ISSN 2395-5945

THE JOURNAL OF RESEARCH PJTSAU

The J. Res. PJTSAU Vol. LI No.1&2 pp 1-81, Jan. - June, 2023

The J. Res. PJTSAU Vol. LI No.1&2 pp 1- 81, Jan. - June, 2023

Professor Jayashankar Telangana State Agricultural University
Rajendranagar, Hyderabad - 500 030, Telangana State

The Journal of Research, PJTSAU

(Published quarterly in March, June, September, December)

ADVISORY BOARD

Dr. P. Raghu Rami Reddy
Director of Research
PJTSAU, Rajendranagar
Hyderabad

Dr. V. Sudha Rani
Director of Extension
PJTSAU, Rajendranagar
Hyderabad

Dr. Seema
Dean of Agriculture
PJTSAU, Rajendranagar
Hyderabad

Dr. V. Anitha
Dean of P. G. Studies
PJTSAU, Rajendranagar
Hyderabad

Dr. V. Vijaya Lakshmi
Dean of Community Science
PJTSAU, Rajendranagar
Hyderabad

Dr. N. P. Ravi Kumar
University Librarian
PJTSAU, Rajendranagar
Hyderabad

Dr. Ch. Srinivasa Rao
Director
ICAR-NAARM
Hyderabad

Dr. K. R. Kranthi
Head
Technical Information Section
International Cotton
Advisory Committee
Washington, USA

Dr. N. K. Singh
Project Director
ICAR-NRCPB
New Delhi

EDITORIAL BOARD

Dr. M. Sambasiva Rao
Professor
Dept. of Soil Science
University of Florida
Florida, USA

Dr. Srinivasulu Ale
Associate Professor
Department of Biological and
Agricultural Engineering
Texas A&M University
USA

Dr. Dharmendra Saraswat
Associate Professor
Department of Agricultural &
Biological Engineering
Purdue University
USA

Dr. Indrajeet Chaubey
Associate Dean and
Director of International
Programs in Agriculture
USA

Dr. S. K. Singh
Director
ICAR-NBSS & LUP
Nagpur, Maharastra

Dr. S. Gopala Krishnan
Principal Scientist
Division of Genetics
IARI, New Delhi

Dr. M. Balram
Associate Dean
Agricultural College
Warangal

Dr. R. Vijaya Kumari
Deputy Director of Research
O/o Director of Research
PJTSAU, Rajendranagar
Hyderabad

Dr. G. Manoj Kumar
Principal & Univ. Head (SWE)
Dept. of Agricultural Engineering
College of Agriculture
Rajendranagar, Hyderabad

EDITOR

Dr. G. Sridevi
Principal Scientist & Head
AINP on Pesticide Residues
Rajendranagar, Hyderabad

MANAGING EDITOR

Dr. Ch. Venu Gopala Reddy
Principal Agricultural Information Officer
AI&CC and PJTSAU Press
Rajendranagar, Hyderabad

RESEARCH EDITOR

Dr. R. Sunitha Devi
Senior Scientist
AI&CC and PJTSAU Press
Rajendranagar, Hyderabad

SUBSCRIPTION TARIFF

Individual (Annual) : Rs. 300/-
Institutional (Annual) : Rs. 1200/-
Individual (Life) : Rs. 1200/-

Printing Charges : Rs. 100/- per page

DD's may be drawn in favour of Principal Agricultural Information Officer and sent to Agricultural Information & Communication Centre and PJTSAU Press, ARI Campus, Rajendranagar, Hyderabad - 500 030 or subscription can be paid online at http://thejournalofresearchpjtsau.com

CONTENTS

PART I : PLANT SCIENCES

PART II : SOCIAL SCIENCES

PART III : COMMUNITY SCIENCE

Research Article
The J. Res. PJTSAU 51(1&2) 1-7, 2023

SOIL FERTILITY STATUS OF THE RICE AND MAIZE GROWING SOILS OF VIKARABAD DISTRICT OF TELANGANA

B. POOJA[1], M. CHANDINI PATNAIK[2], P. SURENDRA BABU[3] and D. SREELATHA[4]

[1] Department of Soil Science and Agricultural Chemistry, College of Agriculture, Rajendranagar
[2] Senior Principal Scientist and University Head (Retd.) AICRP on Micronutrients, ARI, Rajendranagar
[3] Senior Principal Scientist and University Head (Retd.) AICRP on Micronutrients, ARI, Rajendranagar
[4] Department of Agronomy, RARS, Jagtial
Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-30

Date of Receipt: 02-01-2023 Date of Acceptance: 19-01-2023

ABSTRACT

The investigation was conducted at ARI, Ranjendranagar, to know the soil fertility status of the rice and maize growing soils of Vikarabad, Ranga Reddy and Yadadri district of Telangana. Soil samples were collected by random sampling method and soils were analyzed for their fertility status. In paddy grown soils, the pH, electrical conductivity, and organic carbon ranged from 6.06 to 8.08, 0.03 to 0.62 dS m^{-1} and 0.12 to 1.28 percent and in maize grown soils ranged from 5.31 to 7.94, 0.02 to 0.37 dS m^{-1} and 0.12 to 1.26 %, respectively. The paddy soils were very low to medium in available nitrogen, low to very high in available phosphorus, low to high in available potassium. The maize soils were very low to medium in nitrogen content, medium to very high in available phosphorus, low to high in available potassium. Paddy and maize soils were deficient in zinc to an extent of 20 and 37 %.

Soil is the most important constituent to the basic needs of human beings and important component of our farming. Crop production and productivity depends upon physico-chemical characteristics of the soil. The key point of sustainable agriculture is to maintain the balance among physical, chemical and biological constituents of soils. Some elements are required by plants for completing their life cycle and other are less important for plants but their high concentration in soil solution influence the crop growth. The present study was carried out to study the impact of available nutrients on crop performance.

MATERIAL AND METHODS

Sampling Procedure

Survey was carried out during summer of 2020-21 and *kharif* season of 2021-22 in Vikarabad, Rangareddy and Yadadri districts of Telangana state. Soil samples were collected from various villages of Pudur, Pargi, Vikarabad, Dharoor and Yalal *mandals* in Vikarabad district, Bhudan Pochampally and Choutuppal *mandals* in Yadadri district, Abdullapurmet and Hayatnagar *mandals* in Rangareddy districts. Altogether, 71 soil samples were collected during this survey.

Methods of soil analysis

Standard methodologies were adopted for various physico-chemical and chemical characteristics. Determination of soil pH and EC was done in 1:2.5 soil-water suspension using digital pH meter and EC bridge (Jackson, 1958). Organic carbon (%) was estimated by the wet oxidation method of Walkley and Black (1947). Available nitrogen was determined using alkaline potassium permanganate method as given by Subbiah and Asija (1956), available phosphorous by Olsen reagent of ascorbic acid method (Jackson, 1973). available potassium by neutral normal ammonium acetate (Jackson, 1973). Micronutrients *i.e.,* Zinc and heavy metal *i.e.,* lead was determined in the extract by extracting soil samples with diethylene triamine penta acetic acid (DTPA) as described by Miles and Parker (1979). Physico-chemical and chemical characteristics of paddy soils are given in table 1 and maize soils in table 4. Paddy and maize Samples collected were categorized (Surendra Babu *et al*, 2012) and is presented in tables 2 and 5.

Email: poojapoojitha1911@gmail.com

Table 1: Physico- chemical and chemical characteristics of rice soils

S.No.	Soil Characteristics	Range	Mean
1	pH	6.06-8.08	—
2	EC (dSm^{-1})	0.03-0.62	0.19
3	Organic carbon (%)	0.12-1.28	0.39
4	Available nitrogen (kg ha^{-1})	103-304	188
5	Available phosphorus (kg ha^{-1})	17-101	65
6	Available potassium (kg ha^{-1})	49-416	252
7	Available zinc (mg kg^{-1})	0.29-3.11	1.29
8	Available lead (mg kg^{-1})	0.6 – 3.67	1.26
9	Total lead (mg kg^{-1})	4.09-199	74

RESULTS AND DISCUSSION

Physico-chemical Characteristics

pH

The soil pH in paddy soils ranged from 6.06 to 8.08 and in maize soils, it ranged from 5.31 to 7.94 there by indicating the soils are acidic to moderately alkaline in reaction. The variation in soil pH was related to the parent material, and topography. Relatively higher pH value in paddy soils because of more of black soils was due to the accumulation of the high amounts of exchangeable bases in solum as they are poorly drained. (Dasog and Patil, 2011).

Electrical Conductivity

The electrical conductivity of paddy soils ranged from 0.03 to 0.62 with a mean of 0.19 dSm^{-1} and in maize soils it ranged from 0.02 to 0.37 with a mean of 0.13 dSm^{-1} indicating that, these soils were normal in soluble salt content (Sathyanarayana *et al.,* 2021).

Soil Organic Carbon

The organic carbon content of paddy soils ranged between 0.12 and 1.28 with a mean of 0.39 percent. Seventy five percent soils were low, 15 % were medium and 10% were high in organic carbon status (Table 2 and Fig. 1) and in maize soils, it ranged from 0.12 to 1.26 with a mean of 0.42 % (Table 5 and Fig. 2). Organic carbon content of the maize soils was low to high. Soils are low, medium and high in organic carbon status to an extent of 67, 27 and 6 percent, respectively. The low organic matter content in the soils was attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils (Sireesha and Naidu, 2013).

Available Major Nutrients

Nitrogen

The paddy soils were very low to medium in available nitrogen. Available nitrogen content of paddy soils ranged from 103 to 304 kg ha^{-1} with a mean of 188 kg ha^{-1}. The soils were very low (< 140 kg/ha), low and medium in nitrogen to an extent of 22, 76 and 2 percent, respectively (Table 2 and Fig. 1). The available nitrogen content of maize soils ranged from 90 to 341 kg ha^{-1} with a mean of 171 kg ha^{-1}. The soils were very low to medium in nitrogen content. Forty, 57 and 3 percent soils were very low, low and medium in available nitrogen status (Table 5 and Fig. 2). The main reason being low organic matter content, low rainfall and low vegetation were reported to cause faster degradation and removal of organic matter leading to nitrogen deficiency (Ashok, 2001).

Phosphorous

The available phosphorus content in paddy soils ranged from 17 to 101 kg ha^{-1} with a mean of 65 kg ha^{-1}. The collected soils were categorised as low, medium, high and very high (> 82 kg P_2O_5 ha^{-1}) phosphorus status of 5, 29, 34 and 32 percent, respectively (Table 2 and Fig. 1). The maize soils collected are medium to very high in available phosphorus. The soils are categorised as medium, high

Table 2: Percentage of rice samples falling under different categories

	Very Low	**Low**	**Medium**	**High**	**Very High**
OC (%)	0	75	15	10	0
N (kg ha^{-1})	22	76	2	0	0
P (kg ha^{-1})	0	5	24	64	7
K (kg ha^{-1})	0	17	61	22	0
Pb (mg kg^{-1})	0	15	78	7	0
		Deficient	**Sufficient**		
Zn (mg kg^{-1})	0	20	80	0	0

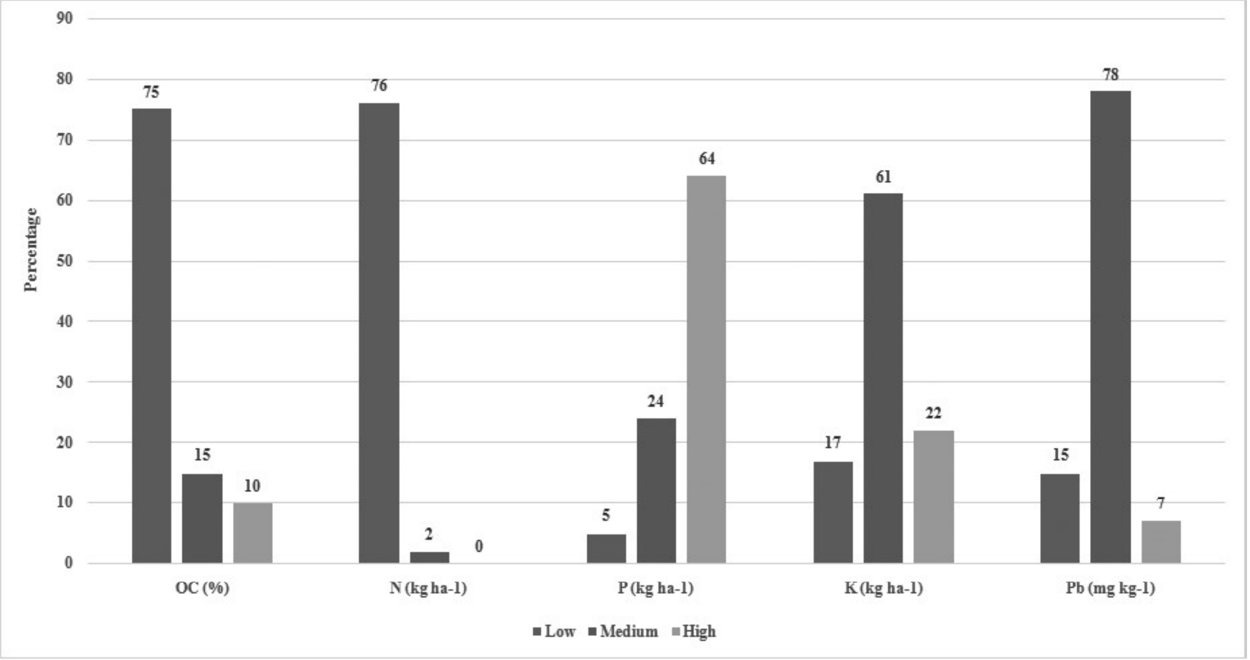


Figure 1. Percentage of rice samples falling under different categories

Table 3: Correlation coefficient between soil properties and available soil nutrients of paddy grown soils

	pH	*EC*	*OC*	*N*	*P*	*K*	*Zn*	*Pb*	*Total Pb*
pH	1								
EC	0.084	1							
OC	-0.045	0.112	1						
N	-0.187	-0.212	-0.017	1					
P	-0.269	0.137	0.102	0.038	1				
K	0.188	0.032	0.164	-0.072	-0.334	1			
Zn	-0.376	0.211	0.021	0.080	0.240	0.115	1		
Pb	-0.247	0.429	0.020	-0.001	0.127	-0.160	0.192	1	
Total Pb	-0.221	-0.141	-0.162	-0.015	0.127	0.013	0.483	-0.097	1

and very high to an extent of 37, 23 and 40 percent (Table 5 and Fig. 2).

Potassium

The available potassium status of these soils is low to high. It varied between 49 and 416 with a mean of 252 kg K_2O ha^{-1} and was grouped to an extent of 17, 61, 22 percent in low, medium and high potassium categories, respectively (Table 2 and Fig. 1). The available potassium content of maize soils ranged from 71 to 412 kg ha^{-1} with a mean of 267 kg ha^{-1}. Maize soils collected were low to high in available potassium and categorized into low, medium and high to an extent of 17, 50 and 33 percent, respectively (Table 5 and Fig. 2). This might be due to predominance of K rich micaceous and feldspar minerals in parent (Pal, 1985 and Ravikumar, 2004).

Zinc

The DTPA extractable Zn content of the paddy soils varied between 0.29 and 3.11 mg kg^{-1} with a mean of 1.29 mg kg^{-1}. Soils were deficient in Zn to an extent of 20 percent and the rest 80 % were sufficient in zinc (Table 2 and Figure 1). The DTPA extractable Zn content of the maize soils collected from Vikarabad district varied between 0.35 and 3.33 with a mean of 0.94 mg kg^{-1}. Maize soils collected were deficient in zinc to an extent of 37 percent (Table 5 and Figure 2). The larger extent of zinc deficiency was attributed to the alkaline soil reaction and richness of $CaCO_3$, which might due to high precipitation of zinc as hydroxide and carbonates.

Available and Total Lead

The available Pb recorded in paddy soils was in the range of 0.60 to 3.67 mg kg^{-1} with a mean of 1.26 mg kg^{-1} and was grouped to an extent of 15, 78, 7 percent in low, medium and high lead categories, respectively (Table 2 and Figure 1). The total lead of paddy soils varied between 4.09 and 199 mg kg^{-1} with a mean of 74 mg kg^{-1}. The maize soils recorded the DTPA extractable lead in the range of 0.23 and 1.77 mg kg^{-1} with a mean of 0.82 mg kg^{-1} and was grouped to an extent of 20, 67, 13 percent in low, medium and high potassium categories, respectively (Table 5 and Figure 2). The total Pb under maize cultivation varied between 7.92 and 347 mg kg^{-1} with a mean of 98 mg kg^{-1}.

Correlation of physico-chemical properties and major nutrients of paddy soils

The data on correlation between soil properties and available nutrients in paddy supporting red soil of Vikarabad district of Telangana are presented in table 3 revealed the pH of the soil is negatively non-significantly correlated with nitrogen (r = -0.187), organic carbon (r = -0.045) and phosphorus (r = - 0.269) and positively non-significantly correlated with potassium (r = 0.188) Fernàndez and Hoeft (2012) reported the similar results. The OC of the soil is negatively non-significantly correlated with nitrogen (r = -0.017) and positively non-significantly correlated with phosphorus (r = 0.102), potassium (r = 0.164) similar results were reported by Kartikeyan *et al.,* (2014). The nitrogen of the soil is positively non-significantly correlated with phosphorus (r = 0.038), and negatively non-significantly correlated with potassium (r = -0.072). Similar results reported by Srinidhi *et al.,* (2020). The phosphorous of the soil negatively significantly correlated with potassium (r = -0.334). The potassium positively non-significantly correlated with zinc (r = 0.115) and negatively non-significantly correlated with lead (r= -0.160).

Correlation of physico-chemical properties and major nutrients of maize soils

The data on correlation between soil properties and available nutrients in paddy supporting red soil of Vikarabad district of Telangana are presented in table 6 revealed the pH of the soil is positively non-significantly correlated with nitrogen (r = 0.113), organic carbon (r = 0.103) and potassium (r = 0.290) and negatively non-significantly correlated with phosphorus (r = -0.177) The OC of the soil is positively non-significantly correlated with nitrogen (r = 0.315), potassium (r = 0.208) and negatively non-significantly correlated with phosphorus (r = -0.085). The nitrogen of the soil is positively non-significantly correlated with phosphorus (r = 0.118) and potassium (r = -0.296). The phosphorous of the soil negatively significantly correlated with potassium (r = -0.279). The potassium positively non-significantly correlated with lead (r = 0.024) and negatively non-significantly correlated with zinc (r= -0.109).

CONCLUSION

It can be concluded that the paddy supporting soils Vikarabad district of Telangana are categorized

Table 4: Physico- chemical and chemical characteristics of maize soils

S.No	Parameters	Range	Mean
1	pH	5.31-7.94	—
2	EC (dSm^{-1})	0.02-0.37	0.13
3	Organic carbon (%)	0.12-1.26	0.42
4	Available nitrogen (kg ha^{-1})	90-341	171
5	Available phosphorus (kg ha^{-1})	28-101	68
6	Available potassium (kg ha^{-1})	71-412	267
7	Available zinc (mg kg^{-1})	0.35-3.33	0.94
8	Available lead (mg kg^{-1})	0.23-1.77	0.82
9	Total lead (mg kg^{-1})	7.92-347	98

Table 5: Percentage of maize samples falling under different categories

	Very Low	Low	Medium	High	Very High
OC (%)	0	70	30	0	0
N (kg ha^{-1})	43	43	13	0	0
P (kg ha^{-1})	0	0	30	50	20
K (kg ha^{-1})	0	17	53	30	0
Pb (mg kg^{-1})	0	20	67	13	0
		Deficient	**Sufficient**		
Zn (mg kg^{-1})	0	40	60	0	0

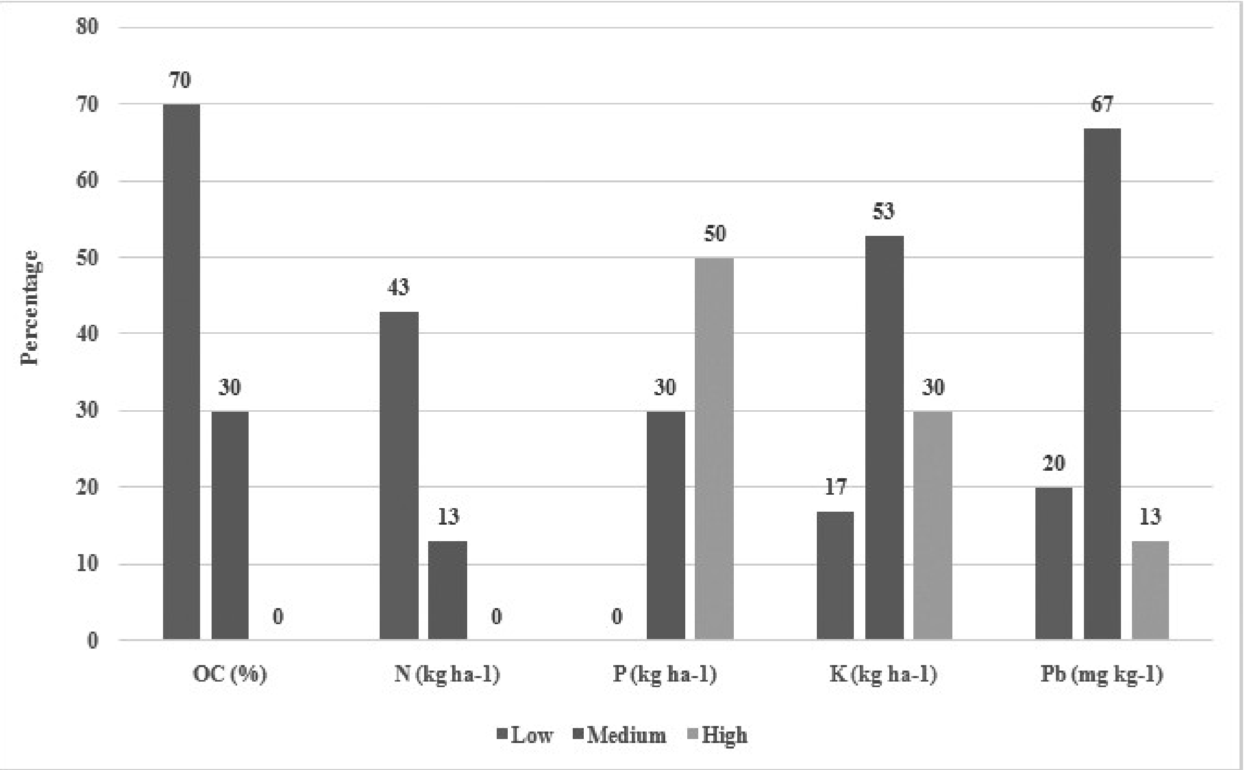


Figure 2: Percentage of maize samples falling under different categories

Table 6: Correlation coefficient between soil properties and available soil nutrients of maize grown soils

	pH	*EC*	*OC*	*N*	*P*	*K*	*Zn*	*Pb*	*Total Pb*
pH	1.000								
EC	0.408	1.000							
OC	0.103	0.079	1.000						
N	0.113	0.017	0.315	1.000					
P	-0.177	-0.283	-0.085	0.118	1.000				
K	0.290	0.361	0.208	0.296	-0.279	1.000			
Zn	0.066	0.194	-0.031	0.065	-0.165	-0.109	1.000		
Pb	0.399	0.312	0.172	0.192	-0.257	0.024	0.490	1.000	
Total Pb	-0.072	-0.409	-0.102	-0.170	-0.165	-0.078	0.457	0.198	1.000

under slightly acidic to moderately alkaline in reaction. soil samples are low in organic carbon content (75 %) and nitrogen (76 %) and high in available phosphorus (64 %), medium in potassium (61 %) and lead (78 %) and 80 % soils are sufficient in zinc. Maize supporting soils were acidic to slightly alkaline in reaction. Low in organic carbon content (70 %) and nitrogen (43 %) and high in available phosphorus (50 %), medium in potassium (53 %) and lead (67 %) and 60 % soils are sufficient in zinc.

REFERENCES

Ashok, L.B. 2001. Sulphur status of selected soil series of Karnataka and studies on direct and residual effect of graded level of sulphur on crop. Ph.D. Thesis. University of Agricultiral Sciences Bangalore, Karnataka

Dasog, G.S., and Patil, P. L. 2011. Genesis and classification of black, red and lateritic soils Of Karnataka. In: Soil Science Research in North Karnataka, Dharwad chapter of ISSS (Ed.), 76th annual convention of ISSS, pp. 1-10.

Fernandez, F.G and Hoeft, R.G. 2012. Managing soil pH and crop nutrients. In: Nafziger (ed.), Illinois Agronomy Handbook. Available online at: http://extension. cropsci. illinois. edu/ handbook/pdfs/ chapter08.pd.

Jackson, M. L. 1958. *Soil chemical analysis.* Verlag: Prentice Hall, Inc., Englewood Cliffs, NJ. 498 (1) 39-40

Jackson, M. L., 1973. Soil Chemical Analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi.

Miles, L.J and Parker, G.R. 1979. DTPA soil extractable and plant heavy metal concentrations with soil-added cd treatments. *Plant and Soil* 51(1): 59-68

Kartikeyan, K., Pushpanjali and Prasad, J. 2014. Soil fertility status of soybean (*Glycine max* L.) growing soils of Malwa plateau, Madhya Pradesh. *Journal of the Indian Society of Soil Science* 62(2): 170-178.

Pal, D.K. 1985. Potassium release from muscovite and biotite under alkaline conditions. *Pedologie* 35: 133-146

Patil, S.S., Patil V.C and AL-Gaddi K.A., 2011. Spatial variability in fertility status of surface soils. *World applied sciences Journal.*, 14(7): 1020-1024. *Pedologie,* 35: 133-136.

Ravikumar, M. A., 2004. Soil resource characterization of 48A distributary of Malaprabha right bank command for sustainable land use planning. M. Sc. (Agri.) Thesis, University of Agricultural Sciences Dharwad, Karnataka.

Sathyanarayana, E., Padmaja, G., Saranya, S., Bharghavi, J, Santhosh Kumar, M., Rajashekhar, M., Veeranna, J and Kumari Sunita. 2021. Soil fertility status of soybean growing soils of Adilabad district, Telangana. *The Pharma Innovation Journal*; 10(10): 1112-1120

Sireesha, P.V.G., and Naidu, M. V. S., 2013. Studies on genesis, characterization and classification of soils in semi-arid agro- ecological region: A case study in Banaganapalle mandal of Kurnool district in Andra Pradesh. *Journal of the Indian Society of Soil science.* 61(3):161-178.

Srinidhi, P., Singh, Y.V., Sharma, P.K., Singh, R.K., Latare, A.M., Srinath, I and Yogesh, Y.C. 2020. Physico-chemical analysis of soils in Madanapalle block, Chittor district of Andhra Pradesh. *International Journal of Communication Systems* 8(3): 154-158.

Subbaiah, B.U., and Asija, G.L., 1956. Rapid procedure for the estimation of the available nitrogen in soil. *Current Science*. 25:259-260.

Surendra Babu, P., Ramana Reddy., Chandini Patnaik,M and Madhavi, A. 2012. Manual for Soil, Water and Plant Analysis

Walkley, A.J., and Black, C.A., 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science* 37: 29-38

Research Article
The J. Res. PJTSAU 51(1&2) 8-16, 2023

STUDIES ON TRAIT ASSSOCIATION AND PATH ANALYSIS FOR PROTEIN AND YIELD RELATED TRAITS IN F_2 POPULATION OF RICE (*Oryza sativa* L.)

G. PRASANNA*[1], L. KRISHNA[1], J. ARAVIND KUMAR[2], APARNA KUNA[3] and S. NARENDAR REDDY[4]

[*1]Dept. of Genetics and Plant Breeding, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad-30
[1]Dept. of Genetics and Plant Breeding, Institute of Rice Research, ARI, PJTSAU, Rajendranagar, Hyderabad-30
[2]Dept. of Genetics and Plant Breeding, Indian Institute of Rice Research, Rajendranagar, Hyderabad-30
[3]Dept. of Food and Nutrition, Quality Control Lab, PJTSAU, Rajendranagar, Hyderabad-30
[4]Dept. of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad-30

Date of Receipt: 11-01-2023 Date of Acceptance: 28-01-2023

ABSTRACT

The present experiment was carried out in rice using F_2 segregating populations of two cross combinations *viz.*, RNR 15048 x JAK 686 and RNR 15048 x JAK 685. Correlation analysis revealed negative and significant correlation of protein content with number of filled grains per panicle, test weight, single plant yield and kernel length and positive non-significant association with panicle length, number of productive tillers per plant and L/B ratio in cross I and positive non-significant association with days to 50% flowering, plant height, number of productive tillers per plant, number of filled grains per panicle, kernel breadth and amylose content and negative association with panicle length, test weight, single plant yield, kernel length and L/B ratio in cross II. Path analysis revealed that L/B ratio exerted highest positive direct effect on the protein content followed by kernel breadth, number of productive tillers per plant and panicle length in cross-I and number of productive tillers per plant, plant height, amylose content, test weight and kernel length exerted highest positive direct effect on the protein content in cross –II.

KEYWORDS: Correlation, path analysis and grain protein content

Rice (*Oryza sativa* L.) is one of the primary cereals and the most widely consumed staple food for more than half of the world's population, as well as one of the major protein sources in Asian countries. Food with nutritional value is always desired for human health. The world population is expected to reach nine billion by 2050, so there will be an increasing demand for varieties with desirable quality and nutritionally enriched in the future. This principal staple food contains a reduced quantity of many essential micro and macro elements such as vitamins, minerals, some phytochemicals, essential amino acids and fatty acids, which are indispensable to human health (Das *et al.*, 2020).

Rice grain protein is the second most abundant component of milled rice grain and has been studied extensively in the context of its important role as a nutrient. The net protein utilization from rice grains is highest among the cereal grains, despite rice having the lowest protein content (Juliano, 1992). With the improvement of people's living standards, rice consumers are paying much attention to good grain quality. Quality of rice is an important character to determine the economic value in the export market and consumer acceptance. Rice grain is composed of approximately 80-85% starch, 4-10% protein, 1% lipid and 10% moisture. Rice grain protein consists of two categories, functional protein (10%) and seed storage protein (SSP, 90%). The SSP in rice can be classified into four fractions: albumin, globulin, prolamin and glutelin according to differences in solubility (Chen *et al.*, 2018). Among them, glutelin is the most abundant one, which comprises about 60-80% of the total SSPs. The nutritional value of rice glutelin is superior to other rice storage proteins due its higher lysine content and greater digestibility by the humans. As a result, any significant change in glutelin content will definitely affect grain nutrition quality (Yang *et al.*, 2019). Protein content affects grain appearance, processing quality and eating quality of rice. In view of this, the present study was carried out to determine the character association and path coefficients analysis of protein and yield related traits by using F_2 segregating populations of two cross combinations.

Email: prasannagricos@gmail.com

MATERIAL AND METHODS

The experiment was conducted at Agricultural Research Institute, Rice Research Centre, PJTSAU, Rajendranagar, Hyderabad during *rabi* 2021-22 to study character association and path analysis of the crosses (RNR 15048 x JAK 686) and (RNR 15048 x JAK 685). Two cross combinations are represented as cross I and cross II. 'Telangana sona' is the popular variety of Telangana having low glycemic index, excellent grain cooking quality and moderate protein content. However, JAK 686 and JAK 685 are having high grain protein content. The F_2 seeds of two cross combinations were sown in nursery. Twenty seven days old seedlings were transplanted as single seedling per hill in the main field with a spacing of 20 × 15 cm and all the recommended package practices were followed during crop growth period. Observations were recorded for 12 traits *viz.,* days to 50% flowering, plant height, panicle length, number of productive tillers per plant, number of filled grains per panicle, test weight, grain yield per plant, kernel length, kernel breadth, L/B ratio, amylose content and grain protein content in 150 selected plants in each cross combinations. Data recorded was further subjected to statistical analysis. Correlation and path coefficient statistical analysis were done using the DOS-based Excel program, TNAUSTAT-Statistical package (Manivannan, 2014).

RESULTS AND DISCUSSION

Correlation analysis provides information about relationship among the various characters and determines the component characters, on which selection can be based for genetic improvement in the grain yield. Positive correlation between desirable traits is favourable as it helps in simultaneous improvement of both the characters. On the other hand, negative correlation will hinder the simultaneous expression of both characters with high values.

In the present investigation, correlations were studied among protein, yield and its related traits in F_2 population of two cross combinations (RNR 15048 x JAK 686 and RNR 15048 x JAK 685). The findings of the correlations among yield, yield contributing traits and grain quality traits are provided in Table 1 and 2.

