997: Rengel and Teng., 2003). ICAR-NAAS (2010) reported about 6.98 million ha. of acid soils (9.4 per cent of total geographical area) spread across several states in between the strongly acidic soils (pH < 4.5) and moderately acidic soils (pH 4.5–5.5) in India, occurring in the different terrains varying environmental conditions of landscape, geology, climate and vegetation. Laterites and various latosolic soils are the large groups among acid soils and other groups are podzolic soils, brown forest soils, peaty soils etc., In Telangana State lateritic acid soils occupies 61284 ha (13.77 %) particularly in Zaheerabad division in Sangareddy district (ICAR-NBSS & LUP, 2016). Adverse effect of acid soils on plant growth is mainly related to nutrient imbalances and slow microbial activity and impairment of nitrogen fixation by legumes and vegetables (Ganeshamurthy *et a*l., 2016).

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Green gram is major pulse crop in the state and cultivated in 1,10,469 ha and in Sangareddy district it is cultivated in 25,232 ha with average yields of 512 kgs and only in 4,826 ha (DES, 2018). Indian spinach (Beta vulgaris), locally called as Palak, is one of the most common leafy vegetables of tropical and sub-tropical regions.

Soil-lime incubation in laboratory study is the rapid method to determine the lime requirement with application of FYM and lime than in field conditions by determining the pH at different days of interval. McLean (1973) defined the lime requirement (LR) of a soil as "the amount of lime or other base needed to neutralize the un-dissociated and dissociated acidity in range from the initial acid condition to a selected neutral or less acid condition." Lime application along with FYM and RDF provides good opportunity to increase the availability of essential nutrients to crops and ameliorate the other acidity induced fertility constraints in acid soils (Manoj kumar *et al.,* 2012). Liming also has several other benefits including, its ability to reduce the toxicity effects of some micro elements by lowering their concentrations while increasing the availability of plant nutrients such as Ca, P, Mo, and Mg in the soil (Naidu *et al.,* 1990) and reducing the solubility and leaching of heavy metals (Lindsay, 1979; Sauvé *et al.,* 2000). Zaheerabad division is comprising of Nyalakal, Mukdhampur, Kohir, Zurasangam and Zaheerabad *mandals* where acidity is observed predominantly, the pH ranged from 4.85 to 7. 94 where acidity was reported to an extent of 29 per cent (Annonymous, 2017-18) and the farmers are resource poor and liming is not a regular practice. Application of lime and FYM alone and along with RDF is a sustainable and comprehensive strategy for the management of acid soils and enhancing the green gram and spinach productivity in this division.

MATERIAL AND METHODS

An incubation study at AICRP on Micronutrients lab and pot culture experiment was conducted during *rabi*, 2019 in the net house of Radio Technique Laboratory (RTL), Agriculture Research Institute (ARI), Rajendranagar, Hyderabad. Two bulk soil samples with different level of pH (4.98 & 5.32) were collected from Zaheerabad division of Sangareddy district in two sites; one from Kalbemal and another one from Gangwar. These soils were analysed for their physical, physico-chemical and chemical properties and FYM in which nutrient status were summarized in Table 1 and Table 2. Incubation studies for determining the nutrient availability with time due to varying combinations of Lime @ 3.2 t ha^{-1} for soil-1 and @ 2.3 t ha^{-1} for soil-2 + FYM @ 10 t ha^{-1} + RDF application. A completely randomized design (CRD) was used and treatments were replicated thrice. Soil samples were drawn at 15, 30, 45 and 60 days of the incubation period and then air dried and used for analysis of soil physical, physico-chemical and chemical properties. Pot culture experiment was conducted with green gram and spinach as a test crop with four replications. The collected acid soils after processing were filled in pots of 5 kg capacity and experiment was conducted. Recommended dose of fertilizer (RDF: 20:50:0 kg ha^{-1} for green gram and 25:25:50 kg ha^{-1} for spinach) were applied during crop growth period and all package practices were followed. The crop was raised till maturity and yield was recorded at harvest and post harvest soil were analysed for physical, physico-chemical and chemical properties.

RESULTS AND DISCUSSION

Applications of lime and FYM in acid soils beneficially effect the yield of green gram and spinach. Significant increasing in grain yield of green gram from 3.49 to 5.11 g pot^{-1} (46.4%) in soil sample-1 and 3.61 to 4.78 g pot^{-1} (32.4%) in soil sample-2 was observed with applications of lime and FYM in acid soils (Table 3). Significant increasing in dry weight of spinach from 9.67 to 12.23 g pot^{-1} (46.4%) in soil-1 and 8.22 to 10.17 g pot^{-1} (23.72%) was found with applications of lime and FYM in acid soils. Applications of RDF(RDF: 20:50:0 kg ha^{-1} for green gram and 25:25:50 kg ha^{-1} for spinach) + FYM @ 10 t ha^{-1} + lime (@ 3.2 t ha^{-1} for soil-1 and @ 2.3t ha^{-1} for soil-2) resulted in highest yields and followed by applications of RDF + lime in acid soils where the lowest yield was observed with application of RDF alone in both green gram and spinach, respectively. Mishtra et al., (2017) revealed that, application of lime + FYM@ 5t/ha +40kg P + 20 kg K to green gram was superior with maximum mean yield of 531 kg ha^{-1}.

Nutrients content and uptake by green gram and spinach significantly increased with application of lime and FYM. Nitrogen content in green gram significantly increased from 1.09 to 1.46% in soil-1 and

Table 1. Salient characteristics of soils employed in experiment

Soil properties	Units	
	Soil sample 1 Kalbemal	Soil sample 2 Gangwar
1. Physical properties		
a) Sand (%)	73.74	73.24
b) Silt (%)	17.50	17.00
c) Clay (%)	8.76	9.76
d) Textural class	Sandy loam	Sandy loam
2. Physico-chemical properties		
a) pH (1:2.5 soil: water suspension)	4.98	5.32
b) EC dSm^{-1}(1:2.5 soil: water extract)	0.180	0.172
3. Chemical properties		
a) Organic carbon (%)	0.55	0.80
b) Available Nitrogen (Kg ha^{-1})	176	135
c) Available Phosphorus (Kg ha^{-1})	31	20.0
d) Available Potassium (Kg ha^{-1})	121	103
e) Available Sulphur (mg kg^{-1})	11.42	5.00
f) Exchangeable Calcium (cmol kg^{-1})	0.87	1.03
g) Exchangeable Magnesium (cmol kg^{-1})	0.25	0.27
h) Available Iron (mg kg^{-1})	23.88	11.76
i) Available Copper (mg kg^{-1})	2.91	1.99
j) Available Manganese (mg kg^{-1})	26.6	23.9
k) Available Zinc (mg kg^{-1})	0.37	0.22

Table 2. Nutrient composition of FYM employed in experiment

NUTRIENT	FYM
pH	7.7
N (%)	1.1
P (%)	0.17
K (%)	1.51
S (%)	0.14
Ca (%)	1.52
Mg (%)	0.72
Fe (mg kg-1)	1.55
Mn (mg kg-1)	3.74
Cu (mg kg-1)	0.20
Zn (mg kg-1)	0.76

1.16 to 2.29% in soil-2 and in spinach from 1.10 to 1.40% in soil-1 and 1.07 to 1.69% in soil-2 (Table 7, 7a, 7b, 7c). The combined effect of applied lime with organic and inorganic plant nutrient sources significantly increased the nutrient concentrations of N from 1.16 to 1.37 % as compared to the control plots (Woubshet *et al.*, 2017).Phosphorus uptake by green gram significantly increased from 10.45 to 45.86 mg pot^{-1} in soil-1 and 11.56 to 45.99 mg pot^{-1} in soil-2 and spinach from 82.48 to 98.36 mg pot^{-1} in soil-1 and 43.70 to 97.81 mg pot^{-1} in soil-2 (Table 8, 8a, 8b, 8c)). Potassium content in green gram significantly increased from 2.67 to 3.68% in soil-1 and 1.79 to 4.0% in soil-2 and in spinach from 2.78 to 3.42% in soil-1 and 2.58 to 4.02% in soil-2 (Table 9, 9a, 9b, 9c). Highest total uptake of K by black gram (45.8 kg ha^{-1}) was recorded due to integrated use of lime + FYM + NPK + ZnSO4 (Laxminarayana and Pradhan, 2017). Manganese

Table 3. Effect of Varied combinations of Lime + FYM + RDF in different pH soils on grain yield of green gram and dry yield of spinach (g pot-1)

Treatment (Varied combinations of LIME + FYM + RDF)	**Soil – 1** (pH 4.98 & LR 3.5 t/ha)		**Soil – 2** (pH 5.32 & LR 2.3 t/ha)		
	Green gram	**Spinach**	**Green gram**	**Spinach**	
	Grain yield (g pot^{-1})	**Dry weight (g pot^{-1})**	**Grain yield (g pot^{-1})**	**Dry weight (g pot^{-1})**	
T1 RDF	3.49	9.67	3.61	8.22	
T2 FYM@ 10 t/ha	4.32	10.55	4.32	8.69	
T3 Lime	4.30	10.33	4.10	9.68	
T4 RDF + FYM	3.82	10.75	4.09	9.47	
T5 RDF + Lime	4.98	10.93	4.67	9.49	
T6 RDF + FYM+ Lime	5.11	12.23	4.78	10.17	
Mean	4.33	10.74	4.26	9.28	
	Soils	Treatments	S X T	C	SXC
SEd (+/_)	0.107	0.169	0.24	0.09	0.13
CD (P=0.05)	0.218*	0.33*	0.47	0.19*	0.27*

* - Significant

Table 4. Effect of varied combinations of lime+ FYM+ RDF in different pH soils on pH and EC (dSm^{-1}) in post harvest soil.

Treatments	**Soil-1**		**Soil-2**		**Soil-1**		**Soil-2**	
	Green gram	**Spinach**	**Green gram**	**Spinach**	**Green gram**	**Spinach**	**Green gram**	**Spinach**
	pH				**E.C (dSm^{-1})**			
T1 RDF	5.39	5.28	5.41	5.80	0.510	0.545	0.415	0.468
T2 FYM@ 10 t/ha	5.96	5.86	6.25	6.30	0.662	0.632	0.722	0.757
T3Lime	7.04	6.98	6.91	6.95	0.735	0.822	0.858	0.913
T4 RDF + FYM	5.59	5.88	6.01	6.14	0.763	0.690	0.597	0.805
T5 RDF + Lime	6.80	7.02	6.09	7.17	0.808	0.863	0.832	0.997
T6 RDF + FYM+ Lime	6.69	7.00	6.81	6.95	0.845	0.865	0.945	1.015
Initial	4.98		5.32		0.180		0.172	
	Soil	Treatments	SXT		Soil	Treatments	SXT	
SEd(+/-)	0.04	0.07	0.07		0.028	0.049	0.07	
CD((P=0.05)	0.08*	0.14*	0.144*		0.057	0.098*	0.139*	

* - Significant

Table 5. Effect of varied combinations of lime+ FYM+ RDF in available nitrogen and phosphorus after harvest

Treatments	Soil-1		Soil-2		Soil-1		Soil-2	
	Green gram	Spinach	Green gram	Spinach	Green gram	Spinach	Green gram	Spinach
	N (kg ha^{-1})				P2O5 (kg ha^{-1})			
T1 RDF	176.2	163.1	164.5	163.1	77.96	76.86	75.96	74.26
T2 FYM@ 10 t/ha	192.6	185.0	178.7	169.3	85.13	79.05	82.17	80.03
T3Lime	200.7	192.8	200.8	200.7	90.62	102.5	88.70	113.9
T4 RDF + FYM	198.6	182.0	202.9	194.4	88.20	95.65	83.87	94.20
T5 RDF + Lime	200.1	227.2	216.5	214.4	98.00	128.5	92.40	109.5
T6 RDF + FYM + Lime	245.2	238.2	219.5	219.5	102.0	141.5	104.0	112.1
Mean	202.2	198.0	197.1	193.5	90.31	104.01	87.85	97.3
Initial	176		135		31.0		20.0	
	Soils	**Treatments**	**SXT**		**Soils**	**Treatments**	**SXT**	
SEd(+/-)	1.2	2.08	2.95		1.9	3.3	4.8	
CD(=0.05)	2.4 *	4.16	5.98 *		3.8 *	6.5 *	9.3	

* - Significant

Table 6. Effect of varied combinations of lime+ FYM+ RDF in exchangeable calcium and magnesium (cmol kg^{-1}) after harvest

Treatments	Soil-1		Soil-2		Soil-1		Soil-2	
	Green gram	Spinach	Green gram	Spinach	Green gram	Spinach	Green gram	Spinach
	Exch.Ca (cmol kg^{-1})				Exch.Mg (cmol kg^{-1})			
T1 RDF	0.85	0.95	1.05	0.95	0.57	0.52	0.72	0.67
T2 FYM@ 10 t/ha	1.55	2.05	1.12	1.59	1.21	0.92	0.92	0.95
T3 Lime	1.82	2.30	1.77	1.84	1.50	1.40	1.32	1.65
T4 RDF + FYM	1.20	1.30	1.82	1.53	1.25	1.02	1.05	1.00
T5 RDF + Lime	2.00	2.15	2.50	2.20	1.47	1,22	1.25	1.33
T6 RDF + FYM+ Lime	2.12	2.17	2.67	2.27	1.52	1.50	1.45	1.57
Mean	1.59	1.82	1.82	1.73	1.25	1.07	1.12	1.19
Initial	0.87		1.03		0.25		0.27	
	Soils	**Treatments**	**SXT**		**Soils**	**Treatments**	**SXT**	
SEd(+/_)	0.03	0.06	0.08		0.04	0.07	0.11	
CD(P=0.05)	0.07*	0.12*	0.17*		0.09	0.15*	0.22	

* - Significant

Table 7. Effect of varied combinations of Lime + FYM + RDF in different pH soils on nitrogen content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Treatments	Soil-1				Soil-2			
	Green gram		Spinach		Green gram		Spinach	
	N content (%)	N Uptake (mg/pot)	N content (%)	N Uptake (mg/pot)	N content (%)	N Uptake (mg/pot)	N content (%)	N Uptake (mg/pot)
T1 RDF	1.09	38.33	1.10	111.3	1.16	41.98	1.07	88.50
T2 FYM	1.35	57.83	1.20	169.6	1.68	72.90	1.10	93.64
T3 Lime	1.54	66.76	1.22	126.6	1.72	70.10	1.30	125.3
T4 RDF+FYM	1.28	48.90	1.25	134.8	2.02	84.59	1.42	133.4
T5 RDF+Lime	1.29	64.60	1.34	147.1	2.04	95.43	1.71	160.1
T6 RDF+FYM+ Lime	1.46	74.73	1.40	170.3	2.29	109.9	1.69	172.9
Mean	1.33	58.52	1.25	143.2	1.81	79.15	1.38	128.9

* - Significant

Table 7a. Effect of varied combinations of Lime + FYM + RDF in different pH soils on nitrogen content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Different pH soils	varied combinations of Lime +FYM+RDF (Treatments)													
	N content							N uptake						
	T1	T2	T3	T4	T5	T6	Mean	T1	T2	T3	T4	T5	T6	Mean
Soil-1	1.12	1.27	1.38	1.26	1.32	1.42	1.29	74.8	113.7	96.6	91.87	105.8	122.5	100.8
Soil-2	1.12	1.39	1.51	1.72	1.87	1.99	1.60	65.2	83.27	97.7	109.00	127.6	141.4	104.0
Mean	1.12	1.33	1.44	1.49	1.59	1.71	1.44	70.0	98.49	97.2	100.45	116.8	131.9	102.4
	Soils		Treatments		S X T			Soils		Treatments		S X T		
SEd (+/_)	0.06		0.10		0.15			4.04		7.00		9.01		
CD	0.12*		0.21*		0.31*			8.05		13.95*		19.7*		

* - Significant

Table 7b. Interaction Effect of Crops and different pH soils on nitrogen content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Crops		N content			N uptake		
		Soil-1	Soil-2	Mean	Soil-1	Soil-2	Mean
Green gram		1.33	1.82	1.57	58.5	79.2	68.85
Spinach		1.26	1.38	1.32	143.3	129.0	136.1
Mean		1.30	1.60	1.45	100.9	104.1	102.5
	Crops	**Soils**	**C X S**		**Crops**	**Soils**	**C X S**
SEd (+/_)	0.06	0.06	0.089		4.04	4.04	5.71
CD(P=0.05)	0.12*	0.12*	0.178*		8.05*	8.05	11.39*

* - Significant

Table 7c. Interaction effect of treatments and Crops on nitrogen content(%) and uptake(mg pot^{-1}) in green gram and spinach in acid soils.

Treatments	N content			N uptake		
	Green gram	Spinach	Mean	Green gram	Spinach	Mean
T1 RDF	1.13	1.11	1.12	40.16	99.89	70.00
T2 FYM@ 10 t/ha	1.52	1.15	1.33	65.37	131.6	98.48
T3 Lime	1.63	1.26	1.44	68.43	125.9	97.16
T4 RDF + FYM	1.65	1.33	1.49	66.75	134.1	100.4
T5 RDF + Lime	1.66	1.53	1.59	80.02	153.6	116.8
T6 RDF + FYM+ Lime	1.87	1.54	1.70	92.31	171.6	131.9
Mean	1.58	1.32	1.45	68.84	136.1	102.4
	Treatments	**Crops**	**T X C**	**Treatments**	**Crops**	**T X C**
SEd (+/_)	0.11	0.06	0.15	7.0	4.04	9.9
CD(P=0.05)	0.21*	0.12*	0.31*	13.9*	8.05*	19.7

* - Significant

Table 8. Effect of varied combinations of Lime + FYM + RDF in different pH soils on phosphorus content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Treatments	Soil-1				Soil-2			
	Green gram		Spinach		Green gram		Spinach	
	P content (%)	P Uptake (mg/pot)	P content (%)	P Uptake (mg/pot)	P content (%)	P Uptake (mg/pot)	P content (%)	P Uptake (mg/pot)
T1 RDF	0.30	10.45	0.85	82.48	0.32	11.56	0.53	43.70
T2 FYM	0.38	16.71	0.90	94.70	0.35	15.32	0.77	66.65
T3 Lime	0.33	16.23	0.87	87.36	0.40	16.24	0.64	61.97
T4 RDF+FYM	0.55	20.96	0.89	95.61	0.67	26.79	0.86	92.30
T5 RDF+Lime	0.74	36.48	0.87	95.60	0.90	42.04	0.91	93.23
T6 RDF+FYM+ Lime	0.90	45.86	0.92	98.36	0.96	45.99	0.92	97.81
Mean	0.53	24.44	0.88	92.35	0.60	26.32	0.77	75.94

* - Significant

Table 8a. Effect of varied combinations of Lime + FYM + RDF in different pH soils on phosphorus content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Different pH soils	varied combinations of Lime +FYM+RDF (Treatments)													
	P content							P uptake						
	T1	T2	T3	T4	T5	T6	Mean	T1	T2	T3	T4	T5	T6	Mean
Soil-1	5.76	0.64	0.60	0.72	0.81	0.91	**1.57**	46.4	55.7	51.8	58.3	66.0	72.11	**58.38**
Soil-2	0.42	0.56	0.51	0.77	0.90	0.94	**0.68**	27.6	40.9	39.1	59.5	67.6	71.9	**51.10**
Mean	**0.50**	**0.60**	**0.56**	**0.74**	**0.85**	**0.92**	**0.69**	**37.0**	**48.3**	**45.45**	**58.9**	**66.8**	**72.0**	**54.74**
	Soils		**Treatments**		**S X T**			**Soils**		**Treatments**		**S X T**		
SEd (+/_)	0.01		0.02		0.03			1.67		2.9		4.01		
CD(P=0.05)	0.02		0.04*		0.068*			3.3*		5.7*		8.18*		

* - Significant

Table 8b. Interaction Effect of Crops and different pH soils on phosphorus content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Crops	P content			P uptake		
	Soil-1	Soil-2	Mean	Soil-1	Soil-2	Mean
Greengram	0.53	0.60	**0.56**	24.45	26.33	**25.39**
Spinach	0.88	0.77	**0.82**	92.35	75.94	**84.14**
Mean	**0.71**	**0.68**	**0.69**	**58.40**	**51.14**	**54.77**
	Crops	**Soils**	**C X S**	**Crops**	**Soils**	**C X S**
SEd (+/_)	0.01	0.01	0.019	1.67	1.67	2.37
CD(P=0.05)	0.028*	0.028	0.039*	3.34*	3.34*	4.72*

* - Significant

Table 8c. Interaction effect of treatments and Crops on phosphorus content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Treatments	P content			P uptake		
	Green gram	Spinach	Mean	Green gram	Spinach	Mean
T1 RDF	0.31	0.69	**0.50**	11.0	63.1	**37.05**
T2 FYM@ 10 t/ha	0.37	0.83	**0.60**	16.0	80.7	**48.35**
T3 Lime	0.36	0.75	**0.55**	16.2	74.7	**45.45**
T4 RDF + FYM	0.61	0.87	**0.74**	23.8	94.0	**58.90**
T5 RDF + Lime	0.82	0.89	**0.85**	39.3	94.4	**66.85**
T6 RDF + FYM+ Lime	0.93	0.92	**0.92**	45.9	98.1	**72.00**
Mean	**0.56**	**0.83**	**0.69**	**25.4**	**84.1**	**54.75**
	Treatments	**Crops**	**TXC**	**Treatments**	**Crops**	**TXC**
SEd (+/_)	0.02	0.014	0.03	2.9	1.67	4.10
CD(P=0.05)	0.048*	0.028*	0.068*	5.78	3.34*	8.18*

* - Significant

Table 9. Effect of varied combinations of Lime + FYM + RDF in different pH soils on potassium content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Treatments	Soil-1				Soil-2			
	Green gram		Spinach		Green gram		Spinach	
	K content (%)	K Uptake (mg/pot)	K content (%)	K Uptake (mg/pot)	K content (%)	K Uptake (mg/pot)	K content (%)	K Uptake (mg/pot)
T1 RDF	2.97	104.1	2.88	278.2	1.79	64.2	2.91	239.9
T2 FYM	2.70	117.1	3.07	323.7	1.63	88.8	3.04	265.20
T3 Lime	2.67	115.2	2.78	290.1	1.95	89.5	2.58	248.4
T4 RDF+FYM	3.61	138.4	3.22	345.7	3.56	145.6	3.63	343.9
T5 RDF+Lime	3.58	178.4	3.93	371.7	3.40	158.8	3.36	318.6
T6 RDF+FYM+Lime	3.68	190.9	3.94	393.8	4.00	191.0	4.02	392.7
Mean	3.20	140.6	3.21	333.8	2.72	122.2	3.25	261.6

* - Significant

Table 9a. Interaction Effect of Soils and varied combinations of Lime + FYM + RDF on potassium content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Different pH soils	varied combinations of Lime +FYM+RDF (Treatments)													
	K content							K uptake						
	T1	T2	T3	T4	T5	T6	Mean	T1	T2	T3	T4	T5	T6	Mean
Soil-1	2.92	2.88	2.72	3.42	3.48	3.55	3.16	191.2	220.4	202.7	242.1	275.1	292.4	237.3
Soil-2	2.35	2.33	2.26	3.59	3.38	4.01	2.98	152.1	174.5	163.6	244.8	238.7	291.9	210.9
Mean	2.64	2.61	2.49	3.50	3.43	3.78	3.07	171.6	197.4	183.1	243.4	256.9	292.2	224.1

	Soils	Treatments	S X T	Soils	Treatments	S X T
SEd (+/_)	0.1	0.17	0.24	8.8	15.2	21.5
CD (P=0.05)	0.19	0.34*	0.49*	17.5*	30.3*	42.9

* - Significant

Table 9b. Interaction Effect of Crops and different pH soils on potassium content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Crops	K content			K uptake		
	Soil-1	**Soil-2**	**Mean**	**Soil-1**	**Soil-2**	**Mean**
Green gram	3.20	2.72	2.96	140.7	121.2	130.9
Spinach	3.12	3.26	3.19	333.9	300.6	317.2
Mean	3.16	2.99	3.07	237.3	210.9	224.1
	Crops	Soils	C X S	Crops	Soils	C X S
SEd (+/_)	0.1	0.1	0.14	8.8	8.8	12.4
CD (P=0.05)	0.19*	0.19	0.28*	17.5*	17.5*	24.8

* - Significant

Table 9c. Interaction effect of treatments and Crops on potassium content (%) and uptake (mg pot^{-1}) in green gram and spinach in acid soils.

Treatments	K content			K uptake		
	Green gram	**Spinach**	**Mean**	**Green gram**	**Spinach**	**Mean**
T1 RDF	2.38	2.89	2.63	84.16	259.1	171.6
T2 FYM@ 10 t/ha	2.16	3.05	2.60	102.9	291.9	197.4
T3 Lime	2.30	2.67	2.48	97.00	269.2	183.1
T4 RDF + FYM	3.58	3.43	3.50	142.0	344.8	243.4
T5 RDF + Lime	3.49	3.37	3.43	168.6	345.2	256.9
T6 RDF + FYM+ Lime	3.83	3.72	3.77	190.9	393.3	292.1
Mean	2.96	3.19	3.07	130.9	317.2	224.0
	Treatments	Crops	T X C	Treatments	Crops	T X C
SEd (+/_)	0.17	0.1	0.24	15.2	8.8	21.5
CD (P=0.05)	0.34*	0.19*	0.488*	30.3*	17.5*	42.9

* - Significant

Table 10. Effect of Varied combinations of Lime + FYM + RDF and Periods of contact in different pH soils on pH under laboratory conditions.

Days of contact period / Incubation	Soil – 1 (pH 4.98 & LR 3.5 t/ha)						Soil – 2 (pH 5.32 & LR 2.3 t/ha)					
	Treatments (Varied combinations of Lime + RDF + FYM)						Treatments (Varied combinations of Lime + RDF + FYM)					
	T1 RDF	T2 FYM@ 10 t/ha	T3 Lime	T4 RDF + FYM	T5 RDF + Lime	T6 RDF + FYM + Lime	T1 RDF	T2 FYM@ 10 t/ha	T3 Lime	T4 RDF + FYM	T5 RDF + Lime	T6 RDF + FYM+ Lime
15-days	5.64	6.08	6.86	5.77	6.33	6.39	5.70	6.20	6.76	5.90	6.58	6.51
30-days	5.67	6.10	6.89	6.04	6.69	6.78	5.72	6.32	6.83	6.19	6.73	6.81
45-days	6.00	6.14	6.93	6.15	6.74	6.81	5.80	6.40	6.95	6.21	6.78	6.91
60-days	5.96	6.24	7.05	6.21	6.82	6.86	5.83	6.46	6.98	6.53	6.89	7.03
	Soils	Treatments	SXT		Incubation	Soils	IXS		Treatments	Incubation	TXI	
SEd(+/_)	0.04	0.07	-		0.06	0.04	-		0.07	0.06	-	
CD(P=0.05)	0.08	0.14*	NS		0.11*	0.08	NS		0.14*	0.11*	NS	

* - Significant

Table 11. Effect of Varied combinations of Lime + FYM + RDF and Periods of contact in different pH soils on Exchangeable calcium under laboratory conditions

Days of contact period / Incubation	Soil – 1 (pH 4.98 & LR 3.5 t/ha)							Soil – 2 (pH 5.32 & LR 2.3 t/ha)							Grand Mean
	Treatments (Varied combinations of Lime + RDF + FYM)							Treatments (Varied combinations of Lime + RDF + FYM)							
	T1 RDF	**T2 FYM@ 10 t/ha**	**T3 Lime**	**T4 RDF + FYM**	**T5 RDF + Lime**	**T6 RDF + FYM + Lime**	**Mean**	**T1 RDF**	**T2 FYM@ 10 t/ha**	**T3 Lime**	**T4 RDF + FYM**	**T5 RDF + Lime Lime**	**T6 RDF + FYM+**	**Mean**	
15-days	1.73	1.43	2.60	1.60	2.07	2.13	1.92	1.73	1.43	2.00	1.27	2.30	2.26	1.83	1.87
30-days	1.23	1.70	2.06	1.37	1.93	2.13	1.73	1.33	1.46	1.80	1.27	1.96	1.86	1.61	1.67
45-days	1.30	1.37	1.93	1.67	1.76	1.83	1.64	1.07	1.27	1.67	1.37	1.66	1.76	1.46	1.55
60-days	0.97	1.20	1.93	1.13	1.66	1.90	1.46	0.90	1.13	1.30	1.20	170	1.83	1.34	1.4
Mean	1.30	1.42	2.13	1.44	1.85	1.99	1.69	1.25	1.32	1.69	1.27	1.90	1.92	1.56	1.62
	Soils	Treatments		SXT			Incubation	Soils	IXS		Treatments		Incubation	TXI	
SEd(+/_)	0.03	0.05		-			0.04	0.03	-		0.05		0.04	-	
CD(P=0.05)	0.06*	0.11*		0.15			0.09*	0.06*	0.12		0.11*		0.09*	0.21*	

* - Significant

Table 12. Effect of Varied combinations of Lime + FYM + RDF and Periods of contact in different pH soils on Available manganese under laboratory conditions

Days of contact period / Incubation	Soil – 1 (pH 4.98 & LR 3.5 t/ha)							Soil – 2 (pH 5.32 & LR 2.3 t/ha)							Grand Mean
	Treatments (Varied combinations of Lime + RDF + FYM)							Treatments (Varied combinations of Lime + RDF + FYM)							
	T1 RDF	**T2 FYM@ 10 t/ha**	**T3 Lime**	**T4 RDF + FYM**	**T5 RDF + Lime**	**T6 RDF + FYM + Lime**	**Mean**	**T1 RDF**	**T2 FYM@ 10 t/ha**	**T3 Lime**	**T4 RDF + FYM**	**T5 RDF + Lime Lime**	**T6 RDF + FYM+**	**Mean**	
15-days	28.48	30.59	21.55	31.03	25.00	25.75	27.06	25.68	29.96	23.37	31.03	23.74	23.67	26.54	26.80
30-days	31.90	34.26	22.09	34.45	25.09	25.77	28.92	28.76	33.55	23.47	34.75	23.80	23.73	28.54	28.73
45-days	32.47	34.87	23.30	36.08	25.29	25.88	29.64	29.27	34.15	23.58	35.37	23.83	23.80	28.90	29.27
60-days	33.32	35.79	23.30	37.03	25.62	25.90	30.16	29.79	34.75	23.68	35.99	23.85	23.85	29.25	29.70
Mean	31.54	33.87	22.56	34.64	25.25	25.82	28.95	28.37	33.10	23.52	34.28	23.80	23.76	31.32	30.13
	Soils	Treatments		SXT		Incubation		Soils		IXS	Treatments	Incubation		TXI	
SEd(+/_)	0.05	0.08		0.12		0.07		0.05		0.09	0.09	0.07		0.169	
CD(P=0.05)	0.098*	0.17*		0.24*		0.15*		0.098*		0.20*	0.185*	0.14*		0.341*	

* - Significant

content in green gram significantly increased from 183.6 to 305.9 mg kg^{-1} in soil-1 and 338.8 to 345.0 mg kg^{-1} in soil-2 and in spinach from 243.4 to 350.3 mg kg^{-1} in soil-1 and 201.6 to 318.9 mg kg^{-1} in soil-2.

Application of lime increased soil pH in acid soils (4.98 to 7.04 in soil-1 and 5.32 to 7.17 in soil-2, Table 4). Liming of acidic soils increased soil pH and exchangeable bases thereby reducing the magnitude of soil acidity, exchangeable acidity and Al saturation (Osundwa *et al.,* 2013). Available nitrogen, phosphorus, potassium, sulphur and exchangeable calcium & magnesium significantly increase with application of lime and FYM where available iron and manganese decrease with application of lime in acid soils. Available N increased from 179 to 245.2 kg ha^{-1} in soil-1 and 135 to 219.5 kg ha^{-1} in soil-2(Table 5), P increased from 31 to 141.5 kg ha^{-1} in soil-1 and 20 to 112.1 kg ha^{-1} in soil-2 (Table 5) , K increased from 121 to 333.4 kg ha^{-1} in soil-1 and 103 to 351.6 kg ha^{-1} in soil-2. Exchangeable Ca increased from 0.87 to 2.17 cmol kg^{-1} in soil-1 and 1.03 to 2.67 cmol kg^{-1} in soil-2 and exchangeable Mg increased from 0.25 to 1.52 cmol kg^{-1} in soil-1 and 0.27 to 1.57 cmol kg^{-1} in soil-2 (Table 6). The highest increased was observed with application of lime + FYM + lime. . Mn decreased from 26.6 to 22.7 mg kg^{-1} in soil-1 and 23.9 to 23.17 mg kg^{-1} in soil-2. Fe decreased from 23.88 to 7.08 mg kg^{-1} in soil-1 and 11.76 to 8.05 mg kg^{-1} in soil-2.

Incubation of acid soils with lime and FYM significantly effect soil physico-chemical properties in a period of incubation (15 days, 30 days, 45 days and 60 days). The highest increased in pH is observed in 60 days of incubation with pH 7.05 (Table 10) in applications of lime alone and EC was highest in 60 days with 0.98 in application of RDF + lime. Organic carbon was observed to increase in the first period (15 days) and gradually decreasing with increasing period where the highest in 15 days with 0.79. Available nitrogen was observed to increased with the period where highest in 60 days with 332.6 kg ha^{-1} in RDF+ FYM+ lime. Available phosphorus was observed to increased from 15 to 30 days and gradually decrease in 45 days where again increased in 60 days with the highest in 30 days with 90.8 in RDF+FYM+ lime. Available potassium was observed to increased from 15 to 30 days and gradually decreased from 45 to 60 days. Exchangeable calcium was observed to increased, where highly increased from 15 to 30 days and gradually decreased from 45 to 60 days and the highest in 15 days of incubation with applications of lime alone (Table 11). Exchangeable magnesium was observed to increased with a period of incubation with the highest in 30 days of 1.36 cmol kg^{-1} in RDF+ FYM+ lime. Available Mn and Fe was observed to decreased with application of lime and slightly increased with FYM. Mn increased in the first period (15 days) and gradually decreased with a period of incubation (Table 12) but Fe increased with a period of incubation.

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ISOLATION AND CHARACTERIZATION OF POTENTIAL ENDOPHYTIC BACTERIA FROM RICE

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ABSTRACT

Rice (*Oryza sativa* L.) is a key staple food for the world's growing population and is widely cultivated in tropical and subtropical locations, where it is affected by many biotic diseases of which bacterial infections are also causing losses. Bacterial endophytes are known to confer tolerance or resistance to the host plant from various biotic and abiotic stresses. Endophytes influence the physiology and developmental processes of the host plant, by releasing antimicrobial metabolites, synthesising phytohormones, siderophore, competing with pathogens for space and nutrients, and modulating the plant resistance response. Because of the crop's economic importance, endophytic bacteria have received a lot of attention as biocontrol agents and are the most common, most efficient, environmentally sustainable, and cost-effective. The serial dilution technique was used to isolate 52 endophytic bacterial isolates from rice roots, stems, and leaves. Colony characteristics were recorded after the isolates were purified. Rice varieties like BPT 5204, JGL, and KNM genotypes had significantly greater mean endophytic bacterial populations. By using the cross-streak method, all the isolates were tested for antagonistic activity against bacterial leaf blight. Disease inhibition zones were found in fifteen isolates. For these fifteen isolates, biochemical characterizations such as siderophore, HCN, IAA, catalase, citrate, oxidase, hydrogen sulphide, indole, voges prausker's, casein, gelatin, pectinase, and cellulose tests were performed. IAA, HCN, Siderophore, Ammonia, Phosphate, Nitrogen, Potassium, and Zinc Solubilization were investigated as growth promoters. Four isolates were chosen for development of bacterial consortium as a biocontrol agent based on antagonistic, biochemical, growth promoting, and nutrient solubilization properties.

Key words: Endophytes, Rice, Isolates, Bacteria, Biochemical characterization.

Rice (*Oryza sativa* L.) is an important cereal crop and a staple food for about half of the world's population (Asmah and sapak, 2020). It has a higher starch content (72.8g/100g) than any other cereals (Rai and Mauria, 1999). The motto "Rice is Life" is particularly fitting for India, as rice is a critical component of our national food security and a source of income for millions of rural people. Rice disease dynamics have changed over time as a result of consistent farming practises, decreased varietal diversity, resulting in a confined genetic base and climatic change. PGPBEs (plant growth promoting bacterial endophytes) promote plant development through both direct and indirect processes. In direct mechanism, plant growth is aided by the creation of phytohormones such as indole acetic acid (IAA), cytokinin, zinc (Zn), phosphorus (P), potassium (K) as well as an increase in assimilable nitrogen availability to the host through biological nitrogen fixation. By releasing antimicrobial metabolites, synthesising phytohormones, siderophore, competing with pathogens for space and nutrients, and modulating the plant resistance response, bacterial endophytes are known to impart tolerance or resistance to the host plant against various biotic and abiotic stresses (Grover *et al.*, 2011). Co-inoculation of endophytic bacteria in rice has become increasingly important in recent years for disease control and nutrient availability in sustainable agriculture production systems. There is an imperative need to identify the potential endophytic isolates with plant growth promoting (PGP) traits and disease suppressing ability.

MATERIAL AND METHODS

Isolation of Endophytic bacteria

Healthy rice plants were collected from Warangal, Nalgonda, Jagtial and Khammam districts of Telangana state. Leaves, roots, and stems were cleaned and sliced into little pieces under running tap water. Surface sterilisation was carried out using 1% NaHClO mixed with a few drops of Tween-20 (Hameed *et al.*, 2015). Samples were rinsed five times with sterilised distilled water and pulverised with a

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mortar and pestle. To obtain bacterial suspension, ground tissues were placed in glass bottles containing sterilised distilled water and shaken on a rotary shaker. The suspension was subjected to dilutions and 10^{-4} dilution was plated on Nutrient agar (NA; HiMedia), Pseudomonas isolation agar (PIA; HiMedia), Yeast extract mannitol agar (YEMA; HiMedia), and Tryptic soy agar (TSA; HiMedia) to attain diverse bacterial population. Bacterial isolates were collected after two days of incubation at 30°C (Piromyou *et al.*, 2015). Purified isolates were maintained on NA plates after purification. Suitable control was plated with water on NA, PIA, YEMA, and TSA medium as control plates.

Characterization of Endophytic bacteria

Morphological Characterization

All the isolates were examined for the colony morphology *viz.*, colour, shape, ability to form endospores and Gram reaction as per the procedure given in Bergey's Manual of Determinative Bacteriology (Berge 1984).

Cell shape

The morphology of the endophytic bacterial isolates was studied using a simple staining approach. A loop of culture was placed on a clean slide, a thin smear of bacterial culture was produced on the slide, crystal violet was used to stain the smear, and the slide was examined under a microscope.

Gram staining Technique

The inoculants were stained with Gram staining according to Huckers modified procedure. (Rangaswami,1975). On the middle of each clear slide, a drop of sterilised distilled water was placed. A loopful of bacterial suspension (young culture) was transferred to a sterile drop of water, and a very thin layer was created on each slide by spreading uniformly. The film was cemented by passing it two or three times over a moderate flame. The slides were soaked in crystal violet solution for 30 seconds before being rinsed thoroughly with a gentle stream of tap water. After that, the slides were submerged in iodine solution for one minute before being completely cleaned with 95 percent alcohol for 10 seconds the alcohol was drained and completely rinsed away with a gentle stream of tap water. After that, the slides were coated with Safranin for one minute. The slides were cleaned and dried with distilled water. Under a microscope, the cellular morphology of inoculants was examined.

Biochemical Characterization (Aneja, 2006)

To characterise the bacterial isolates, biochemical tests such as hydrogen sulphide test, catalase test, citrate utilisation, oxidase test, Indole production, Voges Prausker's test, Gelatin utilisation, and Casein hydrolysis were performed. Standard protocols were followed for biochemical characterization of the isolated bacteria and the protocol followed for each test is mentioned here under.

Hydrogen sulfide production Test

Hydrogen sulphide generation was studied using Sulfide indole motility (SIM) media. SIM agar stabs were made, and endophytic bacterial isolates were introduced into them. Stabs were inoculated and then incubated for 48 hours at 30°C. Black colouring along the line of stab inoculation after 48 hours showed H_2S generation.

Catalase test

Catalase test was performed by taking a drop of 3 per cent hydrogen peroxide and added to 48 hr old bacterial colony on a clean glass slide. The effervescence indicates catalase activity.

Citrate utilization test

Endophytic bacterial isolates were inoculated into Simmons citrate agar media and cultured for 48 hours at 37°C. A change in pH causes the medium to discolour from green to blue, indicating a favourable reaction. The carbon and energy source are citrate, which was found in the Simmons medium.

Oxidase test

The bacterial isolates were grown in nutrient agar slants. Oxidase paper discs of Hi media were kept on fully grown cultures for 48 hr. oxidase paper discs were kept in the slants after full grown of the bacterial isolates. If the colour changes to purple it indicates positive result.

Indole production test

Tryptophan broth tubes were inoculated with the overnight cultures of the isolates and incubated for 48 hrs at 28 ± 2°C. Following incubation, 10 drops of Kovac's Indole reagent was added to each tube.

The isolates showing production of red colour was recorded as positive for indole production.

Voges Prausker's test

The test was performed by adding alpha-naphthol and potassium hydroxide to the Voges Prausker's broth. A cherry red colour indicates a positive result, while a yellow-brown colour indicates a negative result.

Gelatin utilization test

The overnight cultures of the test isolates were inoculated to sterilized nutrient gelatin deep tubes and incubated for 24 hrs at 28 ± 2ºC. Then the tubes were kept in the refrigerator for 30 min at 4ºC. The isolates showing liquefied gelatin was taken as positive and those which resulted in solidification of gelatin on refrigeration was recorded as negative.

Casein hydrolysis

Twenty-four hours old cultures were streaked on Skim milk agar medium plates, which were inverted and incubated for 24 to 48 hours at 37°C. Evidence of clear zone around the growth line in the media plates indicate positive results.

Cellulase production

The activity of cellulase production was tested on Carboxymethyl cellulose (CMC) agar media using the Hankin and Anagnostakis (1977) method, as modified by Kasana *et al.*, (2008). Spot inoculated test isolates on CMC agar medium plates were cultured for 3-4 days at 30±2°C. Plates were flooded with Gram's iodine for 3 to 5 minutes after incubation (2.0 g KI and 1.0 g iodine in 300 ml distilled water). The creation of a clear zone surrounding the colony indicated positive cellulase production activity.

