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GENETIC DIVERSITY STUDIES FOR YIELD, ITS COMPONENTS AND QUALITY TRAITS IN BLACKGRAM (*Vigna mungo* (L.) Hepper)

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ABSTRACT

A total of 89 blackgram accessions were subjected to D² analysis to assess the diversity for 18 quantitative traits. The genotypes were grouped into 14 clusters. Cluster IV consisted of maximum number of accessions (26) followed by cluster I (23), III (16), II (10) and cluster X (5). The clusters *viz.*, V, VI, VII, VIII, IX, XI, XII, XIII and XIV consisted only one accession each. The inter-cluster distances were greater than intracluster distances, revealing that considerable amount of genetic diversity existed among the accessions. Maximum inter cluster distance was observed between cluster IX and X (815.75) followed by clusters III and X (752.52), cluster II and X (746.95) and cluster X and XII (654.83). Genotypes belonging to these diversified clusters could be utilized in the hybridization programme to get desirable recombinants segregating generations. Among all the characters, methionine content contributed maximum (32.33%) towards the in divergence followed by lysine content (27.20%) and tryptophan content (16.32%).

INTRODUCTION

Blackgram [*Vigna mungo* (L.) Hepper] is one of the important short duration nutritious pulse crops grown in a wide range of agroclimatic conditions in all the three seasons. India is the largest producer and consumer of blackgram, with an area of about 5.44 mha, production of 3.56 million tonnes and productivity of 655 kg ha⁻¹. It occupies 17.13 % of total pulse area and contributes 13.40% of total pulse production in India. It ranks third among the major pulses after chickpea and pigeonpea. In Andhra Pradesh, it is grown in an area of about 3.81 lakh hectares with production of 3.13 lakh tonnes and productivity of 902 kg ha⁻¹ (Govt. of India, 2018).

In India, the per capita daily availability of pulses has reduced significantly from 51 g. per day in 1971 to about 42 g. per day in 2015-2016 as against WHO recommendation of 80 g. per day (Singh *et al.*, 2016). Hence, there is a need to develop blackgram cultivars with high yield and better quality. The development of new varieties depends largely on the availability of genetic variability in the base material and the extent of variability for the desired character. The information about the nature and magnitude of genetic divergence is essential for selection of diverse parents which upon hybridization lead to a wide spectrum of recombinations. Mahalanobis D² statistics is very sensitive tool for measuring genetic divergence of quantitative traits and also widely used by many

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breeders for selection of divergent parents for hybridization programme. Keeping this in view, 89 genotypes of blackgram were evaluated for genetic diversity by using Mahalanobis D^2 statistics for yield, yield attributes and quality traits.

MATERIAL AND METHODS

The material consisted of 89 blackgram genotypes obtained from Agricultural Research Station (ARS) Madhira, Telangana; Regional Agricultural Research Station (RARS), Lam, Guntur and Regional Agricultural Research Station (RARS), Tirupati. All these genotypes were sown in randomized complete block design (RCBD) with three replications at dry land farm of S.V Agricultural College, Tirupati, during *Rabi* 2015-16. Each genotype was raised in 3 m length with spacing of 30 cm × 10 cm. Recommended agronomic practices were followed. Observations were recorded for days to 50 % flowering, days to maturity, SPAD chlorophyll meter reading, specific leaf area, plant height, number of primary branches plant⁻¹, number of clusters plant⁻¹, number of pods plant⁻¹, pod length, number of seeds pod⁻¹, 100- seed weight, harvest index, seed yield plant⁻¹, protein content, carbohydrate content, lysine content, tryptophan content and methionine content. The data for yield traits was recorded on five randomly selected plants in each entry in each replication except days to 50% flowering and days to maturity which were taken on plot basis. The data collected on different characters was analysed through Mahalanobis (1936) D^2 analysis. Clustering of genotypes was completed following the Tocher's method as described by Rao (1952).

RESULTS AND DISCUSSION

Analysis of variance showed highly significant differences among the genotypes for all the characters studied indicating the existence of considerable genetic variability in the material. The 89 genotypes were grouped into 14 clusters by using Tocher's method (Rao, 1952) (Table 1). The distribution of genotypes into various clusters was at random. Out of 14 clusters, cluster IV was the largest comprising of 26 genotypes followed by Cluster I, III, II, X with 23, 16, 10 and 5 genotypes, respectively. The clusters viz., V, VI, VII, VIII, IX, XI, XII, XIII and XIV were mono genotypic indicating high degree of heterogeneity among the genotypes. From the clustering pattern (Fig. 1), the distribution of genotypes from different geographical regions into these clusters was apparently random. Genotypes of similar origin were grouped into different clusters and *vice versa*, thereby indicating no relationship between geographical and genetic diversity. The tendency of genotypes to occur in clusters cutting across geographical boundaries demonstrates that geographical isolation is not the only factor causing genetic diversity. It was recorded that the genotypes collected from different regions were independent of their genetic origin. Lack of correlation between genetic diversity and geographic diversity was mainly attributed to free exchange of genotypes from one region to another and also may be due to the character constellation that might be practiced in several regions resulting in segregation of genotypes irrespective of their geographic region. These results are in akin with the findings of Elangaimannan *et al.* (2008) and Srimathy *et al.* (2012) in blackgram.

In the investigation, D^2 values ranged between 0.0 and 815.75 (Table 2), which indicated the presence of adequate amount of genetic diversity in the materials studied. The maximum intra cluster distance was observed in cluster X (160.61) followed by cluster IV (134.21), III (116.52), II (88.09) and I (83.23), thus, suggesting that different genotypes included in this cluster might have different genetic architecture. However, the lowest intra cluster distance found in cluster I (83.23) indicated that the genotypes resembled one another genetically and appeared to have evolved from a common gene pool, which is in accordance with the findings of Panigrahi *et al.* (2014) and Kamannavar *et al.* (2016).

The inter cluster distance was maximum between cluster IX and X (815.75) followed by clusters III and X (752.52), cluster II and X (746.95) and cluster X and XII (654.83), suggesting that the genotypes in these clusters could be selected for hybridization to obtain wider segregation (Table 2). In contrast, the minimum inter cluster distance was found between cluster V and VIII (63.35) indicating that the genetic constitution of the genotypes in both the clusters were in close proximity. Hence, selection of parents from such clusters may be avoided because it may result in narrow genetic base. These results were supported by the findings of Konda *et al.* (2007), Elangaimannan *et al.* (2008) and Srimathy *et al.* (2012).

Among all the characters studied, methionine content contributed the maximum (32.33%) to the diversity followed by lysine content (27.20%) and tryptophan (16.32%) (Table 3) suggesting scope for

improvement in these characters. On contrary, specific leaf area and pod length had negligible contribution towards genetic divergence. Similar findings were reported by Sreevalli Devi *et al.* (2011), Panigrahi *et al.* (2014) and Kamannavar *et al.* (2016).

Cluster means for different traits showed considerable difference between the clusters for all the characters (Table 4). It was observed that Cluster IX with single genotype LBG 752 showed highest mean value for number of clusters (14.27), number of pods per plant (35.93), harvest index (41.58 %) and seed yield per plant (11.05 g) while the cluster XIII recorded maximum *per se* values for plant height (43.93 cm), number of seeds per pod (5.87) and 100-seed weight (5.14 g). Similarly, Cluster X exhibited higher mean values for lysine content (11.81 mg g⁻¹) and tryptophan content (3.59 mg g⁻¹). In addition, the cluster XIV showed high mean values for pod length (5.21cm) and methionine content (2.82 mg g⁻¹) while the cluster VII showed highest mean value for number of primary branches⁻¹ plant (5.13) and carbohydrate content (587.43 mg g⁻¹). Further, clusters VIII registered highest mean value for SCMR (51.49) while, Cluster VI recorded high mean values for protein content (258.31 mg g⁻¹). Therefore, selection of the genotypes among these clusters might result in simultaneous improvement of these traits. Inter crossing of the genotypes from these clusters could be suggested to generate a wide spectrum of variability followed by effective selection for these characters. Similar findings were reported by Parmeswaappa *et al.* (1993), Panigrahi *et al.* (2014) and Srividya *et al.* (2018) in blackgram.

Table 1. Cluster composition of 89 blackgram genotypes based on Tocher's method

Cluster No.	No. of genotypes	Genotypes
I	23	DBGV-5, KDRS-136, KU-10-1164, KU-10-52, KU-11-685, AKU 10-4, DKU-4, KU-15-154, LBG-20, LBG-22, P-1032, P-728, RFU-13-10, RFU-14-02, LBG 653, VBG 10-010, RUG-36, SU-13-509, T-9, TBG-104, TU-67, VBN(Bg)-5, VBN 8
II	10	KPU 01-10, LBG-709, LBG-787, RFU-13-01, RFU-13-9, RFU-14-01, VBG 10-008, RU-13-07, SB 44-4, VBN(Bg)-7
III	16	KU-10-1161, KU-10-1170, BIDHAN KALAI-1, NDUK 13-4, LBG-645, MBG-1042, MBG-1050, MBG-1051, MBG-1061, MBG-207, MBG-217, MBG-223, NDU-11-201, P-726, VBG 10-014, TU 94-2
IV	26	KU-10-1169, RVSU 60, KU-12-1, COBG10-5, UH 08-05, VBG 11-016, SBC-47, KU-14-47, KU-14-50, LBG-402, LBG-623, LBG-685, P-112, PU-205, RFU-13-04, RU-02-05, RU-10-602, TU 18, KPU 01-10, MDU 1, UG-708, VBG-11-031, VBG-11-6, VBN(Bg)-4, VBN-6, WBG-26
V	1	RU-10-627
VI	1	UH 08-05
VII	1	LOP-1070
VIII	1	PU-31
IX	1	LBG-752
X	5	MBG-1045, MBG-1058, NUL-244, IPU 10-4, KU 1006
XI	1	IPU 10-117
XII	1	RU-11-719
XIII	1	BDU 3-04
XIV	1	RU-10-633

Table 2. Per cent contribution of seed yield, yield components and quality traits to diversity in blackgram

S. No.	Character	Times ranked first	Contribution (%)
1.	Days to 50% flowering (days)	68	1.74
2.	Days to maturity (days)	5	0.13
3.	SCMR	4	0.10
4.	Specific leaf area (cm ² g ⁻¹)	0	0.00
5.	Plant height (cm)	4	0.10
6.	No. of primary branches plant ⁻¹	129	3.29
7.	No. of clusters plant ⁻¹	137	3.50
8.	No. of pods plant ⁻¹	12	0.31
9.	Pod length (cm)	0	0.00
10.	No. of seeds pod ⁻¹	4	0.10
11.	100 seed weight (g)	12	0.31
12.	Harvest index (%)	6	0.15
13.	Seed yield plant ⁻¹ (g)	3	0.08
14.	Protein content (mg g ⁻¹)	160	4.09
15.	Carbohydrate content (mg g ⁻¹)	401	10.24
16.	Lysine content (mg g ⁻¹)	1065	27.20
17.	Tryptophan content (mg g ⁻¹)	639	16.32
18.	Methionine content (mg g ⁻¹)	1266	32.33