The results of correlation analysis revealed that positive and significant association of days to 50% flowering with number of filled grains per panicle (0.213) and negative significant association with plant height (-0.407), number of productive tillers per plant (-0.163), single plant yield (-0.209) in cross I and negative significant association with plant height (-0.731), number of filled grains per panicle (-0.177), test weight (-0.239), single plant yield (-0.250), kernel length (-0.554) and L/B ratio (-0.363) in cross II. The results are in accordance with the findings of Shet *et al.* (2012), Devi *et al.* (2019), Bhuvaneswari *et al.* (2018) for single plant yield and Selvaraj *et al.* (2011) for number of productive tillers per plant. It was observed that plant height exhibited significant and positive correlation with panicle length (0.329) and number of productive tillers per plant (0.171) in cross I. The results were in agreement with the findings of Ratna *et al.* (2015) for panicle length. Plant height had positive and significant association with panicle length (0.243), number of filled grains per plant (0.208), test weight (0.234), single plant yield (0.191) kernel length (0.524) and L/B ratio (0.342) in cross II. Similar results were reported by Hajiaqatabar *et al.* (2016) for single plant yield. Panicle length showed negative and significant association with test weight (-0.188) in cross I and positive significant association with L/B ratio (0.197) and negative significant association with kernel breadth (-0.194) in cross II. Positive and significant association of number of productive tillers per plant with single plant yield (0.198) and negative significant association with number of filled grains per panicle (-0.182) in cross I. Similar results were registered by Bhuvaneswari *et al.* (2018), Laxuman *et al.* (2011), Pradeep *et al.* (2018), Kalaiselvan *et al.* (2019), Singh *et al.* (2020), Swapnil *et al.* (2020) for single plant yield. Number of productive tillers per plant had positive significant association with test weight (0.273), single plant yield (0.492) and negative significant association with number of filled grains per panicle (-0.286) in cross II. Number of filled grains per panicle exhibited positive and significant association with single plant yield (0.489) kernel length (0.259) and L/B ratio (0.179) and negative significant association with protein content (0.194) in cross I. The results are in accordance with the findings of Pradeep *et al.* (2018), Kalaiselvan *et al.* (2019) Ratna *et al.* (2015), Sala *et al.* (2015), Singh *et al.* (2020), Swapnil *et al.* (2020) for single plant yield. Positive significant association of number of filled grains per panicle with single plant yield (0.240) and L/B ratio (0.245) and negative significant association with kernel breadth

Table 1. Correlation Coefficient in F_2 Population of Cross-I (RNR 15048 × JAK 686) for yield and its contributing characters with grain protein content in rice

Traits	DFF	PH	PL	PT	GPP	TW	SPY	KL	KB	L/B	AC	PC
DFF	1.000	-0.407**	0.042	-0.163*	0.213**	-0.115	-0.209*	0.068	0.058	0.008	-0.039	-0.041
PH		1.000	0.329**	0.171*	0.025	-0.112	0.158	-0.010	0.007	0.006	0.067	-0.029
PL			1.000	0.070	-0.107	-0.188*	-0.151	-0.156	-0.049	-0.055	0.022	0.073
PT				1.000	-0.182*	0.024	0.198*	-0.002	-0.094	0.076	-0.016	0.113
GPP					1.000	0.098	0.489**	0.259**	0.004	0.179*	0.065	-0.194*
TW						1.000	0.488**	0.257**	0.176*	0.006	0.108	-0.184*
SPY							1.000	0.283**	-0.006	0.188*	0.037	-0.208*
KL								1.000	0.068	0.590**	0.107	-0.192*
KB									1.000	-0.745**	0.083	-0.155
L/B										1.000	-0.017	0.010
AC											1.000	-0.107
PC												1.000

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

DFF- Days to 50% flowering, PH- Plant height, PL-Panicle length, PT-Number of productive tillers per plant, GPP-Number of grains per panicle, TW- 1000 grain weight, SPY- Single plant yield, KL- Kernel length, KB- Kernel breadth, L/B- Kernel L/B ratio, AC- Amylose content, PC- Protein content.

Table 2. Correlation Coefficient in F_2 Population of Cross-II (RNR 15048 × JAK 685) for yield and its contributing characters with grain protein content in rice

Traits	DFF	PH	PL	PT	GPP	TW	SPY	KL	KB	L/B	AC	PC
DFF	1.000	-0.731**	-0.117	-0.012	-0.177*	-0.239**	-0.250**	-0.554**	0.016	-0.363**	-0.051	0.048
PH		1.000	0.243**	-0.051	0.208*	0.234**	0.191*	0.524**	-0.005	0.342**	0.021	0.049
PL			1.000	-0.139	0.149	0.131	0.016	0.045	-0.194*	0.197*	-0.089	-0.002
PT				1.000	-0.286**	0.273**	0.492**	0.001	0.049	-0.034	0.050	0.031
GPP					1.000	-0.075	0.240**	0.042	-0.235**	0.245**	0.133	0.140
TW						1.000	0.390**	0.281**	0.042	0.150	-0.024	-0.054
SPY							1.000	0.103	0.077	-0.033	0.156	-0.130
KL								1.000	0.283**	0.404**	0.016	-0.078
KB									1.000	-0.750**	0.030	0.010
L/B										1.000	-0.024	-0.051
AC											1.000	0.093
PC												1.000

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

DFF- Days to 50% flowering, PH- Plant height, PL-Panicle length, PT-Number of productive tillers per plant, GPP-Number of grains per panicle, TW- 1000 grain weight, SPY- Single plant yield, KL- Kernel length, KB- Kernel breadth, L/B- Kernel L/B ratio, AC- Amylose content, PC- Protein content.

(-0.235) in cross II. Positive and significant association of test weight with single plant yield (0.488), kernel length (0.257) and kernel breadth (0.176) and negative significant association with protein content (-0.184) in cross I. The results were in agreement with the findings of Bhuvaneswari *et al.* (2018), Sala *et al.* (2015), Kumar *et al.* (2018), Singh *et al.* (2020) for single plant yield. Positive and significant association of test weight with single plant yield (0.390) and kernel length (0.281) in cross II. Single plant yield showed positive and significant association with kernel length (0.283) and L/B ratio (0.188) and negative significant association with grain protein content (-0.208) in cross I. Similar results were registered by Ekka *et al.* (2011) for kernel length and Dhakal *et al.* (2017) for protein content. Single plant yield had positive association with kernel length, kernel breadth and amylose content and negative association with L/B ratio and protein content in cross II. Kernel length exhibited positive and significant association with L/B ratio (0.590) and negative significant association with protein content (-0.192) in cross I and positive significant association with kernel breadth (0.283) and L/B ratio (0.404) in cross II. Kernel breadth showed negative and significant association with L/B ratio (-0.745) in cross I and cross II. L/B ratio exhibited negative correlation with amylose content in cross I. Amylose content showed negative association with grain protein content in cross I.

Correlation analysis revealed negative and significant correlation of protein content with number of filled grains per panicle (-0.194), test weight (-0.184), single plant yield (-0.208) and kernel length (-0.192) and positive association with panicle length, number of productive tillers per plant and L/B ratio in cross I and positive association with days to 50% flowering, plant height, number of productive tillers per plant, number of filled grains per panicle, kernel breadth and amylose content and negative association with panicle length, test weight, single plant yield, kernel length and L/B ratio in cross II.

Correlation gives only the relation between two variables, whereas path coefficient analysis allows separation of the direct effect and their indirect effects through other attributes by partitioning the correlations (Wright, 1921) for better interpretation of cause and effect relationship. Hence, this objective was undertaken in the present investigation.

Based on the data recorded in the F_2 population in the present investigation, the correlations coefficients were estimated to determine direct and indirect effects at phenotypic level taking protein content as the dependent character. The results of path coefficient analysis for yield, related traits and quality traits are presented in Table 3 and 4.

Days to 50% flowering exerted negative direct effect (-0.075) on protein content and positive indirect effects on protein content through plant height, panicle length, test weight, single plant yield, kernel breadth, L/B ratio and amylose content and it had negative indirect effects through number of productive tillers per plant, number of filled grains per panicle, kernel length on protein content in cross I and days to 50% flowering exerted positive direct effect (0.086) on protein content in cross II. Plant height exhibited negative direct effect (-0.076) on protein content and indirect positive influence of this trait on protein content was observed through days to 50% flowering, panicle length, number of productive tillers per plant, test weight, kernel length, kernel breadth and L/B ratio and indirect negative effects on protein content through number of filled grains per panicle, single plant yield and amylose content in cross I and plant height exhibited positive direct effect (0.215) on protein content in cross II. Panicle length had positive and direct effect (0.032) on protein content and positive indirect influence of this trait on protein content was observed through number of productive tillers per plant, number of filled grains per panicle, test weight, single plant yield, kernel length and indirect negative effects on protein content through days to 50% flowering, plant height, kernel breadth, L/B ratio and amylose content in cross I and panicle length had negative direct effect (-0.009) on protein content in cross II.

Number of productive tillers per plant exerted positive direct effect (0.123) on protein content and indirect positive effects on protein content through panicle length, number of filled grains per panicle, L/B ratio, amylose content and protein content and indirect negative effects through plant height, test weight, single plant yield, kernel length and kernel breadth in cross I and number of productive tillers per plant had positive and direct effect (0.324) on protein content in cross II. Number of filled grains per panicle had negative direct effect (-0.045) on protein content and indirect positive influence of this trait on protein content was observed through kernel breadth and L/B ratio and indirect

Table 3. Phenotypic path coefficient analysis showing direct and indirect effects of yield related traits with grain protein content in F_2 Population of Cross-I (RNR 15048 × JAK 686)

Traits	DFF	PH	PL	PT	GPP	TW	SPY	KL	KB	L/B	AC	PC
DFF	**-0.075**	0.031	0.001	-0.020	-0.009	0.006	0.032	-0.023	0.011	0.003	0.002	-0.041
PH	0.030	**-0.076**	0.010	0.021	-0.001	0.006	-0.024	0.003	0.001	0.002	-0.004	-0.029
PL	-0.003	-0.025	**0.032**	0.008	0.004	0.010	0.023	0.054	-0.009	-0.021	-0.001	0.073
PT	0.012	-0.013	0.002	**0.123**	0.008	-0.001	-0.030	-0.001	-0.017	0.029	0.001	0.113
GPP	-0.016	-0.001	-0.003	-0.022	**-0.045**	-0.005	-0.074	-0.089	0.008	0.069	-0.004	-0.194
TW	0.008	0.008	-0.006	0.003	-0.004	**-0.056**	-0.074	-0.089	0.033	0.002	-0.006	-0.184
SPY	0.015	-0.012	-0.004	0.024	-0.022	-0.027	**-0.152**	-0.098	-0.001	0.072	-0.002	-0.208
KL	-0.005	0.008	-0.005	0.001	-0.011	-0.014	-0.043	**-0.346**	0.012	0.226	-0.006	-0.192
KB	-0.004	-0.006	-0.001	-0.011	-0.002	-0.010	0.001	-0.023	**0.187**	-0.286	-0.005	-0.155
L/B	-0.006	-0.005	-0.001	0.009	-0.008	-0.001	-0.028	-0.204	-0.139	**0.384**	0.001	0.010
AC	0.002	-0.005	0.007	-0.002	-0.003	-0.006	-0.005	-0.037	0.015	-0.006	**-0.060**	-0.107

Bold values are direct effects

DFF- Days to 50% flowering, PH- Plant height, PL-Panicle length, PT-Number of productive tillers per plant, GPP-Number of grains per panicle, TW- 1000 grain weight, SPY- Single plant yield, KL- Kernel length, KB- Kernel breadth, L/B- Kernel L/B ratio, AC- Amylose content, PC- Protein content.

Table 4. Phenotypic path coefficient analysis showing direct and indirect effects of yield related traits with grain protein content in F_2 Population of Cross-II (RNR 15048 × JAK 685)

Traits	DFF	PH	PL	PT	GPP	TW	SPY	KL	KB	L/B	AC	PC
DFF	**0.086**	-0.157	0.001	-0.004	-0.060	-0.016	0.108	0.040	0.001	0.567	-0.005	0.048
PH	-0.063	**0.215**	-0.002	-0.016	0.071	0.016	-0.082	-0.037	-0.001	-0.053	0.002	0.049
PL	-0.010	0.052	**-0.009**	-0.045	0.051	0.009	-0.007	-0.003	-0.007	-0.030	-0.008	-0.002
PT	-0.001	-0.011	0.001	**0.324**	-0.098	0.018	-0.213	-0.001	0.002	0.005	0.004	0.031
GPP	-0.015	0.045	-0.001	-0.093	**-0.343**	-0.005	-0.104	-0.003	-0.009	-0.038	0.013	-0.140
TW	-0.020	0.050	-0.001	0.088	-0.025	**0.068**	-0.169	-0.020	0.002	-0.023	-0.002	-0.054
SPY	-0.021	0.041	-0.001	0.160	0.082	0.026	**-0.432**	-0.007	0.003	0.005	0.015	-0.130
KL	-0.048	0.112	-0.004	0.005	0.014	0.019	-0.044	**-0.072**	0.001	-0.063	0.001	-0.078
KB	0.001	-0.001	0.001	0.161	-0.080	0.002	-0.033	-0.020	**0.003**	0.116	0.003	0.010
L/B	-0.031	0.073	-0.001	-0.011	0.084	0.010	0.014	-0.002	-0.002	**-0.155**	-0.002	-0.051
AC	-0.004	0.004	0.008	0.016	0.045	-0.001	-0.067	-0.001	0.001	0.003	**0.097**	0.093

Bold values are direct effects

DFF- Days to 50% flowering, PH- Plant height, PL-Panicle length, PT-Number of productive tillers per plant, GPP-Number of grains per panicle, TW- 1000 grain weight, SPY- Single plant yield, KL- Kernel length, KB- Kernel breadth, L/B- Kernel L/B ratio, AC- Amylose content, PC- Protein content.

negative effects on protein content through days to 50% flowering, plant height, panicle length, number of productive tillers per plant, test weight, single plant yield, kernel length and amylose content in cross I and number of filled grains per panicle had positive and direct effects (0.343) on protein content in cross II. Test weight exerted negative direct (-0.056) effects on protein content and indirect positive effects through days to 50% flowering, plant height, number of productive tillers per plant, number of productive tillers per plant, kernel breadth and L/B ratio on protein content and negative indirect effects on protein content through panicle length, number of filled grains per panicle, single plant yield, kernel length and amylose content in cross I and test weight showed positive and direct effect (0.068) on grain protein content in cross II. Single plant yield exhibited negative direct effects (-0.152) on protein content and indirect positive effects of this trait on protein content through days to 50% flowering, number of productive tillers per plant and L/B ratio and indirect negative effects was observed on protein content through plant height, panicle length, number of filled grains per panicle, test weight, kernel length, kernel breadth and amylose content in cross I and single plant yield had negative and direct effects (-0.432) on protein content in cross II.

Kernel length had negative direct effect (-0.346) on protein content and indirect positive effects were recorded on protein content through plant height, number of productive tillers per plant, kernel breadth and L/B ratio and indirect negative effects were observed through days to 50% flowering, panicle length, number of filled grains per panicle, test weight, single plant yield and amylose content in cross I and kernel length exerted negative and direct effects (-0.072) on protein content in cross II. Kernel breadth exhibited positive direct effect (0.187) on protein content and positive indirect influence of this trait through single plant yield and negative indirect effect through days to 50% flowering, plant height, panicle length, number of productive tillers per plant, number of filled grains per panicle, test weight, kernel length, L/B ratio and amylose content in cross I and kernel breadth exhibited positive and direct effects (0.003) on protein content in cross II. Kernel L/B ratio showed positive and direct effect (0.384) on protein content and positive indirect effects through number of productive tillers per plant and amylose content and negative indirect effects through days to 50% flowering, plant height, panicle length, number of filled grains per panicle, test weight, single plant yield, kernel length and kernel breadth in cross I and kernel L/B ratio had negative and direct effect (-0.155) on protein content in cross II. Amylose content exhibited negative direct effect (-0.060) on protein content and positive indirect effect through days to 50% flowering, panicle length, kernel breadth and negative indirect effect through plant height, number of productive tillers per plant, number of filled grains per panicle, test weight, single plant yield, kernel length and L/B ratio on protein content in cross I and amylose content had positive and direct effect (0.097) on protein content in cross II. Positive direct effects on protein content were observed for panicle length, number of productive tillers per plant, kernel breadth and L/B ratio in cross I and days to 50% flowering, plant height, number of productive tillers per plant, test weight, kernel breadth and amylose content in cross II.

The findings of the present investigation revealed that L/B ratio exerted highest positive direct effect on the protein content followed by kernel breadth, number of productive tillers per plant and panicle length in cross-I and number of productive tillers per plant, plant height, amylose content, test weight and kernel length exerted highest positive direct effect on the protein content in cross –II.

CONCLUSION

It was concluded that critical analysis of both correlation and path analysis indicated that L/B ratio, kernel breadth, kernel length, amylose content were determined as most important traits as both the correlation coefficients as well the direct effects were high with protein content.

REFERNCES

Bhuvaneswari, S., Kumar, S., Singh, M., Takhellambam, S., Shashidhar, K.S., Singh, R and Prakash, N. 2018. Genetic variability and association studies on grain yield components in F_2 populations of black rice (*Oryza sativa* L.) of manipur.

Chen, P., Shen, Z., Ming, L., Li, Y., Dan, W., Lou, G., Peng, B., Wu, B., Li, Y., Zhao, D., Gao, G., Zhang, Q., Xiao, J., Li, X., Wang, G and He, Y. 2018. Genetic Basis of variation in rice seed storage protein (Albumin, Globulin, Prolamin and Glutelin) content revealed by Genome-Wide

Association Analysis. *Frontiers in Genetics*. 9:612

Das, P., Adak, S and Majumder A.L. 2020. Genetic manipulation for improved nutritional quality in Rice. *Frontiers in Genetics*.11:776.

Devi, P.S., Veni, B.K., Jyothula, D.P.B and Raja, D.S. 2019. Association studies for yield components, physico-chemical and nutritional quality parameters in coloured rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences*. 8(6): 359-365.

Dhakal, R., Deosarkar, D.B and Paudel, D.P. 2017. Studies of correlation and path analysis of grain yield with yield contributing characters, grain quality characters and iron chlorosis in aerobic (*Oryza sativa* L.) on vertisols. *International Journal of Current Research*. 9:52926-52931.

Ekka, R.E., Sarawgi, A.K and Kanwar, R.R. 2011. Correlation and path analysis in traditional rice accessions of Chattisgarh. *Journal of Rice Research*. 4(1):11-18.

Hajiaqatabar, A., Kiani, G., Kazemitabar, S.K. and Alavi, M. 2016. Correlation and Path coefficient analysis for yield and yield components in F_2 segregating populations of rice. *Jordan Journal of Agricultural Sciences*. 12(3).

Juliano, B.O., 1992. Structure, chemistry and function of the rice grain and its fractions. *Cereal Foods World*. 37: 772-774.

Kalaiselvan, S., Subramanian, S.A., Thirumurugan, T and Rajanbabu, V. 2019. Genetic variability and association studies in F_2 population of rice under sodicity. *Electronic Journal of Plant Breeding*. 10 (2): 601-613.

Kumar, S., Chauhan, M.P., Tomar, A., Kasana, R.K and Kumar, N. 2018. Correlation and path coefficient analysis in rice (*Oryza sativa* L.). 7(6): 20-26.

Laxuman, Salimath, P.M., Shashidhar, H.E., Mohankumar, H.D., Patil, S.S., Vamadevaiah, H.M and Janagoudar, B.S. 2011. Association analysis in genetically diverse non-basmati local aromatic genotypes of rice (*Oryza sativa* L.). *Karnataka Journal of Agriculture Sciences*. 24(5): 626-628.

Manivannan, N. 2014. TNAUSTAT- Statistical Package. Available online at: https://sites.google.com/site/tnaustat (accessed June 03, 2018).

Pradeep, P., Malleshappa, C., Manjunatha, B., and Harish, D. 2018. Genetic variability, path analysis, character association for yield and its attributing traits in F_2 population of cross BPT-5204 x IET-21214 in rice (*Oryza sativa* L.). *Environment and Ecology*. 36(2): 437-442.

Ratna, M., Begum, S., Husna, A., Dey, S. R and Hossain, M.S. 2015. Correlation and path coefficients analysis in Basmati Rice. *Bangladesh Journal of Agricultural Research*. 40(1): 153-161.

Sala, M and Geetha, S. 2015. Correlation and path analysis for iron and zinc content in segregating population of rice. *Rice Genomics and Genetics*. 6(2): 221-225.

Selvaraj, C., Pothiraj N., Thiyagarajan, K., Bharathi, M and Rabindran, R. 2011. Genetic parameters of variability, correlation and path coefficient studies for grain yield and other yield attributes among rice blast disease resistant genotypes of rice (*Oryza sativa* L.). *African Journal of Biotechnology*. 10(17): 3322-3334.

Shet, R.M., Rajanna M.P., Ramesh, S., Sheshshayee, M.S and Mahadevu P. 2012. Genetic variability, correlation and path coefficient studies in F_2 generation of aerobic rice (*Orzya sativa* L.). *Electronic Journal of Plant Breeding*. 3(3): 925-931.

Singh, S.K., Habde, S., Singh, D.K., Khaire, K., Mounika, K and Majhi, P.K. 2020. Studies on character association and path analysis studies for yield, grain quality and nutritional traits in F_2 population of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*. 11(3): 969-975.

Swapnil, P.K., Chakraborty, M., Singh, D.N., Kumari, P and Ekka, J.P. 2020. Genetic variability, correlation and path coefficient studies in F_2 generation of rice (*Orzya sativa* L.). *International Journal of Chemical Stuides*. 8(4): 3116-3120.

Wright, S. 1921. Correlation and causation. *Indian J. Agric. Res.,* 20(7): 557-585.

Yang, Y., Guo, M., Sun, S., Zou, Y., Yin, S., Liu, Y., Tang, S., Gu, M., Yang, Z and Yan, C. 2019. Natural variation of *OsGluA2* is involved in grain protein content regulation in rice. *Nature communications*.10(1): 1-12.

Research Article
The J. Res. PJTSAU 51(1&2) 17-24, 2023

PATTERN OF RELATIONSHIPS AMONG PRODUCTIVITY AND NUTRITIONAL TRAITS IN PEARL MILLET (*Pennisetum Glaucum* (L.) R. Br.)

VIJAYAKUMAR KORABOYANA[1,4], ESWARI KANCHERLA[1], S. N. C. V. L. PUSHPAVALLI[2], K. SUPRIYA[3] and ANIL KUMAR VEMULA[4]

[1]Department of Genetics and Plant Breeding, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana, India.

[2]Institute of Biotechnology, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana, India.

[3]Department of Statistics and Mathematics, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana, India.

[4]International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, Telangana, India.

Date of Receipt: 24-03-2023 Date of Acceptance: 19-04-2023

ABSTRACT

The present investigation was carried out to study the correlation and path analysis amonggrain yield, yield-related and nutritional traits in pearl millet hybrids. This experiment was conducted in a total of 168 hybrids, which were developed by crossing 84 advanced generation seed parental (B) lines with two restorer (R) line testers by line x tester mating design. These hybrids were evaluated in 4 trials (each with 42 hybrids) during rainy season of 2020 at four locations. Observations were recorded on days to 50% flowering, plant height, 1000-seed weight, grain iron content, grain zinc content and grain yield. Correlation analysis revealed that significant positive correlation was found between grain yield and plant height; days to 50% flowering and plant height; and grain Fe and Zn content. Significant negative correlation was observed between grain yield with grain Fe and Zn content. The results of path analysis showed that plant height showed highest direct effect and days to 50% flowering showed highest indirect effects on grain yield. These results suggests that plant height and days to 50% flowering should be given maximum consideration for total grain yield improvement.

KEYWORDS: correlation, grain yield, nutritional traits, path analysis, pearl millet

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is commonly grown in the arid and semi-arid regions of Asia and Africa. It serves as staple food for the people living in relatively dry areas of the India and Sub-Sahelian Africa and an important source of fodder/ feed for livestock and poultry. It can be cultivated even in the poor infertile soils and drought prone environments, where no other cereal crop can survive. It is a rich source of nutrients like iron (Fe) and zinc (Zn). Globally, pearl millet is cultivated in an area about 27 m ha with 31 m tons of production and is staple food for more than 90 million people. India is the largest producer of pearl millet with the of 7.65 m ha of area, 11.6 m tons of production and 1420 kg^{-1}ha of productivity (Indiastat, 2021). In Telangana, pearl millet grown in 10,000 ha of area with 9300 tons of production and 930 kg^{-1}ha productivity (Indiastat, 2021). The ultimate aim in most plant breeding programs is the improvement in the productivity of grains as measured in terms of the yield per unit area. The possibilities of achieving this goal through genetic improvement have been elucidated by evolving high yielding hybrids of pearl millet. The possibilities of achieving this goal through genetic manipulation have been elucidated by evolving high yielding hybrids. These newly evolved varieties and hybrids gets their high yielding ability by reconstruction of an ideal plant type. It is now widely recognized that the improvement in plant type can make a very significant contribution to increase total grain yield. Grain yield character in pearl millet and as in all crop plants is quantitative in nature and is polygenically controlled. Selection based on grain yield character alone is usually not very effective. However, selection based on its component characters could be more efficient and reliable. Knowledge of the association between yield and its component characters and among the

---

Email: vijayakumar-pbg@pau.edu

component characters themselves can improve the efficiency of selection in plant breeding. This necessitates study of the relationship and effects of various yield-contributing traits on grain yield in current breeding programs to derive proper selection criteria for enhancing productivity in pearl millet crop. The present study was undertaken to study the correlations and path analysis in pearl millet hybrids to develop a criterion for selection that could be effectively used for selecting the desirable genotypes with high yield potential in the future.

MATERIAL AND METHODS

A total of 168 hybridswere developed by crossing 84 advanced generation (>F5/F6) seed parental (B) lines with two restorer (R) line testers by line x tester mating design at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, and these hybrids were used for the study. Because the material is too large to evaluate in a single trial, it is divided into four trials, each with 42 hybrids, to reduce experimental error. The experiment was conducted during rainy season of 2020, each trial is evaluated in alpha-lattice design with two replications at 4 locations. In each replication, the size of the plot consisted of 2 rows with a length of 4 meters. The spacing between and within the rows was maintained at 75 cm and 12-15 cm, respectively. Seeds after germination were thinned down to one plant per hill after two weeks of sowing. A basal dose of 100 kg of di-ammonium phosphate (18% N and 46% P) was applied at the time of field preparation and 100 kg of urea (46% N) was applied as top dressing in two-split dose at the stage of three weeks and five weeks after sowing. Trials were regularly irrigated to avoid any moisture stress. All the recommended agronomic practices were followed for raising good crop.

Data collection

Data collection was done for the grain yield, Fe content, Zn content and other yield component characters. The observations were taken on 3 random plants in each replication for plant height (cm) and data for days to 50% flowering, grain yield, 1000-grain weight (g) were recorded on plot basis. Further, data of grain yield was converted to kg ha^{-1}. Grain Fe and Zn densities were estimated by Energy-Dispersive X-ray Fluorescence Spectrometry (ED-XRF) machine.

Data analysis

Phenotypic and genotypic linear correlation coefficients were calculated for all the possible comparisons using the formula suggested by Falconer (1964). The correlation coefficients were partitioned into direct and indirect effects using the path coefficient analysis according to Dewey and Lu (1959). Data analysis was carried out using SAS v 9.4 software (SAS, Inc., 2017).

RESULTS AND DISCUSSION

Phenotypic and genotypic correlation

Correlation analyses the relationship among the characters has great value in the evaluation of the most effective procedures for selection of superior genotypes. Positive association between major yield contributing characters would be desirable and it eases the selection process in breeding program. Correlation analyses was computed at both genotypic and phenotypic level. The genotypic correlation is the heritable association among the traits, and the phenotypic correlation is environmental deviations together with non-additive genetic deviations (Allard, 1960; Falconer and Mackay, 1996). The genotypic correlations were of higher magnitude than their corresponding phenotypic correlations for most of the traits, indicating a strong inherent relationship among the characters studied. This strong genotypic correlation over phenotypic correlations were reported in previous studies in pearl millet (Khairwal *et al.,* 1999, Izge *et al.,* 2006, Bhuri Singh *et al.,* 2015 and Bhasker *et al.,* 2017).

Trial wise correlation coefficient values and across trial significance of correlation between traits were presented in the Tables 1 and 2 respectively. It was observed that at both genotypic and phenotypic level, significant positive correlation was observed between plant height and days to flowering; and between grain yield and plant heightin all 4 trials (TCB (Testcross B-line Trial) 1, TCB 2, TCB 3, TCB 4). Significant positive correlation was observed between Fe content and Zn content at genotypic level in 3 trials and at phenotypic level in all 4 trials. Significant negative correlation was observed between grain yield and Fe content in all 4 trials at genotypic level and in 2 trials at phenotypic level. Significant negative correlation was

Table 1: Trial wise genotypic and phenotypic correlation coefficients between grain yield, nutritional and yield related traits

	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
Days to 50% flowering	TCB 1	G	0.39**	-0.11	-0.28	-0.09	0.06
		P	0.30*	0.24	0.01	0.17	-0.04
	TCB 2	G	1.40***	-0.43**	0.73***	0.43**	1.99***
		P	0.55***	0.1	-0.01	-0.24	0.21
	TCB 3	G	0.65***	0.08	-0.44**	0.55***	1.98***
		P	0.35*	0.05	-0.12	0.11	0.45**
	TCB 4	G	0.61***	-0.17	-0.05	-0.54***	0.18
		P	0.47**	-0.12	-0.03	0.10	-0.09
Plant height	TCB 1	G		0.17	-0.52***	-0.38**	0.64***
		P		0.18	-0.23	0.04	0.46**
	TCB 2	G		-0.31*	0.19	0.32*	2.11***
		P		0.11	-0.18	-0.08	0.46**
	TCB 3	G		0.25	-0.51***	-0.55***	1.92***
		P		0.25	-0.33*	-0.03	0.63***
	TCB 4	G		0.39**	-0.38*	-0.20	0.75***
		P		0.29	-0.21	0.22	0.36*
1000-seed weight	TCB 1	G			0.26	0.43**	-0.44**
		P			0.09	0.28	-0.28
	TCB 2	G			1.99***	1.62***	-0.31*
		P			0.39**	0.36*	0.18
	TCB 3	G			-0.14	-0.16	0.47**
		P			0.10	0.15	0.34*
	TCB 4	G			0.09	-0.16	0.33*
		P			0.03	-0.19	0.22
Iron content	TCB 1	G				0.53***	-0.32*
		P				0.57***	-0.27
	TCB 2	G				0.92***	-1.58***
		P				0.65***	-0.09
	TCB 3	G				0.75***	-2.31***
		P				0.64***	-0.49***
	TCB 4	G				0.24	-0.46**
		P				0.34*	-0.36*
Zinc content	TCB 1	G					-0.12
		P					-0.19

	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
	TCB 2	G					-0.38*
		P					-0.01
	TCB 3	G					-1.18***
		P					-0.16
	TCB 4	G					-0.62***
		P					0.02

*P < 0.05; ** P < 0.01; ***P < 0.001

Table2: Number of trials showing significantgenotypic and phenotypic correlationsbetween grain yield, nutritional and yield related traits

		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
Days to 50% flowering	G	**4 (+)**	3 (NS) 1 (-)	2 (NS) 1 (+) 1 (-)	2 (+) 1 (-) 1 (NS)	**2 (+)** **2 (NS)**
	P	**4 (+)**	4 (NS)	4 (NS)	4 (NS)	**3 (NS)** **1 (+)**
Plant height	G		2 (NS) 1 (+) 1 (-)	3 (-) 1 (NS)	2 (-) 1 (+) 1 (NS)	**4 (+)**
	P		4 (NS)	3 (NS) 1 (+)	4 (NS)	**4 (+)**
1000 Seed Weight	G			3 (NS) 1 (+)	2 (+) 2 (NS)	2 (+) 2 (-)
	P			3 (NS) 1 (+)	3 (NS) 1 (+)	3 (NS) 1 (+)
Iron Content	G				**3 (+)1 (NS)**	**4 (-)**
	P				**4 (+)**	**2 (NS)** **2 (-)**
Zinc Content	G					**3 (-)** **1 (NS)**
	P					**4 (NS)**

+ Significantly positive, - Significantly negative, NS Non-significant

observed between grain yield and Zn content in 3 trials at genotypic level and non-significant at phenotypic level in all 4 trials.

High correlation between Fe and Zn content and negative or no correlation between grain yield and grain Fe content were well reported in earlier studies by Velu *et al.,* (2007), Gupta *et al.,* (2009), Rai *et al.,* (2012), Govindaraj *et al.,* (2013) and Kanatti *et al.,* (2014). Between grain yield and days to 50% flowering significant positive correlation was observed in 2 trials at genotypic level and 1 trial at phenotypic level and non-significant in remaining trials. Sudharshan *et al.,* (2018) and Kamble *et al.,* (2022) reported positive correlation between grain yield and days to 50% flowering, onthe contrary to this, Izge *et al.,* (2006), Bhuri Singh *et al.,* (2015) and Kumar *et al.,* (2020) found negative genotypic correlation between grain yield and days to 50% flowering. Some other studies reported no correlation between days to 50% flowering and grain yield (Chaudhary, 1992, Ezeaku and Mohammed 2006 and Izge al., 2004). Above result suggested that significant positive correlation was found between days to 50% flowering and plant height; grain yield and plant height; grain Fe and Zn content. Significant negative correlation was observed between grain yield with grain Fe and Zn content.