Pectinase production

On pectinase screening agar medium (PSAM), isolates were tested for pectinase producing activity (Oumer and Abate, 2018). The test isolates were spot inoculated on PSAM agar plates and incubated for 2 days at 30 ± 2°C. Plates were flooded with Gram's iodine for 3 to 5 minutes after incubation (2.0 g KI and 1.0 g iodine in 300 ml distilled water). The creation of a clear zone surrounding the colony indicated positive pectinase activity.

Screening for plant growth promoting activities and Nutrient solubilisation assay

Production of IAA (Brick *et al.*, 1991)

Bacteria were cultivated in nutrient media supplemented with 100 and 200 g/ml of Ltryptophan for 48 hours at 25 ± 2°C, then centrifuged (8000 rpm, 10 min). The generation of IAA was confirmed by the formation of pink colour after mixing 2 ml of supernatant with two drops of orthophosphoric acid and 4 ml of the Salkowski reagent (50 ml, 35 percent perchloric acid, 1 ml 0.5 M, $FeCl_3$ solution).

Ammonia production (Cappuccino and Sherman., 1992)

Freshly grown test bacterial isolates were inoculated in 10 ml peptone water and incubated for 48 hours at 28±2°C. In each tube, 0.5 ml of Nessler's reagent was applied, and the development of a brown to yellow tint indicated ammonia generation.

Siderophore production (Schwyn and Neilands., 1987)

The cultured bacterial isolates were spotted on a Chrome azurol S agar plate. The development of a yellow orange halo zone around the bacterial spot indicated siderophore production.

HCN production (Bakker and Schippers., 1987)

Bacterial isolates were streaked on Nutrient agar plates, with a single disc of filter paper in the lid of each plate. The plates were then sealed with parafilm® and incubated for 72 hours at (25±2 °C) For HCN synthesis, the colour change in the filter paper from deep yellow to dark brown was visually examined.

Nitrogen solubilization

The bacterial isolates were inoculated at three to four places on the Jenson media and incubated (28±2 °C) for 2-3 days. The development of a clear halo zone around bacterial isolates indicated positive nitogen solubilization activity.

Phosphate solubilizing activity (Nautiyal, 1999)

The ability of the isolates to solubilize natural phosphate was studied on National Botanical Research Institute's phosphate (NBRIP) agar medium. The test isolates were spot inoculated on NBRIP agar plates and incubated at 30 ± 2°C for 7-10 days. The development of a clear halo zone around bacterial isolates indicated positive Phosphate solubilization activity.

Plate assay for zinc solubilization (Saravanan *et al.*, 2004)

The isolates were inoculated on tris minimal medium containing 0.1 % insoluble zinc compounds (ZnO). The isolates were inoculated on the media and incubated at 30°C for 48 h. The development of a clear halo zone around bacterial isolates indicated positive zinc solubilization activity.

Potassium solubilization (Prajapati and Modi, 2012)

The isolates were inoculated on Aleksandrov agar medium containing 0.5% insoluble potassium aluminium silicate and incubated at 30°C for 48 h. The diameters of the clearing zones around the colonies indicated solubilization activity.

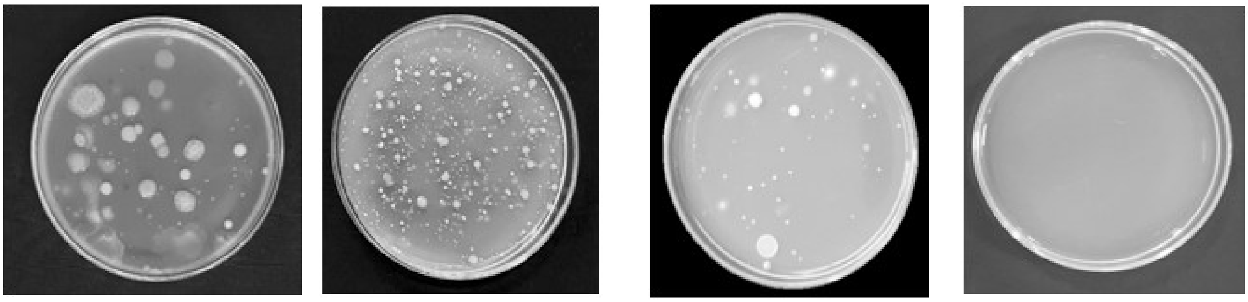
RESULTS AND DISCUSSION

Isolation of Endophytic Bacteria (EB)

A total of fifty-two endophytic bacterial isolates were isolated from the healthy paddy cultivars *viz.*, BPT 5204, JGL, KNM, MTU 1010, RNR 15048 (Telangana sona), Pooja and Kaveri which were popularly cultivated in Nalgonda, Warangal, Jagtial and Khammam districts of Telangana. Maximum number of isolates were from BPT 5204, JGL and KNM genotypes with maximum population on TSA medium.

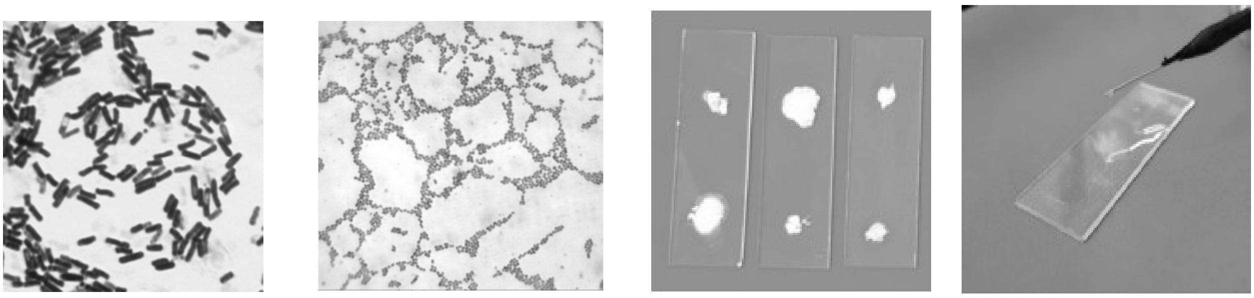
EB have been routinely been isolated from various tissues of rice Ji *et al.*, (2014) isolated 576 EB from the leaves, stems, and roots of ten rice cultivars.

Plate 1 : Isolation of endophytic bacterial isolates from different media

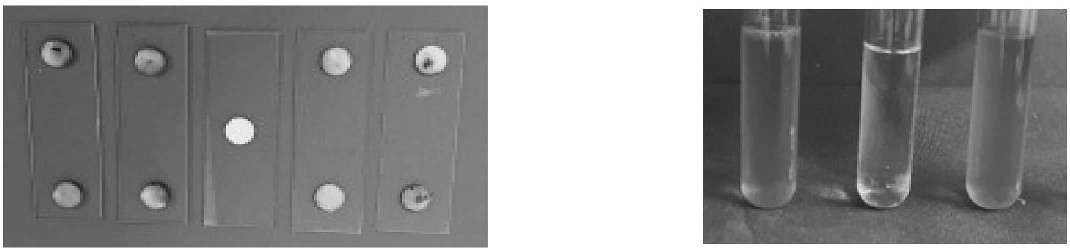


YEMA medium | Pseudomonas isolation agar | Nutrient agar | Control plate

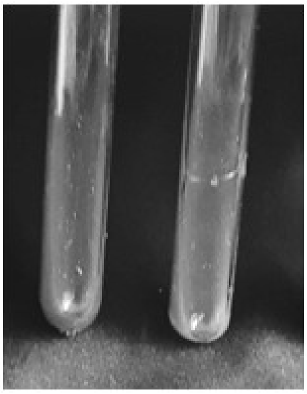
Plate 2: Biochemical characterization of potential endophytic bacterial



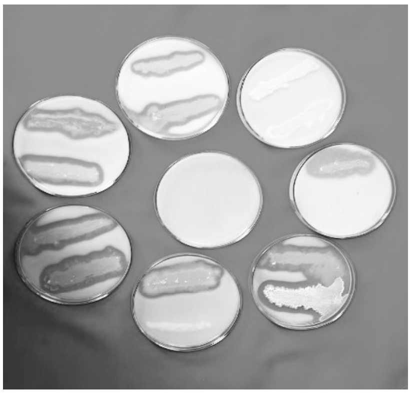
Gram-positive bacteria | Gram-negative bacteria | Catalase test | KOH test



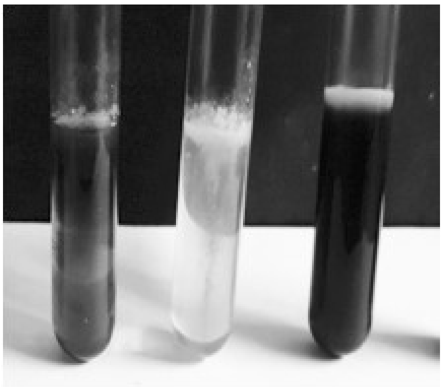
Oxidase test | Voges Prausker's test



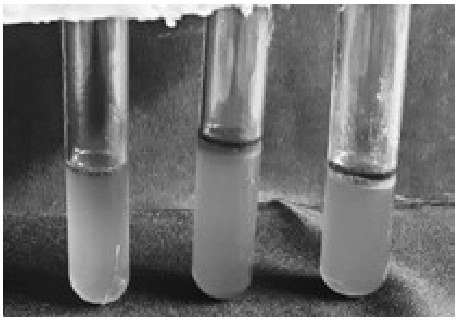
Citrate utilization test



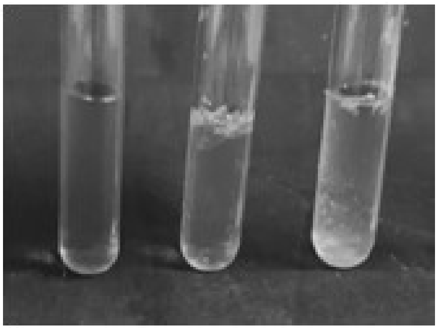
Casein hydrolysis test



Hydrogen sulphide test



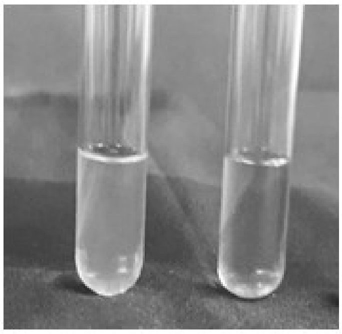
Indole test



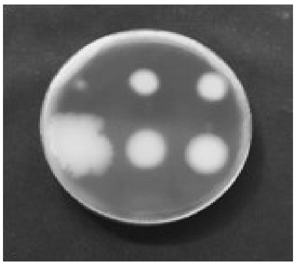
Gelatin test

Plate 3: Screening for plant growth promoting activities of potential endophytic bacterial isolates

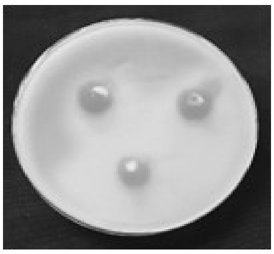
HCN test



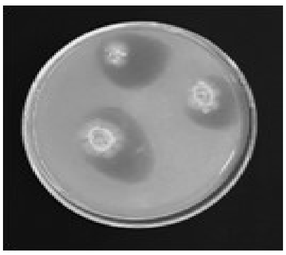
IAA test



Siderophore test



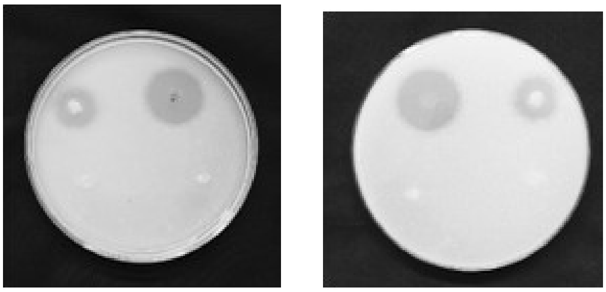
Chitinase test



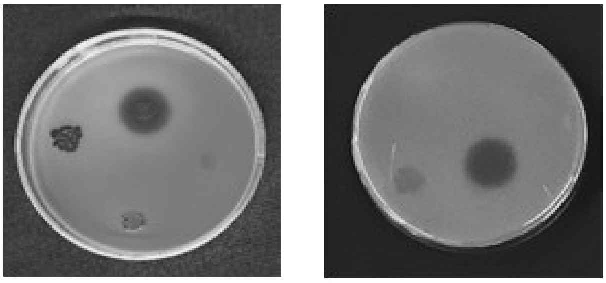
Pectinase test

Ammonia test

Plate 4: Nutrient solubilization assay of potential endophytic bacterial isolates



'N' solubilization assay



'P' solubilization assay

'K' solubilization assay

Kavitha *et al*., (2020) identified 45 endophytic bacterial isolates from healthy paddy cultivars viz., MTU 1010, BPT 5204, and NLR 34449, which are widely grown in Nellore and Chittoor districts of Andhra Pradesh.

Morphological and Biochemical characterization of the endophytic bacterial isolates

Morphological Characterization

The colony morphology of EB isolates was studied for colony characteristics like shape, margin, elevation, size, texture, appearance, pigmentation and optical property of the bacterial isolates were recorded after 48 h incubation (Table 1 & Plate 1).

Preliminary screening was carried out with 52 isolates against bacterial leaf blight pathogen of rice *in vitro* conditions by cross streak method. Based on inhibition zone, 15 isolates were selected for bio chemical characterization (Table 2 & Plate 2), growth promoting traits (Table 3 & Plate 3) and nutrient solubilization (Table 3 & Plate 4).

Colony morphology is commonly used to distinguish bacterial genotypes on plates and it is also a good indicator of ecological diversity (Saxer *et al*., 2010).

Biochemical characterization of potential endophytic bacterial isolates

Biochemical tests were carried out for further characterization of the endophytic bacterial isolates and the results are presented in the Table 3 and Plate 2. All the isolates were shown positive result for catalase test and oxidase test. Similarly, the isolates were positive to citrate utilization test except isolates EBP1, EBP6, EPB26, EBP47 and EBP49.

Isolates EBP26, EBP32, EBP39, EBP44, EBP45, EBP49, EBP52 showed positive reaction to H_2S production. All the isolates were positive to indole test except isolates EBP13, EBP29, EBP51. In Voges Prausker's test EBP6, EBP29, EBP32, EBP44, EBP45 showed negative remaining all isolates showed positive. In gelatin test all showed positive except EBP32. In casein hydrolysis test, all showed positive except EBP1, EBP39, EBP44, EBP49.

Isolates EBP13, EBP19, EBP32, EBP44, EBP47, EBP49, EBP51 and EBP52 showed negative to KOH test. Four isolates EBP6, EBP26, EBP50, EBP51 showed positive to Endospore staining.

In pectinase test, all the isolates showed positive results except isolates EBP29, EBP32,

Table 1: Cultural and morphological characters of different isolates of Endophytic bacteria isolated from Rice

Isolates	Shape	Margin	Elevation	Size	Texture	Appearance	Pigmentation
EBP1	Round	Slightly wavy	Flat	Small	Matte	Shiny	White
EBP2	Irregular	Irregular	Raised	Moderate	Viscous	Shiny	Creamish
EBP3	Round	Entire smooth	Flat	Moderate	Smooth	Shiny	Creamish
EBP4	Filamentous	Serrated	Flat	Moderate	Matte	Dull	Creamish
EBP5	Round	Serrated	Raised	Moderate	Matte	Shiny	Cremaish white
EBP6	Round	Round & Regular	Flat	Moderate	Viscous	Shiny	Slightly brown
EBP7	Irregular	Lobate	Flat	Moderate	Matte	Dull	Slightly white
EBP8	Irregular	Filamentous	Flat	Moderate	Smooth	Shiny	White
EBP9	Circular	Circular	Raised	Moderate	Smooth	Shiny	Creamish
EBP10	Circular	Circular	Flat	Small	Smooth	Shiny	Slightly brown
EBP11	Circular	Entire smooth	Convex	Small	Smooth	Shiny	White
EBP12	Circular	Entire smooth	Raised	Large	Smooth	Shiny	White
EBP13	Circular	Smooth	Flat	Moderate	Smooth	Dull	Creamish
EBP14	Circular	Smooth	Slightly raised	Moderate	Smooth	Shiny	White
EBP15	Irregular	Irregular	Flat	Small	Serrated	Shiny	White
EBP16	Circular	Entire smooth	Slightly raised	Moderate	Smooth	Dull	White
EBP17	Circular	Smooth	Flat	Moderate	Smooth	Shiny	Light yellow
EBP18	Circular	Entire smooth	Raised	Moderate	Smooth	Shiny	White
EBP19	Circular	Irregular	Convex	Moderate	Smooth	Shiny	White
EBP20	Irregular	Irregular	Flat	Large	Smooth	Dull	Light cream
EBP21	Circular	Irregular	Raised	Small	Smooth	Shiny	Light Yellow
EBP22	Circular	Irregular	Raised	Small	Smooth	Shiny	Yellow
EBP23	Irregular	Wavy	Flat	Small	Smooth	Dull	Very light yellow
EBP24	Circular	Smooth	Convex	Moderate	Smooth	Shiny	Light yellow
EBP25	Circular	Smooth	Convex	Moderate	Smooth	Shiny	Light yellow
EBP26	Irregular	Irregular	Flat	Large	Serrated	Shiny	White
EBP27	Circular	Regular smooth	Flat	Moderate	Smooth	Shiny	Yellow
EBP28	Irregular	Irregular	Raised	Moderate	Serrated	Shiny	White
EBP29	Circular	Filamentous	Flat	Moderate	Smooth	Shiny	White

Contd...

Isolates	Shape	Margin	Elevation	Size	Texture	Appearance	Pigmentation
EBP30	Circular	Filamentous	Convex	Small	Smooth	Shiny	Creamish White
EBP31	Circular	Serrated	Raised	Moderate	Smooth	Shiny	Yellow
EBP32	Circular	Wavy	Flat	Small	Smooth	Dull	White
EBP33	Circular	Smooth	Raised	Moderate	Smooth	Shiny	White
EBP34	Irregular	Wavy	Flat	Large	Smooth	Dull	Cream
EBP35	Circular	Wavy	Raised	Moderate	Smooth	Dull	Yellow
EBP36	Circular	Irregular	Flat	Moderate	Smooth	Shiny	Yellow
EBP37	Circular	Regular	Flat	Small	Smooth	Shiny	White
EBP38	Circular	Regular	Raised	Moderate	Smooth	Shiny	Yellow
EBP39	Irregular	Irregular	Raised	Large	Smooth	Shiny	Greenish White
EBP40	Circular	Regular	Raised	Moderate	Smooth	Shiny	Yellow
EBP41	Irregular	Serrated	Raised	Moderate	Smooth	Shiny	Yellow
EBP42	Filamentous	Serrated	Flat	Large	Smooth	Shiny	white
EBP43	Irregular	Wavy	Convex	Small	Viscous	Shiny	white
EBP44	Circular	Regular	Raised	Moderate	Viscous	Dull	Cream
EBP45	Circular	Smooth	Raised	Moderate	Viscous	Dull	Light pink
EBP46	Circular	Irregular	Convex	Large	Smooth	Shiny	Pink
EBP47	Circular	Smooth	Raised	Large	Smooth	Shiny	Creamish white
EBP48	Irregular	Smooth	Raised	Large	Smooth	Dull	Pink
EBP49	Irregular	Wavy	Convex	Moderate	Viscous	Shiny	White
EBP50	Irregular	Wavy	Convex	Moderate	Viscous	Dull	Cream
EBP51	Circular	Smooth	Flat	Large	Matte	Dull	white
EBP52	Circular	Smooth	Raised	Large	Mucilaginous	semitranslucent	Light pink

Table 2: Biochemical characterization of potential endophytic bacteria isolated from Rice after preliminary screening with *Xoo*

Isolate	H_2S	Catalase	Oxidase	Citrate	Indole	Voges prausker's	Gelatin	Casein	KOH test	Pectinase	Cellulase	Grams' staining	Endospore staining
EBP1	-	+	+	-	-	+	+	-	+	+	+	+	-
EBP6	-	+	+	-	+	-	+	+	+	+	-	+	+
EBP13	-	+	+	+	-	+	+	+	-	+	-	-	-
EBP19	-	+	+	+	+	+	+	+	-	+	-	-	-
EBP26	+	+	+	+	+	+	+	+	+	+	+	+	+
EBP29	-	+	+	+	-	-	+	+	+	-	+	+	-
EBP32	+	+	+	+	+	-	-	+	-	-	+	-	-
EBP39	+	+	+	+	+	+	+	+	-	+	+	-	-
EBP44	+	+	+	+	+	-	+	-	-	-	+	-	-
EBP45	+	+	+	+	+	-	+	+	+	+	+	+	-
EBP47	-	+	+	-	+	+	+	+	-	+	+	-	-
EBP49	+	+	+	-	+	+	+	-	-	-	-	-	-
EBP50	-	+	+	+	+	+	+	+	+	+	+	+	+
EBP51	-	+	+	+	-	+	+	+	-	-	-	-	+
EBP52	+	+	+	+	+	+	+	+	-	+	+	-	-

Table 3: Screening of potential isolates of endophytic bacteria for plant growth-promoting traits and nutrient solubilization under *in vitro* conditions

Isolate	IAA	HCN	Siderophore	Ammonia	Nitrogen	Phosphorus	Potassium	Zinc
EBP1	++	++	++	++	-	+	-	-
EBP6	++	+	-	-	-	-	-	-
EBP13	+	-	+	-	-	-	-	+
EBP19	+	-	+	++	++	-	-	-
EBP26	+++	+++	+++	+	++	+++	+++	-
EBP29	+	+	++	++	-	+	-	-
EBP32	-	-	++	+	-	-	-	-
EBP39	+++	++	++	+	-	++	++	+
EBP44	++	-	++	+++	-	+	-	-
EBP45	++	-	+	-	-	-	-	-
EBP47	+++	++	+	+	++	+++	+++	+
EBP49	+++	-	-	-	-	-	-	-
EBP50	+++	+	++	+	-	+	+	-
EBP51	+++	+	-	-	-	++	-	-
EBP52	++++	+++	++++	+++	+++	+++	+++	+

- : negative + : slightly positive ++ : moderately positive +++ : highly positive ++++ : extremely positive

EBP44, EBP49, EBP51. In cellulase test isolates EBP6, EBP13, EBP19, EBP39, EBP49, EBP51 showed negative results.

Similar findings with regard to biochemical characterization of isolates was recorded by Suman *et al.*, (2015) and characterized 30 isolates of *Pseudomonas flourescens* from rice, which were negative for indole production and 21 isolates for methyl red, 22 isolates for Voges Prausker's test showed positive results. All the thirty isolates of *Pseudomonas fluorescens* were positive for gelatin liquefaction.

Screening for plant growth promoting activities and Nutrient solubilisation assay

The potential isolates were tested for their PGP activities *in vitro*. The number of isolates showing PGP activity was shown in Table 3 and Plate 3&4. Isolates EBP26 was highly positive to IAA, HCN, siderophore, P and K. The isolates also showed slightly positive to ammonia, zinc and moderately positive to nitrogen.

Isolates EBP39 was highly positive to IAA, slightly positive to ammonia and moderately positive to HCN, siderophore, phosphate, potassium and Zinc.

Isolates EBP47 was slightly positive to siderophore, moderately positive to HCN, nitrogen and Zn. Highly positive to IAA, P and K.

Isolates EBP52 was extremely positive to IAA, siderophore and highly positive to HCN, Ammonia, Nitrogen, P, K and moderately positive to zinc.

Similar results were obtained by Panhwar *et al.*, (2012) with endophytic PSB from aerobic rice and PGP activities of the isolates like IAA production, siderophore production, antagonistic ability was determined.

Gyaneshwar *et al.*, (2001) isolated six closely related N2-fixing bacterial strains from surface-sterilized roots and stems of four different rice varieties. The strains were identified as *Serratia marcescens* by 16S rRNA gene analysis.

Saravanan *et al.*, (2007) reported that the endophytic isolate *Gluconacetobacter diazotrophicus* PAl5 effectively solubilized the Zn compounds and 5 ketogluconic acid was identified as the major organic acid aiding the solubilization of ZnO.

CONCLUSION

In the present study, the endophytic bacteria isolated from rice roots and stems showed different results (positive and negative) for different biochemical tests. The present study was focused on the isolation, screening, and biochemical characterization of PGPEB traits such as phosphate solubilization, organic acid production, indole acetic acid and ammonia production, biocontrol properties such as hydrogen cyanide production, lytic enzymes production. Four isolates *viz.,* EBP26, EBP39, EBP47 and EBP52 showed PGP traits and biocontrol properties. The results are promising for the design of potentially active plant growth promoting strain-based formulation which would be beneficial for crop improvement and crop protection. The four potential endophytic bacteria (EBP26, EBP39, EBP47 and EBP52) were also utilized for field application. These PGPR can be further explored as potential biofertilizers for sustainable agriculture.

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Research Article
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EFFECT OF ALTERNATE WETTING AND DRYING IRRIGATION REGIMES AND WEED MANAGEMENT PRACTICES ON GROWTH AND YIELD OF WET SEEDED RICE

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ABSTRACT

A field experiment was carried out at College Farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *rabi* 2020-21 and 2021-22. The experiment was laid out in split plot design with two factors i.e., irrigation regimes (I_1: Farmers practice (continuous flooding of 2-5 cm from 3-4 DAS), I_2: AWDI at 5 cm depletion of ponded water, I_3: AWDI at 10 cm depletion of ponded water and I_4: AWDI at 15 cm depletion of ponded water) and weed management practices *viz.*, W_1: Control (Unweeded check), W_2: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE, W_3: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS and W_4: Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding). Among the irrigation regimes significantly higher plant height, leaf area, dry matter production, no.tillers m^{-2}, grain and straw yields were recorded with Farmers practice (continuous flooding of 2-5 cm from 3-4 DAS) and it was on par with AWDI at 5 cm depletion of ponded water during both years of the study respectively. With respect to weed management practices Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding) resulted in significantly highest plant height, leaf area, dry matter production, no.tillers m^{-2}, grain and straw yield and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS) during 2020-21 and 2021-22.

Key words: Direct seeded rice, irrigation regimes, weed management, growth parameters, grain yield, straw yield

In India the national food security depends largely on the productivity of rice (Ganai *et al.*, 2018). Rice occupies an area of 45.7 M ha with a production of 124.3 M tons with average productivity of 27.7 q ha^{-1} in India (Indiastat, 2022). It is the major food crop of Telangana contributing a 1.93 M ha area with a production of 6.66 M tons (Socio Economic Outlook-Telangana, 2020). Transplanting is the most common method of crop establishment in South East Asian countries including India. Transplanting takes about 240 to 250 man hours ha^{-1} which is 25% of the total labour requirement of the crop. This results in increased cost of production and reduced profits for farmers. Due to this reason there is a shift towards less labour demanding alternative methods of rice cultivation like direct seeded rice. Direct wet seeded rice is gaining popularity in many places because of greater saving of labour.

Water saving techniques like alternate wetting and drying saves water input by 30% without reducing the yield (Bouman *et al.*, 2007). The number of days of non-flooded soil in AWDI ranges from 1 to >10 days. This method of irrigation also increased water use efficiency in rice (Suresh Kumar and Pandian, 2017). The AWD significantly reduced the number of irrigations and the amount of irrigation water required compared to continuous flooding.

The sustainability of direct seeded rice is endangered by heavy weed infestation (Mahajan *et al.*, 2013). Rice seedlings under wet seeded conditions suffer more from weed growth than transplanted rice due to the similarity of age and morphological characteristics of grass weeds and rice seedlings. In wet seeded rice weed growth reduced the grain yield up to 53% (Ramzan, 2003). Effective

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weed control at the initial stages of crop growth (0 to 40 days) could help in improving the productivity of direct seeded rice (Maity and Mukherjee, 2008). Currently, herbicide have emerged as the most important weed management tool as it offers timely, effective, economical and practical ways of weed control. However, sole applications of either pre- or post-emergence herbicides could not control diverse weeds effectively in direct seeded rice (Awan *et al.*, 2015). Manual, mechanical and chemical control measures were effective against weeds but the shortage of labour during peak period and escalating of labour wages are making delayed and expensive weed control practices. So, the integration of herbicides with mechanical and manual weeding practices results in timely control of weeds. Keeping these points in view the present research was carried out to study the effect of alternate wetting and drying irrigation regimes and weed management practices on the growth and yield of wet seeded rice during *rabi* season.

MATERIAL AND METHODS

The field experiment was carried out at College Farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad at an altitude of 527 m above mean sea level (MSL), 17° 31' N latitude, 78° 40' E longitude in Southern Telangana zone. The soil of the experimental site was sandy loam in texture with pH 7.9, available nitrogen (251.0 kg ha^{-1}), available phosphorus (42.5 kg ha^{-1} P_2O_5) and available potassium (364.0 kg ha^{-1} K_2O). The experiment was laid out in split plot design with two factors i.e., irrigation regimes (I_1 : Farmers practice (continuous flooding of 2-5 cm from 3-4 DAS), I_2: AWDI at 5 cm depletion of ponded water, I_3: AWDI at 10 cm depletion of ponded water and I_4: AWDI at 15 cm depletion of ponded water) and other weed management practices *viz.*, W_1: Control (unweeded check), W_2: pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE, W_3:Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS and W_4: Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding). The recommended dose of fertilizer for direct seeded rice is 150:60:40 kg ha^{-1} N:P_2O_5:K_2O, respectively which was supplied through urea, single super phosphate and murate of potash. Entire dose of recommended phosphorous was applied as basal dose. Whereas, nitrogen was applied in three equal splits at sowing, maximum tillering stage and panicle initiation stage. The recommended potassium was applied in two equal splits at sowing and panicle initiation stage of rice. The test variety used for the study was Jagtial Rice-1 (JGL-24423) which is a bold grain variety with a duration of 135-140 days in *rabi* season. Sowing was done by drum seeder by maintaining a spacing of 25 cm x 8 cm. Growth parameters viz: plant height, leaf area (cm^2 hill^{-1}), dry matter production (kg ha^{-1}) and tillers no m^{-2} were recorded at 30, 60, 90 DAS and at harvest. Grain and straw yields were also recorded. The data were analyzed statistically by applying the analysis of variance technique for split - plot design. The significance was tested by 'F' test (Gomez and Gomez, 1984)

RESULTS AND DISCUSSION

Plant height (cm)

Plant height was significantly influenced by different irrigation regimes at 60 DAS, 90 DAS and harvest during 2020-21 and 2021-22, respectively. The average plant height was 23.6, 46.7, 67.0 and 86.5 cm at 30, 60, 90 DAS, and harvest during both years of study. The data is presented in Table 1.

At 30 DAS there was no significant difference in plant height between the irrigation regimes during both the years of study. At 60 DAS, (49.4 and 51.0 cm), 90 DAS (73.4 and 73.9 cm) and harvest (92.2 and 94.8 cm) during 2020-21 and 2021-22 significantly highest plant height was achieved with Farmers practice (continuous flooding from of 2-5 cm from 3-4 DAS) and it was on par with AWDI at 5 cm depletion of ponded water during both years of study. This might be due to the maintenance of optimum moisture which helped in maintaining turgid pressure of cells, photosynthates accumulation and partition to the other parts of the plant and also optimizes the metabolic process in the plant which resulted in the production of taller plants. Similar findings were reported by Kumar *et al.*, (2013).

The lowest plant height was recorded with AWDI at 15 cm depletion of ponded water at 60 DAS (43.0 and 44.3 cm), 90 DAS (59.7 and 62.3 cm) and harvest (77.1 and 79.9 cm). The lowest plant height

Table 1. Plant height (cm) of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices during *rabi* season 2020-21 and 2021-22

Treatments	30 DAS			60 DAS			90 DAS			HARVEST		
	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean
Irrigation Regimes (I)												
I_1:Farmers practice (continuous flooding of 2-5 cm from 3-4 days after sowing)	24.6	25.8	25.2	49.4	51.0	50.2	73.4	73.9	73.6	92.2	94.8	93.5
I_2:AWDI at 5 cm depletion of ponded water	23.4	24.6	24.0	46.8	48.2	47.5	68.1	68.9	68.5	88.4	90.7	89.6
I_3: AWDI at 10 cm depletion of ponded water	22.3	23.6	22.9	44.7	46.2	45.5	63.7	65.9	64.8	82.5	85.1	83.8
I_4:AWDI at 15 cm depletion of ponded water	21.4	23.2	22.3	43.0	44.3	43.7	59.7	62.3	61.0	77.1	79.9	78.9
S.Em.±	0.80	0.78	-	1.0	1.3	-	1.7	1.9	-	2.1	2.2	-
CD (p=0.05)	NS	NS	-	3.6	4.4	-	5.8	6.8	-	7.4	7.6	-
Weed Management Practices (W)												
W_1:Control (Unweeded check)	18.0	19.8	18.9	38.8	40.3	39.6	56.7	58.3	57.5	73.7	76.4	75.0
W_2: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE	24.1	25.2	24.7	45.1	46.5	45.8	65.4	66.1	65.7	84.2	86.0	85.1
W_3:Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE +mechanical weeding at 45 DAS	24.5	25.6	25.0	49.0	50.5	49.8	70.1	71.4	70.7	89.7	92.4	91.1
W_4:Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding)	25.2	26.6	25.9	51.1	52.3	51.7	72.8	75.2	74.0	92.6	96.5	94.5
S.Em.±	0.5	0.5	-	1.0	1.1	-	1.3	1.4	-	1.8	1.7	-
CD (p=0.05)	1.4	1.6	-	2.9	3.1	-	3.9	4.0	-	5.2	5.1	-
Interaction												
I x W												
S.Em.±	0.9	1.1	-	1.9	2.2	-	2.7	2.8	-	3.6	3.5	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
W x I												
S.Em.±	1.2	1.2	-	2.0	2.3	-	2.9	3.1	-	3.8	3.7	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	22.9	24.30	23.6	46.01	47.4	46.7	66.2	67.7	67.0	85.1	87.8	86.5

NS= Non significant

might be due to decreased cell division, cell elongation which affected the internodal length and reduced the plant height. Similar findings were reported by Choudary *et al*., (2015) and Chai *et al*., (2016).

Weed management practices significantly affected the plant height at 30 DAS, 60 DAS, 90 DAS and harvest during 2020-21 and 2021-22. At 30 DAS, highest plant height (25.2 and 26.6 cm) during both years of study was observed in Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding) and it was on par with pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE and pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). (24.5 and 25.6 cm). This might be due to very less competition experienced by the crop in weed - free condition and better control of weeds in herbicide applied plots which reduced the competition for essential resources and increased the plant height. The lowest plant height was resulted in Control (unweeded check). (18.0 and 19.8 cm).

At 60 DAS (51.1 and 52.3 cm), 90 DAS (72.8 and 75.2 cm) and harvest (92.6 and 96.5 cm) highest plant height during 2002-21 and 2021-22 was observed in Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding and it was on par with pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to no or fewer weeds in weed free condition and reduced weed competition in W_3 (herbicide + mechanical weeding) which increased the availability of nutrients and resulted in elongation of intermodal length which increased the plant height. Similar results were reported by Chinnamani *et al*., (2018) and Venkatesh *et al*., (2020). Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE resulted in significantly higher plant height than Control (unweeded check) which produced the lowest plant height at 60 DAS (38.8 and 40.3 cm), 90 DAS (56.7 and 58.3 cm) and at harvest (73.7 and 76.4 cm) during both years of the study respectively. The lowest plant height in unweeded control might be due to heavy weed infestation which resulted in severe competition between the crop and weeds and resulted in reduced plant height by restricting the intermodal elongation.

Leaf area (cm^2 hill^{-1})

Leaf area (cm^2 hill^{-1}) was significantly influenced by different irrigation regimes at 60 DAS, 90 DAS and harvest. The average leaf area was 96.5, 472.5, 876.5 and 328 cm^2 plant^{-1} at 30, 60, 90 DAS and at harvest during 2002-21 and 2021-22, respectively. Statistically analyzed data is presented in Table 2.

At 30 DAS there was no significant differencein leaf area between the irrigation regimes. At 60 DAS (517.6 and 533.8 cm^2 hill^{-1}), 90 DAS (969.6 and 985.9 cm^2 hill^{-1}) and harvest (364.8 and 381.2 cm^2 hill^{-1}) highest leaf area were noticed with Farmers practice (continuous flooding from of 2-5 cm from 3-4 DAS) and it was on par with AWDI at 5 cm depletion of ponded water during both years of study. This might be due to the production of more plant dry matter which resulted in greater leaf area. The lowest leaf area (cm^2 hill^{-1}) was achieved with AWDI at 15 cm depletion of ponded water at 60 DAS (395.8 and 428.9 cm^2 hill^{-1}), 90 DAS (728.7 and 783.5cm^2 hill^{-1}) and harvest (266.7 and 285.8 cm^2 hill^{-1}). Reduction in leaf area might be due to reduced turgor pressure under moisture stress conditions which affected the leaf cell expansion. Similar results were reported by Theerthana *et al.* (2020)

Leaf area (cm^2 hill^{-1}) was significantly influenced by weed management practices at 30DAS, 60 DAS, 90 DAS and harvest.At 30 DAS, significantly highest leaf area was noticed in Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding) (100 and 110.3 cm^2 hill^{-1}) and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha $^{-1}$ PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE and Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to lower weed density encouraging vigorous crop growth and resulting in the highest leaf area. Similar results were reported by Sunil *et al*., (2010). The lowest leaf area was recorded in Control (unweeded check) (78.8 and 81.2 cm^2 hill^{-1}) during 2020-21 and 2021-22, respectively.

At 60 DAS (533 and 555.8 cm^2 hill^{-1}), 90 DAS (970.8 and 1026.2 cm^2 hill^{-1}) and harvest (369.3 and 392.4 cm^2 hill^{-1}) significantly highest leaf area was witnessed in Weed free (mechanical weeding at 15,

Table 2. Leaf area (cm^2 $hill^{-1}$) of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices during *rabi* season 2020-21 and 2021-22

Treatments	30 DAS			60 DAS			90 DAS			HARVEST		
	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean
Irrigation Regimes (I)												
I_1:Farmers practice (continuous flooding of 2-5 cm from 3-4 days after sowing)	98.0	105.3	101.7	517.6	533.8	525.7	969.6	985.9	977.7	364.8	381.2	373.0
I_2:AWDI at 5 cm depletion of ponded water	94.6	101.9	98.2	488.5	497.1	492.8	912.0	938.9	925.5	342.4	357.8	350.1
I_3: AWDI at 10 cm depletion of ponded water	90.8	99.3	95.1	451.6	466.7	459.1	827.7	865.7	846.7	300.1	325.4	312.8
I_4:AWDI at 15 cm depletion of ponded water	87.0	94.9	90.9	395.8	428.9	412.4	728.7	783.5	756.1	266.7	285.8	276.3
S.Em.±	2.7	2.6	-	14.1	12.5	-	23.6	20.9		10.0	9.1	-
CD (p=0.05)	NS	NS	-	48.8	43.4	-	81.8	72.2		34.8	31.5	-
Weed Management Practices (W)												
W_1:Control (Unweeded check)	78.8	81.2	80.0	339.9	351.1	345.5	670.1	691.7	680.9	214.2	234.3	224.2
W_2: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) +cyhalofop butyl (5.1%) 120 g ha^{-1}PoE	95.0	104.4	99.7	470.2	490.3	480.2	866.6	882.8	874.7	330.9	345.0	337.9
W_3:Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120g ha^{-1} PoE +mechanical weeding at 45 DAS	97.0	105.6	101.3	510.5	529.3	519.9	930.5	973.3	951.9	359.6	378.5	369.1
W_4:Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding)	100.0	110.3	105.0	533.0	555.8	544.4	970.8	1026.2	998.5	369.3	392.4	380.9
S.Em.±	1.9	2.2	-	11.8	11.5	-	17.9	19.1	-	8.6	7.4	-
CD (p=0.05)	5.7	6.3	-	34.5	33.4	-	52.1	55.8	-	25.2	21.6	-
Interaction												
I x W												
S.Em.±	3.8	4.4	-	23.6	23.0	-	35.7	38.2	-	17.2	14.8	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
W x I												
S.Em.±	4.3	4.6	-	24.8	23.5	-	38.9	39.1	-	18.0	15.7	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	92.6	100.4	96.5	463.4	481.6	472.5	859.5	893.5	876.5	318.5	337.5	328

NS= Non significant

35 and 55 DAS with line weeding) and it was on par with pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to thereduction of weed competition during the critical crop growth period which helped in the proper utilization of resources by the crop resulting in the production of long and broad leaves and increased leaf area. Similar results were reported by Raviteja *et al.*, (2020). Application of herbicide alone i.e., Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE resulted in significantly highest leaf area when compared with Control (unweeded check) which produced the lowest leaf area at 60 DAS (339.9 and 351.1 cm^2 hill^{-1}), 90 DAS (670.1 and 691.7 cm^2 hill^{-1}) and at harvest (214.2 and 234.3 cm^2 hill^{-1}) during 2020-21 and 2021-22 respectively. The lowest leaf area at 30, 60, 90 DAS and harvest in unweeded control might be due to increased weed density which reduced availability of sunlight, moisture and other plant nutrients to the crop and resulted in severe weed competition between the weeds and the crop.

Dry matter production (kg ha^{-1})

Dry matter production was significantly influenced by different irrigation regimes at 60 DAS, 90 DAS and harvest during the 2020-21 and 2021-22, respectively. The average dry matter production during 30 DAS, 60 DAS, 90 DAS and harvest was 1386, 5577, 8939 and 12981 kg ha^{-1} during 2020-21 and 2021-22, respectively. The data is presented in Table 3 and Figure 1a and 1b.

At 30 DAS there was no significant difference in dry matter production between the irrigation regimes. At 60 DAS (5929 and 6094 kg ha^{-1}), 90 DAS (9678 and 9799 kg ha^{-1}) and harvest (14862 and 14944 kg ha^{-1}) significantly highest dry matter production was achieved with Farmers practice (continuous flooding from of 2-5 cm from 3-4 DAS) and it was on par with AWDI at 5 cm depletion of ponded water during both years of study. Frequent irrigations might have facilitated higher water and nutrient uptake which are applied to the crop resulting in increased production of photosynthates, increased plant height and production of a larger number of tillers finally resulted in higher dry matter production. Similar findings were reported by Arjun *et al.,* (2017) and Sarath *et al.,* (2020). The lowest dry matter production was achieved with AWDI at 15 cm depletion of ponded water at 60 DAS (5026 and 5222 kg ha^{-1}), 90 DAS (7993 and 8105) and harvest (10514 and 10603 ha^{-1}) during 2020-21 and 2021-22, respectively. This may be due to increased water stress to the plant during the leaf expansion phase which reduced the accumulation of photosynthates in the plant, in turn reducing the dry matter.

