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COMPARISON OF RESPONSE OF GROUNDNUT GENOTYPES AT DIFFERENT PHOSPHORUS LEVELS

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ABSTRACT

Low phosphorus (P) availability in soil is one of the limiting factors affecting groundnut productivity by reducing leaf area and dry weight. This study evaluated groundnut genotypes for their ability to thrive and produce on calcareous soils with low phosphorus availability. Assessment of shoot biomass, root biomass, shoot P-concentration, kernel P-concentration, P-accumulation and yield were completed using three phosphorus levels and 23 groundnut genotypes. Study was conducted with three phosphorus levels namely no (P_0), normal P (P_{50}) and high P (P_{100}) as the main factor with genotypes as second factor arranged in a factorial completely randomized design. Significant genotypic differences were observed for the characters studied. Shoot P-concentration and accumulation increased with increase in phosphorus levels, whereas, root biomass and kernel P-concentration decreased with increase in phosphorus levels. There was varying response of genotypes for yield, kernel P-concentration and accumulation, shoot P-concentration and accumulation, biomass and harvest index. In addition, genotypes ICG-221, GG-5, TG-37A and FeESG-10 were designated as 'high yielder–non-responsive', whereas, genotypes NRCG-15049, TPG-41, GPBD-4 and NRCG-3498 were identified as 'low yielder - responsive'. These genotypes can be used in breeding programs to develop 'high-yielder– responsive' genotypes.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop grown in an area of about 5.3 mha in India with the production of about 9.2 m ton (FAO, 2017). It is an important source of protein for resource-poor households. Though number of high yielding cultivars have been released, productivity on small fields remains low. Inadequate application and low availability of native phosphorus (P) in the soil limit the groundnut productivity in semi-arid tropics. Groundnut being a leguminous crop most of its nitrogen demand is met by biological N_2 fixation. Insufficient P availability can lead to reduced N_2 fixation *vis-a-vis* N_2 deficiency besides direct effects on crop growth and yield (Brgaz *et al.*, 2012).

Phosphorus deficiency can be overcome by corrective soil fertility amendment strategies such as application of phosphatic fertilizers. However, it

is difficult for farmers in developing countries to undertake soil fertility amendments. Response to P application depends on ability of a genotype to take-up P from soil (uptake efficiency) or use of absorbed P for producing biomass yield (utilisation efficiency). Hence, there is a need for varieties capable of acquiring phosphorus from limiting soil environments. Genotypic differences have been reported in groundnut for its ability to acquire phosphorus from limiting environments (Ajay *et al.*, 2017). Therefore, objective of the study was to determine the effect of phosphorus levels on plant growth and to identify a suitable selection criterion under low-P availability.

MATERIAL AND METHODS

Field screening was conducted during 2012 at ICAR-Directorate of Groundnut Research, Junagadh, in a medium black calcareous (17% $CaCO_3$) clayey, Vertic Ustochrept soil having

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moderate available phosphorus ($15 \text{ kg ha}^{-1} \text{ P}$), 7.5 pH, 0.7% organic C, $268 \text{ kg ha}^{-1} \text{ N}$, $300 - 400 \text{ kg ha}^{-1} \text{ K}$, 5 kg ha^{-1} available S and 1.6 kg ha^{-1} , 15 kg ha^{-1} and 0.78 kg ha^{-1} DTPA extractable Fe, Mn, and Zn, respectively. Experiment was laid out in split-plot design with P levels as main plot and genotypes in sub plot with two replications. Treatments involving three levels of P application *i.e.* no-P (P_0 , $0 \text{ kg P}_2\text{O}_5/\text{ha}$) medium-P (P_{50} , $50 \text{ kg P}_2\text{O}_5/\text{ha}$) and high-P (P_{100} , $100 \text{ kg P}_2\text{O}_5/\text{ha}$) as di-ammonium phosphate were included. Nitrogen (as urea) and potash (as murate of potash) were applied at 50 kg N/ha and $60 \text{ kg K}_2\text{O/ha}$ equally for all the treatments. The recommended crop management practices were adopted for raising a healthy crop. Crop was harvested at maturity dried under sun for a week and yield related traits were recorded. Plant and kernel samples were digested using di-acid mixture of nitric acid and perchloric acid in the ratio of 2: 1 and P-concentrations ([P]; mg/g) was estimated (Fiske and Subbarao, 1925). Phosphorus harvest index (PHI) was calculated as $\text{PHI (\%)} = (\text{P uptake in kernels} / \text{total P uptake}) \times 100$ (Yaseen and Malhi, 2009). Means were separated using least significant difference (LSD) test at 95% significance level.

RESULTS AND DISCUSSION

Analysis of variance indicated that significant effect of phosphorus levels on RDW, SHP, KYP, SP, SPU, KP, KPU and PHI. Similarly, genotypic effect was highly significant for all variables tested and phosphorus by genotypes interaction was significant for most of the variables except HSM and SHP (Table 1). Results agree with earlier studies (Singh *et al.*, 2015) corroborating the hypothesis that groundnut differs in their ability to thrive in P limiting environments. The effect of phosphorus levels was highly significant ($P < 0.05$) on root biomass and it was higher at P_0 and on-par at P_{50} and P_{100} (Table 2). RDW ranged from 0.44 (ICG-4751) to 1.30 g/plant (GPBD-4). RDW decreased with the increase in

phosphorus levels for STARR, GG5, NRCG-15049, SP-250A, VRI-3 and B-95 upto P_{100} (Fig. 1). RDW decreased for genotypes Girnar-3, ICG-221, TG-37A, TPG-41, FeESG-8, NRCG-162 and GG-20 upto P_{50} and increased at P_{100} . However, root biomass obtained from soil culture may not be suitable to use as selection criteria as recovery of whole root system might have been incomplete (Hinsinger, 2001).

There was no significant difference in SDW between P levels, however, it increased when P levels were either decreased (P_0) or increased (P_{100}). SDW ranged from 11.92 (ICG-4751) to 22.01 g/plant (SP-250A) (Table 2). SDW decreased at P_{50} and increased at P_{100} for CHICO, ICGV-86590, JL-24, TG-37A, FeESG-10, NRCG-1308 and VRI-3; increased at P_{50} and decreased at P_{100} for ICG-1955, STARR, GG5, B-95 and GG-20; increased up to P_{100} among genotypes NRCG-15049, TPG-41, GPBD-4, NRCG-3498 and GG-7; decreased up to P_{100} for genotypes ICG-221, FeESG-8, SP-250A and NRCG-162 (Fig. 2). The genotypes that have high mean shoot biomass at deficient phosphorus level may be termed as efficient probably because soil P is somehow sufficient for them or they invest large part of the assimilate to the roots for enhanced soil exploration to support shoot biomass production (Mourice and Tryphone, 2012). In the study, under P_0 , genotypes ICGV-86590 and SP-250A had high shoot biomass till harvest and may be considered as efficient which is also in agreement with our earlier studies (Ajay *et al.*, 2013; Singh *et al.*, 2015). However, there was no significant difference between different P levels for shoot biomass which may be due to the fact that calcareous nature of the soil may fix much of the applied phosphorus thus rendering it unavailable for the plants. Second reason could be the production of more photosynthates than could be utilized for growth and low cytosolic Pi favours starch versus sucrose synthesis *in vivo* by diminishing the export of triose phosphate out of the chloroplast via the

RESPONSE OF GROUNDNUT GENOTYPES AT DIFFERENT PHOSPHORUS LEVELS

phosphate translocation (Cho *et al.*, 2015). Hence, under P limitations, photosynthates are not transported and starch gets accumulated in shoots (Hammond and White, 2008) due to reduction in sink strength. Starch accumulation is responsible for gain in dry matter in shoots under P_0 which increases shoot weight, thus, making P_0 on par with P_{50} and P_{100} .

HSM ranged from 16.49 (NRCG-162) to 44.77 g (B-95). Though HSM did not differ between P levels, it increased with increase in P levels in ICG-221, TPG-41, GPBD-4, VRI-3 and GG-7; decreased with increase in P application in STARR, NRCG-1308 and B-95; increased at P_{50} and decreased at P_{100} among genotypes ICGV-86590, JL-24, GG5, NRCG-15049, TG-37A, SP-250A, NRCG-162 and GG-20; and decreased at P_{50} and increased at P_{100} in Girnar-3 ICG-4751, FeESG-8, FeESG-10 and NRCG-3498 (Table 2). Likewise, SHP was highest at P_{50} and on par at P_0 and P_{100} ranged from 57.90 (SP-250A) to 77.04% (NRCG-15049). In general, SHP increased at P_{50} and decreased at P_{100} for genotypes CHICO, ICG-4751, ICGV-86590, JL-24, STARR, NRCG-15049, TPG-41, GPBD-4, B-95, NRCG-162 and GG-7; increased upto P_{100} in genotypes ICG-1955, ICG-221, FeESG-8 and FeESG-10 and decreased with increase in P levels among genotypes TG-37A, NRCG-1308, NRCG-3498, SP-250A, VRI-3 and GG-20 (Table 2).

Shoot P-concentration (SP) was low in P_0 and on par at P_{50} and P_{100} and it was highly variable among the genotypes ranging from 1.42 (GG-20) to 2.27 g/100g (NRCG-162) (Table 2). There was increase in SP among genotypes Girnar-3, CHICO, ICG-1955, NRCG-15049, TG-37A, FeESG-10, NRCG-1308, B-95 and GG-7 with increase in P levels (Fig. 3) but genotypes ICGV-86590, TPG-41, NRCG-3498 and SP-250A showed reductions in SP. However, there was an increase in SP upto P_{50} among genotypes JL-24, STARR, GG5, GPBD-4, FeESG-8

and NRCG-162 and started decreasing at P_{100} , whereas, genotypes ICG-4751, ICG-221, VRI-3 and GG-20 had reduced SP at P_{50} which still increased at P_{100} .

Shoot P-accumulation (SPU) was high at P_{100} and on par at P_0 and P_{50} and it ranged from 18.04 (ICG-4751) to 45.09 mg/plant (GG-5) (Table 2). There was an increase in SPU with increase in P levels among genotypes ICG-4751, NRCG-15049, TG-37A, B-95 and GG-7, whereas, genotypes ICG-221, SP-250A and NRCG-162 showed reduction in SPU (Fig. 4). However, there was increase in SPU upto P_{50} among genotypes Girnar-3, ICG-1955, STARR, GG5, FeESG-8 and GG-20 and started decreasing at P_{100} whereas genotypes CHICO, ICGV-86590, ICG-221, FeESG-10, NRCG-1308 and NRCG-3498 showed decrease in SPU at P_{50} which still increased at P_{100} .

Kernel P concentration (KP) was high at P_0 and was on-par when P application was increased. KP ranged from 21.82 (NRCG-1308) to 44.04 g/100g (GPBD-4) (Table 2). There was increase in KP with increase in P levels among genotypes ICG-221, TG-37A, VRI-3 and B-95, whereas, it was low in genotypes ICGV-86590, STARR, GG5, NRCG-15049, NRCG-162 and GG-20 (Fig. 5). However, there was increase in KP upto P_{50} among genotypes Girnar-3, ICG-4751, ICG-221, TPG-41, FeESG-8, SP-250A and GG-7 and started decreasing beyond that level whereas genotypes GPBD-4, FeESG-10 and NRCG-3498 showed decrease in KP at P_{50} which still increased at P_{100} .

Kernel P-accumulation (KPU) was on par at P_0 and P_{100} for all genotypes and it ranged from 3.46 mg/plant (NRCG-162) to 15.51 mg/plant (GG-7) (Table 2). KPU increased with increase in P application among genotypes TPG-41, GPBD-4, NRCG-3498 and VRI-3 and decreased in genotypes ICG-221, STARR, FeESG-8, NRCG-1308 and NRCG-162 (Fig. 6). In some of the genotypes such as ICG-4751, ICGV-86590, JL-24, GG5, B-95 and GG-7 KPU

increased upto P_{50} and then decreased at P_{100} , whereas, genotypes CHICO, ICG-1955, NRCG-15049, TG-37A and FeESG-10 showed decrease in KPU at P_{50} and increased at P_{100} .

Kernel yield plant⁻¹ (KYP) was high at P_{50} and reduced at other P levels (P_0 and P_{100}) (Table 2) and it ranged from 0.78 g/plant (NRCG-162) to 3.56 g/plant (GG-7). Generally, KYP increased upto P_{50} and reduced at P_{100} in Girnar-3, ICG-4751, ICGV-86590, JL-24, SP-250A, VRI-3, B-95, GG-7 and GG-20; decreased at P_{50} and increased at P_{100} in genotypes CHICO, ICG-1955, FeESG-8, FeESG-10 and NRCG-1308; decreased upto P_{100} in genotypes ICG-221, STARR, GG5, NRCG-3498 and NRCG-162; and increased with increase in P application among genotypes NRCG-15049, TPG-41 and GPBD-4 (Fig. 7). PHI was high at P_{50} and was on-par when P application was increased or decreased. Similarly, PHI varied significantly among the genotypes ranging from 9.63 (NRCG-162) to 38.04% (NRCG-1308) (Table 2). In general PHI decreased when P

application was either increased or decreased for all the genotypes. In most of the genotypes, PHI increased upto P_{50} and then started decreasing. In few genotypes such as ICG-1955, NRCG-15049, GPBD-4, and FeESG-10 showed decrease in PHI at P_{50} which still increased at P_{100} (Fig. 8). However, in genotypes ICG-221, GG5, TG-37A and FeESG-8 PHI decreased with increase in P application upto P_{100} and genotype TPG-41 showed increase in PHI with increase in P application upto P_{100} . In genotypes Girnar-3, STARR and NRCG-162 PHI was on-par at P_0 and P_{100} .

Kernel yield increased with the application of P upto P_{50} and excess of application reduced yields. Yield reduction under P_{100} is due to antagonistic reaction with other cationic mineral elements such as copper (Cu) iron (Fe) manganese (Mn) and zinc (Zn) (Hopkins and Ellsworth, 2003). Significant interaction between genotype and P level for kernel yields in the study corroborates with earlier studies (Singh *et al.*, 2015). However, this

Table 1. ANOVA for variables measured from 23 groundnut genotypes

Variable	P	G	P x G
RDW	**	**	**
SDW	NS	**	**
HSM	NS	**	NS
SHP	*	**	NS
KYP	**	**	**
SP	**	**	**
SPU	*	**	**
KP	**	**	**
KPU	**	**	**
PHI	**	**	**

RDW = Root dry weight (g); SDW: Shoot dry weight (g) ; HSM: Hundred seed mass (g); SHP: Shelling percentage (%) ; KYP: Kernel yield per plant (g/plant); SP: shoot P- concentration (g/100g); SPU: Shoot P- accumulation (mg/plant) ; KP: Kernel P- concentration (g/100g); KPU: Kernel P- accumulation (mg/plant); PHI: P- harvest index

Table 2. Effect of P levels on yield related characters of 23 groundnut genotypes

Genotype	RDW	SDW	SP	SPU	KP	KPU	PHI	HSM	SHP	KYP
1.GG-7	0.77 c-f	15.39 g-k	1.77 b-h	32.23 b-e	27.36 b-d	15.51 a	36.54 a-b	43.07 a-b	70.58 a-c	3.56 a
2.FeESG-10	0.61 f-j	20.46 a-c	2.23 a	38.04 a-c	45.71 a	14.42 a-c	23.79 d-f	25.74 h-k	64.78 a-c	3.51 a
3.GG-5	0.80 c-e	19.01 b-e	1.69 c-h	45.09 a	32.25 b	14.58 a-b	30.97 a-d	37.36 b-d	73.17 a-b	3.34 a-b
4.TG-37A	0.76 c-f	14.83 g-k	1.62 d-h	26.79 c-f	24.08 c-d	13.06 a-d	35.50 a-c	35.05 c-e	67.23 a-c	3.26 a-c
5.TPG-41	0.84 c-d	14.93 g-k	1.47 g-h	24.81 d-f	21.86 d	13.32 a-d	37.40 a-b	38.48 a-c	64.95 a-c	3.10 a-d
6.VRI-3	0.56 h-j	16.46 f-i	1.82 b-g	36.71 a-d	29.77 b-c	14.77 a-b	31.10 a-d	27.49 g-k	70.74 a-c	2.99 a-d
7.ICG-221	0.74 d-g	16.03 f-j	1.53 f-h	26.59 c-f	24.40 c-d	12.57 a-d	33.37 a-d	27.16 g-k	71.96 a-c	2.97 a-e
8.Gimar-3	0.57 g-j	13.88 i-l	2.05 a-b	27.70 c-f	28.29 b-d	12.34 a-d	30.04 a-d	28.25 f-i	71.28 a-c	2.94 a-e
9.NRCG-1308	0.69 d-h	13.61 j-l	1.60 e-h	28.53 c-f	21.82 d	13.51 a-c	38.04 a	38.42 a-c	72.09 a-c	2.89 a-f
10.SP-250A	0.80 c-e	22.01 a	1.93 a-e	44.10 a-b	42.77 a	13.84 a-c	24.43 d-f	30.68 e-i	57.90 c	2.84 a-f
11.GG-20	0.93 b-c	18.19 c-e	1.42 h	29.51 c-f	25.59 b-d	12.15 a-d	31.96 a-d	41.79 a-b	71.31 a-c	2.82 a-f
12.STARR	0.78 c-e	17.18 e-h	1.59 e-h	35.25 a-d	27.40 b-d	12.29 a-d	30.80 a-d	29.45 e-i	68.18 a-c	2.68 b-f
13.NRCG-15049	0.55 h-i	14.64 h-k	1.77 b-h	21.71 e-f	25.90 b-d	10.84 a-d	29.23 a-e	27.71 f-j	77.04 a	2.64 b-f
14.ICGV-86590	1.06 b	19.71 a-d	1.52 f-h	34.40 a-e	29.81 b-c	10.94 a-d	27.14 b-f	32.49 c-h	61.53 bc	2.48 c-f
15.B-95	0.77 c-f	17.40 d-g	1.70 c-h	32.91 a-e	29.35 b-d	10.69 a-d	25.86 c-f	44.77 a	62.79 a-c	2.44 c-f
16.CHICO	0.50 i-j	14.18 i-l	1.97 a-d	25.84 c-f	27.98 b-d	10.55 a-d	27.68 a-e	30.60 e-i	65.00 a-c	2.35 d-f
17.NRCG-3498	0.67 d-i	14.63 h-l	1.63 d-h	22.08 e-f	23.82 c-d	9.59 c-f	29.30 a-e	34.44 c-f	70.46 a-c	2.15 e-g
18.JL-24	0.83 c-d	15.93 f-j	1.57 f-h	29.73 c-f	24.82 c-d	10.34 b-e	29.98 a-d	31.23 d-h	69.03 a-c	2.15 e-g
19.FeESG-8	0.83 c-e	13.74 j-l	1.83 b-f	30.50 c-f	25.09 b-d	8.50 d-g	23.71 d-f	33.29 c-g	67.08 a-c	2.08 f-g

Contd....

Table2 Contd....

Genotype	RDW	SDW	SP	SPU	KP	KPU	PHI	HSM	SHP	KYP
20.ICG-4751	0.44 j	11.92 l	2.02 a-c	18.04 f	23.82 c-d	5.91 e-g	19.31 e-g	21.07 k-l	68.70 a-c	1.43 g-h
21.ICG-1955	0.66 e-i	15.16 g-k	1.75 b-h	28.17 c-f	26.47 b-d	5.49 f-g	17.60 f-g	24.31 i-l	72.72 a-c	1.33 h
22.GPBD-4	1.30 a	21.30 a-b	2.07 a-b	33.29 a-e	44.04 a	5.23 f-g	10.45 g	21.31 j-l	61.84 b-c	1.13 h
23.NRCG-162	0.56 g-j	12.82 k-l	2.27 a	28.24 c-f	29.06 b-d	3.46 g	9.63 g	16.49 l	63.70 a-c	0.78 h
P ₀	0.84 a	16.30	1.70 b	27.83 b	4.60 a	10.57 b	27.37 b	30.93	66.07 b	2.29 b
P ₅₀	0.70 b	16.06	1.79 a	28.82 b	4.23 b	11.96 a	29.36 a	31.65	70.06 a	2.82 a
P ₁₀₀	0.68 b	16.35	1.83 a	29.62 a	4.34 b	10.59 b	25.94 b	31.41	67.87 b	2.43 b
Mean	0.74	16.24	1.77	28.76	4.39	11.04	27.56	31.33	68.0	2.51
LSD	0.03	0.46	0.06	1.28	0.18	0.86	1.79	NS	NS	0.15

Means followed by the same letter are not significantly different @ $P \leq 0.05$

RDW = Root dry weight (g); SDW: Shoot dry weight (g) ; HSM: Hundred seed mass (g); SHP: Shelling percentage (%); KYP: Kernel yield per plant (g/plant); SP: shoot P- concentration (g/100g); SPU: Shoot P-accumulation (mg/plant) ; KP: Kernel P- concentration (g/100g); KPU: Kernel P-accumulation (mg/plant); PHI: P- harvest index