Direct and Indirect effects

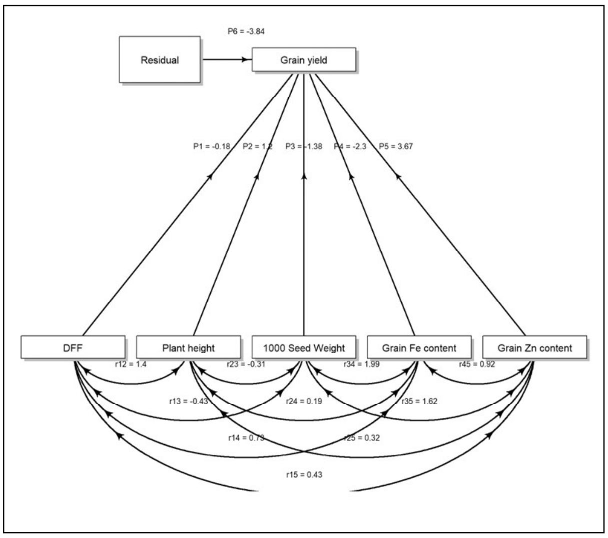
Seed yield is a complex character which is highly influenced by interaction of various component traits and the environment. Compartmentalization of correlation coefficients into direct and indirect effects reveals the true nature of associations observed among various characters. Path coefficients provides an effective way of finding direct and indirect sources of correlation. Path analysis results of 4 trials revealed that plant height showed highest direct effect and days to 50% flowering showed highest indirect effect via plant height on grain yield. Trial wise path coefficient analysis results were mentioned in Table 3. Direct and indirect effects of all characters on grain yield at genotypic level in 4 trials were presented in Figure 1.

Table 3: Trial wise direct and indirect effects of different characters on grain yield at genotypic and phenotypic level

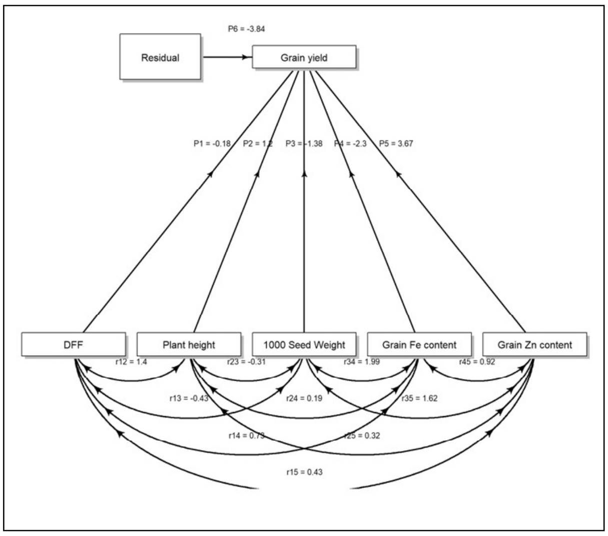
	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
Days to 50% flowering	TCB 1	G	**-0.49**	0.54	0.12	-0.04	-0.07
		P	**-0.11**	0.16	-0.08	0.00	-0.01
	TCB 2	G	**-0.18**	1.68	0.59	-1.68	1.58
		P	**-0.06**	0.26	0.02	0.01	0.01
	TCB 3	G	**0.67**	0.42	0.01	0.79	0.09
		P	**0.27**	0.12	0.01	0.05	0.01
	TCB 4	G	**-32.33**	19.19	3.74	-0.82	10.40
		P	**-0.27**	0.17	-0.01	0.01	0.01
Plant height	TCB 1	G	-0.19	**1.37**	-0.18	-0.07	-0.29
		P	-0.03	**0.53**	-0.06	0.02	0.00
	TCB 2	G	-0.26	**1.20**	0.43	-0.44	1.17
		P	-0.03	**0.46**	0.02	0.01	0.01
	TCB 3	G	0.44	**0.65**	0.01	0.92	-0.09
		P	0.09	**0.34**	0.07	0.13	0.01
	TCB 4	G	-19.72	**31.46**	-8.58	-6.26	3.85
		P	-0.13	**0.36**	0.03	0.07	0.02
1000-Seed Weight	TCB 1	G	0.05	0.23	**-1.09**	0.04	0.32
		P	-0.03	0.10	**-0.33**	-0.01	-0.01
	TCB 2	G	0.08	-0.37	**-1.38**	-4.58	5.95
		P	-0.01	0.05	**0.16**	-0.03	-0.01

	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
	TCB 3	G	0.05	0.16	**0.03**	0.25	-0.03
		P	0.01	0.08	**0.28**	-0.04	0.01
	TCB 4	G	5.50	12.27	**-22.00**	1.48	3.08
		P	0.03	0.10	**0.11**	-0.01	-0.02
Iron content	TCB 1	G	0.14	-0.71	-0.28	**0.14**	0.40
		P	0.00	-0.12	-0.03	**-0.09**	-0.03
	TCB 2	G	-0.13	0.23	-2.75	**-2.30**	3.38
		P	0.00	-0.08	0.06	**-0.07**	-0.01
	TCB 3	G	-0.29	-0.33	0.01	**-1.81**	0.13
		P	-0.03	-0.11	0.03	**-0.39**	0.02
	TCB 4	G	1.62	-11.96	-1.98	**16.48**	-4.62
		P	0.01	-0.08	0.00	**-0.33**	0.03
Zinc content	TCB 1	G	0.04	-0.52	-0.47	0.08	**0.75**
		P	-0.02	0.02	-0.09	-0.05	**-0.05**
	TCB 2	G	-0.08	0.38	-2.24	-2.12	**3.67**
		P	0.01	-0.04	0.06	-0.05	**-0.01**
	TCB 3	G	0.37	-0.36	0.01	-1.35	**0.17**
		P	0.03	-0.01	0.04	-0.25	**0.03**
	TCB 4	G	17.46	-6.29	3.52	3.96	**-19.26**
		P	-0.03	0.08	-0.02	-0.11	**0.10**

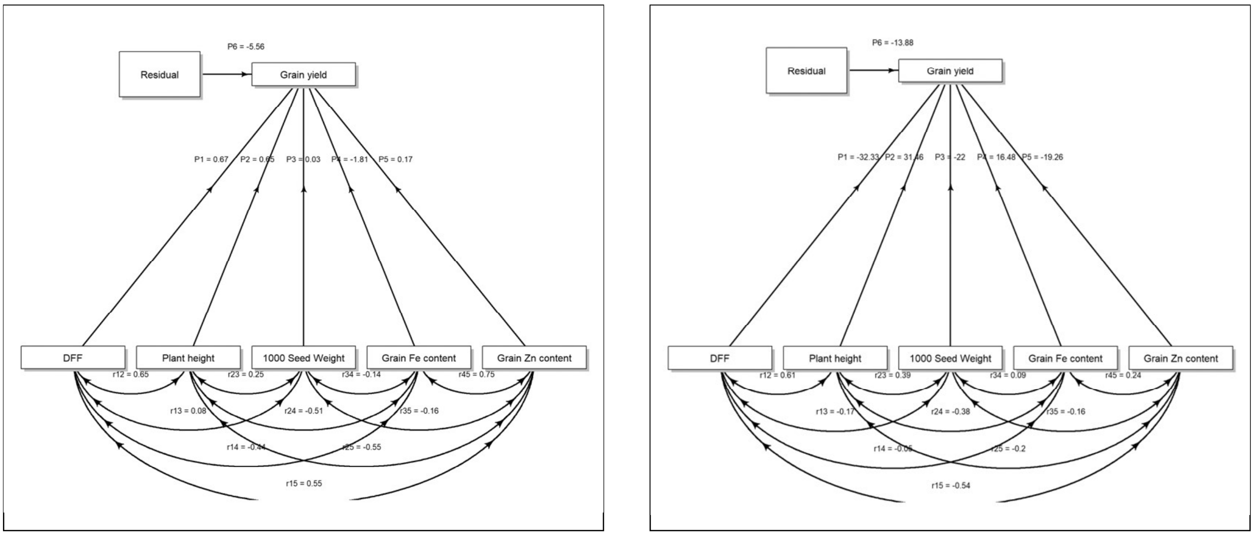
Diagonal and bold values represent direct effects



TCB-1



TCB-2



TCB-3 **TCB-4**

Figure 1. Trial wise path diagrams showing direct and indirect effects of different characters on grain yield at genotypic level

In TCB 1, at genotypic level, plant height (1.37) followed by grain Zn content (0.75) and grain Fe content (0.14) had high and positive direct effect on grain yield. At phenotypic level also plant height (0.53) showed highest direct effect on grain yield. At genotypic level, highest indirect effects on grain yield were showed by days to 50% flowering via plant height (0.54) followed by grain Fe content via grain Zn content (0.40) and 1000-seed weight (0.32) via grain Zn content.

In TCB-2, at genotypic level grain Zn content (3.67) followed by plant height (1.20) showed highest direct effect on grain yield, whereas at phenotypic level plant height (0.46) followed by 1000 seed weight (0.16) showed highest direct effect on grain yield. The highest indirect effects on grain yield at genotypic level showed by 1000-seed weight via grain Zn content (5.95) followed by grain Fe content via grain Zn content (3.38) and days to 50% flowering via plant height (1.68).

In TCB-3, at genotypic level highest direct effect on grain yield was showed by days to 50% flowering (0.67) followed by plant height (0.65) whereas at phenotypic level highest direct effect was showed by plant height (0.34) followed by days to 50% flowering (0.27). The highest indirect effects at genotypic level were caused by days to 50% flowering (0.79) via grain Fe content followed by plant height (0.44) via days to 50% flowering and days to 50% flowering (0.42) via plant height.

In TCB 4, at both genotypic (31.46) and phenotypic level (0.36) plant height showed highest direct effect on grain yield. Highest indirect effect at genotypic level caused by days to 50% flowering (19.19) via plant height, grain Zn content (17.46) via days to 50% flowering and 1000-seed weight (12.27) via plant height.

This study revealed that plant height showed highest direct effect and days to 50% flowering showed highest indirect effect on grain yield. Our results are in accordance with Izge *et al.,* (2006) and Kumar *et al.,* (2020) where they found high direct effects of plant height on grain yield. Bhasker *et al.,* (2017) and Rakesh *et al.,* (2015) reported high direct effects for plant height and 1000-grain weight on grain yield. On the contrary, Sumanth *et al.,* (2014) found high negative direct effects of plant height on grain yield. Thangasamy and Gomathinayagam (2003) and Bhuri Singh *et al.,* (2015) reported that plant height and days to 50% flowering are important traits to consider in selection process to improve grain yield in pearl millet. This investigation therefore suggests that plant height, 1000-seed weight and days to 50% flowering should be given maximum consideration for total yield improvement in pearl millet.

REFERENCES

Allard, R.W. 1960. Principles of Plant Breeding. John Wiley and Sons, Inc. New York, pp: 48.

Bhasker, K., Shashibhushan, D., Murali Krishna, K. and Bhave, M.H.V. 2017. Correlation and path analysis for grain yield and its components in Pearl millet [*Pennisetum glaucum* (L).R.Br.]. Bulletin of Environment, Pharmacology and Life Sciences6(1): 104- 106.

Bhuri Singh, Sharma, K.C. and Meena, H.K. 2015. Character association and path analysis of certain quantitative characters among parental lines and their hybrids in pearl millet. *Agricultural Science Digest* 35(2): 121-125.

Chaudhary, M.S. 1992. Path analysis and correlation in high yielding mungbean varieties. *ARC Training Report*. 1-5.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal*.51: 515-518.

Ezeaku, I.E., and Mohammed, S.G. 2006. Character association and path analysis in grain sorghum. *African Journal of Biotechnology*. 5(14): 1337-1340.

Falconer, D.S and Mackay, F.C.T. 1996. Introduction to Quantitative Genetics. (4th eds.) Longman Group Ltd, England, 122-125.

Falconer, D.S. 1964. Introduction to quantitative genetics. Oliverand Boyd Ltd., London, W.I.

Govindaraj, M., Rai, K.N., Shanmugasundaram, P., Dwivedi, S.L., Sahrawat, K.L., Muthaiah, A.R. and Rao, A.S. (2013) Combining ability and heterosis for grain iron and zinc densities in pearl millet. *Crop Science* 53:507–517. doi:10.2135/cropsci2012.08.0477.

Gupta, S.K., Velu, G., Rai, K.N. and Sumalini, K. (2009) Association of grain iron and zinc content with grain yield and other traits in pearl millet (Pennisetum glaucum (L.) R. Br.). *Crop Improvement*. 36:4–7.

Indiastat2021.https://www.indiastat.com tableagriculture/selected-state-wise-area-production-productivity-b/1423634

Izge, A.U., Alabi, S.O. andMaina, Y.T. 2004. Correlation and path analysis of pod yield and yield components of groundnut (*Arachis hypogeae* L.). *Journal of Sustainable Agriculture and Environment*. 6 (1): 15-21.

Izge, A.U., Kadams, M. andGungula, D.T. 2006. Studies on character association and path analysis of quantitative characters among parental lines of pearl millet (Pennisetum glaucum) and their F1 hybrids in a diallel cross. *African Journal of Agricultural Research*. 1(5): 194-198.

Kanatti, A., Rai, K.N., Radhika, K.,Govindaraj, M., Sahrawath, K.L. and Rao, A.S.2014. Grain iron and zinc density in pearl millet: combining ability, heterosis and association with grain yield and grain size. *SpringerPlus*3: 763.https://doi.org/10.1186/2193-1801-3-763.

Khairwal, I.S., Rai, K.N., Andrew, D.J. and Harinarayana, G. 1999. Pearl millet breeding. Oxford and IBH Publishing Co. New Delhi. p 511.

Kamble, P.S., Barhate, K.K. and Andhale, G. R. (2022). Correlation and Path analysis for zinc, iron and yeild contributing characters in pearl millet [Pennisetum glaucum (L.) R.Br.] genotypes. *The Pharma Innovation Journal*, *05*(06), 596–600. https://doi.org/10.47191/ijmra/v5-i6-03.

Kumar, M., Rani, K., Ajay, B. C., Patel, M. S., Mungra, K. D., & Patel, M. P. (2020). Multivariate diversity analysis for grain micronutrients concentration, yield and agro-morphological traits in pearl millet (Pennisetum glaucum (L) R. Br.). *International Journal of Current Microbiology and Applied Sciences*, *9*(3), 2209–2226. https://doi.org/10.20546/ijcmas.2020.903.253.

Rai, K.N., Govindaraj, M. and Rao, A.S. (2012) Genetic enhancement of grain iron and zinc content in pearl millet. *Quality Assurance and Safety of Crops & Foods*4:119–125. doi:10.1111/j.1757-837X.2012.00135.x.

Research Article
The J. Res. PJTSAU 51(1&2) 25-38, 2023

INFLUENCE OF DIFFERENT PLANT DENSITIES ON PHYSIOLOGICAL PARAMETERS *VIS-À-VIS* ARCHITECTURE ON *BT* COTTON (*Gossypium Hirsutum L.*)

K. VENKATKIRAN REDDY[1], BABY AKULA[1], K. INDUDHAR REDDY[2], A. MADHAVI[3], K. SUPRIYA[4] and T. BHARATH[5]

[1,]Department of Agronomy, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad
[2]AICRP on Women in Agriculture, PGRC, Rajendranagar, Hyderabad
[3]AICRP on Soil Test Crop Response, ARI, Rajendranagar, PJTSAU, Hyderabad
[4]Department of Statistics and Mathematics, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad
[5]Department of Agronomy, ARS, Madhira, Khammam District

Date of Receipt: 11-05-2023 Date of Acceptance: 23-05-2023

ABSTRACT

A field experiment was conducted on "Influence of plant density *vis-à-vis* architecture on *Bt* cotton (*Gossypium hirsutum* L.) yield and quality parameters" was carried out on sandy loam soil at College farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during 2021-23. The experiment was laid out in split plot design with three replications. Results revealed that physiological parameters *viz.,* significant on leaf area index and light interception rate were record highest in semi open type. Specific leaf weight was found to be highest in compact type of plant canopy. Among plant densities, leaf area index and light interception rate were observed to be highest in plants planted under 90 x 20 cm (55,555 plants ha^{-1}), while highest specific leaf weight was noticed highest in plant spacing of 90 x 60 cm (18,518 plants ha^{-1}) during two years of study and pooled mean. Non-significant statistical differences were observed among canopy temperature and SPAD readings (chlorophyll content in leaves).

Cotton crop in India provides direct livelihood to 6 million farmers and textile industry consumes 60% of country's total fibre production. India is the largest producer of cotton and occupies second position in exporting and consumption in the world. In India, Cotton is grown in three different agro - ecological zones *viz.,* Northern, Central and Southern zone. Nearly 70 per cent of the crop is cultivated under rainfed conditions in the Central and Southern regions of the country. India occupies an area of 13 m ha with production of 365 lakh bales (170 kg of each bale) and productivity being 459 kg ha^{-1}. Among the cotton growing states, Maharashtra is the largest producer with an area of 38.06 lakh ha followed by Gujarat (24 lakh ha) and Telangana (21.14 lakh ha).

Cotton production in India is witnessed by low productivity due to various challenges such as rainfed conditions, small farm size, low yielding cultivars, optimum plant population, fertilizer application, increasing pests, diseases etc. Planting density and choice of cultivar are important agronomic practices that have the potential to optimize the canopy photosynthetic rate and crop productivity of any cropping system (Yao *et al.* 2016). Plant canopy architectural attributes such as size, shape, and orientation of shoot components are of major agronomic importance and greatly influence crop resistance to pests and diseases, adaptability, plant density requirements, ease of harvest and yield potential (Stewart, 2005). Differences in canopy architectural attributes among varieties impact cotton growth, lint yield and management.

The response of varieties with contrasting plant architecture to planting densities has important implications to cotton crop management decisions such as seeding rates. Reductions in seeding rates are gaining traction due to high seed costs and technology fees associated with transgenic cotton varieties coupled with increased adoption of seed treatments for disease, insect, and nematode control (Siebert and Stewart, 2006). The consequent reduction in plant density may have implications for variety selection and crop management due to modifications in plant architectural traits. Cotton plant architecture is a hereditary character that can be modified by selection (Morgen, 1917). However, agronomic studies on the effects of the wide

---

Email: kiranvenkat38@gmail.com

ranging plant architectural attributes on cotton growth, yield potential, and crop management are limited (Saeed *et al.* 2011). Manipulations of planting density in cotton have significant impacts on biomass partitioning, nutrient uptake, boll distribution, boll weight, lint yield, changes in the light spectrum, and crop production, which can influence yield of cotton. Thus productivity can be increased by increasing plant population per hectare *i.e* high density planting. Plants at high density can minimize evaporation and irrigation frequency, as well as increase the utilization of irrigation water. Optimal plant density can ensure healthy plant development by maintaining a core population of plants synchronizing boll number and fibre quality to achieve optimal yield (Dong *et al.* 2010). Farmers in Telangana state cultivate cotton hybrids with spacing of either 90×60cm or 90×30cm without exploring full potential of suitable plant architect based density, which is essentially an important low cost agro production strategy to enhance cotton yields. To assess the optimal planting density combined with plant canopy variations an attempt has been made to study influence of cotton plant densities *vis-a vis* plant architectural traits on growth and yield potential in Telangana region.

MATERIAL AND METHODS

The experiment on "Influence of plant density *vis-à-vis* architecture on *Bt* cotton (*Gossypium hirsutum* L.) yield and quality parameters" was conducted during *kharif* season of two consecutive years (2021 and 2022) to find out the influence of various plant densities and different plant types of *Bt* cotton on yield and quality at college farm, Professor Jayashankar Telangana State Agricultural University, College of Agriculture, Rajendranagar, Hyderabad situated at an altitude of 542.3 m above mean sea level at 17°19' N latitude and 78°23' E longitude. It is in the Southern Telangana agro-climatic zone of Telangana state. The soil analysis resulted that the texture of the soil is sandy loam with slightly alkaline in nature and having organic carbon upto 0.52 during 2021 and 0.51 during 2022.The initial soil analysis resulted that available nitrogen is low (201.9 kg ha^{-1}), available phosphorous is high (20.5 kg ha^{-1}) and available potassium is medium (370.5 kg ha^{-1}) during the year 2021. Whereas, during 2022 the available nitrogen is low (197 kg ha^{-1}), available phosphorous is high (21.2 kg ha^{-1}) and available potassium is medium (361.2 kg ha^{-1}).The average weekly maximum temperature during crop growing period was 29.4 °C (2021) and 29.4°C (2022). The weekly mean minimum temperature was 19.9 °C (2021) and 18.6 °C (2022). Total rainfall of 504.6 mm was received during 2021 in 30 rainy days and 673.2 mm during 2022 in 40 rainy days, respectively

The statistical design adopted for the experimentation was Split Plot design, with four replications and nine treatment combinations. The main plots were three plant types *viz.,* P_1: Compact type *Bt* cotton with Siri (Nuziveedu) hybrid; P_2: Open type *Bt* cotton with RCH 659 hybrid and P_3: Semi Open type *Bt* cotton with Sadanand hybrid. Each of these main plots were divided into three sub-plots. The sub-plots consisted of three plant densities *viz.,* D_1: 55,555 plants ha^{-1} with a spacing of 90× 20 cm; D_2: 37,037 plants ha^{-1} with a spacing of 90× 30 cm and D_3: 18,518 plants ha^{-1} with a spacing of 90×60 cm as detailed in the Fig.3.2. The experiment was repeated on the same site for two consecutive years in the same field during *kharif* 2021 and 2022.

RESULTS AND DISCUSSION

PHYSIOLOGICAL PARAMETERS

1. Leaf Area Index

Data on Leaf Area Index (LAI) as influenced by various plant types and plant densities are presented in Table 1. A perusal of the data reveals that, LAI was significantly affected by the plant types and plant densities tried in the experiment at all growth stages except at 30 DAS and interaction.

1.1. Leaf area index as influenced by plant types

The data in Table 4.12 reveals that LAI at 30 DAS was not-significantly influenced by plant types. However, numerically the highest LAI of 0.63 and 0.64 during 2021 and 2022 respectively, was observed with semi open growth type (Sadanand) and the lower LAI of 0.55 and 0.55 during 2021 and 2022 respectively was recorded with the compact type (Siri).

Highest leaf area index at being 1.93, 3.20, 4.29 and 3.74 (2021); 1.91, 3.11, 4.39 and 3.75 (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively, was recorded with semi open type (Sadanand), which was statistically on par with open type (RCH-659) and significantly superior to compact type (Siri) plants. While, minimum LAI (1.51, 2.58, 3.72 and 3.14 (2021); 1.51, 2.48, 3.71 and 3.15 (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) was observed with compact growth of plant type (Siri).

In annuals the initial leaf area development from seedlings is less for much of the early growth phases and may not be significant differences. As leaf area develops the leaf surfaces get expanded for capture of more sunlight. Semi open type growth of cotton plant where leaf is arranged at a certain angled to capture the photosynthetically active radiation at a higher rate and minimize the shading effect on lower leaves. Compared to compact type where erectophile canopy is structured (Less leaf area is exposed to direct sunlight) and open type plants where planophile canopy is available for capturing the sunlight (Shading of lower leaves was observed). The semi open type architecture in sadanand *Bt* cotton hybrid, has higher light interception allowing more light to penetrate to the bottom part of canopy increases the leaf area resulting production of more assimilates which is distributed to the reproductive structures and obtaining more yields. The results are in concurrent with the findings of Chapepa *et al.* (2013), Long *et al.* (2017), Chen *et al.* (2021), Chen *et al.* (2022), Sultana *et al.* (2023).

1.2 Leaf area index as influenced by plant densities

Leaf area index in respect to plant densities were observed to be significant at 60 DAS, 90 DAS, 120 DAS and at harvest except at 30 DAS of *Bt* cotton during the first year and second year of study (Table 1).

At 30 DAS, the LAI was observed to be non-significant indicating that there is no effect of plant densities on LAI. Numerically, the highest LAI 0.65 and 0.66 during 2021 and 2022, respectively, was observed with plant density of 90 x 20 cm (55,555 plants ha^{-1}) followed by 90 x 30 cm (37,037 plants ha^{-1}). While, lowest LAI (0.55 and 0.55 during 2021 and 2022, respectively) was recorded with plant density of 90 x 60 (18,518 plants ha^{-1}).

Data on LAI revealed that at 60 DAS, 90 DAS, 120 DAS and at harvest, LAI was significantly influenced by plant densities during both the years of study. Highest LAI of 1.98, 3.25, 4.32 and 3.73 (2021); 1.99, 3.18, 4.43 and 3.77 (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively, was recorded with density of 90 x 20 cm (55,555 plants ha^{-1}) which was significantly superior to other plant densities *viz.,* 90 x 30 cm (37,037 plants ha^{-1}) and 90 x 60 (18,518 plants ha^{-1}). While, least LAI was found in planting density of 90 x 60 (18,518 plants ha^{-1}) (1.43, 2.40, 3.67, 3.07 (2021); 1.40, 2.38, 3.69, 3.13 (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively).

This highest leaf area index at higher plant densities might be due to higher leaf area per unit area. Narrow row spaced plants covers more leaf area per unit ground area significantly increasing the leaf area index. Earlier finding of Chapepa *et al.* (2013), Long *et al.* (2017), Chen *et al.* (2021), Chen *et al.* (2022), Sultana *et al.* (2023) confirm the current finding.

1.3 Effect of interaction

The interaction effect of plant types and planting densities on leaf area index at various growth stages of *Bt* cotton was significant at 120 DAS during both the years of study and pooled mean.

In respect of interaction, data presented in Table 2 inferred that significantly highest leaf area index was recorded with semi open type (Sadanand) with plant densities 90 x 20 cm (55,555 plants ha^{-1}) (P_3D_1 – 4.51 during 2021, 4.67 during 2022 and 4.59 in pooled mean) which is significantly superior to P_1D_1, P_1D_2 and P_1D_3 during both the years. Least leaf area index was noticed with compact type (Siri) combined with 90 x 60 cm (18,518 plants ha^{-1}) (P_1D_3 – 3.26 during 2021, 3.23 during 2022 and 3.25 in pooled mean). This indicates that semi open type (Sadanand) when planted under plant density of 90 x 20 cm resulted with highest leaf area index. Similar results were also obtained from the field experiments of Mao *et al.* (2014), Chen *et al.* (2022) and Sultana *et al.* (2023).

2. Specific leaf weight (mg cm^{-2})

Data pertaining to specific leaf weight (mg cm^{-2}) as influenced by various plant types and plant densities are tabulated in Table 3 shows that specific leaf weight was significantly affected by the plant types and plant densities at all growth stages except at 30 DAS and interaction.

Table 1: Leaf Area Index of *Bt* cotton at 30DAS, 60DAS, 90DAS, 120DAS and at harvest as influenced by varied plant types and plant densities

Treatments	30 DAS			60 DAS			90 DAS			120 DAS			At harvest		
	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean
Main plot: Plant types															
P$_1$- Siri (Compact)	0.55	0.55	0.55	1.51	1.51	1.51	2.58	2.48	2.53	3.72	3.71	3.71	3.14	3.15	3.15
P$_2$- RCH 659 (Open)	0.60	0.61	0.60	1.68	1.69	1.68	2.71	2.73	2.72	3.92	4.08	4.01	3.34	3.45	3.40
P$_3$- Sadanand (Semi Open)	0.63	0.64	0.63	1.93	1.91	1.92	3.20	3.11	3.15	4.29	4.39	4.34	3.74	3.75	3.75
SE(m)±	0.03	0.03	0.03	0.06	0.06	0.06	0.10	0.10	0.10	0.09	0.10	0.10	0.08	0.09	0.08
CD (p=0.05)	NS	NS	NS	0.24	0.22	0.23	0.41	0.38	0.40	0.36	0.38	0.37	0.30	0.34	0.32
Sub plot treatments: Plant densities															
D$_1$- 90×20cm (55,555 plants ha^{-1})	0.65	0.66	0.65	1.98	1.99	1.98	3.25	3.18	3.22	4.32	4.43	4.38	3.73	3.77	3.75
D$_2$- 90×30cm (37,037plants ha^{-1})	0.58	0.58	0.58	1.71	1.72	1.71	2.83	2.76	2.80	3.96	4.06	4.01	3.41	3.45	3.43
D$_3$- 90×60cm (18,518 plants ha^{-1})	0.55	0.55	0.55	1.43	1.40	1.41	2.40	2.38	2.39	3.67	3.69	3.68	3.07	3.13	3.10
SE(m)±	0.03	0.03	0.03	0.08	0.08	0.08	0.12	0.12	0.12	0.08	0.08	0.08	0.08	0.08	0.08
CD (p=0.05)	NS	NS	NS	0.25	0.25	0.25	0.38	0.37	0.38	0.24	0.24	0.24	0.23	0.24	0.24
Interaction															
P×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.44	0.42	0.41	NS	NS	NS
D×P	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.41	0.46	0.45	NS	NS	NS

P×D: For two subplot means at same level of main plot means; D×P: For two mainplot means at same level of sub plot means

Table 2: Interaction between plant types and plant densities on Leaf Area Index in *Bt* cotton at 120 DAS

Treatments	**2021**				**2022**				**Pooled mean**			
	D_1	**D_2**	**D_3**	**Mean**	**D_1**	**D_2**	**D_3**	**Mean**	**D_1**	**D_2**	**D_3**	**Mean**
P_1 Siri (Compact)	3.99	3.91	3.26	3.72	3.98	3.91	3.23	3.71	3.99	3.91	3.25	3.71
P_2 RCH 659 (Open)	4.47	3.97	3.41	3.92	4.64	4.10	3.44	4.08	4.55	4.07	3.42	4.01
P_3 Sadanand (Semi Open)	4.51	4.00	4.35	4.29	4.67	4.17	4.39	4.39	4.59	4.05	4.37	4.34
Mean	4.32	3.96	3.67		4.43	4.06	3.69		4.38	4.01	3.68	

	SE(m)±	CD (p=0.05)	CV (%)	SE(m)±	CD (p=0.05)	CV (%)	SE(m)±	CD (p=0.05)	CV (%)
P (Plant types)	0.09	0.36	7.93	0.10	0.38	8.29	0.09	0.37	8.11
D (Plant densities)	0.08	0.24	6.67	0.08	0.24	6.72	0.08	0.24	6.68
PXD	0.14	0.44		0.14	0.42		0.13	0.41	
DXP	0.13	0.41		0.15	0.46		0.14	0.45	

Table 3: Specific leaf weight (mg cm^{-2}) of *Bt* cotton at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest as influenced by varied plant types and plant densities

Treatments	30 DAS			60 DAS			90 DAS			120 DAS			At harvest		
	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean
Main plot: Plant types															
P$_1$- Siri (Compact)	1.34	1.36	1.35	2.06	2.17	2.12	2.45	2.55	2.50	2.58	2.60	2.59	2.64	2.65	2.65
P$_2$- RCH 659 (Open)	1.33	1.35	1.34	1.82	1.83	1.82	2.30	2.29	2.30	2.37	2.38	2.38	2.61	2.43	2.52
P$_3$- Sadanand (Semi Open)	0.85	0.85	0.85	1.62	1.61	1.61	1.84	1.83	1.84	1.96	1.96	1.96	1.98	1.97	1.98
SE(m)±	0.09	0.10	0.09	0.06	0.09	0.06	0.10	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11
CD (p=0.05)	NS	NS	NS	0.23	0.37	0.25	0.40	0.43	0.40	0.42	0.41	0.41	0.42	0.42	0.42
Sub plot treatments: Plant densities															
D$_1$- 90×20cm (55,555 plants ha^{-1})	1.05	1.05	1.05	1.51	1.57	1.54	1.95	1.86	1.90	2.01	2.00	2.01	2.09	2.08	2.09
D$_2$- 90×30cm (37,037plants ha^{-1})	1.11	1.12	1.12	1.85	1.88	1.87	2.19	2.22	2.21	2.33	2.33	2.33	2.34	2.34	2.34
D$_3$- 90×60cm (18,518 plants ha^{-1})	1.36	1.39	1.38	2.14	2.16	2.15	2.45	2.59	2.52	2.60	2.67	2.64	2.65	2.69	2.67
SE(m)±	0.08	0.09	0.09	0.09	0.09	0.06	0.08	0.12	0.09	0.10	0.10	0.10	0.08	0.08	0.08
CD (p=0.05)	NS	NS	NS	0.27	0.27	0.18	0.22	0.36	0.28	0.31	0.31	0.31	0.24	0.24	0.24
Interaction															
P×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
D×P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P×D: For two subplot means at same level of main plot means; D×P: For two mainplot means at same level of sub plot means

2.1 Specific leaf weight as influenced by plant types

The data in Table 3 reveals that specific leaf weight at 30 DAS was not-significantly influenced by treatments. However, numerically the highest specific leaf weight of 1.34 and 1.36 mg cm^{-2} during 2021 and 2022 respectively, was observed with compact type (Siri) and the lower specific leaf weight of 0.85 and 0.85 mg cm^{-2} during 2021 and 2022 respectively was noticed with the semi open growth type (Sadanand).

Specific leaf weight at 60 DAS, 90 DAS, 120 DAS and at harvest followed the similar trend during both years. Maximum specific leaf weight of 2.06, 2.45, 2.58 and 2.64 mg cm^{-2} (2021); 2.17, 2.55, 2.60 and 2.65 mg cm^{-2} (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively, was recorded with compact growth of plant type (Siri), which was statistically on par with open type (RCH-659) and significantly superior to semi open type (Sadanand). While, minimum specific leaf weight (1.62, 1.84, 1.96 and 1.98 mg cm^{-2} (2021); 1.61, 1.83, 1.96 and 1.97 mg cm^{-2} (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) was observed with semi open type (Sadanand).