The dry matter production was significantly influenced by weed management practices at 30 DAS, 60 DAS, 90 DAS and at harvest during 2020-21 and 2021-22 respectively. At 30 DAS highest dry matter production resulted in Weed - free (mechanical weeding at 15, 35 and 55 DAS with line weeding) (1546 and 1597 kg ha^{-1}) and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE and Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to effective control of weeds in mechanical weeding + line weeding and herbicide combination resulting in higher dry matter production. Similar results were reported by Chowdary *et al.* (2018) and Saphi *et al.* (2018). The lowest dry matter production resulted in control (unweeded check) (939 and 1004 kg ha^{-1}) during 2020-21 and 2021-22 respectively.

At 60 (6315 and 6489 kg ha^{-1}), 90 DAS (10182 and 10383 kg ha^{-1}) and harvest (15064 and 15145 kg ha^{-1}) significantly highest dry matter production resulted in Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding) and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to effective weed control which reduces weed competition and increased aeration of the soil facilitating increased plant height, leaf area and a number of tillers m^{-2} which in turn increased the dry matter production. Similar findings were reported by Kumar *et al.* (2013). Application of herbicide alone i.e. Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE resulted in significantly highest dry matter production when compared with Control (unweeded check) which produced the lowest dry matter production at 60 DAS (3846 and 3985 kg ha^{-1}), 90 DAS (6159

Table 3. Dry matter production (kg ha^{-1}) of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices during *rabi* season 2020-21 and 2021-22

Treatments	30 DAS			60 DAS			90 DAS			HARVEST		
	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean
Irrigation Regimes (I)												
I_1:Farmers practice (continuous flooding of 2-5 cm from 3-4 days after sowing)	1412	1502	1457	5929	6094	6012	9678	9799	9739	14862	14944	14903
I_2:AWDI at 5 cm depletion of ponded water	1391	1452	1421	5758	5768	5763	9301	9403	9352	13829	13905	13867
I_3: AWDI at 10 cm depletion of ponded water	1349	1406	1378	5281	5542	5411	8573	8658	8615	12560	12626	12593
I_4:AWDI at 15 cm depletion of ponded water	1270	1305	1288	5026	5222	5124	7993	8105	8049	10514	10603	10559
S.Em.±	38.7	46.4	-	161.2	142.6	-	316	315	-	430	399	-
CD (p=0.05)	NS	NS	-	557.9	493.3	-	1093	1090	-	1487	1381	-
Weed Management Practices (W)												
W_1:Control (Unweeded check)	939	1004	971	3846	3985	3915	6159	6228	6193	8653	8745	8699
W_2: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE	1467	1506	1487	5730	5853	5792	9313	9368	9340	13571	13644	13608
W_3:Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE +mechanical weeding at 45 DAS	1469	1558	1514	6104	6299	6201	9889	9987	9938	14477	14544	14511
W_4:Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding)	1546	1597	1571	6315	6489	6402	10182	10383	10282	15064	15145	15105
S.Em.±	33.3	37.3	-	121.6	120.2	-	187.0	189.8	-	264.9	271.0	-
CD (p=0.05)	97.3	108.9	-	354.9	351.0	-	545.8	554.1	-	773.1	791.0	-
Interaction												
I x W												
S.Em.±	66.7	74.6	-	243.1	240.4	-	374.0	379.7	-	530.0	542.0	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
W x I												
S.Em.±	69.5	79.6	-	265.2	253.3	-	452.40	455.3	-	628.6	616.0	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	1355	1416	1386	5499	5656	5577	8886	8991	8939	12941	13020	12981

NS= Non significant

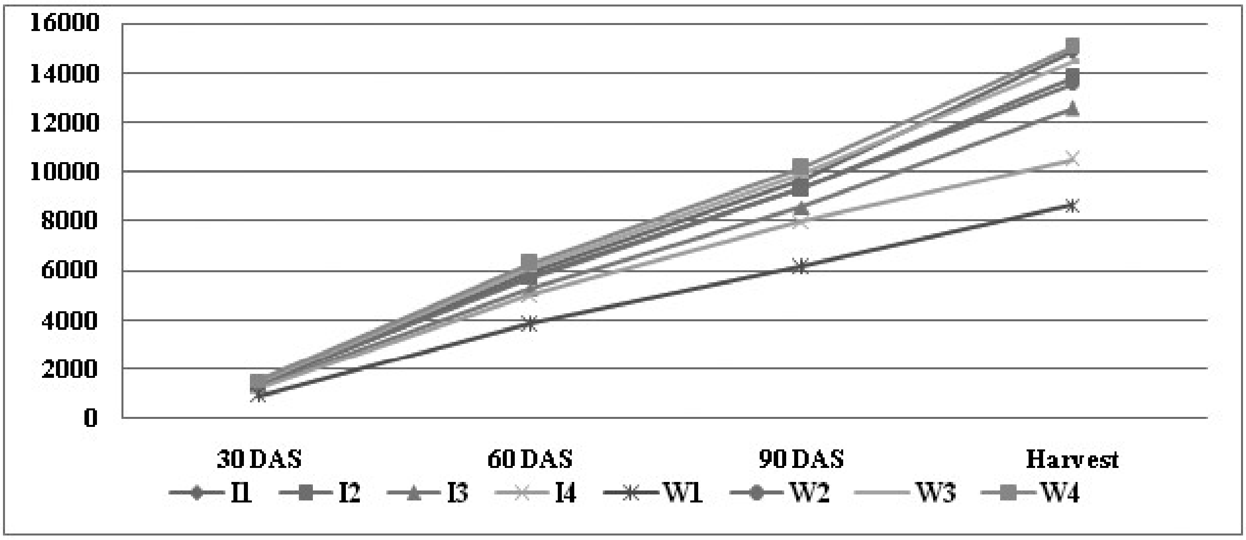

Figure 1a. **Dry matter production (kg ha^{-1}) of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices in *rabi* season (2020-21)**

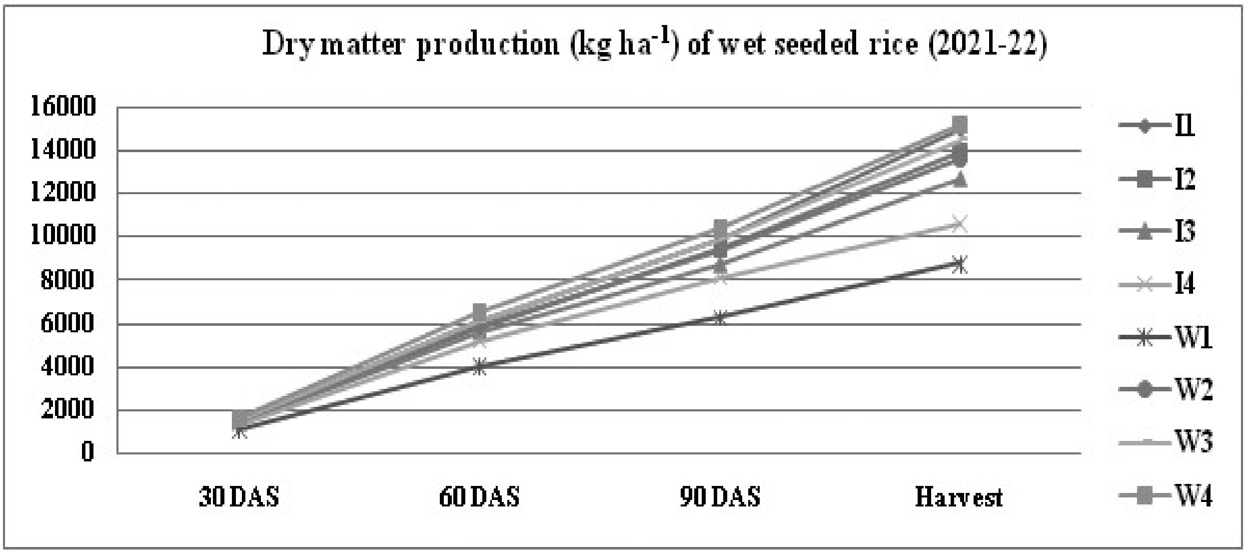

Figure 1b. **Dry matter production (kg ha^{-1}) of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices in *rabi* season (2021-22)**

and 6228 kg ha^{-1}) and harvest (8653 and 8745 kg ha^{-1}) during 2020-21 and 2021-22 respectively. The lower dry matter at 30, 60, 90 DAS and a harvest was recorded with unweeded control due to higher crop weed competition which reduced the leaf area, tillers number m^{-2} which in turn reduced the dry matter production.

Tillers m^{-2}

Tillers m^{-2} was significantly influenced by different irrigation regimes at 60 DAS, 90 DAS and at harvest. The average tillers m^{-2} was 133.6, 320, 349.4 and 276.3 at 30 DAS, 60 DAS, 90 DAS and harvest during 2020-21 and 2021-22 respectively. The data was analyzed statistically and presented in Table 4 and Figure 2a and 2b.

At 30 DAS there was no significant difference in tillers m^{-2} between the irrigation regimes. At 60 DAS (342.7 and 345.5 no. m^{-2}), 90 DAS (380.3 and 383.0 no. m^{-2}) and harvest (324.8 and 332.3 no. m^{-2}) significantly highest tillers m^{-2} was achieved with Farmers practice (continuous flooding from of 2-5 cm from 3-4 DAS) and it was on par with AWDI at 5 cm depletion of ponded water during both years of study. This might be due to favourable moisture regimes

Table 4. Tillers m^{-2} of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices during *rabi* season 2020-21 and 2021-22

Treatments	30 DAS			60 DAS			90 DAS			HARVEST		
	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean	20-21	21-22	Mean
Irrigation Regimes (I)												
I_1:Farmers practice (continuous flooding of 2-5 cm from 3-4 days after sowing)	138.7	142.1	140.8	342.7	345.5	344.1	380.3	383.0	381.7	324.8	332.3	328.6
I_2:AWDI at 5 cm depletion of ponded water	132.7	136.8	134.7	323.2	327.9	325.5	358.2	362.5	360.3	310.7	320.2	315.4
I_3: AWDI at 10 cm depletion of ponded water	128.4	132.7	130.5	311.7	315.2	313.4	333.0	338.7	335.8	295.7	304.2	299.9
I_4:AWDI at 15 cm depletion of ponded water	126.9	130.3	128.6	293.8	299.8	296.8	316.7	323.2	319.9	278.7	283.8	281.3
S.Em.±	3.56	3.42	-	6.90	8.2	-	10.3	11.1	-	6.6	7.6	-
CD (p=0.05)	NS	NS	-	23.86	28.3	-	35.6	38.5	-	22.7	26.3	-
Weed Management Practices (W)												
W_1:Control (Unweeded check)	115.5	120.5	118.0	258.3	261.8	260.1	267.8	272.9	270.4	250.5	258.0	254.3
W_2: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) +cyhalofop butyl (5.1%) 120 g ha^{-1} PoE	134.9	137.9	136.5	322.5	325.6	324.0	346.8	350.1	348.5	299.8	307.8	303.8
W_3:Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1}PoE +mechanical weeding at 45 DAS	136.0	140.5	138.4	338.7	345.3	342.0	374.2	379.3	376.8	321.3	329.3	325.3
W_4:Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding)	140.3	142.9	141.7	351.8	355.7	353.8	399.3	405.0	402.2	338.2	345.3	341.8
S.Em.±	1.88	2.76	-	6.70	6.5	-	8.9	9.6	-	6.31	7.00	-
CD (p=0.05)	5.50	8.05	-	19.50	18.9	-	25.9	28.0	-	18.43	20.4	-
Interaction												
I x W												
S.Em.±	3.77	5.52	-	13.3	13.0	-	17.7	19.2	-	12.63	14.00	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
W x I												
S.Em.±	4.83	5.88	-	13.4	13.9	-	18.5	20.0	-	12.76	14.50	-
CD (p=0.05)	NS	NS	-	NS	NS	-	NS	NS	-	NS	NS	-
General Mean	131.7	135.6	133.6	317.8	322.1	320.0	347.0	351.8	349.4	272.5	280.1	276.3

NS= Non significant

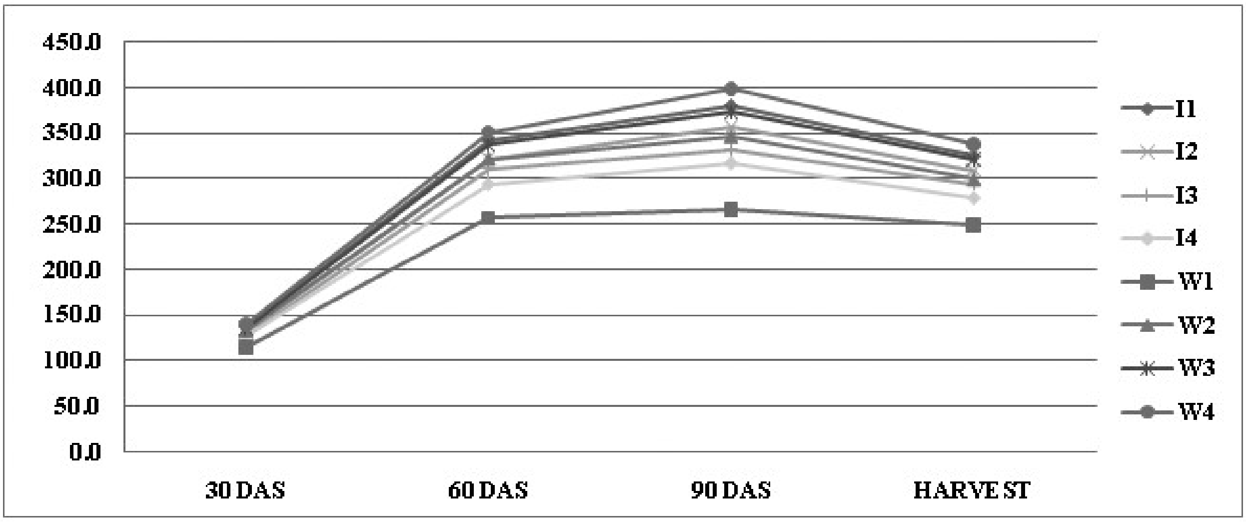

Figure 2a. **Tillers m^{-2} of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices during *rabi* season (2020-21)**

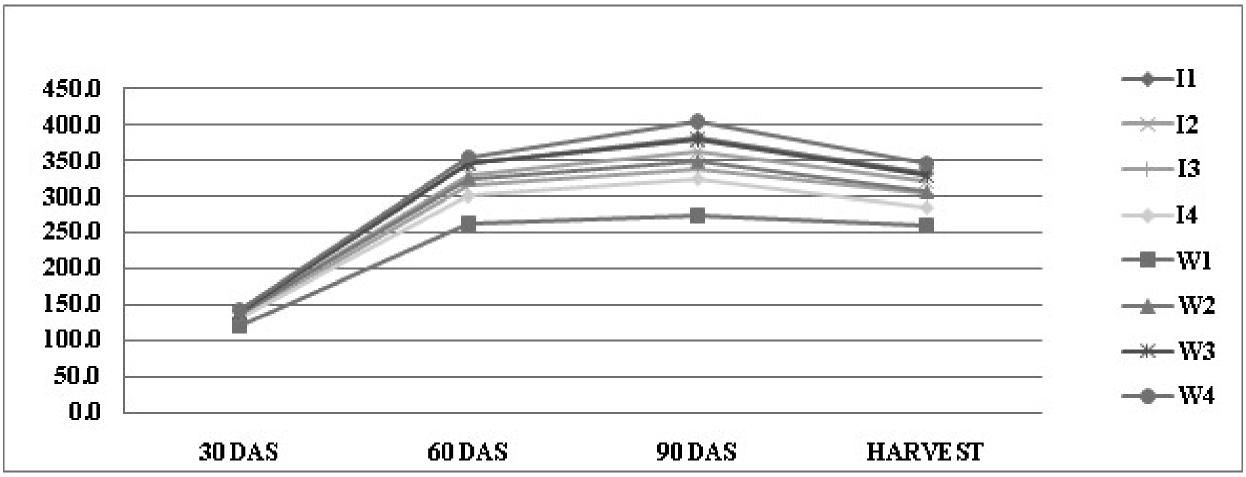

Figure 2b. **Tillers m^{-2} of wet seeded rice as influenced by alternate wetting and drying irrigation levels and weed management practices during *rabi* season (2020-21)**

enabling the abundant growth of plants by providing a conducive microclimate for efficiently utilizing growth - promoting minerals and in turn helped the plants to boost their growth through the supply of more photosynthates towards reproductive sinks which caused to produce more number of tillers. Similar findings were reported by (Gill *et al.,* 2011). The lowest tillers m^{-2} was achieved with AWDI at 15 cm depletion of ponded water at 60 DAS (293.8 and 299.8 m^{-2}), 90 DAS (316.7 and 323.2 m^{-2}) and harvest (278.7 and 283.8 m^{-2}) during 2020-21 and 2021-22 respectively. This might be due to water deficit in soil, especially during leaf elongation process, disrupted plant water balance leading to decrease in leaf initiation which caused insufficient sites for tiller formation, thus reducing tiller number. The stress caused due to the alternate wetting and drying and irrigation 10 and 15 cm depletion led to lower tillers. Similar findings were reported by (Gill *et al.*, 2011).

Tillers m^{-2} was significantly influenced by weed management practices at 30 DAS, 60 DAS, 90 DAS and harvest. At 30 DAS significantly highest tillers m^{-2} was observed in Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding) (140.3 and 142.9 m^{-2}) and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE and pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to no or less existence of weeds in weed free condition and herbicide treatment during the active growing period has provided the most favorable conditions viz., sufficient moisture, sunlight and plant nutrients for growth and tiller production of the crop. Similar findings were reported by Srinithan *et al*., (2021). The lowest tillers m^{-2} was recorded in Control (unweeded check) (115.5 and 120.5 no. m^{-2}). At 60 DAS (351.8 and 355.7 no. m^{-2}), 90 DAS (399.3 and 405.0 m^{-2}) and harvest significantly highest tillers (338.2 and 345.3 m^{-2}) was resulted in Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding) and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). This might be due to a favorable environment for the production of more tiller primordial and maintenance of weed free environment during the critical period of crop weed competition. Similar findings were reported by Sunil *et al.* (2010) and Gangireddy *et al.,* (2020). Application of herbicide alone i.e Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE resulted in significantly highest tillers (no. m^{-2}) when compared with Control (unweeded check) which produced the lowest tillers m^{-2}) at 60 DAS (258.3 and 261.8 m^{-2}), 90 DAS (267.8 and 272.9 m^{-2}) and harvest (250.5 and 258.0 m^{-2}) during 2020-21 and 2021-22 respectively. The lowest number of tillers m^{-2} with unweeded check might be due to severe weed competition which resulted in reduced number of tillers per unit area. Uncontrolled weeds might have competed with crop plants in sharing limited moisture, sunlight and plant nutrients duly limiting the tiller production per m^{-2}

Grain yield (kg ha^{-1})

Grain yield was significantly influenced by different irrigation regimes during both years of study respectively. The average grain yield was 6084 kg ha^{-1} in 2020-21, 6215 kg ha^{-1} in 2021-22 and 6150 kg ha^{-1} was the mean of both years respectively. The data was analyzed statistically and presented in Table 5.

Significantly highest grain yield was achieved with Farmers practice (continuous flooding of 2-5 cm from 3-4 DAS) (7060 and 7168 kg ha^{-1}) and it was on par with AWDI at 5 cm depletion ofponded water (6515 and 6689 kg ha^{-1}). The combined effect of numerous growth and development characteristics determines yield. The increased yields might be due to a favorable growing and nutrition supply environment which resulted in higher dry matter and increased uptake of nutrients which lead to the plants with superior growth. The favourable growth enhanced the yield attributing characters with a higher source to - sink conversion, which in turn resulted in higher grain yields. Similar findings were reported by Das *et al*., (2016) and Nayak *et al.,* (2016). The lowest grain yield was achieved with AWDI at 15 cm depletion of ponded water (4931 and 5045 kg ha^{-1}). The lowest grain yield might be due to moisture stress which caused various structural and functional disruptions in reproductive organs, leading to shortened grain-filling period, reduced photosynthesis and increased soluble sugars remobilization from grains to other vegetative parts at the reproductive stage. The sugars or carbohydrate remobilizations strongly depend on source activity and sink strength which is sensitive to water stress. Under moisture stress conditions, there was a restricted supply of assimilates from the source to the sink, thereby causing limited production of reproductive organs or developing grains in rice plants. Similar findings were reported by Choudhary (2015) and Jaffar *et al*., (2017)

The different weed management practices resulted in significantly highest grain yield (kg ha^{-1}) during the both years of study. Weed-free, application of herbicide combinations and mechanical weeding along with line weeding resulted in higher grain yield (kg ha^{-1}) when compared with unweeded check. Significantly highest grain yield (kg ha^{-1}) was achieved in Weed-free (mechanical weeding at 15, 35 and 55 DAS with line weeding) (7254 and 7307 kg ha^{-1}) which might be due to lower weed density and weed dry matter led to the better utilization of water, light and nutrient resources by the crop in the weed-free condition and resulted in the higher grain yield and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS). (6949 and 7092 kg ha^{-1}). This might be due to sequential herbicide application along with mechanical weeding have controlled the weeds during the critical period of crop weed competition and reduced the competition for resources between the crop and weeds which resulted in higher dry matter production, leaf area, more panicles m^{-2}, filled grains due to better synthesizing of photosynthates and more translocation from sources to sink. Similar findings were reported by Singh *et al.* (2019), Venkatesh *et al.* (2020) and Mahapatra *et al.* (2021). Application of herbicide alone i.e

Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE resulted in higher grain yield (kg ha^{-1}) (6462 and 6565 kg ha^{-1}) when compared with Control (unweeded check) which resulted in lower grain yield. (3672 and 3897 kg ha^{-1}) during 2020-21 and 2021-22 respectively. This might be due to heavy weed infestation during the entire crop growing period which resulted in higher competition between the resources by the crop and weeds and reduced all the growth and yield components and eventually yield. Similar results were reported by Atheena *et al.* (2017).

Straw yield (kg ha^{-1})

Straw yield (kg ha^{-1}) was significantly influenced by different irrigation regimes during both the years of study. The mean straw yield was 6959 kg ha^{-1} in 2020-21, 7186 kg ha^{-1} in 2021-22 and 7072 kg ha^{-1} was the mean of both years respectively. The data were analyzed statistically and presented in Table 5.

Significantly highest straw yield was achieved with Farmers practice (continuous flooding of 2-5 cm from 3-4 DAS) (7928 and 8110 kg ha^{-1}) and it was on par with AWDI at 5 cm depletion of ponded water

Table 5. Grain and Straw Yield (kg ha^{-1}) of wet seeded rice as influenced by alternate wetting and drying irrigation levels andweed management practices during *rabi* season 2020-21 and 2021-22

Treatments	Grain Yield (kg ha^{-1})			Straw Yield (kg ha^{-1})		
	20-21	21-22	Mean	20-21	21-22	Mean
Irrigation Regimes (I)						
I_1:Farmers practice (continuous flooding of 2-5 cm from 3-4 days after sowing)	7060	7168	7114	7928	8110	8019
I_2:AWDI at 5 cm depletion of ponded water	6515	6689	6602	7393	7622	7508
I_3: AWDI at 10 cm depletion of ponded water	5830.	5959	5895	6771	7029	6899
I_4:AWDI at 15 cm depletion of ponded water	4931	5045	4988	5743	5983	5863
S.Em.±	220.4	212.7		218.4	247.6	
CD (p=0.05)	762.6	736.0		755.8	856.8	
Weed Management Practices (W)						
W_1:Control (Unweeded check)	3672	3897	3784	4827	5000	4914
W_2: Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) +cyhalofop butyl (5.1%) 120 g ha^{-1}PoE	6462	6565	6513	7258	7513	7386
W_3:Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE +mechanical weeding at 45 DAS	6949	7092	7021	7714	8044	7879
W_4:Weed free (mechanical weeding at 15, 35 and 55 DAS with line weeding)	7254	7307	7280	8036	8186	8111
S.Em.±	106.9	116.4	-	142.7	131.9	-
CD (p=0.05)	312.1	340.0	-	416.5	385.0	-
Interaction						
I x W						
S.Em.±	213.8	232.7	-	285.4	263.8	-
CD (p=0.05)	NS	NS	-	NS	NS	-
W x I						
S.Em.±	287.8	293.0	-	329.8	336.9	-
CD (p=0.05)	NS	NS	-	NS	NS	-
General Mean	6084	6215	6150	6959	7186	7072

NS= Non significant

(7393 and 7622 kg ha^{-1}). This might be due to adequate moisture availability in the continuous flooding and alternate wetting and drying irrigation at 5 cm depletion of ponded water which resulted in increased dry matter production which greatly influenced straw yield. Similar results were reported by Sarath *et al.* (2020).

The lowest straw yield was achieved with AWDI at 15 cm depletion of ponded water. (5743 and 5983 kg ha^{-1}). This might be due to reduced dry matter production due to insufficient water availability may be the reason for decreased straw yield in reduced irrigation regimes. As moisture stress in root zone escalated, senescence was hastened and diminished photosynthetically active surfaces, which lowered straw yield. Similar findings were reported by Jaffar *et al.* (2017).

The different weed management practices resulted in the highest straw yield (kg ha^{-1}) during both the years of study. Weed-free condition, application of herbicide combination and mechanical weeding along with line weeding resulted in higher straw yield (kg ha^{-1}) when compared with unweeded check. Significantly highest straw yield (kg ha^{-1}) was achieved in Weed-free (mechanical weeding at 15, 35 and 55 DAS with line weeding) (8036 and 8186 kg ha^{-1}) and it was on par with Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS) (7714 and 8044 kg ha^{-1}). Mechanical weeding along with line weeding, pre and post-emergence application of herbicides resulted in effective and timely weed management and recorded lower weed density, dry matter and less competition from weeds to the crop which produced the higher plant height, leaf area and dry matter which resulted in higher straw yield. Similar findings were reported by Deiveegan *et al.* (2017). Application of herbicide alone i.e Pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE resulted in significantly higher straw yield (kg ha^{-1}) (7258 and 7513 kg ha^{-1}) when compared with Control (unweeded check) which resulted in the lowest straw yield (4827 and 5000 kg ha^{-1}).

CONCLUSION

The results of the study revealed that irrigation regimes and weed management practices significantly influenced the growth and yield of wet seeded rice. The highest growth and yield of wet seeded rice observed in Farmers practice (continuous flooding of 2-5 cm from 3-4 DAS) and it was on par with AWDI at 5 cm depletion of ponded water. Similarly highest growth and yield of wet seeded rice under weed management practices was achieved in Weed free condition (mechanical weeding at 15, 35 and 55 DAS with line weeding) and it was on par with pyrazosulfuron ethyl (10% WP) 20 g ha^{-1} PE *fb* penoxsulam (1.02%) + cyhalofop butyl (5.1%) 120 g ha^{-1} PoE + mechanical weeding at 45 DAS).

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Research Article
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ASSESSMENT OF GENETIC VARIABILITY, CHARACTER ASSOCIATION AND PATH ANALYSIS IN MAIZE (*Zea mays* L.)

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ABSTRACT

The present investigation was conducted to estimate the genetic parameters and character association of 62 maize genotypes for eleven characters at Maize Research Centre, Rajendranagar during *Rabi*, 2020-21. Analysis of variance revealed the existence of significant variability among the genotypes. Among the traits studied, plant height, ear height, number of kernels per row and 100 seed weight showed moderate GCV with high heritability and high genetic advance as percent of mean. The grain yield showed a significant positive genotypic correlation coefficient with all the characters except with days to 50 % tasseling, days to 50 % silking and days to maturity. The path coefficient analysis revealed that days to 50 % tasseling, days to 50 % silking, plant height, ear height, ear length, number of kernels rows per ear, number of kernels per row and 100 seed weight exhibited positive direct effects on grain yield whereas days to maturity and ear girth showed a negative direct effect on grain yield. The selection of characters with moderate to high GCV with high heritability, high genetic advance as percent of mean and characters which shows significant positive genotypic correlation coefficient along with positive direct effect contributing towards yield plays an important role in increasing the grain yield.

Keywords: Genetic variability, correlation coefficient, path co-efficient analysis

Maize (*Zea mays* L.) is known as a queen of cereals due to its high genetic potential. Traditionally, maize is a *kharif* crop, but it can be grown in all three seasons. *Rabi* maize is gaining popularity due to low infestation of pests and diseases. In India, it is the third most important food crop after rice and wheat. Maize plays a significant role in human and livestock nutrition worldwide.It is the world's most widely grown cereal and is the primary staple food in many developing countries. It is a versatile crop with wider genetic variability and is able to grow successfully throughout the world covering tropical, subtropical, and temperate agro-climatic conditions (Matin *et al.* 2017)

The acreage and production of maize in the country are increasing, but it is not sufficient to meet the people's demand as compared to the world perspective. In order to overcome this problem, maize breeders need to pay special attention to the identification of maize genotypes with higher yields and better quality. The availability of adequate genetic diversity is crucial for gaining significant genetic progress in applied breeding programs. The yield is attributed to a complex chain of interrelating effects of different characters (Singh *et al.* 2005). Therefore, the determination of genetic parameters, correlation and path coefficients between yield and yield traits are important for the selection of favourable plant types for effective maize breeding programs.

Genetic correlation analysis is a handy technique that elaborates the degree of association among important quantitative traits. The studies on correlation are quite old and extensive but, unfortunately, there is hardly any rule set on how much a character contributes to the expression of other characters (s) in a plant population (Ahmed *et al.* 2020). Path analysis (Wright, 1921) has been used to determine the nature of relationships between grain yield and its contributing components and to identify the components with significant effects on yield to be used as selection criteria. Using this method, it is possible to obtain information on the direct and indirect effects of traits on a principal variable.

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The aim of our present study is to estimate the genetic basis of grain yield components and to develop suitable selection criteria for future maize breeding programs.

MATERIAL AND METHODS

The experiment material comprised of sixty-two maize genotypes which were evaluated in a randomized block design with two replications at Maize Research Centre, Rajendranagar, Hyderabad (27.2046°N, 77.4977°E) during *Rabi*, 2020-21. The experimental units consisted of two rows of 4 m length plots, with a spacing of 0.6 m × 0.2 m (row to row and plant to plant). The recommended agronomic package of practices and plant protection measures were followed to maintain a healthy and proper crop stand. Data were recorded from five randomly selected plants from each entry in all the two replications for the characters like plant height (cm), ear height (cm), ear length (cm), ear girth (cm), number of kernel rows per ear, number of kernels per row and 100-seed weight (g). Whereas for days to 50 % tasseling, days to 50 % silking, days to maturity and grain yield, data were recorded on plot basis and plot yield was converted to kg/ha. Analysis of variance was done for all the characters under study using the mean values (Singh and Choudhury, 1985). Genotypic and phenotypic co-efficient of variations were estimated according to Burton (1952) and Singh and Choudhary (1985). Heritability in a broad sense (h^2b) was estimated according to the formula suggested by Johnson *et al*. (1955) and Hanson (1961). The genetic advance was calculated following the formula given by Johnson *et al*. (1955). The genetic advance as percent of mean was calculated by the formula of Comstock and Robinson (1952). Correlations were estimated as suggested by Al-Jibouri *et al*. (1958). The partitioning of genotypic correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Dewey and Lu (1959). Data were analyzed by using WINDOW STAT 9.2 version software.

RESULTS AND DISCUSSION

The mean sum of squares from the analysis of variance revealed significant effects on yield. All the studied characters, showed the existence of a significant amount of genetic variability among 62 maize genotypes (Table 1). The extent of variability for any character is very important for the improvement of a crop through breeding. The variability of the characters is measured by mean, range, Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation

Table 1. Analysis of variance for yield and yield attributing traits in 62 maize genotypes

Character /Source of variation	Mean sum of squares of		
	Replications	Genotypes	Error
d.f.	1	61	61
Days to 50 % tasseling	2.40	14.46 **	0.70
Days to 50 % silking	2.50	16.45 **	0.97
Days to maturity	0.86	37.74 **	1.92
Plant height (cm)	195.25	743.57 **	56.31
Ear height (cm)	14.23	122.26 **	4.05
Ear length (cm)	0.06	1.64 **	0.23
Ear girth (cm)	0.04	1.48 **	0.32
Number of kernels rows per ear	0.03	1.11 **	0.16
Number of kernels per row	0.14	7.60 **	0.53
100 seed weight (g)	0.01	16.77 **	0.46
Grain yield (kg/ha)	1429.41	357021.79 **	73445.02

* and ** indicates significance at 5% and 1 % level respectively, df= degrees of freedom

Table 2. Estimation of genetic parameters in 62 maize genotypes

Characters	Mean	Range	GCV (%)	PCV (%)	Heritability h^2(%) broad sense	Genetic Advance	Genetic Advance as per cent of mean
Days to 50% tasseling	57.33	55.67-66.17	4.57	4.81	95.00	5.13	8.94
Days to 50% silking	59.83	59.00-69.50	4.65	4.93	94.26	5.40	9.03
Days to maturity	99.80	97.50-113.70	4.20	4.50	95.00	8.30	8.30
Plant height (cm)	141.50	92.83-162.17	13.10	14.13	92.69	35.40	25.02
Ear height (cm)	60.83	35.00-67.00	12.64	13.06	96.74	15.32	25.19
Ear length (cm)	9.61	8.57-12.98	8.74	10.10	86.51	1.50	15.57
Ear girth (cm)	11.67	9.00-12.66	6.54	8.16	80.11	1.26	10.79
No of kernels rows per ear	11.00	9.67-12.67	6.28	7.26	86.48	1.23	11.19
No of kernels per row	14.67	12.00-20.67	12.82	13.74	93.31	3.61	24.65
100 Seed weight (g)	17.33	15.00-26.67	16.47	16.94	97.27	5.72	33.01
Grain yield (kg/ha)	2098.28	1353.16-3131.83	17.95	22.11	81.16	629.58	30.00

GCV- Genotypic coefficient of variation, PCV-Phenotypic coefficient of variation

Table 3. Genotypic correlation for yield and yield attributing characters

Characters	Days to 50 % tasselling	Days to 50 % silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels rows per ear	No. of kernels per row	100 Seed weight (g)	Grain yield (kg/ha)
Days to 50 % tasselling	1.000	0.999 *	0.949	-0.413	-0.146	-0.360	-0.380 **	0.063	-0.227 *	-0.049 *	-0.103 *
Days to 50 % silking		1.000	0.925	-0.425	-0.147 **	-0.355	-0.375	0.063	-0.228 *	-0.049	-0.103 **
Days to maturity			1.000	-0.392 *	-0.079	-0.439 *	-0.368 **	0.098 *	-0.204 *	-0.072 *	-0.136 *
Plant height (cm)				1.000	0.546 **	0.250 **	0.400 **	0.166	0.191 **	0.684 *	0.589 **
Ear height (cm)					1.000	0.053 **	0.032 **	0.015 **	0.022 *	0.256 *	0.284 *
Ear length (cm)						1.000	0.218 *	0.065 *	-0.147 **	0.602 *	0.545 *
Ear girth (cm)							1.000	0.526 *	0.490	0.593 **	0.444 *
No. of kernels rows per ear								1.000	0.237 *	0.597 **	0.578 **
No of kernels per row									1.000	0.356 **	0.314 **
100 Seed weight (g)										1.000	0.878 **
Grain yield (kg/ha)											1.000

***and** indicates significance at 5% and 1 % level respectively.**

Table 4. Estimates of direct (bold diagonal) and indirect effect (off-diagonal) at the genotypic level for different characters on grain yield

Characters	Days to 50% tasselling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernels rows per ear	No. of kernels per row	100 Seed weight (g)	Grain yield (kg/ha)
Days to 50% tasselling	**0.201**	0.213	0.191	-0.083	-0.029	-0.072	-0.076	0.012	-0.045	-0.009	-0.103 *
Days to 50% silking	0.001	**0.001**	0.004	0.001	0.005	0.078	0.015	0.024	0.012	0.015	-0.103 **
Days to maturity	-0.264	-0.268	**-0.278**	0.109	0.022	0.122	0.102	-0.027	0.056	0.020	-0.136 *
Plant height (cm)	-0.024	-0.025	-0.023	**0.058**	0.032	0.014	0.023	0.009	0.011	0.040	0.589 **
Ear height (cm)	-0.012	-0.013	-0.006	0.046	**0.085**	0.004	0.002	0.001	0.001	0.021	0.284 **
Ear length (cm)	-0.048	-0.048	-0.058	0.033	0.007	**0.133**	0.029	0.008	-0.019	0.080	0.545 *
Ear girth (cm)	0.087	0.088	0.084	-0.092	-0.007	-0.050	**-0.229**	-0.120	-0.112	-0.136	0.444 *
No. of kernels rows per ear	0.017	0.017	0.027	0.045	0.004	0.018	0.144	**0.274**	0.065	0.164	0.578 **
No. of kernels per row	-0.028	-0.029	-0.025	0.023	0.002	-0.018	0.060	0.029	**0.123**	0.044	0.314 **
100 Seed weight (g)	-0.032	-0.034	-0.047	0.447	0.167	0.393	0.387	0.390	0.233	**0.653**	0.878 **

Residual effect = 0.426
***and** indicates significance at 5% and 1 % level respectively.**

(PCV), Heritability (h^2 b), Genetic Advance (GA) and GA as a percentage of mean represented in Table 2.

The mean values ranged from 55.67 to 66.17 for days to 50 % tasseling, 59.00 to 69.50 for days to 50 % silking, 97.50 to 113.70 for days to maturity, 92.83 to 162.17 for plant height, 35.00 to 67.00 for ear height, 8.57 to 12.98 for ear length, 9.00 to 12.66 for ear girth, 9.67 to 12.67 for number of kernel rows per ear, 12.00 to 20.67 for number of kernels per row, 15.00 to 26.67 for 100 seed weight and 1353.16 to 3131.83 for grain yield. It clearly indicates a considerable amount of variability is present in the genotypes. The phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the characters studied indicating that they all interacted with the environment.

According to Deshmukh *et al.* (1986) estimates of PCV and GCV were classified as low (< 10 %), medium (10-20 %), and high (> 20 %). The PCV and GCV ranged from 4.50 to 22.11 and 4.20 to 17.95 for days to maturity to grain yield respectively. Grain yield (kg/ha) recorded high PCV (22.00) and moderate GCV (17.95). Whereas plant height, ear height, number of kernels per row and 100 seed weight recorded medium PCV and GCV but ear length showed medium PCV and low GCV. It indicates that the selection may be effective based on these characters with high and medium PCV and GCV values and their phenotypic expression would be a good indication of genetic potential. Similar results were reported by AL-Naggar *et al.* (2021) and Magar *et al.* (2021).

Heritability estimates may be useful in predicting the expected progress to be achieved through the process of selection. Genetic coefficient of variation along with heritability estimate provides a reliable estimate of the amount of genetic advance to be expected through phenotypic selection (Wright, 1921). According to Singh (2001) heritability (broad sense) values greater than 80 % indicate the existence of very high heritability, values from 60-79 % are moderately high, values from 40-59 % are medium and values less than 40 % are low. Heritability ranged from 80.11 % for ear girth to 97.27 % for 100 seed weight. All the studied characters exhibit high heritability (> 80 %). These findings are in accordance with the results obtained by Matin *et al.* (2017). Johnson *et al.* (1955) classified genetic advance as percent of mean (GAM) values from 0-10 % are low, 10-20 % are moderate and > 20 % are high. Genetic advance and genetic advance as percent of mean ranged from 1.23 (for the number of kernels per row) to 692.58 (for grain yield) and 8.30 to 33.01 for days to maturity and 100 seed weight respectively. High genetic advance in the percentage of mean was exhibited by plant height, ear height, number of kernels per row, 100 seed weight and grain yield (kg/ha) *viz*., (GAM > 20 %) indicating a high degree of genetic variability for this character, low genetic advance in the percentage of mean were exhibited by days to 50 % tasseling, days to 50 % silking and days to maturity. Similar results were reported by Belay (2018), Jaiswal *et al.* (2019) and Bhadru *et al.* (2020).

In general, genotypic correlations among traits affecting grain yield explain true association as they exclude the environmental influences, which indicates that improvement in the grain yield of maize can be accomplished through selections based on these correlations. Grain yield showed significant positive genotypic correlation coefficient with 100 seed weight (0.878**), plant height (0.589**), number of kernels rows per ear (0.578), ear length (0.545*), ear girth (0.444*), number of kernels per row (0.314**) and ear height (0.284*). Whereas negative correlation with days to 50% tasseling (-0.103*), days to 50% silking (-0.103**), days to maturity (-0.136*) as represented in Table 3. Similar observations were reported by Tollenaar *et al.* (2004) and El-Shouny *et al.* (2005). These findings are contrary to the results obtained by some of the researchers (Sadek *et al.*, 2006 and Aman *et al.*, 2020).

The path coefficient analysis was done to identify the important yield attributes by estimating the direct effects of the contributing characters to yield and separating the direct from the indirect effects through other related characters by partitioning the correlation coefficient and finding out the relative importance of different characters as selection criteria (Ahmed *et al.,* 2020). The results of path coefficient analysis revealed that days to 50 % tasseling (0.201) days to 50 % silking (0.001), plant height (0.058), ear height (0.085), ear length (0.133), number of kernel rows per ear (0.274), number of kernels per row (0.123) and 100 seed weight (0.653) were found to show positive direct effects on grain yield (Table 4). Similar results were reported by Kumar *et al.* (2013) and Natraj *et al.* (2014). Days to 50% tasseling showed a highly positive indirect effect on grain yield through days to 50 % silking, followed by days to maturity and the number of kernel rows per ear. These results are in accordance with the results obtained by Vara prasad and shivani (2017). Days to 50 % silking and the number of kernel rows per ear showed a positive indirect effect on grain yield through all the studied characters. Plant height, ear height and 100 seed weight showed a positive indirect effect on yield via all the studied characters except days to 50 % tasseling, days to 50% silking and days to maturity. These results are similar to the findings reported by Poudel *et al.* (2016). Days to maturity have yielded a positive indirect effect on yield via plant height, ear height, ear length, ear girth, number of kernels per row and 100 seed weight. Ear length showed a positive indirect effect on grain yield through all the characters except days to 50 % tasseling, days to 50 % silking, days to maturity and number of kernels per row. Similar results were reported by Hailegebrial *et al.* (2015). Ear girth yielded a negative indirect effect on yield through all studied characters except days 50 % tasseling, days to 50 % silking and days to maturity. The number of kernel rows per ear showed a positive indirect effect on yield via plant height, ear height, ear girth, number of kernels per row and 100 seed weight and a negative indirect effect through days to 50 % tasseling, days to 50 % silking, days to maturity and ear length. Similar results were reported by Shikha *et al.* (2020). The residual effect was found to be 0.456, which indicates that there are some other yield attributing characters, which are not included in the study.