GENETIC DIVERSITY STUDIES IN BLACKGRAM

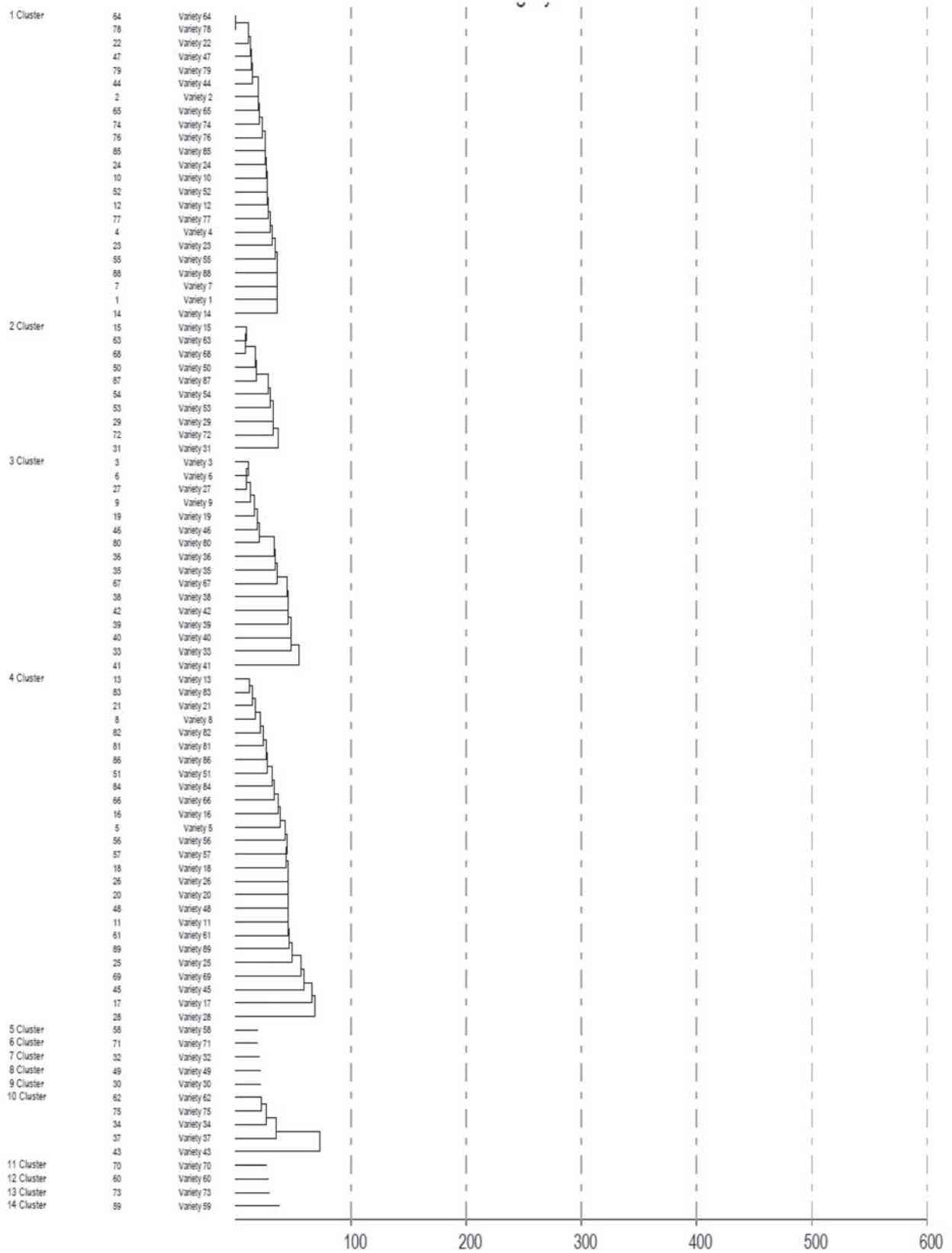


Fig. 1. Grouping of 89 blackgram genotypes into 14 clusters using Tocher's method

Table 3 . Intra cluster (diagonal) and inter-cluster distances of fourteen clusters in blackgram

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster XI	Cluster XII	Cluster XIII	Cluster XIV
Cluster I	83.23 (9.12)	218.50 (14.78)	136.96 (11.70)	186.35 (13.65)	157.66 (12.56)	179.62 (13.40)	134.97 (11.62)	253.14 (15.91)	179.68 (13.40)	525.28 (22.92)	126.08 (11.23)	174.64 (13.22)	180.23 (13.42)	363.26 (19.06)
Cluster II		88.09 (9.39)	219.00 (14.80)	356.83 (18.89)	148.93 (12.20)	146.18 (12.09)	173.36 (13.17)	217.66 (14.75)	163.17 (12.77)	746.95 (27.33)	178.96 (13.38)	350.92 (18.73)	195.69 (13.99)	233.93 (15.29)
Cluster III			116.52 (10.79)	315.18 (17.75)	244.16 (15.63)	247.72 (15.74)	164.84 (12.84)	345.27 (18.58)	178.43 (13.36)	752.52 (27.43)	190.62 (13.81)	243.19 (15.59)	246.09 (15.69)	464.48 (21.55)
Cluster IV				134.21 (11.58)	204.65 (14.31)	205.70 (14.34)	255.39 (15.98)	266.71 (16.33)	378.53 (19.46)	269.46 (16.42)	219.89 (14.83)	278.38 (16.68)	230.98 (15.20)	359.95 (18.97)
Cluster V					0.00 (0.00)	87.10 (9.33)	183.74 (13.56)	63.35 (7.96)	102.99 (10.15)	458.85 (21.42)	91.01 (9.54)	227.15 (15.07)	80.08 (8.95)	155.46 (12.47)
Cluster VI						0.00 (0.00)	173.97 (13.19)	195.82 (13.99)	237.95 (15.43)	435.45 (20.87)	215.17 (14.67)	390.26 (19.75)	182.94 (13.53)	312.30 (17.67)
Cluster VII							0.00 (0.00)	209.29 (14.47)	217.58 (14.75)	574.70 (23.97)	183.89 (13.56)	345.36 (18.58)	227.83 (15.09)	376.40 (19.40)
Cluster VIII								0.00 (0.00)	145.19 (12.05)	449.59 (21.20)	102.91 (10.14)	284.16 (16.86)	114.45 (10.70)	99.88 (9.99)
Cluster IX									0.00 (0.00)	815.75 (28.56)	81.26 (9.01)	176.88 (13.30)	143.41 (11.98)	242.74 (15.58)
Cluster X										160.61 (12.67)	539.06 (23.22)	654.83 (25.59)	515.64 (22.71)	577.99 (24.04)
Cluster XI											0.00 (0.00)	74.36 (8.62)	75.92 (8.71)	147.81 (12.16)
Cluster XII												0.00 (0.00)	154.01 (12.41)	289.36 (17.01)
Cluster XIII													0.00 (0.00)	161.26 (12.70)
Cluster XIV														0.00 (0.00)

Table 4. Cluster means for yield, yield components and quality traits in blackgram

Cluster No.	DFE (days)	DM (days)	SCMR	SLA (cm ² g ⁻¹)	PH	NPB (cm)	NCP	NPP	PL	NSP (cm)	100 SW (g)	HI (%)	SYP (g)	PC (mg/g)	CHO (mg/g)	LC (mg/g)	TC (mg/g)	MC (mg/g)
I	39.99	75.70	41.67	155.26	36.05	3.05	11.69	28.40	4.97	5.19	5.01	32.10	8.35	224.98	514.01	7.09	1.90	1.47
II	42.73	78.00	42.88	159.96	35.29	3.15	11.05	27.43	4.93	5.31	5.12	31.86	7.86	204.27	524.98	5.04	1.29	2.35
III	43.29	79.81	42.47	165.93	41.20	3.96	13.67	28.08	4.92	5.58	5.08	32.30	8.95	215.56	499.87	5.48	1.72	1.31
IV	42.06	76.83	42.48	165.76	38.33	2.89	10.91	24.08	4.85	5.34	5.06	29.41	7.09	222.37	488.91	9.12	2.63	1.84
V	41.67	79.00	46.44	128.36	30.80	3.00	9.60	35.27	4.35	4.73	4.72	38.47	9.79	246.78	404.16	7.55	1.49	2.27
VI	46.33	81.33	42.06	126.84	32.60	2.80	12.00	28.73	4.57	5.46	4.75	25.87	8.39	258.31	565.21	7.44	1.77	2.43
VII	37.67	75.00	42.61	166.28	39.73	5.13	13.40	23.93	5.11	5.00	4.73	36.77	7.21	194.36	587.43	7.20	1.50	2.02
VIII	37.67	75.00	51.49	113.62	28.70	3.80	13.41	32.07	4.88	5.20	4.52	39.66	8.45	220.78	345.66	7.45	1.76	2.66
IX	39.00	78.00	47.39	133.52	26.78	2.93	14.27	35.93	4.53	5.47	4.85	41.58	11.05	235.51	357.93	5.19	1.08	1.79
X	41.53	77.47	40.00	174.30	33.09	3.17	11.65	23.26	4.92	5.47	4.84	32.63	6.11	228.78	471.65	11.81	3.59	2.43
XI	37.67	73.00	39.87	101.98	23.60	2.73	11.47	18.73	4.69	5.80	4.82	40.36	5.87	215.55	385.48	6.38	1.73	1.80
XII	39.33	73.33	38.01	151.11	29.07	1.67	11.20	15.93	4.78	5.40	5.00	37.12	10.82	223.98	503.44	7.85	2.03	1.44
XIII	40.67	75.67	39.13	165.67	43.93	4.07	9.41	17.40	5.14	5.87	5.14	20.10	5.70	246.26	346.02	6.74	1.68	2.16
XIV	38.00	72.33	42.11	179.75	28.27	2.07	9.87	28.40	5.21	5.20	4.57	31.25	7.44	174.59	324.19	6.62	1.83	2.82
General Mean	40.54	76.46	42.76	149.17	33.39	3.17	11.69	26.26	4.85	5.43	4.86	33.06	7.72	221.25	438.17	7.16	1.84	2.03

Note: DFF: Days to 50% flowering; DM: Days to maturity; SCMR: SPAD chlorophyll meter reading; SLA: Specific leaf area; PH: Plant height; NPB: No. of primary branches plant-1; NCP: No. of clusters plant-1, NPP: No. of pods plant-1; PL: Pod length, NSP: No. of seeds pod-1, 100SW:100 seed weight, HW: Harvest index, SYP: Seed yield plant-1, PC: Protein content, LC: Lysine content, TC: Tryptophan content, MC: Methionine content

CONCLUSION

The investigation on blackgram germplasm displayed a wide range of diversity for most of the traits studied. The characters viz., methionine content, lysine content and tryptophan content contributed maximum towards the diversity. Therefore, the more emphasis should be focused on these characters for selection of parental lines to improve quality. Based on the maximum diversity between the clusters, the genotypes from clusters viz., IX and X, III and X, II and X, X and XII and X and XIV could be utilised in the hybridization programme to obtain desirable segregants for improvement of yield and quality traits in blackgram.