RESPONSE OF GROUNDNUT GENOTYPES AT DIFFERENT PHOSPHORUS LEVELS

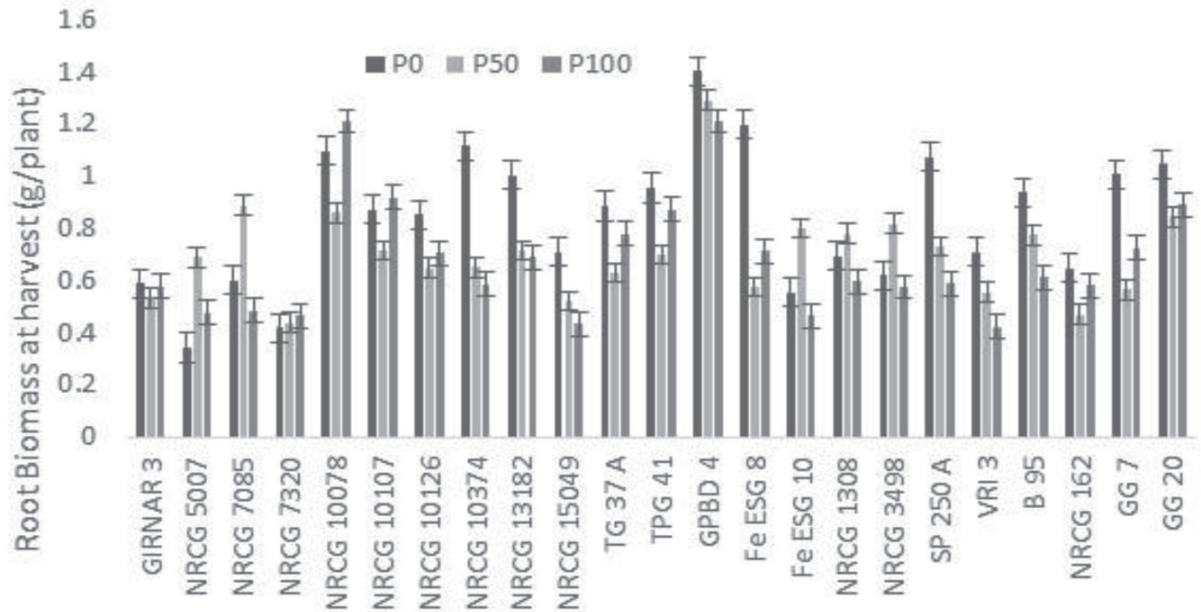


Fig. 1. Phosphorus and genotypic interaction effect on root biomass at harvest

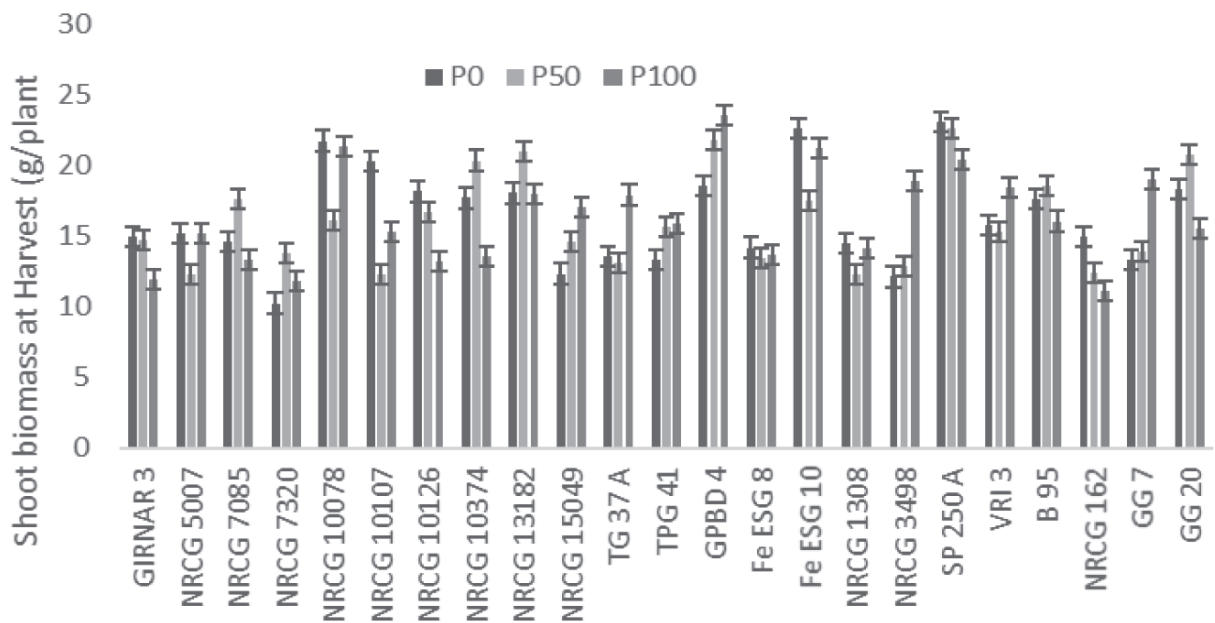


Fig. 2. Phosphorus and genotypic interaction effect on shoot biomass at harvest

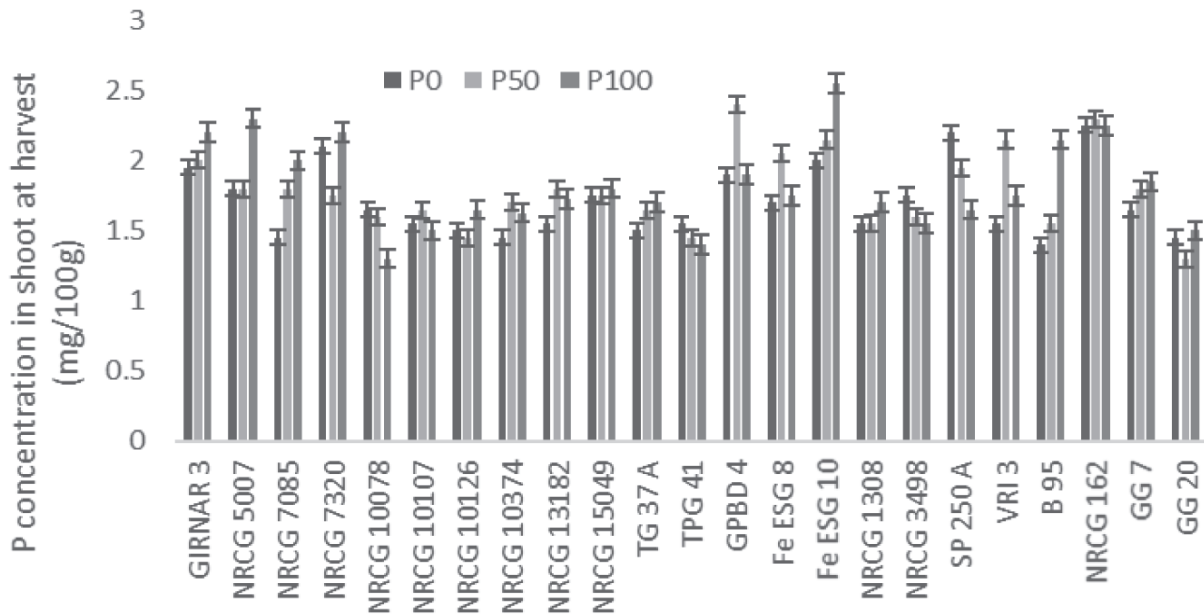


Fig. 3. P and genotypic interaction effect on P concentration in shoot at harvest

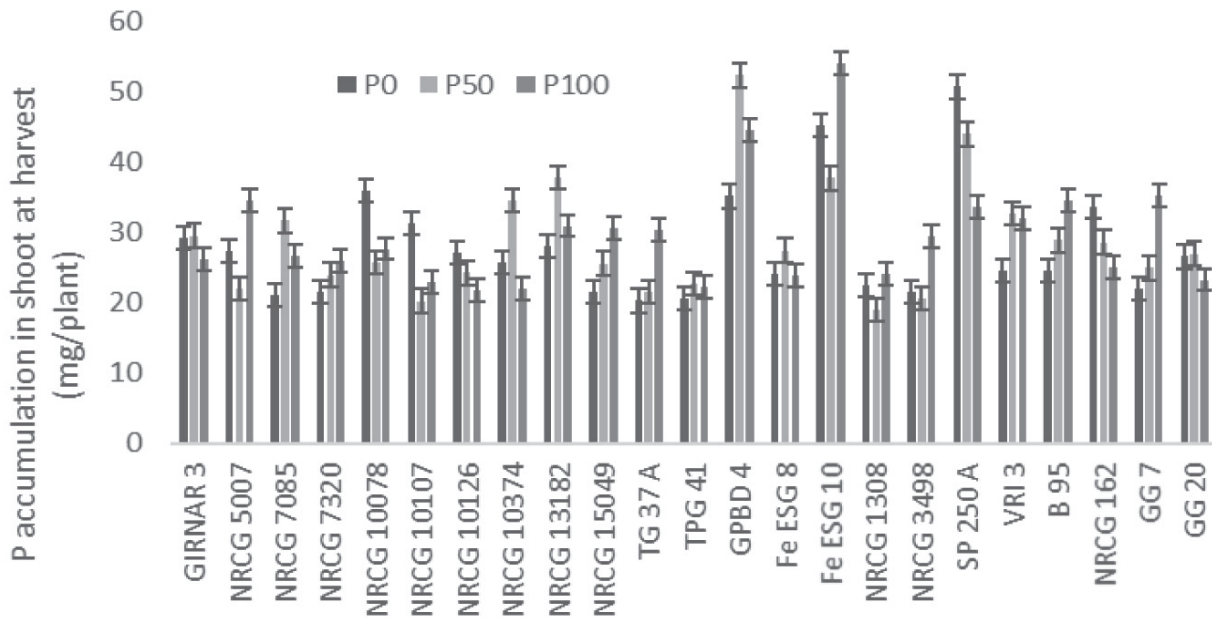


Fig. 4. P and genotypic interaction effect on P accumulation in shoot at harvest

RESPONSE OF GROUNDNUT GENOTYPES AT DIFFERENT PHOSPHORUS LEVELS

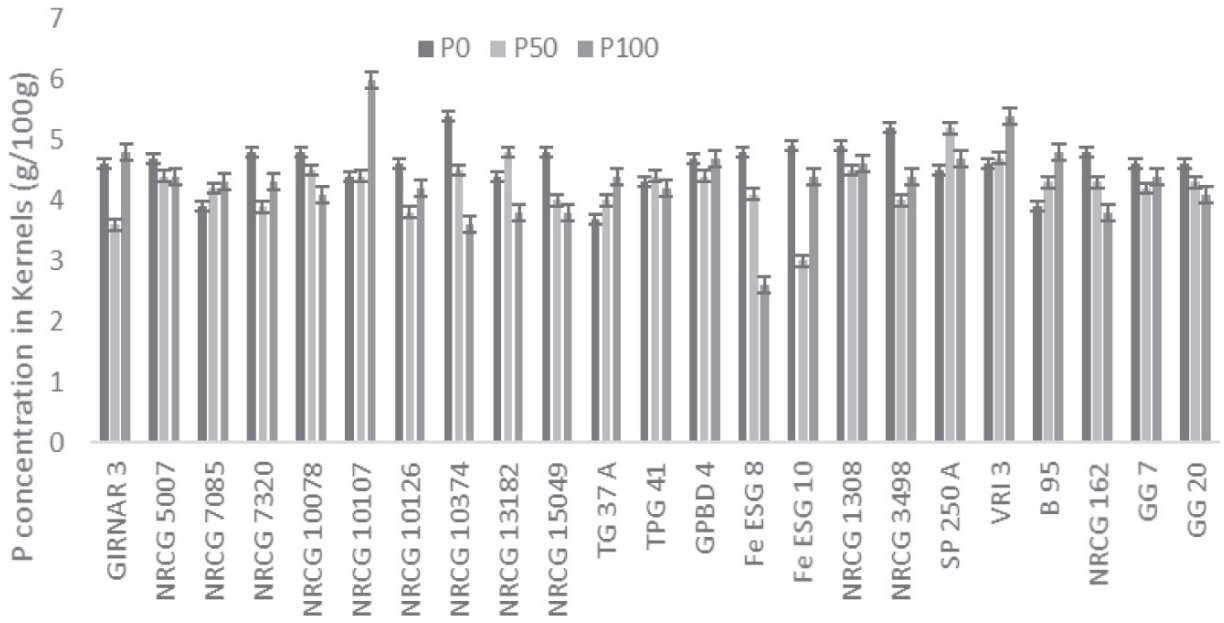


Fig. 5. P and genotypic interaction effect on P concentration in kernels

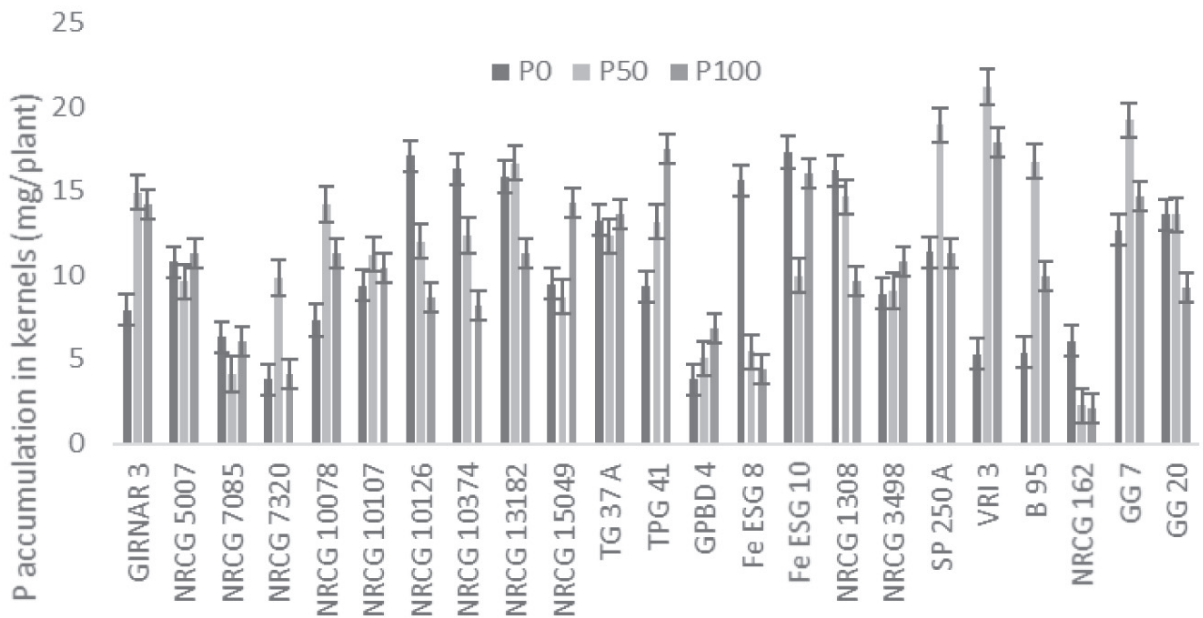


Fig. 6. P and genotypic interaction effect on P accumulated in kernels

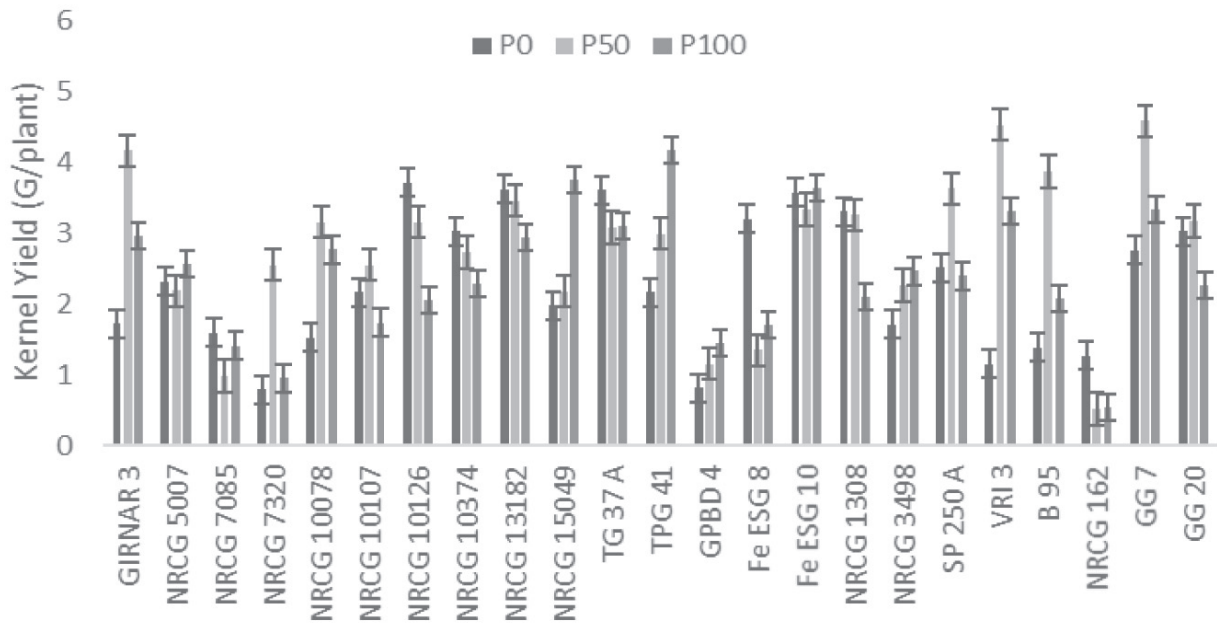


Fig. 7. P and genotypic interaction effect on kernel yield

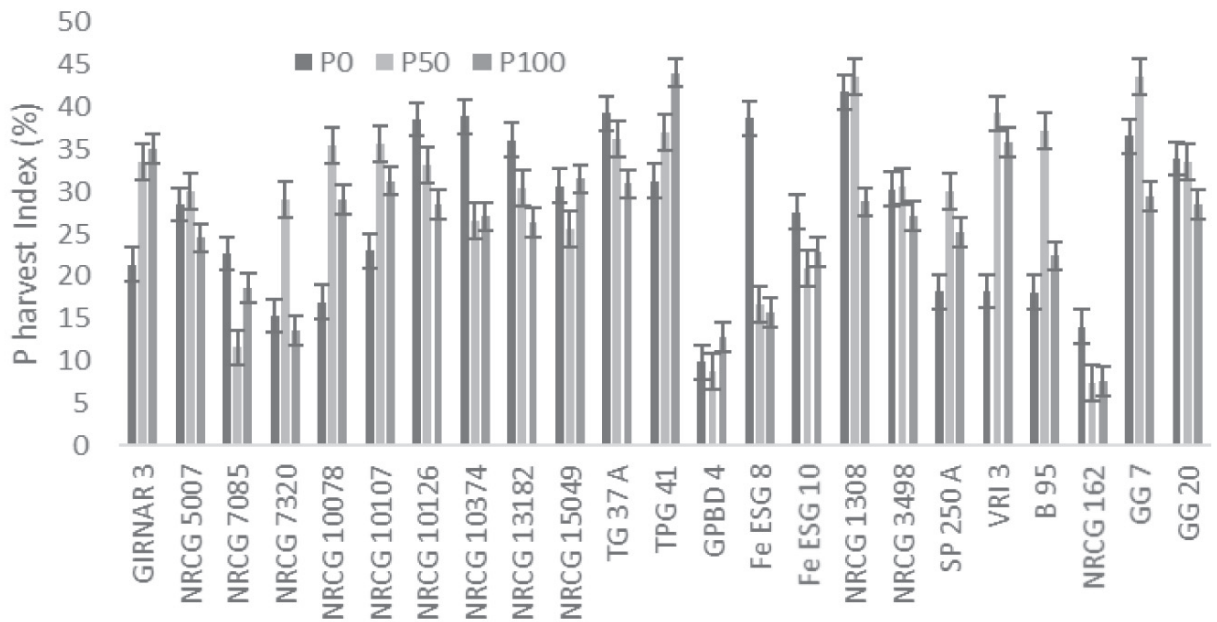


Fig. 8. P and genotypic interaction effect on P harvest index

proportional increase in yield is realistic until a limit is reached after which yield starts decreasing. Genotypes ICG-221, GG5, TG-37A and FeESG-10 had high yield under P limiting conditions but when P was supplied, they had yield loss and hence could be designated as 'high yielder – non-responsive' or 'efficient – non-responsive'. Non-responsiveness of these genotypes could be attributed to their inability to accumulate and translocate more P as a result they had low P-accumulation both in shoots and kernels (Fig. 4 and Fig. 6). Also excess P absorbed may have some inhibitory effect in the absorption of other mineral elements (Hopkins and Ellsworth, 2003). Under P-limiting conditions these 'high yielder – non-responsive' genotypes utilise P efficiently to produce high yields and as a result they have high P harvest index (Fig. 8). Genotypes such as Girnar-3, ICG-4751, ICGV-86590, JL-24, VRI-3, B-95 and GG-7 responded to P application only upto P_{50} and had yield reduction beyond this level. These genotypes are more suitable for optimal conditions where there are no limitations. Genotypes such as NRCG-15049, TPG-41, GPBD-4 and NRCG-3498 had low yield under P_0 conditions but responded to P application upto P_{100} and hence could be designated as 'low yielder - responsive'. These genotypes responded to P application by accumulating more P both in shoots and kernels but excess P-accumulation is not translated into higher yields. The identified 'high yielder – non responsive' and 'low yielder - responsive' genotypes may be used in breeding program to develop 'high yielder - responsive' genotypes.

CONCLUSION

The study revealed that genotypes differ in production of root system, kernel yield, shoot and kernel P-concentration, shoot and kernel P-accumulation and phosphorus harvest index. Soils of the experiment was calcareous in nature which limits the availability of phosphorus due to fixation

by sesquioxides. Genotype FeESG-10 was outstanding in terms of shoot P-concentration and accumulation, kernel P-concentration and accumulation and kernel yield under low P treatment. It can be used for cultivation under low fertility tolerance. This genotype can be used in breeding program along with NRCG-15049, TPG-41, GPBD-4 or NRCG-3498 to breed high yielder and responsive genotypes.

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DISTRIBUTION OF MICRONUTRIENT CATIONS IN DIFFERENT PHYSIOGRAPHIC AND LAND USE UNITS OF THOTAPALLI AYACUT AREA OF NORTH COASTAL ANDHRA PRADESH

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ABSTRACT

The distribution of DTPA extractable micronutrients was studied in six major physiographic and land use units namely tankfed uplands, rainfed uplands, tankfed middle lands, rainfed middle lands, tankfed plains and tankfed lowlands in proposed ayacut area of Thotapalli major irrigation canal of North Coastal Andhra Pradesh. DTPA-extractable zinc and copper were higher (0.11 to 0.93 mg kg⁻¹ and 0.65 to 2.56 mg kg⁻¹, respectively) in Devarapalli, Aamiti and Maddivalas profiles while, lower in Gujjangivalasa, Patikivalasa and Gangada profiles (0.09 to 0.33 mg kg⁻¹ and 0.43 to 1.87 mg kg⁻¹, respectively). DTPA-Fe and Mn were highest in soils of Gujjangivalas, Amiti and Devarapalli pedons. In general, DTPA extractable micronutrients were relatively higher at surface horizons and decreased with soil depth and their distribution followed the similar trend as that of organic carbon. Soil pH and CaCO₃ contents were negatively correlated with DTPA extractable micronutrient cations, whereas, organic matter and clay content positively correlated. The step down multiple regression analysis indicated that pH, EC, OC and clay content influenced 85, 61, 69 and 55 per cent variation in DTPA- Zn, Cu, Fe and Mn, respectively.

INTRODUCTION

It is known that micronutrients are held within the mineral matter (Miller *et al.*, 1986) and finer fractions of soils (Sharma *et al.*, 2006). The availability of micronutrients is sensitive to changes in soil environment as well as physiography, however, land use and landscape position may be the dominant factors of soil properties. Traditionally status of micronutrients was studied in only surface horizons (Takkar *et al.*, 1989). The sub-soil micronutrient status, which varies in the soil profile depending upon parent materials, landforms, climatic conditions, natural vegetation and land use pattern (Deka *et al.*, 1996) is an important characteristic to know the soil resources, especially for crop nutrition practices. As the distribution of micronutrients under different land uses in the proposed ayacut of Thotapalli reservoir of North-Coastal Andhra Pradesh was studied. Hence, an investigation was taken up to find out the distribution of DTPA extractable micronutrients under various land forms and land uses

and to find out the relation between soil properties and micronutrients.

MATERIAL AND METHODS

The study area was located between 18° 12' 820" to 18° 32' 876" N latitude and 83° 29' 889" to 83° 37' 727" E longitudes covering 950 acres, constituting parts of Vizianagaram and Srikakulam districts of North coastal Andhra Pradesh. The soils of uplands have been developed from granite-gneiss parent material and soils of middle and low lands developed from calcareous- granite-gneiss. The climate is sub-humid monsoon type with alternate wet and dry seasons as evidenced by past one decade meteorological data from 2008 to 2017. The mean annual temperature and rain fall were 28.34°C, 950.8 mm and 26.48°C, 1108.7mm in Vizianagaram and Srikakulam districts, respectively. A reconnaissance soil survey was conducted in the ayacut area of Thotapalli major irrigation canal during April to June, 2018 using toposheets of 1: 50,000

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scale as per the procedure outlined by AIS&LUS (1970). Auger bores, mini pits, road cuts of 15 profiles located on uplands and plains were studied. Soil correlation exercise resulted in six typical profiles. Representative six soil profiles depending on the physiography and land use units (Table 1) were exposed and horizon-wise soil samples were collected. These soil samples were processed and passed through a 2 mm sieve and analyzed for pH, Electrical Conductivity (EC in 1:2 soil:water suspension), particle-size distribution, calcium carbonate (CaCO_3) and organic carbon following standard procedures as described by Page *et al.* (1991). The available Fe, Mn, Zn and Cu were extracted with DTPA-TEA buffer (0.005 M DTPA+ 0.01M CaCl_2 + 0.1M TEA pH 7.3) as described by Lindsay and Norvell (1978). The relationship between micronutrients and physico-chemical properties was computed by simple correlation and stepwise regression analysis (Panse and Sukhatme, 1967).