CONCLUSION

The present study concludes that the characters like plant height, ear height, number of kernels per row and 100 seed weight, showed moderate GCV with high heritability, high genetic advance as percent of mean and significant positive genotypic correlation coefficient along with considerable direct and indirect effects on grain yield, indicating that these characters are controlled by additive gene action and phenotypic selection for these characters will be effective for the future breeding program.

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Research Article
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EVALUATION OF *TRICHODERMA* SPP. AGAINST SEED AND SOIL BORNE DISEASES OF GROUNDNUT, SOYBEAN AND SESAMUM UNDER *IN VITRO* CONDITIONS

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ABSTRACT

The present study was conducted to evaluate the efficacy of biocontrol agents against stem rot disease in groundnut, charcoal rot disease in soybean and stem and root rot disease of sesame by employing dual culture technique with six isolates of Trichoderma spp. obtained from ICAR-IIOR during the year 2020. The results indicated that T. harzianum (Th4d) was found effective in inhibiting the mycelial growth of S. rolfsii in groundnut (71.9%), M. phaseolina in soybean (67%) and M. phaseolina in sesamum (66%) followed by T. asperellum (TaDOR 7316) isolate inhibited mycelial growth against three test pathogens to an extent of 61.9 per cent, 61.9 per cent and 55.9 per cent, respectively. Least mycelial inhibition was recorded by T. asperellum (Ta10) against groundnut stem rot (42.8%) and soybean charcoal rot (53.7%) followed by T. asperellum (Ta11) in sesamum stem and root rot with 43.3 per cent inhibition. The antagonists T. harzianum (Th4d) showing its efficacy of more than 50 per cent can be utilized as an effective biocontrol agent against test pathogens in three important oilseed crops under field conditions.

Keywords: Groundnut stem rot (*S. rolfsii*), soybean charcoal rot (*M. phaseolina*), sesamum root rot (*M. phaseolina*), *Trichoderma*, *in vitro*.

Among oilseed crops cultivated soybean, groundnut, sesame, sunflower, mustard, safflower and niger are important edible oilseed crops. Sesame (*Sesamum indicum* L.), groundnut (*Arachis hypogaea* L.), soybean (*Glycine max* L.) are the major oil seed crops grown in India to an extent of 60.15 lakh ha of groundnut with production of 10.2 Mt and productivity of 1703 kg/ha. In Telangana, the crop is grown in area of 1.27 lakh ha with production of 0.29 Mt and productivity of 2286 kg/ha.

Soybean is grown to an extent of 129.18 lakh ha with production of 12.61 Mt and productivity of 976.15 kg/ha. In Telangana state, the crop is grown in an area of 1.62 lakh ha with production of 0.245 Mt and productivity of 1503 kg/ha.

Sesamum is grown in an area of 17.23 lakh ha with production of 0.81 Mt and productivity of 474 kg/ha. In Telangana it is grown in an area of 0.23 lakh ha with production of 14880 tonne and productivity of 647 kg/ha, (India stat, 2020-21).

In groundnut stem rot disease caused by *S.rolfsii* is a major soil borne pathogen and reduced yield up to 10 - 25 per cent. Under severe conditions it may be high as high as 80 per cent. *M. phaseolina* is a major root pathogen that causes charcoal rot in more than 500 plant species worldwide. This disease has caused economically important yield losses of various oilseed crops such as sesame (*Sesamum indicum* L.), soybean (*Glycine max* L.), corn (Z*ea mays* L.), sorghum (*Sorghum bicolor*), sunflower (*Helianthus annuus* L.) and cotton (*Gossypium herbaceum* L.) (Rayatpanah *et al*., 2012).

Therefore, the present study has been taken up to evaluate the isolates of *Trichoderma* (ICAR-IIOR) against major seed – soil borne pathogens of groundnut, soybean and sesamum.

MATERIAL AND METHODS

Diseased / infected roots of sesame, soybean and stem of groundnut were collected from fields of

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ICAR-IIOR, Rajendranagar, Hyderabad during the year 2020. The infected roots were washed thoroughly under running tap water and transferred to blotter paper. They were cut into 0.20 to 1.0 cm thick pieces and surface sterilized with 1% sodium hypochlorite solution for 1 minute followed by three washings in sterile distilled water and placed on Petri plates containing PDA medium. The plates were incubated at 25°C to 28°C for 4 to 5 days. The fungal growth emerging from diseased root and stem pieces were picked up and the cultures were further purified by single hyphal tip method or single spore isolation method (Hansen, 1926) and incubated at 28±2°C for 7 to 8 days. The isolates of *Trichoderma* were collected from rhizosphere soils of ICAR-IIOR were used for *in vitro* studies.

Evaluation of bioagents by dual culture assay under *in vitro*

The antagonistic potential of six isolates of *Trichoderma viz., T. asperellum* (TaDOR 7316), *Trichoderma* (T16), *T harzianum* (Th)*, T. asperellum* (Ta10), *T. asperellum* (Ta11) and *T. harzianum* (Th4d) were evaluated against *S. rolfsii* of groundnut, *M.phaseolina* of soybean and sesame under *in-vitro* conditions by dual culture technique (Dennis and Webster, 1971).

Twenty millilitre of sterilized lukewarm potato dextrose agar (PDA) medium was aseptically poured into 90 mm diameter sterilized Petri plates. Five mm disc of six *Trichoderma* isolates and test pathogens, *S. rolfsii* of groundnut and *M. phaseolina* of soybean and sesamum were cut with sterilized cork borer from the edge of seven day old culture and placed on the solidified medium opposite to each other separately. Similarly, control was maintained by placing 5 mm discs of three test fungal pathogens separately in centre of the PDA plates. Each treatment was replicated three times. The Petri plates were incubated at 25±1°C in a BOD incubator. Petri plates were observed for antagonistic interactions between the pathogen and the biocontrol agent. The per cent inhibition (I) of the test pathogens was calculated when the growth of the pathogen was fully grown in the control plates by using the formula given by Vincent (1947).

$$I = \frac{C - T}{C} \times 100$$

Where

I = Per cent inhibition of mycelial growth

C = Radial growth of pathogen in control (mm)

T = Radial growth of pathogen in treatment (mm)

Statistical analysis

The experiment was laid out in Completely Randomized Block Design (CRD) with three replications. Data was expressed as mean value and results were presented as the average of three replicates. Following one-way analysis of variance (ANOVA) and Duncan's Multiple Range Test, (DMRT). All the calculations were made by using Statistical Package for Social Sciences (SPSS) at 5% probability.

RESULTS AND DISCUSSION

Evaluation of bioagents against stem rot of groundnut under *in vitro*

The results on the efficacy of six bioagents *viz*., *T. asperellum* (TaDOR 7316), *Trichoderma* (T16), *T harzianum* (Th)*, T. asperellum* (Ta10), *T. asperellum* (Ta11) and *T. harzianum* (Th4d) evaluated under *in vitro* conditions indicated that *T. harzianum* (Th4d) was most effective in inhibiting the mycelial growth of the *S. rolfsii* (71.9%) followed by *T. asperellum* TaDOR,7316 (61.9%), *T. harzianum* Th (58.7%), *T.asperellum* Ta11 (46.3%), *Trichoderma* T16, (45.0%), Whereas *T. asperellum* Ta10 isolate showed lowest mycelial growth inhibition of *S. rolfsii* (42.8%) (Table 1, Figure 1 and Plate 1). The present results are in accordance with the findings of Rakholiya (2009) who studied the efficacy of ten *Trichoderma* isolates against *S. rolfsii* under *in vitro* conditions. The highest mycelial growth inhibition of *S. rolfsii* was recorded with *T. harzianum*-4J (77.41%) followed by *T. viride*-54 (68.52%) and *T. harzianum*-2J (64.44%). Similarly, Vineela *et al.* (2017) also reported that *T. harzianum* was most effective with mycelial growth inhibition of *S. rolfsii* to an extent of 74 per cent followed by *T. hamatum* (72.2%). Kushwaha *et al.* (2018) also reported antagonistic activity *Trichoderma* against *S.rolfsii*. After 15 days of incubation, *T. viride* showed significant reduction in sclerotia production (91.31%) followed by *T. harzianum* (84.92%) and *T. virens* (84.29%), respectively.

Table1. Evaluation of the efficacy of *Trichoderma* isolates against *S. rolfsii* in groundnut under *in vitro* conditions

S. No.	Treatments	Mycelial growth (cm)	Per cent mycelial inhibition
1	*Trichoderma asperellum (Ta Dor 7316)*	3.4	61.9bc
2	*Trichoderma (T16)*	5.0	45.0^{b}
3	*Trichoderma harzianum (Th)*	3.7	58.7^{bc}
4	*Trichoderma asperellum (Ta10)*	5.2	42.8^{b}
5	*Trichoderma asperellum (Ta11)*	4.8	46.3^{b}
6	*Trichoderma harzianum (Th4d)*	2.5	71.9^{c}
7	Control	9.0	0.0^{a}

* Means are compared by Duncan's multiple range test (DMRT). Results are expressed as mean values; similar letters are not significantly different from each other at 5% probability.

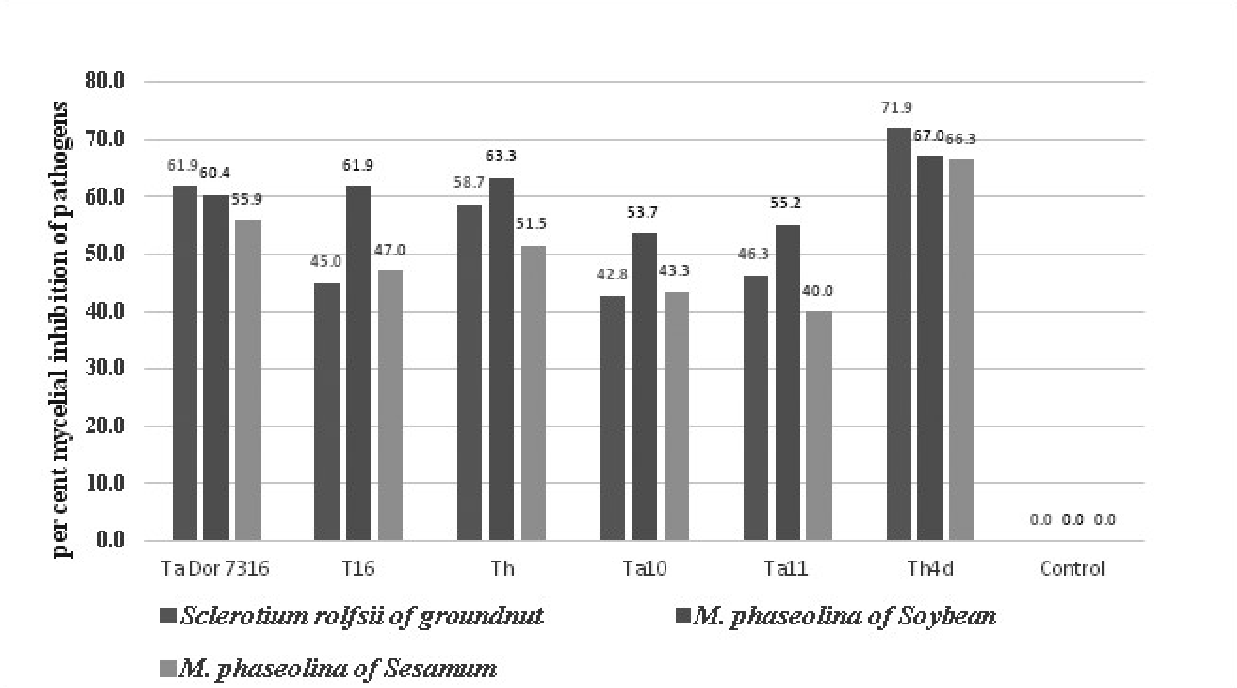


Figure 1. Effect of *Trichoderma* isolates on mycelial inhibition of *S. rolfsii* of groundnut, *M. phaseolina* of soybean and sesamum under *in vitro* conditions.

Evaluation of bioagents against charcoal rot of soybean under *in vitro*

The efficacy of six bioagents *viz.*, *T. asperellum* (TaDOR 7316), *Trichoderma* (T16), *T harzianum* (Th), *T. asperellum* (Ta10), *T. asperellum* (Ta11) and *T. harzianum* (Th4d) were evaluated against *M. phaseolina* under *in vitro* conditions using dual culture technique. The results indicated that *T. harzianum* Th4d was effective in inhibiting the mycelial growth of the test fungus (67%) followed by *T. harzianum* Th (63.3%) and *T. asperellum* TaDOR, 7316, *Trichoderma* T16 (61.9%), *T. asperellum* Ta11 (55.2%), and *T. asperellum* Ta10 (53.7%) showed least mycelial inhibition of *M. phaseolina,* (Table 2, Figure 1 and Plate 2). Similarly, Sreedevi *et al.* (2011) studied five isolates of *Trichoderma* and reported that *T. harzianum* (T3), *T. viride* (T1) had maximum antifungal activity against *M. phaseolina* as compared to other *Trichoderma* spp. by inhibiting the mycelial growth of 64.4 per cent and 61.1 per cent, respectively. Khalili *et al.* (2016) studied

Table 2. Evaluation of *Trichoderma* isolates against *M. phaseolina* in soybean under *in vitro* conditions.

S. No.	Treatments	Mycelial growth (cm)	Per cent mycelial inhibition
1.	*Trichoderma asperellum* (Ta Dor 7316)	3.4	61.9[c]
2.	*Trichoderma* (T16)	3.4	61.9[c]
3.	*Trichoderma harzianum* (Th)	3.3	63.3[c]
4.	*Trichoderma asperellum* (Ta10)	4.2	53.7[b]
5.	*Trichoderma asperellum* (Ta11)	4.0	55.2[b]
6.	*Trichoderma harzianum* (Th4d)	3.0	67.0[d]
7.	Control	9.0	0.0[a]

* Means are compared by Duncan's multiple range test (DMRT). Results are expressed as mean values; similar letters are not significantly different from each other at 5% probability.

Table 3. Evaluation of *Trichoderma* isolates against *M. phaseolina* of sesamum under *in vitro* conditions

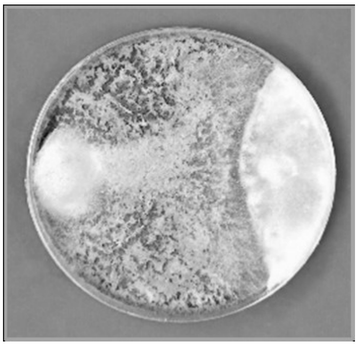
S. No.	Treatments	Mycelial growth (cm)	Per cent mycelial inhibition
1.	*T. asperellum* (Ta Dor 7316)	4.0	55.9[e]
2.	*Trichoderma* (T16)	4.8	47.0[cd]
3.	*T. harzianum* (Th)	4.4	51.5[de]
4.	*T. asperellum* (Ta10)	5.1	43.3[bc]
5.	*T. asperellum* (Ta11)	5.4	40.0[b]
6.	*T. harzianum* (Th4d)	3.0	66.3[f]
7.	Control	9.0	0.0[a]

* Means were compared by Duncan's multiple range test (DMRT). Results are expressed as mean values; similar letters are not significantly different from each other at 5% probability.

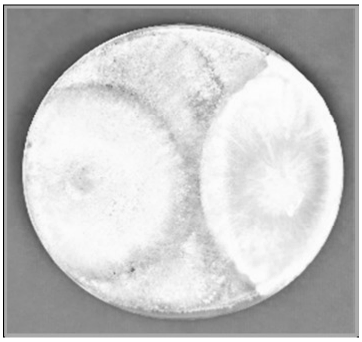
three fungal bioagents isolates (T2, T10 and T12) of *T. harzianum* significantly inhibited the growth of *M. phaseolina* and T12 isolate showing considerably higher growth inhibition (72.31%) than T2 and T10 isolates. Pastrana *et al.* (2016) reported that *T. asperellum* showed 55 per cent radial mycelial growth inhibition of *M. phaseolina*. Patidar and Vibha (2018) evaluated ten isolates of *T. asperellum* against mycelial growth of *M. phaseolina*. The highest mycelial inhibition (30.75 mm) was recorded with *T. asperellum* isolate 1 while least (39.34 mm) with *T. asperellum* isolate.

Evaluation of bioagents against stem and root rot of sesamum under *in vitro*

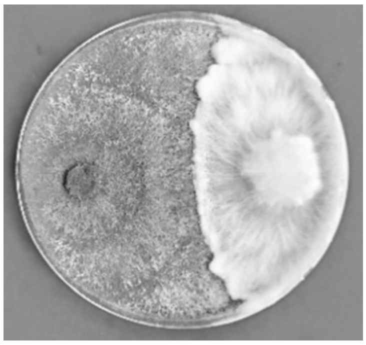
The efficacy of *T. asperellum* (TaDOR 7316), *Trichoderma* (T16), *T harzianum* (Th), *T. asperellum* (Ta10), *T. asperellum* (Ta11) and *T. harzianum* (Th4d) were evaluated under *in vitro* conditions using dual culture technique against *M. phaseiolina* of sesamum. The results presented in Table 3 showed that *T. harzianum,* Th4d was found effective in inhibiting the mycelial growth of the test fungus (66.3%) followed by *T. asperellum* TaDOR,7316 (55.9%), *T. harzianum* Th (55.1%), *Trichoderma* T16 (47 %), *T. asperellum* Ta10 (43.3%) and *T. asperellum* Ta11 (40 %) showed lowest mycelial inhibition of *M. phaseolina,* (Figure 1 and Plate.3). Karthikeyan (2015) who tested the efficacy of *T. harzianum, T. viride, T. hamatum* and *T. reesii* against *M. phaseolina* under *in vitro* conditions. The maximum mycelial inhibition was recorded with *T. viride* (77. 8%) followed by *T. harzianum* (75.5 %) and *T. reesii* (72.2%). Satpathi and Gohel (2018) tested the efficacy of antagonists against mycelial growth of *M. phaseolina* under *in-vitro* conditions and reported significant inhibition by *T. atroviride* (60%), *T. harzianum* (57.78%) and *T. virens* (55.56%).



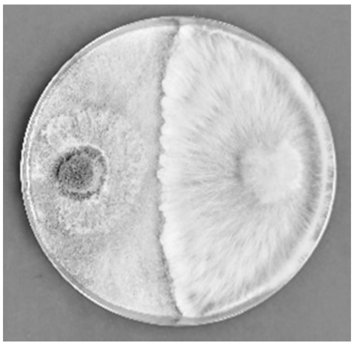
Isolate Ta DOR 7316



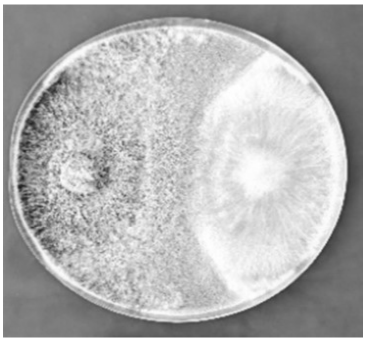
Isolate T16



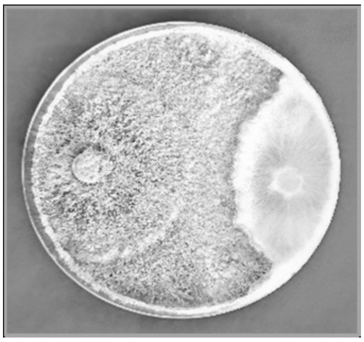
Isolate Th



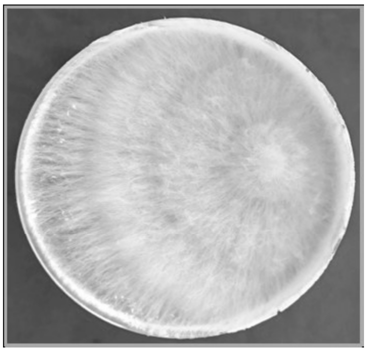
Isolate Ta10



Isolate Ta11



Isolate Th4d



Control

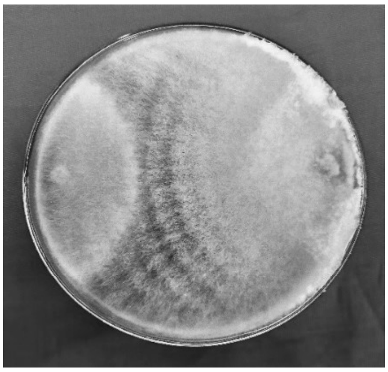
Plate 1: Evaluation of different isolates of *Trichoderma* on radial mycelial growth of *S. rolfsii* of groundnut under *in-vitro*

Isolate Ta DOR 7316

Isolate T16

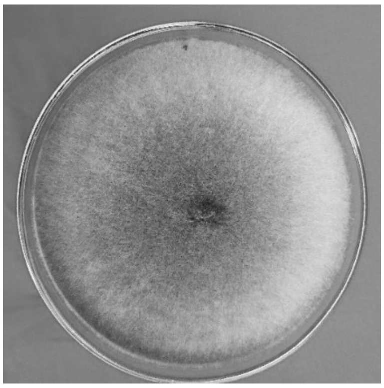
Isolate Th

Isolate Ta10



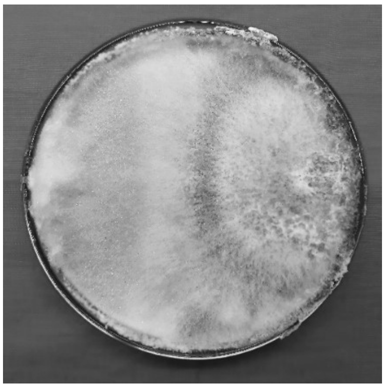
Isolate Ta11

Isolate Th4d



Control

Plate 2: Evaluation of different isolates of *Trichoderma* on radial mycelial growth of *M. phaseolina* of soybean under *in-vitro.*

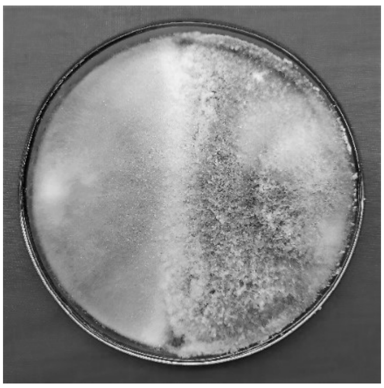


Isolate Ta DOR 7316

Isolate T16

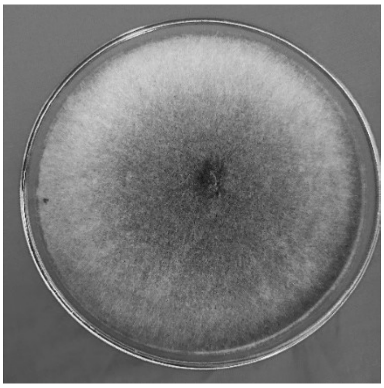
Isolate Th

Isolate Ta10



Isolate Ta11

Isolate Th4d



Control

Plate 3: Evaluation of different isolates of *Trichoderma* on radial mycelial growth of *M. phaseolina* of sesamum under *in-vitro*.

CONCLUSION

Among six isolates of *Trichoderma*, *T. harzianum* (Th4d) was found effective in inhibiting the mycelial growth of three test pathogens. Further, the study suggests that the evaluation of *T. harzianum* (Th4d) isolate under field conditions helps in developing integrated disease management (IDM) strategy against seed and soil borne diseases of oilseed crops.

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Research Article
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SURFACE AND SUBSURFACE WEED SEED EMERGENCE STUDIES IN PUDDLED RICE AS INFLUENCED BY IRRIGATION AND WEED MANAGEMENT OPTIONS

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ABSTRACT

An experiment was conducted to study the effect of irrigation and weed management practices on the emergence of weed seed bank at college farm situated in College of Agriculture, PJTSAU, Hyderabad, during *kharif* 2019 and 2020. The experiment consisted of two main plot treatments and nine subplot treatments laid out in Split plot design replicated thrice. Two irrigation practices (Alternate wetting and drying irrigation and continuous submergence) and nine weed management practices. Pretilachloar 50 EC 660 g ha^{-1}(PE) *fb* mechanical weeding twice, pyrazosulfuron ethyl + pretilachloar 6.15 GR 615 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE), orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) *fb* mechanical weeding twice, penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) *fb* mechanical weeding, flucetosulfuron 10 % WG 25 g ha^{-1} (Early PoE) *fb* mechanical weeding, bispyribac sodium + 2, 4-D sodium salt 56.3 SP 703.75 g ha^{-1} (PoE) *fb* mechanical weeding once, florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1} (PoE) *fb* mechanical weeding once, hand weeding twice and unweeded control. The irrigation practices not influenced the emergence of different species of weeds at surface and subsurface soil as well as total number of weeds. With respect to weed managements, significantly lowest in emergence of different species of weeds recorded in hand weeding treatment, whereas higher emergence of weeds was recorded in unweeded control.

Key words: Irrigation, weed management, soil depth, weed seedbank weeds category.

Rice (*Oryza sativa* L.) is considered as the “global grain” and is the staple food for Asia and for more than half of the global population. In India, it contributes to about 40 per cent of the total food grain production. It provides 43 per cent of calorie requirement for more than 70 per cent of Indian population (Mishra *et al.*, 2016). In world, rice is grown in 169.5 million hectares with production of 761.50 million tones and average productivity of 4501 kg ha^{-1} (FAO, 2018). India ranks first in rice area and second in production and is grown in almost all the states of the country. Total estimated area under rice in India in 2019-20 is 43.6 million hectares with a production of 118.8 million tones and average productivity of 2722 kg ha^{-1} (Indiastat, *2019-20*). Telangana state contributes 2.01 million hectare area with a production of 7.43 million tonnes, at an average productivity of 3694 kg ha^{-1} during 2019-20 (Indiastat, *2019-20*). The country has to produce about 130 million tonnes of rice by 2025 to meet the food requirement of the ever growing population (Kumar, 2015).

AWD technique is a necessity for modern farming of rice as it is profitable over the continuous flooding irrigation system which prevents the wastage of scarce and vital water resources, irrigation cost and protects the environment from degradation. It helps to enhance food security by increasing the production, nutrient content and minimizing the toxic elements in rice. This method of managing the water in which water will not be wasted rather it will aid the root growth; facilitate higher nutrient uptake, and increase land and water productivity (Nagarajan *et al.*, 2021).

A single application of (pre (or) post emergence) herbicide does not provide satisfactory weed control throughout the crop season as some of the broad - leaf weeds and sedges are not controlled effectively (Yadav *et al.,* 2019). Hence there is need to depend on other methods of weed management as a part of integrated weed management for effective control of weeds. Most of the weeds (indigenous and invasive) seeds get preserved in soil horizons as weed seed

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bank which ensure their survival leading to the spoilage of quantitative and qualitative functioning of agricultural farms. Weed seed bank density may vary in different soils ranging from zero in virgin soils to 4100 - 137700 m^{-2} (**Lee and Christian, 2017**). Seeds may remain dormant for a long period of time and seed dormancy also influences weed emergence patterns and weed control decisions (**Forcella *et al.*, 2000**). **Beckie *et al.*, (2005**) found that integrated weed management prevented weeds to shed their seeds in the field, weed patches were reduced by 35%. This study is need of an hour as knowledge is index of efficiency of weed management measures on weed seed bank and thereby passage of generation.

MATERIAL AND METHODS

The present experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State. The farm is geographically situated at an altitude of 542.3m above mean sea level at 17°19' N latitude and 78°23' E longitude in the Southern Telangana agro-climatic zone of Telangana and it is classified under semi-arid tropics (SAT) according to Troll's classification. The average annual temperature is 26.6 °C and monthly mean maximum and minimum temperatures range between 21 - 33 °C. Summers (March – June) are hot and humid, with a 30 °C. Maximum temperatures often exceed 40 °C between April and May. The coolest temperatures occur in December and January. Temperature occasionally drops to 10 °C. More than 75 % of rainfall is due to south-west monsoon and occurs between June to September. The location receives 2,731 hours of sunshine per year. The rainfall during experimental period was 603.6 and 744.6 mm received in 18 and 23 rainy days in 2019 and 2020 respectively. Late onset of monsoon was observed and rainfall mostly received in September (297.4 and 384.8 mm) and October (129.0 and 344.6 mm) months.

The soil of the experimental was sandy loam in texture (70.4 sand, 11.8 % silt, and 17.8 % clay) with an average bulk density of 1.59 Mg m^3 for 0-60 cm depth and is slightly alkaline in reaction with pH around 7.96 and Ec ranging from 1.24 (ds m^{-1}). The available N, P, and K was 153.56, 20.2, and 272.3 kg ha^{-1}. The experiment consisted of two main plot treatments and nine subplot treatments laid out in Split plot design (SPD) replicated thrice, details on treatments follows

Symbol	Treatments
Main plots - Irrigation methods (2)	
I_1	Alternate wetting and drying irrigation of 5 cm, when water level falls below 5 cm from soil surface in perforated pipe
I_2	Recommended submergence of 2 - 5 cm water level as per crop stage
Sub plots - Weed management options (9)	
W_1	Pretilachloar 50 EC 660 g ha^{-1} (PE) fb mechanical weeding twice at 25 and 45 DAT
W_2	Pyrazosulfuron ethyl + pretilachloar 6.15 GR 615 g ha^{-1} (PE) fb penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE)
W_3	Orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) fb mechanical weeding twice at 25 and 45 DAT
W_4	Penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) fb mechanical weeding at 25 and 45 DAT
W_5	Flucetosulfuron 10 WG 25 g ha^{-1} (Early PoE) fb mechanical weeding at 45DAT
W_6	Bispyribac sodium + 2, 4-D sodium salt 56.3 SP 25.0 + 678.75 g ha^{-1} (PoE) fb mechanical weeding at 45 DAT

Symbol	Treatments
W_7	Florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1}(PoE) fb mechanical weeding at 45 DAT
W_8	Hand weeding at 25 and 45 DAT (weed free)
W_9	Control (Unweeded)

The soil seed bank was estimated by the seeding emergence method as described by Ter Heerdt *et al.* (1996). The weed seed bank studies were done at end of each cropping season. In each plot, two soil samples at depth 0 - 5 cm and 5 - 10 cm were collected using a 10 cm diameter and 15 cm depth metal core. Two sets of experiments were done, each for each depth of soil. Soil samples were partially air-dried and then clods are broken by hand. These soil samples were spread in a plastic trays (20 cm length, 5 cm width and 5 cm depth) and placed under sunlight and watered daily. The emerged weed seedlings were identified, counted, and removed until emergence was nil. Soil was then dried, rewatered, and stirred to initiate further emergence and emerged weeds were recorded**.**

Data on emergence of different category of weed seedlings were subjected to analysis of variance procedures as outlined for split plot design (Gomez and Gomez, 1984). Statistical significance was tested by F-value at 0.05 level of probability and critical difference was worked out where ever the effects were significant. As the observation on emergence on weed seedlings, normality of distribution was not seen and hence, the values were subjected to square root transformation ($\sqrt{x}$ + 0.5) prior to statistical analysis to normalize their distribution as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Seedling emergence of grasses, sedges and broadleaved weeds in soil after harvest was counted for two depths of soil *viz*, top soil (0-5 cm) and subsoil (5-10 cm). Data pertaining to weed seed bank studies is presented in Table 1 and Table 2.

A. Emergence of weed seedlings at top soil

Grasses

Irrigation and weed management have influence on the grass seedling emergence (Table 1). Among irrigation practices, AWD recorded comparatively more number of grass seedlings (2.32 and 2.36) over CF (2.29 and 2.32). Among the weed management practices, hand weeding recorded significantly lowest count of grasses emergence (W_8) (1.58 and 1.58) followed by chemical weed control (W_2) (1.71 and 1.83). Unweeded control (W_9) has recorded significantly higher emergence of grasses (2.97 and 2.79). Interaction was found to be non-significant for grass emergence between irrigation and weed management practices.

Sedges

Influence of irrigation on emergence of sedges was found to be non-significant. However, CF has recorded lower number of sedges (1.14 and 1.10), whereas higher number of sedges was noted under AWD (1.08 and 1.07). Among the weed management practices, chemical weed control has recorded significantly lower count of sedges (W_2) (0.71 and 0.71). It was followed by IWM involving penoxsulam + butachloar (PE) *fb* mechanical weeding twice (W_4) (0.71 and 1.0) and hand weeding (W_8) (1.0 and 0.71). Unweeded control (W_9) recorded significantly higher emergence of sedges (1.73 and 1.41). Interaction was found to be non-significant for grass emergence between irrigation and weed management practices.

Broadleaved weeds (BLW's)

Broadleaved weeds emergence also differed due to irrigation and weed management practices. Among irrigation practices, AWD has registered higher number of BLW's (2.32 and 2.05) emergence than CF (2.11 and 1.96). Hand weeding (W_8) has recorded significantly lowest BLW's count in emergence of seedlings (1.35 and 1.28), which was followed by chemical weed control (W_2) (1.49 and 1.47). Unweeded control (W_9) has registered highest emergence of BLW's (3.03 and 2.88). Interaction of tillage and weed management was found to be significant.

Total emergence of weeds

Emergence of total weed seedlings was influenced by both irrigation and weed management practices. Among the irrigation practices, AWD has recorded higher count of total weed seedlings (3.30

Table 1: Weed seed emergence at top soil as influenced by irrigation and weed management in rice

Treatments	Grasses			BLWs			Sedges			Total weeds		
	2019	2020		2019	2020		2019	2020		2019	2020	
Main plot treatments (Irrigation)												
I_1- Alternate wetting and drying irrigation	2.32 (4.88)	2.36 (5.07)	4.98	2.32 (4.88)	2.05 (3.71)	4.30	1.08 (0.66)	1.07 (0.65)	0.66	3.30 (10.42)	3.15 (9.43)	9.93
I_2- continuous submergence as per crop stage	2.29 (4.76)	2.32 (4.87)	4.82	2.11 (3.97)	1.96 (3.34)	3.66	1.14 (0.79)	1.10 (0.70)	0.75	3.17 (9.52)	3.07 (8.91)	9.22
S.E m±	0.05	0.05		0.05	0.04		0.02	0.02		0.06	0.06	
C.D (P=0.05)	NS	NS		NS	NS		NS	NS		NS	NS	
C.V (%)	6.36	7.10		8.41	8.22		5.62	6.54		7.17	7.25	
Sub-plot treatments (Weed management)												
W_1 – Pretilachloar 50 EC 660 g ha^{-1}(PE) *fb* mechanical weeding twice at 25 and 45 DAT	2.35 (5.00)	2.40 (5.25)	5.13	2.30 (4.77)	2.18 (4.25)	4.51	1.0 (0.50)	1.0 (0.50)	0.50	3.28 (10.27)	3.24 (10.00)	10.14
W_2 - Pyrazosulfuron ethyl + pretilachloar6.15 GR 615 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE)	1.71 (2.42)	1.83 (2.85)	2.64	1.49 (1.72)	1.47 (1.65)	1.69	0.71 (0.00)	0.71 (0.00)	0.00	2.15 (4.14)	2.24 (4.50)	4.32
W_3- Orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) *fb* mechanical weeding twice at 25 and 45 DAT	2.24 (4.40)	2.19	4.40 (2.65)	2.21 (0.80)	1.77	3.53 (0.50)	1.14 (9.70)	1.0	0.65 (4.50)	3.19 (4.30)	2.82 (7.45)	8.58
W_4- Penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) *fb* mechanical weeding at 25 and 45 DAT	2.19 (4.30)	1.87 (3.00)	3.65	2.00 (3.50)	1.58 (2.00)	2.75	0.71 (0.00)	1.0 (0.50)	0.25	2.88 (7.80)	2.45 (5.50)	6.65
W_5- Flucetosulfuron 10 % WG 25 g ha^{-1}(Early PoE) *fb* mechanical weeding at 45DAT	2.43 (5.40)	2.62 (6.35)	5.88	2.40 (5.25)	2.09 (3.85)	4.55	1.14 (0.80)	1.22 (1.00)	0.90	3.46 (11.45)	3.42 (11.20)	11.33
W_6 -Bispyribac sodium + 2, 4-D sodium salt 56.3 SP 703.75 g ha^{-1} (PoE) *fb* MW at 45 DAT	2.65 (6.50)	2.74 (7.00)	6.75	2.35 (5.00)	2.09 (3.85)	4.43	1.22 (1.00)	1.41 (1.50)	1.25	3.61 (12.50)	3.58 (12.35)	12.43

Contd...

Treatments	Grasses			BLWs			Sedges			Total weeds		
	2019	2020		2019	2020		2019	2020		2019	2020	
W_7- Florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1} (PoE) *fb* mechanical weeding at 45 DAT	2.43 (5.40)	2.67 (6.65)	6.03	2.35 (5.00)	2.24 (4.50)	4.75	1.0 (0.50)	1.0 (0.50)	0.50	3.38 (10.90)	3.49 (11.65)	11.28
W_8- Hand weeding at 25 and 45 DAT (weed free)	1.58 (2.00)	1.58 (2.00)	2.00	1.35 (1.31)	1.28 (1.15)	1.23	1.0 (0.50)	0.71 (0.00)	0.25	2.08 (3.81)	1.94 (3.15)	3.48
W_9 _ Control (Unweeded)	2.97 (8.30)	2.79 (7.30)	7.80	3.03 (8.71)	2.88 (7.80)	8.26	1.73 (2.50)	1.41 (1.50)	2.00	4.47 (19.51)	4.14 (16.60)	18.06
S.E m±	0.07	0.07		0.07	0.06		0.03	0.03		0.09	0.09	
C.D (P=0.05)	0.13	0.14		0.15	0.12		0.06	0.05		0.19	0.17	
C.V (%)	5.01	5.02		5.92	5.38		4.56	4.61		5.47	5.13	
Interaction	NS	NS		NS	NS		NS	NS		NS	NS	

Table 2: Weed seed emergence from subsoil as influenced by irrigation and weed management in rice

Treatments	Grasses			BLWs			Sedges			Total weeds		
	2019	2020		2019	2020		2019	2020		2019	2020	
Main plot treatments (Irrigation)												
I_1- Alternate wetting and drying irrigation	2.27 (4.67)	2.30 (4.78)	4.72	1.85 (2.91)	1.80 (2.73)	2.82	0.81 (0.16)	0.71 (0.00)	0.08	2.87 (7.49)	2.83	7.62
I_2- Continuous submergence as per crop stage	2.24 (4.52)	2.29 (4.76)	4.65	2.28 (2.77)	2.10 (2.64)	2.71	0.87 (0.26)	0.71 (0.00)	0.13	2.84 (7.55)	2.81 (7.42)	7.49
S.E m±	0.05	0.05		0.04	0.04		0.02	0.01		0.07	0.07	
C.D (P=0.05)	NS	NS		Ns	Ns		NS	NS		NS	NS	
C.V (%)	8.40	8.41		8.65	8.09		8.49	6.64		8.62	8.43	
Sub-plot treatments (Weed management)												
W_1 – Pretilachloar 50 EC 660 g ha^{-1}(PE) *fb* mechanical weeding twice at 25 and 45 DAT	2.12 (4.00)	2.40 (5.25)	4.63	2.28 (4.70)	2.10 (3.90)	4.30	0.84 (0.20)	0.71 (0.00)	0.10	3.07 (8.90)	3.11 (9.15)	9.03
W_2 - Pyrazosulfuron ethyl + pretilachloar 6.15 GR 615 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE)	1.73 (2.49)	1.87 (3.00)	2.75	1.66 (2.25)	1.75 (2.55)	2.40	0.71 (0.00)	0.71 (0.00)	0.00	2.29 (4.74)	2.46 (5.55)	5.15
W_3- Orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) *fb* mechanical weeding twice at 25 and 45 DAT	2.32 (4.90)	2.35 (5.00)	4.95	1.58 (2.00)	1.69 (2.35)	2.18	0.81 (0.16)	0.71 (0.00)	0.08	2.75 (7.06)	2.80 (7.35)	7.21
W_4- Penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) *fb* mechanical weeding at 25 and 45 DAT	2.04 (3.68)	2.16 (4.15)	3.92	1.53 (1.85)	1.41 (1.50)	1.68	0.71 (0.00)	0.71 (0.00)	0.00	2.46 (5.53)	2.48 (5.65)	5.59
W_5- Flucetosulfuron 10 % WG 25 g ha^{-1}(Early PoE) *fb* mechanical weeding at 45 DAT	2.28 (4.68)	2.32 (4.90)	4.79	1.73 (2.50)	1.79 (2.70)	2.60	0.71 (0.00)	0.71 (0.00)	0.00	2.77 (7.18)	2.85 (7.60)	7.39
W_6 -Bispyribac sodium + 2, 4-D sodium salt 56.3 SP 703.75 g ha^{-1} (PoE) *fb* MW at 45 DAT	2.40 (5.27)	2.35 (5.00)	5.14	1.91 (3.15)	1.80 (2.75)	2.95	0.71 (0.00)	0.71 (0.00)	0.00	2.99 (8.42)	2.87 (7.75)	8.09
W_7- Florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1} (PoE) *fb* mechanical weeding at 45 DAT	2.61 (6.30)	2.55 (6.00)	6.15	1.93 (3.22)	1.80 (2.75)	2.99	0.94 (0.39)	0.71 (0.00)	0.20	3.23 (9.91)	3.04 (8.75)	9.33

Contd...

Treatments	Grasses			BLWs			Sedges			Total weeds		
	2019	2020		2019	2020		2019	2020		2019	2020	
W_8- Hand weeding at 25 and 45 DAT (weed free)	1.48 (1.70)	1.69 (2.35)	2.03	1.32 (1.25)	1.22 (1.00)	1.13	0.71 (0.00)	0.71 (0.00)	0.00	1.86 (2.95)	1.96 (3.35)	3.15
W_9 _ Control (Unweeded)	2.87 (7.75)	2.77 (7.15)	7.45	2.29 (4.75)	2.27 (4.65)	4.70	1.32 (1.25)	0.71 (0.00)	0.75	3.76 (13.75)	3.51 (11.80)	12.78
S.E m±	0.08	0.08		0.07	0.06		0.03	0.02		0.11	0.10	
C.D (P=0.05)	0.16	0.16		0.14	0.12		0.07	Ns		0.22	0.20	
C.V (%)	6.26	6.14		6.55	5.64		6.73	5.59		6.19	5.83	
Interaction	NS	NS		NS	NS		NS	NS		NS	NS	

and 3.15), which was comparable with CF condition (3.17 and 3.07). It is due to lesser weed infestation during previous cropping. Similar finding was reported by Petrikovszk *et al*. (2020). Among weed management practices, hand weeding treatment (W_8) has recorded significantly lower emergence of weeds (2.08 and 1.94), which was followed by chemical weed control (W_2) (2.15 and 2.24). IWMs involving pre-emergent herbicides fb mechanical weeding twice (W_2 & W_3) found to be good performer. Unweeded control (W_9) has recorded significantly higher emergence of weeds (4.47 and 4.14). Interaction was found to be non-significant for grass emergence between irrigation and weed management practices. These results were in agreement with findings of Islam (2012) and Riemens *et al*. (2007**).**

B. Weed seed bank studies at subsoil

Grasses

Irrigation and weed management have influence on the grass seedling emergence (Table 2). Among irrigation practices, AWD recorded grass seedlings (2.27 and 2.30), which was comparable to CF (2.24 and 2.29). Among the weed management practices, hand weeding recorded significantly lowest count of grasses emergence (W_8) (1.48 and 1.69) followed by chemical weed control (W_2) (1.73 and 1.87). Unweeded control (W_9) has recorded significantly higher emergence of grasses (2.87 and 2.77). Interaction was found to be non-significant for grass emergence between irrigation and weed management practices.