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RESPONSE OF GROUNDNUT GENOTYPES TO HIGH AND LOW PHOSPHORUS LEVELS

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ABSTRACT

Groundnut production is often limited by low availability of soil phosphorus. Groundnut genotypes differ in their P efficiency and dry matter production under low P availability. Two Groundnut genotypes were used in this study namely ICG(FDRS)-10 (absorb and translocate large amount of P) and JL-24 (not suitable for P insufficient conditions) to study the response of P availability. Plants were grown in pots with two P levels viz. without P (0 mg P/kg soil, LP) and with P (40mg P/kg soil, HP) and parameters such as shoot length, root length, root volume, no. of lateral roots, nodules per plant, stem weight and leaf weight were recorded. Growth of groundnut genotypes was affected at 60 DAE *i.e.* during pegging stage. Low phosphorus (LP) resulted in reduced stem weight, leaf weight, shoot length and root volume, nodules per plant but root length and lateral roots were increased. Shoot and root characters were significantly associated under LP. There is sufficient genetic variability among groundnut genotypes for LP and this variability is mainly visible during pegging stage.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) an important legume crop and a valuable source of oil and protein is grown predominantly by small farmers in tropical and subtropical countries of the world. Various environmental factors such as water stress, low soil nitrogen (N) and phosphorus (P) levels affect groundnut production (Singh, 2011). Phosphorus is one the most important macro-nutrient required for growing plants as it is involved in various biochemical activities related to growth, development, photosynthesis, reproduction and use of carbohydrates (Singh *et al.*, 2004). Inadequate application and low availability of native phosphorus (P) in the soil limit the groundnut productivity in semi-arid tropics (Shenoy and Kalagudi, 2005; Singh *et al.*, 2004). The P deficiency in groundnut reduces

leaf expansion, auxiliary bud growth, shoot canopy and leaf area (Singh *et al.*, 2004). The accumulation of dry matter during different phenophases influences the behaviour of crop growth which in turn decides the final yield (Sudheer *et al.*, 2011). Use of nutrients constitutes a major factor governing the dynamics of plant nutrient stores. Amount of nutrients such as phosphorus remobilized was governed by growth demand rather than soil nutrient supply (Milla *et al.*, 2005). Hence, in this experiment attempts were made to study the effect of phosphorus supply on biomass accumulation in different plant parts and nodules per plant during different phenophases of crop growth in groundnut.

MATERIAL AND METHODS

Two groundnut cultivars *i.e.* 'ICG (FDRS)-10' and 'JL-24' were used. Cultivar ICG(FDRS)-10 can absorb

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and translocate large amount of P into seeds (Krishna 1997), whereas, JL-24 was identified as not suitable for P insufficient conditions (Amit *et al.*, 2009). Two levels of P application (0 mg P/kg soil (LP) and 40mg P/kg soil (HP) were tested by adopting Randomized complete block design and replicated these Pots were filled with soil (Vertisols) with pH of 7.5 having moderately available phosphorus (15 kg ha⁻¹ P). Nitrogen and potash were applied at the rate of 20 mg N/kg soil and 25 mg K/kg soil equally for both the treatments. The experiment was conducted during 2012-13 at ICAR-Directorate of Groundnut Research, Junagadh (latitude 21°31'N, longitude 70°36'E). Plants were harvested at 40 DAE, 60 DAE and 80 days after emergence (Days). At harvest, plants were removed from the containers by carefully sliding out the entire root mass. The stem was cut off, and the root system was first completely immersed in a water-filled container and then cleaned with running tap water until free of soil and sand. Parameters such as shoot length, root length, root volume, number of lateral roots, number of nodules plant⁻¹, stem weight and leaf weight were recorded.

RESULTS AND DISCUSSION

Analysis of variance indicated that the treatment effect on stem weight was significant for days to emergence (D), phosphorus levels, genotype and D × P interactions (Table 1). Significance of D × P interactions indicate that different crop phenophases respond differentially to P availability. Stem weight exhibited a gradual increase starting from DAE 40 to 80 DAE with the maximum increase during 40 DAE to 60 DAE under high phosphorus (HP). Whereas, under low phosphorus (LP) stem weight was very low and maximum increase was observed from DAE

60 to 80 DAE. Both the genotypes showed reduction in stem weight under LP compared to HP but among two genotypes (Fig 1a), JL-24 exhibited a greater reduction in stem weight. Treatment effect on leaf weight was significant for days to emergence, phosphorus levels, D × P, D × genotype and D × P × G. Significance of D × P × G indicates that response of genotypes to changes in P levels differ across phenophases. Similar to stem weight, leaf weight (Fig. 1b) also showed gradual increase from DAE 40 to 80 DAE under HP, whereas, under LP, an increase in leaf weight was very low upto 80 DAE. Among the two genotypes, JL-24 had higher leaf weight under HP and ICG(FDRS)-10 under LP. Total haulm yield (stem weight and leaf weight) was high under HP compared to LP and ICG(FDRS)-10 had higher total haulm yield under both the situations. The highest increase in total haulm yield (Fig. 1c) was observed from 40 DAE to 60 DAE under HP, whereas, under LP it was observed from 60 DAE to 80 DAE. Treatment effect on shoot length was significant for days to emergence and phosphorus levels. Shoot length among the two treatments (Fig. 1d) was high under HP compared to LP and genotype ICG (FDRS)-10 had higher shoot length compared to JL-24 under both the treatments. Increase in shoot length was maximum at 40 DAE to 60 DAE compared to other phenophases and genotype JL-24 suffered a greater reduction in shoot length due to low P availability.

Root length among the two treatments (Fig. 2a) was high at LP compared to HP and genotype ICG(FDRS)-10 had higher root length at 40 DAE and 60 DAE, whereas, JL-24 had higher root length at 80 DAE. The treatment effect of root volume was highly significant for days to emergence, phosphorus levels

and D x genotype interaction. Root volume (Fig. 2b) was high under HP compared to LP and it was higher in ICG(FDRS)-10 under both the treatments upto 60 DAE while at 80 DAE JL-24 had greater root volume. Reduction in root volume was greater at 80 DAE and greater reduction was observed in JL-24. Treatment effect on the number of lateral roots was significant for days to emergence and phosphorus levels (Table 1). No. of lateral roots (Fig. 2c) was high under LP compared to HP and genotype JL-24 had more lateral roots than ICG(FDRS)-10 at 40 DAE and 80 DAE. Lateral roots were high during 40 DAE, while, it was low during 60 DAE. Number of nodules per plant which is an indicator of N mobilization within the plant showed significant difference for days to emergence, phosphorus levels, genotype, D x P, P x genotype and D x P x G. Nodules per plant (Fig. 2d) was high under HP compared to LP and maximum number of nodules was recorded at 60 DAE for both the genotypes under both the treatments.

Correlation analysis under high and low P conditions

Association of root characters, shoot characters and nodules per plant under high P and low P are presented in Table 2. Under HP, a significant positive association was observed for shoot length with root length and stem weight; stem weight with root volume and nodules per plant with leaf weight. Increase in leaf weight with the number of nodules per plant indicates higher nitrogen fixation reflected in leaf weight under HP conditions (Valentine *et al.*, 2017). Lateral roots per plant had a significant negative association with nodules per plant, stem weight and leaf weight. Under LP significant positive association was observed for shoot length with root length, root

volume, stem weight and leaf weight; leaf weight with root volume and stem weight and root volume with stem weight.

Impact of low P availability on plant growth

The more striking effect of low LP was a reduction in stem weight, leaf weight, shoot length and root volume and increase in root length and lateral roots and is in agreement with the findings of Freeden *et al.* (1989). Significance of D x P interaction indicated that different stages of crop respond differentially to P availability as the effect of low P on plant growth was more evident at 60 DAE when compared to other phenophases. This is in agreement with the findings of Sheoran *et al.* (2000), wherein, phosphorus application had no significant effect on flower initiation and maturity. Different genotypes vary in their ability to allocate their available resources between different plant parts. This variation was evident in the study, wherein, genotypes showed differential allocation of resources between shoots and leaves under differential P availability. When there was high P availability, leaf weight of ICG (FDRS)-10 was lesser than JL-24 but under LP, ICG(FDRS)-10 had high leaf weight compared to JL-24. This difference may be attributed to higher root length, the number of lateral roots and nodules per plant of ICG(FDRS)-10 over JL-24 which enabled them to absorb more nutrients for photosynthesis and in turn for translocation and storage. Further, association studies under LP also indicate that stem weight had a positive association with leaf weight and shoot characters in turn had a significant association with root characters.

Effect of P availability on root development

The number of lateral roots and root length were

higher at low-P than at high-P treatments, while the root volume decreased when grown under low-P availability. These results indicated that there can be considerable variation in number of lateral roots depending on the amount of available P. In the high nutrient environment, maybe lateral root growth was inhibited by high-N concentration in the plant (Zhang and Forde, 1998). These variations in the root morphology will help the plants to adapt to available P conditions. A longer root with reduced root volume indicates that root diameter has decreased *i.e.* development of fine roots under LP and these fine roots are efficient in acquiring P than a plant with short, thick ones (Ciro *et al.*, 1999; Xie and Yu, 2003). Root volume has decreased under LP indicating the decrease in root diameter. This reduced root diameter helped in acquiring P efficiently and as a result root volume under low P had a positive association with leaf weight and stem weight. Increase in lateral root density under low-P condition may reflect that root proliferation is important when plants are grown in environments with low available nutrients (Robison,

1994). Morphological plasticity in lateral roots is, thus a functional response to P availability. Increase in lateral roots also promotes more nodule formation which would in turn help in N-mobilisation. Under LP, lateral roots and root length has increased and stem weight and leaf weight has decreased which indicates that root development under LP occurs at the expense of shoot development which is in agreement with the earlier studies (Boutra, 2009).

However, Keerthisinghe *et al.* (1998) concluded that the formation of roots does not necessarily occur at the expense of dry matter production. Under LP, the export of photo-assimilates from leaves allow continued root growth and thus increases in root fraction (Cakmak *et al.*, 1994). The P levels are highly correlated with (Fig 2d) nodules per plant as they increased with the increase in availability of P. This is in agreement with the works of Valentine *et al.* (2017) who showed that under low P availability nodules largely decrease the utilization of atmospheric nitrogen as the nitrogen source and utilize more soil nitrogen (such as NO_3^- and NH_4^+).