Specific leaf weight is the derivation of leaf weight and leaf area. Hence, more leaf area the specific leaf weight is less. Semi open type growth of cotton plant where leaf is arranged at a certain angled to capture the photosynthetically active radiation at a higher rate producing more leaf area has less specific leaf weight. Compared to compact type where erectophile canopy is structured (Less leaf area is exposed to direct sunlight) and open type plants where planophile canopy is available for capturing the sunlight and has less leaf area and resulting higher specific leaf weight. The results are in conformity with the findings of Long *et al.* (2017), Mao *et al.* (2014) and Sultana *et al.* (2023).

2.2 Specific leaf weight as influenced by plant densities

Specific leaf weight in respect to densities were observed to be significant at 60 DAS, 90 DAS, 120 DAS and at harvest except at 30 DAS of *Bt* cotton during the first year (2021) and second year of study (2022). A perusal of data presented in Table 4.13 indicates that, at 30 DAS, the specific leaf weight was observed to be non-significant inferring that there is no effect of plant densities on specific leaf weight. Numerically, the highest specific leaf weight 1.36 and 1.39 mg cm^{-2} during 2021 and 2022, respectively, were observed with plant density of 90 x 60 cm (18,518 plants ha^{-1}) followed by 90 x 30 cm (37,037 plants ha^{-1}). While, lowest specific leaf weight (1.05 and 1.05 mg cm^{-2} during 2021 and 2022, respectively) was recorded with plant density of 90 x 20 cm (55,555 plants ha^{-1}).

Data on specific leaf weight revealed that at 60 DAS, 90 DAS, 120 DAS and at harvest, highest specific leaf weight of 2.14, 2.45, 2.60 and 2.65 mg cm^{-2} (2021); 2.16, 2.59, 2.67 and 2.69 mg cm^{-2} (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively, was recorded with density of 90 x 60 cm (18,518 plants ha^{-1}) which was significantly superior to other plant densities *viz.,* 90 x 30 cm (37,037 plants ha^{-1}) and 90 x 20 cm (55,555 plants ha^{-1}). While, least specific leaf weight was found in planting density of 90 x 20 cm (55,555 plants ha^{-1}) (1.51, 1.95, 2.01 and 2.09 mg cm^{-2} (2021); 1.57, 1.86, 2.00 and 2.08 mg cm^{-2} (2022) at 60 DAS, 90 DAS, 120 DAS and at harvest, respectively).

This highest specific leaf weight at lower plant densities might be due to sufficient availability of nutrients, space, sunlight and soil moisture which lead to thicker leaves resulting in higher leaf specific weight. The higher plant densities recorded less leaf weight due to lower production of photosynthates since competition exists for nutrient, light and moisture. Earlier findings of Long *et al.* (2017), Mao *et al.* (2014) and Sultana *et al.* (2023) confirm the current findings.

2.3 Effect of interaction

The interaction effect of plant types and planting densities on specific leaf weight at various growth stages of *Bt* cotton was non-significant during both the years of study.

3. Light interception rate (%)

Data pertaining to light interception rate (%) as influenced by various plant types and plant densities are tabulated in Table 4 reveals that light interception rate was significantly affected by the plant types and plant densities at all growth stages. Whereas, interaction between the plant types and densities found non-significant.

3.1 Light interception rate (%) as influenced by plant types

The data presented in Table 4 reveals that light interception rate at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest followed the similar trend during both the years of study.

Maximum light interception rate of 24.96, 77.11, 104.45, 113.04 and 103.82 % (2021); 25.59, 77.95, 104.99, 110.01 and 101.68 (2022) at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively, was recorded with semi open type (Sadanand), which was found statistically on par with open type growth of *Bt* cotton plants (RCH-659) and significantly superior to compact type (Siri) plants. While, minimum light interception rate of 18.38, 54.84, 75.16, 80.86 and 73.84 % was recorded during 2021 and 18.55, 55.31, 74.25, 78.91 and 73.06 % was observed during 2022 at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) with compact growth of plant type (Siri).

As leaf area develops the leaf surfaces get expanded for higher interception of radiant energy capture of more sunlight and significant differences can be observed on light interception rate. Semi open type growth of cotton plant where leaf is arranged at a certain angled to capture the photo synthetically active radiation at a higher rate causes more light interception and minimize the shading effect on lower leaves. Compared to compact type where erectophile canopy is structured (Less leaf area is exposed to direct sunlight) and open type plants where planophile canopy is available for capturing the sunlight (Shading of lower leaves was observed). The semi open type architecture in sadanand *Bt* cotton hybrid, has higher light interception allowing more light to penetrate to the bottom part of canopy increases the leaf area resulting production of more assimilates which is distributed to the reproductive structures and obtaining more yields. The results are in concurrent with the findings of Chapepa *et al.* (2013), Long *et al.* (2017), Chen *et al.* (2021), Chen *et al.* (2022), Sultana *et al.* (2023).

3.2 Light interception rate (%) as influenced by plant densities

Light interception rate in respect to densities were observed to be significant at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest of *Bt* cotton during 2021 and 2022. Data on light interception rate presented in Table 4 shows that, at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, highest light interception rate of 26.79, 78.41, 102.48, 110.01 and 100.90 (2021); 26.83, 78.83, 102.90, 108.46 and 99.21 (2022) at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively, was recorded with density of 90 x 20 cm (55,555 plants ha^{-1}) which was significantly superior to other plant densities *viz.,* 90 x 30 cm (37,037 plants ha^{-1}) and 90 x 60 cm (18,518 plants ha^{-1}). While, least light interception rate was found in planting density of 90 x 60 cm (18,518 plants ha^{-1}) (17.10, 53.32, 76.44, 81.30 and 75.92 (2021); 18.47, 53.95, 76.50, 80.41 and 75.22 (2022) at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively).

This higher light interception rate at high plant densities might be due to more leaf area available for interception of radiant energy. The low plant densities recorded lower number of leaves per unit area results in less interception rate. Similar findings were also reported by previous researchers. Chapepa *et al.* (2013), Long *et al.* (2017), Chen *et al.* (2021), Chen *et al.* (2022), Sultana *et al.* (2023).

3.3 Effect of interaction

The interaction effect of plant types and planting densities on light interception rate at various growth stages of *Bt* cotton was non-significant during both the years of study.

4. Canopy temperature (°C)

Data pertaining to canopy temperature as influenced by plant types and plant densities at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest during 2021 and 2022 are presented in Table 5. Non-significant differences were observed in *Bt* cotton among plant types and planting densities and their interaction at all the phenological stages of crop during two years of study.

Numerically, compact type growing cotton hybrids was found with high canopy temperature (29.28, 30.94, 33.09, 34.75 and 35.44 °C during 2021 and 29.29, 30.98, 33.11, 34.77 and 35.47 °C during 2022 and 29.28, 30.96, 33.10, 34.76 and 35.46 °C in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) compared to open type of growing cotton hybrids (26.06, 27.52, 30.36, 31.88 and 32.52 °C during 2021; 26.15, 27.59, 30.45, 31.91 and 32.58 °C during 2022 and 26.10, 27.56, 30.41,

Table 4: Light interception rate (%) of *Bt* cotton at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest as influenced by varied plant types and plant densities

Treatments	30 DAS			60 DAS			90 DAS			120 DAS			At harvest		
	2021	**2022**	**Pooled Mean**	**2021**	**2022**	**Pooled Mean**	**2021**	**2022**	**Pooled Mean**	**2021**	**2022**	**Pooled Mean**	**2021**	**2022**	**Pooled Mean**
Main plot: Plant types															
P$_1$- Siri (Compact)	18.38	18.55	18.47	54.84	55.31	55.08	75.16	74.25	74.70	80.86	78.91	79.89	73.84	73.06	73.45
P$_2$- RCH 659 (Open)	21.64	22.36	22.00	65.52	66.13	65.82	88.24	88.83	88.54	95.34	94.32	94.83	87.76	87.11	87.44
P$_3$- Sadanand (Semi Open)	24.96	25.59	25.28	77.11	77.95	77.53	104.45	104.99	104.72	113.04	110.01	111.52	103.82	101.68	102.75
SE(m)±	0.88	0.94	0.91	3.41	3.47	3.44	4.73	4.41	4.57	5.15	4.30	4.72	4.57	3.73	4.15
CD (p=0.05)	3.46	3.71	3.58	13.39	13.61	13.50	18.59	17.33	17.96	20.21	16.87	18.54	17.93	14.66	16.30
Sub plot treatments: Plant densities															
D$_1$- 90×20cm (55,555 plants ha^{-1})	26.79	26.83	26.81	78.41	78.83	78.62	102.48	102.90	102.69	110.01	108.46	109.24	100.90	99.21	100.06
D$_2$- 90×30cm (37,037plants ha^{-1})	21.18	21.20	21.19	65.74	68.61	67.17	88.93	88.68	88.80	97.93	94.37	96.15	88.61	87.41	88.01
D$_3$- 90×60cm (18,518 plants ha^{-1})	17.10	18.47	17.74	53.32	53.95	53.63	76.44	76.50	76.47	81.30	80.41	80.85	75.92	75.22	75.57
SE(m)±	1.32	1.36	1.34	3.75	3.80	3.78	3.94	4.55	4.23	3.81	4.50	4.16	3.92	3.82	3.87
CD (p=0.05)	4.07	4.20	4.13	11.56	11.70	11.63	12.13	14.01	13.07	11.74	13.86	12.80	12.07	11.77	11.92
Interaction															
P×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
D×P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P×D: For two subplot means at same level of main plot means; D×P: For two mainplot means at same level of sub plot means

Table 5: Canopy temperature (^{0}C) of *Bt* cotton at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest as influenced by varied plant types and plant densities

Treatments	30 DAS			60 DAS			90 DAS			120 DAS			At harvest		
	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean
Main plot: Plant types															
P$_1$- Siri (Compact)	29.28	29.29	29.28	30.94	30.98	30.96	33.09	33.11	33.10	34.75	34.77	34.76	35.44	35.47	35.46
P$_2$- RCH 659 (Open)	26.06	26.15	26.10	27.52	27.59	27.56	30.36	30.45	30.41	31.88	31.91	31.89	32.52	32.58	32.55
P$_3$- Sadanand (Semi Open)	27.87	27.93	27.90	29.44	29.48	29.46	30.60	30.68	30.64	32.13	32.24	32.19	32.78	32.81	32.79
SE(m)±	0.55	0.57	0.56	0.59	0.62	0.61	0.50	0.54	0.52	0.52	0.57	0.55	0.53	0.56	0.55
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot treatments: Plant densities															
D$_1$- 90×20cm (55,555 plants ha^{-1})	28.57	28.59	28.58	30.13	30.17	30.15	31.85	31.87	31.86	33.45	33.47	33.46	34.12	34.14	34.13
D$_2$- 90×30cm (37,037plants ha^{-1})	28.40	28.49	28.44	29.79	29.85	29.82	31.48	31.55	31.51	33.05	33.16	33.10	33.71	33.75	33.73
D$_3$- 90×60cm (18,518 plants ha^{-1})	27.23	27.29	27.26	27.98	28.02	28.00	30.72	30.82	30.77	32.26	32.29	32.28	32.91	32.97	32.94
SE(m)±	0.45	0.46	0.46	0.51	0.53	0.52	0.34	0.38	0.36	0.36	0.39	0.38	0.36	0.38	0.37
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction															
P×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
D×P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P×D: For two subplot means at same level of main plot means; D×P: For two mainplot means at same level of sub plot means

31.89 and 32.55 °c in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively).

With respect to plant densities, high density planting provided higher canopy temperature (28.57, 30.13, 31.85, 33.45 and 34.12 °C during 2021 and 28.59, 30.17, 31.87, 33.47 and 34.14 °C during 2022 and 28.58, 30.15, 31.86, 33.46 and 34.13 °C in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) at all the stages when compared to high density planting (27.23, 27.98, 30.72, 32.26 and 32.91 °C during 2021 and 27.29, 28.02, 30.82, 32.29 and 32.97 °C during 2022 and 27.26, 28.00, 30.77, 32.28 and 32.94 °c at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively).

Similar reports of non-significant influence of plant types and planting densities on canopy temperature was reported by the previous workers Santosh *et al.* (2019) and Maheswari and Krishnaswamy (2019).

5. SPAD readings (chlorophyll content in leaves)

A perusal of data pertaining to SPAD readings as influenced by plant types and plant densities at 30 DAS, 60 DAS, 90 DAS, and 120 DAS and at harvest during 2021 and 2022 are presented in Table 6. The chlorophyll content determines the photosynthetic capacity and influence the rate of photosynthesis, drymatter production and yield. SPAD readings (chlorophyll content in leaves) increased up to 120 DAS and thereafter it declined till harvest. *Bt* cotton as influenced by plant types and planting densities and their interaction did not differ significantly with respect to chlorophyll content in leaves at all growth stages of cotton crop during two years of study.

Canopy temperature was not influenced by plant type and densities of open type growing cotton hybrids was found with high chlorophyll content in leaves (32.90, 34.88, 40.81, 44.07 and 36.14 during 2021 and 33.08, 34.94, 40.90, 44.11 and 36.07 during 2022 and 32.99, 34.91, 40.86, 44.09 and 36.11 in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) compared to compact type of growing cotton hybrids (31.44, 33.33, 38.99, 42.11 and 34.53 during 2021 and 31.61, 33.36, 39.09, 42.18 and 34.68 during 2022 and 31.53, 33.35, 39.04, 42.15 and 34.61 in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively).

With respect to plant densities low density planting provided higher chlorophyll content values (32.30, 34.24, 40.06, 43.27 and 35.48 during 2021 and 32.48, 34.31, 40.16, 43.31 and 35.41 during 2022 and 32.39, 34.28, 40.11, 43.29 and 35.45 in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) at all the stages when compared to high density planting (31.99, 33.91, 39.67, 42.85 and 35.13 during 2021 and 32.07, 34.01, 39.76, 42.86 and 35.22 during 2022 and 32.03, 33.96, 39.72, 42.86 and 35.18 in pooled mean at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, respectively) this is due to the fact that, low plant densities are provided with all the natural resources required for their growth and attributed in better performance of individual plant.

Similar reports of non-significant influence of plant types and planting densities on canopy temperature was reported by Yang *et al.* (2014).

CONCLUSION

Leaf Area Index (LAI) was significantly influenced by various plant types and plant densities at all growth stages except at 30 DAS and interaction during 2021 and 2022 and pooled mean. Highest leaf area index at 60 DAS, 90 DAS, 120 DAS and at harvest was recorded with semi open type (Sadanand), which was statistically on par with open type (RCH-659) and significantly superior to compact type (Siri) plants. Among plant densities LAI revealed that at 60 DAS, 90 DAS, 120 DAS and at harvest significantly highest LAI was found in planting density of 90 x 20 cm (55,555 plants ha^{-1}) which was significantly superior to other plant densities *viz.,* 90 x 30 cm (37,037 plants ha^{-1}). While, least LAI was found in planting density of 90 x 60 (18,518 plants ha^{-1}).

Data pertaining to specific leaf weight (mg cm^{-2}) shows that specific leaf weight was significantly affected by the plant types and plant densities at all growth stages except at 30 DAS and interaction. Specific leaf weight at 60 DAS, 90 DAS, 120 DAS and at harvest followed the similar trend during both years and pooled mean. Maximum specific leaf weight was recorded with compact type (Siri) plants which was statistically on par with open type (RCH-659) and significantly superior to semi open type (Sadanand). While, minimum specific leaf weight was observed with semi open type (Sadanand). Specific

Table 6: SPAD Chlorophyll meter readings of *Bt* cotton at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest as influenced by varied plant types and plant densities

Treatments	30 DAS			60 DAS			90 DAS			120 DAS			At harvest		
	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean	2021	2022	Pooled Mean
Main plot: Plant types															
P$_1$- Siri (Compact)	31.44	31.61	31.53	33.33	33.36	33.35	38.99	39.09	39.04	42.11	42.18	42.15	34.53	34.68	34.61
P$_2$- RCH 659 (Open)	32.24	32.32	32.28	34.17	34.27	34.22	39.98	40.07	40.03	43.18	43.19	43.19	35.41	35.5	35.46
P$_3$- Sadanand (Semi Open)	32.90	33.08	32.99	34.88	34.94	34.91	40.81	40.90	40.86	44.07	44.11	44.09	36.14	36.07	36.11
SE(m)±	0.78	0.66	0.72	0.83	0.80	0.82	0.97	0.97	0.97	1.05	1.05	1.05	0.86	0.87	0.87
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plot treatments: Plant densities															
D$_1$- 90×20cm (55,555 plants ha^{-1})	31.99	32.07	32.03	33.91	34.01	33.96	39.67	39.76	39.72	42.85	42.86	42.86	35.13	35.22	35.18
D$_2$- 90×30cm (37,037plants ha^{-1})	32.29	32.46	32.38	34.23	34.26	34.25	40.05	40.15	40.10	43.25	43.32	43.29	35.47	35.62	35.55
D$_3$- 90×60cm (18,518 plants ha^{-1})	32.30	32.48	32.39	34.24	34.31	34.28	40.06	40.16	40.11	43.27	43.31	43.29	35.48	35.41	35.45
SE(m)±	0.50	0.58	0.54	0.53	0.57	0.55	0.62	0.68	0.65	0.67	0.7	0.69	0.55	0.49	0.52
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction															
P×D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
D×P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P×D: For two subplot means at same level of main plot means; D×P: For two mainplot means at same level of sub plot means

leaf weight in respect to densities were observed to be significant at 60 DAS, 90 DAS, 120 DAS and at harvest and highest was found in density of 90 x 60 cm (18,518 plants ha^{-1}) which was significantly superior to other plant densities *viz.,* 90 x 30 cm (37,037 plants ha^{-1}) and 90 x 20 cm (55,555 plants ha^{-1}). While, least specific leaf weight was found in planting density of 90 x 20 cm (55,555 plants ha^{-1}) at 60 DAS, 90 DAS, 120 DAS and at harvest during 2021, 2022 and pooled mean.

Data pertaining to light interception rate (%) reveals that light interception rate was significantly affected by the plant types and plant densities at all growth stages. Whereas, interaction between the plant types and densities found non-significant. Significantly highest light interception rate at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest followed the similar trend during both the years of study and pooled mean. Maximum light interception rate at all growth stages were recorded with semi open type (Sadanand), which was found statistically on par with open type growth of *Bt* cotton plants (RCH-659) and significantly superior to compact type (Siri) plants. With regard to plant densities highest light interception rate was recorded with density of 90 x 20 cm (55,555 plants ha^{-1}) which was significantly superior to other plant densities *viz.,* 90 x 30 cm (37,037 plants ha^{-1}) and 90 x 60 cm (18,518 plants ha^{-1}) at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest.

Data pertaining to canopy temperature and SPAD readings (chlorophyll content in leaves) were not significantly influenced by canopy architectures and plant densities at 30 DAS, 60 DAS, 90 DAS,120 DAS and at harvest during 2021 and 2022 and pooled mean.

REFERENCES

Chapepa, B., Mudada, N and Mapuranga, R. 2020. The impact of plant density and spatial arrangement on light interception on cotton crop and seed cotton yield: an overview. *Journal of Cotton Research*. 3(1): 1-6.

Chen, H., Zhao, X., Han, Y., Xing, F., Feng, L., Wang, Z., Wang, G., Yang, B., Lei, Y., Xiong, S and Li, X. 2021. Competition for light interception in cotton populations of different densities. *Agronomy*. 11(1): 176.

Chen, Y., Zhang, Z., Wang, X., Sun, S., Zhang, Y., Wang, S., Yang, M., Ji, F., Ji, C., Xiang, D and Zha, T. 2022. Sap velocity, transpiration and water use efficiency of drip-irrigated cotton in response to chemical topping and row spacing. *Agricultural Water Management*. 267: 107611.

Dong, H., Kong, X., Li, W., Tang, W and Zhang, D. 2010. Effects of plant density and nitrogen and potassium fertilization on cotton yield and uptake of major nutrients in two fields with varying fertility. *Field Crops Research*. 119(1): 106-113.

Long Yang, Y., Xiao, F., Xu, S., Wang, Y., Zuo, W., Liang, F and Zhang, W. 2017. Development of cotton canopy structure characteristics of cotton varieties grown in different decades in northern Xinjiang. *Acta Agronomica Sinica*. 43(10): 1518-1526.

Maheswari, M.U and Krishnasamy, S.M. 2019. Effect of crop geometries and plant growth retardants on physiological growth parameters in machine sown cotton. *Journal of Pharmacognosy and Phytochemistry*. 8(2): 541-545.

Mao, L., Zhang, L., Zhao, X., Liu, S., van der Werf, W., Zhang, S., Spiertz, H and Li, Z. 2014. Crop growth, light utilization and yield of relay intercropped cotton as affected by plant density and a plant growth regulator. *Field Crops Research.* 155: 67-76.

Morgan, T.H. 1917. The theory of the gene. *The American Naturalist*. 51(609): 513-544.

Saeed, A., Hovsepyan, H., Darvishzadeh, R., Imtiaz, M., Panguluri, S.K and Nazaryan, R. 2011. Genetic diversity of Iranian accessions, improved lines of chickpea (*Cicer arietinum* L.) and their wild relatives by using simple sequence repeats. *Plant Molecular Biology Reporter*. 29: 848-858.

Santhosh, B., Thatikunta, R., Reddy, D.V.V., Hussain, S.A and Shankar, V.G. 2019. Physiological basis of improved yields in rainfed cotton under high density planting system. *The Journal* of Research *PJTSAU.* 47(3): 12-19.

Siebert, J.D and Stewart, A.M. 2006. Influence of plant density on cotton response to mepiquat chloride application. *Agronomy Journal*. 98(6): 1634-1639.

Stewart, S. 2005. Suggested guidelines for plant growth regulator use on Louisiana cotton. LSU AgCenter.

Sultana, F., Dev, W., Xin, M., Han, Y., Feng, L., Lei, Y., Yang, B., Wang, G., Li, X., Wang, Z and Xing, F. 2023. Competition for light interception in different plant canopy characteristics of diverse cotton cultivars. *Genes*. 14(2): 364-378.

Yang, G.Z., Luo, X.J., Nie, Y.C and Zhang, X.L. 2014. Effects of plant density on yield and canopy micro environment in hybrid cotton. *Journal of Integrative Agriculture*. 13(10): 2154-2163.

Yao, H., Zhang, Y., Yi, X., Zhang, X and Zhang, W. 2016. Cotton responds to different plant population densities by adjusting specific leaf area to optimize canopy photosynthetic use efficiency of light and nitrogen. *Field Crops Research.* 188: 10-16.

Research Article
The J. Res. PJTSAU 51(1&2) 39-48, 2023

SCREENING OF RECOMBINANT INBRED LINE (RIL) POPULATION OF GROUNDNUT (*Arachis hypogaea* L.) AGAINST STEM ROT DISEASE INCIDENCE (*Sclerotium rolfsii*)

B. KIRANMAYEE[1], D. SHIVANI[1], H. K. SUDINI[2] , D. SRINIVASA CHARY[3] and C. V. SAMEER KUMAR[1]

[1]Department of Genetics & Plant Breeding, College of Agriculture, PJTSAU Rajendranagar, Hyderabad.

[2]Department of Groundnut Pathology, ICRISAT, Patancheru

[3]Department of Statistics and Mathematics, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad

Date of Receipt: 19-06-2023 Date of Acceptance: 28-06-2023

ABSTRACT

Stem rot of groundnut, caused by the necrotrophic pathogen *Sclerotium rolfsii*is a devastating soil borne disease. Its incidence has been increasing in the hot and humid groundnut growing regions since the past decade. Chemical and cultural practices have been under practice to manage this disease. However, these measures cannotfully control the pod losses incurred by the crop, owing to the non-uniform distribution of the pathogen. Host resistance to the disease appears to be the most feasible solution to control the disease. In the present study, hundred genotypes of a groundnut RIL population (ICGV 91114 X ICGV 86590) along with resistant and susceptible checks have been screened during *Kharif,*2021 under artificially inoculated controlled conditions in poly-house. Disease was assessed using percent mortality which was recorded at 15, 30, 45 and 60 days after inoculation (DAI). Analysis of variance revealed significant differences among the genotypes for 45 and 60 DAI indicating that these could be the best scoring times. It was observed that most of the genotypes were susceptible to the disease, while a very few were resistant and moderately resistant. The genotypes ICGN 184776, ICGN 184806, ICGN 184849, ICGN 184784, ICGN 184783, ICGN 184836, ICGN 184809, ICGN 184811, ICGN 184812, ICGN 184846, ICGN 184768 and ICGN 184823 were found to have considerable resistance against the disease. They have the potential to be considered for selections to be used as parents in crossing programs for the transfer of resistance to cultivated breeding lines.

Keywords: Stem rot, resistance, groundnut, recombinant inbred line population.

Cultivated groundnut or peanut (*Arachis hypogaea* L.) is an important oil seed and food legume crop. It has originated in South America and is now grown in more than 100 countries all over the world. China, India, Nigeria, the United States, Senegal, Myanmar,Indonesia, Sudan, Argentina, Ghana, and Vietnam are the primary groundnut producing nations, accounting for 84% of global groundnut output (Pasupuleti *et al.,* 2013). In India,it is grown in the states Andhra Pradesh, Telangana, Gujarat, Karnataka and Tamil Nadu. Andhra Pradesh, Telangana and Gujarat account for more than half of the country's groundnut growing area (DGR Annual Report, 2013). Globally, it is cultivated over an area of 32.7 Mha with a production of 53.9 Mt leading to a productivity of 1.6 t/ha (FAOSTAT, 2021).

Groundnut is rich in its nutritional value. Kernels contain 40-54% oil, protein content of 22-36% and carbohydrate content of 10-20%. It is also high in B vitamins such as thiamine (B1), riboflavin (B2), niacin (B3), and tocopherol (Nagaraj, 1995). From 100 g of kernels, 564 K calories of energy is supplied (Jambunathan, 1991). The seeds are high in mono-unsaturated fatty acids and include several health-promoting minerals, antioxidants and vitamins (Pasupuleti *et al.,* 2013). Groundnut haulms serve as fodder for livestock. The crop has a variety of industrial applications, including food, feed, paints, lubricants and pesticides (Variath*et al.,* 2017). Being a legume crop, groundnut improves soil health and fertility by releasing N_2 and organic matter into soil (Alagirisamy, 2016).

Frequently, groundnut cultivation in India is suffering a considerable yield loss as a result of biotic and abiotic stresses, which are the main obstacles in achieving higher productivity (Divya Rani *et al.,* 2018). Among the biotic factors, seed and soil-borne diseases have been identified as the major constraints affecting groundnut production (Palaiah *et al.,* 2019). Stem rot disease, caused by the necrotrophic fungus*Sclerotium rolfsii*, is an emerging soil borne disease of groundnut.

Email: bangaru.kiranmayee1993@gmail.com

It is a serious limitation to groundnut production in many warm and humid countries (Bera *et al*., 2014). Groundnut yield loss due to stem rot disease typically ranges from 10-40%, but can exceedto 80% in heavily infected fields (Mehan *et al.,* 1995). *S. rolfsii* also causes indirect losses such as decrease in the dry weight and oil content of groundnut kernels as well as decrease in the quality of pod and fodder (Bera *et al*., 2014).

Chemical and cultural practises are the primary control strategies utilised to manage soil-borne diseases (Krishnakanth *et al*., 1999). The pathogen persistence in the soil and its vast host range frequently hinder the efficiency of chemical and cultural management of soil-borne diseases (Palaiah *et al*., 2019). Host plant resistance offers the best possible solution for controlling stem rot disease in groundnut. Growing resistant cultivars against stem rot disease is also a cost-effective, long-term strategy that fits well into integrated disease management (Divya Rani *et al.,* 2018). Earlier studies have been conducted to screen the groundnut genotypes for stem rot disease resistance identification by using artificial inoculation techniques (Divya Rani *et al.,* 2018; Bera *et al.,* 2014; Palaiah *et al.,* 2019). However, a highly resistant line against this disease has not yet been identified. The pathogen's non-uniform geographic distribution complicates large-scale screening for resistance in segregating populations under field conditions with natural or artificial infection. As a result, consistent data is difficult to be generatedwhen screened only under field conditions (Bera *et al.,* 2016a). To overcome the barriers faced under field screening conditions, it is also essential to screen for the same genotypes under controlled/glasshouse conditions. Hence, the present study has been conducted with the following objectives: To screen groundnut RIL population under controlled conditions in the poly-house, to identify groundnut genotypes resistant against stem rot disease.

MATERIAL AND METHODS

The plant material comprised of RIL population (ICGV 91114 X ICGV 86590) with 100 genotypes including parents and checks. ICGV 91114 is the stem rot susceptible parent. It is a Spanish bunch line with short duration. ICGV 86590 is the resistant parent. It is also a Spanish bunch line with medium duration and reported to be foliar disease resistant (Divya Rani *et al*., 2018). CS 319 and ICGV 86856 were used as the resistant checks whereas TMV-2 and GG-20 served as susceptible checks. The list of genotypes included in the present study is presented in Table 2. The experiment was conducted during *Kharif,* 2021 under controlled conditions of temperature (26 ± 2°C) and humidity (80-90%) in the poly-house (23.8 m x 6.1m) at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru. The pots were arranged in a completely randomized block design (CRD), plastic pots 22.8 of centimetre were utilised. The pots were filled with sterilised soil mix (red soil and sand in 3:2 ratio) and five seeds were planted per pot (one pot per genotype in each replication).

S. rolfsii, the stem rot pathogen had been mass multiplied on sorghum grains (Bera *et al*., 2016a). The sorghum grains served as a medium for the pathogengrowth and multiplication. Each of the plants in the pots were artificially inoculated at 35 days after sowing through the application of the pathogen that had multiplied on the sorghum grains. After inoculation, the pots were immediately watered for two days. The pots were maintained at 26 ± 2°C and 90% RH until they were harvested. Regular irrigations were given. The number of plants in each pots (number of germinated plants) were recorded prior to inoculation. The stem rot disease progress was assessed in terms of number of dead plants after every 15 days starting from the day of inoculation. Plant mortality was used to measure the disease in terms of number of dead plants. Percent mortality was calculated using the formula:

Percent mortality = (Number of dead plants/total number of plants before inoculation) *100. Later, the plants were scored based on the disease scale given by Bera *et al.,* (2016b). The scale is denoted as:

Table1: Disease scale designated for the classification of genotypes

Mortality range (%)	Scoring
$< 10\%$	Highly resistant (HR)
10 - 19%	Resistant (R)
20 - 29%	Moderately Resistant (MR)
$\geq 30\%$	Susceptible (S)

To assess the variability among the genotypes, analysis of variance (ANOVA) was performed using R software (ver. 4.2.1).

RESULTS AND DISCUSSION

Stem rot of groundnut is a complex disease and host plant resistance is the most effective method of managing this disease. Identification of resistant lines is the initial step towards breeding for disease resistance. A total of 100 groundnut lines of the RIL population ICGV 91114 X ICGV 86590 along with the checks (ICGV 86856, CS 319, TMV-2, CS 319) were screened under poly-house conditions. The results of the present study are described herewith.