Sedges

Influence of irrigation on emergence of sedges was found to be non-significant. CF has recorded number of sedges (0.81 and 0.71), whereas higher number of sedges was noted under AWD (0.87 and 0.71). Among the weed management practices, chemical weed control has recorded significantly lower count of sedges (W_2) (0.71 and 0.71), IWM involving penoxsulam + butachloar (PE) *fb* mechanical weeding twice (W_4) (0.71 and 0.71) and hand weeding (W_8) (0.71 and 0.71). Unweeded control (W_9) recorded significantly higher emergence of sedges (1.32 and 0.71). Similar finding was reported by Robert and Shirtliffe (2009). Interaction was found to be non-significant for grass emergence between irrigation and weed management practices.

Broadleaved weeds (BLW's)

Broadleaved weeds emergence also differed due to irrigation and weed management practices. Among irrigation practices, AWD has registered higher number of BLW's (1.85 and 1.80) emergence than CF (2.28 and 2.10). Hand weeding (W_8) has recorded significantly lowest BLW's count in emergence of seedlings (1.32 and 1.22) followed by IWMs involving preemergent herbicides (W_3 and W_4) and chemical weed control (W_2). Unweeded control (W_9) has registered highest emergence of BLW's (2.29 and 2.27). Interaction of tillage and weed management was found to be significant.

Total emergence of weeds

Among the irrigation practices, AWD (2.87 and 2.83) has recorded comparable count of total weed seedlings with CF condition (2.84 and 2.81). Similar finding was reported by Srivastava and Singh (2014). Among weed management practices, hand weeding treatment (W_8) has recorded significantly lower emergence of weeds (1.86 and 1.96), which was followed by chemical weed control (W_2) (2.29 and 2.46). IWMs involving pre-emergent herbicides fb mechanical weeding twice (W_2 & W_3) found to be good performer. Unweeded control (W_9) has recorded significantly higher emergence of weeds (3.76 and 3.51). Interaction was found to be non-significant for grass emergence between irrigation and weed management practices.

CONCLUSION

Based on the results obtained in the present investigation, it is concluded from irrigation management of different weed management practices, hand weeding and chemical weed control found to be superior by having reducing weed seed bank in soil in both top and sub soil. IWMs involving pre-emergent herbicides *fb* mechanical weeding twice was also good performer in reducing weed seed load to succeeding seasons. Emergence of broad leaved weeds and sedges in sub soil considerably low compared to top soil whereas as grassy weeds had comparable counts in both the depths.

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Research Article
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GENETIC PARAMETERS, CHARACTER ASSOCIATION AND PATH COEFFICIENT ANALYSIS IN POST-RAINY SORGHUM LANDRACES

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ABSTRACT

Field experiment involving 97 post-rainy (rabi) sorghum landraces was conducted at the Indian Institute of Millets Research (ICAR-IIMR), Hyderabad (Telangana) during 2020-21 to estimate genetic parameters, character association and path coefficients for grain yield, its component traits, and other agronomic traits. Significant variation between genotypes was noticed for all the 12 traits studied. Estimates of heritability varied from 25% (number secondary branches on central primary branch of panicle) to 94% (panicle length). Grain yield per plant, test weight, panicle weight, panicle length and number of grains on central primary branch of panicle have shown high estimates of heritability and genetic advance. Genotypic correlation analysis of grain yield showed positive significant association with all the traits except number of grains on central primary branch of panicle. Panicle weight and number of grains per panicle are strongly correlated with grain yield genotypically. Further, path coefficient analysis revealed that test weight, plant height, panicle weight, and seed hardness were the traits showing positive direct effect on grain yield at both phenotypic and genotypic level. CSV-216R (114g), Malegaon local (104g), CSV-29R (97g), IC345199 (92g) are the genotypes which yielded highest among all the genotypes in terms of grain yield per plant. Selection of tall plants with more green leaves and medium length panicles holding a greater number of primary branches with bold seeds could be fetching for improvement of grain yield in post-rainy sorghum.

Key words: Post-rainy sorghum, landraces, heritability, correlation, path coefficient analysis.

Sorghum (*Sorghum bicolor* (L.) Moench), also known as *Jowar* and *Jonnalu* (in telugu) is used worldwide for its nutritious grain as food, fodder, and feed for animals. It is the third most important food crop after rice and wheat. It is drought tolerant cereal cultivated with less water requirement, thereby making it an excellent choice for semi-arid and dry areas. Sorghum is being cultivated globally in an area of 40.82 m ha with a grain production of 61.49 m t and productivity of 1506 kg ha^{-1}. In India, sorghum is grown as second most important dryland crop after bajra. Its total production in the country is 34.75 m t from an area of 40.93 m ha and productivity of 849 kg ha^{-1} (FAOSTAT, 2019).

The main objective of a plant breeder is to evolve high yielding varieties for meeting growing demands of food and fodder (Chauhan and Pandey, 2021). Grain yield is a quantitative trait and highly influenced by several genes and environmental changes. Direct selection for grain yield as such could be misleading due to the complexities in the genetic control of grain yield and its components (Khandelwal *et al.,* 2015). A successful plant breeding program depends basically on the information on the trait genetic variability, heritability, and association of morpho-agronomic traits with grain yield. Grain yield in sorghum is a factor of component traits like, grain number and grain size. Grain number depends on the number of primary branches and secondary branches on the panicle, and they differ from genotype to genotype.

Exploitation of existing released varieties may not be rewarding for grain yield improvement due to lack of genetic diversity, as reflected in the yield plateau being observed in recent times (Patil *et al.,* 2022). Landraces, evolved and maintained by farmers have not been systematically characterized though being excellent sources for trait diversity, needs to be exploited for the presence of positive alleles. The importance of estimation of genetic parameters for different traits and their association with grain yield in germplasm evaluation is the basic step for a successful breeding programme (Prakash *et al.,* 2010). Correlation analysis does the job of finding positive and negative associations between the characters with grain yield.Hence it should be the foremost important study to be carried out in choosing the characters for improving

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the grain yield. On the other hand, Path coefficient analysis which splits the correlation coefficient into the measures of direct and indirect effects, measures the relative importance of the causal factor individually and useful tool in selection.

Therefore, to bring about any grain yield improvement, the knowledge of association of grain yield with its component traits will be of immense help. Hence, the current study was conducted to analyze and determine trait diversity, genetic parameters, traits interrelationship and to establish cause-effect relationships with grain yield. In our opinion, this is possibly the first study to involve primary and secondary branches along with grain number as components of grain yield.

MATERIAL AND METHODS

Experimental material

A set of 97 sorghum landraces representing the states of Maharashtra, Karnataka, and Telangana were used as the experimental material in this study along with seven checks viz., M35-1, CSV-22R, CSV-26R, CSV-29R, CSV-216R, Phule Revati, and RS585. The list of genotypes used in this study was given in Table 3.

Location and season of experiment

Experiment was carried out during the post-rainy season of 2020-2021 at the ICAR-Indian Institute of Millets Research (ICAR-IIMR), located at an altitude of 523 m above mean sea level, at the latitude of 17.19°N and longitude of 78.23°E in Rajendranagar, Hyderabad, Telangana. The experiment was planted on 27th of November 2020, on deep black soils, and the average annual rainfall of the location is 854.6 mm (https://city.imd.gov.in).

Layout and field design

The experiment was laid out in Alpha Lattice design (Patterson and Williams, 1976) with three replications. Hand planting was carried out in 3 m row length and trials were planted in rows at a spacing of 60 cm between rows and 10 cm between plants in a row. A total of 104 entries were fitted in 13 incomplete blocks in a replicate with 8 plots per block in each replication according to the design generated by the Breeding Management System software (Provided by the Integrated Breeding Platform).

Traits Evaluation

Observations were recorded on 12 trait., namely days to 50% flowering (DFF; days), plant height (PH; cm), number of green leaves at boot leaf stage (NOGL), panicle length (PL; cm), panicle weight per plant (PWPP; g), number of primary branches per panicle (NPBPP), number of secondary branches on central primary branch of the panicle (NBSBPP), number of grains on central primary branch of the panicle (SeedsperSB), number of grains per panicle (SeedPP) grain yield per plant (GYPP; g), 100-grain weight (TW; g) and seed hardness (SH; kgf; taken according to Aruna *et al.,* 2020). All traits were measured as per the procedure given by Brown *et al.* (2006) and Reddy *et al.* (2013). All the observations were recorded on five randomly selected plants in each plot except days to 50% flowering, 100 seed weight and seed hardness. A minimum of 25 plants were maintained per plot, and 5 random plants were tagged for agronomic observations.

Statistical analysis and interpretation of data

Descriptive statistics and genetic parameters

The plot data was compiled by taking the mean values of five plants from each treatment and replication for different traits. The pooled mean values of those were then subjected to further statistical and biometrical analysis. Simple statistical estimates, viz. mean, range and coefficient of variation were analyzed according to Steel *et al*., (1997). Phenotypic and genotypic coefficient of variations, heritability, and genetic advance as percentage of mean were also analyzed.

Analysis of variance

In the data analysis, normalizing the data distribution as one of the primary assumptions was conducted by using R software. The data of the experiment was statistically analyzed according to the technique of analysis of variance (ANOVA) for the alpha lattice design developed by Patterson and Williams (1976) (Table 1).

The arrangement of treatments in alpha lattice into groups gave possibility to the data analysis as a randomized complete block experiment. ANOVA was conducted with the use of the “metan” package (Olivoto and Lúcio, 2020) in R software. The linear model of observations in alpha design is of the form:

$$y_{ijk} = \mu + t_i + r_j + b_{jk} + e_{ijk}$$

Table 1: Form of analysis of variance for alpha lattice design

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F_{cal}
Replications	r-1	SS_r	MS_r	
Blocks (within replications)	rs-r	SS_b	MS_b	
Treatments	t-1	SS_t	MS_t	F_0
Error	rt-rs-t+1	SS_e	MS_e	
Total	tr-1	SS_T	-	

where y_{ijk} denotes the value of the observed trait for i-th treatment received in the k-th block within j-th replicate (superblock), t_i is the fixed effect of the i-th treatment ($i = 1,2,\ldots,t$); r_j is the effect of the j-th replicate (superblock) ($j = 1,2,\ldots,r$); b_{jk} is the effect of the k-th incomplete block within the j-th replicate ($k = 1,2,\ldots s$) and e_{ijk} is an experimental error associated with the observation of the i-th treatment in the k-th incomplete block within the j-th complete replicate.

Simple correlation and genotypic correlations

To analyze the relationships between grain yield and yield components, simple, and genotypic correlations were performed using "*variability*" package in R software.

Path coefficient analysis

Path coefficient analysis (Dewey and Lu, 1959) was done based on phenotypic and genotypic correlation coefficients taking grain yield as effect (dependent variable) and the remaining characters as cause (independent variable). Direct and indirect effects of component characters on grain yield were worked out using path coefficient analysis using "*path_coeff()*" function in "*metan*" package of R software.

RESULTS AND DISCUSSION

Descriptive statistics and genetic parameters

Basic statistical and genetic parameters like mean values, range (minimum value and maximum value), phenotypic coefficient of variability, genotypic coefficient of variability, heritability, and genetic advance as percent of mean were presented in Table 2. The mean values for genotypes were given in Table 3. In the present study, phenotypic coefficient of variation was recorded higher than genotypic coefficient of variation for all the traits indicating the influence of environmental factors. Similar results were reported by Chauhan and Pandey (2021).

Table 2: Genetic parameters of twelve traits studied during post rainy season 2020-21

TRAIT	MEAN	RANGE	C.V	h^2	GCV	PCV	GAM	CD @ 5%
GYPP	55	19.5 -114	34.44	90	31.94	38.93	53.99	19.73
TW	3.04	1.6 - 4.5	22.00	89	20.76	24.30	36.54	0.62
SH	6.04	4.03 - 7.51	12.63	76	11.03	15.36	16.3	1.04
DFF	90	76.3 – 106	6.03	90	5.60	6.79	9.53	5.53
PH	214	134 – 290	11.81	76	10.11	14.62	14.42	36.38
PWPP	68	23.9 – 134	30.36	89	27.98	34.64	46.55	22.46
NOGL	10	9 - 13.5	6.60	56	4.93	8.96	5.58	1.29
PL	17	9.37 – 24	22.46	94	21.82	23.67	41.44	2.5
NPBPP	68	17.4 - 88.6	16.54	71	14.09	20.57	19.89	16.3
NBSBPP	7	4.65 - 10.5	15.22	25	7.62	24.10	4.97	2.55
Seeds per SB	43	27.6 – 234	45.94	90	43.64	50.44	77.79	17.54
Seed PP	2855	1260 – 4498	23.45	44	15.90	33.82	15.41	1371.93

Table 3: Mean values of 104 genotypes studied for 12 traits during post-rainy season 2020-21

S.No.	GENOTYPE	GYPP	TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedsperSB	SeedPP
1	M35-1	62.1	2.87	6.32	88	198	72.9	11.9	16.1	71.3	8.9	46.7	3304
2	CSV-22R	86	2.97	5.7	88	249	108	11.7	21.8	84.9	6.43	51.3	4280
3	CSV-26R	68.7	3.33	5.76	84	222	82.7	10.8	20.3	63.3	7.07	46.7	2939
4	CSV-29R	97.4	3.3	5.57	90.7	290	112	12	22.9	82.1	9.7	49.7	4247
5	CSV-216R	114	3.67	5.45	93.7	278	134	12.3	14.9	84.2	8.9	52	4498
6	Phule Revati	71.3	3.27	6.01	85	191	86.7	11.7	20.4	78.1	7.23	52.5	4099
7	RS585	72.2	3.53	6.17	83.3	240	82.2	11.6	16.5	57.7	5.77	39	2230
8	RSLG2367	74.3	4.03	6.96	91.3	245	86.1	10.8	17.2	61.9	8.53	42.6	2634
9	IS 17774	38	1.6	4.63	93	217	58.7	10.9	11.2	84.2	6.2	39.7	3333
10	IS 17909	53.4	3.33	6.84	84.7	202	63	10.7	17.4	62.3	4.97	36.8	2318
11	IS 17913	78.6	3.67	5.91	88	256	91.4	11.2	18.8	69	6.63	40	2771
12	IS 18437	48	3.2	6.54	81.7	180	62.1	9.87	20.4	51.2	7.13	44	2256
13	IS 18509	34.2	2.63	5.5	83.3	212	44.8	9.87	11.2	55.8	5.93	48	2726
14	IS 18511	33.7	2.87	6.61	91	209	44	10.7	11	86.4	5.8	27.6	2381
15	IS 18512	26	1.7	4.5	81	193	36.5	9.73	11.5	53.5	6.03	32.6	1719
16	IS 18513	19.8	2.5	6.46	76.3	188	23.9	9.73	14.6	43.7	4.65	29.8	1260
17	IS 22109	34.9	2.6	5.38	84.7	178	45.1	9.8	15.7	61.6	6.77	50.8	3135
18	IS 22116	51.1	2.83	5.56	89.7	203	64.9	10	9.37	85	6.83	42.6	3613
19	IS 22117	59.9	2.7	7.23	87.7	222	74	10.7	21.7	64.3	7.57	49.8	3212
20	IS 22125	52.6	2.87	7.51	88	230	66.3	11.3	21.9	65.1	7.23	42.2	2744
21	IS 22127	42.9	2.2	6.29	88.7	246	54.8	10.9	20.2	61.6	6.83	40.3	2487
22	IS 22152	35.2	2.4	5.61	84.7	244	46	10.3	15.9	59.4	6.83	44.1	2622
23	IS 3815	29.6	2.23	6.49	91.7	168	41	10.2	11.2	80.1	5.7	32.6	2664
24	IS 4506	48.9	3.27	7.19	87.3	228	57.9	10.7	17.4	55.6	7.37	36.5	2030

Contd...

S.No.	GENOTYPE	GYPP	TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedsperSB	SeedPP
25	IS 5544	52.6	2.87	5.32	92	211	72.1	10.1	20.7	62.6	6.37	41.2	2605
26	IS 5581	59.9	4.33	6.6	85.7	213	68.3	10.8	17.3	63.2	6.97	44.9	2838
27	IS 5586	77.8	3.8	6.34	94.7	225	88.3	11.1	18.8	73.7	6.23	35.8	2712
28	IS 5659	68	3.3	6.45	92	204	85.9	10.2	13.2	81	8.13	43.7	3624
29	IC345186	57.6	3.07	6.25	85.7	228	67.7	10.9	17.8	69.3	5.67	38.4	2720
30	IC345188	54.7	3.13	6.25	88.3	224	65.7	11.3	21.4	65.1	7.87	44.7	2908
31	IC345189	83.7	3.93	6.7	91.3	256	97	11.4	24	58.7	6.53	48.9	2934
32	IC345191	76.9	3.13	6.54	90.7	222	94	10.3	17.6	68.7	6.57	46.4	3272
33	IC345198	72.8	3.37	6.16	93.3	222	87	10.7	19.4	64.5	7.37	39.1	2509
34	IC345199	92.7	3.93	5.86	90	240	110	10.8	21.6	73.1	6.63	47.6	3582
35	IC345202	50.5	2.8	7.04	85.7	216	63.1	11.5	20.8	67.1	7.9	36.3	2401
36	IC345206	52.5	2.4	5.9	87.3	220	67.4	10.8	23.9	61.4	10.5	35.7	2202
37	IS 1412	29.9	2.1	4.7	81.7	202	37.9	11.1	13.1	53.8	5.3	34.3	1909
38	IS 5518	30.9	1.67	5.92	93	237	48.1	10.8	22	78.2	6.43	47.8	3740
39	IS 22174	30.8	2.5	4.85	85	195	39.8	10.1	13.5	62.1	6.2	46.9	2932
40	IS 22176	38.1	2.57	5.77	85.7	208	48.3	10.4	14.3	65.1	9.67	37.1	2412
41	5-4-1	54.2	3.57	7.09	87.3	230	62.4	10.5	20.1	65.2	7.17	42.2	2760
42	TSLC-1	77.8	4.2	5.97	98	205	91	11.3	13	73.6	6.17	40.8	2978
43	TSLC-3	60.3	3.77	6.92	106	223	71	10.8	14.2	65.9	7.13	40.8	2690
44	TSLC-4	68.7	4.17	5.67	95	205	84.1	10.3	20.3	69.4	7.63	37.8	2623
45	TSLC-5	71.2	4.5	6.68	94.7	219	84.3	10.3	18.2	74.1	5.5	38.2	2834
46	TSLC-9	67.9	3.17	6.02	93.3	236	84.4	11.3	18	73.4	8.1	50	3657
47	TSLC-11	75.1	4.07	6.57	92	234	89.7	10.7	22.1	70.2	6.83	45.2	3285
48	TSLC-12	77.1	3.8	6.07	93.7	218	91.3	10.7	20.3	78.8	7.03	45.2	3506
49	TSLC-14	45.8	2.87	6.51	94	213	63.3	10.8	17.6	74.4	6.7	40.2	3020

Contd...

S.No.	GENOTYPE	GYPP	TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedsperSB	SeedPP
50	TSLC-15	67.2	3.67	6.31	92.7	208	83.3	9.67	16.3	78.5	7.3	39.8	3144
51	TSLC-17	70	3.57	6.18	101	211	80.3	10.6	16.2	75	6.3	39.4	2934
52	TSLC-18	61.7	4.2	5.96	92.7	212	72.3	10.8	13.6	70	5.27	30.1	2110
53	TSLC-19	56.8	3.83	6.12	93.7	202	71.3	9.87	19.5	66.2	6.13	49.4	3301
54	TSLC-20	47.6	3.55	5.5	105	266	58.5	11.7	16.4	70.4	7.4	48.1	3632
55	TSLC-21	45.5	3.87	7.01	89.7	213	53.8	10.8	13	57.8	6.53	33	1892
56	TSLC-22	75.3	3.6	6.2	89	253	86.7	11.3	23.4	73.4	7.38	48.1	3526
57	TSLC-23	47.8	4.23	7.3	89	225	54.3	11.1	13.1	66.3	7.29	40	2669
58	TSLC-25	57.7	3.83	6.5	91.7	212	66.2	10.3	13.5	68.9	6.18	42.6	2918
59	TSLC-26	62.7	3.77	6.98	89	212	75.2	11.5	18	61.7	7.13	41.4	2547
60	TSLC-27	21.7	2.3	4.51	79	134	31	9.93	20.3	55.7	7.08	43.4	2379
61	IS 18411	19.5	2.3	5.57	82.7	193	26.5	10	12.3	50.1	5.6	27.7	1403
62	IS 24329	28.9	2.1	4.03	92	176	46.9	9.6	19.3	54.7	5.71	27.6	1511
63	IS 5123	59.1	2.97	6.2	95.3	219	70.1	11.4	11.5	74.2	8.18	36	2668
64	IS 5221	44.8	2.9	7.26	87	188	55.7	9.8	12	60.6	6.33	37.5	2251
65	IS 5241	61.8	3.83	7.04	88.3	198	72.8	10.4	11.7	48.1	7.36	31.8	1558
66	IS 5289	60.7	2.93	6.56	90	213	72.4	11.1	14.1	76	7	47.9	3687
67	IC345708	50.4	3.47	6.19	96.7	213	59.3	10.9	12.9	66	6.47	41.3	2792
68	IC345709	47.8	3.27	7.09	83.3	195	61.3	10.3	19	59.1	7.49	39	2288
69	IC345711	47.8	2.83	6.57	87.3	186	56.9	10	16.8	62.5	6.51	34.4	2159
70	IC392141	81	4.07	7.07	93.7	251	94.9	11.6	13.5	72.3	9.53	41.3	2935
71	IS 1522	25.4	2.07	4.86	80.3	177	32.8	10.1	11.9	48.5	6.4	33.5	1601
72	IS 17756	46.1	3.07	5.79	104	229	55.4	10.7	9.91	77.2	6.42	36.2	2815
73	PVRL16-1	51.4	3.5	6.28	89	210	64.1	10.4	11.9	69.4	6.16	37.7	2646
74	PVRL16-4	31.9	2.67	5.68	92	183	44.6	9.93	11.5	80.8	7.27	35.1	2981

Contd...

S.No.	GENOTYPE	GYPP	TW	S H	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedsperSB	SeedPP
75	PVRL16-6	60.5	2.97	6.87	87	202	73.9	10.5	18.3	84.7	7.6	48.7	4136
76	PVRL16-10	60.4	3.33	6.74	93.3	235	74.2	11.1	19.9	88.6	7.2	41.8	3712
77	PVRL16-11	54.2	3	5.93	99.3	175	65.7	10.1	11.2	65.4	5.82	37.9	2536
78	Wardha local	46.2	2	4.97	93.3	245	57.9	11.7	22.3	83.2	7.22	40.1	3318
79	Malegaon local	102	2.7	5.38	92	229	124	10.5	22.7	83.4	6.13	47.7	3990
80	Washim local-9	74	3.43	7.16	94	232	87.6	11.2	17.2	67.7	6.38	45.6	3033
81	Hinganghat local-17	52	2.73	6.95	88	223	63.2	11	18.6	64.7	6.64	37.8	2482
82	Kutki local -15	47.3	2.3	6.5	97.3	168	72.8	9	22.3	84.7	6.91	40.3	3371
83	RSLG2218	77.2	3.83	6.09	90.3	217	95.2	11	18.7	76.6	8.43	48	3634
84	RSLG2238	75.3	2.6	5.98	87.3	255	88.7	12.2	19.8	82.8	6.89	46.8	3879
85	RSLG2276	48.2	2.3	4.73	90	211	59.2	11.8	19.9	57.2	8.51	39	2416
86	RSLG2380	62.1	3.27	5.5	91.7	225	83.9	10.8	18.4	68.7	5.91	46	3210
87	RSLG2387	45	2.43	7.38	92.3	216	57.9	10.3	21.7	17.4	8.78	234	4022
88	RSLG2413	61.6	2.6	5.76	90.3	197	75.6	9.8	17.1	70.8	6.31	47.9	3410
89	IS 17957	41.4	2.9	5.44	84.7	182	63	9.93	13.8	64.5	6.91	44.2	2956
90	IS 17959	28	1.9	4.72	84	200	37.9	10.4	12.4	64.8	6.16	38	2419
91	IS 17962	31.6	1.97	5.18	86	182	45.9	9.8	12	71.5	5.61	41.2	2931
92	IS 18424	46.3	2.33	5.85	83.3	188	67.3	9.87	17.9	59.3	6.87	44.2	2644
93	IS 24338	25.5	2.47	5.63	85	219	34	11.5	19	56.8	7.67	32.8	1890
94	IS 24342	34.2	2.8	5	83.3	196	46	10.6	19.5	47.3	7.44	37	1772
95	IS 24361	65	3.07	5.14	98	223	79	11.1	13.2	78.5	6.6	48.6	3771
96	IS 4592	32.2	2.83	5.64	81.7	187	42.7	10.3	12.4	57.8	7.02	39.1	2262
97	IS 4895	37.5	2.23	5.09	90.7	200	57.7	10.2	19.8	62.6	7.64	49.1	3068
98	IS 4959	45.4	2.33	4.5	92.3	192	66.6	9.6	22.2	68.7	7.89	50.9	3512
99	IS 5010	33.5	2.2	5.4	83.7	203	47.4	10.6	12.9	63.3	5.24	40	2501

Contd...

S.No.	GENOTYPE	GYPP	TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedsperSB	SeedPP
100	IS 5031	47.9	2.1	5.07	90.7	199	71.1	11.2	22.2	85	8.62	37.9	3288
101	IS 5641	48.5	3.1	6.14	84	208	60.7	10.7	17	58.9	6.58	39.8	2359
102	IC343578	67.1	2.9	6.39	91.7	209	83	10.5	16.8	76.8	8.8	33.6	2621
103	IC420956	85.2	3.3	5.4	96	280	102	13.5	14.2	73.8	6.65	39.6	2922
104	IC343573	60.4	3.1	6.51	81	202	73.1	10.1	15.9	67.1	6.6	35.5	2392

Table 4: Analysis of variance for twelve traits studied during post rainy season 2020-21

SOV	Df	GYPP	TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedPP	SeedsperSB
Replications	2	43.29	0.23	2.69 **	38.37 **	5100.61 **	62.02	0.24	5.38	74.92	0.34	200017.44	133.00
Blocks	36	344.03 **	0.16	0.44	26.85 **	726.59 *	441.02 **	0.64	2.20	80.96	2.50	628553.25	123.70
Genotypes	103	1078.18 **	1.34 **	1.75 **	87.40 **	1918.57 **	1290.57 **	1.48 **	43.49 **	374.91 **	3.36 *	1345277.25 **	1180.38 **
Error	170	109.09	0.14	0.41	8.60	465.02	142.45	0.64	2.46	107.18	2.52	747045.43	117.70

** = Significant at 1% level. * = Significant at 5% level.

Genetic variability: Highest PCV and GCV were recorded by number of grains on central primary branch of panicle (50.44 and 43.64 respectively), followed by grain yield per plant (38.93 and 31.94 respectively), panicle weight (34.64 and 27.98 respectively), number of grains per panicle (33.82 and 15.9 respectively), test weight (24.3 and 20.76 respectively), number of secondary branches on central primary branch of panicle (24.1 and 7.62 respectively), panicle length (23.67 and 21.82 respectively), number of primary branches per panicle (20.57 and 14.09 respectively), seed hardness (15.36 and 11.03 respectively), plant height (14.62 and 10.11 respectively), number of green leaves (8.96 and 4.93 respectively) and days to 50% flowering (6.79 and 5.6 respectively).

Heritability and genetic advance

All the traits are exhibiting heritability in the range of 25% to 94%. According to Johnson *et al.,* (1955), broad sense heritability is classified as low (<30%), moderate (30-60%) and high (>60%). Grain yield per plant (90%), test weight (89%), days to 50% flowering (90%), plant height (76%), panicle weight per plant (89%), panicle length (94%) and number of grains on central primary branch of panicle (90%) have shown character heritability above 70%, which indicates these characters have high heritability and can be improved through selection. Seed hardness, number of green leaves and number of grains per panicle are showing moderate heritability values whereas the remaining trait i.e., number of secondary branches on central primary branch of panicle had shown low heritability values (24%).

Genetic advance as percentage of mean was ranged between 4.97% in number of secondary branches on central primary branch of panicle to 77.79% in number of grains on central primary branch of panicle. Highest GAM was recorded for number of grains on central primary branch of panicle as mentioned followed by grain yield per plant (53.99%), panicle weight (46.55%), panicle length (41.44%) and test weight (36.54%). Moderate GAM was recorded by number of primary branches per panicle (19.89%), seed hardness (16.3%), number of grains per panicle (15.1%) and plant height (14.42%). Low values of GAM were recorded by days to 50% flowering (9.53%), number of green leaves (5.58%) and number of secondary branches on central primary branch of panicle (4.97%).

High estimates of heritability and genetic advance were observed in the case of traits grain yield per plant, test weight, panicle weight, panicle length and number of grains on central primary branch of panicle. This indicates that there is a scope for improvement of these traits upon selection. These findings align with the reports of Chauhan and Pandey (2021) for days to 50% flowering, plant height, panicle weight, 100 seed weight and grain yield per plant.

Analysis of variance

Statistical analysis according to the technique of analysis of variance (ANOVA) for alpha lattice design studied for twelve traits is summarized in Table 4. Based on the results obtained, statistical analysis revealed that the genotypes included in the study had variation significant at 1% level for all traits except for number of secondary branches on central primary branch of the panicle (significant at 5% level). It could be concluded that differences between sorghum landraces may be due to genetical differences and indicating considerable amount of variation present in this material and revealing a higher level of diversity among the cultivars for these traits. This provides evidence for sufficient variability and selection based on these traits can be useful. Selection for grain yield can only be effective if desired genetic variability is present in the genetic stock.

Phenotypic and genotypic correlation analysis

This study reported that the genotypic correlation values are greater than phenotypic correlation values (Table 5). Similar results were reported by Jain *et. al.,* (2010); Kavya *et al.,* (2020); Rohila *et al.,* (2020); Rajarajan *et al.,* (2017). The phenotypic correlation analysis revealed that grain yield and panicle weight have positive significant correlation with all the traits except days to 50% flowering. Panicle weight, test weight, plant height, number of grains per panicle, number of green leaves, number of primary branches per panicle, panicle length and seed hardness are strongly in positive correlation with grain yield ($p<0.001$) whereas number of secondary branches on central primary branch of the panicle has positive correlation with the same at 5 % level of significance. Days to 50% flowering, panicle weight, seed hardness, plant height, number of green leaves and number of grains per panicle are in positive significant correlation with test weight. Seed hardness,

Table 5: Genotypic and phenotypic Correlation matrix between 12 traits studied during post rainy season 2020-21

		GYPP	TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedPP	SeedsperSB
GYPP	**P**	1	0.57 **	0.27 **	0.28 **	0.48 **	0.98 **	0.36 **	0.28 **	0.35 **	0.13 *	0.38 **	0.08
	G	1	0.72 **	0.31 **	0.49 **	0.76 **	0.99 **	0.71 **	0.38 **	0.53 **	0.62 **	0.86 **	0.09
TW	**P**		1	0.49 **	0.29 **	0.26 **	0.50 **	0.16 **	0.04	0.11	0.01	0.12 *	-0.02
	G		1	0.57 **	0.39 **	0.45 **	0.63 **	0.37 **	0.05	0.15	0.198 *	0.16	-0.06
SH	**P**			1	0.08	0.14 *	0.21 **	0.06	0.04	0.00	0.08	0.07	0.14 *
	G			1	0.15	0.25 *	0.23 *	0.15	0.12	-0.07	0.25 *	-0.08	0.17
DFF	**P**				1	0.18 **	0.29 **	0.14 *	-0.01	0.30 **	0.08	0.25 **	0.09
	G				1	0.48 **	0.52 **	0.35 **	-0.01	0.63 **	0.23 *	0.67 **	0.09
PH	**P**					1	0.45 **	0.45 **	0.22 **	0.20 **	0.10	0.28	0.09
	G					1	0.71 **	1.11 **	0.33 **	0.357 **	0.68 **	0.62 **	0.10
PWPP	**P**						1	0.32 **	0.32 **	0.37 **	0.15 **	0.42 **	0.10
	G						1	0.64 **	0.43 **	0.59 **	0.64 **	0.94 **	0.10
NOGL	**P**							1	0.16 **	0.18 **	0.13 *	0.18	0.03
	G							1	0.24 *	0.42 **	0.82 **	0.56 **	0.00
PL	**P**								1	0.05	0.23 **	0.27	0.23 **
	G								1	0.00	0.63 **	0.41 **	0.24 *
NPBPP	**P**									1	0.05	0.64 **	-0.20 **
	G									1	0.19	0.63 **	-0.46 **
NBSBPP	**P**										1	0.12 *	0.13 *
	G										1	0.91 **	0.51 **
SeedPP	**P**											1	0.48 **
	G											1	0.34 **
SeedsperSB	**P**												1
	G												1

*,** Significant at 5% and 1% respectively

Table 6: Genotypic and phenotypic path analysis for direct (diagonal) and indirect (off diagonal) effects of 11 traits on grain yield per plant

		TW	SH	DFF	PH	PWPP	NOGL	PL	NPBPP	NBSBPP	SeedPP	SeedsperSB
TW	P	**0.101**	0.011	-0.008	0.011	0.456	0.007	-0.001	0.002	0.000	-0.004	0.000
	G	**0.043**	0.031	-0.008	0.064	0.613	-0.012	-0.004	-0.022	-0.002	0.0079	0.005
SH	P	0.050	**0.022**	-0.002	0.006	0.193	0.003	-0.001	0.000	-0.001	-0.003	0.002
	G	0.025	**0.054**	-0.003	0.035	0.224	-0.005	-0.009	0.011	-0.0027	-0.0039	-0.015
DFF	P	0.029	0.002	**-0.026**	0.008	0.264	0.006	0.000	0.004	-0.001	-0.009	0.001
	G	0.017	0.008	**-0.021**	0.068	0.504	-0.0115	0.0009	-0.092	-0.003	0.03375	-0.008
PH	P	0.026	0.003	-0.005	**0.044**	0.409	0.019	-0.006	0.003	-0.001	-0.010	0.001
	G	0.019	0.0135	-0.009	**0.141**	0.69	-0.04	-0.026	-0.052	-0.008	0.0311	-0.009
PWPP	P	0.051	0.005	-0.008	0.020	**0.914**	0.014	-0.008	0.005	-0.001	-0.015	0.001
	G	0.027	0.013	-0.011	0.101	**0.969**	-0.021	-0.035	-0.087	-0.007	0.047	-0.009
NOGL	P	0.016	0.001	-0.004	0.020	0.296	**0.043**	-0.004	0.003	-0.001	-0.006	0.000
	G	0.016	0.008	-0.007	0.156	0.627	**-0.033**	-0.019	-0.062	-0.009	0.028	-0.000
PL	P	0.004	0.001	0.000	0.010	0.292	0.007	**-0.026**	0.001	-0.002	-0.009	0.003
	G	0.002	0.006	0.0002	0.047	0.421	-0.008	**-0.079**	0.0009	-0.0069	0.021	-0.022
NPBPP	P	0.011	0.000	-0.008	0.009	0.339	0.007	-0.001	**0.015**	0.000	-0.022	-0.003
	G	0.0064	-0.004	-0.013	0.05	0.577	-0.014	0.0005	**-0.147**	-0.002	0.032	0.042
NBSBPP	P	0.001	0.002	-0.002	0.004	0.137	0.006	-0.006	0.001	**-0.009**	-0.004	0.002
	G	0.0085	0.0135	-0.005	0.096	0.626	-0.028	-0.051	-0.028	**-0.011**	0.046	-0.046
SeedPP	P	0.012	0.002	-0.006	0.012	0.384	0.008	-0.007	0.009	-0.001	**-0.035**	0.006
	G	0.0068	-0.004	-0.014	0.087	0.918	-0.019	-0.033	-0.094	-0.01	**0.05**	-0.03
SeedsperSB	P	-0.002	0.003	-0.002	0.004	0.089	0.001	-0.006	-0.003	-0.001	-0.017	**0.013**
	G	-0.002	0.009	-0.002	0.015	0.104	-0.00	-0.019	0.068	-0.006	0.017	**-0.089**

number of secondary branches on central primary branch of the panicle, panicle length and number of grains per panicle showed positive significant correlation with number of grains on central primary branch of the panicle, but number of primary branches per panicle is negatively correlated at 0.1% level of significance. Genotypic correlation matrix showed that days to 50% flowering, test weight, seed hardness, plant height, panicle weight, panicle length, number of green leaves, number of primary branches per panicle, number of secondary branches on central primary branch of panicle and number of grains per panicle are showing high positive significant correlation values with grain yield.

A similar study by Abd El-Raheem *et al.,* (2020) indicated that test weight, panicle length and plant height have positive and significant correlation with grain yield. Plant height had maximum positive direct effect on grain yield/plant followed by 1000-grain weight. On contrary to it, a study conducted by Khandelwal *et al.,* (2015) using 224 genotypes in sorghum, indicated negative correlation of days to 50% flowering, number of leaves, plant height, panicle length and test weight with grain yield.

Path coefficient analysis

Genotypic and phenotypic path coefficient analysis was carried out for this study and the values were given in Table 6. Test weight, seed hardness, plant height, panicle weight and number of grains per panicle were showing positive genotypic direct effects on grain yield, whereas number of green leaves, number of primary branches on panicle and number of grains on central primary branch of panicle were the traits which have shown positive phenotypic direct effects on grain yield in addition to the above mentioned traits. Panicle weight was showing largest direct genotypic and phenotypic effect on grain yield and is also largest contributor which is showing highest indirect effects on every trait studied. Days to 50% flowering, panicle length and number of secondary branches on central primary branch of panicle were showing negative direct effects on grain yield both genotypically and phenotypically.

Similar kinds of findings were reported by Chauhan and Pandey (2021) and Thant *et al.*, (2021). Hundekar *et al.,* (2016) reported the characters that had positive direct effects on grain yield at both phenotypic and genotypic levels were test weight (0.543; 0.557), panicle length (0.352; 0.354) days to 50% flowering (0.169; 0.206) and days to maturity (0.113; 0.084). Plant height (-0.108; -0.0829) had direct effect in negative direction at both phenotypic level and genotypic level.

CONCLUSION

Based on the above findings, it may be concluded that there is sufficient variability and high heritability for all the yield and component traits studied in this set of post-rainy sorghum landraces. Genotypic correlations revealed high positive correlation of days to 50% flowering, test weight, seed hardness, plant height, panicle weight, panicle length, number of green leaves, number of primary branches per panicle, number of secondary branches on central primary branch of panicle and number of grains per panicle with grain yield and positive direct effects on it. However days to 50% flowering, number of green leaves, number of primary branches per panicle, number of secondary branches on central primary branch of panicle, number of grains per panicle were showing negative direct effect on grain yield. Selection of tall plants with more green leaves and medium length panicles holding a greater number of primary branches with bold seeds could be rewarding for improvement of grain yield in post-rainy sorghum.

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Research Article
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REACTION OF RICE VARIETIES TO YELLOW STEM BORER, *Scirpophaga incertulas* (Walker) POPULATIONS

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ABSTRACT

The effect of two rice yellow stem borer (YSB), *S. incertulas* populations collected from Rangareddy (RGD) and Medak (MDK)on damage in three varieties of rice *viz*., PB1, W1263 and TN1 were tested during *kharif* (wet season) of 2019. Infestation was created by releasing the neonate YSB larvae @ two larvae per tiller onto the plants grown in pots under greenhouse conditions at both maximum tillering stage for dead heart damage and booting stage for white ear damage. The dead heart damage by Rangareddy population of yellow stem borer ranged from 19.61 to 35.15 percent, in which PB1 variety showed maximum damage. The yellow stem borer population from Medak caused 27.25 to 35.67 per cent dead hearts with maximum damage to PB1 variety. Infestation by neonate larvae of both the populations resulted in maximum White ear damage in PB1, which was significantly different from TN1 and W1263. However, all the three varieties recorded Damage Score 9 on SES scale for white ear damage. Based on the results of the current study, it can be concluded that there is no significant difference in the infestation level of *S. incertulas* populations collected from Rangareddy and Medak on PB1, W1263 and TN1.

Key words: Rice yellow stem borer, *Scirpophaga incertulas,* neonate larvae, dead hearts, white ears, varieties and damage

Rice (*Oryza sativa* L.) is the most important and staple food crop for more than two thirds of the population of India. Insect pests are the major constraints to the rice production. Among all the insect pests, the rice stem borers are the chief devastators and responsible for economic yield losses under natural condition (Mahar and Hakro, 1979).Out of eight stem borer species recorded from rice, rice yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) is the major devastatingand widely occurring insect pest of rice that attacks all stages of the crop from the seedling stage to maturity (Bandong and Litsinger, 2005). At vegetative stage, the larva causes damage to the tillers causing dead hearts, in which the young tiller and leaves of the tiller turn brown and die, which can be easily pulled out. During the reproductive phase, injury to the panicles results in the formation of white earheads or ill filled panicles. Yield loss estimates across India varied from 11.2 to 40.1 per cent due to dead hearts and 27.6 to 71.7 per cent due to white ears, respectively (Krishnaiah and Varma, 2012).

The damage level or the yield loss in rice depends on resistance of rice variety, stage of the crop and the environmental conditions. Our current study aimed at testing the virulence of *S.incertulas*(YSB) populations collected from Rangareddy (RGD) and Medak(MDK)at two phases of crop growth on three varieties used in the evaluation of varieties for stem borer tolerance.*viz.,* PB1, W1263 and TN1.