Table 1. Analysis of variance of two Groundnut genotypes grown with high P and low P

Source of variance	Root length	Shoot length	Lateral roots	Nodules plant ⁻¹	Root volume	Stem weight	leaf weight
Days to emergence (D)	**	**	*	**	**	**	**
Phosphorus (P)		**	**	**	**	**	**
Genotype (G)				*		*	
D × P				**		**	**
D × G					*		**
P × G				*			
D × P × G	*			*			*

* , ** significant at $P < 0.05$ and $P < 0.01$, respectively

Table 2. Association among root characters, shoot characters and nodules under HP (below diagonal and LP (above diagonal)

	Root length	Shoot length	Lateral roots	Nodules plant ⁻¹	Root volume	Stem weight	Leaf weight
Root length		0.58*	-0.09	0.11	0.18	0.14	0.11
Shoot length	0.69*		-0.25	0.12	0.76**	0.83**	0.72**
Lateral roots	-0.05	-0.31		-0.51	-0.21	-0.43	-0.36
Nodules plant ⁻¹	-0.02	0.33	-0.77**		0.01	0.32	0.42
Root volume	-0.02	0.47	-0.51	0.28		0.75**	0.69**
Stem weight	0.38	0.66*	-0.60*	0.40	0.65*		0.94**
Leaf weight	-0.03	0.39	-0.71*	0.92**	0.43	0.56	

*, ** significant at P<0.05 and P <0.01, respectively

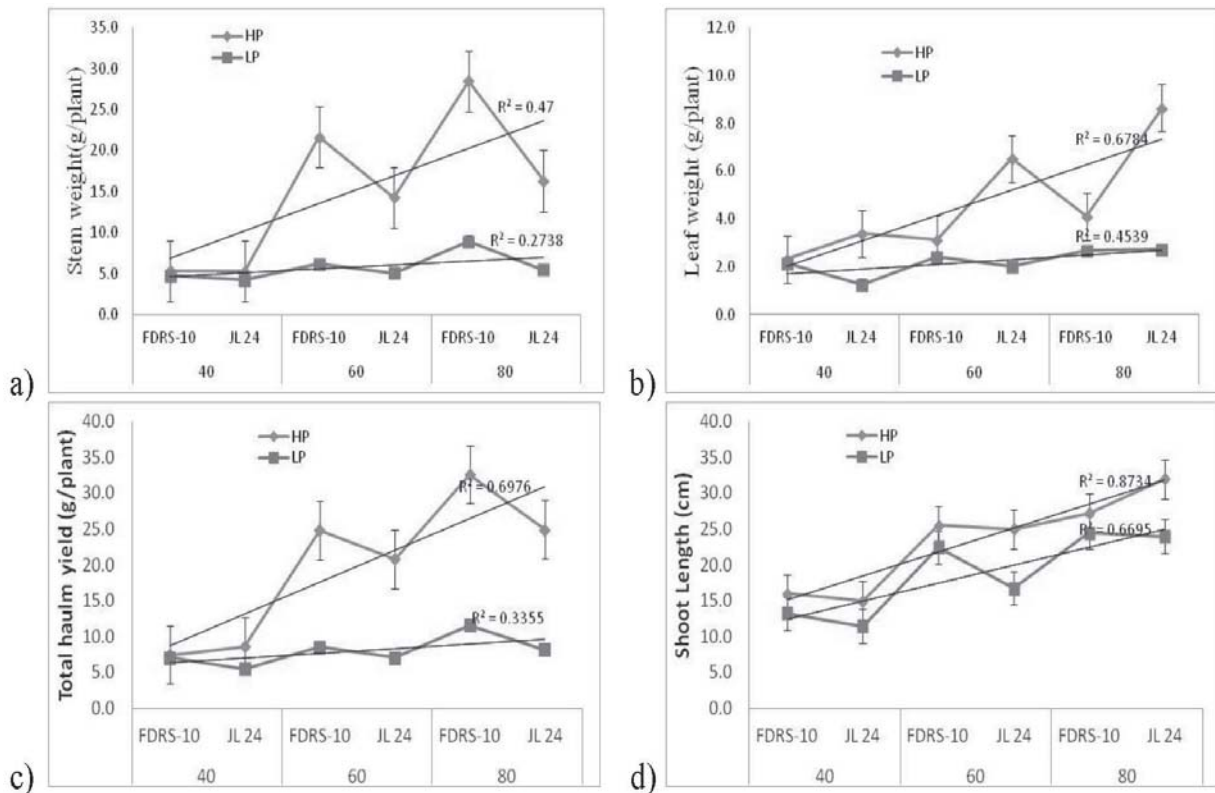


Fig. 1. Effect of P treatment at 40 DAE, 60 DAE and 80 DAE on shoot weight without leaf lets (a), weight of leaflets (b), total haulm yield (c) and shoot length (d) in high phosphorus (40 mg P/kg soil) and low phosphorus (0mg P/kg soil). Vertical bars represent SE.

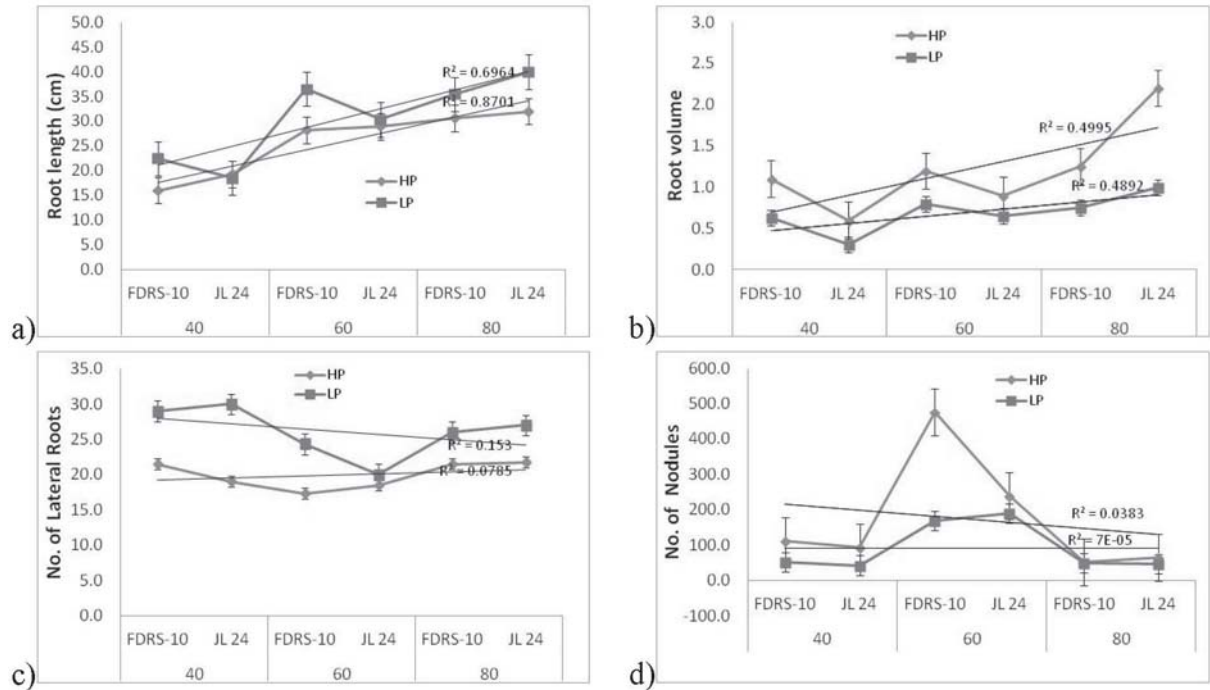


Fig. 2. Effect of P treatment at 40 DAE, 60 DAE and 80 DAE on root length (a), root volume (b), number of lateral roots (c) and (d) number of nodules per plant in high phosphorus (40 mg P/kg soil) and low phosphorus (0mg P/kg soil). Vertical bars represent SE.

CONCLUSION

Results confirmed that genotypes and yield components respond differently to P supply. The low P availability significantly affected the growth of groundnut genotypes mainly at 60 DAE *i.e.* during the pegging stage.

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EFFECT OF VARIOUS NUTRIENT SOURCES ON YIELD, YIELD ATTRIBUTES AND ECONOMICS OF GROUNDNUT (*Arachis hypogaea* L.) UNDER RAINFED AND PROTECTIVE IRRIGATED CONDITIONS

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ABSTRACT

The experiment was conducted during two consecutive *Kharif* seasons of 2014 and 2015 in groundnut. The highest level of yield attributes viz., number of filled pods plant⁻¹, 100 pod weight, 100 kernel weight, shelling percentage, the lowest number of ill-filled pods plant⁻¹, pod and haulm yield were recorded with the supply of 100 per cent of N through sheep penning and found comparable with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM and recommended dose of fertilizer under rainfed situation. Whereas, under protective irrigation, which was in turn comparable with supply of 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost. The highest gross returns and net returns in groundnut were obtained with supply of 100 per cent of N through sheep penning, which was at par with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM in both the situations during two consecutive years of investigation. The highest benefit-cost ratio was registered with supply of 100 per cent N through sheep penning, which was, however comparable with recommended dose of fertilizer under both situations except during second year under protective irrigation, where it was significantly superior over rest of the nutrient management practices tried.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is the premier oilseed crop contributing 40 per cent of the total oil seed production in India. However, its production and productivity needs to be significantly enhanced to meet the national requirement of edible oil in India, which is about 14.10 kg head⁻¹ year⁻¹ against the balanced nutritional requirement of 14.80 kg head⁻¹ year⁻¹. The productivity of *kharif* groundnut is low and highly fluctuating in *alfisols* of drylands mainly due to low organic matter content, poor fertility status, imbalanced use of high analysis chemical fertilizers accompanied by restricted use of organic manures, which made the soils not only deficient in secondary and micronutrients, but also deteriorated the soil health

(Akbari *et al.*, 2011). To alleviate the problem, the effective and integrated use of locally available organic resources such as the farm yard manure, leaf compost, groundnut shells, sheep manure along with inorganic sources are the suitable strategies to improve the yield and quality of groundnut. Apart from the integrated use of nutrient sources, the exploration of the predominant practice of sheep penning in the region is at most necessary to build the soil fertility for enhanced groundnut productivity in the rainfed *alfisols* of Andhra Pradesh (Reddy *et al.*, 2010). The nutrient management with organic and inorganic sources along with protective irrigation at critical crop growth stages despite the vagaries of rainfall will sustain the production system. Keeping these in view,

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the investigation was carried for two consecutive years (*kharif*, 2014 and *kharif*, 2015) at Agricultural Research Station, Ananthapuramu to find out the most suitable combination of chemical fertilizer and locally available organic sources for improving the productivity of groundnut.