It was revealed from the present study that the stem rot disease severity increased gradually from 15 DAI to 60 DAI and genotypes exhibited significant variation in the disease incidence. Table 2 represents the mean percent mortality (PM) at 15,30,45,60 DAI. The mean PM was between 0-62.5% at 15 DAI, 0-65.7% at 30 DAI, 0-100% at 45 DAI and 7.14-100% at 60 DAI. The percent mortality at 60 DAI (final observation) was used to assess the number of resistant genotypes identified through the study based on the scale to score the genotypes (Bera *et al.*, 2016b). Only one genotype showed PM <10% and was rated as highly resistant (HR), two genotypes showed PM between 10-19% and were rated as resistant (R). The PM range for ten

Table 2: Trait means for the genotypes under study

Note: PM- Percent mortality; DAI- Days after inoculation, RC- Resistant check, SC- Susceptible check, P1- Parent1, P2- Parent 2

S No.	GENOTYPES	PM 15 DAI	PM 30 DAI	PM 45 DAI	PM 60 DAI
1	CS 319 (RC)	10.00	34.29	48.57	48.57
2	GG 20 (SC)	0.00	22.50	45.00	57.50
3	ICGN 184767	0.00	27.14	39.29	44.29
4	ICGN 184768	16.67	26.67	26.67	26.67
5	ICGN 184770	16.67	29.17	29.17	45.83
6	ICGN 184771	10.00	30.00	50.00	60.00
7	ICGN 184772	8.33	35.00	70.00	90.00
8	ICGN 184773	10.00	10.00	32.50	45.00
9	ICGN 184774	0.00	33.33	33.33	33.33
10	ICGN 184776	0.00	7.14	7.14	7.14
11	ICGN 184779	22.50	32.50	55.00	55.00
12	ICGN 184781	7.14	28.57	42.86	64.29
13	ICGN 184783	0.00	22.50	22.50	22.50
14	ICGN 184784	0.00	10.00	20.00	20.00
15	ICGN 184785	0.00	20.00	40.00	40.00
16	ICGN 184786	0.00	45.83	54.17	66.67
17	ICGN 184787	7.14	38.57	62.86	70.00
18	ICGN 184788	0.00	25.00	43.75	50.00
19	ICGN 184789	48.57	65.71	92.86	92.86
20	ICGN 184790	0.00	7.14	21.43	71.43
21	ICGN 184791	0.00	43.33	53.33	53.33
22	ICGN 184792	12.50	41.67	83.33	91.67

S No.	GENOTYPES	PM 15 DAI	PM 30 DAI	PM 45 DAI	PM 60 DAI
23	ICGN 184793	0.00	10.00	22.50	32.50
24	ICGN 184794	14.29	33.93	54.46	54.46
25	ICGN 184795	16.67	43.33	53.33	83.33
26	ICGN 184796	10.00	32.50	55.00	55.00
27	ICGN 184797	0.00	35.71	57.14	71.43
28	ICGN 184799	10.00	28.33	38.33	46.67
29	ICGN 184800	0.00	24.29	31.43	41.43
30	ICGN 184801	0.00	10.00	20.00	30.00
31	ICGN 184802	12.50	25.00	50.00	62.50
32	ICGN 184803	0.00	25.00	47.22	55.56
33	ICGN 184804	0.00	58.33	75.00	100.00
34	ICGN 184805	0.00	37.50	60.00	60.00
35	ICGN 184806	12.50	12.50	12.50	12.50
36	ICGN 184807	10.00	10.00	32.50	55.00
37	ICGN 184808	0.00	20.00	30.00	30.00
38	ICGN 184809	12.50	12.50	25.00	25.00
39	ICGN 184810	0.00	45.00	55.00	87.50
40	ICGN 184811	0.00	0.00	12.50	25.00
41	ICGN 184812	0.00	25.00	25.00	25.00
42	ICGN 184815	0.00	55.00	73.33	73.33
43	ICGN 184816	0.00	7.14	28.57	100.00
44	ICGN 184817	0.00	0.00	50.00	75.00
45	ICGN 184818	0.00	10.00	10.00	75.00
46	ICGN 184819	12.50	25.00	35.00	47.50
47	ICGN 184820	16.67	36.67	46.67	46.67
48	ICGN 184821	0.00	28.57	42.86	50.00
49	ICGN 184822	0.00	20.00	30.00	52.50
50	ICGN 184823	7.14	14.29	29.76	29.76
51	ICGN 184825	0.00	35.00	70.00	70.00
52	ICGN 184826	22.50	45.00	70.00	80.00
53	ICGN 184827	16.67	50.00	75.00	83.33
54	ICGN 184828	0.00	30.00	48.33	48.33
55	ICGN 184829	10.00	10.00	10.00	50.00
56	ICGN 184830	0.00	30.95	61.90	78.57
57	ICGN 184831	0.00	10.00	20.00	45.00
58	ICGN 184832	20.00	50.00	60.00	70.00

S No.	GENOTYPES	PM 15 DAI	PM 30 DAI	PM 45 DAI	PM 60 DAI
59	ICGN 184833	10.00	10.00	20.00	30.00
60	ICGN 184834	21.43	26.98	26.98	45.24
61	ICGN 184835	18.33	38.33	56.67	56.67
62	ICGN 184836	8.33	8.33	25.00	25.00
63	ICGN 184837	0.00	41.67	41.67	41.67
64	ICGN 184838	0.00	50.00	70.00	90.00
65	ICGN 184839	62.50	62.50	75.00	75.00
66	ICGN 184841	0.00	40.00	60.00	70.00
67	ICGN 184842	12.50	33.33	41.67	75.00
68	ICGN 184843	16.67	25.00	51.67	51.67
69	ICGN 184844	0.00	39.29	58.93	73.21
70	ICGN 184845	0.00	7.14	13.39	64.29
71	ICGN 184846	0.00	8.33	16.67	25.00
72	ICGN 184847	8.33	22.62	38.10	38.10
73	ICGN 184848	16.67	55.56	69.44	75.00
74	ICGN 184849	0.00	0.00	0.00	12.50
75	ICGN 184850	13.39	32.14	45.54	52.68
76	ICGN 184851	0.00	41.43	58.57	58.57
77	ICGN 184852	0.00	18.75	37.50	68.75
78	ICGN 184853	0.00	16.67	16.67	33.33
79	ICGN 184854	0.00	35.00	43.33	81.67
80	ICGN 184856	0.00	25.00	50.00	50.00
81	ICGN 184857	0.00	29.76	60.71	75.00
82	ICGN 184858	0.00	51.25	83.75	90.00
83	ICGN 184859	0.00	60.00	80.00	100.00
84	ICGN 184860	0.00	16.67	66.67	66.67
85	ICGN 184861	8.33	33.33	50.00	58.33
86	ICGN 184863	16.67	58.33	70.83	83.33
87	ICGN 184864	25.00	50.00	100.00	100.00
88	ICGN 184865	0.00	28.33	38.33	46.67
89	ICGN 184866	0.00	41.67	66.67	83.33
90	ICGN 184867	0.00	7.14	7.14	31.43
91	ICGN 184868	0.00	21.43	41.07	53.57
92	ICGN 184869	10.00	32.50	55.00	55.00
93	ICGN 184870	12.50	29.17	70.83	70.83

genotypes was 20-29%, they were rated as moderately resistant (MR). Eighty-six genotypes of the hundred under study were rated as susceptible (S) with their PM e”30% (Table 3). This indicates that most of the genotypes were susceptible to the disease, while a very few were resistant and moderately resistant.

Table 3: Number of lines identified under each class based on percent mortality@60DAI (days after inoculation)

Number of genotypes	Mortality range	Scoring
1	<10%	HR
2	10-19%	R
10	20-29%	MR
86	≥30%	S

Similar results where a very few resistant lines and a large number of susceptible lines were identified have been reported by earlier researchers (Krishnakanth *et al.*, 1999). The designations of the genotypes under each scoring category are represented in Table 4. The susceptible check TMV -2 showed PM of 75% whereas the resistant check ICGV 86856 showed PM of 20%. In comparison to the resistant parent ICGV 86590, a total of twelve genotypes recorded PM <30% at 60 DAI (Table 6 and Figure 1).

Analysis of variance was performed to assess the variation among the genotypes for the PM at 15,30,45 and 60 DAI. It was revealed from the ANOVA that the genotypes showed highly significant variation for PM at 45 DAI (1% level of significance). At 60 DAI, the genotypes showed a significant variation (5% Level of significance). There was no significant variation among the genotypes for PM at 15 and 30 DAI. Significant variations were observed among the genotypes at 45 and 60 DAI, this indicates that the PM observations taken at 45 and 60 DAI could be the best ones to assess the disease among the genotypes under study (Table 5). From the present study, the genotypes ICGN 184776 (HR); ICGN 184806, ICGN 184849 (R); ICGN 184784, ICGN 184783, ICGN 184836, ICGN 184809, ICGN 184811, ICGN 184812, ICGN 184846, ICGN 184768 and ICGN 184823 (MR) could be considered to be the best against the stem rot disease among all the genotypes under study.

Stem rot of groundnut is an emerging disease among the groundnut growing regions. As mentioned, host plant resistance offers a long-term solution against the disease and no highly resistant breeding line has been identified to fight against this disease. Hence, screening of germplasm lines is an essential and initial step towards disease resistant breeding. It can be done in the field and/or glasshouse (controlled) conditions. The present study was conducted in a poly-house under controlled conditions. Screening for diverse genetic materials in the field conditions is a valuable selection approach for identifying truly resistant/tolerant genotypes (Guclu *et al.*, 2020). Certain genotypes (ICG 12083) have showed field resistance but are less resistant in greenhouse experiments (Singh *et al.,*1997). To discover and characterise resistance components, promising genotypes should be investigated in field, micro plot and greenhouse conditions (Bera *et al.,* 2014). Hence the genotypes from the current study can be further evaluated for stem rot disease under field conditions to further confirm the truly resistant lines. After confirmations from the field and glasshouse studies, elite lines with significant resistance responses to the disease can be employed as parents in breeding programs to transfer this resistance into cultivable germplasm (Divya Rani *et al.,* 2018).

CONCLUSION

Screening of 100 groundnut genotypes under poly-house conditions revealed that the genotypes were highly variable for the disease and the best time to score for the disease is at 45 and 60 days after inoculum application. It was observed from the study that most of the lines were susceptible to the disease. However, a set of lines with some degree of resistance could be identified. Since stem rot disease is highly

Table 4: The genotypes under each scoring category of disease score

	Percent mortality (%) at 60 DAI			
Classification	**<10%**	**10-19%**	**20-29%**	**≥ 30%**
Genotypes	ICGN 184776	ICGN 184806, ICGN 184849	ICGN 184784, ICGV 86856, ICGN 184783, ICGN 184836, ICGN 184809, ICGN 184811, ICGN 184812, ICGN 184846, ICGN 184768, ICGN 184823	ICGN 184801, ICGN 184808, ICGN 184833, ICGV 86590, ICGN 184867, ICGN 184793, ICGN 184774 ICGN 184853, ICGN 184847, ICGN 184785, ICGN 184800 ICGN 184837, ICGN 184767, ICGN 184773, ICGN 184831 ICGN 184834, ICGN 184770, ICGN 184799, ICGN 184820, ICGN 184865, ICGN 184819, ICGN 184828, CS 319 ICGN 184788, ICGN 184821, ICGN 184829, ICGN 184856, ICGN 184843, ICGN 184822, ICGN 184850, ICGN 184791, ICGN 184868, ICGN 184794, ICGN 184779, ICGN 184796, ICGN 184807, ICGN 184869, ICGN 184803, ICGN 184835, GG 20, ICGN 184861, ICGN 18485, ICGN 184771, ICGN 184805, ICGN 184802, ICGN 184781, ICGN 184845, ICGN 184860, ICGN 184786, ICGN 184852, ICGN 184787, ICGN 184825, ICGN 184832, ICGN 184841, ICGN 184871, ICGN 184870, ICGN 184797, ICGN 184790, ICGN 184844, ICGN 184815, ICGN 184817, ICGN 184818, ICGN 184839, ICGN 184842, ICGN 184848, ICGN 184857, TMV 2, ICGN 184830, ICGN 184826, ICGN 184854, ICGN 184795 ICGN 184827, ICGN 184863, ICGN 184873, ICGN 184866, ICGN 184810, ICGN 184874, ICGN 184772, ICGN 184838, ICGN 184858, ICGN 184792, ICGN 184789, ICGN 184804, ICGN 184816, ICGN 184859, ICGN 184864

Table 5: Analysis of variance (ANOVA) for the disease assessment traits

Note: PM – Percent mortality, DAI- days after inoculation, Rep- Replications, Df- degrees of freedom, Sum sq- sum of squares, Mean sq- mean sum of squares

'**'@1%LOS, '*'@5%LOS; LOS- level of significance

		Df	Sum Sq	Mean Sq	F value	Pr(>F)
PM15DAI	Rep	1	1.8	1.755	0.0098	0.9214
	Genotypes	96	20754.5	216.192	1.2049	0.1813
	Residuals	96	17224.5	179.422		
PM30DAI	Rep	1	38	38.43	0.0994	0.7532
	Genotypes	96	46783	487.32	1.2605	0.1293
	Residuals	96	37115	386.62		
PM45DAI	Rep	1	260	260.31	0.399	0.52908
	Genotypes	96	88802	925.02	1.418	0.04435**
	Residuals	96	62624	652.33		
PM60DAI	Rep	1	0	0.32	0.0004	0.9832
	Genotypes	96	95018	989.77	1.3724	0.06136*
	Residuals	96	69237	721.22		

Table 6: Best genotypes identified based on mean PM at 60 DAI in comparison to the parents and checks

GENOTYPES	PM@60 DAI
ICGV 86590(Parent2)	30.95
TMV 2 (Susceptible check)	75.00
ICGV 86856 (Resistant check)	20.00
ICGN 184776	7.14
ICGN 184806	12.50
ICGN 184849	12.50
ICGN 184784	20.00
ICGN 184783	22.50
ICGN 184836	25.00
ICGN 184809	25.00
ICGN 184811	25.00
ICGN 184812	25.00
ICGN 184846	25.00
ICGN 184768	26.67
ICGN 184823	29.76

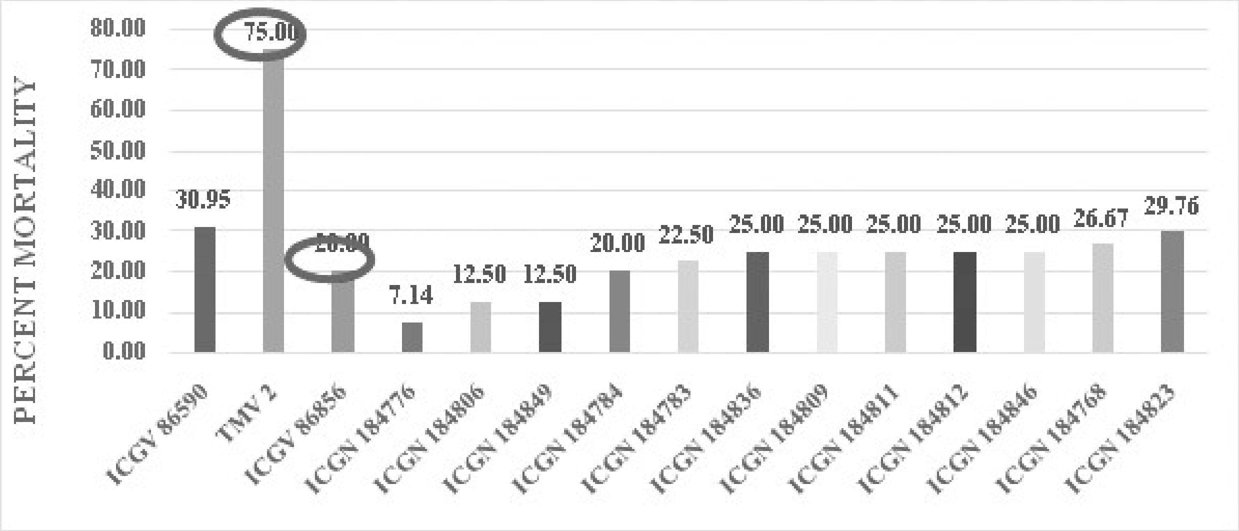


Figure 1. Representation of the best genotypes (PM at 60 DAI < 30%) in comparison to the parents and checks

variable under different environmental conditions, it is further required to screen these lines under field conditions to confirm the resistance levels. The identified lines after further confirmations could be used as parents in breeding programs to transfer the resistance trait to the cultivated varieties.

REFERENCES

Alagirisamy, M. 2016. Groundnut. In Breeding Oilseed Crops for Sustainable Production. 89-134. Academic Press.

Bera, S.K., Kasundra, S.V., Kamdar, J.H., BC, A., Lal, C., Thirumalasmy, P.P., Dash, P. and Maurya, A.K. 2014. Variable response of interspecific breeding lines of groundnut to *Sclerotium rolfsii* infection under field and laboratory conditions. Electronic Journal of Plant Breeding. 5 (1): 22-29.

Bera, S.K., Kamdar, J.H., Kasundra, S.V., Darvhankar, M., Jasani, M.D., Ajay, B.C. and Thirumalaisamy, P.P. 2016b. An efficient phenotyping technique for wild *Arachis* species and groundnut breeding lines resistant to stem rot disease under field conditions. Indian Phytopathology. 69(4s): 646-648.

Bera, S.K., Kamdar, J.H., Kasundra, S.V. and Thirumalaisami, P.P. 2016a. Identification of groundnut genotypes and wild species resistant to stem rot using an efficient field screening technique. Electronic Journal of Plant Breeding. 7 (1): 61-70.

DGR Annual Report. Annual meeting of groundnut researchers. 2013. Directorate of Groundnut Research, Gujarat. 2-3

Divya Rani, V., Sudini, H., Narayan Reddy, P., Vijay Krishna Kumar, K. and Uma Devi, G. 2018. Resistance screening of groundnut advanced breeding lines against collar rot and stem rot pathogens. International Journal of Pure & Applied Bioscience. 6(1): 467-474.

FAO 2021 http://www.fao.org/faostat/en/#data/QC

Guclu V., Aydogdu M., Basak M., Kizil S., Uzun B.U., Yol, E.N. Characterization of a groundnut collection to stem rot disease caused by *Sclerotium rolfsii*. 2020. Australasian Plant Pathology.49:691-700.

Jambunathan, R. 1991. Groundnut quality characteristics. In: Uses of tropical grain legumes: proceedings of a consultants meeting, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Center, Patancheru, 267–275

Krishnakanth, A., Gowda, M. V. C. and Motagi, B. N. 1999. Response of Spanish groundnuts to stem and pod rots caused by *Sclerotium rolfsii* Sacc. International *Arachis* Newsletter. 19: 27-28

Mehan, V.K., Mayee, C.D. and McDonald, D. 1995. Resistance in groundnut to *Scleroderma rolfsii*-caused stem and pod rot. *International Journal* of *Pest Management* 41: 79-83.

Nagaraj, C. 1995. Quality and utility of oilseeds, Directorate of Oilseeds Research, Rajendranagar, Hyderabad.

Palaiah, P., Narendrappa, T. and Mallesh, S.B. 2019. Screening of groundnut varieties and germplasm against collar rot, stem rot and dry root rot diseases. *International Journal* of *Current Microbiology* and *Applied* Sciences *8*(6): 2321-2328.

Pasupuleti, J. and Nigam, S.N., 2013. Phenotyping for groundnut (*Arachis hypogaea* L.) improvement. Phenotyping for plant breeding: applications of phenotyping methods for crop improvement. 129-167.

Singh, A.K., Mehan, V.K. and Nigam, S.N. 1997. Stem and pod rots. In: Sources of resistance to groundnut fungal and bacterial diseases: an update and appraisal. Information bulletin No. 50, ICRISAT, Patencheru Hyderabad. 25-27.

Variath, M.T. and Janila, P.2017. Economic and academic importance of peanut. The peanut genome. 7-26.

Research Article
The J. Res. PJTSAU 51(1&2) 49-54, 2023

INFLUENCE OF LEVELS OF PHOSPHORUS AND MOLYBDENUM SEED TREATMENT ON PERFORMANCE OF SOYBEAN IN VERTISOLS OF TELANGANA

FIRDOZ SHAHANA[1], A. MADHAVI LATA[2], S. N. SUDHAKARA BABU[3], S. TRIVENI[4] and T. PRABHAKAR REDDY[5]

[1]Department of Agronomy, PJTSAU, Rajendranagar, Hyderabad-30
[2]Department of Agronomy, APT, Malthummeda
[3]Department of Agronomy, ICAR-IIOR, Rajendranagar, Hyderabad-30
[4]Department of Microbiology, College of Agriculture, Rajendranagar, Hyderabad-30
[5]Department of Soil Science & Agricultural Chemistry, KVK, Palem

Date of Receipt: 04-06-2023 Date of Acceptance: 18-06-2023

ABSTRACT

Field experiment entitled "Phosphorus and Molybdenum studies on productivity, quality and soil fertility of soybean – maize cropping system" was conducted during 2018-19 & 2019-20. at the Regional Sugarcane and Rice Research Station, Rudrur, Professor Jayashankar Telangana State Agriculture University situated at an altitude of 286.3. m above mean sea level (MSL) at 180 49'41' latitude and 78056'45" E longitude, (PJTSAU). The experiment consisted of 16 treatments *viz.*, four levels of phosphorus (0, 30 60, and 90 kg P_2O_5 ha^{-1}) and four levels of seed treatment with molybdenum (0, 2, 4 and 6 g kg^{-1} seed) laid out in a randomized block design with factorial concept and replicated thrice. Perusal of mean results of two years indicated that interaction effect of varying levels of phosphorus and molybdenum seed treatment was significant on plant height at harvest. Phosphorus dose of 60 kg P_2O_5 ha^{-1} + molybdenum seed treatment @ 4 g kg^{-1} seed produced significantly higher plant height of 98.28 cm .Phosphorus dose of 90 kg P_2O_5 ha^{-1} + seed treatment with molybdenum @ 4 g kg^{-1} seed produced significantly higher number of pods 231.8 simlilar to that produced with 60 kg P_2O_5 ha^{-1} at similar level of molybdenum (226) and higher level of molybdenum 6 g kg^{-1} seed with 60 kg P_2O_5 ha^{-1} (225.8). Significantly higher grain yield was recorded at higher level of phosphorus at 90 kg P_2O_5 ha^{-1} with molybdenum seed treatment 4 g Mo per kg seed (3397kg ha^{-1}).

Keywords: Phosphorus, Molybdenum, Plant height, Number of pods, Test weight, Grain yield

Soybean (*Glycine max* L.) is basically a member of Fabaceae family and mainly supplies protein and oil. Its oil is considered the world's largest constituent of edible oils (Arif *et al.*, 2010). It serve's as a good rotational crop and helps in enrichment of soil fertility. It is popularly called as "Golden bean or miracle bean" and one of the foremost important oil seed crop known for its excellent protein (42 - 45%), oil (20%) and starch content (21%). It gives 2-3 times more protein yield (kg ha^{-1}) than other pulses and becomes an economical source of protein. Soybean can substitute for meat and to some extent to milk (Endres *et al.*, 2013). Mo requirement of soybean is higher in initial stages than at later stages. Soil-Mo may be hardly absorbed by soybean plants during the early growing period, that the Mo within or on the surface of the seeds may represent the only utilizable source of Mo, and that the Mo nutrition in this period strongly influences the later growth. The common method of correcting Mo deficiency in plants is treatment of the seeds with Mo. Up to the flower-bud-appearing stage, little absorption of Mo was detected. The Mo accumulation in the nodules may thus be highly dependent on the Mo contained in the seeds during the early growing period, and it can be said that the Mo contained in the seeds may play an important role in the early plant growth and probably in the nitrogen fixation by nodules(Junji Ishizuka,1982).

Phosphorus (P) is one of the most important nutrients for soybean crop, being absorbed from 0.2 to 0.4 kg. $ha^{-1}.day^{-1}$ among phenological stages V_4(fourth trifoliate leaf) and R6(complete pod fill growth stages). This nutrient participates in many metabolic processes, such as in energy transfer (adenosine triphosphate (ATP)), photosynthesis, respiration, synthesis of nucleic acids and glucose, membrane synthesis and stability (phospholipids), activation and deactivation of enzymes (Thavarajah *et al.*, 2010).

Hence the present study emphasises the importance of Mo and P in soybean cultivation.

Email: shahanaagro34@gmail.com

MATERIALS AND METHODS

Field experiment entitled "Phosphorus and Molybdenum studies on productivity, quality and soil fertility of soybean – maize cropping system" was conducted during 2018-19 & 2019-20.at the Regional Sugarcane and Rice Research Station, Rudrur, Professor Jayashankar Telangana State Agriculture University situated at an altitude of 286.3m above mean sea level (MSL) at 180 49'41' latitude and 78056'45" E longitude, (PJTSAU). The soil of the experimental site was clay loam with a pH of 7.9, electrical conductivity 0.24 dSm^{-1}, low in organic carbon (0.41 %), medium in available N (151 kg ha^{-1}) and available P (42 kg P_2O_5 ha^{-1}) and available K (372 kg ha^{-1}). Initial available Mo (0.29 ppm) was above critical level. The experiment consisted of 16 treatments *viz.*, four levels of phosphorus (0, 30 60, and 90 kg P_2O_5 ha^{-1}) and four levels of seed treatment with molybdenum (0, 2, 4 and 6 g kg^{-1} seed) laid out in a randomized block design with factorial concept and replicated thrice.

RESULTS AND DISCUSSION

An overview of the average data of two years of study period on plant height, number of pods $plant^{-1}$ and grain yield (kg ha^{-1}) indicated that they were significantly influenced by application of varying levels of phosphorus and seed treatment with molybdenum.

Effect of different phosphorus levels

Pooled mean

Application of 60 kg P_2O_5 ha^{-1} resulted in significantly higher mean plant height (91.71 cm) at harvest, higher number of pods $plant^{-1}$ (200.7) on par with 90 kg P_2O_5 ha^{-1}(199.6) and significantly higher test weight (14.11g).But application, 90 kg P_2O_5 ha^{-1} recorded significantly higher grain yield (3229 kg ha^{-1}) over 60 (2926 kg ha^{-1}) ,30(2043 kg ha^{-1}) and 0(1576 kg ha^{-1}) kg P_2O_5 ha^{-1}).

Year wise

At harvest all levels of phosphorus increased plant height significantly over control. Phosphorus application of 90 kg P_2O_5 ha^{-1} resulted in maximum plant height ((91.52 and 91.90cm) on par to 60 kg P_2O_5 ha^{-1} (87.73 and 89.94cm) and 30 kg P_2O_5 ha^{-1}((88.93 and 82.98 cm). Lowest plant height was observed at no P application (81.85 and 82.98 cm) during both the years. This increase could be because of the fact that phosphorus acts a critical character in root development and is vital for respiration, energy synthesis and plant photosynthesis, which resulted in improved growth (Ali *et al.*, 2014). Results are in confirmation by (Jabbar *et al.*, (2012) who found taller plants height of the mungbean crop plant with an increase in phosphorus dose.

It can be observed that from data that number of number of pods $plant^{-1}$ was influenced significantly by different phosphorus levels during both the years .Application of 90 kg P_2O_5 ha^{-1}(201.8 and 204.0) and 60 kg P_2O_5 ha^{-1} (197.5 and 197.4) produced higher number of pods $plant^{-1}$ and differed significantly with 30 kg P_2O_5 ha^{-1} (171.2 and 173.1) and 0 kg P_2O_5 ha^{-1} (118.7 and 120.1). (Table 1)

Application of 60 kg P_2O_5 ha^{-1} recorded significantly higher test weight (14.21 g and 14.02g) over,90 (13.47g and 13.67g), 30 (13.57 g and 13.58g) and 0 (13.09 g) kg P_2O_5 ha^{1}during both the years.

Varying levels of phosphorus fertilization had significant effect on grain yield of soybean. Higher grain yield of 3123 and 3335 kg ha^{-1} was produced with phosphorus fertilization @90 kg P_2O_5 ha^{-1} which was significantly superior over other levels of phosphorus applied @60(2827 and 3026 kg ha^{-1}),30(1941 and 2144 kg ha^{-1}) and 0(1443 and 1709 kg ha^{-1})kg P_2O_5 ha^{-1} during 2018 and 2019.

Effect of molybdenum seed treatment

Different levels of molybdenum did not significantly influence plant height. But significantly higher number of pods $plant^{-1}$ (170.1), were recorded with molybdenum seed treatment @ 6 g kg^{-1} seed on par with 4g (169.3) kg^{-1} seed. Contrary to this maximum test weight (13.84 g) was recorded with molybdenum seed treatment @ 2 g kg^{-1} seed and followed by 4 (13.76 g), 6g (13.68 g) over no seed treatment with molybdenum (13.08 g). Grain yield increased significantly with 6 g kg^{-1} seed (2583kg ha^{-1}) on par with 4 g kg^{-1} seed (2577 kg ha^{-1}) and statistically superior over 2g kg^{-1} seed (2419 kg ha^{-1}) and no seed treatment (2196 kg ha^{-1})

Different molybdenum seed treatment levels did not influence plant height significantly any how significantly higher number of pod $plant^{-1}$ was noticed with molybdenum seed treatment @ 4 g kg^{-1} seed

Table 1. Influence of levels of phosphorus and molybdenum seed treatment on performance of soybean in vertisols

Treatments	Plant height (cm) at harvest			No .of pods per plant $^{-1}$			100 seed weight (g)			Seed yield (kg ha^{-1})		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
Phosphorus level (P_2O_5 kg ha^{-1})												
P_1 - 0	81.85	82.98	82.42	118.7	120.1	119.4	13.03	13.16	13.09	1443	1709	1576
P_2 - 30	88.93	90.12	89.52	171.2	173.1	172.1	13.57	13.58	13.57	1941	2144	2043
P_3 - 60	91.52	91.90	91.71	197.5	204.0	200.7	14.21	14.02	14.11	2827	3026	2926
P_4 - 90	87.73	89.94	88.83	201.8	197.4	199.6	13.47	13.67	13.57	3123	3335	3229
S. Em±	1.24	1.26	1.25	5.2	2.3	2.7	0.19	0.18	0.18	31	49	27
CD (p=0.05)	3.59	3.65	3.62	14.9	6.5	7.8	0.55	0.52	0.53	89	141	78
Molybdenum level as seed treatment (g kg^{-1})												
Mo_1 – 0	85.66	86.10	85.88	150.8	145.4	137.8	13.07	13.13	13.08	2079	2312	2196
Mo_2 - 2	88.56	89.09	88.83	162.1	163.6	150.0	13.87	13.82	13.84	2335	2502	2419
Mo_3 - 4	87.94	90.19	89.07	189.3	192.3	169.3	13.76	13.78	13.76	2440	2714	2577
Mo_4 – 6	87.85	89.56	88.71	187.0	193.3	170.1	13.63	13.73	13.68	2480	2685	2583
S. Em±	1.24	1.26	1.25	5.2	2.3	2.7	0.19	0.18	0.18	31	49	27
CD (p=0.05)	NS	NS	NS	14.9	6.5	7.8	0.55	0.52	0.53	89	141	78
Interaction (P × Mo)												
S. Em±	2.48	2.53	2.51	10.3	4.5	5.4	0.38	0.36	0.36	62	97	54
CD (p=0.05)	7.18	7.30	7.24	29.8	13.1	15.7	NS	NS	NS	178	281	157
CV (%)	4.92	4.93	4.93	10.4	4.5	5.4	4.91	4.56	4.65	5	7	4

(189.3 and 193.3) on par with 6 g kg^{-1} seed (187 and 192.3) which was significantly superior over 2 g kg^{-1} seed (162.1 and 163.6) and no seed treatment (150.8 and 145.4) during both years .Seed treatment with molybdenum increased test weight significantly at all levels over no seed treatment during both the years. Maximum test weight was recorded with molybdenum seed treatment @ 2 g kg^{-1} seed (13.87 and 13.82) followed by 4g (13.76g and 13.78 g) and 6g (13.63 g and 13.73g). Lower test weight was observed with no seed treatment with molybdenum (13.07 g and 13.13g). Data on grain yield revealed that in comparision to no seed treatment (2079 and 2312 kg ha^{-1}) and molybdenum seed treatment @ 2 g kg^{-1} seed(2335 and 2502 kg ha^{-1}) ,molybdenum seed treatment @ 4 g kg^{-1} seed (2440 and 2714 kg ha^{-1}) and 6 g kg^{-1} seed(2480 and 2685 kg ha^{-1}) recorded significantly superior grain yield during both the years.

The increase in yield attributes was probably due to source and sink relationship. The improvement in photosynthesis and carbohydrate metabolism resulting into greater formation of photosynthates and metabolites in source and later on translocated in the newly formed sinks i.e., reproductive structures (flowering and seed setting) which ultimately increased pods per plant and test weight (Pareek ,(2005)These consequences are in close complement with conclusions of Padhi *et al.* (2018), they found utilization of molybdenum resulted in maximum performance and performance related attributes in mung bean. While in the occasion of phosphorus application, rise in phosphorus doses up to 60 kg ha^{-1} caused in greater pods followed by P at 90 kg ha^{-1} and less pods observed in control treatments. Rise in the important attributes may be because of holding of extra nodules that actually provide enough nitrogen for vegetative growth (Ali *et al.,* 2010). These achievements were in accordance with Khan *et al.* (2017) who described that the pods numbers improved by enhancement in phosphorus. Ali *et al.* (2014) also explained that applied phosphorus of 65 kg ha^{-1} improved pointedly pods numbers of mung bean.

Increase in seed yield with application of molybdenum might be due to increased growth characters like nodulation, plant height and yield attributing characters viz; pods per plant, seeds per pod. These results are in agreement with those conveyed by Pattanayak *et al.* (2000) who confirmed that the yield of mungbean increased with increasing molybdenum levels compared to control. The reason for the increase in seed yield with higher phosphorus could be due to the development of the root, the greater absorption of nutrients and a greater accumulation of dry matter during the growth period and the translocation of more photosynthesis to the seed (Anwar *et al.*, 2018). Phosphorus fertilizer helped the crop create extra seeds and other reproductive measures that eventually subsidised to yield (Rani *et al.*, 2016).

Interaction

However interaction effect of varying levels of phosphorus and molybdenum seed treatment was not significant on plant height at harvest and test weight. But significant on number of pods $plant^{-1}$ and grain yield. Application of P @ 90 kg P_2O_5 ha^{-1} along with molybdenum seed treatment @ 4 g kg^{-1} seed recorded significantly higher number of pods (231.8) $plant^{-1}$ on par with P @ 60 kg P_2O_5 ha^{-1} along with seed treatment with molybdenum @ 6 g kg^{-1} seed (225.8) or 4g kg^{-1} seed (225) over rest of the treatment combinations. Phosphorus fertilization @90 kg P_2O_5 ha^{-1} along with molybdenum seed treatment @4 g kg^{-1} seed produced significantly superior grain yield(3397 kg ha^{-1}) on par to seed treatment @6g kg^{-1} seed at same level of phosphorus(3294 kg ha^{-1}).

The synergistic effect of Mo with phosphorus might have enhanced the phosphorus availability to plants thereby leading to higher plant metabolic processes. Phosphorus is the major constituent of cell nucleus and growing root tips, which helps in cell division and root elongation thus increasing the nodule number and size. (Table 2)

CONCLUSION

For profitable soybean cultivation ,it can be recommended to enhance phosphorus dose to 90kg P_2O_5 ha^{-1} along with molybdenum seed treatment @4 g kg^{-1}

REFERENCES

Ali, A., A. Amjadi, A. Javed and Y. Muhammad. 2010. Effects of phosphorus in combination with rhizobium inoculation on growth and yield parameters of mung bean. Crop. Environ., 1(1): 53- 56.