MATERIAL AND METHODS

Three rice varieties PB1, W1263 and TN1 were screened to assess the damaging potential of two populations (Rangareddy and Medak) at ICAR-IIRR during *kharif* (wet season) 2019. Plants were raised in pots (size 30cm diameter and 28 cm height) @ three plants per pot replicated five times for each variety.

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The freshly collected moths from Medak and Rangareddy populations were released separately in oviposition cages planted with susceptible variety PB1. The adult moths laid the egg mass on the leaves preferably at the leaf tip. The egg masses were collected on 4th day and placed in Petri-plates lined with moist filter paper. The freshly emerged larvae (neonate larvae) from the egg mass were carefully released @ two larvae/tiller (Padmakumari, 2018) on to test entries at maximum tillering and booting stage, separately with the help of a camel air brush (Figure 1).

Observations on total tillers and dead hearts at vegetative phase, and at reproductive phaseon panicle bearing tillers and white ears were noted. The DH (%)and WE (%) on three varieties infested by RGD and MDK populations of YSB was calculated according to Heinrich *et al.*, 1985 and the formulae are given below and also scored on 0-9 SES scale (IRRI,2013) based on original values. The data was analysed using R based statistical software (Gopinath *et al.*, 2020).

$$\text{Per cent of dead hearts} = \frac{\text{No of dead hearts}}{\text{Total no. of tillers}} \times 100$$

Per cent of white ears

$$= \frac{\text{No of white ears}}{\text{Total no. of panicle bearing tillers}} \times 100$$

RESULTS AND DISCUSSION

Reaction of varieties to MDK population of YSB

The DH (%) and WE (%) recorded from the three varieties after screening with YSB population of MDK is given in Table 1. The dead heart damage across varieties under infested condition ranged from 21.34 (DS -5) to 34.16 per cent (DS-7)and was not significantly different among the three varieties. However, PB1 recorded a DS of 7. TN1and W1263 recorded DS of 5. The WE damage ranged from 31.69 per cent (DS9) to 78.76 (DS 9) per cent with maximum damage being recorded from PB1 variety and lowest in W1263. The WE damage in PB1variety (78.76 %) was significantly higher and different from TN1 (34.46 %) and W1263 (31.69 %), though on SES scale all the three varieties scored as 9.

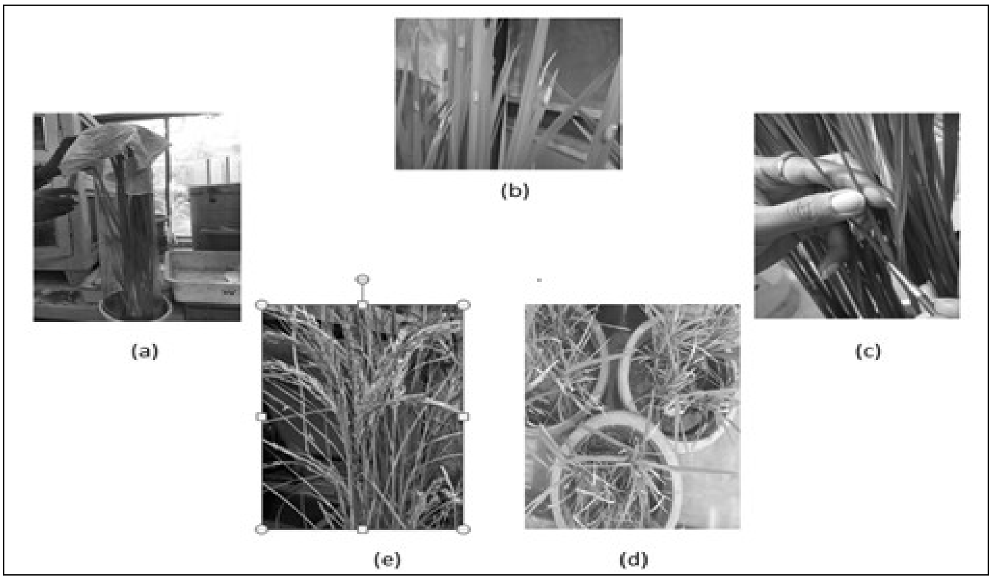

Figure1. Release of YSB adults and infestation of neonate larvae

(a) Release of YSB moths for egg laying (b) Egg mass laid by YSB (c) Release of neonate larvae (d) Dead heart damage (e) White ear damage

Table 1. Yellow stem borer damage in test entries against Medak population

Varieties	DH %	Damage score (DS)	WE%	Damage score (DS)
PB1	34.16 (35.61a)	7	78.76(63.47a)	9
W1263	21.34(27.25a)	5	31.69 (31.36b)	9
TN1	25.94(27.93a)	5	34.46(35.83b)	9
F value at 8 df	1.07		10.42	
pd" 0.05	0.37 NS		0.00*	

Values in parentheses are arcsine transformed; NS-Not Significant * significant at pd" 0.05

Reaction of varieties to RGD population of YSB

The mean DH and WE damage recorded from the three varieties due to YSB population of RGD is given in Table 2. Significant difference was noticed in the DH damage across the three varieties, which ranged from 13.80 (DS-3) to 33.26 per cent (DS-7). PB1 recorded significantly high per cent DH (33.26 %; DS-7) damage as compared to TN1(13.80%; DS-3) and W1263 (20.10 %; DS-5). The WE damage ranged from 25.94 to 68.48 per cent. The per cent WE damage was also significantly high in PB1variety (68. 48 %; DS-9), as compared to the other two varieties W1263 (37.94 %; DS-9) and TN1 (25.94%; DS-9), which were on par with each other. But on SES scale all the entries scored as DS-9

Table 2. Yellow stem borer damage in test entries against Rangareddy population

Varieties	DH %	Damage score (DS)	WE%	Damage score (DS)
PB1	33.26 (35.15[a])	7	68.48 (58.92[a])	9
W1263	20.10 (26.57[ab])	5	37.94 (37.88[b])	9
TN1	13.80 (19.61[b])	3	25.94 (30.43[b])	9
F value at 8 df	5.99		7.86	
pd" 0.05	0.02*		0.01*	

Values in parentheses are arcsine transformed; * significant at pd" 0.05

Effect of two YSB populations on damage in three rice varieties

Dead heart damage by YSB populations at vegetative phase

Virulence of two YSB populations (RGD and MDK) on three rice varieties *viz*., PB1, W1263 and TN1 were tested and compared(Table 3, Figure 2). There were no significant differences between DH damage of PB1 caused by RGD and MDK YSB populations on the varieties.

White ear damage by YSB populations at reproductive phase

White ear damage caused by two YSB populations (RGD and MDK) on three rice varieties *viz*., PB1, W1263 and TN1 is given in Table 3. There were no significant differences between DH and WE damage caused by YSB populations of MDK and RGD. The results revealed that the neonate larvae from both the populations caused damaged to the same extent in each of the test varieties. However, there was significant difference in the performance level of each variety against YSB infestation across both the locations. Among the three varieties tested, PB1 recorded maximum infestation in terms of both DH and WE damage. It was also observed that there is no interaction effect between YSB populations and varieties.

Table 3. Effect of YSB populations on damage in rice varieties

Varieties	Dead Heart (%)			White Ear (%)		
	MDK for varieties	RGD	Mean value	MDK	RGD	Mean value for varieties
PB1	34.16 (35.61)	33.26 (35.15)	33.70 (35.38)[a]	78.76 (63.47)	68.48 (58.99)	73.62 (61.23)[a]
W1263	21.34 (27.25)	26.57 (20.10)	23.95 (23.67)[b]	31.69 (31.15)	37.94 (37.88)	34.81 (34.51)[b]
TN1	25.94 (27.93)	13.80 (19.41)	19.87 (23.67)[b]	34.46 (35.83)	25.94 (30.43)	30.20 (33.13)[b]
Mean Values for locations	27.15 (30.26)	24.54 (24.89)	48.30 (43.49)	44.12 (42.44)		
	F value at 24 df	**p value**	**Significance**	**F value at 24 df**	**p value**	**Significance**
Populations	0.96	0.34	NS	0.06	0.813	NS
Varieties	4.78	0.02	*	17.54	0.00	**
Populations X Varieties	0.65	0.53	NS	0.80	0.46	NS

Values in parentheses are arcsine transformed; NS-Not Significant;* significant at pd” 0.05;**significant at pd” 0.01

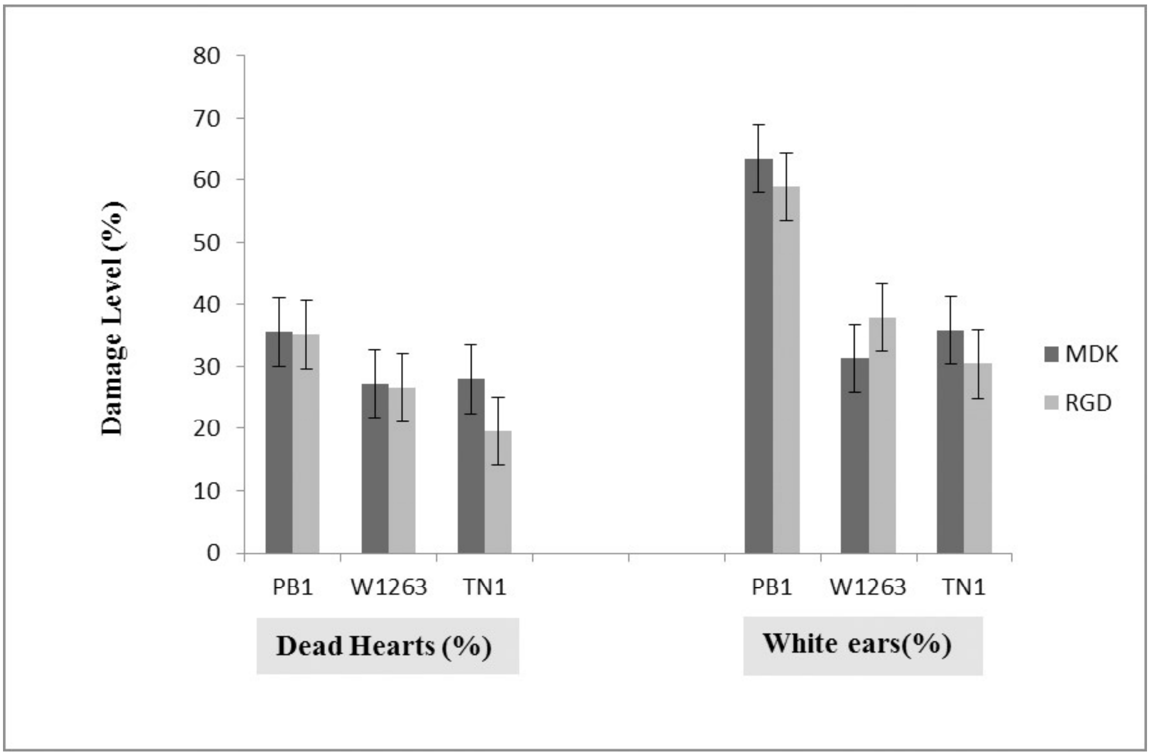

Figure 2. Yellow stem borer damage on rice varieties across two locations

Identification of varietal resistance has been in progress for the past three decades. Many cultivars are susceptible to YSB. Very high levels of resistance have not been found yet and there is the continuous variation for this trait among rice varieties, from highly susceptible to moderately resistant. In recent times many lines have been identified as tolerant to yellow stem borer in the multi-location evaluation of breeding lines (ICAR-IIRR, 2015-2021)

Varietal evaluation was conducted to study and compare the damage by *S. incertulas* populations collected from Rangareddy and Medak. Based on the results of the current study it can be concluded that there is no significant difference in the infestation level of *S. incertulas* populations collected from Rangareddy and Medak in terms of dead hearts and white ears ineach of the test entries (Table 3).The maximum dead heart and white ear damage was observed in Pusa basmati1 variety. Similar findings were reported wherein the aromatic variety like Pusa basmati was highly susceptible to the yellow stem borer compared to the coarse grain varieties (Saroja *et al*., 1993; Zhu *et al*., 2002, Padmakumari and Pasalu, 2003). Based on the susceptibility of Pusa basmati1 as compared to TN1, it has been tested as a trap crop for stem borer management in endemic areas of this pest (Padmakumari *et al*., 2017**)**. Prakash and Padhi (1987) identified W1263 variety as field resistant to YSB. The present study further confirms that there is no variation in the virulence of the populations to these varieties. Various workers evaluated many rice varieties against rice yellow stem borer (Mohankumar *et al.,* 2003; Khan *et al*., 2010; Elanchezhyan and Arumugachamy, 2015), but the results cannot be compared as they used different cultivars under different seasons and environmental conditions. Marwat *et al*., (1985) reported basmati variety of rice as highly susceptible variety, which is in concordance with our findings.

CONCLUSION

Varietal evaluation was conducted to study and compare the damage caused by *S.incertulas* populations collected from two districts, Rangareddy and Medak of Telangana state. Irrespective of YSB populations, PB1 variety recorded maximum dead hearts and white ear damage under infested conditions. The present study further confirms that there is no variation in the virulence of the YSB populations to these varieties. Further studies may be carried out to generate data with varieties of different duration and tillering capacity.

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Research Article
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YIELD AND PROFITABILITY OF DRUM SEEDED *RABI* RICE AS INFLUENCED BY NITROGEN LEVELS AND WEED MANAGEMENT PRACTICES

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ABSTRACT

A field experiment was conducted at College Farm, Agricultural College, Rajendranagar, Hyderabad during Rabi 2020-21 and 2021-22 to study effect of nitrogen levels and weed management practices of drum seeded rice. Field trial consisted of 16 treatments having four weed management practices and four nitrogen levels laid out in factorial randomized block design. Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS (W_4) has yielded significantly higher grain and straw yield followed by Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE (W_2). Regarding economics, W_2 had resulted in higher B C ratio followed by W_4. Among the nitrogen levels, 125 % RDN (N_4) had higher yield and B.C.R statistically comparable with 100 % RDN (N_3). Interaction of W_4N_4 had attained higher yield while the economics gained was highest with W_2N_4.

Keywords: Drum seeded rice, RDN, gross returns, net returns, B: C ratio

Rice is the principle food crop cultivated throughout India covering an area of 44 M ha with production of 118.43 Mt (Agriculture statistics at glance, 2020). In Telangana it is cultivated in 104.23 lakh acres with production of 218.51 lakh million tones. Transplanting of rice has been the traditional system of rice establishment but cultivation of drum seeded rice is gaining momentum in India due to scarcity of labour during peak season of transplanting and availability of water for shorter periods. Sowing of sprouted rice seed with drum seeder in puddled soil is less labour intensive requiring 4-5 labour ha^{-1} saving 20 % of total labour, reducing production costs by 40 %, increasing productivity and profits by 8 and 56 % (Gangaiah *et al.,* 2019). But major constraints in drum seeded rice are severe weed competition and low nitrogen use efficiency.

Crop fertilization is one important component and it is observed that nitrogen (N) fertilizer has profound effect on growth and yield of rice by 70-80 % increase in yield (Salam *et al.,* 2004). Insufficient and inappropriate fertilizer nitrogen management in wet DSR may account for one half to two thirds of the gap between actual and potential yields (Alagesan and Babu, 2011). Many farmers use low /very high nitrogen amount detrimental to crop growth and development. Hence use of appropriate level of nitrogen is of major concern from both economic and environmental view point.

Success of drum seeded rice depends on effective weed control, with yield loss as high as 50-60 % by weeds, due to simultaneous germination of both crop and weed seeds in wet DSR. (Pinjari *et al.*, 2016). Chemical weed control with pre-emergence herbicides is another alternative in drum seeded rice. But broad spectrum of weed flora is not controlled by spraying pre-emergence herbicides alone, due to weed flushes erupting at different stages. Hence, use of sequential application of pre fb post-emergence herbicides or pre-emergence herbicides fb mechanical weeding can overcome weed menace. Keeping in view the above facts and very limited work has been

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conducted on weed and nitrogen management in drum seeded *Rabi* rice in Telangana region, hence the present research work was planned.

MATERIAL AND METHODS

Field experiment was conducted at College Farm, Agriculture College, Rajendranagar, geographically situated at 17°19'9.1"N Latitude, 78°24'30"E Longitude and Altitude of 534 m. Experimental site was loamy sand, slightly alkaline with low in organic carbon and available N, medium in phosphorus and high in potassium. Trial was conducted in R*abi* 2020-21 and 2021-22 in FRBD design with four weed management practices as Factor1 (F_1) viz., W_1: Unweeded (control), W_2: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE, W_3: Pyrazosulfuron-ethyl 70 % WDG 21 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE, W_4: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS and four nitrogen levels as Factor 2 (F2) *viz.,*N_1- No nitrogen (control), N_2-75 % RDN (112.5 kg N ha^{-1}), N_3-100 % RDN (150 kg N ha^{-1}), N_4-125 % RDN (187.5 kg N ha^{-1}) replicated thrice.

Sprouted seeds of paddy variety, JGL-24423 were sown at 20 x 8-10 cm with drum seeder. Applied 60 kg P_2O_5 basally, while 40 kg ha^{-1} K_2O in two equal splits as basal and at panicle initiation stage. Nitrogen was incorporated in three equal splits at the time of sowing, tillering and panicle initiation stages. At 3DAS, pre-emergence and at 2-3 leaf stage of weeds, post emergence herbicides were sprayed, while mechanical weeding was done at 25 and 50 DAS with conoweeder. Grain and straw yields were estimated from net plot excluding border plants in the plot. Cost of cultivation, Gross and Net returns (₹ ha^{-1}) and benefit cost ratio was calculated for each treatment. Data was analyzed statistically applying analysis of variance technique for FRBD design. The significance was tested by 'F' test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Grain yield (kg ha^{-1})

Grain yield is the ultimate result for final assessment of treatments in any agronomical investigation. During two years of field trial, weed management practices and nitrogen had pronounced and significant effect on grain yield (Table 1). Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS (W_4) registered significantly higher yield of 5830 and 6024 kg ha^{-1} followed by Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE] (W_2) (5606 and 5773 kg ha^{-1}). While lowest grain yield was observed with unweeded (W_1) (2178 and 2326 kg ha^{-1}) during both the years. Lower yield with unweeded (W_1) was caused by weed competition for resources throughout the growth period, affecting the dry matter production per hill, poor yield components, while improved yield may be due to effective and prolonged weed control that led to nutrient uptake of rice with more sink capacity.

Among nitrogen levels, 125 % RDN (N_4) yielded higher grain yield of 6065 and 6256 kg ha^{-1} on par with 100 % RDN (N_3) (5672 and 5857 kg ha^{-1}) and lowest was yielded by control (N_1) (2125 and 2275 kg ha^{-1}) during study period. Increased nitrogen levels might have assisted in greater photosynthesis and efficient translocation of photosynthates from source to sink which ultimately contributed to higher grain yield. Findings are similar to those Bhuiyan *et al.,* (2018), Kumar *et al.,* (2019) and Ajmal (2020).

Among the interaction combinations W_4N_4 resulted in higher yield of 7608 and 7685 kg ha^{-1} followed by W_2N_4 (7312 and 7522 kg ha^{-1}) and lowest grain yield was shown by N_1W_1 (1100 and 1064 kg ha^{-1}) during both the years.

Straw yield (kg ha^{-1})

Effect of nitrogen levels and weed management practices on straw yield had significant effect but their interaction was found be no significant (Table 2). Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS W_4 treatment had significantly higher straw yield of 7807 and 8097 kg ha^{-1}, while unweeded had lowest straw yield (4218 and 4426 kg ha^{-1}) during both the years of study. This might be due to maintenance of weed free environment at critical stages of crop growth, which led to complete utilization of nutrients and other resources by crop plants, resulting in vigorous growth and greater dry matter production by crop. Due to fierce competition from weeds for growth resources,

Table 1. Grain yield (kg ha^{-1}) of drum seeded *Rabi* rice as influenced by weed management practices and nitrogen levels

Treatments	*Rabi,* 2020-21					*Rabi,* 2021-22				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
W_1	1100	2116	2633	2862	2178	1064	2249	2849	3142	2326
W_2	2509	5753	6849	7312	5606	2709	5750	7112	7522	5773
W_3	2283	4913	6021	6477	4924	2517	5047	6181	6677	5105
W_4	2609	5917	7186	7608	5830	2809	6317	7286	7685	6024
Mean	2125	4675	5672	6065		2275	4841	5857	6256	
	W	N	W x N					W	N	W x N
SEm±	140	140	280					142	140	284
CD(P=0.05)	404	404	808					410	410	820

Weed management (F_1)	Nitrogen levels (F_2)
W_1 :Unweeded	N_1 :No nitrogen
W_2:Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_2 :75 % RDN (112.5 kg N ha^{-1})
W_3:Pyrazosulfuron – ethyl 70 % WDG 21 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_3 :100 % RDN (150 kg N ha^{-1})
W_4:Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb mechanical weeding 25 and 50 DAS	N_4 :125 % RDN (187.5 kg N ha^{-1})

Table 2. Straw yield (kg ha^{-1}) of drum seeded *Rabi* rice as influenced by weed management practices and nitrogen levels.

Treatments	2020-21	2021-22
Weed management		
W_1	4218	4426
W_2	7584	7818
W_3	6934	7258
W_4	7807	8097
SEm±	189	164
CD(P=0.05)	546	474
Nitrogen Levels		
N_1	4101	4282
N_2	6683	6962
N_3	7666	7980
N_4	8094	8375
SEm±	189	164
CD(P=0.05)	546	474
Interaction		
SEm±	378	328
CD(P=0.05)	NS	NS

Weed management (F_1)	Nitrogen levels (F_2)
W_1 : Unweeded	N_1: No nitrogen
W_2: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_2:75 % RDN (112.5 kg N ha^{-1})
W_3: Pyrazosulfuron – ethyl 70 % WDG 21 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_3:100 % RDN (150 kg N ha^{-1})
W_4: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb mechanical weeding 25 and 50 DAS	N_4:125 % RDN (187.5 kg N ha^{-1})

Table 3. Gross returns (₹ ha^{-1}) of drum seeded *Rabi* rice as influenced by weed management practices and nitrogen levels.

Treatments	*Rabi*, 2020-21					*Rabi*, 2021-22				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
W_1	26686	48284	59026	63267	49315	26690	52327	65391	69062	53368
W_2	56513	122973	145527	153350	119591	61610	127418	156067	163761	127214
W_3	52072	105649	129562	137664	106236	57420	112027	140035	148856	114584
W_4	58636	126530	152413	161165	124686	64052	138963	162512	168899	133607
Mean	48477	100859	122095	128740		52443	107684	131001	137645	
	W	**N**	**W x N**			**W**	**N**	**W x N**		
SEm±	2481	2481	4962			2488	2488	4976		
CD(P=0.05)	7166	7166	14332			7187	7187	14373		

Weed management (F_1)	Nitrogen levels (F_2)
W_1 : Unweeded	N_1: No nitrogen
W_2: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_2: 75 % RDN (112.5 kg N ha^{-1})
W_3: Pyrazosulfuron – ethyl 70 % WDG 21 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_3: 100 % RDN (150 kg N ha^{-1})
W_4: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb mechanical weeding 25 and 50 DAS	N_4: 125 % RDN (187.5 kg N ha^{-1})

decreased the growth parameters and thus lowest straw yield with unweeded was recorded.

Increased straw yield of 8094 and 8375 kg ha^{-1} was obtained by 125 % RDN and lowest was yielded by control (4101 and 4284 kg ha^{-1}) during both years. Increased N supply would have improved the metabolic activity and cell division which have raised growth parameters viz., plant height, leaf area, number of tillers and higher dry matter production leading to higher straw. These findings are consistent with those of Senthivelu and Prabha (2007) and Mahajan and Timsina (2011).

Economics (₹ ha^{-1})

Nitrogen levels and weed management practices significantly influenced gross returns, net returns and B : C ratio in both the years of experimentation and the interaction was found significant between nitrogen levels and weed management practices

Gross and net returns of drum seeded rice differed significantly with nitrogen and weed management practices as well as their interaction, with unaltered trend during both the years of study (Table 3

Table 4. Net returns (₹ ha^{-1}) of drum seeded *Rabi* rice as influenced by weed management practices and nitrogen levels

Treatments	*Rabi,* 2020-21					*Rabi,* 2021-22				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
W_1	-14192	5131	15468	19301	6427	-16577	6687	19313	22544	7992
W_2	10110	74295	96444	103859	71177	12818	76253	104464	111711	76311
W_3	6484	57786	81294	88988	58638	9443	61677	89247	97628	64499
W_4	8433	74052	99530	107874	72472	11460	83998	107109	113056	78906
Mean	2709	52816	73184	80005		4286	57154	80033	86235	
	W	N	W x N			W	N	W x N		
SEm±	2417	2417	4834			2273	2273	4547		
CD(P=0.05)	6981	6981	13961			6566	6566	13132		

Weed management (F_1)	Nitrogen levels (F_2)
W_1 : Unweeded	N_1: No nitrogen
W_2: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_2: 75 % RDN (112.5 kg N ha^{-1})
W_3: Pyrazosulfuron – ethyl 70 % WDG 21 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_3: 100 % RDN (150 kg N ha^{-1})
W_4: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb mechanical weeding 25 and 50 DAS	N_4: 125 % RDN (187.5 kg N ha^{-1})

Table 5. B: C ratio of drum seeded *Rabi* rice as influenced by weed management practices and nitrogen levels

Treatments	*Rabi,* 2020-21					*Rabi,* 2021-22				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
W_1	0.65	1.12	1.36	1.44	1.14	0.62	1.15	1.42	1.48	1.17
W_2	1.22	2.53	2.96	3.10	2.45	1.26	2.49	3.02	3.15	2.48
W_3	1.14	2.21	2.68	2.83	2.22	1.20	2.22	2.76	2.91	2.27
W_4	1.17	2.41	2.88	3.02	2.37	1.22	2.53	2.93	3.02	2.43
Mean	1.05	2.07	2.47	2.60		1.07	2.10	2.53	2.64	
		W	N	W x N				W	N	W x N
SEm±		0.05	0.05	0.09				0.04	0.04	0.08
CD(P=0.05)		0.14	0.14	0.27				0.12	0.12	0.24

Weed management (F_1)	Nitrogen levels (F_2)
W_1 : Unweeded	N_1: No nitrogen
W_2: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_2: 75 % RDN (112.5 kg N ha^{-1})
W_3: Pyrazosulfuron – ethyl 70 % WDG 21 g ha^{-1} PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} POE	N_3: 100 % RDN (150 kg N ha^{-1})
W_4: Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} PE fb mechanical weeding 25 and 50 DAS	N_4: 125 % RDN (187.5 kg N ha^{-1})

and 4). Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS (W_4) gained higher gross (₹ 124686 and 133607) and net returns (₹ 107874 and 113056) which was on par with Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE (W_2) (₹ 119591 and 127214) and (₹ 71177 and 76311) and lower economics was shown by unweeded (W_1) (₹ 49315 and 53368) and (₹ 6427 and 7992) during both the years. Among nitrogen levels 125 % RDN (N_4) resulted in maximum gross (₹128740 and 137645) and net returns (₹ 80005 and 86235) statistically comparable with 100% RDN [N_3] (₹ 122095 and 131001) and (₹ 103859 and 76311) and lower returns with no nitrogen [N_1] (₹ 48477 and 52443) and (₹ 2709 and 4286) during two years. Similar finding were reported by Ajmal (2020).

Among the interaction treatment combinations W_4N_4 had obtained higher gross (161165 and 168899) and net returns (₹ 107874 and 113056) followed by W_2N_4 (₹ 153350 and 163761) and (₹ 103859 and 111711) during both the years and lowest was recorded with W_1N_1 (₹ 26686 and 26690) and (₹ -14192 and -16577).

Regarding B C ratio, during both the years, Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE (W_2) had registered higher BC ratio of 2.45 and 2.48 which was on par with Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS (W_4) (2.37 and 2.43) and least was with unweeded (W_1) (1.14 and 1.17) Among nitrogen levels, 125 % RDN recorded higher B : C ratio (22.6 and 2.64) comparable with 100 % RDN (2.47 and 2.93) and least with control [no nitrogen] (1.05 and 1.07) during two years. Among the interaction treatments W_2N_4 had resulted in higher BCR (3.1 and 3.15) followed by W_4N_4 (3.02 and 3.02), but lowest was recorded with W_1N_1 (Table 5) Similar findings were reported by Ramulu *et al.*, (2019) and Ajmal (2020).

Among the weed management practices, the highest gross and net returns were realized with W_4 followed by W_2which might be due to effective control of all weeds, improved weed control efficiency, lesser competition by weeds thus improving yield components and higher yields. Whereas the highest B: C ratio was realized with W_2 [Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE] might be due to comparable returns associated with low cost of weed management practice. The lowest economic returns were recorded with un-weeded due to severe competition by weeds for growth resources which reduced yield components and yield of drum seeded rice.

Between different levels of nitrogen, the highest gross, net returns and B : C ratio was recorded with application of 125 % RDN which might be attributed to increased nitrogen supply, improving yield components and higher grain and straw yield of drum seeded rice during both the years of study. The lowest economic returns were recorded with no nitrogen, due to lower stature of yield components and yield of rice because of limited resources.

CONCLUSION

Results of the present study reveal that both nitrogen levels and weed control methods and their interaction had significant influence on yield and profitability of drum seeded rice. 125 % RDN (187.5 kg N ha^{-1}) and W_4 [Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb mechanical weeding at 25 and 50 DAS] had resulted in higher yields and monetary gains, though the BCR was reflected by W_2 [Pretilachlor 6 % + Pyrazosulfuron-ethyl 0.15 % GR 615 g ha^{-1} as PE fb Penoxsulam 1.02 % + Cyhalofop butyl 5.1 % OD 120 g ha^{-1} as POE] which is on par with W_4.

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Research Article
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AN EVALUATION OF THE SOCIO-ECONOMIC PROFILE AND PERCEPTION OF PERI-URBAN FARMERS: A STUDY IN THE PERIPHERY OF HYDERABAD METROPOLITAN REGION

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ABSTRACT

Farm diversification is emerging as an adaptive strategy among the farmers especially those near to the city centers, as availability of land for cultivation is under question with the expanse of developmental activities. The present study was conducted in the peripheries of Hyderabad Metropolitan Region in the year 2021 to assess the socio-economic profile of farm households. A multistage random sampling method was chosen for sampling by which a total of eight mandals were surveyed using a pre-tested structured interview schedule totaling the sample size to 330. The study purely depends on primary data and relevant descriptive statistics were employed for analysis. The socio-economic variables selected for the study include age, education, experience in farming, operational land holding, crop diversity index and income only from agriculture. It was observed that diversified farmers were younger than non-diversified group while level of education was more or less same for both the groups. Farmers with more experience tend to specialize their farmland as against those who diversify even when farming experience is low. In addition, with the increase in landholding size, farmers tend to diversify their farm activities more. While considering the variable only farm as source of income, it was observed that majority of diversified farmers depend on farm alone than non-diversified farmers. Additionally, the perception of peri-urban inhabitants on the social and economic impacts of urban sprawl on their locations was also assessed using Garrett Ranking Technique. Policies should be formulated to support smallholders to pool their land so that they could take up diversification activities profitably.

Key words: Farm diversification, socio-economic analysis, descriptive statistics

According to UN-HABITAT, the UN agency for human settlements, the 21st century will be the century of urbanisation. Urban population in the world will almost double from the current 3.5 billion to more than 6 billion by 2050 (Awasthi, 2013). In India, the neo culture of urban expansion is taking place at a faster rate.

Hyderabad, located in Telangana state in southern India, is the fifth largest metropolis in the country with a population of 8 million as per 2011 Census survey, is under the grip of urbanisation and its sprawling nature. The growth of the city has occurred at a much faster rate in peripheries in recent decades. Rapid development, especially in the information technology (IT) sector, infrastructural facilities such as Outer Ring Road and other developmental works has attracted skilled and unskilled labour from the nearby cities as well from other parts of the country (Gumma *et al.,* 2017). Hence, the growth in the Hyderabad city is extending towards its peripheries bringing changes in its structure and form.

Usually, under the influence of urbanisation, different types of agricultural land users in the peripheral regions of metropolitan centres have had to adapt their farming systems while competing with an increasing number of non-agriculture land users (Bansal *et al.,* 2020). Around the peripheries of Hyderabad, the situation remains the same. Diversification from lower to higher-value commodities like fruits and vegetables are taking place in the transitory spaces of Hyderabad Metropolitan Region, and are a driving force to faster rapid and sustained growth in agriculture, and an opportunity for small farmers to improve their income, and escape poverty (Reddy, 2011).

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Farm diversification may be determined by both internal factors—related to the characteristics of farmers and the farm land and external factors—related to territorial features, including regional and spatial patterns (Mazzocchi *et al.,* 2020). From reviewing past literatures, it was found that the socio-economic characteristics of a farm as well as farmer's household such as gender, household head age, level of education, household size and income level, fixed assets, livestock or technological limitations (Aribi and Sghaier, 2020; Mazzocchi *et al.,* 2020; Mulwa and Visser, 2020), have an impact on crop diversification.

From several literatures it was observed that age has a positive effect on diversification (Dembele *et al.,* 2018; Anuja *et al.,* 2020).Similarly, level of education (Hoo *et al.,* 2017; Wojewodzic *et al.,* 2015), landhold size (Rehima *et al.,* 2013; Makate *et al,* 2016; Bansal *et al.,* 2020) household members (Kurdy´s-Kujawska *et al.,* 2021), degree of literacy (Geetu and Sharma, 2020), and farm income (Manko and Plonka, 2010) also significantly influence a household's decision to diversify their farm activities.

As such, it is imperative to understand the background of the farm households in the study region. A detailed look upon the socio-economic profile of farm households will lay a foundation for further studies wherein the impact of developmental activities on the population could be assessed. Assessment of social and economic parameters of population is also necessary from the point of view of policy making as the constraints faced by each group will be different and need to be addressed with great caution.

With this backdrop, the present study was framed with the objective to evaluate the socio-economic profile of farmers in the peri-urban areas of Hyderabad Metropolitan Region. The study will contribute to the ambiguous research on the diversification parameters which further has the prospect for broader exploration arenas. The rest of the section is structured as Materials and methods followed by results on socio-economic profile in the study area, concluding with a policy recommendation.

MATERIALS AND METHODS

Study location

The peri-urban areas of Hyderabad Metropolitan Region were chosen as the study area. The study area selection was inspired and drawn from the works of South Asia Consortium for Interdisciplinary Water Resource Studies (saciWATERs), whose main focus area of research is in peri-urban areas. Zone lying between Greater Hyderabad Municipal Cooperation (GHMC) and Hyderabad Metropolitan Development Authority (HMDA) is generally identified as transitory spaces or peri-urban of Hyderabad. However, to perceive the peri-urban interface more clearly, a map was constructed (Figure 1), with the support of field level data collected using three basic indicators-social, economic and psychological factors along with spatial analysis (Banerjee et al.,2014). The classified map demarcates peri-urban areas into 3 different zones- (1) Peri-urban to Urban (Urban-Peri-urban), (2) Peri-urban to Peri-urban (Peri-urban-Peri-urban), and (3) Rural to Peri-urban (Peri-urban- Rural). Under this classification, out of the total 39 blocks, 22 blocks/mandals fall under 'Peri-urban- Rural' category, 12 blocks/mandals belong to 'Peri-urban-Peri-urban' category and the rest are 'Urban-Peri-urban' blocks.

Since the study focuses on peri-urban spaces, areas which were chosen for the study falls in the category of peri-urban – peri-urban and peri-urban-rural areas. Thus the mandals selected as study locations are Medchal, Ghatkesar, Sangareddy and Ibrahimpatnam from peri-urban-peri-urban region and Bibinagar, Pochampally, Shamshabad and Chevella from peri-urban-rural region. From the eight mandals selected, two villages each were further chosen for survey. As such, a total of sixteen villages were randomly selected for study. A detailed description of the study location is given in Table 1. The study adopted a Multistage Random Sampling method where mandals (8 out of total 39) as the first stage and farm households as the second stage. The sample size fixed for the study was 330 comprising only farmer households.

Source of data

The study entirely depends on primary data collected from the survey area in the year 2021 from August to October. The data were gathered through the method of personal interview using pretested structured interview schedule. A pilot study was conducted to test and finalise the schedule.

Data analysis

The study is more of explorative in nature hence descriptive statistics was used for describing the data.

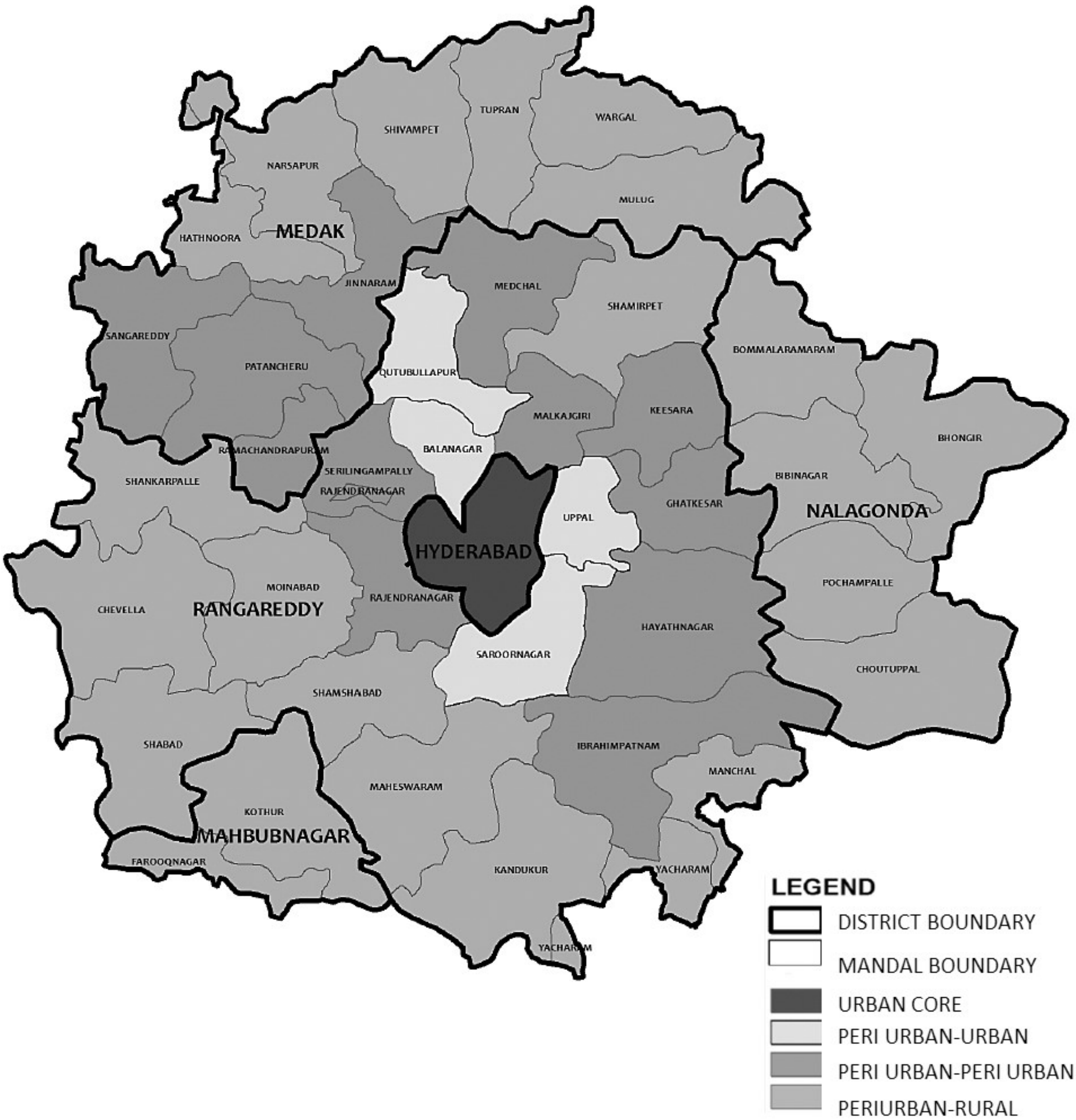


Figure 1. Peri-urban regions of Hyderabad Metropolitan Region

Table 1. Description of the study area

	Peri-urban	**Rural**
Mandal	1. Sangareddy 2. Ibrahimpatnam 3. Medchal 4. Ghatkesar	1. Chevella 2. Shamshabad 3. Bibinagar 4. Pochampally
Village (2 villages from each mandal)	1. Fasalwadi, Nagapur 2. Firozguda, Pocharam 3. Dabilpur,Atevelle 4. Edulabad, Yamnampet	1. Chanvelli, Pamena 2. Tondapalli, Sanghiguda 3. Jiya palli, Rayaraopet 4. Julur, Jiblakpalli

a) To compute Crop Diversity Index, Simpson's Diversification Index was used. Simpon's Diversification Index (SID) is an empirical measure to gauge extent of diversification (Joshi *et al.,* 2003). The index ranges from 0 to 1, where 1 is the degree of highest diversification.

$$\text{SID} = 1 - \sum_{wi} 2$$

Where W_i is the proportionate area (or value) of i^{th} crop in the gross cropped area.

b) To assess the socio-economic impacts of the urban sprawl, Garret ranking technique was employed. Garrett's ranking technique is used to rank the relative status of each of the responses, indicated by the respondents on the impact of urban sprawl. To cite, several studies on perception analysis such as Sheetal *et al.,* (2021), Mayakkannan (2018), Wongnaa et al., 2019 employed Garret Ranking method to assess the impact of technologies, urban production systems and buying behavior respectively. So in the study, to assess the socio-economic and environmental impacts of urban sprawl in transforming the survey area through the inhabitants' perception. Hence, the respondents were asked to rank all statements associated with each of these impact category and the outcomes of such ranking were converted into scores using Garrett score table.

Garrett's formula for converting ranks into percent is:

$$\text{Percent position} = \frac{100\,(R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij}=Rank given for the ith variable by jth respondent

N_j = Number of variable ranked by jth respondent

The percent position of each rank was converted into scores following Garrett and Woodworth, 1969. The scores of each individual are added and then total value of scores and mean values of score is calculated. The factors having highest mean value is considered to be the most important factor.

RESULTS AND DISCUSSION

SOCIO ECONOMIC PROFILE OF THE SAMPLE FARMERS

Socio economic analysis provides comprehensive picture of the socio-economic conditions of the respondents which influence the decision of farmers to diversify their farmland.