MATERIAL AND METHODS

The experiment was carried out during *Kharif* seasons of 2014 and 2015 at Agricultural Research Station, Ananthapuramu of scarce rainfall zone of A.P. located between 14° 41'104" N latitude, 77° 40'281" E longitude with an altitude of 350 m above MSL, which falls under semi-arid tropics (SAT) according to Trolls classification, to study the effect of various nutrient sources on productivity and economics of groundnut. The experiment was laid out in completely randomized block design with three replications in two separate blocks *viz.*, purely rainfed block and with protective irrigation block with eleven treatments *viz.*, T₁ : Control (no organics and inorganics), T₂ : Recommended dose of fertiliser (RDF) (20 kg N ha⁻¹: 40 kg P₂O₅ ha⁻¹: 40 kg K₂O ha⁻¹), T₃ :50 % nitrogen through urea + 50 % nitrogen through FYM, T₄ :100 % nitrogen through FYM, T₅ :50 % nitrogen through urea + 50 % nitrogen through leaf compost, T₆ :100 % nitrogen through leaf compost, T₇ :50 % nitrogen through urea + 50 % nitrogen through sheep manure, T₈ :100 % nitrogen through sheep manure, T₉ : 100 % nitrogen through sheep penning, T₁₀ : 100 % nitrogen through enriched groundnut shells and T₁₁ :50 % nitrogen through urea + 50 % nitrogen through enriched groundnut shell. The soil type is *alfisols* with pH 6.42, EC 0.42 dS m⁻¹, low in available nitrogen (198 kg ha⁻¹), medium in available P₂O₅ (48 kg ha⁻¹), low in available K₂O (191 kg ha⁻¹) and low organic carbon (0.38%). Organics were applied two weeks before

sowing of the crop. The FYM, well-rotten gliricidia leaf compost, sheep manure were applied as per treatments on equivalent nitrogen basis to meet the nitrogen requirement of the crop. Enriched groundnut shells were prepared by spreading the groundnut shells overnight on the floor of the cattle shed so that groundnut shells were trampled well and mixed with the cattle dung and urine. In the following day, the enriched groundnut shells along with dung and urine were collected and applied to the experimental plots as per the treatments. The sheep penning plots were temporarily netted to keep the flock uniformly in the allocated plots overnight. The droppings of both urine and fecal matter falling the soil were incorporated to a shallow depth by running a blade harrow. Nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash respectively at the time of sowing. During the crop period of first year (2014), a total rainfall of 234.6 mm was received in 16 rainy days as against the decennial average of 363.7 mm in 22 rainy days for the corresponding period and during the second year (2015), a total rainfall of 318 mm was received in 23 rainy days against the decennial mean rainfall of 371.8 mm in 23 rainy days for the corresponding period. Under protective irrigation, two irrigations were given at 55 DAS and 75 DAS during 2014 *kharif* and one protective irrigation was given at 75 DAS during 2015 (20 mm of irrigation each time). Groundnut variety 'Kadiri-6' was sown. The total cost of cultivation of groundnut was calculated for each treatment on the basis of inputs used. Gross returns were calculated based on the prevailing market price. Net returns and benefit- cost ratio were calculated as per the standard procedure. Data was statistically analyzed as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield attributes

Number of filled and unfilled pods plant⁻¹

Under rainfed condition, the highest number of filled pods plant⁻¹ in groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T₉), which was, however comparable with recommended dose of fertilizer (T₂) and 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T₃) (Table 1).

Under protective irrigation in both years of study, the highest number of filled pods plant⁻¹ were produced with supply of 100 per cent nitrogen through sheep penning (T₉), which was at par with recommended dose of fertilizer (T₂), 50 per cent nitrogen through urea and substitution of 50 per cent nitrogen either through FYM (T₃) or leaf compost (T₅). Significantly lowest number of filled pods plant⁻¹ was recorded with non-supply of nitrogen (T₁) during both years of study under both situations. The pod formation is the complex process and governed by complementary interaction between source and sink. Thus, the favourable effect of readily available nutrients with 100 per cent nitrogen through sheep penning (T₉) is evident with higher dry matter accumulation and effective translocation of photosynthates to the sink, which, in turn might have resulted in higher number of filled pods plant⁻¹. Further, supply of 50 per cent nitrogen through urea and 50 per cent through FYM (T₃) or recommended dose of fertilizers alone under rainfed conditions, along with leaf compost under protective irrigation was attributed to increased size of the source and consequently, the enhanced partitioning of photosynthates towards newly formed sink. Reddy *et al.* (2010) reported that sheep penning in groundnut

recorded significantly higher number of filled pods plant⁻¹.

Under both the farming situations, the number of ill-filled pods plant⁻¹ did not exhibit any significant difference among the treatments except control (T₁) although the lowest number of ill filled pods plant⁻¹ were recorded in treatment T₉ (100 per cent nitrogen through sheep penning) (Table 1). This might be due to better source sink relationship owing to formation of more number of two seeded pods. Control (T₁) recorded the higher number of ill-filled pods plant⁻¹ due to poor nutritional status of the soil. The results of Yadav and Shivaramu (1997) revealed that the good fertility status besides the moisture holding capacity of the soil correlated significantly and positively with the growth and yield of groundnut besides reducing the ill-filled pods per plant.

Hundred pod weight

Under rainfed condition during *Kharif*, 2014 and *Kharif*, 2015, significantly highest hundred pod weight in groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T₉), and found on par with recommended dose of fertilizer (T₂) and 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T₃) (Table 2). Under protective irrigation also, supply of 100 per cent nitrogen through sheep penning (T₉) recorded significantly higher hundred pod weight, which was at par with recommended dose of fertilizer (T₂), 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T₃) and 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost (T₅). Significantly lowest hundred pod weight was recorded when groundnut crop did not receive any source of nitrogen (T₁). The higher pod weight recorded with the above treatments can be

ascribed to adequate supply of nutrients to the crop. Kamalakannan and Ravichandran (2013) stated that the yield attributing characters of groundnut such as 100 pod weight and shelling per cent were found improved to the maximum extent with the application of recommended dose of NPK either with the combination of micronutrients or FYM among the integrated nutrient management practices studied. Application of FYM @ 8 t ha⁻¹ along with 50 per cent recommended dose of fertilizers recorded significantly higher 100 pod weight (Ola *et al.*, 2013).

Hundred kernel weight and shelling percentage

During both the years of study, under rainfed condition, the highest kernel weight and shelling percentage was recorded with supply of 100 per cent nitrogen through sheep penning (T₉), which was at par with recommended dose of fertilizer (T₂) and 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T₃). Under protective irrigation, it was in turn found comparable with the application of 50 per cent nitrogen through urea + 50 per cent nitrogen through leaf compost (T₅) (Table 2). This might be due to improved soil fertility and other biological process, leading to higher outturn of photosynthates and production of bold seeds. Similar results were reported by Datta *et al.* (2014) who recorded that application of rhizobium culture in combination with 50 kg P₂O₅ + 50 kg K₂O/ha. The higher kernel weight with the above treatments might have resulted in higher shelling percentage. More number of bigger sized pods plant⁻¹ might have accommodated larger kernels providing sufficient space for development of kernel with balanced and adequate supply of nutrients (Bala and Nath, 2015). The lowest hundred kernel weight and shelling percentage were recorded with control

(T₁) due to poor soil fertility status.

Pod yield and haulm yield

Under both rainfed protective irrigation conditions during both *Kharif*, 2014 and *Kharif*, 2015, the highest pod yield of groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T₉), which was at par with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T₃) and recommended dose of fertilizer (T₂) (Table 3). Application of 100 per cent nitrogen through sheep penning (T₉) resulted in 69 % and 89 % higher pod yield during 2014 and 2015 over control under rainfed conditions and 83% and 57% under protective irrigation respectively. Pod yield of groundnut is a function of yield attributes, which was significantly higher with these nutrient management practices. Groundnut responded well to organic sources of nutrients under protective irrigation as compared to rainfed situation. Higher pod yield under protective irrigation might be due to coincidence of protective irrigation with critical stages *i.e.*, at pod formation and pod development stage. Protective irrigation at pod formation and pod development might have resulted in better moisture, nutrient availability and thereby regaining photosynthetic efficiency of the plant, which, in turn resulted in elevated yield attributes. Under arid and semi-arid conditions, crop yields are strongly influenced by rainfall and there is a strong correlation between the pod yield and the soil moisture at the critical stages of the crop growth *viz.*, pegging, pod formation and pod development (Rao *et al.*, 2012). Patil *et al.* (2015) reported that the integrated use of organic and inorganic nutrient sources (50% organics + 50% inorganics) produced significantly higher pod

yield of groundnut (1282 kg ha^{-1}) than 100% inorganics (1196 kg ha^{-1}) and 100% organics (1089 kg ha^{-1}). The lowest pod yield recorded in control (T_1) can be attributed to poor soil nutrient supply, low water holding capacity, resulting in deflated growth parameters, yield attributes and finally lower yields as reported by Yadav and Shivaramu (1997).

Similar trend of results were recorded with haulm yield also as that of pod yield (Table 3) under rainfed condition. Highest haulm yield of groundnut was recorded with supply of 100 per cent nitrogen through sheep penning (T_9) under rainfed and protective irrigation in both the years. The increase in biological yield is also attributed to increase in plant population, number of leaves and higher dry matter accrual under protective irrigation. Patil *et al.* (2015) reported that haulm yield was significantly higher with the application of 100% inorganics (2889 kg ha^{-1}) compared to application of 50% organics + 50% inorganics (2729 kg ha^{-1}) and 100% organics (2301 kg ha^{-1}). When nitrogen was not supplied either through organic or inorganic source, crop has to depend obviously upon soil nitrogen, which is not sufficient to produce even reasonable haulm yields. In the study, non-supply of nitrogen through any source in control (T_1) resulted in poor performance of the crop which could be noticed in all the growth parameters, yield attributes, nutrient uptake and pod yield. However, haulm yield was significantly higher in application of 100% inorganics compared to application of 50% organics + 50% inorganics and 100% organics.

Economics

Gross returns and net returns

Under rainfed condition and protective irrigation, significantly highest returns (gross and net) were obtained with application of 100 per cent nitrogen through sheep penning (T_9), which were, however, at par with 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM (T_3), recommended dose of fertilizer (T_2) (Table 4). It is obvious that realization of higher gross returns was the result of higher yield. The increase in net returns might be due to increased pod yield and reduced cost of cultivation. The highest net returns were obtained with 50 per cent fertilizer N + 50 per cent organic N in groundnut as reported by Malleswari (2009). The lowest returns were realized with control (T_1) due to lower yields.