RESULTS AND DISCUSSION

Physical and chemical characteristics of soils:

The sand content ranged from 67.8 % to 76.5% in soils of rainfed uplands, 53.5 % to 62.2 % in soils of tankfed uplands, 58.2%- 63.2% in tankfed middle lands, 56.4 % – 65.3 % in tankfed plain lands, 48.1-55.2 % in soils of rainfed middle land 37.3 % to 43.0% in soils of tankfed low lands (Table 2). However, reverse trend was observed for silt and clay content. The soils were acidic in rainfed uplands (profile 2) with pH ranging from 4.87 to 5.96, alkaline in rainfed middlelands (profile 4) with pH ranging from 7.88 to 8.71, while, all other pedons recorded neutral to slightly alkaline soil reaction. High pH in profile 4 (rainfed midland) may be due to higher concentration of calcium carbonate. The conductivity reflects the non-salinity nature of the soil profiles, however, relatively higher EC values were associated with fine textured soils (profile 4 and profile 6). Organic Carbon (OC) content in general was relatively higher in surface soil horizons and showed decreasing trend

with soil depth. The decreasing trend of organic carbon with soil depth could be due to surface layer enriched with crop residue like left over roots mass and added FYM to the surface soil due to cropping activity (Vijayakumar *et al.*, 2011). Significant calcareousness was found in profiles 3 and 4 as these profiles developed from the granite gneiss parent material mixed with calcarious murrum. Profiles 5 and 6 had insignificant CaCO_3 and profiles 1 and 2 were non-calcarious. Higher cation exchange capacities (CEC) were associated with fine textured soils (profile 4 and 6), while lower CEC was recorded in coarse textured soils. High surface area and high charge development in fine textured soil results in high CEC (Tripathi *et al.*, 2006).

Distribution of DTPA-extractable micronutrients:

The DTPA-Zn varied from 0.09 mg kg^{-1} to 0.33 mg kg^{-1} in the soils of rainfed uplands, and 0.12 to 0.66 mg kg^{-1} in soils of tankfed uplands, 0.09 mg kg^{-1} -0.75 mg kg^{-1} in tankfed middle lands, 0.09- 0.30 mg kg^{-1} in rainfed middle lands and 0.12 to 0.93 mg kg^{-1} in tankfed low lands (Table 3). There were significant differences in different physiographic units for DTPA-Zn. The DTPA-Zn content was highest (0.93 mg kg^{-1}) in surface horizon of fine-textured soils of tankfed low lands (profile 6) followed by surface horizons of tankfed middle lands (profile 5) and tankfed uplands (profile 1) and lowest (0.30 mg kg^{-1}) in tankfed middle lands (profile 3). Sharma *et al.* (2006) also reported higher Zn content in fine textured soils than coarse textured soils. The higher content of available Zn in surface horizons may be due to higher organic carbon addition through crop residues and it decreased at lower soil depths (Dhane and Shukla, 1995; Setia and Sharma, 2004). In case of profiles 2, 3 and 4, the available Zn status showed low, which might be due to low organic carbon status in the respective profiles. The correlation between organic carbon and available Zn content of soils were significantly positive ($r= 0.58^*$). All the soil profiles of the study area irrespective of land forms and land use were found sufficient in available copper status

Table 1. Location physiography and land use characteristics of representative soil profiles

Profile	Profile location	Mandal/ Tehsil	District	Slope (%)	Physiography	Land use
1	Devarapalli	Ranastalam	Srikakulam	1-3	Gently sloping Tankfed uplands	Cultivation of Rice- maize/pulses
2	Gujjangivalasa	Gurla	Vizianagaram	1-3	Gently sloping Rainfed uplands	Mango/Cashew orchard
3	Patikavalasa	Cheepurupalli	Vizianagaram	1-3	Gently sloping Tankfed middle lands	Cultivation of Rice - maize/pulses
4	Gangada	Balijipeta	Vizianagaram	0-1	Rainfed middle lands	Cotton/Rice-pulses
5	Aamity	Therlam	Vizianagaram	1-3	Gently sloping Tankfed plain lands	Sugarcane / Rice -pulses
6	Maddivalasa	Vangara	Srikakulam	0-1	Tankfed lowlands	Rice- Maize/ pulses

(0.38 ppm to 2.56 ppm) and all the profiles recorded more than critical level (0.2 ppm) of available copper.

The available iron (Fe) content ranged from 5.06 mg kg⁻¹ to 7.82 mg kg⁻¹ in the soils of rainfed uplands, and 4.59 mg kg⁻¹ to 7.68 mg kg⁻¹ in soils of tankfed uplands, 1.95- 4.60 mg kg⁻¹ in tankfed middle lands, 2.69- 4.12 mg kg⁻¹ in rainfed middle lands and 3.16 mg kg⁻¹ to 4.54 mg kg⁻¹ in tankfed low lands. (Table 3). The variations of available Fe may be attributed to ferromagnesium parent materials and sensitivity of iron fluctuations with soil moisture (Han and Banin, 1996). In general, available Fe decreased with increasing soil depth. The surface horizons contained relatively more available iron than subsurface horizons, which is ascribed to presence of relatively more organic carbon in the surface horizons. The affinity of organic carbon to influence the solubility and availability of iron by chelation effect might have protected the iron from oxidation and precipitation, which consequently increased the availability of iron

(Prasad and Sakal, 1991; Thangasamy *et al.*, 2005). Soil profiles 3, 4 and 6 were found deficient in available iron content in subsurface, which can ascribed to the presence of significant amounts of calcium carbonate in these profiles. The variation in the available iron content is also influenced by soil reaction, organic matter and calcium carbonate content.

The data in Table 3 indicates that available Mn varied from 9.86 mg kg⁻¹ to 15.64 mg kg⁻¹ in soils of rainfed uplands (profile 2), 11.32 mg kg⁻¹ to 22.13 mg kg⁻¹ in tankfed uplands (profile 1), 6.55 mg kg⁻¹ to 18.69 mg kg⁻¹ in tankfed middle lands (profile 3) and 6.81 mg kg⁻¹ to 12.66 mg kg⁻¹ in tankfed low lands (profile 6). The available Mn was highest in tankfed uplands and tankfed middle lands. The higher content of available Mn was observed in surface soils which could be attributed to the chelation effect of organic compounds. The observations are in confirmation with the findings of Sreedhar Reddy and

Table 2. Characteristics of soils under different physiographic and land use units of Thotapalli ayacut area

Pedon No & horizon	Depth (m)	Sand (%)	Silt (%)	Clay (%)	Soil pH	EC (dSm ⁻¹)	Organic carbon (%)	CaCO ₃ (%)	CEC cmol kg ⁻¹
Pedon 1. Devarapalli profile- Tankfed uplands (Rice- Maize/ pulses)									
Ap	0.00-0.10	62.2	18.6	19.2	6.23	0.13	0.534	-	13.50
Bw	0.10-0.25	58.0	17.5	24.5	6.61	0.17	0.301	-	15.40
Bt ₁	0.25-0.58	53.5	17.5	29.0	7.34	0.17	0.231	-	17.00
Bt ₂	0.58-0.70	56.0	16.0	28.0	7.41	0.21	0.215	-	15.40
Bt ₃	0.70-0.90	60.5	15.5	24.0	7.35	0.23	0.220	-	14.20
Bt ₄	0.90-1.19+	58.0	17.0	25.0	7.48	0.23	0.205	-	14.20
Pedon 2. Gujjangivalasa profile – Rainfed uplands (Mango/ cashew orchards)									
Ap	0.00-0.10	76.5	10.9	12.6	4.87	0.11	0.376	-	6.40
Bw	0.10-0.22	68.0	14.8	17.2	5.43	0.13	0.256	-	7.10
Bt ₁	0.22-0.40	69.1	10.4	20.5	5.51	0.15	0.250	-	9.63
Bt ₂	0.40-0.70	67.8	11.0	21.2	5.96	0.20	0.135	-	8.15
Bt ₃	0.70-0.98+	68.0	11.5	20.5	5.50	0.26	0.123	-	8.15
Pedon 3. Patikivalasa Profile – Tankfed middle lands (Rice- maize/pulses)									
Ap	0.00-0.10	61.3	14.4	24.3	7.23	0.19	0.330	1.3	15.30
Bw ₁	0.10-0.30	60.5	13.0	26.5	7.48	0.20	0.226	3.4	17.20
Bw ₂	0.30-0.50	58.2	16.1	25.7	7.54	0.22	0.196	3.0	14.20
Bw ₃	0.50-0.80	59.9	13.6	26.5	7.91	0.23	0.180	7.0	11.70
Bw ₄	0.80- 0.95+	63.2	12.5	24.3	8.28	0.31	0.135	9.5	13.50
Pedon 4. Gangad Profile- Rainfed middle lands (Cotton/Rice-pulses)									
Ap	0.00-0.09	55.2	15.8	29.1	7.88	0.39	0.450	3.15	27.35
Bw ₁	0.09-0.40	51.0	14.1	34.9	8.04	0.43	0.316	6.30	31.80
Bw ₂	0.40-0.62	48.1	15.0	36.9	8.26	0.44	0.291	7.10	29.50
Bw ₃	0.62-0.82	53.4	13.2	33.4	8.50	0.47	0.253	9.8	30.10
Bw ₄	0.82-1.02+	54.3	14.1	31.6	8.71	0.58	0.213	13.8	28.80

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Pedon No & horizon	Depth (m)	Sand (%)	Silt (%)	Clay (%)	Soil pH	EC (dSm ⁻¹)	Organic carbon (%)	CaCO ₃ (%)	CEC cmol kg ⁻¹
Pedon 5. Aamiti Profile- Tankfed plain lands (Sugarcane / Rice –pulses)									
Ap	0.00-0.16	65.3	13.7	21.0	6.53	0.24	0.520		16.80
Bw ₁	0.16-0.30	63.2	13.6	23.2	7.20	0.26	0.376	-	14.90
Bw ₂	0.30-0.48	58.1	16.6	25.3	7.61	0.31	0.226	-	14.90
Bw ₃	0.48-0.70	56.4	18.4	25.2	7.14	0.39	0.110	1.1	16.10
Bw ₄	0.70-0.90+	61.4	15.0	23.6	7.10	0.45	0.110	1.35	15.25
Pedon 6. Maddivalas Profile- Tankfed lowlands (Rice- Maize/pulses)									
Ap	0.00-0.13	43.0	18.9	38.1	7.80	0.48	0.619	-	29.10
Bw	0.13-0.32	41.5	17.0	41.5	8.16	0.56	0.302	1.1	32.50
Bss ₁	0.32-0.55	39.0	17.0	44.0	8.12	0.45	0.231	1.1	32.50
Bss ₂	0.55-0.74	39.0	18.9	42.1	8.04	0.53	0.110	1.5	28.90
Bss ₃	0.74-1.15+	37.3	17.5	45.2	7.91	0.60	0.110	2.9	31.10

Naidu (2016). The available manganese was sufficient in all the profiles studied because the values are well above the critical limit (1.0 ppm) of Lindsay and Norvell (1978).

Relationship between soil properties and DTPA-

extractable micronutrients: The DTPA-extractable Zn, Cu, Fe and Mn had significant and positive correlation with organic carbon 0.580*, 0.456*, 0.623*, 0.429*, respectively (Table 4). Organic carbon due to its affinity to influence the solubility of micronutrient cations by chelation effect might have protected them from oxidation and precipitation, which consequently increased their availability (Prasad and Sakal, 1991). The soil reaction had negative correlation with DTPA extractable cations viz., available Zn (-0.623), Cu (-0.36), Fe (-0.697) and Mn (-0.574). Bhogal *et al.* (1993) also reported a negative relationship between available Zn and pH. Calcium carbonate had a significant negative effect on cationic micronutrient availability such as Zn ($r = -0.581^*$), Cu (-342), Fe (-0.549) and Mn (-0.574). Electric

conductivity (EC) of soils had positive correlation with available micronutrients, however it was significant only for DTPA Cu and non-significant for other micronutrient cations. Cation exchange capacity (CEC) also had positive correlation with DTPA extractable micronutrients but not at significant level. Clay content of soils also had positive correlation with micronutrient cations but significant only for Zn and Cu. Haque *et al.* (2000) also reported a positive correlation between available micronutrients and clay content. Non- significant negative correlation was found between sand content and with micronutrients. Negative correlation of sand and micronutrient cations was reported by Chhabra *et al.* (1996).

The regression equations showed that pH contributed 43 per cent towards variation in Zn availability in soils. The coefficient of determination (R²) increased by 54 per cent with inclusion EC in the regression analysis (Table 5). The inclusion of organic carbon (OC) improved the R² value by 73 per cent. The R² value suggested that the predictability

Table 3. Distribution of DTPA extractable micronutrients in the soils under different physiographic and land use units of Thotapalli ayacut area of North coastal Andhra Pradesh

Profile No. & horizon	Depth (m)	DTPA-extractable micronutrients (mg kg ⁻¹)			
		Zn	Cu	Fe	Mn
Pedon 1. Devarapalli profile- Tankfed uplands (Rice- Maize/ pulses)					
Ap	0.00-0.10	0.66	2.56	7.68	22.13
Bw	0.10-0.25	0.27	2.40	4.94	14.87
Bt1	0.25-0.58	0.14	2.06	6.23	16.85
Bt2	0.58-0.70	0.14	2.06	5.16	16.85
Bt3	0.70-0.90	0.11	1.56	4.88	13.66
Bt4	0.90-1.19+	0.11	1.32	4.59	11.32
Pedon 2. Gujjangivalasa profile – Rainfed uplands (Mango/ cashew orchards)					
Ap	0.00-0.10	0.33	1.87	7.82	15.64
Bw	0.10-0.22	0.14	1.32	7.45	14.11
Bt1	0.22-0.40	0.09	1.09	6.39	10.85
Bt2	0.40-0.70	0.09	1.32	7.13	13.26
Bt3	0.70-0.98+	0.09	1.18	5.06	9.86
Pedon 3. Patikivalasa Profile – Tankfed middle lands (Rice- maize/pulses)					
Ap	0.00-0.10	0.38	1.87	4.60	18.69
Bw1	0.10-0.30	0.25	1.56	4.29	12.33
Bw2	0.30-0.50	0.31	1.56	3.24	7.16
Bw3	0.50-0.80	0.14	1.06	2.49	6.55
Bw4	0.80- 0.95+	0.14	1.06	1.95	6.55
Pedon 4. Gangad Profile- Rainfed middlelands (Cotton/Rice-pulses)					
Ap	0.00-0.09	0.30	1.56	4.12	13.04
Bw1	0.09-0.40	0.11	1.20	3.94	12.31
Bw2	0.40-0.62	0.09	0.95	3.56	9.28
Bw3	0.62-0.82	0.09	0.86	2.90	8.00
BC	0.82+	0.09	0.43	2.69	9.86

Contd...

DISTRIBUTION OF MICRONUTRIENT CATIONS IN THOTAPALLI AYACUT AREA OF A.P.

Profile No. & horizon	Depth (m)	DTPA-extractable micronutrients (mg kg ⁻¹)			
		Zn	Cu	Fe	Mn
Pedon 5. Aamiti Profile- Tankfed plain lands (Sugarcane / Rice –pulses)					
Ap	0.00-0.16	0.75	2.34	9.54	14.90
Bw1	0.16-0.30	0.39	1.31	8.62	11.86
Bw2	0.30-0.48	0.24	1.96	6.54	9.23
Bw3	0.48-0.70	0.14	0.38	7.14	10.20
BC	0.70-0.90+	0.09	0.43	5.12	9.6
Pedon 6. Maddivalas Profile- Tankfed lowlands (Rice- Maize/pulses)					
Ap	0.00-0.13	0.93	2.56	4.54	12.66
Bw	0.13-0.32	0.32	2.42	4.23	9.36
Bss1	0.32-0.55	0.18	1.92	4.10	10.2
Bss2	0.55-0.74	0.12	0.65	3.94	8.52
Bss3	0.74+	0.12	0.65	3.16	6.81

Table 4. Correlation between soil properties and DTPA extractable micronutrients

Micronutrients/ Soil properties	Soil pH	EC(dSm ⁻¹)	Organic carbon (%)	CaCO ₃ (%)	CEC cmol kg ⁻¹	Sand (%)	Clay (%)
Zn	-0.623**	0.242	0.580*	-0.481*	0.276	-0.276	0.411*
Cu	-0.436*	0.414*	0.456*	-0.342	0.321	-0.421*	0.426*
Fe	-0.697**	0.267	0.623**	-0.449*	0.186	-0.186	0.208
Mn	-0.574*	0.341	0.429*	-0.432*	0.208	-0.208	0.277

*Significant at 5% level ; ** Significant at 10% level

Table 5. Relation between soil properties and DTPA extractable micronutrients using regression analysis

Soil Properties/ Micronutrients	Zn	Cu	Fe	Mn
pH	0.43*	0.32	0.51*	0.21
pH+EC	0.54*	0.41*	0.59*	0.33
pH+EC+OC	0.73*	0.50*	0.65*	0.40*
pH+EC+OC+%Clay	0.85*	0.61*	0.69*	0.55*

*Significant at 5% level

of relationship between available Zn and soil properties further improved when clay was also taken into consideration. Thus, pH, EC, OC and clay accounted for maximum variation in DTPA-Zn. (Table 5). The R² value increased by 61 per cent with the inclusion of pH, EC, OC and clay. The stepwise regression equation indicates that all the soil properties accounted for 69 per cent variation in available Fe. The main contributing factor for variation (31 percent) in available Mn was pH. Inclusion of EC and OC and clay significantly improve the prediction value by 40 per cent.

CONCLUSION

The DTPA extractable micronutrient cations distribution in soils of Thotapalli major irrigation project of North Coastal Andhra Pradesh showed decreasing trend with soil depth. The surface soils of tankfed uplands, tankfed middle lands and tankfed low lands were sufficient in available Zn, however, rainfed uplands and rainfed middle lands showed low status. The available Zn content in soil profiles showed decreasing trend with soil depth. All the soil horizons showed sufficiency in available copper. Available iron content was sufficient in surface and deficient in subsurface particularly in soils having CaCO₃. Available Mn was sufficient in all the soil profiles. Soil properties such as pH, CaCO₃ showed negative correlations and organic carbon and texture showed positive correlation with available micronutrients.

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THRIPS SPECIES DIVERSITY IN COTTON ECOSYSTEM OF TAMIL NADU AND THEIR MANAGEMENT

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ABSTRACT

Comprehensive study on cotton thrips diversity in cotton ecosystem of Tamil Nadu was conducted based on the collection and the random surveys undertaken by the Department of Cotton, Tamil Nadu Agricultural University. Three species belonging to three genera in two families of Thysanoptera order were recorded in Coimbatore cotton ecosystem. Phylogenetic analysis and diversity indices were completed to identify the species and their variation revealed the maximum prevalence of *Scirtothrips dorsalis* (3.25) followed by *Thripstabaci* (1.34) and *Thripspalmi*(0.24) which showed high diversity of thrips species in cotton ecosystem system and the importance of its management. The dominant species of *Scirtothrips dorsalis* exhibited the tendency to be the most alarming key pest of cotton in Tamil Nadu. It might be possible that the abundance and status of diversity of thrips population could be prominent and transmit the Tobacco Streak Virus disease in cotton. Flonicamid 50 WG @ 75 g a.i. ha⁻¹ has recorded significantly lowest reduction of thrips population from 7.93 to 0.40 thrips / 3 leaves followed by acephate 75 SP @ 290 g a.i.ha⁻¹ with a population reduction from 7.93 to 0.60 thrips per leaf.

INTRODUCTION

Cotton is one of the most important cash crops and plays a key role in Indian agriculture. India is the largest producer of cotton in the worldwide (6.205 million metric tons, Statista, 2018). About 162 species of arthropod pests are infesting the cotton plant during vegetative and reproductive stages of which about 12 species are important in India. Thrips are generally one of the main early season cotton pests. Thrips initially damage the cotyledons and then several other parts including the bolls and the types of damage vary according to the parts of the plant attacked. Most damage occurs during early vegetative stage of the crop, when nutritional quality of tissues is ideal for these insects. Both adults and nymphs usually remain on the under surface of leaves, lacerate the tissues and suck the cell sap. The affected leaves become thickened, blistered and bronzed due to continuous feeding (Kirk, 1995). Thrips damage is not expressed immediately as effects are delayed. Oviposition and feeding injury cause direct damage to crops (Childers, 1997). Thrips may also cause indirect damage by

transmitting viruses or bacteria (Childers and Achor, 1995). The study analysed species richness in the cotton ecosystem of Tamil Nadu and their management by newer chemicals.

MATERIAL AND METHODS

Thrips diversity

Surveys were conducted in cotton growing areas of Tamil Nadu during 2015 -2016 and 2016 - 2017. Thrips samples were collected by shaking cotton leaf, flowers and bolls by beating over the vegetation and collecting the thrips with using a cloth, and transferring the specimens with a fine camel hair brush to 1.5 ml Eppendoff tubes containing 70% ethanol (Burriss *et al.* 1989). They should be transferred to a freshly made mixture (10:1:1) of 10 parts 70% ethyl alcohol, one part glycerine, one part acetic acid. This helps to keep specimens soft and distended from which better slide preparations are obtained, but 70% alcohol alone is adequate. Eppendoff tubes containing thrips were kept at room temperature for further taxonomic identification. The sample was then examined, and the

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number of insects was recorded. Thrips were identified to species based on morphological characteristics (body colour, antennae, pigmentation and ornamentation). These characteristics were consistent across the individuals observed. Sex was determined by the presence or absence of the ovipositor, and by abdomen width and curvature (Fedor *et al.*, 2008 and Moritz *et al.*, 2011).

Species richness - Fishers alpha (Fisher *et al.*, 1943)

Species richness and diversity Version II (Pisces Conservation Ltd., www.irchouse.demon.co.uk) (Henderson, 2003) programmes were used to assess and compare the diversity of thrips species in cotton ecosystem. This presents the alpha log series parameter for each sample. This is a parametric index of diversity that assumes the abundance of species following the log series distribution.

$$ax, \frac{ax^2}{2}, \frac{ax^3}{3}, \frac{ax^n}{n}$$

Where, each term gives the number of species predicted to have 1, 2, 3, ... n individuals in the sample.