Table .2 Interaction effect of levels of phosphorus and molybdenum seed treatment on growth and yield of soybean

	Plant height(cm)					**Number of pods plant**					**Grain yield (kg ha^{-1})**				
	P_1	**P_2**	**P_3**	**P_4**	**Mean**	**P_1**	**P_2**	**P_3**	**P_4**	**Mean**	**P_1**	**P_2**	**P_3**	**P_4**	**Mean**
$M0_1$	73.08	91.95	95.10	83.38	85.88	83.4	162.6	164.6	181.8	148.1	1440	1762	2461	3120	2196
$M0_2$	83.90	97.22	86.08	88.13	88.83	110.9	165.2	187.6	187.6	162.8	1590	2110	2870	3106	2419
$M0_3$	83.00	87.27	87.73	98.28	89.07	127.6	178.7	226.0	231.8	190.8	1623	2070	3217	3397	2577
$M0_4$	89.69	81.66	97.93	85.56	88.71	155.5	182.0	225.8	197.3	190.1	1651	2228	3158	3294	2583
Mean	82.42	89.52	91.71	88.83		119.4	172.1	200.7	199.6		1576	2043	2926	3229	
Interaction	levels of phosphorus		molybdenum seed treatment		Interaction	levels of phosphorus		molybdenum seed treatment		Interaction	levels of phosphorus		molybdenum seed treatment		Interaction
SEm±	1.25		1.25		2.51	2.7		2.7		5.4	28		28		55
CD (*P 0.05*)	3.62		NS		7.24	7.8		7.8		15.7	80		80		160
	$P_{1:}0\ P_2O_5$ kg ha^{-1}		$P_{2:}30\ P_2O_5$ kg ha^{-1}		$P_{3:}60\ P_2O_5$ kg ha^{-1}	$P_{4:}90\ P_2O_5$ kg ha^{-1}		Mo_1 – 0g Mo kg^{-1}		Mo_2 – 2g Mo kg^{-1}	Mo_2 – 4g Mo kg^{-1}		Mo_2 – 6g Mo kg^{-1}		

Ali, M.A., A. Ali, M.I. Ahmed, S.W. Hassan, S.R. Khan and A.A. Abid. 2014. Phosphorus effect on growth and yield parameters on mung bean. Sci. Int., 26(4): 1821-1824.

Anwar, S., Z.U. Rehman, B. Saeed, M. Islam, M.O. Kham and J. Ahmad. 2018. Response of mung bean to organic sources and nitrogen levels. Pure Appl. Biol., 7(2): 692-699.

Arif M, Jan MT, Khan NU, Khan A, Khan MJ, Munir I. Effect of seed priming on growth parameters of Soybean. Pakistan Journal of Botany. 2010; 42(4):2803-2812

Endres, J., Barter, S., Theodora, P and Welch, P. (2013). Soybean enhanced lunch acceptance by preschoolers. *Journal of American Dietetic Association. 103:* 346-351

Jabbar, B.K.A and H.M. Saud. 2012. Effects of phosphorus on biological nitrogen fixation in soybean under irrigation using saline water. Glob. J. Sci. Front. Res. Agric. Biol., 12(1): 1-10.

Junji Ishizuka.1982 Characteristics of molybdenum absorption and translocation in soybean plants. *Soil Science and Plant Nutrition.* 28 (1): 63-77

Khan, F.U., A.A. Khan, A. Iqbal, A. Ali, M. Iqbal, M. Alamzeb, M.F. Jan and B. Parmar. 2017. Effect of phosphorus and rhizobium inoculation on yield and yield components of mungbean. J. Pharm. Phytochem., 4(3): 252-258.

Padhi, P.P. and S.K. Pattanayak. 2018. Effect of lime coating and molybdenum seed treatment on nodulation, growth and yield of different pulses. Int. J. Curr. Microbiol. App. Sci., 7(2): 1417- 1426. https://doi.org/10.20546/ijcmas.2018.702.171

Pareek N. Effect of sulphur and molybdenum on growth, yield and quality of cowpea [Vigna unguiculata (l.) walp] under rainfed condition. M.Sc. (Ag.) Thesis, Sri Karan Narendra Agric. Univ., Jobner; c2005.

Pattanayak, S.K., D. Das, M.R. Jena and R.K. Nayak. 2000. Seed treatment of green gram with molybdenum and cobalt: Effect on nodulation, bio-mass production on N uptake in an acid soil. *J. Ind. Soc. Soil. Sci., 48: 769-773.*

Rani, M., P. Ved and K. Khalil. 2016. Response of mung bean to phosphorus, Sulphur and PSB during summer season. Agric. Sci. Digest., 36(2): 146-148. https://doi.org/10.18805/asd.v36i2.10637

Thavarajah, D.,Havarajah, P.S.E.E, C and Vandenberg, A.2010. Phytic acid and Fe and Zn concentration in lentil (*Lens culinaris* L.) seeds is influenced by temperature during seed filling period. *Food Chemistry.*122(1) :254-259.

Research Article
The J. Res. PJTSAU 51(1&2) 55-62, 2023

EVALUATION OF GREEN HOUSE GAS EMISSIONS FROM VARIOUS COMPONENTS AND FARMING SYSTEM MODELS IN SOUTHERN TELANGANA ZONE

RAYAPATI KARTHIK*[1], M. VENKATA RAMANA[2], CH. PRAGATHI KUMARI[3], T. RAM PRAKASH[4], G. KIRAN REDDY[3], D. SAIDA NAIK[5] and M. YAKADRI[1]

[1]Department of Agronomy, College of Agriculture, Rajendranagar, PJTSAU, Telangana
[2]Registrar, Admin office, PJTSAU, Telangana
[3]AICRP on IFS, Rajendranagar, PJTSAU, Telangana
[4]AICRP on Weed Management, Rajendranagar, PJTSAU, Telangana
[5]Dept. of Crop Physiology, Agricultural College, Jagtial, PJTSAU, Telangana
[1]Professor and Head, Dept. of Agronomy, College of Agriculture, Rajendranagar, PJTSAU, Telangana

Date of Receipt: 04-07-2023 Date of Acceptance: 18-07-2023

ABSTRACT

An experiment was conducted to compare and evaluate the greenhouse gas emissions from various components (crop, horticulture and livestock) and farming system models at IFS Unit, College farm, College of Agriculture, PJTSAU, Rajendranagar during 2021-22 and 2022-23. Theintegrated farming system was planned for 1.00 acre area and consisted of four cropping systems *i.e.,* Rice – Groundnut; Pigeonpea + Sweetcorn (1:3) – Bajra; Bt cotton + Greengram (1:2) – Maize; Pigeonpea + Maize (1:3) – Sunhemp, Napier grass and Hedge lucerne as fodder crops, guava orchard, poultry and two sheep units (each 5+1 each). Seven integrated farming system models were formulated by using suitable combinations ofdifferent components and compared. M_1: Rice – Groundnut; M_2: Rice – Groundnut, Pigeonpea + Sweetcorn (1:3) – Bajra, Bt cotton + Greengram (1:2) – Maize; M_3: Rice – Groundnut, Pigeonpea + Sweetcorn (1:3) – Bajra, Pigeonpea + Maize (1:3) – Sunhemp; Napier grass, Sheep (5+1); M_4: Rice – Groundnut, Pigeonpea + Sweetcorn (1:3) – Bajra, Bt cotton + Greengram (1:2) – Maize, Pigeonpea + Maize (1:3) – Sunhemp, Poultry unit; M_5: Guava, Hedge Lucerne, Napier grass, Bt cotton + Greengram (1:2) – Maize, Sheep (5+1); M_6: Guava, Bt cotton + Greengram (1:2) – Maize, Rice – Groundnut, Poultry; M_7: Rice – Groundnut, Pigeonpea + Sweetcorn (1:3) – Bajra, Pigeonpea + Maize (1:3) – Sunhemp; Napier grass, Hedge lucerne, Poultry, Sheep (5+1). Among different IFS models, higher mean negative net emissions (-2542 kg CO_2 eq.) were recorded in M_4 which was significantly at par with M_3 (-2360 kg CO_2 eq.), M_2 (-2372 kg CO_2 eq.) and M_7 (-2215 kg CO_2 eq.). Based on the findings, it can be concluded that integration of crops with livestock components results in net negative emissions and maintains the sustainability as compared to cropping systems.

Keywords: Green house gas emissions, farming systems, livestock, Telangana

The IFS approach comprises of optimal utilization of resources, and waste recycling which helps small and marginal farmers in obtaining good profits with less investment. Waste is utilized as a resource in IFS (Gupta *et al*., 2012), it eliminates the waste in the ecosystem and in addition increases the farm productivity and reduces the cost of production. Given the growing population pressure and the gap between demand and supply, deterioration of natural resources, agricultural enterprises diversification/intensification is the most suggestive means for rapid and yearround income generation. The approach of food and nutritional security through a wide range of food items within the farm and economic security which is possible with IFS improves the livelihood through individual farm holdings (Behera and France, 2016). The emergence of Integrated Farming Systems has enabled the development of framework for an alternative 'development model' to improve the feasibility of small sized farming operations over larger ones. Our honourable prime minister has intended to double the farmer's income in the coming years which could be potentially possible through IFS. The small farms (up to 2 ha) hold the key to ensure the food and nutritional security of India. Therefore, location-specific integration of field crops, orchard, floriculture, agro-forestry, livestock such as dairy, poultry, piggery, fishery, and other less land requiring activities such as mushroom, apiary, and boundary plantations are the keys to improve the livelihood of marginal and small holders.

An integrated farming system enables family nutrition, resource recycling for soil sustainability and generates more income and employment. Development

---

Email: karthikrayapati48@gmail.com

of a suitable IFS model by the integration of two or three components may produce higher yields, income, soil sustainability, and employment compared to Rice-Groundnut system. The different components of the system have complementarities like waste products of one component becoming the source of food and energy for other components. The integration and advantage of each component need to be studied for their contribution to income, sustainability, and employment generation.

The contribution of farming to greenhouse gas emissions is around 10-12% from the world and 18% for India, where it is third placed after energy and industry sectors (USDA report, 2015). The IFS model creates a crop ecosystem where the CO_2 absorption is more with less emission which makes it climate resilient compared to cropping systems and it also reduces the dependence on external resources through efficient recycling of on-farm biomass and other resources. Conducting research on IFS helps to find out the contribution of each component and especially the contribution to soil sustainability. There is a need to develop location specific IFS models as soil, climatic and cultural conditions vary from place to place. Developing a climate smart IFS model for farmers is the need of the hour in the climate changing scenario.

MATERIAL AND METHODS

An experiment was conducted at IFS Unit, College farm, College of Agriculture, PJTSAU, Rajendranagar during 2021-22 and 2022-23 with a view to compare and evaluate the green house gas emissions from various components and farming system models. The details of the materials used and the methods adopted during the course of investigation are described in this chapter.

Location of the experimental site

The experimental site was situated at an altitude of 527 m above Mean Sea Level (MSL) at 17° 32'10.45" N latitude and 78° 41' 02.77" E longitude E longitude in Southern Telangana Zone (STZ), India. The experiment was laid out in field No. B-20 of Agricultural College Farm, Rajendranagar.

Weather

The meteorological data recorded during the crop growth period of experimentation was taken from the meteorological observatory of Agro Climatic Research Centre (ACRC) located at Agricultural Research Institute, Rajendranagar, Hyderabad.

During the both years, the mean maximum and minimum weekly temperature duringthe study period ranged from 27.6°C to 39.3°C with the average of 32.1°C and from 9.6°C to 26.1°C with the average of 20.5°C, respectively.Mean weekly morning relativehumidity ranged from 67 to 98.9 per cent with the average of 88.1 per cent and evening relative humidityranged from 24.7 to 88.9 per cent with the average of 56.3 per cent, respectively. Mean weekly sunshine hours ranged between 1.4 and 10 with the average of 6.3. The average annual rainfall was 1017 mm with 32 rainydays whereas total evaporation was 256 mm.

Experiment details

Table 1: Treatment wise components allocation in 1 Acre area

IFS Model	Composition	Components	Area
M_1	Pre-dominant cropping system	Rice – Groundnut	4000 sq.m
M_2	Cropping systems (Family nutrition & income generating crops)	Rice – Groundnut Pigeonpea + Sweetcorn (1:3) – Bajra Bt cotton + Greengram (1:2) – Maize	1000 sq.m 1000 sq.m 2000 sq.m
M_3	Cropping systems (Family, livestock nutrition & income generating crops) + Sheep (5+1)	Rice – Groundnut Pigeonpea + Sweetcorn (1:3) – Bajra Pigeonpea + Maize (1:3) – Sunhemp Napier grass	1500 sq.m 1000 sq.m 1000 sq.m 500 sq.m
M_4	Cropping systems (Family nutrition & income generating crops) + Poultry (50)	Rice – Groundnut Pigeonpea + Sweetcorn (1:3) – Bajra Pigeonpea + Maize (1:3) – Sunhemp] Bt cotton + Greengram (1:2) – Maize	1000 sq.m 1000 sq.m 1000 sq.m 1000 sq.m

IFS Model	Composition	Components	Area
M_5	Fruit orchard + Field crops + Fodder grass + Sheep (5+1)	Guava Hedge lucerne Napier grass Bt cotton + Greengram (1:2) – Maize	2000 sq.m 500 sq.m 500 sq.m 1000 sq.m
M_6	Fruit orchard + Field crops + Poultry (50)	Guava Bt cotton + Greengram (1:2) – Maize Rice – Groundnut	2000 sq.m 1000 sq.m 1000 sq.m
M_7	Cropping systems (Family nutrition, fodder grass & income generating crops) + Sheep (5+1) + Poultry (50)	Rice – Groundnut Pigeonpea + Sweetcorn (1:3) – Bajra Pigeonpea + Maize (1:3) – Sunhemp Napier grass Hedge lucerne	1000 sq.m 1000 sq.m 1000 sq.m 500 sq.m 500 sq.m

Table 2: Recommended package of practices of all crops in integrated farming system

S.No.	Name of the crop	Season	Seed rate (kg) unit area^{-1}	Spacing	Fertilizer dose ha^{-1}	Variety
1	Rice	*Kharif*	5	20 × 15 cm	120:60:40	RNR 21278
2	Groundnut	*Rabi*	15	22.5 × 10	20:50:30	K-6
3	Pigeonpea	*Kharif*	0.5	240 × 20	20:50:30	WRG-97
4	Sweetcorn	*Kharif*	1	60 × 20	200:60:40	Sugar 75
5	Bajra	*Summer*	1	45 × 15	80:40:30	
6	Bt Cotton	*Kharif*	0.5	90 × 30	150:60:60	Magna (RCH 530 BG II)
7	Greengram	*Kharif*	2	30 × 10	20:50:30	WGG 42
8	Maize	*Rabi*	2	60 × 20	240:80:60	Pioneer 3396
9	Pigeonpea	*Kharif*	0.5	240 × 20	20:50:30	WRG-97
10	Maize	*Kharif*	2	60 × 20	240:80:60	Pioneer 3396
11	Sunhemp	*Summer*	4	30 × 10	10:20:0	
	Fodder crops					
11	Hedge Lucerne	*Perennial*	1 kg	30 cm	40:60:20	RL-88
12	Hybrid napier	*Perennial*	926 cuttings	90 cm× 60 cm	180:60:60	
	Horticultural crops					
13	Guava	*Perennial*		4 × 4 m	100:40:100 2.5 kg Vermicompost plant^{-1} at the time of planting	Allahabad Safeda

Sheep

Two units of sheep were grown (each unit consists of 5+1) separately on platform system in partial grazing manner. One unit of sheep were fed napier grass whereas second unit were fed hedge lucerne in addition to napier grass. Every morning sheep were taken for grazing for 4-5 hrs and stall fed in the evening time. Deworming is done once in 3 months on the advise of veterinary doctors and they used to visit sheep shed every fortnight for health check-up.

Sheep were given serial number and the periodical live weight, growth rate per every 15 days (twice a month) were observed for a period of 24 months (June 2021 - May 2023). Sheep manure was collected at the end of year and supplied to the fields

Poultry birds

Each batch of one day old chicksconsisted of 50 birds. Everyday chick feed and water were provided as per the requirement. The periodical live weight of poultry birds, increase in live weight and manure production were monitered. Once they attain around 1.1 kg weight, they were sold @ Rs.300/kg.

Table 3. Details of livestock components

S. No.	Component	Breed name	Number of birds/animals
1	Sheep (2 units)	*Nellore Jodipi*	5 Ram+ 1 Ewe
2	Poultry	*Aseel*	50 batch^{-1} and 2 batches year^{-1}

Greenhouse gas emissions

GHG emissions from the experiment plot were estimated using Cool Farm tool. The cool farm tool is a Microsoft Excel spreadsheet basedprogramme that calculates global GHG emissions. The tool was developed by Unilever, the University of Aberdeen and the Sustainable Food Laboratory. The tool has global applicability as it uses equations based on modifications of the IPCC approach. It captures on-farm activity data easily as certained whilst in the field through seven input sections, each on a separate Excel worksheet related to crop, soil, inputs, fuel&energy use, irrigation, carbon and transport. Each section was properly fed with inputs according to specific plot conditions to get an estimation of CO_2, N_2O and CH_4 emissions separately as well as also total GHG emissions in terms of equivalents of carbon dioxide emissions (https://coolfarmtool.org).

Statistical analysis

The data generated from field experiment were analyzed in randomized block design (Gomez and Gomez, 1984) in three replications with ten treatments by analysis of variance (ANOVA). The significance of different sources of variation was tested by the error mean square of Fisher Snedecor's 'F' test at probability level 0.05. Standard error of mean (SE) and least significant difference (LSD) at 0.05 level of significance were used to compare treatments.

RESULTS AND DISCUSSION

Component wise greenhouse gas emissions

Mean GHG emitted by Rice - Groundnut system was found to be 400 kg CO_2 eq and sink capacity recorded by this system was found to be 483 kg CO_2 eqwhereas mean net emission were -82.5 kg CO_2 eq.Pigeonpea + Sweetcorn - Bajra system had emitted mean GHG emission of 172 kg CO_2eq and meansink capacity recorded by this system was 1344 kg CO_2 eq whereas mean net emission were -1172 kg CO_2 eq.Bt cotton + Greengram - Maize system had emitted mean GHG emission of 201 kg CO_2eq andsink capacity recorded by this system was 782 kg CO_2eq whereas mean net emission were -581 kg CO_2 eq.Pigeonpea + Maize- Sunhemp system had emitted mean GHG emission of 155 kg CO_2 eq andsink capacity recorded by this system was 928 kg CO_2eq whereas mean net emission were -773 kg CO_2eq (Table 4). Sink capacity increases with increase in biomass production. Sink capacity of Pigeonpea + Sweetcorn- Bajra system followed by Pigeonpea + Maize- Sunhemp system is higher mainly because of higher grain and straw yield which leads to higher negative net emissions in these systems. Total cropping unit system had emitted mean GHG emission of 928 kg CO_2 eq andmean sink capacity recorded by this system was 3536 kg CO_2eq whereas mean net emission were -2609 kg CO_2 eq. in total cropping unit (Table 4).

Mean GHG emission of guava orchard was 126 kg CO_2 eq and mean sink capacity recorded by this orchard was 1131 kg CO_2 eq whereas mean net emission were -1005 kg CO_2 eq. Mean GHG emitted by hedge lucerne was 12.7 kg CO_2eq andsink capacity recorded was found to be 84 kg CO_2 eqwhereas mean net emission were -71 kg CO_2 eq. in hedge lucerne.Mean GHG emitted by hybrid napier was 81 kg CO_2 eqand mean sink capacity recorded was found to be 1601 kg CO_2 eq whereas mean net emission were -1520 kg CO_2 eq. in hybrid napier.Mean GHG emitted by poultry unit was also 5.3 kg CO_2 eq and

Table 4. Component wise Greenhouse gases emission and its contribution in total sink and source (CO_2-e (kg))

Enterprise	Area (sq.m.) / Number	Source (kg CO_2-e)			Sink (kg CO_2-e)			Net emissions (kg CO_2-e)		
		2021-2022	2022-2023	Mean	2021-2022	2022-2023	Mean	2021-2022	2022-2023	Mean
Rice-Groundnut	1000	396	404	400	467	498	482.5	-71	-94	-82.5
Pigeonpea + Sweetcorn- Bajra	1000	171	172	171	1224	1463	1344	-1053	-1291	-1172
Bt cotton + Greengram- Maize	1000	200	202	201	737	827	782	-537	-625	-581
Pigeonpea + Maize- Sunhemp	1000	155	155	155	850	1006	928	-695	-851	-773
Cropping unit (Total)		**922**	**933**	**928**	**3278**	**3794**	**3536**	**-2356**	**-2861**	**-2609**
Guava orchard	2000	122.61	129.5	126	1130	1132	1131	-1007.39	-1002.5	-1004.9
Hedge Lucerne	500	12.5	12.8	12.65	83.1	85	84.05	-70.6	-72.2	-71.4
Napier grass	500	80.4	80.7	81	1582	1619	1600.5	-1501.6	-1538.3	-1519.9
Poultry	100 birds	5.25	5.25	5.25	-	-	-	5.25	5.25	5.25
Sheep unit I	5+1	639	1740	1190	-	-	-	639	1740	1190
Sheep unit II	5+1	653	2067	1360	-	-	-	653	2067	1360

mean GHG emitted by sheep unit I and II were 1190 and 1360 kg CO_2 eq, respectively. Increase in thenumber of sheep during 2nd year resulted in more GHG emissions. Meena *et al.* (2022) and Rathore *et al.* (2019) also found that presence of livestock led to high GHG emissions which could be offset by integrating them with cropping unit, trees and orchards.

Greenhouse gas emissions from different integrated farming system models

Model M_3 had emitted higher mean GHG emissions of 2197 kg CO_2 eq. which was significantly at par with Model M_7 which had emitted mean GHG emission of 2185 kg CO_2 eq (Table 5 & Fig 1). Rice crop and sheep are mainly responsible for the GHG emissions in these models. These results are in agreement with Babu *et al.* (2023) who noticed that greenhouse gas emissions are more from livestock and rice crop. Models having either sheep or rice crop in larger area have emitted more GHG compared to other models. Model M_6 had emitted lower mean GHG emissions of 733.0 kg CO_2 eq. which might be due to low input requirement of guava orchard.

Sink capacity also follows the same trend as GHG source. Model M_3 had recorded mean sink capacity of 4557 kg CO_2 eq. which was significantly at par with Model M_7 which recorded mean sink capacity of 4400 kg CO_2 eq (Table 5 & Fig 1). This might be due to having cropping components and napier grass which have produced higher biomass ultimately resulted in higher sink capacity. Although these models have sheep component, having cropping components and napier grass offsets the higher emissions of sheep. These results are supported by Pasha *et al.* (2020) and Li *et al.* (2017) whofound that integrating livestock with crop production is viable option to decrease GHG emissions that helps in environmental sustainability.

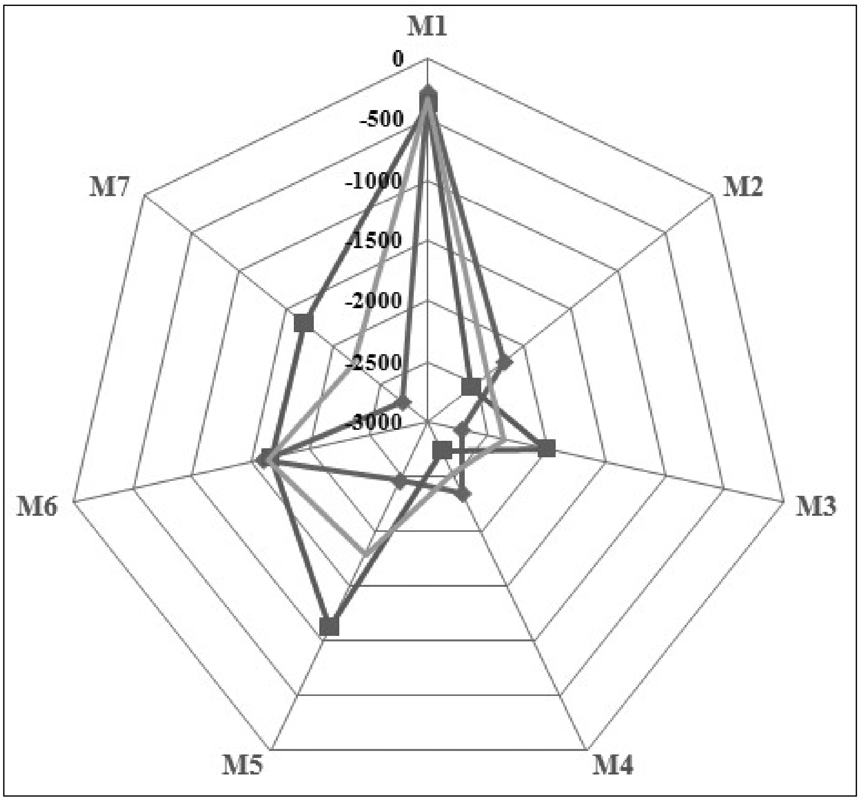


Fig 1: Greenhouse gas emissions from different integrated farming system models

Model M_1 recorded lowestmean sink capacity of 1930 kg CO_2 eq. as well as mean negative net emissions of -330 kg CO_2 eq. among all the models. This might be due to higher GHG emissions from rice crop and lower sink capacity compared to other crops which has resulted in low negative net emissions. Islam *et al.* (2015) reported that rice enhanced the methane emissions which should be integrated with livestock components like duck, fish etc. to reduce the GHG emissions.

Table 5. Greenhouse gas emissions from different integrated farming system models

IFS Models	Source (kg CO_2-e)			Sink (kg CO_2-e)			Net emissions (kg CO_2-e)		
	2021-2022	**2022-2023**	**Mean**	**2021-2022**	**2022-2023**	**Mean**	**2021-2022**	**2022-2023**	**Mean**
M_1:C_1	1584	1616	1600	1868	1992	1930	-284	-376	-330
M_2:C_1+ C_2+ C_3	967	980	974	3165	3525	3345	-2198	-2545	-2372
M_3:C_1+ C_2+ C_4 + N + S_1	1639	2754	2197	4356	4757	4557	-2717	-2003	-2360
M_4:C_1+ C_2+ C_3 +C_4 + P	927	939	933	3278	3671	3475	-2351	-2732	-2542
M_5:G + H+ N+ C_3+S_2	1069	2492	1781	3532	3618	3575	-2464	-1126	-1795
M_6:G+ C_1+ C_3 +P	724	741	733	2334	2412	2373	-1610	-1671	-1641
M_7:C_1+ C_2+ C_4+H+ N + S_2+ P	1473	2897	2185	4206	4593	4400	-2733	-1696	-2215
SEm(±)	50.22	80.66	63.43	140.27	150.58	145.05	88.42	71.47	77.96
LSD (p=0.05)	154.76	248.56	195.46	432.21	463.98	446.90	272.47	220.24	240.22

Model M_4 had recorded higher mean negative net emissions of -2542 kg CO_2 eq. in which was significantly at par with M_3(-2360 kg CO_2 eq), M_2 (-2372 kg CO_2 eq.) and M_7 (-2215 kg CO_2 eq.). Multiple enterprises or components present in a integrated farming system enhances the sink capacity which results in negative net emissions. These results are supported by Meena *et al*. (2022) and Sridevi *et al*. (2021) who identified that more intensification of crops and other components enhances the carbon sink which makes the IFS model environmentally benign.

CONCLUSION

In this experiment, we have compared and evaluated the greenhouse gas emissions from various integrated farming system models. Among all the cropping systems, Pigeonpea + Sweetcorn- Bajra recorded higher mean net emissions (-1172 kg CO_2 eq.) followed by Pigeonpea + Maize- Sunhemp system (-773 kg CO_2 eq.). Compared to all components, mean net emission were higher in hybrid napier (-1520 kg CO_2 eq.). Mean GHG emitted by poultry unit, sheep unit I and II were 5.25, 1189.5 and 1360 kg CO_2 eq., respectively. The IFS model M_4 recorded higher mean negative net emissions (-2542 kg CO_2 eq.) which was significantly at par with M_3 (-2360 kg CO_2 eq.), M_2 (-2372 kg CO_2 eq.) and M_7 (-2215 kg CO_2 eq.) which indicates that multiple enterprises enhanced the sink capacity leading to higher negative net emissions.

REFERENCES

Babu, S., Das, A., Singh, R., Mohapatra, K.P., Kumar, S., Rathore, S.S., Yadav, S.K., Yadav, P., Ansari, M.A., Panwar, A.S and Wani, O.A. 2023. Designing an energy efficient, economically feasible, and environmentally robust integrated farming system model for sustainable food production in the Indian Himalayas. *Sustainable Food Technology*.

Behera, U. K and France, J. 2016. Integrated Farming Systems and the Livelihood Security of Small and Marginal Farmers in India and Other Developing Countries. *Advances in Agronomy*. 138:235-282.

Gomez, K.A and Gomez, A. 1984. Statistical Procedure for Agricultural Research—Hand Book. John Wiley & Sons, New York.

Gupta, V., Rai, P.K and Risam, K.S. 2012. Integrated Crop-Livestock Farming Systems: A Strategy for Resource Conservation and Environmental Sustainability. *Indian Research Journal of Extension Education*. 2:49-54. https://coolfarmtool.org

Islam, A.H.M.S., Barman, B.K and Murshed-e-Jahan, K. 2015. Adoption and impact of integrated rice–fish farming system in Bangladesh. *Aquaculture*. 447:76-85.

Li, Z., Sui, P., Wang, X., Yang, X., Long, P., Cui, J., Yan, L and Chen, Y. 2017. Comparison of net GHG emissions between separated system and crop-swine integrated system in the North China Plain. *Journal of Cleaner Production*. 149:653-664. DOI: http://dx.doi.org/10.1016/j.jclepro.2017.02.113.

Meena, L.R., Kochewad, S.A., Prusty, A.K., Bhanu, C., Kumar, S., Meena, A.L., Meena, L.K., Raghavendra, K.J., Kumar, D., Subash, N., Singh, S.P. 2022. Sustainable integrated farming system model for small farm holders of Uttar Pradesh. *Indian Journal of Agricultural Sciences*. 92(9):1080-1085.

Pasha, Md. L., Reddy, G.K., Sridevi, S., Govardhan, M., Ali Baba, Md and Rani, B. 2020. Energy use efficiency and greenhouse gas emissions from integrated crop-livestock systems in semi-arid ecosystem of Deccan Plateau in Southern India. *Journal of Experimental Biology and Agricultural Sciences*. 8(2):98-110.

Rathore, V.S., Tanwar, S.P.S., Kumar, P and Yadav, O.P. 2019. Integrated Farming System: Key to sustainability in arid and semi-arid regions. *Indian Journal of Agricultural Sciences*. 89(2):181–92.

Sridevi, S., Goverdhan, M., Kumari, Ch. P., Pasha, Md. L., Ramana, M.V. and Reddy, G.K. 2021. Carbon footprint in crop + horti-pastoral + livestock integrated farming systems under irrigated dry conditions of Telangana, India. Extended summaries:5th International Agronomy Congress, Nov 23-27, 2021, India.

United States Department of Agriculture report. 2015. USDA's building blocks for climate smart agriculture and forestry fact sheet. Available at http://www.usda.goc/documents/climate-smart-factsheet.pdf.

Research Article
The J. Res. PJTSAU 51(1&2) 63-68, 2023

PERFORMANCE OF MAIZE UNDER DIFFERENT PHOSPHORUS LEVELS AND PLANTING METHODS IN HIGH PHOSPHORUS SOILS IN NORTHEN TELANGANA ZONE

K. SHEKAR[1], P. LAXMINARAYANA[2], G. MANJULATHA[3], G. PADMAJA[4] and S. NARENDER REDDY[5]

[1]Department of Agronomy, College of Agriculture, Rajendranagar, Hyderabad

[2]Department of Agronomy, College of Agriculture, Rajendranagar, Hyderabad

[3]Department of Agronomy, ARS, Karimnagar, PJTSAU

[4]Department of Soil Science and Agricultural Chemistry, Director of Polytechnics, Administrative Office,
Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad

[5]Department of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad

Date of Receipt: 07-06-2023 Date of Acceptance: 18-06-2023

ABSTRACT

A field experiment was conducted at Agricultural Research Station, Karimnagar, Northern Telangana Agro Climatic Zone of Telangana State during *kharif* 2018 and 2019 to study the effect of different levels of phosphorus on growth and yield of maize in high phosphorus soils (79 kgha^{-1})under raised and flat beds. The experiment was laid out in strip plot design for maize in *kharif* 2018 and 2019 with 2 main treatments *i.e.,* M_1 (Raised beds) and M_2 (Flat beds) and five phosphorus levels applied as basal dose as sub treatments *viz.*, S_1: 100 % RDP (60 kg ha^{-1}), S_2: 75 % RDP (45 kg ha^{-1}), S_3: 50 % RDP (30 kg ha^{-1}), S_4: 25 % RDP (15 kg ha^{-1}) and S_5: 0 % RDP (0 kg ha^{-1})and replicated four times. The performance of the maizewas found superior whenplanted on raised beds with higher final plant population (per cent) and growth parameters viz., plant height (cm)and dry matter production (kg ha^{-1}) at 30, 60 DAS and at harvest. The highest grain, stover yield (kg ha^{-1}) and harvest index of maize were found significantly higher underraised beds (M_1) compared to the flat beds (M_2). In the sub treatments application of 100% RDP (S_1) and 75 % RDP (S_2) recorded higher plant height at different stages of crop growth that resulted highest dry matter accumulation at 30, 60 DAS and at harvest. The grain yield and stover yield were significantly higher with the 100 % RDP and was followed by the application of 75% RDP and 50 % RDP and which were at par with each other and superior over 25 % RDP and 0 % RDP. The interaction between planting methodsand different levels of phosphorus was found non significant.