Benefit - Cost ratio

Both under rainfed and protective irrigation conditions, the highest benefit-cost ratio was recorded with 100 per cent nitrogen through sheep penning (T_9), which was at par with recommended dose of fertilizer (T_2) and significantly superior over rest of the nutrient management practices tested during both the years of the study (Table 4). The benefit-cost ratio recorded with conjunctive use of 50 per cent nitrogen through urea + 50 per cent nitrogen either through FYM (T_3) or leaf compost (T_5) were comparable with each other. CRIDA (2011) reported highest benefit: cost ratio with the application of 50 per cent N each through fertilizer and organic sources in groundnut.

Table 1. Number of filled and ill-filled groundnut pods plant⁻¹ as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed Condition				Protective Irrigation			
	No. of filled pods plant ⁻¹		No. of ill-filled pods plant ⁻¹		No. of filled pods plant ⁻¹		No. of ill-filled pods plant ⁻¹	
	2014	2015	2014	2015	2014	2015	2014	2015
T ₁ : Control (no organics and inorganics)	6.3	9.3	6.0	6.6	10.0	14.5	5.3	6.0
T ₂ : Recommended dose of fertilizer (RDF)(20-40-40 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	10.3	15.0	4.3	3.3	16.1	21.8	3.6	2.7
T ₃ : 50% nitrogen through urea + 50% nitrogen through FYM	10.0	14.3	4.0	3.6	16.0	22.6	3.3	2.4
T ₄ : 100% nitrogen through FYM	9.3	13.3	4.2	3.6	14.2	20.5	3.6	2.9
T ₅ : 50% nitrogen through urea + 50% nitrogen through leaf compost	8.6	13.0	4.0	3.8	15.6	21.7	3.3	3.2
T ₆ : 100% nitrogen through leaf compost	8.0	11.3	4.4	3.9	11.5	18.6	3.8	3.1
T ₇ : 50% nitrogen through urea + 50% nitrogen through sheep manure	8.6	13.0	4.3	3.6	14.0	20.3	3.1	3.0
T ₈ : 100% nitrogen through sheep manure	7.6	11.6	4.1	3.7	11.2	18.5	3.3	3.7
T ₉ : 100% nitrogen through sheep penning	10.6	15.3	4.0	3.0	16.9	23.1	3.0	2.3
T ₁₀ : 100% nitrogen through enriched groundnut shells	7.5	11.6	4.2	3.8	11.0	18.1	3.8	3.2
T ₁₁ : 50% nitrogen through urea + 50% nitrogen through enriched groundnut shells	9.0	12.6	4.3	3.3	13.3	19.6	3.6	3.0
	0.37	0.44	0.15	0.31	0.48	0.51	0.26	0.33
	1.0	1.3	0.4	0.9	1.4	1.5	0.8	0.9
	SEm ±		CD @ 5%					

Table 2. Yield attributes of groundnut as influenced by organic and inorganic sources of nitrogen

	Rainfed Condition						Protective Irrigation					
	100 pod weight (g)		100 kernel weight (g)		Shelling percentage%		100 pod weight (g)		100 kernel weight (g)		Shelling percentage%	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T ₁ : Control (no organics and inorganics)	61.0	69.7	30.7	35.2	63.2	69.9	69.5	72.8	32.4	38.6	66.2	70.5
T ₂ : Recommended dose of fertilizer (RDF) (20-40-40 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	66.7	76.6	33.7	39.2	68.3	73.8	74.9	79.9	38.5	41.8	71.2	74.5
T ₃ : 50% nitrogen through urea + 50% nitrogen through FYM	66.3	76.3	33.5	38.9	68.1	73.2	74.5	79.6	38.3	41.0	71.9	75.0
T ₄ : 100% nitrogen through FYM	64.8	75.3	32.9	37.6	67.5	72.9	73.3	77.8	37.2	40.2	70.6	73.4
T ₅ : 50% nitrogen through urea + 50% nitrogen through leaf compost	65.5	75.7	33.1	37.9	67.6	73.1	74.1	78.9	38.1	40.9	70.9	75.4
T ₆ : 100% nitrogen through leaf compost	63.1	74.0	31.3	36.3	66.1	70.0	71.2	75.1	35.3	37.8	68.3	70.9
T ₇ : 50% nitrogen through urea + 50% nitrogen through sheep manure	64.5	74.8	32.8	37.4	67.2	72.4	72.9	77.5	36.7	40.0	70.1	73.2
T ₈ : 100% nitrogen through sheep manure	63.5	74.1	31.5	36.5	66.2	71.2	72.0	76.0	35.5	38.1	69.0	71.4
T ₉ : 100% nitrogen through sheep penning	67.3	77.4	34.9	40.1	69.0	74.5	75.1	79.6	39.0	42.5	72.3	75.4
T ₁₀ : 100% nitrogen through enriched groundnut shells	63.0	72.8	31.1	36.1	66.0	71.0	71.8	75.6	35.0	37.4	67.9	71.1
T ₁₁ : 50% nitrogen through urea + 50% nitrogen through enriched groundnut shells	64.4	74.6	32.4	37.3	67.1	71.8	72.4	77.1	36.2	39.7	69.8	73.0
SEM ±	0.40	0.48	0.51	0.43	0.41	0.45	0.40	0.51	0.55	0.62	0.52	0.64
CD @ 5 %	1.2	1.4	1.5	1.3	1.2	1.3	1.1	1.5	1.6	1.8	1.5	1.9

Table 3. Pod and haulm yield (kg ha⁻¹) of groundnut as influenced by organic and inorganic sources of nitrogen

Treatment	Rainfed Condition				Protective Irrigation			
	Pod yield		Haulm yield		Pod yield		Haulm yield	
	2014	2015	2014	2015	2014	2015	2014	2015
T ₁ : Control (no organics and inorganics)	497	807	1018	1746	698	1284	1530	2236
T ₂ : Recommended dose of fertilizer (RDF) (20-40-40 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	780	1429	1550	2823	1119	1951	2675	3320
T ₃ : 50% nitrogen through urea + 50% nitrogen through FYM	801	1496	1496	2738	1209	1997	2763	3401
T ₄ : 100% nitrogen through FYM	739	1290	1437	2530	1070	1768	2507	3097
T ₅ : 50% nitrogen through urea + 50% nitrogen through leaf compost	758	1319	1471	2612	1098	1879	2641	3231
T ₆ : 100% nitrogen through leaf compost	638	1074	1209	2243	842	1437	2184	2840
T ₇ : 50% nitrogen through urea + 50% nitrogen through sheep manure	709	1228	1418	2490	1012	1715	2361	3004
T ₈ : 100% nitrogen through sheep manure	671	1104	1260	2302	869	1528	2291	2961
T ₉ : 100% nitrogen through sheep penning	842	1530	1696	2944	1280	2013	2807	3441
T ₁₀ : 100% nitrogen through enriched groundnut shells	611	1020	1187	2198	817	1395	2156	2750
T ₁₁ : 50% nitrogen through urea + 50% nitrogen through enriched groundnut shells	697	1167	1391	2430	997	1603	2340	3021
	22.1	61.0	69.0	100.2	66.5	77.9	56.8	85.7
	65	181	205	298	197	231	169	254

Table 4. Gross returns (Rs. ha⁻¹), Net returns (Rs. ha⁻¹), Net returns (Rs. ha⁻¹), Net returns (Rs. ha⁻¹) and B: C ratio of groundnut as influenced by organic and inorganic sources of nitrogen

Treatments	Rainfed Condition						Protective Irrigation					
	Gross returns (Rs.) Ra ⁻¹		Net returns (Rs.) Ra ⁻¹		B : C ratio		Gross returns (Rs.) Ra ⁻¹		Net returns (Rs.) Ra ⁻¹		B : C ratio	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T ₁ : Control (no organics and inorganics)	29570	47859	5595	23884	1.23	1.99	41449	75386	15974	50661	1.62	3.04
T ₂ : Recommended dose of fertilizer (RDF) (20-40-40 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	46018	84574	18353	56909	1.66	3.06	66915	113945	37750	85530	2.26	4.03
T ₃ : 50% nitrogen through urea + 50% nitrogen through FYM	47067	87775	16669	57103	1.54	2.83	72003	116637	40105	85216	2.25	3.71
T ₄ : 100% nitrogen through FYM	43538	76010	10377	42317	1.31	2.25	63883	103416	29222	68973	1.84	3.00
T ₅ : 50% nitrogen through urea + 50% nitrogen through leaf compost	44633	77788	16427	49565	1.58	2.76	65651	109808	35945	80865	2.20	3.79
T ₆ : 100% nitrogen through leaf compost	37491	63738	8703	34980	1.30	2.21	50679	84715	20391	55207	1.67	2.86
T ₇ : 50% nitrogen through urea + 50% nitrogen through sheep manure	41831	72502	12952	43678	1.44	2.51	60340	100332	29961	70758	1.98	3.39
T ₈ : 100% nitrogen through sheep manure	39461	65305	9347	35295	1.31	2.16	52359	88844	20745	58084	1.65	2.89
T ₉ : 100% nitrogen through sheep penning	49722	90038	22497	62813	1.82	3.28	76032	117598	47307	89623	2.64	4.20
T ₁₀ : 100% nitrogen through enriched groundnut shells	35997	60514	7769	32276	1.27	2.14	49265	82243	19537	53255	1.65	2.83
T ₁₁ : 50% nitrogen through urea + 50% nitrogen through enriched groundnut shells	41100	69046	13171	41215	1.47	2.48	59399	94086	29970	65505	2.01	3.29
SEm ±	2020.6	2061.2	2020.6	2060.6	0.07	0.07	2457.1	3029.8	2457.1	3029.8	0.08	0.10
CD @ 5 %	6003	6123	6003	6121	0.20	0.22	7299	9000	7299	9000	0.24	0.32

CONCLUSION

The study revealed that there is ample scope for enhancing the productivity and economic returns of groundnut as well as soil health in rainfed *alfisols* with supply of 100 per cent nitrogen through sheep penning or 50 per cent nitrogen through urea + 50 per cent nitrogen through FYM. However, sheep penning practice is proved as promising, economically viable, environmentally safe and ecologically sustainable option for rainfed *alfisols* of scarce rainfall zone of Andhra Pradesh.