Thrips management

The experiment was laid out in Randomized Block Design with eight treatments and three

replications. ‘Suraj’ cotton variety was sown on 05.08.2015 in P₂ field and confirmation trial was sown on 27.08.2016 at Department of Cotton with 100 cm x 45 cm spacing. Three rounds of sprayings were given in two seasons based on the economic threshold level. One acre plot has been taken for population assessment to count the nymphs and adult thrips from randomly selected plant in the micro plot. The field is divided into five micro plots one each from the four corners and one from centre of the field. From each micro plot, four plants were selected at random. From each plant three leaves (top, middle and bottom) were observed. The number of nymphs and adults were counted. Totally 20 plants / field were observed and the mean was worked out. It was expressed as number of insects/leaf. ETL: 5-10 adult insects or nymphs /leaf /ha or 15% infected plants. If it has crossed the ETL, apply the chemical management method. The percent reduction formula of pests population reduction was worked out based on the Henderson and Tilton (1955) method. The experimental design and statistical analysis were followed as per the procedure mentioned by Regupathy and Dhamu (2001).

RESULTS AND DISCUSSION

Thrips diversity

Results revealed that three different species were identified from the collected samples. The most commonly encountered species were *Scirtothrips dorsalis*

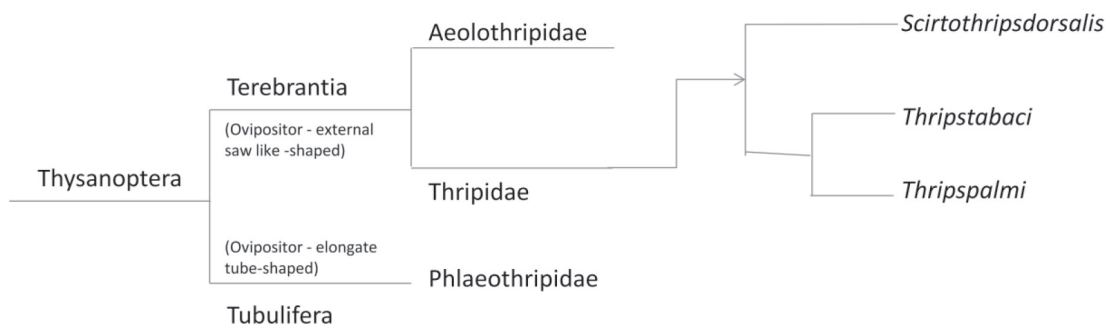


Fig.1. Phylogenetic classification of Thysanoptera (Fedor *et al.*, 2008)

dorsalis. Based on species level analysis, the species richness was distinguished in species variation from the alpha diversity indices values. Table 1 indicates at species level, the value was the highest for *Scirtothrips dorsalis* (3.25) followed by *Thrips tabaci* (1.34) and *Thrips palmi* (0.24). Thysanoptera exhibit two distinct forms of ovipositor and this characteristic is used to phylogenetic variations in suborders:

- Terebrantia - external saw like ovipositor
- Tubulifera - elongate tube-shaped tenth abdominal segment and females that have an internal eversible chute-like ovipositor.

Table 1. Thrips diversity in cotton ecosystem – Alpha diversity species richness indices

Thrips indices	Diversity richness
<i>Scirtothrips dorsalis</i>	3.2542
<i>Thrips tabaci</i>	1.3437
<i>Thrips palmi</i>	0.2416

Thrips management

The study showed that severe infestation at early stage resulted in death of young seedlings while in later stages cotton plants exhibited crinkling and upward curling, silvering followed by browning of leaves. Telford and Hopkins (1957) reported upward curling of leaf margins upon infestation by thrips in cotton. Reed (1988) also reported death of the apical meristem upon severe infestation by thrips during early stage of cotton. The consequences of feeding injury by thrips nymphal instars and adults to plant growth parameters result in delayed maturity (Wilson *et al.*, 1994).

The first season results revealed that spraying of all the insecticides were significantly effective against thrips compared to untreated check.

The population of thrips was uniform and ranged from 7.87 numbers per leaf to 8.67 numbers per leaf prior to spraying. Seven days after the third spray of insecticides, there was significant reduction in the thrips population in all the treatments (Table 2). However, flonicamid 50 WG @ 75 g a.i. ha⁻¹ recorded significantly lowest thrips population (reduced from 7.93 thrips / 3 leaves to 0.40 thrips / 3 leaves) followed by acephate 75 SP @ 290 g a.i. ha⁻¹ which had population reduction from 7.93 thrips per leaf to 0.60 thrips per leaf. The next best treatment was imidacloprid 17.8 SL @ 25 g a.i. ha⁻¹ which reduced population from 7.93 thrips per leaf to 0.67 thrips per leaf after the third spray. Similar trend was noticed with thiamethoxam 25 WG @ 25 g a.i. ha⁻¹ at seven days after the third spray (0.80 number / 3 leaves). Neem products such as NSKE and neem oil maintained its efficacy by reducing the thrips population significantly and was statistically on a par with each other. The population of thrips recorded at the end of the seven days after the third spray was 1.13 numbers / 3 leaves and 1.27 numbers / 3 leaves on NSKE and neem oil, respectively. Earlier reports revealed that NSKE 5% has recorded effective mortality against thrips in grapes (Samota *et al.*, 2017). Neem oil recorded an average of 63.27% mortality of thrips under field conditions in cotton. Seed treatment with imidacloprid 600 FS (10ml/kg) alone was ineffective and increased thrips from 7.87 numbers / 3 leaves to 8.33 numbers / 3 leaves. The same trend was noticed in untreated check that was ranging from 8.67 numbers / 3 leaves to 11.20 numbers / 3 leaves.

Similar trend was noticed in second season trial. The results showed that spraying of all the insecticides were significantly effective against thrips compared to untreated check. Population of thrips has ranged from 6.40 numbers per 3 leaves to 6.50 numbers per 3 leaves before the spray. After, third round spray of

Table 2. Efficacy of insecticides against thrips population

S. No.	Treatments	Dose (g. a.i./ ha.)	I st Season			II nd Season		
			Pre treatment	7 Days after 3 rd Spray	% reduction over control	Pre treatment	7 Days after 3 rd Spray	% reduction over control
1	Acephate 75 SP	290	7.93a (2.90)	0.60ab (1.05)	94.14	6.40a (2.67)	0.33ab (0.91)	95.77
2	Thiamethoxam 25 WG	25	7.87a (2.89)	0.80b (1.14)	92.13	6.50a (2.70)	0.47ab (0.98)	94.07
3	Imidacloprid 17.8 SL	25	7.93a (2.90)	0.67ab (1.08)	93.46	6.40a (2.67)	0.40ab (0.95)	94.88
4	Fonicomid 50 WG	75	7.93a (2.90)	0.40a (0.95)	96.10	6.40a (2.67)	0.27a (0.88)	96.54
5	NSKE	5%	7.93a (2.90)	1.13c (1.28)	88.97	6.47a (2.69)	1.60b (1.45)	79.73
6	Neem oil	1%	7.87a (2.89)	1.27c (1.33)	87.51	6.40a (2.67)	2.87c (1.83)	63.24
7	Seed treatment with imidacloprid 600 FS	10ml/kg	7.87a (2.89)	8.33d (2.97)	18.06	6.40a (2.67)	5.93d (2.54)	24.05
8	Un treated Seed (Control)	-	8.67a (3.03)	11.20e (3.42)	-	6.50a (2.70)	7.93e (2.90)	-
	CD @ 5 %		0.3798	0.2653	-	0.2295	0.3452	-
	CV		0.034	1.3849	-	0.0073	1.1868	-

- Mean of three replications

- Figures in the parentheses are $\sqrt{x + 0.5}$ transformed values

- In a column, means followed by same letter(s) are not significantly different at P=0.05 by DMRT.

flonicomid 50 WG @ 75 g a.i. ha⁻¹ recorded significantly the lowest thrips population (0.27 number / 3 leaves) followed by other insecticides and plant products. Seed treatment with imidacloprid 600 FS (10 ml/kg) alone maintained thrips population with a meager difference in both seasons. At the end of the third spray, the increasing trend was noticed in untreated check that was ranging from 7.67 numbers / 3 leaves to 7.93 numbers / 3 leaves after 7 days after treatment.

CONCLUSION

The dominant species of *Scirtothrips dorsalis* exhibited the tendency to be the most alarming key pest of cotton in Tamil Nadu. It might be possible that the abundance and status of insect pests could be prominent and transmit the Tobacco Streak Virus disease in cotton. During the study period, three species of thrips (*Thrips tabaci*, *Thrips*

palmi and *Scirtothrips dorsalis*) were identified in cotton ecosystem. Eventhough diversification of crop habitats may provide the effective cotton pest control method, it tends to be restricted for less developed regions. Further, studies in different communities will be beneficial to a better understanding of insect pests complex in cotton ecosystem and pest management. Flonicamid 50 WG @ 75 g a.i. ha⁻¹ was highly effective, in reducing thrips population from 7.93 thrips / 3 leaves to 0.40 thrips/3 leaves with highest population reduction (96.54%) followed by acephate 75 WP population reduction (95.77%) in this treatment. Seed treatment with imidacloprid or Thiomethaxam offers a greater degree of protection for upto 45 days after sowing.

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EFFECT OF *INSITU* GREEN MANURING ON SOIL FERTILITY, GROWTH AND YIELD OF RICE UNDER ORGANIC FARMING

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ABSTRACT

The experiment was conducted to study the effect of *insitu* green manuring on soil fertility, growth and yield of rice under organic farming during *kharif* season for three consecutive years from 2012-13 to 2015-16. It was observed that the application of 100 kg Nequivalent FYM for preceding dhaincha (*Sesbania aculeata*) has produced higher green biomass yield (21.55 t ha⁻¹) as compared to other green manuring crops with or without manuring. Incorporation of green manuring crop fertilized with 100 kg N equivalent FYM along with recommended dose of FYM (10 t ha⁻¹) for succeeding rice crop has recorded significantly higher growth, yield attributes, grain (50.49 q ha⁻¹) and straw yield (80.60 q ha⁻¹). Also, the microbial population and final nutrient status of soil was found highest in the treatment which received 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice (10 t ha⁻¹) during incorporation of dhaincha. The continuous application of FYM along with green manure for four consecutive years enhanced the soil chemical and biological properties.

INTRODUCTION

Rice is a staple food for nearly half of the world's population with more than 90 per cent of it being consumed in Asia itself. Rice production in Asian countries has increased considerably by virtue of the green revolution, providing solutions to food shortages and reducing poverty.

India is one among the major rice producing countries in the world. In India, the rice yield per unit area increased from 668 kg ha⁻¹ in 1951 to 2404 kg ha⁻¹ in 2016 and rice harvested area increased from 31 mha in 1951 to 43 mha in 2016. However, annual rice production increased nearly five-fold from 20 m tons in 1951 to 104 m tons in 2016 [Indiastat, 2017]. India is currently the second biggest producer of rice in the world. Concurrently, domestic rice consumption has been increasing each year as a result of dietary changes associated with population growth and economic development, making India a leading global rice consumer.

Rice being an important staple food crop of India, constitutes 36 per cent of total food grain production of India. Compound annual growth rate of

production (CAGR) of Rice during 2001-2011 is less (1.78 %) as compared CAGR of 1980-90 (3.62 %). There is a drastic reduction in fertilizer use efficiency from 1970 (13.8 kg/kg NPK) to 2010 (3.7 kg/kg NPK). Lack of inclusion of organic manures, crop residues, manures and green manuring crops, as nutrient sources especially under intensive cropping system is leading to decline in productivity of food crops in general and rice in particular in the country. An efficient organic nutrient management approach needs to be developed for increased productivity of rice under submerged conditions, in a sustainable manner. Organic nutrient management represents an important strategy for increasing the productivity of rice cropping system, as it also leads to improved soil chemical, physical and biological properties (Thakuria *et al.*, 2009). In organic nutrient management practices, huge quantity of organic matter needs to be applied to soil in order to meet the nutrient requirement of the crop. Non-availability of organic manures in required quantity is the major drawback in adopting the organic farming. However, through the adoption of *insitu* green manuring technique the required quantity of biomass can be

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generated within the field, which is an efficient management approach for enhancing the productivity, nutrient use efficiency and to bring sustainability without affecting soil quality. Combined application of organic manures and green manures with or without crop residue incorporation is known to improve nutrient use efficiency and productivity of rice-based cropping system (Pampolino *et al.*, 2007). Hence, there is a need to evaluate the suitable *insitu* green manuring crops along with suitable nutrient management practices to enhance the yield of rice in sustainable manner.

MATERIAL AND METHODS

The field experiments were conducted during 2012 - 2015 *Kharif* seasons at Organic Farming Research Centre, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka (13.977245 N, 75.578708 E) to study the effect of *insitu* green manuring on soil fertility, growth and yield of rice under organic farming and long term effect of green manuring on soil physical chemical and biological properties. Soil of the experimental site was shallow, well drained, sandy loam in texture, near neutral in reaction (pH 6.5) and non-saline soil (EC 0.45 dSm⁻¹) and low in organic carbon (4 g kg⁻¹), low soil available P₂O₅ (15 kg ha⁻¹), medium available K₂O (135 kg ha⁻¹), low available N (165 kg ha⁻¹), Zn (1.10 ppm), Mn (15.0 ppm), Fe (18.5 ppm) and Cu (1.25 ppm). The experiment was laid out in Randomized Complete Block design with three replications and eight treatments (Table 1). The quantity of manure applied was on N equivalent basis by considering N content of FYM as 1.02 per cent and neem cake as 5.6 per cent as per the treatments. Based on the treatments, dhaincha and other green manure crops were sown in each plot eight weeks prior to transplanting of main crop. Six weeks old green manure crop was incorporated into the soil by ploughing and allowed to decompose for 15 days. Three week old rice seedlings were transplanted manually with a spacing of 22.5cm x 10cm @ 3

seedlings per hill in 24 m² plot. One spray of econeem 50000 ppm @ 4ml per L (65 DAT), one spray of cow urine and water (1:10) ratio at 35 DAT and two sprays at 30 DAT & 55 DAT of panchagavya @ 3% were given as a measure of pests, disease management and to enhance the plant growth. Representative surface soil samples (0-15cm depth) were collected before initiating the experiment and after harvest of the rice crop using core sampler. The air dried processed soil samples were used for analysis. The standard methods and procedures suggested by Piper (1966) and Jackson (1973) are adopted. Treatment wise soil samples were collected from the rhizosphere of the plants at harvest. The soil samples collected were placed in a polyethylene bag and brought to the laboratory and stored in refrigerator at 5°C until used for analysis. Samples were analyzed for different soil microorganisms *viz.*, total bacteria, total fungi and total actinomycetes using standard dilution plate count technique and plating on specific nutrient media.

Uniform cultivation practices were followed in all the four years. At each season the plant growth parameters were recorded, soil and microbial analysis was carried out. The data obtained from each season was pooled and statistical analysis of the data was completed using computer aided MSTAT.

RESULTS AND DISCUSSION

Effect of application of manures on green biomass production

Pooled data pertaining to green biomass production by green manure crop as influenced by application of organic manure revealed that among the treatments, application of 100 kg N equivalent FYM for dhaincha during sowing (T₅) has recorded significantly highest green biomass yield (21.55 tons ha⁻¹) as compared to rest of the treatments. However, it was closely followed by mixed green manure crops (16.94 tons ha⁻¹) supplied with 100 kg N equivalent

Table 1. Effect of organic nutrient management practices on biomass yield of green manure crops

Treat- ment	Details	Green Biomass Yield (t ha ⁻¹)				
		2012	2013	2014	2015	Pooled
T ₁	<i>Insitu</i> dhaincha(Without Manure) + Supply of recommended FYM at incorporation	6.86	7.88	7.02	7.40	7.29
T ₂	<i>Insitu</i> mixed green manure(Without manure) + Supply of recommended FYM at incorporation	5.92	8.05	6.48	6.37	6.45
T ₃	<i>Insitu</i> dhaincha(Without Manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation	6.56	8.27	7.80	8.68	7.72
T ₄	<i>Insitu</i> mixed green manure(Without manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation	6.11	8.13	7.42	8.35	7.32
T ₅	100 % N through FYM at sowing of dhaincha green manure crop + Supply of recommended FYM at incorporation	20.60	20.93	21.45	23.24	21.55
T ₆	100 % N through FYM at sowing of mixed green manure crop + Supply of recommended FYM at incorporation	16.26	18.14	18.02	15.34	16.94
T ₇	50 % N through FYM at sowing of dhaincha green manure crop+ 50% recommended N through Neem cake at incorporation	12.29	14.69	14.19	12.24	13.35
T ₈	50 % N through FYM at sowing of mixed green manure + 50% recommended N through Neem cake at incorporation	11.36	13.44	13.40	10.23	12.11
SEM±		0.886	1.350	1.120	0.91	0.72
CD@5%		17.73	18.37	16.25	13.77	14.12

Mixed green manure includes: dhaincha + sunhemp + niger + cow pea ; Recommended FYM: 10 t ha⁻¹; 100 per cent N equivalent FYM: 20 t ha⁻¹

Table 2. Effect of organic nutrient management practices on growth and yield parameters of rice (pooled data of four years)

Treatment	Plant height (cm)	No. of tillers per hill	Productive tillers per hill	No. of panicles per plant	Test weight (g)	No. of filled grains/panicle	No. of unfilled grains/panicle
T ₁	74.3	18.7	17.7	11.0	26.3	146.0	37.3
T ₂	75.0	20.0	19.0	11.3	27.2	138.0	37.7
T ₃	78.3	20.3	18.3	12.0	27.8	157.3	27.7
T ₄	77.0	19.3	18.3	11.7	28.1	156.7	28.0
T ₅	86.0	25.0	24.0	14.0	30.3	172.7	16.33
T ₆	84.0	23.3	22.0	13.7	29.0	167.0	18.3
T ₇	83.3	22.0	21.0	13.0	26.3	161.7	22.7
T ₈	79.7	20.0	19.7	12.7	29.3	158.3	25.7
SEM±	0.42	1.72	0.85	0.45	0.56	2.25	1.19
CD@5%	1.35	NS	2.32	1.37	1.62	6.83	3.61

T₁ *In situ* dhaincha (without manure) + Supply of recommended FYM at incorporation

T₂ *In situ* mixed green manure(without manure) + Supply of recommended FYM at incorporation

T₃ *In situ* dhiancha (without manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation

T₄ *In situ* mixed green manure(without manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation

T₅ 100 % N through FYM at sowing of dhaincha green manure crop + Supply of recommended FYM at incorporation

T₆ 100 % N through FYM at sowing of mixed green manure crop + Supply of recommended FYM at incorporation

T₇ 50 % N through FYM at sowing of dhaincha green manure crop+ 50% recommended N through Neem cake at incorporation

T₈ 50 % N through FYM at sowing of mixed green manure + 50% recommended N through Neem cake at incorporation

FYM. The least biomass yield of green manure crops was noticed in treatments which were devoid of basal nutrient application (T_1 , T_2 , T_3 & T_4). Individual year data also recorded the same trend. Hence, in order to produce highest biomass of green manure crops it is essential to apply the basal dose of nutrients in the form of FYM. Similar results were also recorded by Ganapathi *et al.* (2014).

Effect of incorporation of green manure crops and manure application on growth and yield parameters of rice

Data pertaining to plant height of rice pooled over years revealed that application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice (10 t ha^{-1}) during incorporation of dhaincha has recorded significantly higher plant height (86.0 cm) as compared to rest of the treatments. This might be due to greater availability and steady release of nutrients from the combined organic sources of FYM and incorporation of green manures, which perhaps enabled the plants to grow tall. The number of tillers hill^{-1} (25), number of panicles plant^{-1} (14), test weight (30.3 g) and number of filled grains panicle^{-1} (172.7) were also found significantly higher in the treatment which received 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice during incorporation of dhaincha crop. The higher growth and yield parameters realized with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice during incorporation of dhaincha was attributed to availability of high quantity of nutrients to rice. Due to non-supply of basal dose of FYM for preceding green manuring crops remaining treatments produced lower quantity of green biomass which in turn resulted less nutrients availability to rice crop and finally reduction in growth and yield of rice. Green manures added lot of organic matter to the soil and helped in recycling the nutrients into soil besides preventing

nutrients being leached out of root zone. The benefits of green manuring are generally interpreted as its capacity to produce or provide nitrogen as substitute for fertilizers. Green manures, particularly the legumes have relatively more N, narrow C-N ratio and behave almost like chemical nitrogenous fertilizers there by enhance the growth and yield of succeeding crop (Bhuiyan and Zaman, 1996). Hence, the treatment which produced highest biomass yield of dhaincha has provided higher quantity of nutrients to succeeding rice crop which in turn resulted in higher growth and yield attributes of rice.

Effect of incorporation of green manure crops and manure application on yield of rice

In the experiment, fertilization of preceding green manuring crop played an important role in realizing the highest growth, yield parameters and finally yield of rice. Pooled data pertaining to yield of main crop revealed that significantly highest straw (80.6 q ha^{-1}) and grain yield (50.49 q ha^{-1}) of rice was recorded with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice (10 t ha^{-1}) during incorporation of dhaincha as compared to rest of the treatments. However, it was closely followed by the treatment which received 100 kg N equivalent FYM for mixed green manure crop during sowing along with application of recommended dose of FYM for rice. The lower growth attributes, yield and yield parameters associated with remaining treatments may be due to non-application of manure to preceding green manuring crop. Higher yields obtained with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice (10 t ha^{-1}) during incorporation of dhaincha could be attributed to superior growth parameters associated with the treatment. It could have been due to the slow and steady release of N into soil to match the required absorption pattern of rice and probably, the adequate supply of nutrients might have promoted

the grain yield. Dhaincha (*Sesbania aculeata* L.) upon its incorporation in the soil at succulent stage adds 60 kg N ha⁻¹ - 90 kg N ha⁻¹ (Pandey *et al.*, 2008). This helps to improve the physical and biochemical structure of the soil, prevent leaching losses of nutrients, enhancing water holding capacity, preventing weed growth, reducing residual effect of chemicals and also helps in reducing the soil borne inoculum of phytopathogens (Kumar, 2010). Due to all these reasons, treatments which produced highest biomass yield of green manure crop has provided optimum condition for production of highest yield of rice crop. Similar results were also reported by Ganapathi *et al.* (2014).

Effect of long term organic nutrient management practices on soil fertility

Due to continuous use of bulk quantity of organic manures for four consecutive years the important soil parameters *viz.*, OC, pH, EC and nutrient concentrations varied significantly over the years. There was a buildup in Organic Carbon content over the years, irrespective of the treatments as compared to initial soil carbon content of 4 g kg⁻¹ soil. Among the treatments, the highest buildup of OC was recorded with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice. Application of 100 kg N equivalent FYM for preceding dhaincha crop resulted in highest biomass production (22.6 t ha⁻¹) which upon incorporation into soil along with recommended dose of FYM ultimately enhanced the soil organic carbon content. The regular green manuring results in high organic matter reserve which enhances both soil chemical and physical properties of soil. Enhanced soil qualities of cultivated lands reflected in higher crop yields (Egodawatta *et al.*, 2011). Although, variation in pH of soil across the treatments was recorded, the variation was negligible as compared to initial level. The highest pH (6.74) was noticed with application of 100 kg N equivalent FYM for dhaincha crop during

sowing along with application of recommended dose of FYM. Electrical conductivity (EC) also followed the same trend.