Keywords: Maize, raised beds, flat beds, phosphorus levels and grain yield.

Maize (*Zea mays* L.) is one of the most important cereal crops next to wheat and rice in the world. In India, it ranks fourth after rice, wheat and sorghum. Maize is grown throughout the world under a wide range of climatic conditions. The major producers are USA followed by China, Brazil, Mexico, Argentina and India. Maize occupies more than 80 per cent area under rainfed conditions.In India, maize area and production have steadily increased during the past two decades and 75 per cent of the total production comes from the states of Bihar, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh. In India it occupies in an area of 9.9 M. ha with 31.64 million tonnes of production and 2509 kg ha^{-1} productivity while in Telangana state respective figures are 0.57 M. ha, 1.74 million tonnes and 3199 kg ha^{-1} (Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Govt. of India 2020-21).For establishing a good crop stand the lack of adequate moisture in the seed zone is the major constraint and excess rain situations causing waterlogging at root zone which reduces palnt growth and results in lower grain yield in maize. Which requires adoption of location specific *in situ* soil moisture conservation techniques. Agronomic manipulations to soil such as raised planting enhance the establishment, crop growth, yield attributes and yield in maize. Phosphorus becomes an important nutrient in maize. It plays a key role in the vital energy transformation, cell division and meristematic growth in living tissues. It is an important constituent of nucleic acids, proteins, enzymes and phospholipids. Phosphorus nutrition in desired and balanced dose enhances root development, nodulation and hastens maturity. During 1990's use of DAP increased to such an extent that farmers using DAP as a source of nitrogen even for split application of nitrogen as a result there has been accumulation of phosphorus in soil as the use efficiency of applied P is only 15-20%. Therefore,

Email: kaluvalashekar333@gmail.com

phosphorus management in relation to land configuration practices and with particular reference to maize.

An experiment was conducted for two consecutiveyears, 2018 and 2019 at Agricultural Research Station, Karimnagar which is geographically situated at 18. 44 Latitude, 79.09Longitude and at an altitude of 259.15 m above mean sea level, covered under Northern Telangana Agro Climatic Zone of Telangana State.

MATERIAL AND METHODS

The experiment was conducted in D5 block of Agriculture Research Station, Karimnagar, Prof. Jayashankar Telangana State Agricultural University, Telangana State. The results of soil analysis indicated that the experimental site wassandy loam in texture, alkaline in reaction, low in organic carbon, medium in available nitrogen, high in available phosphorus with 79 kg ha^{-1} under high phosphorus soils and high in potassium. The field experiment was carried out during *kharif* 2018 and 2019 for maize, which was laid out in strip plot design during *kharif* season of 2018 and 2019 with raised beds and flat beds as main plot treatments and in phosphorus management, there were five treatments of phosphorus for application in maize with sub plot treatments as $S_{1:}$ 100 % RDP (60 kg ha^{-1}), S_2: 75 % RDP (45 kg ha^{-1}), S_3: 50 % RDP (30kg ha^{-1}), S_4: 25 % RDP (15 kg ha^{-1}), S_5: 0 % RDP (0 kg ha^{-1}) (Control). The source of phosphorus for maize is DAP. The calculated quantity of DAP for phosphorus were applied to the maize crop as basal application. Thus, there were ten treatment combinations replicated four times in *kharif* season. The land was ploughed once with mould board plough and harrowed twice to bring the soil to fine tilth after receiving pre-monsoon rain. Stubbles and weeds were removed from the experimental site. The raised beds were freshly prepared (both years) mechanically by a raised bed planterone day before sowing. The raised beds dimensions were 90 cm width and 15 cm height with the furrow of 30 cm. The layout of raised beds was depicted in fig 1.0.

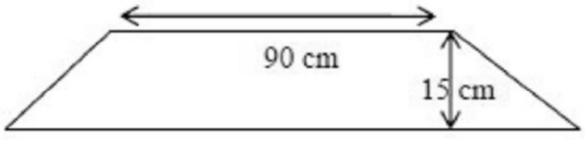


Fig 1.0. Layout of raised bed

The cultivar selected was Karimnagar makka (KNMH-4010141) is an early maturity, yellow semi flint grain single cross maize hybrid suitable for *kharif* season developed by PJTS Agricultural University at Agricultural Research Station, Karimnagar, Telangana State. This hybrid highly responsive to fertilizers and suitable for both early and late plantings. Duration of the hybrid is 95-100 days with an average yield potential of 6500-7000 kg ha^{-1}. Farm yard manure @ 10 t ha^{-1} was applied and incorporated into soil one week before sowing. The recommended dose of nitrogen and potassium fertilizers *i.e.*, 200 and 50 kg N and K ha^{-1} was applied through Urea and muriate of potash (MOP) respectively. Entire phosphorus as per treatments and potassium were applied in the form of DAP and MOP as basal by placement and covered with the soil. Nitrogen in the form of urea after calculating the proportion supplied through DAP, applied in three splits as per schedule *i.e.,* 1/3rd N as basal, 1/3rd N at 30 DAS and remaining 1/3rd N at 60 DAS. Entire phosphorusas per the treatments was applied basally by placement and covered with the soil. Maize crop was sown as hand dibbling by adopting 60x20 cm spacing between the rows and within the plants respectively. Five plants were randomly selected and tagged in the net plot of the all treatments for recording biometric observations in maize.

RESULTS AND DISCUSSION

The perusal of the data recorded on growth parameters, yield attributes and yield of *kharif* maize and in *rabi* groundnut crops, data pertaining to plant population, growth parameters, yield attributes, yield, nutrient uptake and economics along with phosphorus fractions as influenced by raised and flatbeds and phosphorus management in high phosphorus soils during 2018 and 2019 (Table.1-2).

Significantly higher plant height was recorded by raised beds (M1) at 30 (53.0 cm), 60 DAS (144.1 cm) and at harvest (168.6 cm) than flatbeds (M2) (47.0, 132.5, 156.3 cm) respectively during 2018. Similar trend was noticed in 2019 and mean of two years. Increase in plant height under the raised beds might be due to favorable conditions for establishment and availability of sufficient amount of moisture at vegetative growth resulting in higher plant height. These results are in line with those of Vishuddha Nand *et al.* (2022). At 60 DAS, significantly higher plant height registered with

Table 1. Plant height (cm) and dry matter production (kg ha^{-1}) in maize as influenced by phosphorus levels in high phosphorus soilsunder raised and flat beds.

Treatments	Plant height (cm)									Dry matter production (kg ha^{-1})								
	30 DAS			60 DAS			at harvest			30 DAS			60 DAS			at harvest		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
Maintreatments (Beds)																		
M_1: Raised beds	53.0	63.7	58.3	144.1	156.8	150.4	168.6	180.0	174.3	1224	1452	1338	6885	7293	7089	13685	14093	13889
$M_{2:}$ Flat beds	47.0	50.8	48.9	132.5	137.7	135.1	156.3	166.5	161.4	959	1122	1040	5537	6318	5927	12802	12603	12553
SEm(±)	1.2	1.3	0.8	1.7	3.8	1.9	2.3	2.9	2.6	52	46	42	140	200	73	172	213	163
CD(P=0.05%)	5.4	5.8	3.8	7.8	17.0	8.7	10.5	13.0	11.7	236	209	190	631	899	330	776	960	736
Sub treatments (Phosphorus levels)																		
$S_{1:}$ 100 % RDP	55.6	64.8	60.2	145.3	150.6	147.9	170.3	180.3	175.3	1411	1518	1464	6836	7284	7060	13757	13847	13802
S_2: 75 % RDP	54.3	62.4	58.3	141.0	150.1	145.6	166.0	176.0	171.0	1125	1329	1227	6565	7205	6885	13520	13768	13644
S_3: 50 % RDP	51.9	60.0	55.9	138.9	146.5	142.7	163.9	173.9	168.9	1059	1325	1192	6506	7001	6754	13438	13564	13501
S_4: 25 % RDP	45.8	51.5	48.6	134.4	145.3	139.8	156.9	169.4	163.1	957	1189	1073	5806	6410	6108	12996	13048	12647
S_5: 0 % RDP (Control)	42.4	47.5	44.9	131.9	143.5	137.7	155.0	166.6	160.8	904	1075	989	5341	6126	5734	12506	12514	12510
SEm(±)	1.9	1.3	1.5	3.3	2.7	2.5	2.9	3.5	3.1	36	40	28	228	136	141	271	290	302
CD(P=0.05%)	5.9	4.1	4.7	10.0	8.3	7.6	9.1	9.9	9.6	111	123	86	701	418	435	835	893	930
Interaction effect																		
Main at same level of sub treatment																		
SEm(±)	3.6	3.6	2.6	6.6	7.4	5.1	7.5	8.2	7.6	106	106	90	532	475	288	656	602	626
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Subatsame level of main treatment																		
SEm(±)	1.6	1.3	1.2	2.8	2.2	2.0	2.8	3.1	2.8	31	35	26	210	141	122	255	242	263
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Girth of cob (cm), number of seed rows cob^{-1} and grain yield (kg ha^{-1}) in maize as influenced by phosphorus levels under raised and flat beds in high phosphorus soils

Treatments	Girth of cob (cm)			Number of seed rows cob^{-1}			Grain yield(kg ha^{-1})		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
Maintreatments (Beds)									
M_1: Raised beds	13.50	17.09	15.29	17.1	17.2	17.3	5888	6211	6299
$M_{2:}$ Flat beds	11.63	14.05	12.84	15.2	15.8	15.8	5496	5660	5828
SEm(±)	0.15	0.44	0.28	0.3	0.3	0.3	84	89	78
CD(P=0.05%)	0.69	1.98	1.26	1.2	1.3	1.4	378	402	350
Sub treatments (Phosphorus levels)									
S1: 100 % RDP	13.75	17.19	15.47	17.5	17.3	17.4	6017	6186	6351
S2: 75 % RDP	13.31	17.00	15.16	17.0	17.3	17.1	5885	6114	6250
S3: 50 % RDP	13.19	16.66	14.92	16.5	17.0	16.8	5798	5963	6130
S4: 25 % RDP	11.63	14.25	12.94	15.3	15.8	15.8	5509	5791	5900
S5: 0 % RDP (Control)	10.94	12.75	11.84	14.5	15.3	15.5	5253	5622	5688
SEm(±)	0.22	0.72	0.37	0.5	0.3	0.3	119	93	88
CD(P=0.05%)	0.69	2.22	1.13	1.4	1.0	1.0	366	285	271
Interaction effect									
Main at same level of sub treatment									
SEm(±)	0.34	1.38	0.72	1.2	0.6	1.0	302	194	171
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Subatsame level of maintreatment									
SEm(±)	0.16	0.59	0.29	0.5	0.2	0.3	114	72	67
CD(P=0.05%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

S_1 (170.3 cm) over S_4 and S_5 but on par with S_2 (145.3 cm) and S_3 (138.9 cm) during 2018. Similar trend was observed at harvest and mean of two years. These results are in conformity with Vijaya Bhaskar Reddy *et al.* (2018).

Significantly higher dry matter production was recorded by raised beds (M_1) at30 (1224 kg ha^{-1}),60 DAS (6885 kg ha^{-1}) and at harvest (13685 kg ha^{-1}) than flatbeds(M_2)(959, 5537, 12802 kg ha^{-1}) respectively during 2018. Similar trend was noticed in 2019 and for mean of two years. These results are in conformity with the findingsofHarish *et al.* (2021). Among the phosphorus levels, $S_{1,}$ S_2 and S_3 were recorded significantly higher dry matter production over $S_4$and S_5 but among themselves they were on par with each other. Lowerdry matter production (904 kg ha^{-1}) recorded under S_5 which was on par with S_4 (957 kg ha^{-1}) at 30 DAS during 2018.

At 60 DAS, significantly higher dry matter production was registered with S_1 (6836 kg ha^{-1}) over S_4 and S_5which was on par with S_2 (6565 kg ha^{-1}) and S_3 (6506 kg ha^{-1}) during 2018. Similar trend was observed at harvest. Similar trend was noticed during 2019 and for mean of two years. Interaction effect at main at same level of sub treatments and sub treatments at same level of main treatments found to be non significant.

Girth of cob was significantly influenced by land configurations during both the years. Higher girth of cob (13.50 cm) recorded with raised bed over flatbed (11.63 cm) during 2018. Similar trend was noticed during 2019 and for the mean of two years. Similar results are in line with the findings of Kumar and Chawla (2015) where higher yield attributes in raised planted might be attributed to access of roots to nutrients and water resulting in good plant growth.With regard to phosphorus levels significantly higher girth of cobwasobtained with S_1 (13.75 cm) followed by S_2 (13.31 cm) and S_3 (13.19 cm) which were on par with each other and significantly superior over S_4 and S_5. While lowest girth of cob registered with S_5(10.94 cm) which was on par with S_4 (11.63 cm) during the year 2018. Similar trend was observed during 2019 and for mean of two years. Interaction effect at main at same level of sub treatments and sub treatments at same level of main treatments found to be non significant. Number of seed rows cob^{-1} was significantly influenced by land configurations during both the years. Higher number of seed rows cob^{-1} (17.1) recorded with raised bed over flatbed (15.2) during 2018. Similar trend was noticed during 2019 and for the mean of two years. Similar results are in line with the findings of Kumar and Chawla (2015). With regard to phosphorus levels significantly higher number of seed rows cob^{-1} was obtained with S_1 (17.5) followed by S_2 (17.0) and S_3 (16.5) which were on par with each other and significantly superior over S_4 and S_5. Grain yield was significantly influenced by land configurations during both the years. Higher grain yield (5888 kg ha^{-1}) recorded with raised bed over flatbed (5496 kg ha^{-1}) during 2018. The percentage increase in grain yield under raised bed over flatbed ranged from 7.13 to 9.73 during 2018 and 2019 respectively. These findings are in line with the findings of earlier studies conducted by Kumar and Chawla (2015). The increasing phosphorus levels resulted in significantly higher grain yield with S_1 (6017 kg ha^{-1}) followed by S_2 (5885 kg ha^{-1}) and S_3 (5798 kg ha^{-1}) which were on par with each other and significantly superior over S_4 and S_5. While lowest grain yield was registered with S_5 (5253 kg ha^{-1}) which was on par with S_4 (5509 kg ha^{-1}) during the year 2018. Similar trend was observed during 2019 and for mean of two years. Interaction effect at main at same level of sub treatments and sub treatments at same level of main treatments found to be non significant. The results are in conformity with the observations of Kumar *et al.* (2019) and Bekele *et al.* (2019).

CONCLUSION

Among planting methods, higher growth and yield of maize was recorded under raised bed method. Among phosphorus levels studied, 50 % RDP and 25% RDP recorded on par performance in terms of growth and yield of maize to that of 100 % RDP which indicated that phosphorus levels can be reduced to even 50% RDP to get equal yield of 100% RDP particularly in high phosphorus soils.

REFERENCES

Bekele, G., Dechassa, N., Tana, T and Sharma, J.J. 2019. Effect of nitrogen, phosphorus and vermicompost fertilizers on productivity of groundnut (Arachis hypogaea L.) in Babile, Eastern Ethiopia. *Agronomy Research*. 17.

Directory of Economics and Statistics, 2020-21. Ministry of Agriculture and Farmers Welfare.Government of India.https://eands.dacnet.nic.in.

Harish, M.N., Choudhary, A.K., Dass, A., Singh, V.K., Pooniya, V and Varatharajan, T. 2021. Tillage and phosphorus management in maize (*Zea mays* L.) under maize–wheat cropping system. *Indian Journal of Agricultural Sciences*. *91(1):*117-122.

Kumar M and Chawla J S (2015) Influence of methods of sowing on productivity of spring maize (*Zea mays* L.) hybrids. *Journal of Plant Science Research.*31: 97-99.

Kumar, D.P., Shankar, T and Maitra, S. 2019. Growth, yield and quality of summer groundnut (Arachis hypogaea L.) as affected by graded levels of phosphorous. *International Journal of Bioresource Science*. 6(2): 81-86.

Vijaya Bhaskar Reddy, U., Prabhakara Reddy, G., Srinivasa Reddy, M and Kavitha P. 2018. Effect of different nitrogen and phosphorus levels on growth and yield of maize during *kharif* season.*International Journal of Current Microbiology and Applied Sciences. 7*(1): 3548-3555.

Vishuddha Nand, Vinay Kumar Patel and Ashish Kumar Srivastav. 2022. “Effect of land configuration and moisture regimes on productivity of hybrid maize (Zea mays L.) in summer season. *International Journal of Plant and Soil Science.* 34(1): 63-70.

Research Article
The J. Res. PJTSAU 51(1&2) 69-74, 2023

CONSTRAINTS ANALYSIS OF FARMERS IN ADOPTION OF PRECISION FARMING TECHNOLOGIES IN TELANGANA STATE

P. NIKITHA[1], V. SUDHA RANI[2], V. RAVINDER NAIK[3], B. PADMAJA[3] and D. SRINIVASA CHARY[4]

[1]Department of Agricultural Extension, College of Agriculture,PJTSAU, Hyderabad, Telangana
[2]Director of Extension, Administrative Office, PJTSAU, Hyderabad, Telangana
[3]Department of Agricultural Extension, College of Agriculture, PJTSAU, Hyderabad, Telangana
[3]AICRP on Weed Management, PJTSAU, Hyderabad, Telangana
[4]Department of Statistics & Mathematics, College of Agriculture, PJTSAU, Hyderabad, Telangana

Date of Receipt: 30-01-2023 Date of Acceptance: 27-02-2023

ABSTRACT

This study was attempted to identify the constraints faced by farmers in adoption of precision farming technologies transferred by extension professionals. Three districts of Telangana state were purposively selected for the study. A sample of 120 respondents were surveyed under the study. The survey results showed that among the perceived constraints related to the farmers in adoption of precision farming technologies, majority (97.50%) identified Lack of subsidy from the government as their major constraint.It was found that majority (95.83%) of the respondents suggested that the awareness programmes and motivational campaigns need to be conducted by extension personnel to generate awareness and motivation among farmers for popularization of precision farming technologies.

The present agriculture scenario in India has led to certain vital points of concern for the planners and agricultural scientists to feed its growing population. Land is precious natural resource for agriculture and per capita availability of the land has decreased drastically to nearly one third from 0.46 ha in 1951 to 0.15 ha in 2016-17. This led the agricultural sector with the need to increase productivity of existing land by increasing number of crops or improving the input efficiency like fertilizers, herbicides, pesticides and irrigation etc. Agricultural production system is an outcome of a complex interaction of seed, soil, water and agro-chemicals. Hence with the sole pursuit of high productivity in order to meet the ever growing demand for agricultural products, it has resulted in indiscriminate utilization of resources which in turn resulted in neglecting the critical linkage between agriculture and the environment and has posed a threat to future of Indian agriculture on sustainable basis. Therefore judicious management of inputs is essential for the sustainability of such a complex system. It is clear that more accurate agricultural management practices with improved technology have the potential to benefit the farmer financially. Indiscriminate use of inputs coupled with improper management practices over a longer period has resulted in land degradation and decline in its productivity. Inspite of these the human population continues to grow steadily with the shrinking resources being used for production situates great challenge against Indian farming system to attain food and environmental security. To counter these twin challenges in the country like India there is a urgent need of application of modern Hi-tech technologies for enhancing the productivity and sustainability of farming system for long term on scientific basis. Among the technological developments, Precision farming (PF) looks a win-win strategic advancement technology towards improving the potential of agricultural land to produce crops on sustainable basis and to increase agriculture productivity in the future (Kumar *et al.,* 2017). Raj Khosla (2008) stated that precision agriculture is doing the right thing, in the right place at the right time. From the farmer's perspective, precision agriculture is primarily driven by economic return, but, in many cases, site-specific management also provides a positive environmental impact. Soil and water quality can benefit

---

Email: nikithaagext@gmail.com

from reduced or targeted application of input such as nutrients, pesticides, and irrigation water. The other very significant benefit of precision farming is reduced soil compaction and erosion (Lowenberg- DeBoer, 2004). The success of future farming practices, output, efficiency and sustainability, would rely heavily on "farming the data" as much as "farming the land" and we can manage what we can measure. (Souhza Filho *et al.,* 2011). Therefore, agricultural research seeks the generation of new technologies to reorient the current and future needs and constraints.(references quoted in text)

Precision farming has emerged as a promising option in modern agriculture which enhances judicious crop management through application of farm inputs only in precise amounts to get increased average yields compared to conventional farming techniques. Precision farming helps in dealing with this challenge by proper and effective management of soil and crop variability with the use of information technology.

MATERIAL AND METHODS

An *Ex-post-facto* research design was used in the present investigation. Three districts of Telangana state namely Nizamabad district from Northern Telangana zone, Warangal district from Central Telangana zone and Ranga Reddy district from Southern Telangana zone were selected purposively for the study based on the frontline extension activities promoted related to precision farming technologies in major crops. Six mandals from three districts i.e, from Nizamabad district, Kotgiri and Armurmandals, from Warangal district Ghanpur (station) and Atmakurmandals, from Ranga Reddy district Yacharam and Manchalmandals were selected as sample. Two villages were selected purposively from each mandal which includes the adopted villages of ICAR/SAU from one mandal and frontline extension activities promoted villages by the department of agriculture & horticulture on precision farming technologies in major crops from another mandal thus constituting 12 villages for the study. Ten farmers from each village were selected purposively based on the adoption of precision farming technologies in major crops thus constituting the sample size of (10x12) 120 respondents for the study.

Constraints in adoption was operationally defined as the difficulties or problems faced by the farmers in adoption of precision farming technologies. The respondents were asked to express the problems faced by them in adoption of precision farming technologies transferred by the extension professionals. The responses stated by the respondents were recorded. The results were expressed in the form of frequencies and percentages for each problem for the purpose of discussion.

Suggestions were operationally defined as solutions offered by the farmers for continuous adoption of precision farming technologies. Respondents were asked to offer their suggestions in order to adopt the precision farming technologies being transferred by the extension professionals that are relevant to their farming situations and were also asked for measures to overcome the problems of technology rejection/ discontinuance of precision farming technologies by them. The results were expressed in the form of frequencies and percentages for the purpose of discussion.

RESULTS AND DISCUSSION

1. Constraints expressed by the respondents on adoption of precision farming technologies

It could be observed from the Table.1 that among the perceived farmer related constraints in adoption of precision farming technologies, majority (98.33%) of respondents identified small size fragmented landholdings as their major problem followed by lack of knowledge about precision farming technologies (91.67%), Lack of awareness about precision farming technologies (87.50%), Lack of motivation to adopt from officials (83.30%), Difficulty in understanding the usage of precision farming technologies (79.16%), Low literacy level of farmer (75.00%), Lack of self-confidence to adopt the precision farming technologies (66.67%) and Rigidity to adopt precision farming technologies as they believe in traditional farm practices (62.50%) in the order of priority.

Among the perceived technological constraints, majority (97.50%) opined that high infrastructure requirement followed by complexity of technology usage (90.83%), lack of dissemination of the technology related to precision farming which is compatable to their farming situations (87.50%), lack of practicability of precision farming technologies transferred (85.00%), limitation of technology usage (83.33%), Prohibitive costs of precision farming technologies (73.33%) and low observability of precision farming technologies transferred (70.83%) in the order of priority.

Among technical constraints majority (95.83%) of the farmers reported lack of technical Know-how as major constraint followed by non availability of skilled labour (93.33%), lack of technical skills to assess in-field variations (85.00%) and lack of awareness of agro-environmental problems (81.67%) in the order of priority.

Among economic constraints majority (100.00%) identified lack of subsidy from the government as major constraint followed by high initial investment (98.33%), inadequate financial support (90.83%), high operational cost (84.16%), low annual income of farmers (81.67%), lack of assets like land, farm inputs etc (74.16%) and market Imperfection (62.50%) in the order of priority.

Among the perceived social constraints, majority (98.33%) opined that Lack of success stories related to precision farming technologies as major constraint followed by Lack of support from other social groups for adoption of precision farming technologies (97.50%), Lack of confidence among the community members to adopt the precision farming technologies due to fear of failure (93.33%), Overriding isolated approach over community spirit (91.67%), Lack of community action for adoption of precision farming technologies (84.16%), Lack of enthusiasm among the community members to adopt the precision farming technologies (76.67%) and Lack of regular meetings by the community regarding adoption of precision farming technologies (68.33%) in the order of priority.

Among extension related constraints majority (98.33%) identified lack of dissemination of the precision farming technologies which are compatable to their farming situations as major constraint followed by lack of training assistance related to precision farming technologies (95.83%), less number of Frontline demonstrations related to precision farming technologies (94.16%), lack of skill oriented training programmes related to precision farming technologies (93.33%), lack of training skills among officials (91.67%), The precision farming technologies demonstrated were not location specific (79.16%) and lack of continuous technical guidance and supervision (75.00%) in the order of priority.

Table 1. Constraints faced by farmers in adoption of precision farming technologies

(N=120)

S No	Perceived Constraints	Frequency*	Percentage	Rank
A.	**Farmer related constraints**			
	1. Lack of awareness about precision farming technologies.	105	87.50	III
	2. Lack of motivation to adopt from officials.	100	83.33	IV
	3. Small size fragmented land holdings.	118	98.33	I
	4. Low literacy level of farmer.	90	75.00	VI
	5. Lack of knowledge about precision farming technologies.	110	91.67	II
	6. Rigidity to adopt precision farming technologies as they believe in traditional farm practices.	75	62.50	VIII
	7. Lack of self confidence to adopt the precision farming technologies.	80	66.67	VII
	8. Difficulty in understanding the usage of precision farming technologies.	95	79.16	V
B.	**Technological constraints**			
	1. Complexity of technology usage.	109	90.83	II
	2. Limitation of technology usage.	100	83.33	V

S No	Perceived Constraints	Frequency*	Percentage	Rank
	3. High infrastructure requirement.	117	97.50	I
	4. Lack of dissemination of the technology related to precision farming which is compatable to their farming situations.	105	87.50	III
	5. Low observability of precision farming technologies transferred	85	70.83	VII
	6. Prohibitive costs of precision farming technologies.	88	73.33	VI
	7. Lack of practicability of precision farming technologies transferred.	102	85.00	IV
C	**Technical constraints**			
	1. Lack of technical Know-how.	115	95.83	I
	2. Non availability of skilled labour.	112	93.33	II
	3. Lack of technical skills to assess in-field variations.	102	85.00	III
	4. Lack of awareness of agro-environmental problems.	98	81.67	IV
D	**Economic constraints**			
	1. High initial investment.	118	98.33	II
	2. High operational cost.	101	84.16	IV
	3. Inadequate financial support.	109	90.83	III
	4. Lack of subsidy from the government.	120	100.0	I
	5. Lack of assests like land, farm inputs etc.	89	74.16	VI
	6. Low annual income of farmers.	98	81.67	V
	7. Market Imperfection.	75	62.50	VII
E	**Social constraints**			
	1. Lack of confidence among the community members to adopt the precision farming technologies due to fear of failure.	112	93.33	III
	2. Lack of community action for adoption of precision farming technologies.	101	84.16	V
	3. Lack of support from other social groups for adoption of precision farming technologies.	117	97.50	II
	4. Overriding isolated approach over community spirit	110	91.67	IV
	5. Lack of enthusiasm among the community members to adopt the precision farming technologies.	92	76.67	VI
	6. Lack of success stories related to precision farming technologies.	118	98.33	IV
	7. Lack of regular meetings by the community regarding adoption of precision farming technologies.	82	68.33	II
F	**Extension constraints**			
	1. Lack of training assistance related to precision farming technologies.	115	95.83	II
	2. Lack of training skills among officials.	110	91.67	V

S No	Perceived Constraints	Frequency*	Percentage	Rank
	3. Lack of dissemination of the precision farming technologies which are compatable to their farming situations.	118	98.33	I
	4. Lack of skill oriented training programmes related to precision farming technologies.	112	93.33	IV
	5. Less number of Frontline demonstrations related to precision farming technologies.	113	94.16	III
	6. The precision farming technologies demonstrated were not location specific.	95	79.16	VI
	7. Lack of continuous technical guidance and supervision.	90	75.00	VII

2. Suggestions offered by the respondents for adoption of precision farming technologies

From the Table. 2 it was evident that majority (95.83%) of the respondents suggested that awareness programmes and motivational campaigns need to be conducted by extension personnel to generate awareness and motivation for popularization of precision farming technologies followed by presence of subsidy from the government (93.33%), availability of training assistance related to precision farming technologies (90.00%), need of Skill oriented training programmes related to precision farming technologies (87.50%), presence of technical Know-how (86.67%), The precision farming technology transferred should be compatable to their farming situation (83.33%), availability of adequate credit from financial institutions (81.67%), use of low cost, simple, effective farm technology (80.83%), presence of location-specific precision farming technologies (79.16%), presence of success stories related to precision farming technologies (75.00%), availability of skilled labour (73.33%), presence of continuous technical guidance and supervision (71.66%), ease in understanding the usage of precision farming technologies (68.33%), more number of Frontline demonstrations related to precision farming technologies (66.67%) and presence of community action in adoption of precision farming technologies (62.50%) in the order of priority.

Table 2. Suggestions as given by the respondents for adoption of precision farming technologies.

(N=120)

S No	Suggestions	Frequency*	Percentage	Rank
1.	Awareness programmes and motivational campaigns need to be conducted by extension personnel to generate awareness and motivation for popularization of precision farming technologies.	115	95.83	I
2.	Need of Skill oriented training programmes related to precision farming technologies.	105	87.50	IV
3.	Presence of subsidy from the government.	112	93.33	II
4.	The precision farming technology transferred should be compatable to their farming situation.	100	83.33	VI
5.	Use of low cost, simple, effective farm technology.	97	80.83	VIII
6.	Presence of technical Know-how.	104	86.67	V
7.	Availability of training assistance related to precision farming technologies.	108	90.00	III

S No	Suggestions	Frequency*	Percentage	Rank
8.	Presence of location-specific precision farming technologies.	95	79.16	IX
9.	Availability of adequate credit from financial institutions.	98	81.67	VII
10.	Presence of community action in adoption of precision farming technologies.	75	62.50	XV
11.	Presence of success stories related to precision farming technologies.	90	75.00	X
12.	Availability of skilled labour.	88	73.33	XI
13.	Presence of continuous technical guidance and supervision.	86	71.66	XII
14.	More number of Frontline demonstrations related to precision farming technologies.	80	66.67	XIV
15.	Ease in understanding the usage of precision farming technologies.	82	68.33	XIII

CONCLUSION

It could be concluded from the paper that awareness programmes and motivational campaigns need to be conducted by extension personnel to generate awareness and motivation among farmers for popularization of precision farming technologies. However, Precision farming is still only in the early stages of implementation in most developing countries. The strategic support from the public and private sectors is also in the conception stage. Lack of information, connectivity problems faced in remote areas and lack of financial support are hurdles in the path of Precision Agriculture. Successful adoption of Precision farming comprises of three phases including exploration, analysis and execution. While exploration and analysis are way ahead, execution is steadily catching-up. Precision farming addresses both economic and environmental issues that surround agriculture production today. Coordination between famers and both the MNCs and the government is gaining momentum. However, concerns about cost-effectiveness and the most effective ways to use the technological tools we now possess, still remains a work-in-progress. In the light of tomorrow's expected need and today's urgent requirement, Precision farming needs to become the only choice and not a choice in the field of agriculture.

REFERENCES

Khosla R (2008), Paper presented on Precision Agriculture In: The 9th International Conference on Precision Agriculture July 20-23.

Kumar, S., Karaliya, S.K., Choudhary, S. 2017. Precision farming technologies towards enhancing productivity and sustainability of rice-wheat cropping system. *International Journal of Current Microbiology and Applied Sciences*, 6(3): 142-151.

Lowenberg-DeBoer, Lambert, D.M., Peone, J. 2004. Precision Farming: Adoption, Profitability and making better use of data, Site Specific Management Center - Purdue University.

Souhza Filho, H. M., Buanian, A. M., Silveira, J. M. F. 2011. Adoption of Precision Agriculture technologies by farmers: A systematic review and proposition of an integrated conceptual framework. *Annual Proceedings and workshop on Technologia*, Brasília. 28(1): 223-2.