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EFFECT OF BIOCHAR ON CONTENT AND UPTAKE OF MACRONUTRIENTS BY *RABI* GROUNDNUT (*Arachis hypogaea* L.) IN SANDY LOAM SOILS OF NORTH COASTAL ANDHRA PRADESH

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ABSTRACT

A field experiment was conducted to evaluate the effect of biochar on *Rabi* groundnut nutrition in red sandy loam soils. Eight treatments viz., control (T_1), 100% RDF only (T_2), 100% RDF + biochar @ 2 t ha⁻¹ (T_3), 100% RDF + biochar @ 4 t ha⁻¹ (T_4), 100% RDF + biochar @ 6 t ha⁻¹ (T_5), 75% RDF + biochar @ 2 t ha⁻¹ (T_6), 75% RDF + biochar @ 4 t ha⁻¹ (T_7) and 75% RDF + biochar @ 6 t ha⁻¹ (T_8) were laid out in RBD design replicated thrice. Soil application of biochar significantly increased the N, P₂O₅, K₂O and Ca concentration in both groundnut haulms and pods, however, Mg and S contents slightly increased by biochar addition. Highest nitrogen content of 2.86% was observed in groundnut pods when biochar applied @ 6 t ha⁻¹ along with 100% RDF (T_5), which found statistically on par with other treatments except T_6 and T_1 in which the N was significantly lower than in T_5 . The N, P₂O₅ and K₂O content were significantly high in all the treatments when compared to control (T_1). Calcium content in groundnut haulm and pods was significantly higher in biochar applied treatments (T_3 , T_4 , T_5 , T_6 , T_7 and T_8) compared to no biochar applied treatments (T_1 and T_2). However, calcium content with the biochar application @ 6 t ha⁻¹ (T_5 and T_8) was significantly higher when compared to treatments with biochar application @ 2 t ha⁻¹ (T_3 and T_6). The total uptake of N, P₂O₅, K₂O, Ca, Mg and S by groundnut crop was significantly influenced by biochar application in combination with 100% RDF (T_5 , T_4 , T_3) or 75% RDF (T_6 , T_7 & T_8) and RDF alone (T_2) when compared to control (T_1). The increased nutrient uptake was found mainly due to enhanced groundnut haulm and pod yield.

INTRODUCTION

The cropping system involving oilseed crops may remove as much as 350 kg to 780 kg of major nutrients (Nadaf and Chidanandappa, 2013). Biochar is the charcoal obtained by the low temperature pyrolysis of biomass, *i.e.*, by incomplete thermal decomposition of organic material under low oxygen conditions at relatively low temperatures (300°C - 350°C). Thus, its potential effects on the chemical, physical and biological properties of the soil may extend over a long period. (Atkinson *et al.*, 2010). Most of the available studies focused on the

biochemical effects of biochar as amendment to soil, availability, as well as on its impact on CEC, pH, crop growth and crop yield. (Mukherjee and Lal, 2013). Groundnut crop grows well in the soils with good soil physical properties and nutrition. Biochar offers a potential source of improving soil physical, physico-chemical properties of soil thus ensure proper plant nutrition. Information in this regard is very limited, therefore, a study was undertaken to know the effect of biochar on macronutrient content and uptake and the results obtained during the investigation are discussed.

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MATERIAL AND METHODS

The study was carried out during *Rabi* 2018-19. The experimental plot was geographically situated at an altitude of 12 m above MSL, 83° 56.602' E longitude and 18° 22.752' N latitude in the Agricultural College farm, Naira. A composite soil sample was collected from the experimental site at the beginning of the experiment and analysed for its physical and chemical properties. The soil was sandy loam in texture with pH 6.13, EC 0.27 dS m⁻¹ at 25 °C, organic carbon 0.36 %, CEC 14.62 cmol (p⁺) kg⁻¹. Soil available nitrogen, available P₂O₅ and available K₂O 130.50 kg ha⁻¹, 15.67 kg ha⁻¹ and 195.4 kg ha⁻¹, respectively. The exchangeable Calcium was 6.10 cmol (p⁺) kg⁻¹, Magnesium 1.72 cmol (p⁺) kg⁻¹ and available Sulphur was 17.20 (mg kg⁻¹). Biochar was prepared by pyrolysis process with dried Mesta sticks with 29.4 per cent recovery. The biochar was alkaline in reaction (pH 8.38), slightly saline (EC 2.39) with organic carbon content of 35.04% and CEC 54.26 cmol (p⁺) kg⁻¹ soil. Eight treatments were laid in a completely Randomized Block Design (RBD) and replicated thrice using groundnut (*Arachis hypogaea* L.) as test crop (variety K-6). T₁ - Control; T₂ - 100% RDF (30-40-50) only; T₃ - 100% RDF + biochar @ 2t ha⁻¹; T₄ - 100% RDF + biochar @ 4t ha⁻¹; T₅ - 100% RDF + biochar @ 6t ha⁻¹; T₆ - 75% RDF + biochar @ 2t ha⁻¹; T₇ - 75% RDF + biochar @ 4t ha⁻¹ and T₈ - 75% RDF + biochar @ 6t ha⁻¹.

Groundnut seeds were sown with a spacing of 30 cm between the rows and 15 cm between the plants. The crop was raised duly following the recommended package of practices published by Acharya N. G. Ranga Agricultural University in Farmers' Almanac (ANGRAU, 2019). The samples of haulm and kernels were dried at 60 °C, powdered

and preserved for analysis (Jackson, 1973). Total nitrogen, phosphorous, potassium, calcium, magnesium and sulphur of plant samples was determined by adopting standard method. The nitrogen content in groundnut plants was estimated by micro Kjeldahl method (Piper, 1966). Phosphorus in the diacid extract of plant samples was estimated by vanado molybdate phosphoric yellow colour method using spectrophotometer at 420 nm wavelength as described by Jackson (1973). Potassium in the diacid extract of plant samples was determined using flame photometer as per the method described by Jackson (1973). The Turbidimetric procedure was used for estimation of sulphur in the diacid extract with the help of spectrophotometer at wave length of 440 nm (Vogel, 1979). Calcium and magnesium contents in diacid digestion were estimated by Versenate method as described by Jackson (1973).

RESULTS AND DISCUSSION

Nutrient Content

Nitrogen Content: The N content varied from 2.25% (T₁) to 2.86% (T₈) in pods and 1.06% (T₁) to 1.24 % (T₅) in haulms (Table 1) and there was a significant difference between control and combined application of fertilizers and biochar applied treatments. Application of recommended fertilizer nitrogen along with biochar resulted in higher nitrogen content in 100% RDF applied with biochar (T₂, T₃, T₄, T₅) than 75% RDF applied treatments (T₆, T₇, T₈) and control. Increased nitrogen concentration in both grain and straw of legume with biochar addition was also reported by Budania *et al.* (2014). Biochar enhances biological nitrogen fixation in legume plants by stimulating signalling for nodulation with adsorption

of flavonoids and nod factors (Thies *et al.*, 2009) which leads to an increase in nitrogen content and its availability to shoots.

Phosphorus Content: Significant difference was noticed in phosphorus content when plants supplied with biochar + RDF (T_3 , T_4 & T_5) and RDF alone (T_2) compared to control (T_1). The highest phosphorus contents (0.24% and 0.37%, in groundnut haulm and pod respectively) were recorded in the T_5 treatment where 100% RDF + biochar @ 6 t ha⁻¹ were applied. T_5 was on par with T_4 (100% RDF + biochar @ 4 t ha⁻¹), T_3 (100% RDF + biochar @ 2 t ha⁻¹), T_8 (75% RDF + biochar @ 6 t ha⁻¹) and T_7 (75% RDF + biochar @ 4 t ha⁻¹). RDF alone (T_2) and RDF + biochar application (T_5 , T_4 & T_3) were found with significantly higher P content than control. The phosphorus was accumulated more in pod than in haulm. Biochar application lead to increase in the availability of phosphorus by reducing sorption and forming organo-phosphorous complexes which in turn increases its absorption by crop plants (Agegnehu *et al.*, 2015). Significant increase in plant phosphorus content with the application of biochar was also reported by Nguyen *et al.* (2012).

Potassium Content: The data in Table 1 represents significant difference in potassium contents between the treatments with the application of biochar + fertilizers addition (T_5 , T_4 , T_3 , T_8 , T_7 and T_6) compared to control. The potassium content in haulm (1.43%) and pod (1.11%) were highest in T_5 (RDF + biochar @ 4 t ha⁻¹) which was on par with 100% RDF alone (T_2), 100% RDF + biochar applied treatments (T_2 , T_3 , T_4) and 75% RDF + biochar applied treatments (T_8 , & T_7). Addition of 100% RDF alone (T_2), 100% RDF + biochar (T_3 , T_4 , T_5) and 75% RDF +

biochar (T_8 and T_7) significantly increased K content in groundnut pods compared to control (T_1) except in 75% RDF + biochar @ 2t ha⁻¹ (T_6) treatment which does not differ significantly. Relatively high potassium contents were observed in haulm than in pod. Addition of biochar leads to a significant increase in the concentration of potassium in the plant tissues due to the higher ash content of the biochar (Yusof *et al.*, 2015). Evangelou *et al.* (2014) also recorded that the application of biochar significantly increases potassium content in plant shoots.

Calcium content: calcium content of groundnut pod was relatively higher than haulms. Addition of biochar with RDF significantly increased the Ca content of both haulm and pod. Further, a non-significant increase in the Ca content of both haulm and kernels was observed when biochar was applied @ 2 t ha⁻¹ and 4 t ha⁻¹. Highest Ca content in haulm (0.70 %) and pod (0.81 %) was recorded in the T_5 treatment, which received 100% RDF + biochar @ 6 t ha⁻¹, however, the significant increase in Ca content of pod was found when biochar addition increased from 2 t ha⁻¹ to 6 t ha⁻¹. Similar trend was found in case of haulms also. Biochar is rich source of calcium, upon its application to soil increases Ca availability to plants and thus increases its uptake.

Magnesium content: Magnesium (Mg) contents of both haulm and pods were not influenced by the imposed treatments (Table 1). However, a slight increase in Mg content was observed with increased rates of biochar addition form 2 t ha⁻¹ to 6 t ha⁻¹. The results were in tune with those of Lehmann *et al.* (2003) who reported that Ca and Mg leaching was delayed due to charcoal addition and Mg content was not higher when charcoal was added to the soil.

Sulphur Content: In general, the sulphur content was higher in pods than in haulms. Highest plant sulphur content (0.36% in pod and 0.21% in haulm) was recorded in the T₅ treatment (100% RDF + biochar @ 6 t ha⁻¹), lowest corresponding values (0.31% and 0.17%) were noticed in T₁ (control). The Sulphur content of plants did not differ significantly with the addition of biochar but slight increase could be noticed. Similar contents of S both in pods and haulms was due to the application of gypsum to all the treatments equally at flowering as part of common management practice. The results were in tune with those of Lehmann *et al.* (2003).