Age of the sample farmers

Age is an important parameter that positively influences farmers' decision to diversify the farm activities (Finocchio and Esposti, 2008). From the Table 2, it is clear that average age of diversified farmers was less than that of non-diversified farmers (48.98 and 50.27 years respectively). It is in line with the result reported by Meraner, 2015 wherein the average age of diversifying farmer was about two years younger than that of its counterpart. It indicates that as the age of farmer increases, the choice of engaging in diverse farm activities decreases.

The result also shows that the young farmers age group (20-40 years) was constituted by 14 per cent of non-diversified farmers and 25 per cent of diversified farmers. Furthermore, a major share of both non-diversified and diversified farmers fall under the age group of 41-50 years (50.35% and 40.11 % respectively).

Among the total 330 farmers, majority fall under the ctegory of 41-50 years (45%) followed by 25 per cent in the 51-60 years age group, 19 per cent in

Table 2. Age group of the sample farmers

Age group (Years)	Non diversified (N=143)		Diversified (N=187)		Total (N=330)	
	Number	Percent	Number	Percent	Number	Percent
20-30	2	1.40	3	1.60	5	1.52
31-40	18	12.59	45	24.06	63	19.09
41-50	72	50.35	75	40.11	147	44.55
51-60	39	27.27	45	24.06	84	25.45
Above 60	12	8.39	19	10.16	31	9.39
Average	50.27		48.98		49.54	

31-40 years group and 9 percent in above 60 years age group. Hardly 2 per cent of the total group constituted the 20-30 years age group.

Education level of the sample farmers

Level of education is yet another important demographic variable among the socio-economic characteristics. The choice of farmers to engage in multiple farm activities or not is influenced by their level of education (Yoshida and Yagi, 2017). Table 3 summarizes the level of education attained by both diversified and non-diversified farmer groups. Among the five categories under consideration, the major share from both the groups fall into secondary level classes with a notable variation in the figures. When 44 per cent of the diversified farmers attained secondary level education, only 38 percent of non-diversified farmers could get into the same level. Almost 14 per cent of the non-diversified farmers were illiterate while it was around 11 per cent for the diversified farmers. In both the groups, less than 10 per cent of the respondents had graduation and above degree.

Considering the total respondents, the figures show a similar pattern. 42 per cent of the total size had secondary level education followed by 11 per cent illiterates, 24 percent got into primary level classes, 15 per cent into intermediate and 8 per cent of the total had graduation and above. The result substantiates that there is not much variation in the level of education gained by diversified and non- diversified groups. Also, as the level of education increases the number of diversified farmers decreases. It is confirming to the inference put forward by Meraner, 2018 that farmers with a higher level of education are less likely to start with a diversification activity.

Operational land holding of the sample farmers

The relationship between diversification and farm size is an indicator of trade-offs between risk reduction and possible economies of size in a particular activity (Pope and Prescott, 1980).

From the Table 4, it is clear that as the farm size increases the tendency to diversify farm activities also increase. Out of the non-diversified farmers, more than half of the respondents were having marginal size of farm (71%) followed by small (22%) and semi-medium (5%). Merely 2 per cent of the total non-diversified farmers were having medium size of farm.

However, the pattern was totally different for diversified farmers. Among them, 36 per cent were of small farmers followed almost nearly by marginal (33%) and semi-medium (23%) farmers. Interestingly, on the whole, 7 per cent of the diversified farmers were having medium farm size. This clearly shows a positive relationship between diversification and farm size which came in accordance with the report that the variance in local food production increases with farm size (Frederik and Ashley, 2019).

With regard to the total respondents, majority fall under marginal category (50%) followed by small (30%), semi-medium (15%) and medium (5%) categories.

Experience in farming

There are contrasting findings on the relationship between farming experience and farm diversification. The farmer who has more experience in farming was reported to have more odds for diversifying his crops (Aheibam *et al.,* 2017). On the other hand, there were reports showing negative correlation

Table 3. Education level of the sample farmers

Category	Non diversified (N=143)		Diversified (N=187)		Total (N=330)	
	Number	Percent	Number	Percent	Number	Percent
No school	20	13.99	20	10.70	37	11.21
Primary level classes (1-5)	40	27.97	39	20.86	79	23.94
Secondary level classes (6-10)	54	37.76	83	44.39	137	41.52
Intermediate	19	13.29	30	16.04	49	14.85
Graduation and above	10	6.99	15	8.02	28	8.48

Table 4. Operational land holding of the sample farmers

Farm Size	Non diversified (N=143)		Diversified (N=187)		Total (N=330)	
	Number	Percent	Number	Percent	Number	Percent
Marginal (<1 hec)	102	71.33	62	33.16	164	49.70
Small (1-2 hec)	31	21.68	68	36.36	99	30.00
Semi-medium (2-4 hec)	7	4.90	43	22.99	50	15.15
Medium (4-10 hec)	3	2.10	14	7.49	17	5.15

between farming experience and farm diversification (Makate *et al.,* 2016).

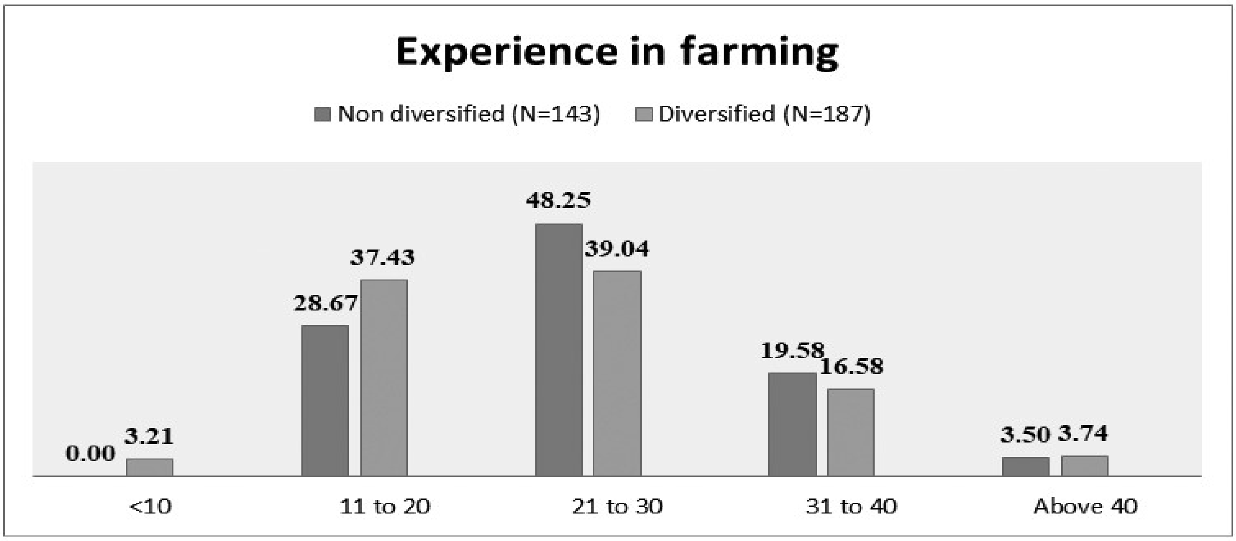
The results from the study are presented below (Figure 2).

Within the sample, on comparing the groups, it was observed that the category with less than 20 years of experience was dominated by diversified farmers (around 40% for diversified and 29% for non-diversified) while non-diversified farmers were predominant in 21 years above experienced category (71% for non-diversified and 60% for diversified). The average experience in farming for non-diversified farmers was 27.26 years while it is 25.97 years for diversified farmers. Apparently, the result confirms a negative relationship between farming experience and diversification and is in line with the work done by Makate *et al.,* 2016.

Crop Diversity Index

Crop diversity index is a principal characteristic which demarcate both diversified and non-diversified farmers. It is a prominent variable that can be brought under farm diversification study wherein crop diversity is one type of the deepening activities. In the Table 5 below, the results of Simpson's Diversity Index are clearly depicted.

Diversifying farming activities by growing different types of crops more towards commercial side rather than on conventional side is a way of general livelihood strategy for farmers (Waha *et al.,* 2018). Reinforcing this finding, it is evident from the results that



Average experience in farming (Years)	Non-diversified	Diversified
	27.26	25.97

Figure 2. Farming experience of sample farmers

Table 5. Crop Diversity Index of sample farmers

CDI	Non diversified (N=143)		Diversified (N=187)		Total (N=330)	
	Number	Percent	Number	Percent	Number	Percent
0	128	89.51	56	29.95	184	55.76
<0.5	14	9.79	51	27.27	65	19.70
0.5-1	1	0.70	80	42.78	81	24.55

majority of the non-diversified farmers carry out specialized farming (90%), particularly paddy being the sole crop in the study area. On the contrary, majority of the diversified farmers (43%) have high diversity index between 0.5-1 indicating that such farmers tend to grow different kinds of crops to spread the risk and inturn, avail more benefits. Specifically, crops preferred by highly diversified farmers in the study area include high value crops like fruits, vegetables and flowers.

Only farm as source of income

The idea of a person relying on one source of income depends on how much he is able to fetch from it. In our context of study, there is a supporting finding reported by Torres *et al.,* 2018, that higher the income derived from crop production by a cultivator, the more is his tendency to diversify into crop production. The figure below (Figure 3), clearly portrays the percentage of diversified and non-diversified farmers depending only on farm as a source of income.

On collating the percentage of two groups, it can be observed that among the diversified farmers, Chevella-the most diversified mandal, is having the largest share of farmers (28%) with only farm as source of income. This is followed by Shamshabad- the next best diversified mandal, with a share of 17 per cent and then by Ibrahimpatnam which trails the same line. The least diversified mandals like Pochampally, Bibinagar, Medchal contribute lower shares (8%, 8% and 5% respectively). Our finding is in line with the observations of Das and Kumar (2017) which states that the higher the level of diversification in crop production as well as in other types of farm activities, the greater its impact on farm income.

SOCIO-ECONOMIC CONSEQUENCES OF URBAN SPRAWL IN THE STUDY AREA

Urban sprawl has manifold consequences, both positive as well as negative, in different fields such as social, economic, political, technological, cultural

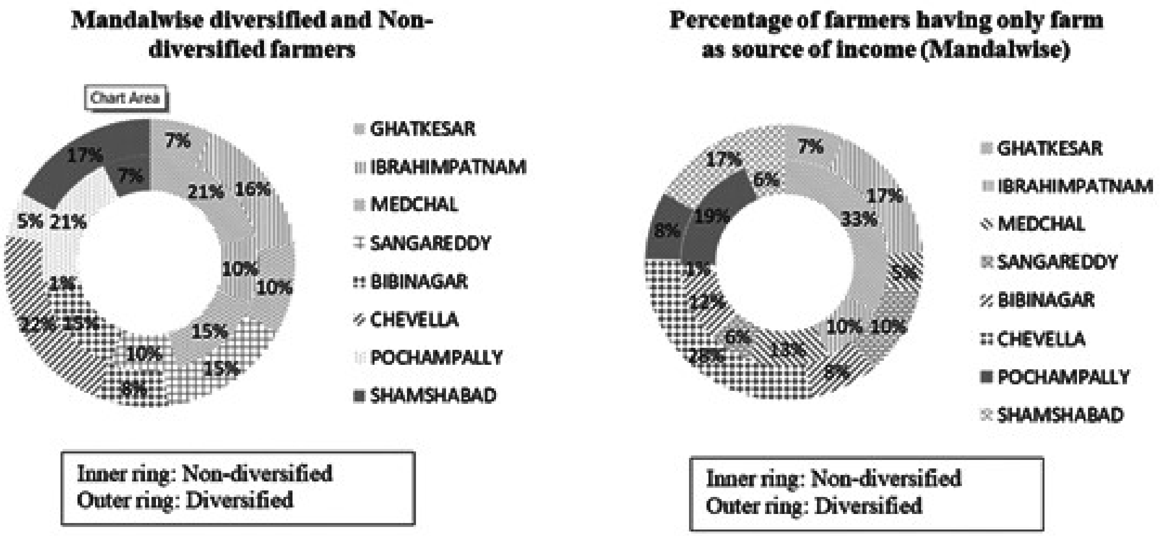


Figure 3. Percentage of diversified and non-diversified farmers with only farm income

and environmental (Jarah *et al.,* 2019). The perception on the long term consequences of urban sprawl was collected from the inhabitants of the survey location and further the weightage was assessed using Garret Ranking method. Previous studies have shown that urban sprawl serves a platter of constraints and opportunities (Jarah *et al.,* 2019; Mandere *et al.*, 2010) wherein the major impacts are related to social and economic aspects. The ranks of each impacts based on the Garret score values obtained are presented in Table 6 and 7.

Social Impacts due to urban sprawl

With regard to social impacts, improvement in social status of women was ranked as the major effect of urban sprawl by the respondents with a Garret score of 59.85 (Table 6). Several studies have reported that the social impact of urban expansion towards its peripheries has a positive side of changing the outlook of the society on its women population (Mabala and Tacoli, 2010). Women have started to enjoy relatively better opportunities and their participation in decision making has relatively improved (Tacoli and Chant, 2013).

Increased migration rate was ranked as the second major social impact by the respondents. Previous studies have cited evidences for the influence of urban sprawl on massive rural-urban migration (Hossain, 2013; Potts, 2015). As mentioned by Hatab *et al.,* 2021, urban sprawl influenced migration could be 'from the area' as well as 'to the area'. The movement 'from the area' ie., from peripheries to urban centres mainly concentrate on availability of non-farm activities and informal jobs in the construction, transport or commercial sectors (Li *et al.,* 2016), while reverse migration 'to the area' is due to push factor ie., extreme population density in the core areas which would spread the growing population towards the peripheries (Agergaard *et al.,* 2019).

Yet another social impact includes better access to public services, which is positioned at third rank with a Garret score of 54.99. The respondents stated that due to the spillover effects from urbanisation, there is an increase in the accessibility of public services such as schools, primary health centres, infrastructural facilities etc., in and around the peripheries. Not only have the basic social amenities in the peri-urban spaces increased, facilities like higher education institutions, hospitals and government offices in the nearby centres could also be better accessed unlike a few decades before, due to stronger rural-urban linkages (Aberra and King, 2005; Tacoli, 2013).

Social division among the population in the sprawled region is a serious concern and several studies proposed that due to urban sprawl the extent of connectedness and solidarity among the societal groups have declined and social stratification has increased (Afriyie *et al.,* 2014; Mckinzie, 2008). The respondents in the study area also felt in the similar way and they ranked 'social division' on fourth position. A potential increase in the crime rate under the influence of urban extension was ranked as having the least impact among the statements, as the respondents felt there is not much relation between urban sprawl and crime incidence in their area.

Table 6. Perception of respondents on the social impacts of urban sprawl

Social Impacts	Garret score	Rank
Improved social status of women	59.85	I
Improved access to public services	54.99	III
Increased migration rate	55.93	II
Social division	53.73	IV
Increased the incidence of crime	51.84	V

Economic Impacts due to urban sprawl

Hyderabad being the fastest growing metropolises in India, has gone through diverse city centric developmental projects such as IT related services. It is expected to be home to about 19 million residents by 2041 (GoAP, 2013; Census of India, 2011). The developmental growth in the city centre acts as a catalyst to the advancements in the peripheral region. A study conducted by ICRISAT on the rural non-farm employment has cited the extensive growth in employment opportunities in the peripheries of this metropolitan region (Reddy *et al.,* 2014). There is a significant increase in both farm and non-farm related business opportunities and apparently the rural-urban linkage has opened diverse livelihood portfolio for the peri-urban dwellers (Hussain and Hanisch, 2014).

The peri-urban inhabitants in the survey area could relate the economic development in their region with the urban sprawl. On addressing the economic impacts under the influence of urban sprawl, the respondents collectively ranked two positive effects as topmost (Table 7). Creation of new business opportunities and increased employment opportunities were given the highest scores positioning them at first and second rank respectively. As observed in the labour diversification section, among the entire sample, 42 percent of the total households were engaging in activities other than farming (Pluriactivity + Non-farm only). It was also observed that as the distance from city increases, probability of household to engage in pluriactivity also increases. This itself is a clear evidence of improving business and other employment opportunities in the area. Similar response was reported by Afriyie *et al.* (2014), Mandere *et al.* (2010) which commented that investment and scale opportunities are positively associated with city size and the effect gets extended to a wider radius.

Out of the five stated economic impacts, majority of the respondents agreed to the rise in property value to be a resultant of urban sprawl and overall ranked it as the third most important effect, followed by increasing household expenses. According to the respondents, there are many potential buyers for the land in the region due to eroding urban growth and hence land prices are sky rocketing. Apart from this, government is also engaged in buying plots from the residents to extend developmental activities. One such extensive land grabbing happened during 2004 to 2011 near the transitional zone of Hyderabad Metropolitan Region for the construction of Outer Ring Road, which resulted in increasing property value in the region. The dwellers claim that land prices for example in Shamshabad (a mandal 23 km from the city centre) were approximately Rs.458 per square yard during 2009, but due to the city development linked land acquisitions, land prices reached a minimum of Rs.6300 per square yard during 2022 (GoT, 2022). The official government statistics shows similar rise in land value in all the survey area within a period of ten years. Previous studies by Jarah *et al.,* (2019) and Li *et al.,* (2016) also found similar rise in property value in the suburban areas due to urban explosion. Similarly, increase in household expenses is yet another economic impact of urban extension into the rural corridor. The dwellers in the survey area complained about problems such as rise in food prices, high rental charges and other externalities which makes their cost of living high and hence they ranked it as the fourth important economic impact with a Garret score of 52.96. However, enhancement in overall standard of living was ranked as the least by the respondents.

Table 7. Perception of respondents on the economic impacts of urban sprawl

Economic Impacts	Garret score	Rank
Created new business opportunities	62.90	I
Increased employment opportunities	57.44	II
Enhanced overall standard of living of householders	52.80	V
Increased the values of land and houses	56.23	III
Increased household expenditure	52.96	IV

CONCLUSION

The socio-economic characteristics of farmers are an important arena to look upon as a preliminary study before any further analysis. Since diversification of farmland is a latest strategy, it was expected that the average age of diversified farmers would be less than that of non-diversified farmers. As increase in farm size encourage farmers to take up diversification, and fragmentation of land being an undeniable truth, policies should be formulated to support smallholder farmers to pool their land. Apart from crop diversification, farmers should also be motivated to take up other on-farm portfolios to raise their income. The perception of peri-urban dwellers on urban sprawl also throws a light on the need to formulate urban policies keeping a balance between city development and sustainable production.

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CHALLENGES FACED BY THE MEMBERS OF THE FARMER PRODUCER ORGANISATIONS IN TELANGANA STATE

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ABSTRACT

Present study was conducted to know the challenges associated with the performance of Farmers' Producers Organisation (FPO). Present study was conducted in Telangana state, random sampling techniques were followed in case of selecting the area and the respondents of the present study. Data collection was done by structured interview schedule after pre-testing with the help of personal interview method. Henry Garett ranking technique was used to analyse the data and draw conclusion. Results showed that majority of the members were facing problems with respect to irregular procurement of produce (61.29) followed by inadequate infrastructure facilities (59.92) and credit facilities are not available to the members (54.64).

Key words: farmer producer organisation, members, non-members, challenges

Agriculture is the backbone of the Indian economy and plays a pivotal role in its growth and development, with approximately 17% contribution to the country's Gross Domestic Product (GDP). Over two third of India's working population is engaged directly or indirectly with agriculture and allied activities for livelihood. Shrinking acreage is one of the prime challenges to Indian agriculture, which is making the profession less economical for farmers. As per the National Sample Survey Office (NSSO,2011) more than 50% of small and marginal farmers in India are in debt. Small land holdings generate low annual agricultural production and marketable surplus, and eventually trap farmers into a vicious cycle of debt. To overcome the challenges there are various alternatives but one of the potential alternative for efficient farming, information sharing, delivery of inputs, marketing and profit making is mobilizing farmers for group action through developing farmer's organizations. The Government of India has been promoting a new form of collectives called Farmer Producer Organizations (FPOs) under Companies Act, 1956. Farmer producer organizations are groups of rural producers coming together based on the principle of membership, to ensure specific common interests of their members and developing technical and economic activities that benefit their members and maintaining relations with partners operating in their economic and institutional environment.The major constraint in the agriculture sector in rural areas is lack of infrastructural facilities such as procurement centers, godowns, transport, farm-implements, affordable quality inputs, technology, quality extension, investment in natural resources, credit facilities, secondary agriculture activities, and marketing (Makal *et al.,* 2017). The majority of the cooperative institutions are currently facing a severe financial crisis and heavily dependent on the state's subsidy for existence (Prabhakar *et al.,* 2012). Lack of financial capital and lack of knowledge about running business are major problems that confront the board of directors of the FPC (Ganesh, 2017). Likewise, there may be many other related issues experienced by the FPOs farmers. The study therefore, was planned and conducted to answer the above research question as objectively as possible with specific objective to find out the challenges faced by the members of FPOs in Telangana state.

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MATERIAL AND METHODS

The present study was conducted in Telangana state during the year 2021-2022. Frame of registered FPOs in Telangana state was obtained from the Small Farmers Agribusiness consortium (SFAC) and the National Bank for Agriculture and Rural Development (NABARD, 2015). At the time of data collection, all the FPOs representative (CEO) were contacted telephonically (some through personal visits also) in order to check the status. The information obtained was tabulated under functional and non-functional FPOs. From the final frame 9 functional FPOs having more than three years of operation were selected randomly, consequently a total of 9 FPOs were selected for the present study. The respondents were selected randomly based on the location of FPOs. Total 360 (180 members and 180 non-members) farmers representing nine functional FPOs were selected randomly by choosing 20 members from each FPO. Ex-post facto research design was adopted in this study. The data were collected with the help of pretested interview schedule. The statistical methods and tests such as frequency, percentage and Henry Garett ranking technique were used for the analysis of data.

Henry Garett ranking technique: was used to assess the challenges faced by the members in FPOs. In this technique, the respondents were asked to rank the given attribute according to the magnitude of the problem. The orders of merit given by the participants were converted into ranks by using the following formula.

$$\text{Per cent position} = \frac{100(Rij - 0.5)}{Nj}$$

Where,

R_{ij} = Rank given for the i^{th} item j^{th} individual

N_j = Number of items ranked by j^{th} individual

The percentage position of each rank obtained was converted into scores by referring to the table given by Henry Garett. Then for each factor, the scores of individual respondents were added together and divided by the total number of respondents for whom the scores were added. The mean scores for all the factors were arranged in the order of their ranks and inferences were drawn.

RESULTS AND DISCUSSION

Table 1 showed that majority of the members were facing problems with respect to irregular procurement of produce (61.29) followed by inadequate infrastructure facilities (59.92), credit facilities are not available to the members (54.64), inadequate transportation facilities (50.52), lack of staff (49.58) and distant location from centre village (45.78) However, the organisation was not taking the whole of members' produce (44.67), centralized administration (43.87), political interference (42.50) and organisation procures produce of non-members (39.97) were the least observed challenges. The results were in agreement with the findings of Bharathi (2005), Chandargi (2007), Darshan *et al* (2019) and Chauhan *et al* (2021).

Table 1. The rank order of operational and technical challenges as perceived by the members of FPOs (n=180)

Sl. No	Technical and operational challenges	GRS	Rank
1	Irregular procurement of produce	61.29	I
2	Inadequate infrastructure facilities	59.92	II
3	Credit facilities are not available	54.64	III
4	Inadequate transportation facilities	50.52	IV
5	Lack of staff	49.58	V
6	Distant location from centre village	45.78	VI
7	The organisation is not taking the whole of members' produce	44.67	VII
8	Centralized administration	43.87	VIII
9	Political interference	42.50	IX
10	Organisation procures produce of non-members	39.97	X

In case of organisational challenges it could be observed from the Table 2 the members faced the problem with respect to the non-uniform rotation of governing body (57.49) followed by members tries to achieve key positions in the organisation (56.33), competition among villages for getting benefits (54.75), benefit sharing is not uniform among members (50.95) and personal gain is of utmost importance than the group goals (48.73) However, opposition of each other's views during meetings (47.36), members share formal relationships (46.20) and lack of team spirit (42.29) were the least observed problems. The above trend was observed due to the existence of constant BoD (Board of Directors) over a period of time. Even though the procedure of election was followed after every three years, few members felt that there was a necessity for modification in leadership. The results were in agreement with the findings of Dhakal (2013), Gundlach (2013), Darshan *et al* (2019) and Chauhan *et al* (2021) the respondents perceived some of the problems with respect to the functioning of promoting institutions. From Table 3, it could be observed that the majority of members felt that promoting institutions were focusing only on resource-rich areas (65.83) and on progressive farmers (64.03), followed by profit motive (60.34) and interfering in the decision making the process of FPOs (59.28). But, forcing their own organisational agenda on FPOs (56.75). inability to guide coordinators and ABAs (Agribusiness Advisors) (50.21) and exploiting the members to meet their objectives (48.94) were the least observed constraints. It was observed that distant villagers were mostly dissatisfied with the functioning of FPOs. They felt that promoting institutions were focusing only near the centers of operations. Even though there was an agreement with respect to profit sharing in business in the range of 50:50 between promoting institution and FPO (Board of Directors), the members were feeling dissatisfied because they were of the opinion that the resource institute was not helping in negotiating with the input agencies. They also felt that there were possibilities of partnership between agencies and promoting institutions for profit sharing. Findings were in agreement with the findings of Stockbridge *et al.* (2003),

Table 2. The rank order of organisational challenges in FPOs as perceived by the members of FPOs.

(n=180)

Sl. No	Organisational challenges	GRS	Rank
1	Governing body is not rotated uniformly	57.49	I
2	Each tries to achieve key positions in the organisation	56.33	II
3	There is a competition among villages for getting benefits	54.75	III
4	Benefit sharing is not uniform	50.95	IV
5	Personal gain is of utmost importance than the group goals	48.73	V
6	Members always oppose each other in the meetings	47.36	VI
7	Members share formal relationships	46.2	VII
8	Lack of team spirit	42.29	VIII

Table 3. The rank order of challenges related to Promoting institution's support as perceived by members of FPOs

(n=180)

Sl. No	Challenges	GRS	Rank
1	Focussing only on resource-rich areas	65.83	I
2	Focussing only on progressive farmers	64.03	II
3	Profit motive	60.34	III
4	Interfere in the decision-making process of FPOs	59.28	IV
5	Forcing their own organisational agenda on FPOs	56.75	V
6	Unable to guide coordinators and ABAs	50.21	VI
7	Exploiting the members to meet their Objectives	48.94	VII

Raghuprasad *et al.* (2004), Darshan *et al* (2019) and Chauhan *et al* (2021).

It could be observed from the Table.4 that the majority of members felt that the members faced the problem with respect to the untimely, costly and poor quality inputs (68.47), followed by lack of proper infrastructure facilities (65.62), storage facilities (63.08), and processing facilities (61.18) However, high incidence of diseases and pests, crop failure (58.23), unable to derive benefits of the ICT tools (55.59) and lack of awareness about grading and packaging (51.05) were the least observed challenges. Results were in agreement with the findings of Shashikant *et al.* (2012), Chodavadia *et al.* (2013), Ahire *et al.* (2015), Darshan *et al* (2019) and Chauhan *et al* (2021).

It could be noticed from the Table 5, that the majority of members felt that the members faced the problem with respect to the non-availability of labour during transplanting, sowing, harvesting etc. (69.00), followed by lack of technical skill of labourers in harvesting, processing (66.00), high cost of labour (58.97) and lack of sufficient finance (55.91). However, lack of awareness of credit facilities (49.89), non-availability of crop insurance facilities (47.36) and lack of price policy by the government (45.60) were the least observed challenges. The results were in agreement with the findings of Darshan *et al* (2019) and Chauhan *et al* (2021).

Table 6 showed that majority of the members were facing problems with respect to lower price for produce and distress sale (68.05), followed by exploitation by middle men (66.46), yearly price fluctuation (63.08) and distant market and high cost of transportation (60.55). However, lack of latest market information (57.70), perishable nature of products (55.59) and delayed payment (53.06) were the least observed challenges. The results were in agreement with the findings of Shashikant *et al.* (2012), Chodavadia *et al.* (2013), Darshan *et al* (2019) and Chauhan *et al* (2021).

Table 4. The rank order of technical challenges as perceived by non-members

(n=180)

Sl. No	Technical challenges	GRS	Rank
1	Untimely, costly and poor quality inputs	68.47	I
2	Lack of proper infrastructure facilities	65.62	II
3	Lack of well-developed storage facilities	63.08	III
4	Lack of well-developed processing facilities	61.18	IV
5	High incidence of diseases and pests, crop failure	58.23	V
6	Computer illiteracy which makes them unable to derive benefits of the ICT tools	55.59	VI
7	Lack of awareness about grading and packaging	51.05	VII

Table 5. The rank order of labour and economic challenges as perceived by non-members

(n=180)

Sl. No	Labour and economic challenges	GRS	Rank
1	Non availability of labour during transplanting, sowing, harvesting etc.	69.00	I
2	Lack of technical skill of labourers in harvesting, processing	66.00	II
3	High cost of labour	58.97	III
4	Lack of sufficient finance	55.91	IV
5	Lack of awareness of credit facilities	49.89	V
6	Non availability of crop insurance facilities	47.36	VI
7	Lack of price policy by the government	45.60	VII

Table 6. The rank order marketing challenges as perceived by non-members

(n=180)

Sl. No	Marketing challenges	GRS	Rank
1	Lower price for produce and distress sale	68.05	I
2	Exploitation by middle men	66.46	II
3	Yearly price fluctuation	63.08	III
4	Distant market and high cost of transportation	60.55	IV
5	Lack of latest market information	57.70	V
6	Perishable nature of products	55.59	VI
7	Delayed payment	53.06	VII

CONCLUSION

The challenges associated with FPOs are very definite and complex in nature which needs immediate intervention from the policy makers and planners to deal with the challenges for sustaining the existing FPOs towards economic development of the rural poor. Some of the issues related to FPOs in technical, marketing, organisational, social aspects need strategic interventions to make the existing FPOs more vibrant, sustainable and profitable towards income enhancement of the farming community. There is a need for the district level agencies like ATMA and KVKs to encourage for the collectivization of farmers into Farmers Producer Organizations (FPOs) and coordinate and streamline the efforts of stakeholders like NGOs, Private agencies, line departments of agriculture, State Agricultural Universities, etc., to provide adequate forward and backward linkages for improving the production and productivity.

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CUSTOM HIRING CENTER MODELS FOR ENHANCED FARM MECHANIZATION IN TELANGANA STATE

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ABSTRACT

Farm mechanization has become unavoidable in order to boost agricultural production and keep agriculture growing in lockstep with population expansion. A growing shortage of agricultural labour needs the timely delivery of agricultural machinery at a reasonable cost to farmers. Furthermore, through improving input use efficiency and judicious use of inputs, the use of appropriate farm machinery lowers the unit cost of output. Farm mechanization demands a significant investment in farm power sources and equipment, which is neither necessary nor viable for India's small and marginal farmers, who account for more than 80% of all farm holdings. In this context, the most rational and acceptable institutional action proposed in recent years appears to be custom hiring of agricultural machinery.

Key words: Custom hiring, Farm Mechanization, Agricultural machinery.

Agriculture is the mainstay of Indian economy and plays an important role in its growth and development. Farm Mechanization is the process of developing machines and substituting this machine power for human and animal power in agriculture and allied production practices. Farm mechanization has become mandatory for escalating agricultural production and achieving the steady growth in agriculture in synchronization with population growth (Reddy, S.Y. and Sudharani, 2021). A Custom Hiring Centre (CHC) is a convenient, one stop solution for farm equipments owned and managed by community based organizations like Farmer Producer Organizations (FPOs) /Mandala Samakhya (MS)/ Voluntary Organisations (VO) and Non Governmental Organisations with the goal of meeting local farmer requirements and reducing drudgery.

The centre has a collection of farm machinery, implements, tools, and equipment that are rented out to small and marginal farmers, women and agricultural labourers. CHCs enhance access to quality tools, implements and machinery services for ensuring quick response and timely operations such as land preparation, sowing, inter-cultivation, other crop management, harvesting and post harvesting specific to existing cropping pattern of the cluster (Uday *et al.,* 2020).

The goal of the Custom Hiring Center is to keep the inventory of equipment in such a way that it is used to its full potential during the season, rather than sitting idle. The Community Based Organisations (CBOs)/ Farmer Producer Organizations (FPOs) control the CHC, and the day-to-day management of the CHC may be handed to one of the professionals (manager-incentive based) for smooth operation and revenue model sustainability. The FPOs and CBOs rent out the equipment. To ensure transparency and equipment tracking, the CHC centre will keep a set of registers and accounting procedures. During the year 2020–21, Society for Elimination of Rural Poverty (SERP), Department of Rural Development has sanctioned 31 CHCs under NRLM (National Rural Livelihoods Mission) one in each district in Telangana State. The number of CHCs established in Telangana is presented in Table 1.

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The Government of India through several schemes and policies has tried to enhance the spread of Custom Hiring Centers. Rashtriya Krishi Vikas Yojna (RKVY), Mission for Integrated Development of Horticulture (MIDH), National Mission on Oilseeds and Oil Palm (NMOOP) and National Food Security Mission (NFSM) are the schemes that are intended to expand country's agricultural productivity. The youth can be specifically trained and financially supported (credit linked back-end subsidy) to set up Custom Hiring Centers (CHCs). In order to make such enterprises viable, other agricultural services can also be integrated to offer 'One Stop Shop'. Uberization is feasible in agricultural mechanization. This can be made possible by networking of individual owners, Custom Hiring Centers (CHCs), Agriculture Machinery Banks (AMBs) and Regional/ State Service Centres by on boarding a common platform and meeting the demand in real time and cost effectively. Keeping this in view, study was undertaken to understand the functioning of the Custom Hiring center Models of Farm Mechanization in Telangana State.

MATERIAL AND METHODS

Descriptive research design was adopted for the study. The state of Telangana was selected purposively for current study. The districts with availability of Custom Hiring Center Models namely Government based CHC Model of Pottipally village, Sadasivpet Mandal of Medak district, Non

Table 1. List of Custom Hiring Centers established in Telangana State

S.No	Name of district	Mandal Name where CHC located	Major Crops	Model	No of farmers to be benefitted
1	Jayashankar Bhupalpally	Kataram	Cotton	Mandal Samakhya	400
2	Peddapally	Srirampur	Paddy	Mandal Samakhya	400
3	Karimnagar	Ellanthakunta	Paddy, Maize	Mandal Samakhya	500
4	Rajanna sircilla	Yellareddypet	Paddy	Mandal Samakhya	500
5	Jagitial	Korutla	Maize, Paddy, Turmeric	FPO	500
6	Siddipet	Jagdevpur	Paddy	FPC	400
7	Siddipet	Siddipet	Vegetables	FPO	300
8	Medak	Shankarampet-R	Pulses	FPC	400
9	Mahabubnagar	Nawabpet	Cotton	FPO	500
10	Mahabubnagar	Bhootpur	Paddy	FPC	400
11	Wanaparthy	Kothakota	Paddy	FPC	300
12	Wanaparthy	Athmakuru	Pulses	Mandal Samakhya	600
13	Wanaparthy	Rajapeta	Paddy	Samatha & BAIF NGO and RECL	300
14	Wanaparthy	Peddagudem	Paddy	Samatha & BAIF NGO and RECL	200
15	Wanaparthy	Kadukuntla	Paddy	Samatha & BAIF NGO and RECL	300
16	Wanaparthy	Mentapalle	Paddy	Samatha & BAIF NGO and RECL	250
17	Wanaparthy	Madanapuram	Paddy	YFA, KVK	300
18	Jogulamba Gadwal	Maldakal	Paddy, Groundnut, Cotton	Mandal Samakhya	600

Contd...

S.No	Name of district	Mandal Name where CHC located	Major Crops	Model	No of farmers to be benefitted
19	Narayanpet	Dhanwada	Paddy, Groundnut	FPO	500
20	Nagarkurnool	Thimajipet	Cotton	FPO	600
21	Badradri	Mulakalapalli	Paddy	Mandal Samakhya	400
22	Khammam	Nacharam,	Paddy, Cotton, Maize	KVK,ARS Wyra	100
23	Khammam	Singareni	Vegetables	FPO	600
24	Mahaboobabad	Nellikuduru	Paddy, Cotton	Mandal Samakhya	450
25	Warangal Rural	Chennaraopet	Pulses	FPO	500
26	Warangal Urban	Bheemadevarapally	Paddy, Maize	Mandal Samakhya	600
27	Jangoan	Devruppala	Paddy, Vegetables	FPO	600
28	Mulugu	Eturnagaram	Paddy	Mandal Samakhya	300
29	Rangareddy	Kandukuru	Vegetables	FPC	600
30	Rangareddy	Manchala	Paddy	BAIF NGO	300
31	Vikarabad	Mominpet	Paddy	FPO	600
32	Sangareddy	Kohir	Maize	FPC	600
33	Kamareddy	Tadwai	Vegetables	FPC	600
34	Nizamabad	Dhamannapet	Paddy	FPC	600
35	Nizamabad	Navipet	Paddy, Turmeric,	Mandal Samakhya	600
36	Kamareddy	Kalwaral	Paddy	Dharani FPO	650
37	Adilabad	Gudihathnoor	Groundnut	FPC	600
38	Mancherial	Bheemaram	Paddy, Cotton	FPO	500
39	Nirmal	Kubeer	Paddy ,Cotton	Mandal Samakhya	600
40	Asifabad	chinthalamanepally	Paddy	BBWS FPC	500
41	Asifabad	Asifabad	Vegetables	FPO	400
42	Nalgonda	Miryalaguda	Paddy ,Cotton, Pulses	Mandal Samakhya	600
43	Nalgonda	Nandyalagudem & Boring Thanda Atmakuru	Paddy, Cotton, Maize	KVK,Gaddipalli	300
44	Suryapet	Chivvemla	Paddy, Vegetables	FPC	600
45	Yadadri Bhongir	Mothkur	Paddy, Vegetables, Pulses	Mandal Samakhya	600
46	Suryapeta	Nandyalagudem	Paddy	NGO	300
47	Rangareddy	Mubaraknagar Nawabpet Village	Maize	Mythri Rythu Mitra Sangam Group	300
48	Medak	Sadasivapet Pottipally village	Cotton	RKVY-2014-15	300
49	Mahabubnagar	Kothakota	Paddy	RKVY 2014-15	300

Governmental Organisation (NGO) based CHC Model of Rajapeta Village of Wanaparthy district, Farmer Producer Organisation (FPO) based CHC Model of Dharani FPO in Sadasivanagar Mandal of Kamareddy district and Krishi Vigyan Kendra (KVK) based CHC Model of Youth For Action, KVK of Madanapuram in Wanaparthy district of Telangana state were purposively selected for the study. Secondary data related to list of Custom Hiring Centers was collected from Agriculture Commissionerate Office, Basheer Bagh, Hyderabad and Society for Elimination of Rural Poverty (SERP), Department of Rural Development, Government of Telangana, Khairatabad, Hyderabad. Compartive Analysis of Cost and Benefit ratio of four CHC Models is carried out to know viability.

1. FPO based CHC (Model I)

Dharani FPO's journey began in January 2017. It has been promoted by Andhra Pradesh Mahila Abhivruddi Society (APMAS) with the main objective of encouraging and strengthening self-reliant FPOs in Telangana state to engage in agriculture value chains. APMAS has assisted Dharani FPO at every stage - mobilisation, registration, capacity building, creating linkages, business planning and operations. Dharani Agricultural Producers Mutually Aided Cooperation Federation Ltd. (Dharani FPO) registered in February 2018 under MACS Act 1995. Dharani is currently having 786 Farmer members. It is established to help its member farmers sustainably increase their income and enhance the capacities of farmers and APMAS is the promoter of this farmer producer organisation under the project 'Sector Own Control' supported by DGRV, Germany in Sadhasiva Nagar Mandal of Kamareddy District. Dharani FPO established Farmer Service Centre in 30th December 2017 at Kalwaral village from where it sells inputs, rents farm equipment, extended fund for the purchase of all the Farm machinery at the Custom Hiring Centre (CHC). The farmer service centre provides essential services like land preparation, seeding, weeding and others by renting out its machinery through its CHC.

The average size of landholding is 1.53 acres in Sadhasiva nagar Mandal and around 91% of the farmers in the area are small and marginal farmers. The main crops grown in the area are Maize, Paddy, Cotton, Soybean. The FPO provides small farm equipment's for farmers. To meet the demand for sprayers, FPO supplies sprayers to the member farmers at 30% lesser price compared to the market. Non-member business forms 83% of their business turnover. The FPO did not get any grants or bank loans but had market linkages with some success. The member patronage and satisfaction level is fairly high.

The total revenue of the FPO through renting out agricultural equipment through the Custom Hiring Centre (CHC) during the financial year of 2018-19 is Rs.84,053. Dharani FPO had a turnover of Rs. 1,99,759 through farmer Service Center (Table 2). List of implements available in Farmers service center with charges is provided in Table 3.

2. Government Based Custom Hiring Center (Model II)

Telangana state adopted the Custom Hiring Centre by finalizing the package of machinery for

Table 2: Farm equipment profit of CHC

S.No	Particulars	2018-19 (Rs.)	2019-20 (Rs.)	2020-21 (Rs.)	Total turnover (Rs.)
1	Farmer Service Center	84,053	68,011	47,000	1,99,759

Table 3: Farm equipments in the CHC in 2019-20.

S.No	Name of Implement	Quantity (No.)	Charges Per Hour (Rs.)
1	Power weeder	2	500
2	Power tiller	2	500
3	Rotavator	1	1000
4	Maize sheller	1	1000
5	Tractor	1	700
6	Brush cutter	2	200
	FSC's Equipments Total	**9**	

different crops including pulse crops. Apart from this, it also developed CHC model, operation wise like land preparation, nursery raising and harvesting operation. Shri B. Srinivas a resident of Pottipally village, Sadasivpet Mandal of Medak district has about 2 ha land. To augment his net income, he became interested in custom hiring of agricultural machinery and bought CHC-cotton through RKVY scheme. He rents out these machines to many farmers of his village and also surrounding villages for cultivation of cotton.

The CHC–Cotton package farm mechanization is operating successfully. Initially in the village, farmers were not interested in using combine harvester, but now there is a demand. Other village farmers have also shown their interest in using combine harvester. In this package, the rental charges are less than that of private operators. The farmer is getting net income of Rs. 35,250/- per month. Total cost of the CHC Cotton package is Rs. 8,45,020 in which he got a subsidy of Rs. 3,34,997 from Department of Agriculture. Most of the centres are running successfully with marginal profits in Telangana. Profits are in the range of Rs. 3 lakh to Rs. 5 lakh per annum.