The availability of N, P and K also enhanced due to application of organic manures as compared to initial status. At the end of four years of experimentation available soil N varied from 155 to 219 kg ha⁻¹. The highest available N (219 kg ha⁻¹) was noticed with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice. The lowest N content in soil was noticed in T₄. The highest available P₂O₅ (205.7 kg ha⁻¹) at the end of experiment was noticed with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice. Potassium content varied significantly due to different manurial treatments. Highest soil available potassium content (326.4 kg ha⁻¹) was noticed with application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice. Significantly highest Ca (3.70 C mol kg⁻¹), Mg (1.85 C mol kg⁻¹), Fe (83.37 ppm), Zn (2.22 ppm), Mn (29.46 ppm), Cu (1.82 ppm) and S (26.6 ppm) content in soil was also recorded with the application of 100 kg N equivalent FYM for dhaincha crop during sowing along with application of recommended dose of FYM for rice as compared to rest of the treatments. Green manures upon its decomposition not only add to the organic matter of the soil but also provides mineral nutrients required by the crop plants grown in the field. Decomposition of green manures serve as major source of energy for the growth of microflora and supplies carbon for formation of new cell material to soil-biota which colonizes aphytically on the decomposing litter. During decomposition a series of biochemical changes takes place which ultimately lead to the simplification of various compounds. The use of green manure crops reduces soil borne diseases, suppress the weeds and other pests

Table 3. Effect of organic nutrient management practices on yield of Rice

Treatment	Yield (q ha ⁻¹)												
	2012		2013			2014			2015			Pooled	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	
T1	26.40	48.56	31.78	53.84	35.10	54.16	36.43	51.93	36.43	51.93	32.43	52.12	
T2	22.70	43.12	32.19	55.80	37.89	58.377	33.33	49.30	33.33	49.30	31.53	51.65	
T3	26.82	47.87	34.14	59.91	42.49	61.91	40.30	58.45	40.30	58.45	36.06	54.63	
T4	23.20	43.25	33.61	59.30	41.57	63.747	38.76	54.26	38.76	54.26	34.29	55.14	
T5	44.0	82.01	48.86	79.30	53.60	80.743	52.56	80.34	52.56	80.34	50.49	80.60	
T6	38.50	79.68	46.69	76.30	51.80	77.867	47.82	71.73	47.82	71.73	46.20	76.39	
T7	36.40	71.40	43.64	69.20	46.18	67.440	44.18	62.47	44.18	62.47	42.60	67.16	
T8	34.50	69.40	41.53	65.35	44.34	64.673	42.63	61.23	42.63	61.23	40.75	65.63	
SEM±	1.97	4.21	2.09	2.04	3.13	6.03	2.50	4.10	2.50	4.10	4.20	2.30	
CD@5%	5.64	12.02	6.35	6.19	9.49	18.29	7.26	12..5	7.26	12..5	12.40	6.76	

T₁ *In situ* dhaincha (without manure) + Supply of recommended FYM at incorporation

T₂ *In situ* mixed green manure (Without manure) + Supply of recommended FYM at incorporation

T₃ *In situ* dhaincha (without manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation

T₄ *In situ* mixed green manure (Without manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation

T₅ 100 % N through FYM at sowing of dhaincha green manure crop + Supply of recommended FYM at incorporation

T₆ 100 % N through FYM at sowing of mixed green manure crop + Supply of recommended FYM at incorporation

T₇ 50 % N through FYM at sowing of dhaincha green manure crop+ 50% recommended N through Neem cake at incorporation

T₈ 50 % N through FYM at sowing of mixed green manure + 50% recommended N through Neem cake at incorporation

Table 4. Effect of organic nutrient management practices on soil chemical properties

Treatment	pH	EC (dS m ⁻¹)	N	P ₂ O ₅ Kg ha ⁻¹	K ₂ O	OC g/kg	Ca (Cmol (p ⁺) kg ⁻¹)	Mg	Fe	Zn	Mn	Cu	S
T ₁	6.62	0.533	172	103	109.	5.8	3.13	1.42	67.44	1.88	7.32	1.52	16.5
T ₂	6.36	0.640	199	202	175	5.0	3.23	1.55	61.48	2.06	21.08	1.68	15.7
T ₃	6.57	0.735	185	105	147	5.7	3.13	1.75	63.52	1.51	23.14	1.74	19.4
T ₄	7.14	0.587	156	105	227	4.5	3.40	1.50	50.49	2.03	14.44	1.64	21.2
T ₅	6.74	0.595	219	206	326	8.5	3.70	1.85	83.37	2.22	13.41	1.82	26.6
T ₆	6.26	0.671	207	200	299	7.1	3.60	1.65	80.37	2.34	29.46	1.78	25.3
T ₇	6.62	0.568	213	100	290	6.7	3.50	1.35	77.47	2.03	26.41	1.73	21.8
T ₈	6.66	0.633	188	107	207	6.0	3.40	1.45	57.48	1.44	24.48	1.73	20.6
SEM±	0.17	0.09	12.66	1.30	35.84	0.60	0.29	0.05	12.31	0.11	1.76	0.11	1.08
CD at 5 %	NS	NS	33.57	3.93	104.34	1.90	0.89	0.15	NS	0.33	5.15	NS	3.12
Initial	6.5	0.45	165.0	20.2	135.0	0.40	2.80	1.42	18.5	1.10	15.0	1.25	8.24

T₁ *In situ* dhaincha (Without Manure) + Supply of recommended FYM at incorporation

T₂ *In situ* mixed green manure(Without manure) + Supply of recommended FYM at incorporation

T₃ *In situ* dhaincha (Without Manure) + Supply of recommended FYM along with 50 % additional N through Neem cake at incorporation

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T₈ 50 % N through FYM at sowing of mixed green manure + 50% recommended N through Neem cake at incorporation

Table 5. Effect of organic nutrient management practices on biological properties of soil (after harvest, 2015)

Treat- ment	Bacteria			Fungi			Actinomycetes			PSM			N-fixer		
	cfu x 10 ⁵			cfu x 10 ⁴			cfu x 10 ³			cfu x 10 ³			cfu x 10 ³		
	30 DAP	60 DAP	At Harvest	30 DAP	60 DAP	At Harvest	30 DAP	60 DAP	At Harvest	30 DAP	60 DAP	At Harvest	30 DAP	60 DAP	At Harvest
T ₁	64.3	80.0	61.3	8.0	8.6	7.0	4.3	9.0	5.0	7.0	12.0	7.6	17.0	23.0	14.0
T ₂	63.0	82.0	61.3	6.6	8.3	6.0	4.0	8.0	4.0	5.0	11.0	7.0	15.0	20.0	11.6
T ₃	65.6	80.3	62.6	9.0	10.3	9.0	5.6	10.0	7.0	8.7	13.6	8.6	19.0	14.3	15.3
T ₄	67.3	82.6	64.6	8.3	9.0	8.6	5.0	9.6	6.6	8.0	13.0	8.0	18.3	24.0	15.0
T ₅	75.6	90.6	70.6	10.6	13.6	10.3	8.6	13.0	8.3	11.3	16.0	10.3	22.0	27.0	17.0
T ₆	72.3	87.0	68.0	10.3	12.6	10.0	7.0	10.0	8.0	10.0	14.6	9.0	20.3	26.3	16.6
T ₇	70.6	85.3	65.3	9.6	11.3	9.6	6.6	11.6	7.0	9.6	14.0	8.6	20.0	25.6	16.6
T ₈	67.0	82.3	65.0	9.0	11.0	9.3	6.0	11.0	7.6	9.0	14.0	8.0	19.6	25.0	16.0
SEm±	0.29	0.370	0.32	0.360	0.268	0.360	0.330	0.256	0.310	0.270	0.375	0.362	0.306	0.289	0.309
CD @ 5 %	0.72	0.925	0.86	0.920	0.800	0.900	0.826	0.630	0.870	0.675	0.937	0.905	0.762	0.850	0.772
Initial	54.00			5.43			5.00			6.80			11.00		

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T₆ 100 % N through FYM at sowing of mixed green manure crop + Supply of recommended FYM at incorporation

T₇ 50 % N through FYM at sowing of dhaincha green manure crop+50% recommended N through Neem cake at incorporation

T₈ 50 % N through FYM at sowing of mixed green manure + 50% recommended N through Neem cake at incorporation

getting emphasis because of its sustainable and environmental friendly nature, thus, helps to promote organic cultivation (Parajuli, 2011).

Effect of long term organic nutrient management practices on soil microbial activities

In the investigation treatment which involved application of 100 kg N equivalent FYM for preceding dhaincha crop and its incorporation along with application of recommended dose of FYM for succeeding rice recorded higher population of actinomycetes, bacteria and fungi as compared to rest of the treatments (Table 5). There was a gradual increase in the microbial population towards end of the growing season as compared to initial microbial status (Table 5). Enhancement of microbial population results in effective utilization of the soil organic matter supplied through incorporation of green manure crops and FYM. Soil enzymatic activities are closely related to microbial activity or biomass as they catalyse biochemical reactions and nutrient cycling in the soils (Burns, 1982). The population of free living nitrogen fixers also found significantly highest in T₅ as compared to rest of the treatments at different growing period of crop *viz.*, 30 days, 60 days and at harvesting (Table 5). Another important functional group of agriculturally important microorganisms is phosphate solubilizers. Phosphate solubilizing microorganisms are known to improve P-solubilization, thereby improving crop growth and yield. In the study, abundance of P-solubilizers are observed in rhizosphere of soils in T₅ (Table 5). Among different crop growth stages the highest microbial population was found at 60 DAS as compared to remaining growth stages which can be attributed to higher root exudations by the plants at this stage. Root exudates includes various organic and inorganic acids and it will attract more beneficial soil microflora and results in the higher growth and yield of the crops.

The application of green manures to soil is considered as a good management practice in any agricultural production system because it stimulates soil microbial growth and activity, with subsequent mineralization of plant nutrients (Eriksen, 2005), and, therefore, increase soil fertility and quality (Doran *et al.*, 1988). From the microbiological point of view, green manure and organic manures have two main positive effects— enhances microbial biomass which converts unavailable nutrients in plant residues to available form and also enhances biodiversity of soil micro-organisms. These positive effects can be enhanced by supplying huge biomass of green manure crop as achieved in treatment T₅. Increase in beneficial microbial activity was often related to increase in organic matter (Sikora and Stott, 1996). Organic matter is vital as a food source for beneficial microorganisms that are related to disease suppression, soil structure, improvement in soil properties and crop health (Schutter and Dick, 2001). The use of green manures in between successive crops helps maintain or increase organic matter in soils (Pung *et al.*, 2004). Hence, the treatment T₃ which added the higher green biomass (21.55 t ha⁻¹) to the soil has recorded significantly higher microbial population. Similar results were recorded by Ganapathi *et al.* (2014).

CONCLUSION

The study revealed that in order to achieve highest yield in rice in sustainable manner, application of 100 kg N equivalent FYM to preceding dhaincha crop at sowing and incorporating the dhaincha crop 15 days prior to transplanting of the succeeding rice along with recommended dose of FYM (10 t ha⁻¹) is essential. Supply of 100 kg N equivalent FYM to dhaincha crop has enhanced biomass production of dhaincha crop. Incorporation of dhaincha crop 15 days prior to transplanting has enhanced the physical, chemical and biological properties of soil, which in turn resulted in higher yield of rice.

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ESTIMATES OF DIRECT AND INDIRECT EFFECTS AMONG YIELD, YIELD CONTRIBUTING AND QUALITY TRAITS IN AMERICAN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

Correlation and path coefficient analysis for yield and yield contributing characters in American cotton with 56 genotypes for 14 traits was studied during *Kharif*, 2017-18. The character association analysis revealed that plant height (cm), number of monopodia plant⁻¹, number of sympodia plant⁻¹, number of bolls plant⁻¹, boll weight (g), seed index (g), lint index (g), micronaire value (10⁻⁶g/inch) and uniformity ratio were found to have significant positive association with seed cotton yield plant⁻¹ at genotypic level. The path analysis indicated that the plant height (cm), number of monopodia plant⁻¹, number of bolls plant⁻¹, boll weight (g), seed index (g) and micronaire value (10⁻⁶g/inch) showed direct positive effects and significant positive correlation with seed cotton yield plant⁻¹ (g). It is revealed that priority should be given in selection process with more number of bolls plant⁻¹ and more boll weight and there should be economic balance among these characters to get higher seed cotton yield plant⁻¹.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a major crop of global importance and has high commercial value. In India, cotton is being grown over an area of 122 lakh ha with an annual production of 377 lakh bales (1 bale = 170kg of lint) and productivity of 524 kg lint per ha (AICCIP, 2018). There are four cultivated cotton species including two diploids (*Gossypium herbaceum* L. and *Gossypium arboreum* L.) and two tetraploids (*Gossypium hirsutum* L. and *Gossypium barbadense* L.). Approximately, 95 per cent of the world cotton production is from *Gossypium hirsutum* L. Both correlation and path coefficient analysis form a basis for selection and also helps in understanding those yield components affecting yield improvement through the study of their direct and indirect effects.

MATERIAL AND METHODS

The study was conducted during *Kharif*, 2017-2018 in randomized block design with 56 genotypes with three replications following 120 cm × 60 cm spacing at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh. The soils are of black cotton type. The recommended dose of fertilizers @120 N, 60 P₂O₅, 40 K₂O kg ha⁻¹ was added with entire P. as basal, both N and K applied in three slit doses at 30DAS, 60DAS and 90 DAS. Each plot consisted of three rows of 6 m length and observations were recorded on five randomly selected plants from each genotype per replication. The data was recorded on 14 characters *viz.*, plant height (cm), days to 50% flowering, number of monopodia plant⁻¹, number of sympodia plant⁻¹, number of bolls plant⁻¹, boll weight

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(g), seed index (g), lint index (g), ginning outturn (%), 2.5% span length (mm), micronaire value (10^{-6} g/inch), bundle strength (g/tex), uniformity ratio and seed cotton yield plant⁻¹ (g). The fibre quality parameters were studied at Central Institute for Research on Cotton Technology (CIRCOT), Regional Unit, RARS, Lam, Guntur. The data was statistically analysed to estimate the character association pattern; direct and indirect effects of various yield attributes on yield.

RESULTS AND DISCUSSION

The analysis of variance indicated significant differences among the genotypes for all the characters studied (Table 1). Genotypic correlation coefficients were presented in Table 2. Seed cotton yield plant⁻¹ was significant and positively correlated with characters *viz.*, plant height (cm) (0.3742**), number of sympodia plant⁻¹ (0.3336**), number of bolls plant⁻¹ (0.5609**), boll weight (g) (0.3742**), seed index (g) (0.3104**), lint index (g), (0.1783*), micronaire value (10^{-6} g/inch) (0.3425**) and uniformity ratio (0.2122**) at genotypic level. Similar results of positive association of seed cotton yield plant⁻¹ with plant height, number of sympodia plant⁻¹, number of bolls plant⁻¹, boll weight, seed index, lint index, micronaire value and uniformity ratio were earlier reported by Santosh Kumar *et al.* (2012); Rumesh Ranjan *et al.* (2014); Pujer *et al.* (2014) and Bayyapu Reddy *et al.* (2016). Similarly, the traits namely days to 50 per cent flowering, ginning out turn and 2.5% span length(mm) showed negative association with seed cotton yield per plant, which was in accordance with the findings of Farooq *et al.* (2014).

Among the yield components, the trait number of bolls plant⁻¹ showed significant positive association with the traits *viz.*, plant height, number of monopods plant⁻¹ and number of sympodia plant⁻¹, boll weight, seed index, lint index and micronaire value. The current findings are in agreement with the

results of Farooq *et al.* (2014) for boll weight; Chitti *et al.* (2014) for seed index, lint index and micronaire value. However, boll weight had positive and significant association with plant height, number of sympodia plant⁻¹, number of bolls plant⁻¹, seed index and lint index, which are in line with the observations of Kumar *et al.* (2014).

It is clear that plant height (cm), number of sympodia plant⁻¹, number of bolls plant⁻¹, boll weight (g), seed index (g), lint index (g), micronaire value (10^{-6} g/inch) and uniformity ratio would help to improve the seed cotton yield coupled with quality in cotton, as these traits had strong positive association with seed cotton yield. Similarly, selecting the plants with more number of monopods would fetch as it had positive association with yield. Hence, these characters may be considered while formulating the selection strategies for improving seed cotton yield and quality as well.

The estimates of correlation coefficient mostly indicated inter-relationship of different characters, however, it did not furnish the information on cause and effect. Under such situation path analysis would help the breeder to identify the index of selection. Path coefficient analysis was completed in order to study the direct and indirect effects of individual component characters on dependent variable *i.e.*, seed cotton yield plant⁻¹. Study of path coefficients enable the breeder to concentrate on the variables which show high direct effect on seed cotton yield. The genotypic correlation coefficients of seed cotton yield with other and fiber quality traits were further partitioned into direct and indirect effects and the results presented in Table 3 and Fig. 1.

The component of residual effect of path analysis in yield and fibre quality trait is 0.027 at genotypic level. The lower residual effect indicated that the characters chosen for path analysis were

Table 1. Analysis of variance for yield and yield components in cotton during *kharif*, 2017-18

Source	d.f.	Plant height	Days to 50% flowering	Number of monopodia per plant	N umber of sympodia per plant	Number of bolls per plant	Boll weight	Seed index
Mean sum of squares								
Replications	2	42.82	3.59	0.07	0.97	10.32	0.01	1.70
Treatments	55	481.72**	12.02**	1.21*	12.07**	111.52**	0.50**	3.18**
Error	110	91.65	4.03	0.09	2.68	19.46	0.03	0.73
Source	d.f.	Lint index	Ginning outturn	2.5% span length	Micronaire value	Bundle strength	Uniformity ratio	Seed cotton yield plant ⁻¹
Mean sum of squares								
Replications	2	0.18	2.73	0.03	0.02	0.5	0.25	15.74
Treatments	55	1.24**	6.81**	8.41**	0.18**	4.53**	2.97**	1942.95**
Error	110	0.47	1.02	0.73	0.03	0.41	1.55	216.69

* Significant at 5% level ; ** Significant at 1% level

Table 2. Genotypic correlation coefficients for 14 characters in intra-specific hybrids of cotton during *kharif*, 2017-18

Character	Plant height (cm)	Days to 50% flowering	No. of monopodia plant ⁻¹	No. of sympodia plant ⁻¹	No. of bolls plant ⁻¹	Boll weight (g)	Seed index (g)	Lint index (g)	Ginning outturn (%)	2.5% span length (mm)	Uniformity ratio	Micronaire value (10-6 g/inch)	Bundle strength (g/tex)	Seed cotton yield per plant (g)
Plant height (cm)	1.000	-0.0278	-0.0573	0.6533**	0.3559**	0.3559**	0.2644**	0.1704*	-0.1040	-0.1139	0.1261	0.0779	0.1591*	0.3742**
Days to 50% flowering	-0.0278*	1.000	0.2262**	0.0096	-0.0410	-0.0590	-0.1462	-0.1627*	-0.0263	0.0596	-0.0776	-14.04	0.1135	-0.0940
Number of monopodia plant ⁻¹	-0.0573	0.2262**	1.000	0.0358	0.3677**	0.0151	0.0094	-0.1278	-0.1696*	-0.0766	-0.0145	0.2458**	-0.0829	0.0594
Number of sympodia plant ⁻¹	0.6533**	0.0096	0.0358	1.000	0.4515**	0.3394**	0.3109**	0.1941*	-0.1573*	0.0021	0.0657	0.1788*	0.1810*	0.3336**
Number of bolls plant ⁻¹	0.3559**	-0.0410	0.3677**	0.4515**	1.000	0.1926*	0.2782**	0.1732*	-0.1366	-0.1006	0.0579	0.3551**	0.0340	0.5609**
Boll weight (g)	0.3538**	-0.0590**	0.0151	0.3394**	0.1926*	1.000	0.4971**	0.2138**	-0.3728**	0.2428**	0.2344**	0.1152	0.3833**	0.3742**
Seed index (g)	0.2644**	-0.1462**	0.0094	0.3109**	0.2782**	0.4971**	1.000	0.5775**	-0.4491**	0.2462**	0.1443	0.0941	0.3696**	0.3104**
Lint index (g)	0.1704*	-0.1627**	-0.1278	0.1941*	0.1732*	0.2138**	0.5775**	1.000	0.3682**	0.0199	0.1282	-0.0040	0.1889*	0.1783*
Ginning outturn (%)	-0.1040	-0.0263	-0.1696**	-0.1573*	-0.1366*	-0.3728**	-0.4491**	0.3682**	1.000	-0.2703**	0.0447	-0.1317	-0.1692*	-0.1008
2.5% span length (mm)	-0.1139**	0.0596	-0.0766	0.0021	-0.1006	0.2428**	0.2462**	0.0199	-0.2703**	1.000	-0.2461**	-0.1199	0.6229**	-0.0679
Uniformity ratio	0.1261	-0.0776	-0.0145	0.0657	0.0579	0.2344**	0.1443	0.1282	0.0447**	-0.2461**	1.000	0.0432	0.0804	0.2122**
Micronaire value (10-6 g/inch)	0.0779	-0.1404	0.2458**	0.1788*	0.3551**	0.1152	0.0941	-0.0040	-0.1317	-0.1199*	0.0432	1.000	-0.1238	0.3425**
Bundle strength (g/tex)	0.1591*	0.1135	-0.0829	0.1810*	0.0340	0.3833**	0.3696**	0.1889*	-0.1692*	0.6229**	0.0804	-0.1238**	1.000	-0.0099*
Seed cotton yield plant ⁻¹ (g)	0.3742**	-0.0940*	0.0594**	0.3336**	0.5609**	0.3742**	0.3104**	0.1783*	-0.1008	-0.0679*	0.2122**	0.3425**	-0.0099*	1.000

* Significant at 5% level ; ** Significant at 1% level

Table 3. Direct and indirect effects (genotypic) of 14 characters on seed cotton yield in intra-specific hybrids of cotton during Kharif, 2017-18