Research Article
The J. Res. PJTSAU 51(1&2) 75-81, 2023

DEVELOPMENT AND EVALUATION OF PASSION FRUIT-TOMATO PROBIOTIC DRINK

P. M. MEERA, C. L. SHARON, SEEJA THOMACHAN, E. R. ANEENA and P. S. LAKSHMY

Department of Community Science, College of Agriculture,
Kerala Agricultural University, Vellanikkara, Thrissur- 680 656

Date of Receipt: 07-01-2023 Date of Acceptance: 27-01-2023

ABSTRACT

The growing demand for probiotics has widened the scope for innovation and development of new probiotic products. Passion fruit is as an underutilised fruit crop and a good source of vitamins, like A and C and minerals. Hence, an attempt was made to develop a probiotic drink containing passion fruit and tomato involving *L. acidophilus.* In the study, five treatments along with one control with three replications were standardized. The most acceptable combination (70% Passion fruit + 30 % Tomato) of the drink was pasteurised at 80^{0}C for 20 minutes and allowed to cool. The pasteurised drink was then inoculated with 4ìl *L.acidophilus* and incubated for a period of one hour at 37^{0}C which had availability of 13. 39 log cfu g^{-1}. The probiotic passion fruit based drink along with its control (non-probiotic drink) had TSS content of 12.30 and 13.10 ^{0}Brix, titratable acidity of 2.68 % and 1.67 %, total sugar content of 14.28 and 15.20g $100g^{-1}$, reducing sugar content of 3.08 and 4.18 g $100g^{-1}$, protein content of 1.37 and 0.61 g $100g^{-1}$, carbohydrate content of 13.94 and $14.74100g^{-1}$, energy of 61.24 and 61.40 Kcal, ascorbic acid of 10.52mg $100g^{-1}$ and 13.20 mg $100g^{-1}$ and total ash 2.07 % and 2.05 %, respectively.

Keywords: Passion fruit, *Lactobacillus acidophilus*, Tomato, Organoleptic evaluation

The deeply entwined relationship between food and health benefits has been a fertilefield for research since the dawn of the scientific age. This in turn has triggered thedevelopment of functional food products. Probiotic food isan example for such type of food which provide various beneficial effects on human body. Probiotics are live microorganisms when administered in adequate amounts confer a health benefit on the host (WHO, 2001). Addition of probiotics to food provides several health benefits such as decreasing the number of pathogenic gastrointestinal microorganisms, reducing the serum cholesterol level, improving the gastrointestinal function, strengthening immune system, protection of proteins and lipids from oxidative damage and has anticarcinogenic and antimutagenic effects (El-Deeb *et al.*, 2018). The growing demand for probiotics has widened the scope for innovation and development of new probiotic products. According to Krishnakumar and Gordon (2001) the widely used probiotic strains are lactobacilli, bifidobacterium and streptococci. *Lactobacillus acidophilus* is one of the most commonprobiotic bacteria which have beneficial effects on the microbiota of the gastrointestinal tract.

Probiotic products are usually marketed as dairy products. This initiated the development of non-dairy based probiotic products. The presence of vitamins, minerals, antioxidant compounds, dietary fibres and minerals, makes fruits and vegetables idealvehicles for probiotic culture. The incorporation of probiotics to underutilised fruits like passion fruit can improve their acceptability, nutrient profile and market potential.

Yellow passion fruit (*Passiflora edulisflavicarpa*), which is native to tropical America, is considered as an underutilized fruit crop but can be a good source of vitamins, like A and Cand minerals (Kishore *et al.*, 2010). Passion fruit stands out not only for its exotic and unique flavour and aroma but also for its amazing nutritional and medicinal properties. Passion fruit contains anti-inflammatory, anticonvulsant, antimicrobial, anticancer, antidiabetic, antihypertensive, antisedative, antioxidant properties and is used in treating conditions such asosteoarthritis, asthma and also act as colon cleanser (Thokchom and Mandal, 2017). Considering these factors, passion fruit can serve as a potential science for the incorporation of

Email: sharon.cl@kau.in

probiotics. If a probiotic product is developed from this fruit, it would definitely attract consumer attention and improve its economic value.

MATERIAL AND METHODS

For the study, ripepassion fruits (yellow variety) were collected from Cashew Research Station of Kerala Agricultural University. Tomato and all other ingredients needed for the study were procured from the local market. Pure cultures of the probiotic strain *L. acidophilus* MTCC 10307 needed for the study was obtained from Institute of Microbial Technology (IMTECH), Chandigarh.

Standardisation of passion fruit drink

Drink combinations were prepared using ripe passion fruit and tomato (Table 1). For the preparation of passion fruit based drink, the standard procedure of the FSSAI (2010) was followed. The quantity of ingredients used for preparation of drink was taken by calculating the acidity and TSS of the sample and then adding other ingredients in accurate quantity to maintain the FSSAI limits. Juices were strained and measured. Sugar syrup was prepared by heating appropriate amount of sugar in required amount of water. After cooling, measured quantity of juice was mixed with sugar syrup. It was then pasteurized at 80^{0}C for 20 minutes.

Organoleptic evaluation

Organoleptic evaluation of the drinks were conducted using a score card (9 point hedonic scale) by a panel of 15 judges. A series of acceptability trials were carried out using simple triangle test at the laboratory level to select the panel of judges between the age group of 18-35 years as suggested by Jellinek(1985). Based on the organoleptic qualities the best combination of the drink was selected.

Development of passion fruit based probiotic drink

For the preparation of passion fruit based drink, different combinations of passion fruit juice (50% to 90%) and tomato juice (10% to 50%) were tried. The selected fruit drink (25ml) was pasteurised at 80^{0}C for 20 minutes and allowed to cool. The pasteurised drink was then inoculated with 4ìl *L. acidophilus* and incubated for a period of one hour at 37^0 C. The 5 probiotic passion fruit based drinks along with their control (non-probiotic drink) were then packed in food grade plastic bottles and stored under refrigerated condition.

Viability of *L. acidophilus* in passion fruit based probiotic drink

The viable count of *L. acidophilus* present in the passion fruit based probiotic drink was enumerated by serial dilution and plate count method as detailed by Agarwal and Hasija (1986). The microbial enumeration was completed by pour plate method using MRS agar and the results are expressed as 10^9 cfu g^{-1}.

Physicochemical qualities of the drinks

The developed probiotic drink along with its control (non-probiotic sample) was assessed for TSS, titratable acidity, reducing sugar and total sugar according to the method of Ranganna (1986). Protein, carbohydrate, energy and ascorbic acid of the drinks were determined according to the standard procedure of Sadasivan and Manickam (1992). Total ash was analysed by the procedure of AOAC (1994).

Statistical analysis

The observations were analysed statistically in completely randomised design (CRD). The scores of organoleptic evaluations were assessed by Kendall's coefficient of concordance and the differences among treatments in nutritional qualities were assessed using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Standardisation of combination of ingredients in the drink

For the preparation ofpassion fruitbased drink, different combinations of passion fruit juice (50% to 90%) and tomato juice (10% to 50%) were tried (Table 1). Blending of two or more juices enable to produce beverages of superior quality with sensory, nutritional and medicinal properties (Bhagwan and Awadhesh, 2014). The mean scoresfor the organoleptic evaluation of passion fruitbased tomato drinks (Table 2), revealed that the treatment which contained 70 percent passion fruit juice and 30 per cent tomato juice (T$_3$) scored maximum for the organoleptic attributes, with a mean score of 8.88, 8.02, 7.63, 8.81, 7.84 and 7.83 for appearance, colour, flavour, texture, taste and overall acceptability, respectively and thetotal score of this treatment was 49.01 (Table 2). The scores of

Table 1. Proportion of ingredients in the passion fruit drinks

Treatments	Combinations
T_0(Passion fruit) - Control	100%
T_1 (Passion fruit + Tomato)	90% + 10 %
T_2 (Passion fruit + Tomato)	80% + 20 %
T_3 (Passion fruit + Tomato)	70% + 30 %
T_4 (Passion fruit + Tomato)	60% + 40 %
T_5 (Passion fruit + Tomato)	50% + 50 %

Table 2. Mean score and mean rank scores for the organoleptic qualities of passion fruit based drinks

Treatments	Mean score						Total Score
	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability	
T_0- Control (100% Passion fruit)	8.57 (3.93)	8.48 (4.30)	7.84 (3.07)	8.04 (4.47)	7.82 (4.47)	8.10 (4.13)	48.89
T_1- (90% Passion fruit +10% Tomato)	7.53 (3.40)	7.62 (3.07)	7.57 (3.27)	7.82 (3.37)	7.46 (2.83)	7.60 (2.63)	45.60
T_2- (80% Passion fruit + 20% Tomato)	7.68 (3.27)	7.75 (3.37)	7.68 (3.30)	8.02 (3.40)	7.84 (3.73)	7.79 (3.77)	46.76
T_3- (70% Passion fruit + 30% Tomato)	8.88 (4.60)	8.02 (4.17)	7.63 (4.43)	8.81 (4.27)	7.84 (3.93)	7.83 (3.90)	49.01
T_4- (60% Passion fruit + 40% Tomato)	7.64 (3.10)	7.68 (2.63)	7.53 (2.97)	7.64 (3.20)	7.17 (3.20)	7.53 (2.83)	45.19
T_5 - (50% Passion fruit + 50% Tomato)	7.46 (2.47)	7.34 (2.53)	7.22 (2.97)	7.26 (2.10)	6.77 (2.53)	7.21 (2.47)	43.26
Kendall's W value	0.25	0.34	0.29	0.34	0.36	0.38	

organoleptic evaluations were assessed by Kendall's coefficient of concordance and it was found that there was agreement between the judges.

Earlier, Shaw and Wilson (1988) prepared passion fruit orange blended nectar with sensory acceptance score between 5.1 and 6.8 and also concluded that nectar having high proportion of passion fruit had better acceptance. Deliza *et al.* (2005) reported that, passion fruit juice prepared in the ratio 6:9 (water:juice) and 13g of sugar in 100ml have strong fruity passion fruit aroma, sweet flavour and refreshing mouthfeel.A passion fruit nectar developed by Charan (2016) had total score of 52.1, 50.9 and 47.3, respectively for first, second and third months of storage under ambient condition.

Viability of *L. acidophilus* in passion fruit based probiotic drink

L. acidophilus present in the drinks was enumerated and given in Table 3. The viable count of *L. acidophilus* was 13.39 log cfu g^{-1} as against the desired level of 8 log cfu g^{-1} in probiotic foods.

Beverages from fruits, vegetables, cereals etc. are the new probiotic products that serveas a good medium for probiotic organism to survive and are also equally accepted among allage groups (Prado *et al.*, 2008). Probiotication of fruit juice is important to provide health beneficial products toconsumers who are allergic to milk products. Even though fruit juices are established inmarkets, market for probiotic fruit juices are growing. Fruit juice act as a good medium for growth ofprobiotic organism (Mattila *et al.*, 2002) and also to maintain minimum therapeuticlevel 10^9 cfu/g or ml (WHO, 2001).

Table 3. Viable cell count of *L. acidophilus* in the drinks

Fruit juice drink	Viable count (log cfu g^{-1})
Non-probiotic drink	Nil
Probiotic drink	13.39

Babu *et al.* (1992) reported that the growth of *L. acidophilus* was stimulated by addition of tomato juice to skimmed milk and resulted in higher viable counts, shorter generation time and improved sugar utilisation with more acid production and lower pH. Yoon *et al.* (2004) said that the viable cell counts of tomato juice inoculated with*Lactobacillus acidophilus* increased till third week storage and reduced on fourth week ofstorage. The count was 1.4 ± 0.1 x109 during the first week and then increased to 2.4 ± 0.1 x 10^9 during third week. They concluded that the organism rapidly utilised tomato juice for cellsynthesis and also lactic acid production. The initial cell count of *Lactobacillus acidophilus* in tomato juice sample was 2.49x10^8 and after 72hr incubation, the cell counts of *L. acidophilus* increased to 2.95 x 10^8. Reports also say that the organisms utilise tomato juice sugar and increase lactic acidproduction without any additional nutrient addition or pH adjustments (Kaur *et al.*, 2016).

Physico-chemical qualities of the drinks

The physico-chemical qualities such asTSS, titrable acidity, total sugar, reducing sugar, protein, carbohydrate, energy, ascorbic acid and total ash in the probiotic and non-probiotic drinks were analysed (Table 4). There was significant reduction in the TSS content of probiotic drink (12.30° Brix) compared to non-probiotic drinks (13.10° Brix). The reduction may be due to the utilisation of sugars for the metabolic activity of the probiotic organism. This metabolic activity convert starch to fermentable simple sugars which is used by probiotic organisms (Adams *et al.*, 2008).

It was observed that there was significant increase in titratable acidity of probiotic drinks (2.68) compared to non-probiotic drink (1.67). Titratable acidity increased significantly (Pd”0.05) with increasing fermentation time irrespective of the medium. Similar finding was observed by Shukla (2013), in which, whey-pineapple juice blend gave higher titratable acidity for 5 and 10 hours of fermentation. Sivudu *et al* (2014) concluded that total sugar content of watermelon and tomato probiotic drink with *L. casei* asprobiotic organism was 20.70 ± 4.99 mg/ml and the probiotic culturesutilised sugar in the juice for their growth subsequently reducing the pH of the product.

The probiotic drinks showed a significantly lower content of total sugar and reducing sugar compared to non-probiotic drink. According to Yoon *et al.* (2004), a decrease in sugar and pH and increased acidity intomato juice inoculated and incubated with *Lactobacillus delbrueckii*, *L. acidophilus*, *L.plantarum* and *L. casei*and observed the sugar gets converted into acid in the presence of bacteriaand thus get reduced with time, and the acidity content increase. Fernandes *et al.* (2011) concluded that on pasteurising passion fruit juice there was difference in total sugar and reducing sugar. The pasteurized juice had 9.63 per cent totalsugar and 8.33 per cent reducing sugar.

A higher value of proteincontent was observed in the probiotic drink (1.37 g 100 g^{-1}) than non probiotic control (0.61g 100 g^{-1}). The carbohydrate content was higher in non-probiotic juice compared to probiotic samples. Total energy content was 61.40 Kcal and 61.24 Kcal in non-probiotic and probiotic drinks, respectively. Stanton*et al.* (2005) reported that both genera *Lactobacillus* and *Bifidobacterium*were reported to have high requirements of free aminoacids, peptides, vitamins and fermentable carbohydrates for their growth and development. The reduction in energy content of probiotic drink compared to non-probiotic drink was due to higher carbohydrate and fat content in fresh juice than probiotic juice (Rafiq *et al.*, 2016).

Non-probiotic passion fruit and tomato drink combination showed comparatively higher ascorbic content of (13.20 mg 100g^{-1}) than the probiotic drink (10.52 mg 100g^{-1}). Shukla *et al.* (2013) reported that reduction in ascorbic acid content of probiotic drinks may be due to pasteurisation of juice and exposure to light. The ascorbic acid content in RTS drink prepared by blending juices of passion fruit and cashew apple in different ratios such as 25:75, 50:50, 25:75 + ginger drops and 50:50 + ginger drops was 80.26 mg 100 g^{-1}, 79.73 mg 100 g^{-1}, 76.39 mg 100 g^{-1} and 79.29 mg 100 g^{-1}, respectively (Sobhana *et al.*, 2011). The study reported non-significant changes in the total ash of probiotic and non-probioticdrinks. As stated by Jood and Khetarpaul (2005), bacterial culture might increase the bioavailability of various minerals but there need not be any change in the total mineral content in probiotic foods.

CONCLUSION

It can be concluded that good quality probiotic drink can be prepared by using 70 % passion fruit juice and 30 % tomato juice with good acceptability, nutritional qualities and with a viable count of 13.39

Table 4. Physico-chemical qualities of the drinks

Treatments	TSS (° Brix)	Titrable acidity (%)	Total Sugar ($g100g^{-1}$)	Reducing sugar ($g100g^{-1}$)	Protein ($g100g^{-1}$)	Carbohydrate ($g\ 100g^{-1}$)	Energy (Kcal)	Ascorbic acid ($mg100g^{-1}$)	Total ash (%)
Non Probiotic (control)	13.10^{a}	1.67^{b}	15.20^{a}	4.18^{a}	0.61^{b}	14.74^{a}	61.40^{a}	13.20^{a}	2.05
Probiotic	12.30^{b}	2.68^{a}	14.28^{b}	3.08^{b}	1.37^{a}	13.94^{b}	61.24^{b}	10.52^{b}	2.07
CD Value (0.05)	0.0227	0.023	0.161	0.023	0.023	0.023	0.023	0.161	0.023
Significance	S	S	S	S	S	S	S	S	NS

S- Significant, NS- Non Significant

Values with different superscript differ significantly at 5%

DMRT Column wise comparison

log cfu/ ml. The probiotic passion fruit-tomato drink had a TSS content of 12.30 ^{0}Brix, 2.68 percent titratable acidity, 14.28 g 100g^{-1} $^{o=}$total sugarcontent, 3.08 g 100g^{-1} reducing sugarcontent, 1.37 g 100g^{-1} proteincontent, 13.94 100g^{-1} carbohydratecontent, 61.24 Kcal energy, 10 mg 100g^{-1} ascorbic acid and a total ash 2.07 percent. Passion fruit can be a suitable substrate for the development of probiotic foods with good nutritional profile.

REFERENCES

Adams, M.R., Moss, M.O and Mcclure, P. J. 2008. Bacterial agents of foodborne illness *Staphylococcus aureus*. Food Microbiology. (2): 252-256.

Agrawal, G.P and Hasija, S.K. 1986. Micro-organism in the laboratory: A Laboratory guide of Microbiology, Mycology and Plant Pathology. Print House (India), Lucknow. pp. 155-156.

AOAC (Association of Official Analytical Chemists). 1994. Official Method for Analysis. Association of Official Analytical Chemists. 14th Edition.Washington D.C, USA.pp.1141-1142.

Babu, V., Mital, B. K., and Garg, S. K. 1992. Effect of tomato juice addition on the growth and activity of Lacobacillus acidophilus. Int. J. Food Microbiol. 7(1): 67- 70.

Bhagwan, D and Awadhesh, K. 2014. Development and storage of mango ginger RTS beverage. International Journal of Food, Agriculture and Veterinary Science. 4(3): 15-20.

Charan, S. M. 2016. Value addition of passion fruit (*Passiflora edulis* Sims.). M.Sc. (Processing Technology) thesis submitted to Kerala Agricultural University, Thrissur.

Deliza, R., MacFie, H. A. L., and Hedderley, D. 2005. The consumer sensory perception of passion fruit juice using free choice profiling. J. Sensory Stud. 20(1): 17-27.

El-Deeb, N.M., Yassin, A.M., Al-Madboly, L.A., and El-Hawiet, A. 2018. A novel purified *Lactobacillus acidophilus* 20079 exopolysaccharide, LA-EPS-20079, molecularly regulates both apoptotic and NF-ÊB inflammatory pathways in human colon cancer. Microbial Cell Factories 17(1): 1-15.

Fernandes, A.G., Santos, G.M.D., Silva, D.S.D., Sousa, P.H.M.D., Maia, G.A and Figueiredo, R.W.D. 2011. Chemical and physicochemical characteristics changes during passion fruit juice processing. Food Science and Technology. 31(3): 747-751.

Food Safety and Standards Authority of India (FSSAI). 2010. Food safety and standards regulations. Retrieved from the website (fssai.gov.in.) on 25 May 2021.

Jellinek, G. 1985. Sensory Evaluation of Food: Theory and Practice. Ellis Horwood, Chichester, England.pp. 596 -598.

Jood, S and Khetarpaul, N. 2005. Improving nutritional quality of course cereals through probiotic fermentation. Processing Food Industry. Vol. 23:17-25.

Kaur, S., Kaur, H.P., and Grover, J., 2016. Fermentation of tomato juice by probiotic lactic acid bacteria. Int. J. Adv. Pharmacy Biol. Chem. 5(2): 212-219.

Kishore, K., Pathak, K. A., Shukla, R., and Bharali, R. 2010. Effect of storage temperature on physico-chemical and sensory attributes of purple passion fruit (*Passiflora edulis*). J. Food Sci. Tech. 48(4): 484- 488.

Krishnakumar, V. and Gordon, I.R. 2001. Probiotics: Challenges and opportunities. Dairy Industries Int. 66(2): 38-40.

Mattila-Sandholm, T., Myllarinen, P., Crittenden, R., Mogensen, G., Fonden, R., and Saarela M. 2002. Technological challenges for future probiotic foods. Int. Dairy J. 12:173–182.

Prado, F. C., Parada, J. L., Pandey, A., and Soccol, C. R. 2008. Trends in non-dairy probiotic beverages. Food Res. Int. 41(2): 111-123.

Rafiq, S., Sharma, V., Nazir, A., Rashid, R and Sofi, S.A. 2016. Development of probiotic carrot juice. Journal of Nutrition and Food Science. Vol.6: 2-5.

Ranganna, S. 1986. Manual of Analysis of Fruits and Vegetable Products. Tata Mc Graw Hill Publishing Co. Ltd, New Delhi.pp.130-131.

Sadasivam S and Manickam, A. 1992. Biochemical Methods (2nd Edition.). New Age International Private Limited, New Delhi. pp. 254-256.

Shaw, P. E. and Wilson III, C.W. 1988. Sensory evaluation of passion fruit - orange juice blends. Lebensmittel Wissenshaft und Technologie, 21: 358- 359.

Shukla, M., Jha, Y. K and Admassu, S. 2013. Development of probiotic beverage from whey and pineapple juice. Journal of Food Processing and Technology. 4(2): 1-4.

Sivudu, S.N., Umamahesh, K., and Reddy, O.V.S. 2014. A Comparative study on probiotication of mixed watermelon and tomato juice by using probiotic strains of Lactobacilli. Int J. Curr. Microbiol.Appl. Sci. 3(11): 977-84.

Sobhana, A., Mathew, J., AmbiliAppukutan, A and MredhulaRaghavan, C. 2011. Blending of cashew apple juice with fruit juices and spices for improving nutritional quality and palatability. Proceedings of International symposium on Cashewnut.International Society of Horticultural Science held during 9th December-12 December, 2011, Madurai. pp.375- 376.

Stanton, C., Ross, R. P., Fitzgerald, G.F and Sinderen, D.V. 2005. Fermented functional foods based on probiotics and their biogenic metabolites. Current Opinion in Biotechnology. 16(2): 198-203.

Thokchom, R. and Mandal, G. 2017. Production preference and importance of passion fruit (*Passiflora edulis*): A review. J. Agric. Eng. Food Technol. 4(1): 27-30.

WHO (World Health Organisation). 2001. Health and Nutritional Properties of Probiotics in Food Including Powder Milk with Live Lactic Acid Bacteria. WHO, Cordoba, Argentina. pp.168-169.

Yoon, K. Y., Edward, E. W., and Hang, D. Y. 2004. Probiotication of tomato juice by lactic acid bacteria. J. Microbiol. 42(4): 315-318.

ESSENTIAL REQUIREMENTS
FOR CONSIDERATION TO PUBLICATION

1. Research of not less than 2 years and of high standard will be considered as Research Article. If the research is not upto the standards it may be considered for Research Note.
2. M.Sc. Research should be submitted in the style and format of Research Note.
3. The total number of pages should not exceed 10 for Research Article and 5 for Research Note including tables and figures. The figures should be legible.
4. Prior research of more than 5 years before the date of submission will not be considered.
5. All the authors should subscribe for the Journal, otherwise articles are not considered for publication.
6. The manuscript should be submitted in duplicate as per the guidelines of the Journal to The Managing Editor, Journal of Research, AI&CC and PJTSAU Press, ARI Campus, Rajendranagar, Hyderabad - 500 030
7. The manuscript should accompany the declaration certificate and subscription enrollment form.
8. The authors should accept the editorial / referees comments until the quality of the article is improved.
9. The revised manuscript should be submitted in duplicate along with a soft copy.
10. **DD** may be drawn in favour of **"Principal Agricultural Information Officer, AI&CC and PJTSAU Press"** Payable at Hyderabad or Payment can be paid online at **http://thejournalofresearchpjtsau.com.**

    Subscription Tariff

    Annual

    Individual : Rs. 300/-

    Institution : Rs. 1200/-

    Life

    Individual (till retirement) : Rs. 1200/-

    Reprints Charges : Rs. 100/- per page
11. DD should be handed over/posted to The Managing Editor, The Journal of Research, AI&CC and PJTSAU Press, ARI campus, Rajendranagar, Hyderabad - 500 030.
12. Any corrrespondence related to the publication may be communicated to The Managing Editor, Journal of Research, AI&CC and PJTSAU Press, ARI campus, Rajendranagar, Hyderabad - 500 030.

GUIDELINES FOR THE PREPARATION OF MANUSCRIPT

1. Title of the article should be short, specific, phrased to identify the content and indicate the nature of study.
2. Names should be in capitals prefixed with initials and separated by commas. For more than two authors the names should be followed by 'and' in small letters before the end of last name. Full address of the place of research in small letters should be typed below the names. Present address and E-mail ID of the author may be given as foot note.
3. Manuscript should be written in English; spelling and grammar must be checked well. Author may get help using Microsoft Office Tools. Author must ensure that manuscript has not been submitted in any journal. Manuscripts should be type written in **12 size Times New Roman font with normal margins** (1" at top, bottom, left and right) and **line spacing of 1.5 throughout.**
4. The full length paper should have the titles ABSTRACT, KEYWORDS, MATERIAL AND METHODS, RESULTS AND DISCUSSION, CONCLUSION, REFERENCES - all typed in capitals and bold font - 12. **The Research Note will have only one title REFERENCES.**
    - **E-mail ID** will be followed by **Abstract** which will be followed by **Keywords** (indexing terms) maximum up to a 8 words in lower case only
    - e.g. **Keywords :** Genetic variability, disease resistance, high yielding variety (without a full stop at the end)
5. **ABSTRACT**: The content should include the year, purpose, methodology and salient findings of the study not exceeding 250 words and not below the 200 words (within 200-220). It should be so organised that the reader need not refer to the article except for details.
6. **INTRODUCTION** : Should be without title and indicate the reasons which prompted the research, objectives and the likely implications. The review of recent literature should be pertinent to the problem. The content must be brief and precise.
7. **MATERIAL AND METHODS** : Should include very clearly the experimental techniques and the statistical methods adopted. Citation of standard work is sufficient for the well known methods.
8. **RESULTS AND DISCUSSION** : Great care should be taken to highlight the important findings with support of the data well distinguished by statistical measures like CD, r, Z test etc. Too descriptive explanation for the whole data is not desirable. The treatments should be briefly expressed instead of abbreviations like T_1, T_2 etc. The discussion should be crisp and relate to the limitations or advantages of the findings in comparison with the work of others.

Tables

The data in tables should not be duplicated in graphs and vice versa. Mean data for main treatment effects should be presented with appropriate SE± and CD values wherever necessary. The 2 or 3 way tables should be furnished only if the results are consistent over years and are distinguished to have consideration of significant practical value. SE± and CD values however, should be furnished in the tables for all interactions and should be explained in the results and discussion. The treatments should be mentioned at least in short forms if they are lengthy, but not abbreviated as T_1, T_2 and T_3 etc. The weights and measures should be given in the metric system following the latest units eg. kg ha^{-1}, kg ha^{-1} cm, mg g^{-1}, ds m^{-1}, g m-3, C mol kg^{-1} etc.

- Figure/bar diagram/artwork with caption. Tables must be numbered in the run of the text. Text should include references to all tables
- Figures / values in the column of the table should be uniform regarding the number of digits after decimal point. One can show either one or two digits after decimal point depending on the types of data or values, e.g. (100.0), (0.0), (3.1) or (100.00) (0.00) (3.19)

Graph/bar diagram/artwork/figure

- All graphs or diagrams should have clarity to represent the values and should be well explained
- Avoid shading for better quality printing. Lines or bars of black and white only be preferred
- All Graphs/Bar Diagrams/Art Works/Figures should be presented in the run of the text

- In case of lack of knowledge or inability to follow the instructions as above, one may request Editor for further help after sending original excel data sheet

9. **CONCLUSION:** Should be precise, focused to the objective not exceeding 100 words.
10. **REFERENCES :** Literature cited should be latest. References dating back to more than 10 years are not desirable. **Names of authors, their spelling and year of publication should coincide both in the text and references**. The following examples should be followed while listing the references from different sources. List of references should be arranged alphabetically by authors' names, and chronologically per author.

Journals and Bulletins

Abdul Salam, M and Mazrooe, S.A. 2007. Water requirement of maize (*Zea mays* L.) as influenced by planting dates in Kuwait. Journal of Agrometeorology. 9 (1): 34-41.

Hu, J., Yue, B and Vick, B.A. 2007. Integration of trap makers onto a sunflower SSR marker linkage map constructed from 92 recombinant inbred lines. Helia. 30 (46): 25-36.

Books

AOAC. 1990. Official methods of analysis. Association of official analytical chemists. 15th Ed. Washington DC. USA. pp. 256.

Federer, W.T. 1993. Statistical design and analysis for intercropping experiments. Volume I: two crops. Springer - Verlag, Cornell University, Ithaca, New York, USA. pp. 298-305.

Thesis

Rajendra Prasad, K. 2017. Genetic analysis of yield and yield component in hybrid Rice *(Oryza sativa.* L). Ph.D Thesis submitted to Professor Jayashankar Telangana State Agriculutural University, Hyderabad.

Seminars / Symposia / Workshops

Naveen Kumar, P.G and Shaik Mohammad 2007. Farming Systems approach – A way towards organic farming. Paper presented at the National symposium on integrated farming systems and its role towards livelihood improvement. Jaipur, 26 – 28 October 2007. pp.43-46

Proceedings of Seminars / Symposia

Bind, M and Howden, M. 2004. Challenges and opportunities for cropping systems in a changing climate. Proceedings of International crop science congress. Brisbane –Australia. 26 September – 1 October 2004. pp. 52-54
(www.cropscience 2004.com 03-11-2004)

Typing : The article should be typed in 12 pt font on A_4 size paper leaving a margin of 2 cm on all sides. There should be a single line space between the rows in abstract and double line in rest. **Verify the manuscript thoroughly for errors before submitting it for publication.**

Note : Latest issue of the Journal may be referred. Further details can be obtained from the book "Editors style Manual, edn 4. American Institute of Biological Sciences, Washington DC".

REVIEW PROCESS

The articles will be initially screened by the editor. It will be sent to an expert for peer review only if it contains adequate original information and is prepared as per the guidelines. The author, then, may also be asked to revise it if the expert desires. After getting the article suitably revised and edited, it will be placed before the editor for a final decision. The accepted article will be finally checked for language and grammar by the english editor before being sent to the press. The decision however to publish the paper lies with the editor. Any article which is not able to meet the expected standards or is not prepared in conformity with guidelines will be rejected without assigning any reason.

URL : http://thejournalofresearchpjtsau.com
http://www.pjtsau.edu.in/Publications.aspx

E-mail : pjtsau.editor@gmail.com, paio.pjtsau@gmail.com

THE JOURNAL OF RESEARCH PJTSAU

DECLARATION CERTIFICATE TO BE SUBMITTED BY THE AUTHOR(S)

Certified that the article entitled____

____

1. is based on my / our original research work / M.Sc / Ph.D thesis (strike off whichever is not applicable)
2. The article has been seen by all the authors and the order of authorship is agreed.
3. The results presented have not been published or submitted for publication else where in part or full under the same or other title
4. The names of the authors are those who made a notable contribution.
5. **No authorship is given to anyone who did not make a notable contribution.**

S.No.	Name(s)	Present address	Permanent address	Signature
1.				
2.				
3.				

CERTIFICATE BY THE COMPETENT AUTHORITY

(Professor & Head of the Department/ Head of the station/ Associate Director of Research).

Certified that the article authored by ____

____

____

_______________ is fit for publication. It fulfills all the requirements for publication in The Journal of Research, PJTSAU.

Name :

Signature :

Office seal :

Note: In case if it is not possible to obtain the signature of a particular author for reasons beyond his/her reach, the reasons thereof should be explained.

Statement about ownership and other particulars about
THE JOURNAL OF RESEARCH PJTSAU
Form IV (See Rule 8)

1.	Place of Publication	:	Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad - 500 030
2.	Periodicity of Publication	:	Quarterly
3.	Printer's Name	:	**Dr. G. Sridevi**
	Nationality	:	Indian
	Address	:	Principal Scientist & Head, AINP on Pesticide Residues, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500 030
4.	Publisher's Name	:	**Dr. G. Sridevi**
	Nationality	:	Indian
	Address	:	Principal Scientist & Head, AINP on Pesticide Residues, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500 030
5.	Editor's Name		**Dr. G. Sridevi**
	Nationality	:	Indian
	Address	:	Principal Scientist & Head, AINP on Pesticide Residues, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500 030
6.	Name and address of the individuals who own the newspaper & partners or share holders holding more than one per cent of the total capital	:	Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad - 500 030

I, G. Sridevi hereby declare that the particulars given above are true to the best of my knowledge and belief.

G. Sridevi

Dated : 30-06-2023

Signature of Publisher

SUBSCRIPTION ENROLLING FORM

I/we, herewith enclose D.D. No... dated.................................for Rs. .... drawn in favour of **Principal Agricultural Information Officer, AI&CC and PJTSAU Press** as Individual (Annual/Life) or Institutional Annual Membership for The Journal of Research, PJTSAU for the calendar year (January - December).............

S.No.	Name of the Author(s)	Address for Correspondence	Name of the article contributed	Signature

Note : The receipt of payment will be sent only if a self addressed and stamped envelope is enclosed along with DD.

Printed at PJTSAU Press, Hyderabad and Published by Dr. G. Sridevi,
Principal Scientist & Head (Pesticide Residues) and Editor of The Journal of Research PJTSAU
Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad - 500 030
e-mail: pjtsau.editor@gmail.com, paio.pjtsau@gmail.com
URL: http://thejournalofresearchpjtsau.com, www.pjtsau.edu.in/publications