3. Non Governmental Organisation (NGO) based CHC (Model III)

This CHC is established in April, 2021 in Rajapeta Village of Wanaparthy district with funds of Samatha & Bharatiya Agro Industries Foundation (BAIF) NGO and Rural Electrification Corporation Limited (RECL), New Delhi with technical supportof International Crop Research Institute for Semi Arid Tropics (ICRISAT). They got a sanction of 8 lakhs. It is covering an area of 300 Acres and 3-4 villages. Around 500 farmers are benefitted from this Custom Hiring Centre. This CHC is having seven implements namely Power tillers, Paddy transpanter, Straw Baler, Cultivator, Rotavator (2), Seed cum fertilizer drill, and Taiwan sprayers (5). Mechanization leading to greater sowing and weeding efficiency, hiring a Power weeder helped in reducing the costs to farmers. Seed drill helped in cutting the labour cost by almost 60%.

The local government (panchayat) operates the centers and Sarpanch is the head of the Custom Hiring Center. It provides direct employment to one village officer and one youth caretaker from the village for handling the center's operations. B Balaraj, who was hired as the caretaker for the custom hiring center said that they earned Rs. 36,000 in first month of its establishment.

Farmer J Praveen who hired the Power weeder said that "Labor shortage is a major problem in his village and for longer duration vegetables, like the tomatoes he was growing, more weeding sessions were needed. Using the hired machinery he reduced weeding costs and saved a lot of time too. Farmer B Anil Kumar who hired the seed cum fertilizer drill said that, "With the traditional method of sowing he could cover about half a hectare in a day, but with the drill he sowed Pigeon pea on his entire 1.6 ha of land in a single day. He said that seed drill cut the labor cost by 60%".

4. Krishi Vigyan Kendra (KVK) based CHC (Model IV)

Youth For Action, Krishi Vigyan Kendra Madanapuram established Custom Hiring Center in 2017. This Custom Hiring Center is having 15 implements for hiring i.e, Multicrop thresher, Drum seeder, Cultivator, Guntaka, Shredder, Seed cum fertilizer drill, Zero till drill, Cage wheels, Dual Power Sprayer, Disc Plough, Power Sprayer, MB Plough Power weeder and Rotavator (Table 4). It was established with funds of SC/ST supply and KVK revolving funds. This Custom Hiring Center is operational in around 10-12 villages in Wanaparthy district. This Custom Hiring Center is having two technical staff for its repair and maintenance service.

Cost - Benefit Analysis

It is the cost involved in the development and maintenance of Custom Hiring Center machinery and profit derived from it in one year. It is an economic feasibility analysis. If B:C ratio of more than 1, then that model is viable. Cost Benefit Analysis of four CHC Models is presented in Table 5 and Figure 1.

$$\text{Cost-benefit Analysis} = \frac{\text{Total Benefits}}{\text{Total Costs}}$$

CONCLUSION

The study shows the status and functioning of four Custom Hiring Center Models Government based CHC Model, Non-Governmental Organisation based

Table 4: List of Implements available for hiring with CHC Charges

S.No	Name of Implements	Charges/day
1	Rotavator	2000 Rs/day
2	Power weeder	500 Rs/day
3	Drum seeder	500 Rs/day
4	Cultivator	1000 Rs/day
5	Seed cum fertilizer drill	1000 Rs/day
6	Zero till drill	1000 Rs/day
7	Cage wheels	1000 Rs/day
8	Multicrop thresher	1000 Rs/day
9	Dual Power Sprayer	500 Rs/day
10	Brush cutter	5000 Rs/day
11	Power Sprayer	1000 Rs/day
12	MB Plough	1000 Rs/day
13	Guntaka	1000 Rs/day
14	Shredder	500 Rs/day
15	Disc Plough	1000 Rs/day

Table: 5 Cost - Benefit Analysis of Custom Hiring Center Models

S. No.	Cost	Govt. CHC	NGO CHC	KVK CHC	FPO CHC
1	Total Costs	2,38,000	30,000	32,000	23,800
2	Total Benefits	3,20,000	42,000	55,000	47,000
3	Benefit : Cost- ratio	1.34	1.40	1.71	1.97

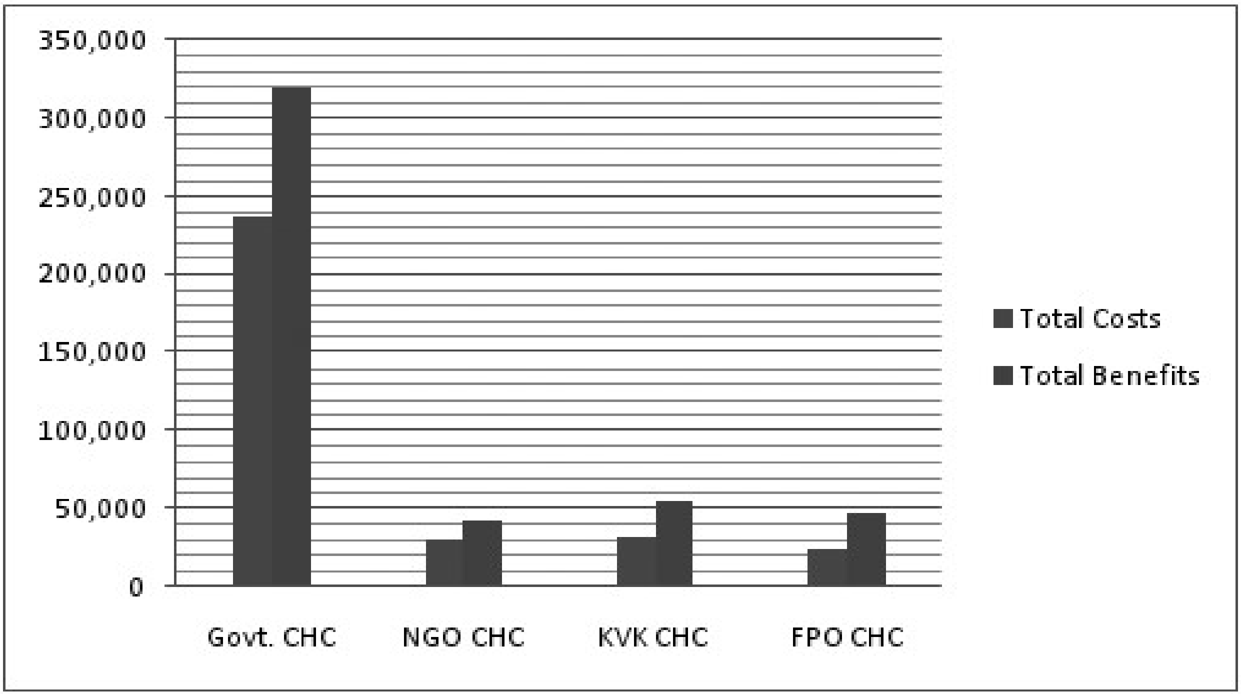

Figure 1: Distribution of Custom Hiring Center Models based on total costs and benefits

CHC Model, Krishi Vigyan Kendra based CHC Model and Farmer Producer Organisation based CHC Model in Telangana State. All four Custom Hiring Center models are viable as there B:C Ã 1. Among the four Custom Hiring Center Models, Farmer Producer Organisation based CHC Model is best model and viable on long run.

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Research Article
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FARMERS' AWARENESS AND ITS DETERMINANTS OF DIGITAL TECHNOLOGIES IN AGRICULTURE-EVIDENCE FROM RURAL TELANGANA

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ABSTRACT

Digital technologies in agriculture are expected to play an important role in dissemination of new knowledge timely and quickly, as well as in providing solution to growing labour shortage in agriculture. This study was carried out in three districts representing three agricultural zones in Telangana state to assess farmers' level of awareness about digital technologies in agriculture. A sample of 180 farmers, 90 from progressive regions and another 90 from backward regions in selected districts were interviewed during the year 2020-21 using a pre structured schedule. Farmers' responses (Yes or No) to a set of twelve questions were elicited to assess farmers' awareness of five selected digital technologies. Farmers' Digital Awareness Index (FDAI) was developed using farmers' responses and its determinants were examined through a multiple linear regression analysis. Results indicated that average FDAI in progressive regions was comparatively higher than backward regions. Nearly two third of sample farmers have the FDAI of 40 per cent and above. FDAI was positively and significantly associated with education and farm size, while age was negatively associated.

Key words: Digital technologies, Agriculture, Awareness, Famers' Digital Awareness Index

Digital technologies in agriculture are paving a way towards meeting global food needs by improved production, productivity and efficiency. These technologies in India are going to play a key role in future agriculture and also put forward the way for meeting sustainable development goals (Rao, 2022).

Indian government has taken initiatives to promote digital farming in the country. Indian government launched National e-Governance Plan in Agriculture in 2010-11 to improve timely accessibility of Information and Communication Technology (ICT) to obtain required information regarding agriculture and allied activities for farmers (agricoop.nic.in). Under this scheme the government focused on use of novel technologies such as AI, Drones and Robotics. The government has also developed various farmer portals and mobile apps such as Kisan Suvidha, AgriApp for providing extensive advisory services for farming community (mkisan.gov.in). In 2018 NITI Aayog along with IBM has started crop yield prediction technology using Artificial Intelligence. Later, government in association with Microsoft has undertaken a project on AI sensors for improved yields. They also took a step to empower small farmers and to boost the adoption of AI based technologies in farming.

In Telangana the importance of Precision farming is increasing day by day due to shrinking land water resources and labor scarcity (Annual Progress Report, 2019). Agriculture in Telangana was identified as a priority sector and digital measures are being promoted to support farmers with simplified methods and improved efficiency in farming. The state is keen towards providing AI based solutions for farming community. Telangana government and PJTSAU together have developed AgHub which works as a new incubator for digital agriculture technologies (telanganatoday.com). This initiation has been taken to provide expertise and mentorship from agriculture specialists. The government of Telangana in collaboration with ICRISAT is working towards enhancing the adoption of ICTs in agriculture by farmers (www.icrisat.org).

Although digital technologies are growing at a rapid rate, many farmers in India are lacking awareness and technical know-how. In view of the expected role of digital technologies in future agriculture, the current study was undertaken with the objective to assess farmers' awareness and its determinants with respect to digital technologies in Telangana under two different scenarios

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1. Progressive Villages
2. Backward Villages

MATERIAL AND METHODS

Telangana state was purposively selected in view of rapid transformation of rural agriculture through innovative technologies. Three districts were selected from three zones *i.e.,* Nalgonda, Jagtial and Warangal. Based on the number of farmers who have self registered for selected government agricultural schemes and apps, two mandals from each district were selected. Among these, one was progressive mandal with highest number of self registered farmers and the other was backward with lowest number of self registered farmers. Three villages from each mandal were selected to make a total of 18 villages (9 progressive and 9 backward). From each village 10 respondents were surveyed making a sample size of 180. The required data was collected through field surveys by using well structured and pretested schedule.

Tools and Techniques of Analysis

Statistical tools such as percentages and measures of central tendency were employed to make it simpler to interpret results. Farmers' Digital Awareness Index (FDAI) was developed to measure the level of farmer' awareness regarding digital technologies. Farmer's opinions were elicited with the help of structured interview schedule with respect to following questions related to five selected digital technologies.

The response was recorded as one if it was "Yes" and zero otherwise. Considering these responses FDAI was constructed as follows

$$\text{FDAI (\%)} = \frac{\sum X_1......X_n}{N} \times 100$$

Where,

X_1 to X_n – responses elicited by farmers for question

N = total number of questions asked

Multiple linear regression analysis was carried out to assess the factors influencing farmers' awareness. It is applied to study how each independent variable is affecting the value of dependent variable. The analysis was performed using the following regression

$$y = \beta_0 + \beta_1 X_1 + ------+ \beta_n X_n + \in$$

Where, y = Farmers' Digital Awareness Index

X_1 - Age (years)

X_2- Education (number of schooling years)

X_3- Farm Size (hectares)

X_4- Irrigated area (hectares)

X_5- Number of graduates in family

$\beta_0, \beta_1 --- \beta_n$ – regression coefficients of respective variables

S. No.	Question	Response	
		YES	NO
1.	Are you aware of IT based SMS/ mobile app services for providing technical information regarding agriculture?	1	0
2.	Do you know about subscription for any of the apps/SMS services?	1	0
3.	Have you ever heard of drones in agriculture?	1	0
4.	Did you see how drones look like?	1	0
5.	Have you ever seen drones in agriculture?	1	0
6.	Do you know for what purpose drones are used in farming?	1	0
7.	Did you see how robots look like?	1	0
8.	Have you ever heard of robots in agriculture?	1	0
9.	Have you ever seen robots in agriculture?	1	0
10.	Do you know for what purpose robots are used in farming?	1	0
11.	Have you ever seen censor based water management technologies in agriculture?	1	0
12.	Do you know for what purpose of censor based water management technologies in agriculture?	1	0

∈ - Error term

In the present study, FDAI was considered as dependent variable whereas the factors such as Age, Education, Farm size, Irrigated area and Number of graduates in family were taken as independent variables to study their impact on the awareness level of farmers regarding digital technologies.

RESULTS AND DISCUSSION

The primary focus of the study was to compute FDAI to understand farmers' level of awareness and to examine the factors affecting FDAI. Computed results were presented in the tables in this section.

I. Socio economic profile of sample villages

The sample size of 180 farmers was divided into two groups, where half of those belong to progressive villages and the other half to backward villages. As shown in Table 1, among the sample respondents, more than half of the farmers belong to the age group of 30 to 44 years. There were very few farmers (6.11%) with the age below 30 years. This had shown the lack of youth participation in farm activities. This might be due to the reason that most of them are heading towards jobs with stable non farm income (www.business-standard.com).

With regard to education, nearly half of the sample farmers from progressive villages have completed their matriculation and above. In backward villages 18.89 per cent farmers were not having completed their primary education. Average farm holding size was 2.26 ha for overall villages whereas it was 2.50 and 2.01 ha in case of progressive and backward villages, respectively. Highest number of farmers in villages on overall basis was accumulated in the category of semi medium farmers. The maximum *i.e.,* 45.56 per cent of farmers in backward villages were small farmers whereas in progressive villages

Table 1: Socio economic characteristics of sample farmers

S. No.	Particulars	Progressive Villages (n=90)	Backward Villages (n=90)	Overall Villages (n=180)
1.	Age (% of n)			
	a. < 30 years	5.56	6.67	6.11
	b. 30 to 44 years	50.00	52.22	51.11
	c. 45 to 60 years	37.78	27.78	32.78
	d. > 60 years	6.67	13.33	10.00
2.	Education in years of schooling (% of n)			
	a. < 5 years	7.78	18.89	13.33
	b. 5 to 10 years	32.22	32.22	32.22
	c. 11 to 15 years	47.78	37.78	42.78
	d. > 15 years	12.22	11.11	11.67
3.	Average Farm Size (in hectares)	2.50	2.01	2.26
4.	Category of farmers (% of n)			
	a. Marginal	16.67	13.33	15.00
	b. Small	23.33	45.56	34.44
	c. Semi Medium	42.22	33.33	37.78
	d. Medium	17.78	7.78	12.78
	e. Large	-	-	-
5.	Major crops grown	Paddy, Maize, Cotton, Chilli, Tomato	Paddy, Maize, Cotton, Chilli, Tomato	Paddy, Maize, Cotton, Chilli, Tomato

Source: Authors estimate based on primary data the maximum share was occupied by semi medium farmers (42.22%). The major crops grown in the sample villages were paddy, maize, cotton, chilli, tomato and other vegetables.

II. Farmers awareness and its determinants of digital technologies

Level of farmers' awareness pertaining to digital technologies in agriculture sector was determined by FDAI. The sample respondents from the progressive villages were having 47.31 per cent awareness index whereas it was comparatively higher with regard to backward villages (41.20 %). The same was represented in Figure 1. The FDAI was found to be 44.26 per cent for overall villages. This had shown that the farmers were aware of only less than half of digital technologies that are being currently available in agriculture.

The level of FDAI according to various farm sizes was computed and presented in Table 2. It was seen that on overall village basis medium farmers were having highest awareness index (44.6%). With respect to progressive villages, marginal farmers were possessing highest level of awareness followed by medium and semi medium farmers, respectively. In backward villages, medium farmers were having the highest awareness index (41.82%) whereas marginal farmers were having lowest awareness index (37.72%). The results have shown that FDAI of digital technologies was by and large same across different farm categories.

From Table 3, it was found that the two third of farmers from overall villages were having the FDAI of 40 per cent and above. In case of progressive the highest number of farmers (38.89%) was found to have the FDAI of 40-60 per cent which means they were aware of most of the digital technologies considered. Almost half of the sample farmers (44.44%) from backward villages were having very low awareness level with the FDAI of less than 20 per cent.

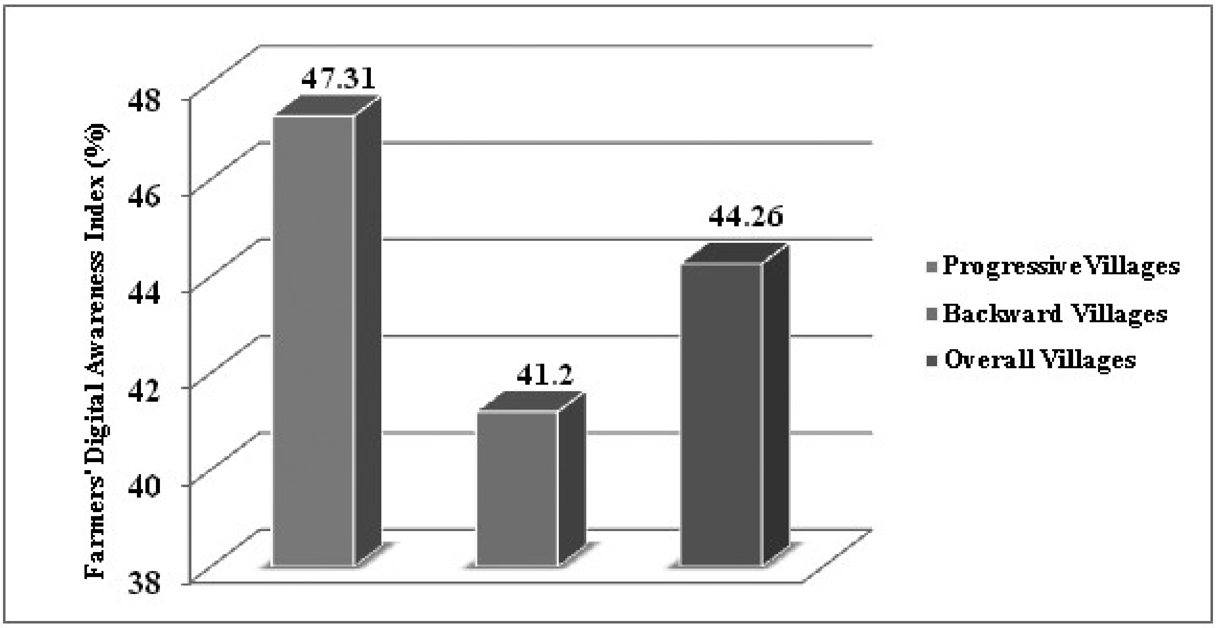

Figure 1. FDAI for progressive and backward villages

Table 2: FDAI by farm size of sample farmers

	Awareness Index (%)		
Category	**Progressive**	**Backward**	**Overall**
Marginal (< 1 ha)	47.73	37.72	43.45
Small (1 to 2 ha)	46.49	40.63	43.45
Semi Medium (2 to 4 ha)	47.31	40.73	44.26
Medium (4 to 10 ha)	47.32	41.82	44.6

Source: Authors estimate based on primary data

The regression results related to determinants of FDAI were reported in Table 4.

Adjusted R-square of the fitted regression was 55 per cent (Table 4) which indicates that 55 per cent variation in dependent variable was explained by the independent variables that were considered. From Table 4, it was observed that among the selected independent variables Age was found to have more significant and negative impact on level of awareness. This implies that young farmers have more awareness about digital technologies as compared to the other age groups. Similar findings were reported by Chaung *et al.* (2020) in their study conducted in Taiwan. Education level of farmers had a positive and significant impact on awareness which means the respondents with higher education levels were having higher levels of awareness. This result was also in conformity with the study of Reichardt and Jurgens (2019) conducted in Germany. FDAI was positively influenced by the farm size. It indicates that with increase in farm holding size, the awareness level also increases. These results were in line with the findings from Germany reported by Michels *et al.* (2020).

CONCLUSION

The results of the study concluded that farmers from progressive villages were having more awareness as compared to backward villages. On overall basis, medium farmers have the highest awareness than the other farm categories. More than 60 per cent farmers in overall villages were having awareness index of greater than 40 per cent. Young farmers, farmers with larger land holdings and farmers with higher education have more awareness about digital technologies in agriculture. The results suggested that the emphasis has to be given to capacity building programs, training and demonstration programs for improving farmers' awareness level regarding digital agriculture technologies.

Table 3. Frequency distribution of sample farmers by FDAI

	Categories		
Awareness Index (%)	**Progressive Villages (n=90)**	**Backward Villages (n=90)**	**Overall Villages (n=180)**
< 20 %	28.89	44.44	36.67
20 to 40 %	2.22	2.22	2.22
40 to 60 %	38.89	26.67	32.78
> 60 %	30.00	26.67	28.33

Source: Authors estimate based on primary data

Table 4. Regression results of factors influencing FDAI

S. No.	**Variable**	**Coefficient (b)**	**Standard error (SE)**	**t- value**
1.	Intercept	91.72	14.84	6.18***
2.	Age	-1.69	0.24	-6.98***
3.	Education	1.16	0.60	1.94**
4.	Farm size	2.42	1.31	1.84*
5.	Irrigated Area	0.17	1.27	0.13
6.	Number of graduates in family	2.39	2.48	0.96
	Adjusted R square	0.55		
	F-Value	44.37		

Source: Authors estimate based on primary data

N = 180

(***, ** and * indicates level of significance at 1%, 5% and 10%, respectively)

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Research Article
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PHYTOCHEMICAL COMPOSITION IN *Moringa oleifera*

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ABSTRACT

Moringa oleifera, known as drumstick tree is widely cultivated throughout India. It is widely used as a nutritive herb and possess valuable pharmacological activities. Due to its amazing abilities for various ailments and even some chronic diseases, it is also named as “the miracle tree”. Phytochemicals are chemical compounds that are naturally found in plant. Phytochemicals could be available as a dietary supplement, but the potential health benefits of phytochemicals are derived from consumption of the whole plant. Non-nutritive plant compounds with disease preventive or protective characteristics are known as phytochemicals. Seasonal variability of primary and secondary metabolites in moringa leaves evaluated in the month of July-August through LC-MS/MS (non-volatile) and GC-MS/MS (volatile) technique. Non-volatile toxic compounds identified were adenosine, oligomycin C, euphormin and umbelliferone present in the month of July-August. Volatile compounds identified during this period were morphinan and dihydromorphine. The compounds hematoporphyrin, euphormin and umbeliferone are intermediates in cyanide pathway during July-August and it effects the human health causing nausea, vomiting and gastrointestinal disturbances.

Key words:- *Moringa oleifera,* phytochemicals, adenosine and phenyl alanine

Moringa oleifera has been used as a dietary supplement due to its rich nutritional content. It is an outstanding indigenous source of proteins, vitamins and minerals. The tree contains digestible proteins, iron, magnesium, calcium, vitamins (B_6, B_2, C) and carotenoids (Rockwood *et al.,* 2013).

Moringa oleifera is one of the richest natural sources of provitamin A. Every part of this tree has been found to possess many nutrients. The *Moringa oleifera* plant provides a rich and rare combination of zeatin, quercetin, kaempferol and many other phytochemicals. The leaves are used as a source of vitamins A and C. They are also good sources of vitamin B and are also a sources of minerals. The leaves, flowers and immature pods of this plant are used as highly nutritive supplements with many pharmacological properties (Kumar and Pari, 2003).

Gas chromatography in *Moringa oleifera* contain octadecanoic acid (stearic acid) $C_{18}H_{36}O_2$ and cis octadecenoic acid ($C_{18}H_{34}O_2$) which had hypolipidemic activity. It contains 5-alpha reductase inhibitor which may have blocked HMG-CoA reductase which is a major enzyme in the cholesterol biosynthetic pathway (Gapalakrishnan and Vadivel 2011).

Sultana and Anwar (2008) reported as the most common flavonoids such as apigenin-8-C-glucoside, quercetin 3-O-β-D-glucopy-ranoside, kaempferol-7-O-α-L-rhamnoside, and 5,7,-tetrahydroxyflavone were identified in *Moringa oleifera* leaves. Siperstein and Fagan (2006) shown that *Moringa oleifera* is capable of carrying various sugar attachments which may affect the function of the consortium of flavonoid molecules. For instance, molecules harboring hydroxy-methylglutarate (and on its own) are known to suppress the synthesis of cholesterol.

In Kerala, it is believed that during the Malayalam month of *Karkidakam* (July to August), drumstick leaves contain antinutritional principles. This may be due to the ability to absorb large amount of water along with other toxins. Chances are that during this period, the toxins would be released into leaves. The fact is not yet scientifically proven. Hence, this study attempts to evaluate the seasonal variations in primary and secondary metabolites of *Moringa oleifera* leaves.

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MATERIAL AND METHODS

Collection of raw materials

Fresh moringa leaves were collected from Department of Vegetable Science, Kerala Agricultural University, Thrissur. The KAU moringa variety Anupama was selected for the study. The collected moringa leaves are shade dried in traditional method (moringa leaves are laid out on a mat and left to dry for 48 hrs). The dried parts was ground and sieved to get uniform flour and the flour was used for analysis of chromatography. This was done in the period of July-August *ie.* malayalam month of *Karkidakam.*

RESULTS AND DISCUSSION

- Non-volatile compounds present in *Moringa oleifera* leaves (LC-MS/MS)

HR-LCMS analysis of methanol extract of *Moringa oleifera* leaves show the presence of various phytochemical constituents. On comparison of the high resolution liquid chromatography, all these compounds were characterised and probably identified in the period of July-August.

Compounds are present in the monthly intervals of July-August (*karkidakam*) such as adenosine, phenyl alanine, ketotifen, umbeliferone, benzofuran, oxopalmitate, gingerglycolipid A, hematoporphyrin, euphormin and oligomycin C with more than 80 per cent abundance and the results are furnished in Table 1.

Abundance is a measure related to how well the various samples ionized under the specific HPLC method and the MS parameters.

These compounds possess many positive effect on health and to increase milk production as lactogogues. They also shows negative effect on health and other manifestations. The results are furnished in Table 2.

Table 1. Non-volatile compounds in *Moringa oleifera* leaves

S.No	Name	July-August
		Abundance value
1	Indoleacrylic acid	29350
2	Anthranilic acid	341745
3	3-Hydroxycoumarin	27578
4	Fabianine	17645
5	19-Noretiocholanolone	78086
6	Pheophorbide a	445400
7	Quercetin	70140
8	Maritimetin	104220
9	23-Acetoxysoladulcidine	34356
10	Irinotecan	26222
11	Myricetin 7-rhamnoside	57001
12	Adenosine	65332
13	N-(1-Deoxy-1-fructosyl) phenylalanine	61363
14	Ketotifen	26166
15	Umbelliferone	21899
16	2-Benzofuran carboxaldehyde	35959
17	16-Oxo-palmitate	24044
18	Gingerglycolipid A	43420
19	Hematoporphyrin	151423
20	Euphormin	918261
21	Oligomycin C	25625

✦ Volatile compounds present in *Moringa oleifera* leaves (GC-MS/MS)

Gas chromatography analysis of hexane extract of *Moringa oleifera* leaves show the presence of various phytochemical constituents. All these compounds were characterised and probably identified at an interval of July-August and the results are furnished in Table 3.

In the period of July-August (*Karkidakam*), identified compounds such as α-tocopherol-β-D-mannoside and triacetyltrithiophosphite. α-tocopherol–β-Dmannoside, dihydromorphine, morphinan. These are the compounds have some effect on human health such as toxic and beneficial effects are noticed in certain compounds and the results are furnished in Table 4.

Non-nutritive plant compounds with disease preventive or protective characteristics are known as phytochemicals. Myrecytin, quercetin, and kaempferol are the primary flavonoids contained in moringa leaves, with amounts of 5.8, 0.207, and 7.57 mg/g, respectively (Augustin *et al.,* 2011).

Chlorogenic acid (CGA) is a significant phenolic acid in Moringa and is an ester of dihydrocinnamic acid. CGA is involved in the metabolism of glucose. It reduces hepatic gluconeogenesis and glycogenolysis by inhibiting glucose-6-phosphate translocase in the rat liver (Kasolo *et al.,* 2003).

Moringa leaves contain bioactive chemicals such as nitrile, mustard oil glycosides, and

Table 2. Non-volatile compounds present in *Moringa oleifera* leavesin the month of July-August (*Karkidakam*) and their manifestations

Compounds	Effects	References
Adenosine	Toxic	Hershfield *et al.,*1977
Oligomycin c	Toxic	Kramar *et al.,*1984
16-oxopalmitate	Nausea	Hardy, 1997
Euphormin	Toxic	Madariaga *et al.,* 2019
2-Benzofuran carboxaldehyde	Respiratory tract irritation	Kappus, 1987
Gingerglycolipid A	Gastrointestinal disorders	Pizzorono and Murray, 2020
Hematoporphyrin	Immune function	Canti, 1984
N-(1-Deoxy-1-fructosyl) phenylalanine	Vomiting, nausea	Hardy, 1997
Umbelliferone	Toxic	Ferreira *et al.,*2008
Haplophytine	Apoptosis	Won *et al.,* 2010
3-beta, 6-beta- Dihydroxynortropane	Treating cardiovascular diseases	Abalaka *et al.,* 2012

Table 3. Volatile compounds in *Moringa oleifera* leaves

Sl. no.	Name	July-August
1	Docosane	✓
2	α-tocopherol-β-D-mannoside	✓
3	Octadecanoic acid	✓
4	1,2,3-propanethyl ester	✓
5	Triacetyl trithiophosphite	✓
6	Dihydromorphine	✓
7	Morphinan	✓

✓ Presence of specific compounds

Table 4. Volatile compounds in *Moringa oleifera* leaves in the month of July-August (*Karkidakam*) and their manifestations

Compounds	Effects	References
Docosane	Antifungal activity	Adeyami *et al.,* 2014
α-tocopherol-β-D-mannoside	Inhibits hepatic oxidative stress	Niki and Traber , 2012
Morphinan	Toxic	Hellerbach *et al.,* 1966
Triacety ltrithiophosphite	Gastrointestinal irritations	Aggarwal *et al.,* 2007
Dihydromorphine	Less toxic	Vasantha, 2022
Triacontane	Nausea, vomiting	Cohen *et al.,* 2009
Isophytol	Production of vitamins	Akubor, 2004
Methyl ester	Skin and eye irritants	Coriolano *et al.,* 2018
Eicosaneoic acid	Treating diabetes and improving lipid metabolism	Guevera *et al.,* 1999

thiocarbamate glycosides, which have been used to lower blood pressure. The four pure chemicals extracted from ethanol extract of Moringa leaves, niazinin A, niazinin B, niazimicin, and niazinin A + B, demonstrated a blood pressure reducing action in mice, potentially via a calcium antagonist effect. Moringa was found to reduce vascular oxidation in spontaneously hypertensive rats in a recent study (Kumbhare *et al.,* 2012).

Moringa oleifera contains octadecanoic acid (stearic acid) $C_{18}H_{36}O_2$ and cisoctadecenoic acid (cis oleic acid) $C_{18}H_{34}O_2$, both of which have hypolipidemic activity. This could be due to the presence of a 5-alpha reductase inhibitor, which may have blocked HMG-CoA reductase, a key enzyme in the cholesterol biosynthetic pathway (Gapalakrishnan and Vadivel, 2011).

Ndong *et al.* (2007) used HPLC analysis to identify significant polyphenols in *Moringa oleifera* powder, including quercetin glucosides, rutin, kaempferol glycosides, and chlorogenic acids. Gallic acid, chlorogenic acid, ellagic acid, ferulic acid, kaempferol, quercetin, and vanillin were found in aqueous extracts of *Moringa oliefera* leaves, fruits and seeds, according to Singh *et al.* (2009).

Antinutritional factors like oxalates, tannins, phenols and flavonoids during rainy period (July-August) may impart some toxic effects and bitterness in their leaves and makes it unfit for human consumption and also less palatable in this period (Asalou *et al.,* 2012).

CONCLUSION

Phytochemicals are biochemical substances with biological properties. The study has shown the presence of these phytochemicals in *Moringa oleifera*, which justifies the contribution of the plant to nutrition as vegetable as well as to folk medicine. Therefore, *Moringa oleifera* could be used as a good source of useful drugs for treatment of various ailments, and could also be recommended as a food supplement due to its medicinal potential.

Seasonal variability of primary and secondary metabolites in moringa leaves evaluated in the month of July-August through LC-MS/MS (non-volatile) and GC-MS/MS (volatile) technique. Non-volatile toxic compounds identified were adenosine, oligomycin C, euphormin and umbelliferone present in the month of July-August. Volatile compounds identified during this period were morphinan and dihydromorphine. The compounds hematoporphyrin, euphormin and umbeliferone are intermediates in cyanide pathway during July-August.

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Research Note
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CONSTRAINTS IN ADOPTION OF SCIENTIFIC FISH FARMING IN TELANGANA STATE

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Fishery in India is a very important economic activity and a flourishing sector with varied resources and potentials. India is the 3rd largest fish producing and 2nd largest aquaculture nation in the world after China. Fisheries and aquaculture remain an important source of food, nutrition, employment and income for millions, especially the rural populations. In fact, the sector provides livelihood to about 25 million fishers and fish farmers at the primary level and twice the number along the value chain.

Although inland fisheries and aquaculture have grown in absolute terms, the development in terms of its potential is yet to be realized. The vast inland aquatic resources offer great opportunities for enhanced production along with livelihood development and ushering economic prosperity.

Telangana is the 29th state of India, formed on 2nd of June 2014. Fisheries is one of the most important traditional occupation and is providing livelihoods to around 5 lakh families in the State apart from being an important source of food nutrient. Fisheries is one of the fast growing sectors generating income and employment in the state of Telangana. The sector is contributing 0.6 percent to the GSDP and plays an important role in the overall socio-economic development of fisher families in Telangana by providing nutrition & food security. Inland fisheries in Telangana have been mostly confined to capture fisheries in reservoirs and tanks under lease/license system. With focus on enhancing irrigation and drinking water facilities in the form of irrigation projects in Krishna and Godavari river systems and Mission Kakatiya, a renewed focus is laid on improving the water storage capacity of water bodies thus increasing the water spread area (7.76 lakh ha). The fish production has increased from an estimated 1.93 lakh tonnes in 2016-17 to 2.94 lakh tonnes in 2018-19, catapulting the State to secure a spot among top five inland fish producing States in the country.

The Telangana state was chosen as the locale of the study. The existing 31 districts of the state are divided into three nearly homogeneous strata (each stratum with a given a number of districts-10-11) based on climate, rainfall, soil quality, resource spread, intensity and diversity of fisheries and aquaculture activities. For sampling, two districts from each strata were selected in consultation with the Department of Fisheries. Thus six districts were selected for study. Karimnagar, Kamareddy, Medak, Wanaparthy, Mahabubabad and Yadadri Bhuvanagiri districts were selected. Ten fish farmers were selected from each of the selected districts using simple random sampling technique thus constituting 60 fish farmers.Ex-post facto research design was adopted in this study. The data was collected with the help of pretested interview schedule. The statistical methods and tests such as frequency, percentage and Henry Garett ranking technique were used for the analysis of data.

Henry Garett ranking technique: It was used to assess the challenges faced by the fish farmers. In this technique, the respondents were asked to rank the given attribute according to the magnitude of the problem. The orders of merit given by the participants were converted into ranks by using the following formula.

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$$\text{Per cent position} = \frac{100(Rij - 0.5)}{Nj}$$

Where,

R_{ij} = Rank given for the i^{th} item j^{th} individual

N_j = Number of items ranked by j^{th} individual

The percentage position of each rank obtained was converted into scores by referring to the table given by Henry Garett. Then for each factor, the scores of individual respondents were added together and divided by the total number of respondents for whom the scores were added. The mean scores for all the factors were calculated and ranked accordingly and inferences were drawn.

From the Table 1, it was observed that lack of nursery pond, high cost of balanced fish feed, lack of modern fish culture tools and implements, non-availability of fish disease medicines, poor water retention capacity of pond, non-availability of fingerlings were found to be the major resource constraints. Majority of respondents do not have nursery pond because they are unaware of nursery pond management and high risk involved in it. The cost of fish farming increased due to high cost of feed, fingerlings and medicines. Majority of respondents reported that medicines are ineffective in controlling diseases. The study therefore, suggested that nursery ponds should be created, modern fish culture tools and implements, production inputs like fish seed and fish disease medicines should be procured through line department and provided to the fish farmers at subsidized price.

The results from Table 2 indicated that lack of value addition for enhancing profit margin, algal bloom and oxygen management in pond, lack of knowledge about technological know-how, complex improved fish production technology were found to be the major technological constraints. The reason might be due to lack of trainings and demonstrations on improved fish production technologies and their management. High cost of value addition equipments resulted in poor value addition of produce. The findings therefore, suggested that efforts should be made by line department staffs in conducting trainings and demonstrations on technological improvements in pisciculture, provide sufficient operational procedures for algal bloom and oxygen management in pond.

A look into the Table 3 revealed that Inadequate and untimely technical advice by extension functionaries, Inadequate supply of farm publications in local language, Lack of co-operation and co-ordination among farmer, extension personnel and scientists, Lack of training facility were found to be the major technological constraints. The probable reason might be due to very low extension staff in fisheries department in the state. It was suggested from the findings that providing farm publications in local language that are easily understood and conducting a good number of demonstrations on different aspects of pisciculture involving community approach should

Table 1. The rank order of resource constraints as perceived by fish farmers

(n=60)

S.No	Resource constraints	Garrett mean score	Rank
1.	Unavailability of suitable pond	40.35	VIII
2.	Poor water retention capacity of pond	50.19	V
3.	Excessive silt deposition in the pond	36.17	X
4.	Non-availability of herbicides	39.54	IX
5.	Non-availability of fingerlings	46.81	VI
6.	Non-availability of fish disease medicines	53.21	IV
7.	Lack of irrigation source	42.13	VII
8.	High cost of balanced fish feed	59.26	II
9.	Lack of modern fish culture tools and implements	57.51	III
10.	Lack of nursery pond	62.83	I

Table 2. The rank order of technological constraints as perceived by fish farmers

(n=60)

S.No	Technological constraints	Garrett mean score	Rank
1.	Complex improved fish production technology	46.41	IV
2.	High expenditure on technology management	33.62	VI
3.	Lack of knowledge about technological know-how	50.24	III
4.	Lack of pond soil and water testing facility	40.23	V
5.	Algal bloom and oxygen management in pond	54.35	II
6.	Lack of value addition for enhancing profit margin	61.13	I

Table 3. The rank order of extension constraints as perceived by fish farmers

(n=60)

S.No	Extension constraints	Garrett mean score	Rank
1.	Lack of co-operation and co-ordination among farmer, extension personnel and scientists	52.81	III
2.	Lack of training facility	48.32	IV
3.	Lack of demonstration	45.51	V
4.	Inadequate and untimely technical advice by extension functionaries	66.21	I
5.	Lack of mass media and other sources of information	36.12	VI
6.	Inadequate supply of farm publications in local language	55.62	II

be tailor made into the plan of work of the related extension organization.

From Table 4 it can be seen that lack of financial assistance, credit for fish farming not available as per requirement and in time, high expenditure in fish farming, complicated procedure to avail loan from banks were found to be the major financial constraints. The study therefore, suggested that complicated procedure for getting bank loan should be made simpler and easier. The fish growers should be provided with adequate credit at the time of need to overcome the financial problems in management of pisciculture practices.

The results from Table 5 indicates that preservation of the undisposed fishes, low price for the fishes in the local market, less market demand for exotic carps, lack of adequate marketing network were found to be the major marketing constraints. The study therefore, suggested that adequate efforts should be made by concerned research organizations for development of suitable post-harvest processing technologies from farmers' perspective.

From Table 6 it is clear that poaching and illegal fishing, poisoning in fish pond due to jealousy or revenge, multiple use of pond water especially domestic purposes restrict the commercial fish farming, inadequate family labour were found to be the major social constraints. The study therefore, suggested that legal action/punishments should be given to the persons involved in poaching and poisoning of fish pond. Special provisions should be made for the adequate water availability to fish ponds, low cost technology for fish pond management should be made available.

CONCLUSION

The study indicated that high cost of balanced fish feed, lack of modern fish culture tools and implements, lack of value addition for enhancing profit margin, inadequate and untimely technical advice by extension functionaries, lack of financial assistance for fish farmers, poor post harvest management techniques were found to be the major constraints. To overcome the above constraints few measures are suggested like the government should provide subsidized price

Table 4. The rank order of financial constraints as perceived by fish farmers

(n=60)

S.No	Financial constraints	Garrett mean score	Rank
1.	Lack of financial assistance	59.32	I
2.	High expenditure in fish farming	55.82	III
3.	Credit for fish farming not available as per requirement and in time	57.21	II
4.	Complicated procedure to avail loan from banks	42.31	IV
5.	Stringent recovery procedure	51.22	V

Table 5. The rank order of marketing constraints as perceived by fish farmers

(n=60)

S.No	Marketing constraints	Garrett mean score	Rank
1.	Lack of adequate marketing network	54.43	IV
2.	Less market demand for exotic carps	59.62	III
3.	Low price for the fishes in the local market	61.21	II
4.	Transporting of fishes to distant market	41.23	V
5.	Preservation of the undisposed fishes	67.35	I

Table 6. The rank order of social Constraints as perceived by fish farmers

(n=60)

S.No	Social Constraints	Garrett mean score	Rank
1.	Poaching and illegal fishing	67.53	I
2.	Poisoning in fish pond due to jealousy or revenge	64.14	II
3.	Multiple use of pond water especially domestic purposes restrict the commercial fish farming	58.25	III
4.	Lack of family encouragement considering lower prestigious occupation	32.62	V
5.	Inadequate family labour	42.13	IV

for the fish feed, low cost fish pond management technology should be developed, creating awareness and improving knowledge of fish farmers on post harvest management and value addition by strengthening/capacity building of extension functionaries of line department. There are several problems being faced by fishermen in their farming. Fish farming like most other types of farming, a risky business that requires special knowledge, skills and careful considerations. Therefore, there is need to improve extension activities from grass root level to solve the various emerging problems. The observations of the prevailing study may assist all stakeholders related to fisheries sector to take suitable steps to inspire and assist the fish farmers and triumph over the discovered issues confronted by them.

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Thesis

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