Character	Plant height (cm)	Days to 50% flowering	No. of monopodia plant ⁻¹	No. of sym-podia plant ⁻¹	No. of bolls plant ⁻¹	Boll weight (g)	Seed index (g)	Lint index (g)	Ginning outturn (%)	2.5% span length (mm)	Uniformity ratio	Micronaire value (10 ⁻⁶ g/inch)	Bundle strength (g/tex)
Plant height (cm)	0.6365	0.0365	-0.0353	0.5656	0.3719	0.2671	0.2369	0.1731	-0.1117	-0.0106	0.0804	0.1260	0.1908
Days to 50% flowering	0.0089	0.1554	0.0307	-0.0367	-0.0171	-0.0249	-0.0545	-0.0576	0.0142	0.0168	-0.0025	-0.0698	0.0162
Number of monopodia plant ⁻¹	-0.0015	0.0052	0.0264	0.0020	0.0119	0.0002	-0.0006	-0.0071	-0.0064	-0.0021	-0.0014	0.0072	-0.0037
Number of sym-podia plant ⁻¹	-0.5689	0.1510	-0.0490	-0.6402	-0.3884	-0.2566	-0.2524	-0.2148	0.0901	-0.0426	-0.0729	-0.1838	-0.1285
Number of bolls plant ⁻¹	0.2796	-0.0525	0.2146	0.2903	0.4785	0.0928	0.1424	0.0992	-0.0862	-0.0450	-0.0104	0.2662	-0.0138
Boll weight (g)	0.1864	-0.0712	0.0038	0.1781	0.0862	0.4442	0.3019	0.1588	-0.1960	0.1380	0.1504	0.0798	0.2083
Seed index (g)	0.4704	-0.4429	-0.0264	0.4983	0.3761	0.8590	1.2638	0.7468	-0.7794	0.5568	0.4061	0.3665	0.6758
Lint index (g)	-0.0361	0.0492	0.0358	-0.0445	-0.0275	-0.0474	-0.0784	-0.1327	-0.0498	-0.0165	-0.0872	-0.0081	-0.0615
Ginning outturn (%)	-0.1668	0.0865	-0.2310	-0.1337	-0.1711	-0.4192	-0.5860	0.3568	0.9501	-0.3622	0.1563	-0.2837	-0.1959
2.5% span length (mm)	-0.0002	0.0010	-0.0008	0.0006	-0.0004	-0.0009	0.0029	0.0012	-0.0036	0.0095	-0.0045	-0.0014	0.0071
Uniformity ratio	-0.0421	0.0054	0.0180	-0.0380	0.0072	0.1128	-0.1071	-0.2191	-0.0548	0.1573	-0.3332	0.0171	-0.0306
Micronaire value (10 ⁻⁶ g/inch)	0.0002	-0.0005	0.0003	0.0003	0.0007	0.0002	0.0004	0.0001	-0.0004	-0.0002	-0.0001	0.0012	-0.0003
Bundle strength (g/tex)	-0.2082	-0.0725	0.0983	-0.1394	0.0200	-0.3257	-0.3714	-0.3221	0.1432	-0.5234	-0.0638	0.1672	-0.6945
Correlation with seed cotton yield per plant	0.5584**	-0.1493*	0.0855**	0.5027**	0.7475**	0.4799**	0.4993**	0.5826	-0.0907	-0.1242*	0.2171**	0.4846**	-0.0306**

* = Significant at 5% level; ** = Significant at 1% level; Residual effect = 0.0271; Bold and diagonal values indicate direct effect

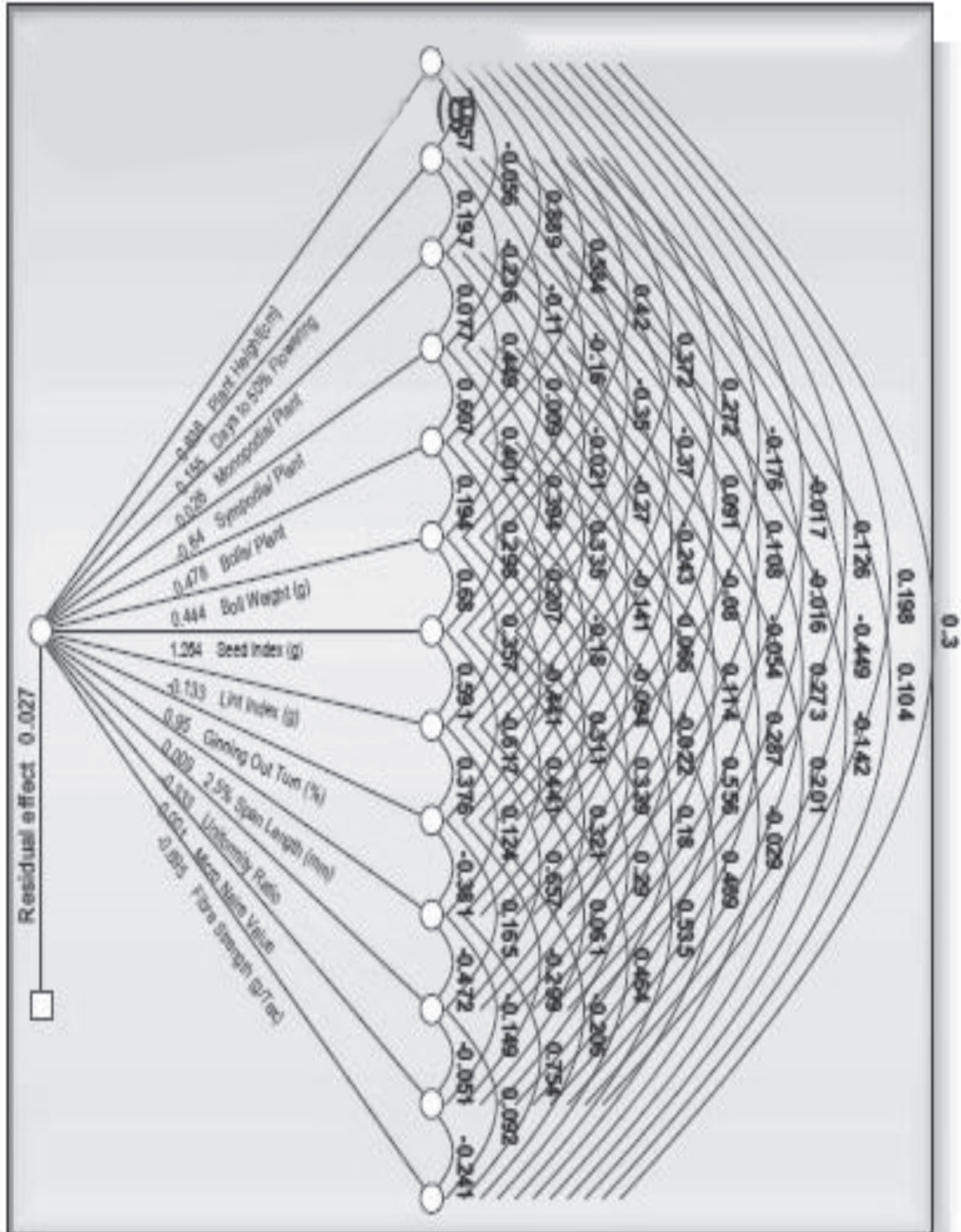


Fig.1. Genotypical path diagram showing direct and indirect effects of yield components on seed cotton yield plant⁻¹ in cotton

adequate, appropriate and further indicated that characters included in this study were effective for improving the yield too.

Path coefficient analysis indicated that plant height (cm), number of monopodia plant⁻¹, number of bolls plant⁻¹, boll weight (g), seed index (g) and micronaire value (10⁻⁶g/inch) showed direct positive effects and significant positive correlation with seed cotton yield plant⁻¹ (g) at genotypic level. These results are in conformity with the findings of Rajanna *et al.* (2011) for plant height (cm), number of monopodia plant⁻¹; Kumari Vinodhana *et al.* (2013), Rumesh Ranjan *et al.* (2014) for number of bolls plant⁻¹ and boll weight (g); Bayyapu Reddy *et al.* (2016) for seed index (g) and micronaire value (10⁻⁶g/inch). While the indirect positive effect on seed cotton yield plant⁻¹ at genotypic level by days to 50% flowering, ginning outturn (%), 2.5% span length (mm) and bundle strength (g/tex) was observed. It is very clear through path analysis results that most important characters accounting for cause and effect relationships on seed yield of cotton were number of bolls plant⁻¹, boll weight (g), seed index (g) and plant height (cm).

The progress in breeding by component traits of seed cotton yield may be limited due to strong negative association of quality traits like ginning out turn and fibre length with seed cotton yield and yield components as the fibre traits should be at acceptable level to the seed industry. Hence, from the correlation and path coefficient analysis study it was inferred that the traits plant height (cm), number of bolls per plant, boll weight (g), seed index (g) and micronaire value (10⁻⁶g/inch) had significant association and also showed positive direct effects on seed cotton yield per plant. Hence, in the improvement programmes importance may be given for these traits to improve genetic yield potential in cotton.

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FORECASTING OF THE BROWN PLANT HOPPER DAMAGE IN RICE AT TELANGANA STATE – A STATISTICAL APPROACH

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ABSTRACT

Research was conducted to forecast the damage due to Brown Plant Hopper in Rice in Telangana state using the forecasting techniques Artificial Neural Network model (ANN), Autoregressive Integrated moving Average model (ARIMA) and Autoregressive Integrated Moving Average model with exogenous variables (ARIMAX) and also to compare their prediction accuracies. To forecast the damage pertaining to the BPH, data pertaining to the damage caused by BPH was collected for 27 years during both *kharif* and *rabi* seasons of the Telangana state *i.e.*, during 1990-2016. The results showed that artificial neural network (ANN) performed reasonably well compared to the other models *i.e.*, autoregressive integrated moving average model (ARIMA) and ARIMAX model and hence, can be applied for real life predictions and modeling problems.

INTRODUCTION

Rice (*Oryza sativa* L.) is an important cereal crop of the world with respect to area and production. It is the important staple food for more than 50% of the world population and provides 60%-70% body caloric intake to the consumers. The total rice production in the world is 487.46 million metric tonnes as estimated by the United States Department of Agriculture (USDA) in November, 2017. India ranks second in rice production in the world with the production of 165.3 million metric tonnes, whereas, China ranks first with 210.1 million metric tonnes (Statistica, the statistical portal, 2017). Further, rice crop is prone to the attack of weeds, several insect pests and diseases causing crop losses to the extent of 30%- 40% which further adds to the complexity to achieve high yield potential.

Among the biotic stresses, insect pests cause major damage to the crop yields. The average yield losses in rice have been estimated to vary between 21%-51% (Chaudhary, 2014). There are about more than 100 varieties of insect pests which cause damage to the rice crop. Among the different insect pests of rice, brown plant hopper (BPH), *Nilaparvata lugens* (Stal.) has long been known as a

major pest of rice in South Asia and South-East Asia (Dyck *et al.*, 1979). This notorious pest is known to damage rice plant by way of sucking the sap and ovipositing in leaf sheath at the base of the plant causing the crop to wilt and dry. When the population increases significantly, early symptoms of damage manifest on relatively healthy crop in the form of circular yellow patches in the field. With severity of infestation, the patches manifest as typical symptom of "hopperburn". It was observed that the seasonal occurrence of *N. lugens* in rice fields has increased during September-October (Nasu, 1964). Prabhswamy (1972) reported two peaks of BPH during April-May (summer) and October-November. It was also observed that the higher population of BPH was during December and July on grasses in the absence of paddy crop. The seasonal occurrence of the Brown Plant Hopper varies between areas where it undergoes diapause (temperate regions) and in areas it is active throughout the year (Tropical countries) (Alam, 1971). In Asia, it has been recorded as major pest of rice because of the unpredictable nature of the infestations and the dramatic severity of the damage it inflicts to the crop. It became Asia's worst rice pest during the 1970's, causing heavy losses and economic desperation for thousands of

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farmers. The brown plant hopper (BPH) is common in rainfed and irrigated wetland environments especially during the reproductive stage of the rice during both *kharif* and *rabi* seasons. In the study, attempt was made to forecast the damage caused by BPH which was measured in terms of number of BPH per 10 hills with the help of Artificial Neural Network, Autoregressive Integrated Moving Average model and Autoregressive Integrated Moving Average with Exogenous variables model. The measures Root mean square error (RMSE) and R^2 were used to compare the prediction accuracies of the models.

MATERIAL AND METHODS

The main purpose of this study (Conducted during 2016) is to fit the forecasting models ANN, ARIMA and ARIMAX to forecast the damage caused by the brown plant hopper (*Nilaparvata Lugens*) in the Telangana state. In the study, the data pertaining to the damage caused by the brown plant hopper which is expressed in terms of number of BPH per 10 hills during both *Kharif* and *Rabi* seasons pertaining to the Telangana State has been taken for the past 27 years *i.e.*, during the period 1990-2016. Hence, there are totally 27 (years) x 2 (*Kharif* & *Rabi*) = 54 data points. Also, the weekly data pertaining to the weather parameters affecting the damage due to Brown Plant Hopper *i.e.*, maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening), rainfall and sunshine hours has been taken for the same 27 years. Based on the agro-climatic conditions, Telangana state was classified into three zones *viz.*, Northern Telangana zone, Southern Telangana zone

and Central Telangana zone. The data pertaining to the Southern Telangana zone has been taken from the ICAR- Indian Institute of Rice Research, Rajendranagar, Hyderabad. Similarly, the data pertaining to the Northern Telangana and Central Telangana zones has been taken from the Regional Agricultural Research Station, Jagtial and Regional Agricultural Research Station, Warangal.

Artificial Neural Networks

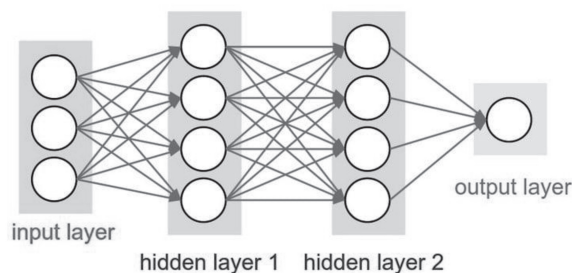
An Artificial neural network is a computer system that simulates the learning process of human brain. The greatest advantage of neural networks is its ability to model nonlinear complex data series. The basic architecture consists of three types of neuron layers: input, output and hidden layers. The ANN model performs a nonlinear functional mapping from the input observations ($y_{t-1}, y_{t-2}, y_{t-3}, \dots, y_{t-p}$) to the output value y_t .

$$Z_{yt} = a_0 + \sum a_j f(W_{oj} + \sum W_{ij} y_{t-1}) + e_i \tag{1}$$

Where a_j ($j=0,1,2,3,\dots, q$) is the bias on the j^{th} unit and W_{ij} ($i=0,1,2,\dots,p, j=0,1,2,\dots,q$) is the connection weights between layers of the model, $f(.)$ is the transfer function of the hidden layer, p is the number of input nodes and q is the number of hidden nodes (Lai *et al.*, 2006). The activity function utilized for the neurons of the hidden layer was the logistic sigmoid function that is described by

$$f(x) = 1/1+e^{-x} \tag{2}$$

This function belongs to the class of sigmoid functions which has advantages characteristics such as being continuous, differentiable at all points and monotonically increasing.



II. Auto Regressive Integrated Moving Average (ARIMA)

ARIMA model has been one of the most popular approaches to forecasting. The ARIMA model is basically a data-oriented approach that is adapted from the structure of the data themselves. An autoregressive integrated moving average (ARIMA) process combines three different processes namely an autoregressive (AR) function regressed on past values of the process, moving average (MA) function regressed on a purely random errors and an integrated (I) part to make the data series stationary by differencing. In an ARIMA model, the future value of a variable is supposed to be a linear combination of past values and past errors. Generally, a non-seasonal ARIMA model, denoted as ARIMA (p,d,q), is expressed as

$$Y_t = F_0 + F_1 Y_{t-1} + F_2 Y_{t-2} + F_3 Y_{t-3} + \dots + F_p Y_{t-p} + e_t - G_1 e_{t-1} - G_2 e_{t-2} - \dots - G_q e_{t-q}$$

Where Y_{t-1} and e_t are the actual values and random error at time t respectively. F_i ($i = 1, 2, \dots, p$) and G_j ($j = 1, 2, \dots, q$) are the model parameters. Here 'p' is the number of autoregressive terms, 'd' is the number of non-seasonal differences and 'q' is the number of lagged forecast errors. Random errors e_t are assumed to be independently and identically distributed with mean zero and the common variance σ_e^2 .

Basically, this method has three phases:

- 1) Model Identification
- 2) Parameter estimation and
- 3) Diagnostic Checking.

The auto-regressive integrated moving average (ARIMA) model deals with the non-stationary linear component. However, any significant nonlinear data set limit the ARIMA.

III. Autoregressive Integrated moving Average with Exogenous variables (ARIMAX) model

Autoregressive integrated moving average with exogenous variable (ARIMAX) is the generalization of ARIMA (Autoregressive Integrated moving average) models. Simply an ARIMAX model is like a multiple regression model with one or more autoregressive terms and one or more moving average terms. This model is capable of incorporating an external input variable. Identifying a suitable ARIMA model for endogenous variable is the first step for building an ARIMAX model. Testing of stationarity of exogenous variables is the next step. Then transformed exogenous variable is added to the ARIMA model in the next step.

Forecasting Model

In the study, the data pertaining to the damage caused by brown plant hopper which is expressed in terms of number of brown plant hoppers per 10 hills for the past 27 years was considered to fit the ANN, ARIMA and ARIMAX models. The total data is divided into two groups, they are training data and testing data. The training data is a set of data that will be used to perform analysis and determine the model. The testing data is a set of data that will be used to test the accuracy of the forecast results. Hence, out of 27 years, 70% of the data (19 data points) is considered for testing data. The data was analyzed using the softwares MATLAB and SPSS 20 version.

RESULTS AND DISCUSSION

The study was carried out to develop forecasting models for damage due to key insect pest of rice *i.e.*, brown plant hopper in Telangana state in India. The forecasting techniques used in developing the models were Artificial Neural Networks, ARIMA (Autoregressive Integrated Moving Average) and

ARIMAX (Autoregressive Integrated Moving Average Model with Exogenous variables). The models have been developed on the basis of the secondary data of the past 27 years i.e., from 1990-2016 (both years inclusive) for the three different zones of the Telangana state. The three different zones of the state are a) Southern Telangana Zone b) Northern Telangana zone and c) Central Telangana zone. The data on the best

check varieties has been used in the study to nullify the varietal differences. This is the standard practice while using the time series data. The Root mean square error and R^2 were used to compare prediction accuracies. A comparative study of the three zones is given in Table 1. Also, forecasted values for the years 2017, 2018 and 2019 using different forecasting techniques is given below.

Table 1. Zone wise performances of Forecasting models and forecasted values for damage due to Brown plant hopper in the Telangana State

Zone	Forecasting Model and forecasted value	ANN		ARIMAX		ARIMA	
		<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>	<i>Kharif</i>	<i>Rabi</i>
Southern Telangana Zone	2017	273.62	265.12	231.04	265.41	255.36	266.39
	2018	273.92	264.29	228.31	264.82	255.89	265.69
	2019	274.67	263.72	226.52	263.72	256.78	265.52
	RMSE	118.72	82.25	125.40	103.38	174.62	104.88
Central Telangana Zone	R^2	0.70	0.97	0.45	0.27	0.17	0.16
	2017	238.24	247.48	206.23	252.61	188.52	282.55
	2018	244.01	246.47	200.65	245.11	189.64	269.55
	2019	248.89	238.49	199.62	202.38	189.26	267.88
	RMSE	14.94	28.29	74.27	92.19	101.45	98.72
Northern Telangana Zone	R^2	0.98	0.95	0.17	0.28	0.22	0.28
	2017	213.85	181.99	198.26	172.22	211.08	190.23
	2018	213.78	181.39	199.12	178.31	210.83	189.92
	2019	213.95	181.66	208.11	192.23	208.67	192.02
	RMSE	39.70	33.29	51.52	46.94	66.22	61.58
	R^2	0.70	0.82	0.17	0.41	0.09	0.21

CONCLUSION

It is observed from comparison of RMSE and R^2 values that the Artificial Neural Network model with lowest value of RMSE gave the model of best fit in

comparison to ARIMA and ARIMAX. Hence, it can be concluded that Artificial Neural Network gives precise results than ARIMA and ARIMAX models when the data shows non-linear trend.

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CONSTRAINTS AND SUGGESTIONS OF THE RAWEP FUNCTIONARIES FOR EFFECTIVE IMPLEMENTATION OF RAWEP

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ABSTRACT

The study was conducted to analyse the constraints faced by the RAWEP functionaries of ANGRAU and suggestions of the RAWEP functionaries for the effective implementation of RAWEP. The most important constraints faced by the RAWEP functionaries were: non-coincidence of RAWEP with crop season, difficulty in providing girl students accommodation, traditional nature of external evaluation, low stipend amount to students, inadequate budget allocation for training programmes and field visits, lack of seriousness, dedication and punctuality among the students, last minute selection of host farmers and villages, allotment of more number of students to each DAATTC and unequal involvement of the all faculty in RAWEP. Suggestions offered by RAWEP functionaries includes timely payment of RAWEP stipend, coinciding RAWEP with crop season, adequate staffing arrangement at DAATTC/KVKs, reducing work load of scientists looking after RAWEP at DAATTC/KVKs, advance selection of RAWEP village and providing updated knowledge on crop protection.

INTRODUCTION

Agricultural education is an important tool in ensuring increased agricultural productivity, sustainability, environmental and ecological security, profitability, job security and equity. Agricultural Sciences attempt to provide a systematic understanding of the agricultural phenomena in order to make the cultivation of plants and rearing of animals more profitable. A properly trained agricultural graduate will, therefore, have knowledge of the fundamental principles of Genetics and Plant Breeding, Plant Pathology, Physiology, Entomology, Soils, Agronomy, Agricultural Economics, Agricultural Extension, etc., in relation to the production environments of plants and animals and such other discipline that have direct or indirect bearing on the understanding of the plant-animal complex, including Social Sciences.

Different committees (ICAR Review Committee, 1979; Deans Committee, 1981) recommended for strong linkage of agricultural education with actual farming situation through the programme. In this programme, the final year students

of B.Sc (Agriculture) are deputed (in the seventh semester) to stay in villages along with farmers for one full semester, wherein, they will interact with the farmers of the village, work with them, understand their problems, apply the latest knowledge, acquire necessary skills and gain self-confidence. Accordingly, Randhawa Committee (1992) in India recommended the Rural Agricultural Work Experience Programme (RAWEP) for imparting quality, practical and productive oriented education for the agriculture degree programme. Keeping the increasing importance of RAWEP in view, an attempt has been made to identify the constraints being faced by functionaries in RAWEP and eliciting suggestions for improvement of RAWEP.

MATERIAL AND METHODS

The study was conducted in Andhra Pradesh during the year 2016-17. The State of Andhra Pradesh was selected purposively as Acharya N. G. Ranga Agricultural University is located in A.P. and the researcher is a scholar belonging to ANGRAU. All the teachers and scientists associated with the implementation of RAWEP 2015-16 such as Associate Deans, Associate Directors of Research

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(ADRs), Heads of the Department of Agricultural Extension, Associate Deans Representatives, Co-coordinators of the concerned DAATTCs, Programme Co-ordinators of KVKs, Scientists (TOT). *Ex-postfacto* research design was used and 30 sample size was selected for the study by proportionate random sampling method. Constraints being faced by functionaries in RAWEP and eliciting suggestions offered by them for improvement of RAWEP were collected through interview schedule.

RESULTS AND DISCUSSION

The constraints in percentage rank order of their importance include non- coincidence of RAWEP with

crop season (I rank), Difficulty in providing girl students accommodation (II rank), traditional nature of external evaluation (III rank), low stipend amount to students (IV rank), Inadequate budget allocation for training programmes and field visits (V rank), Inadequate duration of RAWEP (VI rank), Lack of seriousness, dedication and punctuality among the students (VII rank), last minute selection of host farmers and villages(VIII rank), Allotment of more number of students to each DAATTC (IX rank), Inadequate supervision by the Associate Dean Representatives and Scientists (TOT) (X rank) and unequal involvement of the all faculty in RAWEP (XI rank).

Table 1. Constraints of RAWEP functionaries

n=30

S.No.	Constraints of RAWEP functionaries	Frequency	Percentage	Rank
1	Inadequate supervision by the Associate Dean Representatives and Scientists (TOT)	4	13.33	X
2	Non- coincidence of RAWEP with crop season	27	90.00	I
3	Allotment of more number of students to each DAATTC	7	23.33	IX
4	Inadequate duration of RAWEP	16	53.33	VI
5	Traditional nature of external evaluation	22	73.33	III
6	Lack of seriousness, dedication and punctuality among the students	13	43.33	VII
7	Last minute selection of host farmers and villages	9	30.00	VIII
8	Inadequate budget allocation for training programmes and field visits	19	63.33	V
9	Difficulty in providing girl students accommodation	25	83.33	II
10	Low stipend amount to students	20	66.66	IV
11	Unequal involvement of the all faculty in RAWEP	2	6.66	XI

Early sowing of crops is being in practice, however, sowing is being delayed as it depends on timely receipt of rainfall and also irrigation source in allotted RAWEP village. The registration for RAWEP semester was also not coinciding with crop season in some of the villages (Table 1). Among the RAWEP students allotted in villages nearer the DAATTC, girls

were facing accommodation problems as in most of the villages the facilities are meagre and also traditional methods are followed for evaluating the students' records. Enhancement of stipend to the students is need of the hour and important because students have to prepare food on their own, bear the room rent and other expenses for six months. Budget

CONSTRAINTS AND SUGGESTIONS OF THE RAWEP FUNCTIONARIES

provided for the training programmes and field visits was low. Selection of host farmer in advance in the village is important because to create rapport between host farmer and student and full-fledged involvement of students in farmer's field operations. Allotment of more number of students to each DAATTC due to less number of faculty and inadequate supervision by the Associate Dean Representatives and Scientists (TOT) due to long distance of villages is also one of the constraint. Faculty are engaged with multiple works and equal involvement of the all the faculty in RAWEP is also needed.

These findings are similar to those as reported by Reddy (1985) who recorded that facilities available for the students were average. Shareef and Rambabu (1999) reported less stipends as the major constraint faced by majority of the students, followed by constraints such as selected host farmers did not have the desired components, heavy load of report writing, improper orientation to students, non-existence of the desired components in the selected villages and unsatisfactory accommodation. Kumar and Sharma (2012) reported that B.Sc. (Agri) graduates perceived proper facilities of lodging, boarding and transportation as equally important for the success of RAWEP programme.

Table 2. Suggestions given by RAWEP functionaries

n=30

S.No.	Constraints of RAWEP functionaries	Frequency	Percentage	Rank
1	Providing knowledge on crop protection	7	23.33	X
2	Coinciding RAWEP with crop season	25	83.33	II
3	Adequate staffing arrangement at DAATTC/KVKs	20	66.66	III
4	Timely payment of RAWEP stipend	26	90.00	I
5	Timely release of stipend	15	50.00	VI
6	Detailed analysis of cropping pattern of host farmer	10	33.33	IX
7	Reducing work load of scientists looking after RAWEP at DAATTC/KVKs	19	63.33	IV
8	Active involvement of Associate Dean Representatives	12	40.00	VIII
9	Advance selection of RAWEP village	17	56.66	V
10	Involvement of students in the all agriculture related activities	14	46.66	VII

Based on the constraints, suggestions offered by RAWEP functionaries for effective implementation were collected (Table 2). Suggestions were ranked based on frequency and percentages. Suggestions in percentage rank order of their importance include timely payment of RAWEP stipend (I rank), coinciding RAWEP with crop season (II rank), adequate staffing arrangement at DAATTC/KVKs (III), reducing work load of scientists looking after RAWEP at DAATTC/KVKs (IV rank), advance

selection of RAWEP village (V rank), timely release of stipend (VI rank), involvement of students in the all agriculture related activities (VII rank) active involvement of Associate Dean representatives (VIII rank), detailed analysis of cropping pattern of host farmer (IX rank) and providing knowledge on crop protection (X rank).

Students can use the increased stipend for food, accommodation and other expenditures during

RAWEP. Students shall observe complete package of practices of all crops. More number of faculty shall guide the students in efficient manner. Selection of RAWEP village in advance will help the students to create good environment in village and rapport with farmers. Involvement of students in all agriculture activities helps in increasing their agricultural exposure and skills. A detailed analysis of cropping pattern of host farmer and knowledge on crop protection leads to complete understanding about seasonal cropping, identification of pest and diseases of crops among the students.

These findings are similar to Helen *et al.* (2000) who suggested planning of RAWEP in such a way that final year students are sent to RAWEP for a full cropping season by the adjustment of their semester. Singh and Tyagi (2012) reported that contact farmers suggested for more use of videos and projector presentation in training programmes, more use of common and local words by students, more number of demonstrations to be conducted, less use of English words by students, less use of technical words by students and give more publicity to make RAWEP more effective.

CONCLUSION

Rural Agricultural Work Experience (RAWEP) Programme is for imparting quality, practical and productive oriented education to the agricultural degree programme. Keeping these in view, before starting the RAWEP and allotment of village to the RAWEP students, colleges and DAATTCs must ensure that cropping season must coincide with the RAWEP. Villages selected should have minimum facilities. Amount of stipend should be revised. Funds

should be provided for conducting training programmes and field visits. The number of visits by the RAWEP functionaries should be increased. Selection of the host farmer should be completed in advance to create good rapport between host farmer and student and also to ensure full participation of students in host farmer activities.

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IMPACT OF BATCH-I (2009-10) PMKSY – WATERSHEDS PROGRAMME ON CROPPING PATTERN, CROP YIELDS AND HOUSEHOLD INCOME IN SRIKAKULAM DISTRICT OF ANDHRA PRADESH

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ABSTRACT

The study mainly focused to assess the impact of the programme on incremental changes in cropping pattern, productivity and household income levels of *Pradhan Mantri Krishi Sinchai Yojana* (PMKSY) -Watersheds projects of Srikakulam District. The programme has created a positive impact and could be attributed to the adoption of sustainable development activities. Rice, maize, red gram, black gram, green gram are cultivated in *kharif*, whereas, vegetables, sesame and groundnut are grown during *rabi* seasons. In addition cashew, banana and mango are also cultivated in large scale. Maize, red gram, black gram, green gram, vegetables, mango and cashew crops areas have been increased. Maize productivity has shown tremendous increase *i.e.* from 2866 kg ha⁻¹ to 3578 kg ha⁻¹, whereas, rice productivity increased from 3744 kg ha⁻¹ to 4413 kg ha⁻¹ during project period. Increase of productivity of maize is 25 % during *kharif* and 23% in *rabi*, whereas, in rice, 19 % in *kharif* and 21% in *rabi*. The productivity of green gram increased from 321 kg ha⁻¹ to 408 kg ha⁻¹, an increase of 27% over the pre project period. Similarly, black gram productivity increased from 326 kg ha⁻¹ to 400 kg ha⁻¹, an increase of 23% during the project period. Implementation of PMKSY-Watersheds has increased the number (31 No.) of higher income group households (>Rs.10,000 per month) indicating the beneficial effect of the program.

INTRODUCTION

Watershed development is one of the most effective interventions used to stabilize rainfed agriculture by providing sources of water for small scale irrigation. It is one of the flagship programmers of the government with substantial budget allocation during the last two decades that assist in rural poverty alleviation, particularly in the marginal semi-arid and rain fed areas. Major thrust was laid on developing the untreated areas during the 12th Five Year Plan and all degraded lands were prioritized for development under various watershed development projects. The main objective of the PMKSY-Watersheds is to improve water conservation, irrigation facility and land use pattern which would lead to improved biophysical and socio-economic environment through increased agricultural productivity in rain fed areas. Common benefits arising from Watershed development include

improved crop yields, employment generation and augmentation of income.

Moreover, more than 55% of population in our country are still depending on agriculture and about two-thirds of total arable land being rain-fed and characterized by low productivity, primitive agricultural practices etc. Hence, there is an increased focus on sustainable use of water and other natural resources. The analysis was aimed for undertaking the evaluation of Batch-I (2009-10) watershed projects of Srikakulam district, Andhra Pradesh as these projects have completed project period with the following objectives in order to assess the social and economic indicators.

The main objectives of the study are to analyze the changes in cropping pattern before and after project, to find out the changes in productivity of different/major crops during the study period and to

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estimate the incremental changes in household incomes of the respondents.

MATERIAL AND METHODS

The survey based approach was adopted in the study (conducted during 2018) for data collection exercise comprising open-ended questionnaires. Two independent sets of questionnaires were used to collect the data, which were developed by Monitoring, Evaluation, Learning and Documentation (MEL&D) Agency as per the indicators/parameters suggested by the State Level Nodal Agency (SLNA). The two questionnaires were prepared to capture the changes occurred due to the implementation of the PMKSY-Watersheds. Two participatory methods used in the data collection process were survey and focused group discussions.

Focused group discussions (FGDs) were conducted in all 44 micro-watersheds with the support provided by the staff of respective micro-watersheds. The participants in the discussions were

Sarpanches, Members of Gram Panchayat, Watershed Committee, User Groups, Village Organization and Watershed Assistants. The opinion of the participants was collected on three important indicators/parameters viz., cropping pattern, yield and household income through interaction and transact walk in watershed area as well as in the village. Primary data was collected from five (5) percent sample households from the total families in Detailed Project Report (DPR) for both pre and post project periods. Primary information was collected from respective Sarpanches, Members of Gram Panchayat, Watershed Committee, User Groups and Watershed Assistants. Secondary information was collected from the unpublished records of WCCs. The data thus collected was analyzed. The pre and post project changes have been attributed to the impact of the interventions carried during the project period. Srikakulam district has been assigned the following four projects under Batch-I (2009-10) PMKSY-Watersheds (Table 1).

Table 1. Project -wise Batch- I PMKSY-Watersheds Projects evaluated

S.No.	Name of the District	Name of the Project	No. of Micro-Watersheds
1	Srikakulam	Laveru	11
2		J.L.Kota	11
3		Kondalogam	10
4		Khallada	12

Source: Field Survey data & Impact Evaluation Report PMKSY-Watersheds (2017)

The total area covered under these projects was 19513.29 Ha. The predominant soil types in the project area are red soils, red loams, sandy loams, sandy soils and alluvial soils. The predominant crops grown in the project area are paddy, maize, green gram, black gram, red gram, groundnut, sesame, vegetables, cashew, mango, coconut, etc.

Incremental change = Difference between post project and pre project periods

RESULTS AND DISCUSSION

The impact of PMKSY-Watersheds Implementation was assessed and the results are presented below under different heads.

1. Demographic Details

The total number of families residing in the project area was 18064 with a total population of 81754 constituting 49.91% of males and 50.08% of

females with a sex ratio of 997, which indicates more number of female population in the study area.

Table 2. Demographic details

S.No.	Particulars	Number
1	Male	40810
2	Female	40944
3	Children	8463
4	Sex ratio	997

Source: Field Survey data & Impact Evaluation Report PMKSY-Watersheds (2017)

Literacy levels

The average literacy rate of male increased from 54% to 66% and female literacy rate also enhanced from 42% to 57% between pre project and post project periods. Hence, the increase in literacy rate was 22% and 36%, respectively for male and female in the project due to implementation of the program.

Table 3. Change in Literacy levels (%)

S.No.	Period	% of literacy level	
		Male	Female
1	Pre project	52	42
2	Post project	66	57
3	Change in education levels	12	15
4	% of change	22	36

Source: Field Survey data & Impact Evaluation Report PMKSY-Watersheds (2017)

2. Changes in Cropping Pattern

Major source of income and livelihood in the cluster villages was agriculture which was largely under rainfed conditions. The area under different crops during pre-project and post project periods is presented in Table 4.

Kharif crops grown during ex-ante period were Rice, maize, green gram, black gram, sesame and groundnut mostly under rainfed conditions. However, Rice was grown under irrigated conditions also in the pre project time. During *rabi* in addition to these crops, ragi was also grown in the pre project period. In the post project period the same crops have been grown, however, in much larger areas.

The total area under different crops in *kharif* in the pre project period was 10157 ha and in the post project it increased to 11842 ha accounting to 16.59% increase. The total area under crops in *rabi* in the pre project area was 1236 ha and in the post project it was 1548 ha with an increase of 312ha. Due to the implementation of watershed project additional area was brought under cultivation resulting in an overall increase in area under agricultural crops to the extent of 17.53%. A considerable increase in area under horticultural crops, particularly under vegetables is also noticed by the end of the project period.

The crop wise analysis indicates that rice area has been increased in *kharif* and *rabi* to the tune of 16% and 15% respectively. Similarly, in case of maize the increase in area was 18% in *kharif* and the same in *rabi* was 44%, with an overall increase of 18.48% which is considered to be the incremental increase in maize crop.

In case of greengram, the increase in area was 25% in *kharif* while in *rabi*, it was 84% with overall increase of 35%. The increase in area in terms of acreage was from 564 ha to 762 ha from pre project to post project period with a difference of 198 ha. Similarly, the area under black gram in *kharif* increased from 533 ha to 638 ha with a difference of 105 ha accounting to an increase of 25% in post project period compared to pre project period. Also, in *rabi* season there was an increase in area under black gram by 38 ha due to PMKSY-Watersheds programme. Overall, there was 23% increase in area under black gram during post project compared to

Table 4. Area under important agricultural crops (ha) of PMKSY watershed programme during pre and post periods

KHARIF									
		Pre implementation			Post implementaion			Total	
	Crops	Rainfed	Irriga- ted	Total	Rain fed	Irriga- ted	Total	Addi- onal area brought under cultivation%	
Cereals	Paddy	6584	2176	8760	7612	2530	10142	1382	15.77
	Maize	227	0	227	267	0	267	40	17.65
	Greengram	467	0	467	577	6	584	117	24.96
Pulses	Blackgram	529	4	533	620	17	638	105	19.67
	Redgram	39	0	39	47	0	47	8	20.83
Oil Seeds	Sesame	40	0	40	50	0	50	11	26.53
	Groundnut	11	80	91	14	101	115	23	25.66
	Total	7897	2260	10157	9188	2654	11842	1685	16.59
RABI									
Cereals	Paddy	0	880	880	1014	0	1014	134	15.22
	Maize	0	7	7	11	0	11	3	44.44
	Ragi	0	22	22	25	0	25	3	14.81
Pulses	Green gram	0	97	97	179	0	179	82	84.17
	Blackgram	0	81	81	119	0	119	38	46.50
Oil Seeds	Sesame	0	119	119	160	0	160	41	34.69
	Groundnut	0	30	30	41	0	41	11	36.49
	Total	0	1236	1236	1548	0	1548	312	25.24
Kharif+Rabi (Grand Total)		7897	3497	11393	10737	2654	13391	1997	17.53
HORTICULTURE									
Vegetables	Vegetables	193	300	494	219	418	637	143	29.02
Horticulture	Cashew	1532	0	1532	1581	0	1581	49	3.20
	Coconut	27	0	27	32	0	32	5	19.40
Fruits	Mango	100	0	100	111	0	111	11	10.48
	Total	1853	300	2153	1943	418	2361	208	9.66
Grand total (Agriculture & Horticulture)		9750	3797	13547	12679	3072	15752	2205	16.28

Source: Field Survey data & Impact Evaluation Report PMKSY-Watersheds (2017)

TABLE 5. Crop productivity of different crops (kg ha⁻¹) of PMKSY watershed programme during the pre and post periods

KHARIF													
	Crop	Pre-project			Post-project			Rainfed		Irrigated		Total	
		Rainfed	Irrigated	Total	Rainfed	Irrigated	Total	Difference	%	Difference	%	Difference	%
Cereals	Paddy	3168	3744	6911	3818	4413	8231	650	20.51	670	17.89	1320	19.09
	Maize	2866	0	2866	3578	0	3578	712	24.83	0	0.00	712	24.83
	Greengram	321	0	321	408	0	408	86	26.92	0	0.00	86	26.92
Pulses	Blackgram	326	0	326	400	0	400	74	22.73	0	0.00	74	22.73
	Redgram	427	0	427	507	0	507	79	18.50	0	0.00	79	18.50
Oil Seeds	Sesame	247	0	247	309	0	309	62	25.00	0	0.00	62	25.00
	Groundnut	1458	0	1458	1853	0	1853	395	27.12	0	0.00	395	27.12
RABI													
Cereals	Paddy	0	3734	3734	0	4502	4502	0	0.00	768	20.58	768	20.58
	Maize	0	3104	3104	0	3830	3830	0	0.00	726	23.41	726	23.41
	Ragi	0	988	988	0	1248	1248	0	0.00	259	26.25	259	26.25
Pulses	Green gram	0	371	371	0	469	469	0	0.00	99	26.67	99	26.67
	Blackgram	0	346	346	0	400	400	0	0.00	54	15.71	54	15.71
Oil Seeds	Sesame	0	363	363	0	465	465	0	0.00	101	27.89	101	27.89
	Groundnut	0	2780	2780	0	3442	3442	0	0.00	662	23.82	662	23.82
Vegetables	Vegetables	4028	18715	22743	4584	21888	26472	556	13.80	3173	13.95	3729	16.40
	Coconut	6548	0	6548	7314	0	7314	766	11.70	0	0.00	766	11.70
Horticulture	Cashew	4831	0	4831	5441	0	5441	610	12.63	0	0.00	610	12.63
	Mango	3410	0	3410	3763	0	3763	353	10.36	0	0.00	353	10.36

Source: Field Survey data & Impact Evaluation Report PMKSY-Watersheds (2017)

pre project period. Further, for other crops in the selected projects an increase in area under redgram was 21%, sesame 33%, groundnut 28%, vegetables 29%, cashew 3%, coconut 20% and mango 11%. This increase could be attributed to the project impact.

3. Crop Productivity

For increasing the productivity of crops in the selected areas, several interventions such as improved crop varieties, soil fertility management through INM and IPM were taken up apart from improving the know-how and capacity building of farms through training and Information, training and communication. Due to integrated approaches and programmes, the productivity of all the crops in the project area increased considerably from pre project to post project period both under rain fed and irrigation areas during *kharif* as well as *rabi* (Table 5).

The average yield of rainfed paddy increased from 3168 kg ha⁻¹ to 3818 kg ha⁻¹ and for irrigated paddy the same from 3744 kg ha⁻¹ to 4403 kg ha⁻¹ from pre project to post project period; which accounts for 20% and 18% respectively. The overall increase in paddy average yield under rain fed and irrigation was 19% during *kharif* and in *rabi* it was 21% under irrigation. In the project area, maize was grown as rainfed crop in *kharif* and in *rabi* it was grown under irrigation to some extent. The increase in productivity of maize was 25% during *kharif* and in *rabi* it was 23% due to proper implementation of capacity building programmes. Ragi was grown in *Rabi* under irrigation. Ragi yield increased by 26% in post project period compared to pre project period.

Green gram, black gram and red gram were grown in *kharif* as rainfed crops both during pre-project and post project years. The percentage increase in yield was 27%, 23% and 18% during the post project period compared to pre project period. Whereas, in *rabi*, green gram and black gram were grown only as irrigated- dry crops and the increase

in yield of these crops were 26% and 16%, respectively in post project period compared to pre project period. Sesame and groundnut were grown both during *kharif* and *rabi* in the watershed areas. The increase in yield of sesame and groundnut were 25% and 19% during *kharif* and 28% and 24% during *rabi*, respectively due to implementation of PMKSY-Watersheds activities.

The yield of horticulture crops also increased due to project initiatives. The yield of vegetables, coconut, cashew and mango increased by 16%, 12%, 13% and 10%, respectively during the post project period compared to pre project period.

It is clearly evident that the productivity of crops has increased after implementation of the project. The reason might be due to increase in water availability, adoption of improved package of practices, training and capacity building provided by the project.

4. Household Gross Income

Implementation of PMKSY-Watersheds program has considerably increased the income of households indicating the beneficial effect of the program.

The impact on household income was evaluated taking Rs.10,000/- per month as critical income and households were divided into two groups *viz.*, houses having income less than Rs.10,000/- per month and more than Rs.10,000/- per month.

In the pre-project period in Batch-I (2009-10) PMKSY-Watershed projects in Srikakulam district, the number of households with income more than Rs.10,000/- per month were 317 and in post project the number of households were 348. The number of households with income less than Rs.10,000/- in pre project were 456 and in post project the number of households were 425 (Fig.1). Thus, the number of households with more than Rs.10,000/- per month increased to 31. The total income derived from agriculture, dairying, MGNREGS, labour, etc. have been considered for evaluation purpose.

IMPACT OF PMKSY WATERSHED PROGRAMMES IN SRIKAKULAM DISTRICT

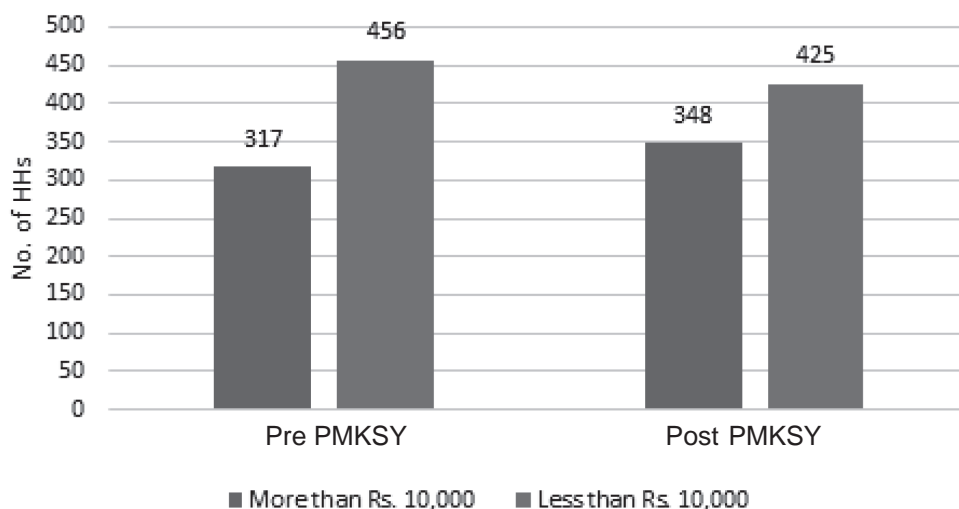


Fig 1: Household Income

CONCLUSION

The Batch-I PMKSY-Watershed programmes have shown positive impact on cropping pattern, crop productivity and household income levels in Srikakulam District of Andhra Pradesh due to sustainable development activities taken up during the project period. Increase in productivity of maize was 25 % during *kharif* and in *rabi* 23%, whereas, in rice it was 19 % in *Kharif* and 21% in *Rabi*. The productivity of green gram increased from 321 kg ha⁻¹ to 408 kg ha⁻¹, an increase of 27% over pre project period. Similarly, black gram increased from 326 kg ha⁻¹ to 400 kg ha⁻¹, an increase of 23% during the project period. Implementation of PMKSY-Watersheds has considerably increased the number of higher income group (>Rs.10,000 per month) households (31 No.) indicating the beneficial effect of the program.

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CORRELATION AND PATH COEFFICIENT ANALYSIS FOR FIELD PERFORMANCE OF INVIGORATED AGED SEED OF CHICKPEA

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Chickpea (*Cicer arietinum* L.) is an annual grain legume crop grown mainly for human consumption. It plays an important role in human nutrition as a source of protein, energy, fibre, vitamins and minerals. However, the productivity is low and unstable as most of the cultivated area of chickpea is under rainfed situation. Seed invigoration is one of the most important practices for rapid and uniform germination and emergence of seedling and to increase its tolerance to adverse environmental conditions. Under invigoration, metabolic repair occur in the deteriorated seed before the onset of germination process. There are reports that seed priming permits early DNA replication, increase RNA and protein synthesis, enhance embryo growth, repairs deteriorated seed parts and reduces leakage of metabolites, thus increasing the germination, seedling establishment and consequently crop growth in the field (McDonald, 2000).

Since yield is a polygenic trait influenced by several characters related among themselves and with yield, an evaluation of different traits and a study of their inter-relationships are of great importance for identifying potentially useful traits for yield improvement. Correlation co-efficient analysis measures the mutual relationship between various characters. Such information is useful in planning chickpea improvement programs efficiently and effectively.

Path coefficient analysis helps in partitioning of the correlation coefficients into direct and indirect

effects of independent variable on dependent variable. Correlation in combination with path analysis would give a better insight into cause and effect relationship between different pairs of characters. Hence, the investigation was carried out to determine the inter-relationship between various crop growth and yield parameters by conducting a field experiment using aged seed of chickpea subjected to various invigoration treatments.

Field experiment was conducted at Agricultural Research Station, Jangamaheswara-puram, Guntur dist. during *Rabi* 2017-18 with aged (*Rabi*, 2015-16 harvested) seed of chickpea variety, NBEG-3, having initial germination of 81.75%. The seed was subjected to various seed invigoration treatments *viz.*, hydration, hydration followed by seed treatment with thiram, seed treatment with 50 ppm GA_3 , 2 % KH_2PO_4 , 2 % $CaCl_2$ and 2 % KNO_3 for eight hours and osmo-conditioning with -0.5 MPa PEG for 6 hours and shade dried to 9 % moisture content. The experiment was laid out in Randomised Block Design with three replications with a spacing of 45 cm x 10 cm and a net plot size of 3 m x 4 m. All the recommended package of practices were adopted to raise the crop.

Data on four parameters *viz.*, field emergence, plant population, days to 50 % flowering and seed yield per plot were recorded on plot basis and data on the remaining five parameters *viz.*, plant height at maturity, number of branches plant⁻¹, number

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Table 1. Simple correlation matrix of crop growth and yield parameters in invigorated aged seed of chickpea

	PP	PH	DF	NBP	NPP	SP	SW	SYP	SY
FE	-0.093	0.496	-0.185	0.746	0.776*	0.772*	0.503	0.717	0.806*
PP		0.150	-0.197	0.227	-0.146	-0.312	-0.331	-0.278	-0.011
PH			0.261	0.774*	0.822*	0.455	0.607	0.651	0.690
DF				-0.268	-0.108	-0.433	0.045	-0.234	-0.295
NBP					0.825*	0.780*	0.638	0.761*	0.764*
NPP						0.774*	0.766*	0.942**	0.947**
SP							0.573	0.789*	0.719
SW								0.886**	0.603
SYP									0.882**

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

FE	- Field emergence (%)	NPP	- Number of pods plant ⁻¹
PP	- Plant population m ⁻²	SP	- Shelling percentage
PH	- Plant height at maturity (cm)	SW	- 100 seed weight (g)
DF	- Days to 50 % flowering	SYP	- Seed yield plant ⁻¹ (g)
NBP	- Number of branches plant ⁻¹	SY	- Seed yield plot ⁻¹ (kg)

Table 2. Direct (bold diagonal) and indirect effects (off diagonal) of various characters on seed yield in chickpea

	FE	PP	PH	DF	NBP	NPP	SP	SW	SYP
FE	-0.2135	-0.0864	-0.4237	-0.1067	-0.5114	1.1703	0.5669	-0.1795	0.5898
PP	0.0199	0.9263	-0.1285	-0.1132	-0.1559	-0.2200	-0.2290	0.1180	-0.2286
PH	-0.1059	0.1393	-0.8544	0.1526	-0.5308	1.2384	0.3343	-0.2166	0.5352
DF	0.0395	-0.1821	-0.2233	0.5761	0.1838	-0.1622	-0.3178	-0.0161	-0.1926
NBP	-0.1592	0.2106	-0.6614	-0.1544	-0.6857	1.2430	0.5728	-0.2274	0.6254
NPP	-0.1657	-0.1352	-0.7019	-0.0620	-0.5654	1.5074	0.5682	-0.2730	0.7743
SP	-0.1647	-0.2888	-0.3889	-0.2492	-0.5347	1.1661	0.7345	-0.2044	0.6487
SW	-0.1075	-0.3065	-0.5189	0.0260	-0.4372	1.1542	0.4210	-0.3566	0.7281
SYP	-0.1531	-0.2576	-0.5561	-0.1350	-0.5215	1.4196	0.5795	-0.3158	0.8222

Residual effect = 0.0063

FE	- Field emergence (%)	NPP	- Number of pods plant ⁻¹
PP	- Plant population m ⁻²	SP	- Shelling percentage
PH	- Plant height at maturity (cm)	SW	- 100 seed weight (g)
DF	- Days to 50 % flowering	SYP	- Seed yield plant ⁻¹ (g)
NBP	- Number of branches plant ⁻¹		

of pods plant⁻¹, shelling percentage and seed yield plant⁻¹ was recorded on ten randomly selected plants in each plot. Hundred seed weight was recorded in each treatment. Correlation co-efficient analysis was carried out to study the nature and degree of relationship between all the field parameters recorded from invigorated seed. Path coefficient analysis as elaborated by Dewey and Lu (1959) was used to calculate the direct and indirect contribution of various traits to yield.

The analysis of variance indicated significant influence of treatments on field emergence, plant height at maturity, days to 50 % flowering, number of branches plant⁻¹, number of pods plant⁻¹, seed yield plant⁻¹ and seed yield per plot. Highly significant positive association of seed yield per plot was observed with number of pods plant⁻¹ (0.947) and seed yield plant⁻¹ (0.882) and significant positive association with field emergence (0.806) and number of branches plant⁻¹ (0.764) (Table 1). The correlation coefficients showed that the field emergence, number of pods plant⁻¹ and shelling percentage had significant positive correlation among themselves. Plant height exhibited significant positive correlation with number of branches plant⁻¹ and number of pods plant⁻¹. Number of branches plant⁻¹ had significant positive association with number of pods plant⁻¹, shelling percentage and seed yield plant⁻¹. Number of pods plant⁻¹ showed highly significant positive association with seed yield plant⁻¹ and significant positive association with 100 seed weight and shelling percentage. Shelling percentage showed significant positive association with seed yield plant⁻¹. Seed yield plant⁻¹ also had significant positive correlation with 100 seed weight.

Highly significant positive correlation between number of pods plant⁻¹ and seed yield was earlier reported in chickpea by Yucel *et al.* (2006) and Malik *et al.* (2009). Yucel *et al.* (2006) observed significant positive correlation between plant height and number of pods plant⁻¹. Highly significant positive

association of 100 seed weight and seed yield per plant was noticed by Renukadevi and Subbalakshmi (2006). Talebi *et al.* (2007) reported significant positive correlation of number of pods plant⁻¹ and 100 seed weight. Kobraee *et al.* (2010) observed highly significant positive correlation of number of pods plant⁻¹ and grain yield per ha. Significant positive association of plant height and number of secondary branches was earlier reported by Zali *et al.* (2011).

Among the characters studied, number of pods plant⁻¹ (1.5074) exhibited high positive direct effect on seed yield per plot. Plant population (0.9263) exhibited high positive direct effect followed by seed yield plant⁻¹ (0.8222), shelling percentage (0.7345) and days to 50 % flowering (0.5761) on seed yield per plot (Table 2). Number of pods plant⁻¹ showed high positive indirect effect through seed yield plant⁻¹ and shelling percentage on seed yield per plot. It had high negative indirect effects through plant height and number of branches plant⁻¹, moderate negative indirect effect through 100 seed weight, low negative indirect effect through field emergence and plant population and negligible negative indirect effect through days to 50 % flowering on seed yield per plot. Plant population had low positive indirect effect through 100 seed weight and negligible positive indirect effect through field emergence on seed yield per plot. The indirect effect of plant population was moderate and negative through shelling percentage, seed yield plant⁻¹ and number of pods plant⁻¹, low and negative through number of branches plant⁻¹, plant height and days to 50 % flowering on seed yield per plot. Seed yield plant⁻¹ had very high positive indirect effect through number of pods plant⁻¹ and high positive indirect effect through shelling percentage. Seed yield plant⁻¹ had high negative indirect effect through plant height, number of branches plant⁻¹ and 100 seed weight, moderate negative indirect effect through plant population and low negative indirect effect through field emergence and days to 50% flowering on seed yield per plot.

Shelling percentage had very high positive indirect effects *via* number of pods plant⁻¹ and high positive indirect effects *via* seed yield plant⁻¹ on seed yield per plot. Shelling percentage had high negative indirect effects *via* number of branches plant⁻¹ and plant height, moderate negative indirect effect *via* plant population, days to 50 % flowering and 100 seed weight and low negative indirect effect *via* field emergence on seed yield per plot. Days to 50 % flowering had low positive indirect effect *via* number of branches plant⁻¹ and negligible positive indirect effect *via* field emergence. It had high negative indirect effect *via* shelling percentage, moderate negative indirect effect *via* plant height, low negative indirect effect *via* seed yield plant⁻¹, plant population and number of pods plant⁻¹ and negligible negative indirect effect *via* 100 seed weight on seed yield per plot.

Plant height exhibited high negative direct effect followed by number of branches plant⁻¹ and 100 seed weight on seed yield per plot. Field emergence had moderate negative direct effect on seed yield per plot. The indirect effect of plant height on seed yield per plot was very high and positive *via* number of pods plant⁻¹, high and positive *via* seed yield plant⁻¹ and shelling percentage, low and positive *via* days to 50 % flowering and plant population, while it had high negative indirect effect *via* number of branches plant⁻¹, moderate negative indirect effect *via* 100 seed weight and low negative indirect effect *via* field emergence. Number of branches plant⁻¹ exhibited very high positive indirect effect through number of pods plant⁻¹, high positive indirect effect through seed yield plant⁻¹ and shelling percentage and moderate positive indirect effect through plant population on seed yield per plot. It had high negative indirect effect *via* plant height, moderate negative indirect effect *via* 100 seed weight and low negative indirect effect *via* field emergence and days to 50 % flowering on seed yield per plot. 100 seed weight had very high positive indirect effect *via* number of

pods plant⁻¹, high positive indirect effect *via* seed yield plant⁻¹ and shelling percentage and negligible positive indirect effect *via* days to 50 % flowering. It had high negative indirect effect *via* plant height, number of branches plant⁻¹ and plant population and low negative indirect effect *via* field emergence on seed yield per plot. Field emergence had very high positive indirect effect *via* number of pods plant⁻¹, high positive indirect effect *via* seed yield plant⁻¹ and shelling percentage on seed yield per plot. Field emergence had high negative indirect effect *via* number of branches plant⁻¹ and plant height, low negative indirect effect *via* 100 seed weight and days to 50 % flowering and negligible negative indirect effect *via* plant population on seed yield per plot.

Direct negative effect of plant height on seed yield was reported by Arshad *et al.* (2004) in chickpea. Yucel *et al.* (2006) earlier obtained positive direct effects of days to 50 % flowering on seed yield per plot in chickpea. Negative direct effect of 100 seed weight on seed yield in chickpea was earlier obtained by Renukadevi and Subbalakshmi (2006). Direct positive effect of number of pods plant⁻¹ on seed yield was reported by Arshad *et al.* (2004), Renukadevi and Subbalakshmi (2006) in chickpea. Talebi *et al.* (2007) noticed negative direct effect of number of secondary branches and 100 seed weight and positive direct effect of number of pods plant⁻¹ on seed yield in chickpea.

Correlation studies showed highly significant positive association of number of pods plant⁻¹ and seed yield plant⁻¹ and significant positive association of field emergence and number of branches plant⁻¹ with seed yield per plot indicating that improvement of any of these traits could lead to an increase in seed yield. Path coefficient analysis revealed that number of pods plant⁻¹, plant population m⁻², seed yield plant⁻¹, shelling percentage and days to 50 % flowering had positive direct effects on seed yield per plot.

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PRODUCTION SYSTEM IMPROVEMENT ACTIVITIES AND THEIR IMPACT ON LIFESTYLE OF WATERSHED COMMUNITY OF PRAKASAM DISTRICT IN ANDHRA PRADESH

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Prime Minister *Krishi Sinchayee Yojana* (PMKSY) Watershed (erstwhile IWMP) projects are being implemented in Andhra Pradesh in accordance with the common guidelines for Watershed Development Projects- 2008 and Operational Guidelines of PMKSY (Department of Land Resources, Gol, 2011). One of the important component of watershed development programme is production systems improvement. Production systems improvement activity enhances the productivity of the natural resources and sustainable livelihood for the watershed community in rainfed areas, especially in agriculture, animal husbandry and allied sectors. In the total project outlay of PMKSY watershed projects, production systems improvement was given top priority along with conservation measures during work phase *i.e.* 3rd to 5th year of project implementation. As per the guidelines, 10 per cent of the project cost is allocated for production system improvement activities on each micro watershed basis.

Under PMKSY watershed program, the Department of Land Resources (DoLR)s, Gol have sanctioned projects from 2009-10 onwards in various districts of Andhra Pradesh. An attempt was made to review the production system improvement activities in 18 PMKSY watershed projects of Batch-II (2010-11) implemented in Prakasam district during the period 2010-18.

The production systems improvement activities are implemented by the Project Implementation Agency (PIA) through voluntary organizations (VO) in coordination with watershed committees (WC). The production system improvement activities are identified in consultation with line departments for carrying out different productive system improvement activities interventions, either community or individual based. In case of individual based interventions, the action plans are prepared activity wise, and beneficiary wise. (GoAP Glance Reports, 2018).

The secondary data existing in Management Information System (MIS) (Source: PSI MIS Reports - Government of Andhra Pradesh, 2018) of PMKSY watershed projects, Panchayat Raj and Rural Development Department are systematically reviewed and interpreted to gain insights into implementation of Production System Improvement (PSI) activities in watershed villages and to assess the impact of these interventions on the production enhancement in agriculture and allied sectors, and livelihoods (Centre for Good Governance (CGG), 2006). Besides, the field team visited the project areas and interacted with beneficiaries, members of watershed committee and staff of project implementation agency. Production system improvement activities are implemented as per the

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action plan prepared at micro watershed level duly analysing existing situations in participatory manner.

Production system improvement activities - Implementation

Production system improvement activities funds are utilized in convergence with line departments. Out of the total fund, the tentative allotment was 50 per cent for agricultural sector, 30 per cent for animal husbandry and 20 per cent for allied sectors *viz.*, horticulture, fisheries and sericulture, subject to revisiting based on local needs. Among the identified activities, the total cost of community based interventions are met from PMKSY funds. In case of individual based interventions, only 50 per cent of cost was met from project fund and remaining 50 per cent was borne by the beneficiary individual.

Intensification of farm production systems was completed through revolving fund and convergence with line departments (agriculture and allied sectors for technical support and credit). Activities are implemented in convergence with agriculture inclusive of Community Managed Sustainable Agriculture (CMSA), animal Husbandry and horticulture departments. The activities (Animal Husbandry)

action plan for both community and individual based interventions was prepared for each Micro Watershed (MWS) by the Village Organizations. The action plan of activities/interventions and funding pattern are decided in convergence meeting with district heads of line departments.

Production system improvement progress - Financial achievement

Utilization of funds in all the 18 watershed projects was maximum for agricultural production activities followed by animal husbandry and horticulture. (Source: PSI MIS Reports- Government of Andhra Pradesh, 2018.). The performance of projects in utilization of fund was not the same as seen from the ranking secured by each project. First rank was secured by konanki watershed project, which not only utilized total allocated amount of Rs.57.28 lakhs, but also incurred additional expenditure of Rs.3.77 lakhs, with an overall utilization of 106.6 per cent (Fig.1). Fund utilization in konanki project for production system improvement activities was well planned to benefit large number of people in the watershed community. Thurimella watershed project ranked last due to poor utilization of fund (74.2 per cent). Mean utilization of fund across all watersheds is 94.06 per cent.

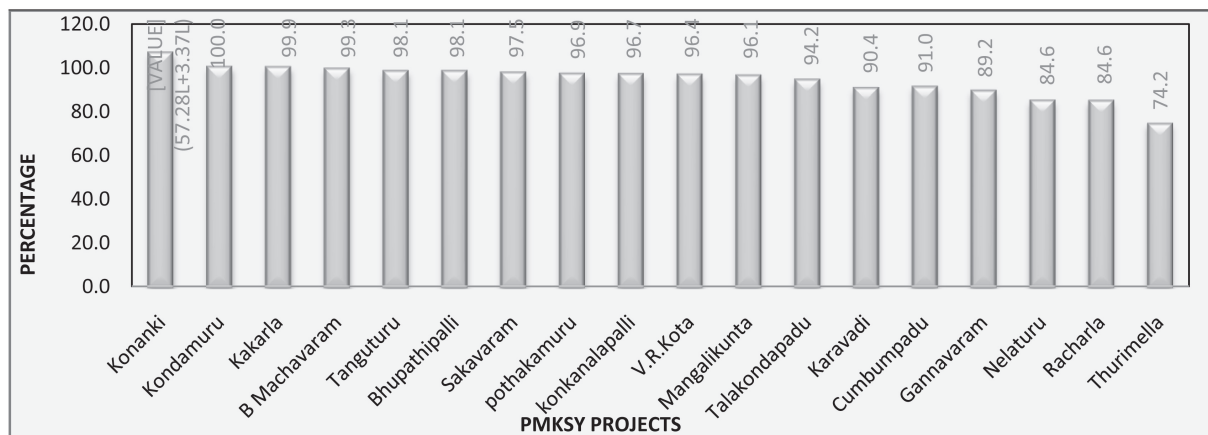


Fig.1 Per cent utilization of Production System Improvement (PSI) activities fund

Convergence of Production System Improvement activities for crop and animal production enhancement

Convergence in programs and departments is to bring in a holistic approach (Suvarna *et al.*, 2012). In convergence mode, the productive system improvement activities pursuit was focused with ongoing activities such as farm implements for individuals; custom hiring centers; implements service station; sprinkler irrigation systems; water carrying pipes; and additional farm mechanization in all the watershed projects with Department of Agriculture including Community Managed Sustainable Agriculture (CMSA) scheme; animal health coverage (animal health camps, fertility camps, small ruminant health camps); infrastructure development (establishment of travices, supply of castrators); nutritional support (feed supply to pregnant milch animals during last 100 days of pregnancy, mineral mixture to milch animals and calves); Supply of livestock units(sheep units) with animal husbandry department; and tarpaulin sheets & silpaulins (60 ft.X40 ft. with 120 gauge) with horticulture department.

Production System Improvement(PSI) activities in agriculture, horticulture and animal husbandry sectors

The Production system improvement activities implemented in all 18 watershed projects have impacted directly 6167 beneficiaries, in enhancing the crop and animal production. Priority was given to SC, ST, small and marginal farmer beneficiaries in sanction of productive system improvement activities. Total number of beneficiaries across all components of production system improvement activities largely varied from 235 in konakanapally to 419 in gannavaram watershed projects (Source: PSI MIS Reports- Government of Andhra Pradesh, 2018.). Maximum number of beneficiaries (3164) availed productive system improvement activities fund for agriculture activities, constituting 51 per cent of total

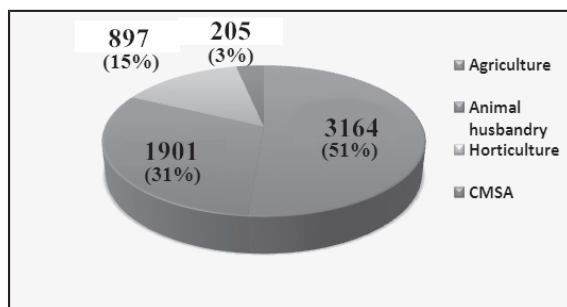


Fig.2. No. of Production System Improvement (PSI) activities beneficiaries in agriculture, animal husbandry and horticulture

beneficiaries, followed by 31 per cent for animal husbandry and 15 per cent for horticulture activities (Fig 2). Custom Hiring Centers with high- tech agro machinery under Community Managed Sustainable Agriculture are availed by 205 beneficiaries, constituting 3 per cent of total beneficiaries of productive system improvement activities fund.

Impact of Production System Improvement activities on agriculture and horticulture

Farm mechanization benefited the watershed community for less dependence on labour, clean cultivation, reduced number of field operations, timely operations, increased efficiency & reduced cost of farm operations including harvesting and threshing; improvement in quality of produce, uniform placement of fertilizers and efficient utilization of inputs, ideal seed bed preparation, better weed control, reduction in drudgery of farmers, increased crop yields, etc. Many individual farmers have availed the subsidy to purchase farm machinery for use in their farm operations.

Custom hiring centers have not only benefited the group operating the center, but also other individual farmers in watershed community. Establishment of high-tech agro machinery centers in the district by the selected agencies with all farm machines facilitated small and marginal farmers and who are working on leased lands to bring down the investment on machinery.

Interventions such as sprinkler irrigation saved 25 per cent of available irrigation water and is beneficial for irrigating the sloppy and light textured soils. Supply of portable tarpaulin and silpaulin has many agricultural applications and versatile uses, more so in horticulture crops. The beneficiaries used them for covering of crop produce, seeds, and fertilizers from rain. These sheets are used extensively for drying the crop produce and for other multiple uses such as covering material for vermicomposting beds and fodder hay making, and as curtains for poultry and cattle sheds.

Impact of Production System Improvement activities on animal husbandry

Community based animal health camps, fertility camps and small ruminant health camps are conducted in convergence with the Department of A.H. duly consulting the watershed community. Animal health camps for vaccination of both viral and bacterial, and deworming prevented the vulnerability of livestock to seasonal diseases and poor health during monsoon and post monsoon seasons; decreased abortion rate, increased production of milk, meat & wool and income. Andhra Pradesh is the first state in India, to be free from Foot and Mouth disease. Foot and Mouth disease free status is considered as an indicator of development. Other benefits of animal health care support included better reproductive health management, reduction in mortality rate and morbidity. Fertility camps improved the reproductive efficiency of milch cattle, small ruminants such as sheep and goat.

Under nutritional support intervention, feed supplied to the pregnant milch animals during last 100 days of pregnancy, whose production is minimum of 3L and impregnated by A.I., have impacted the beneficiaries by sharing the burden during unproductive or low productive period and also supported for healthy growth of the foetus; and to sustain the productivity during succeeding milking

season. Nutritional support through supply of mineral mixture and mineral blocks to milch animals, calves, sheep and goats reduced the infertility due to anestrus ovaries and decreased the inter calving period by improving the breeding health of the milch animals, sheeps, and goats in PMKSY watershed villages.

Strengthening of infrastructure by establishing of travices and supply of castrators helped the individual beneficiaries in breed development, reduction in inter-calving period, reduction in repeat breeding, reduction in distress sale, reduction in management costs, improvement in calf birth rate, increased household income and there by facilitated taking up other income generating activities. Supply of livestock units (sheep units) in convergence with animal husbandry department have impacted the farmers and landless poor by increasing their income and contributing to more profitable livelihoods.

It can be concluded that Production System Improvement activities interventions implemented in convergence with agriculture, animal husbandry and horticulture departments have impacted in enhancement of crop and animal production and productivity levels with considerable improvement in livelihood opportunities to the rural poor.

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