Yield and nutrient uptake

Significantly higher pod and haulm yield was recorded in T₅ (100% RDF+ biochar@6 t ha⁻¹) over T₂ but on par with T₄ and T₃ (Table 2). Total uptake of N, P and K by groundnut (Table 2) has significantly increased with the addition of 100 % RDF alone (T₂) and in the combination of biochar (T₃, T₄, T₅) compared to control. Increased application of biochar from 4 t ha⁻¹ to 6 t ha⁻¹ significantly increased N uptake, over all other treatments. However, application of 100% RDF + biochar @ 2 t ha⁻¹ (T₃) did not significantly influence NPK uptake compared to T₂ (100% RDF alone). This may be attributed to an increased availability of N in the soil which increased the haulm and kernel yield and, thus, their corresponding uptake. Highest N, P₂O₅ and K₂O uptake of 178.6 kg ha⁻¹, 27.2 kg ha⁻¹, 122.4 kg ha⁻¹ was noticed in T₅ treatment (100% RDF + biochar @ 6 t ha⁻¹), which was on par with T₄ (100% RDF + biochar @ 4 t ha⁻¹) and significantly superior to T₂, T₃, T₆, T₇, T₈ and T₁ (Control). Further, T₂ (100% RDF alone) and T₇ (75% RDF + biochar from 4 t ha⁻¹) were on par with each

other in N, P₂O₅ and K₂O uptake. Lowest N, P₂O₅ and K₂O uptake was noticed in T₁ (control). Reduction of nutrient losses from soil due to biochar application might be due to their improved availability in soil and subsequent uptake by the groundnut crop (Agegnehu *et al.*, 2015; Laxman Rao *et al.*, 2017). When biochar was added to the soil, it's surface oxidation by biotic and abiotic agents results in the development of negative charges that give the ability to biochar to sorb more cations like potassium which leads to increased uptake of nutrients (Danish *et al.*, 2014).

The uptake of secondary nutrients was also significantly influenced by the addition of biochar. Highest uptake of Ca, Mg and S (67.7 kg ha⁻¹, 42.4 kg ha⁻¹, 25.3 kg ha⁻¹, respectively) was noticed in T₅ treatment (100% RDF + biochar @ 6 t ha⁻¹). Among secondary nutrients, Ca uptake was on a par in T₅, T₄ and T₈, however, T₅ is significantly superior to T₂, T₃, T₆, T₇ and T₁. In case of the uptake of Mg and S, T₅ was on par with T₄, but T₅ is significantly superior to T₂, T₃, T₆, T₇, T₈ and T₁. Similarly, increased uptake of Ca, Mg by addition of biochar to soil was also reported by Danish *et al.* (2014). Enhanced nutrient availability to crop plants by addition of biochar to soil resulted in enhanced dry matter production which in turn resulted in higher uptake of sulphur (Chan *et al.*, 2007)

CONCLUSION

Biochar application in combination with the recommended dose of fertilizers (100% RDF or 75% RDF) to red sandy loam soil significantly increased pod yield and haulm yield of groundnut and N, P₂O₅, K₂O of groundnut haulm and pods. Calcium (Ca) content was significantly influenced by biochar application, however, Mg and S contents did not differ significantly.

Table 1. Effect of biochar on Nitrogen (N), Phosphorous (P) and Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S) content in haulm and pods of groundnut.

Treatments	Nitrogen(%)		Phosphorous(%)		Potassium (%)		Calcium (%)		Magnesium (5)		Sulphur (%)	
	Haulm	Pod	Haulm	Pod	Haulm	Pod	Haulm	Pod	Haulm	Pod	Haulm	Pod
T ₁	1.06	2.25	0.12	0.29	1.21	1.02	0.62	0.71	0.31	0.52	0.17	0.31
T ₂	1.15	2.61	0.18	0.33	1.34	1.16	0.63	0.71	0.32	0.52	0.17	0.33
T ₃	1.18	2.72	0.19	0.35	1.37	1.19	0.65	0.76	0.34	0.54	0.18	0.35
T ₄	1.22	2.76	0.21	0.36	1.41	1.20	0.67	0.77	0.36	0.55	0.20	0.36
T ₅	1.24	2.86	0.24	0.37	1.43	1.22	0.70	0.81	0.36	0.57	0.21	0.36
T ₆	1.09	2.47	0.14	0.33	1.29	1.08	0.66	0.76	0.34	0.54	0.17	0.31
T ₇	1.11	2.55	0.15	0.34	1.31	1.14	0.67	0.77	0.35	0.55	0.19	0.32
T ₈	1.15	2.64	0.17	0.36	1.33	1.18	0.69	0.80	0.35	0.56	0.19	0.33
SEm±	0.05	0.10	0.009	0.01	0.04	0.03	0.011	0.013	0.02	0.03	0.01	0.02
CD @ 5%	0.15	0.31	0.02	0.03	0.12	0.08	0.03	0.04	NS	NS	NS	NS

Table 2. Total uptake of primary and secondary nutrients by groundnut as influenced by biochar application

Treatments	Pod yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Total nutrient uptake (kg ha ⁻¹)					
			Nitrogen	Phosphorous	Potassium'	Calcium	Magnesium	Sulphur
T ₁	2876.7	3646.0	103.37	12.72	73.46	43.03	25.97	15.12
T ₂	3436.8	4565.6	143.24	19.56	101.05	53.51	32.48	19.10
T ₃	3538.6	4829.1	153.23	21.56	108.27	58.28	35.53	21.08
T ₄	3886.8	4943.8	167.59	24.37	116.35	63.05	39.17	23.88
T ₅	4019.6	5131.9	178.60	27.19	122.43	67.68	42.41	25.25
T ₆	3392.9	4357.7	131.30	17.30	92.86	54.55	33.14	16.62
T ₇	3613.0	4409.0	141.07	18.90	98.95	57.36	36.18	18.18
T ₈	3782.5	4775.1	154.77	21.73	108.14	63.21	39.81	20.12
SEm±	157.0	219.5	7.43	1.19	3.74	1.86	1.54	1.17
CD @ 5%	476.3	665.7	22.63	3.57	11.15	5.53	4.62	3.52

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COMBINING ABILITY AND GENE ACTION FOR QUALITY CHARACTERS IN RICE (*Oryza sativa* L.)

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ABSTRACT

A line X tester analysis was studied in rice with seven lines and four tester parents to identify suitable general and specific combiner for breeding programme. The variances due to SCA were of greater magnitude than GCA for all the traits indicating the preponderance of non-additive gene action for these characters. Among the lines STBN 25, STBN 26 and RNR 15048 and testers ADT 43 and IR 64 were considered as the best general combiners for grain yield per plant, while hybrids RNR 15048/ADT 43, MTU 1010 / IR 64, STBN 25 / IR 64, STBN 14 / ADT 37 and STBN 26 / ADT 43 as good specific combiners for grain yield per plant. The crosses RNR 15048 / ADT 43 and MTU 1010 / IR 64 exhibited good SCA effects for grain yield per plant and quality traits, so these hybrids may be exploited for better yield and quality either by exploiting them through heterosis breeding or multiple cross-breeding programme for obtaining transgressive segregants and broad genetic base population for improvement in quality rice.

INTRODUCTION

Rice is the most important staple crop of India. It contributes to total food grain and cereal production of the country to nearly 43% and 46%, respectively (Bhati *et al.*, 2014). However, the productivity of rice is stagnant over years. The present world rice area, production and productivity is 161.6 m ha, 480.7 mt and 2.97 t ha⁻¹, respectively. In India, it is being grown in 44.0 mha area with production of 106.0 mt and productivity of 2.41 t ha⁻¹ contributing 25% to agricultural GDP (USDA, 2014).

The success of any breeding programme depends on the choice of right parents for hybridization programme. Combining ability studies reveal the nature of gene action and lead to identification of parents with high general combining ability effects and the cross combinations with high specific

combining ability effects. This in turn helps in choosing the parents to be included in a hybridization or population breeding programme. Among the different biometrical methods employed to study combining ability, the one proposed by Kempthorne (1957) known as the line X tester analysis was followed in this analysis.

MATERIAL AND METHODS

Seven lines STBN 14, STBN 15, STBN 25, STBN 26, STBN 27, MTU 1010 and RNR 15048 and four testers ADT 37, ADT 43, CO 41 and IR 64 were crossed in line X tester model at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University during Navarai, 2017. The twenty- eight hybrids along with their parents were sown in a randomized block design replicated thrice by adopting 20 cm X 15 cm spacing

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during Samba 2017. Each parents and hybrid was accommodated in a single row of 3 m length. Data was recorded on five randomly selected plants for grain length, grain breadth, grain L/B ratio, kernel length, kernel breadth, kernel L/B ratio and grain yield per plant. The data were analysed for combining ability and their variances were calculated according to the model suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences among the hybrids, lines and L X T interaction effects for all the seven traits *viz.*, grain length, grain breadth, grain L/B ratio, kernel length, kernel breadth, kernel L/B ratio and grain yield per plant. Significant differences among the testers were observed for all the characters except grain L/B ratio and kernel L/B ratio (Table 1). Similar results was observed by Roy *et al.* (2009), Tiwari *et al.* (2011) Satheesh Kumar and Saravanan (2011), Satheesh Kumar *et al.* (2016), Rukmini Devi *et al.* (2017) and Goswami (2018). The variances due to SCA were of greater magnitude than GCA, for all the characters indicating the preponderance of non-additive gene action for all the characters. Similar results were also reported by Ghosh *et al.* (2013), Satheesh Kumar *et al.* (2016) and Rukmini Devi *et al.* (2017). The proportional contribution to the total variance by lines and testers revealed that the lines and line X tester have contributed more than testers in respect of all characters (Table 2).

General combining ability effects

There was close association between the GCA

effects and mean performance of the parents (Table 3). Similar finding was reported by Satheesh Kumar *et al.* (2016) in rice. The GCA effects revealed that, among the female parents, STBN 25, STBN 26 and RNR 15048 was the best general combiner for grain yield plant⁻¹. RNR 15048 was the significant general combiner for grain L/B ratio and kernel length.

Among the testers, ADT 43 and IR 64 were very good general combiners for grain yield plant⁻¹. IR 64 was a good general combiners for kernel length and kernel L/B ratio.

Specific combining ability effects

The specific combining effects were high for grain yield plant⁻¹ in RNR 15048 / ADT 43, MTU1010 / IR 64, STBN 25 / IR 64, STBN 14 / ADT 37, STBN 26 / ADT 43 and STBN 27 / CO 41 (Table 4). These results are in conformity with the earlier findings of Sanghera and Hussain (2012), Vikas Sahu (2013), Adilakshmi and Upendra (2014), Waza *et al.* (2015), Satheesh Kumar *et al.* (2016), Devi *et al.* (2017), Saren *et al.* (2018), Parimala *et al.* (2018) and Vanave *et al.* (2018).

The crosses RNR 15048 / ADT 43 and MTU 1010 / IR 64 were the very good specific combiners for grain length, grain L/B ratio, kernel length and kernel L/B ratio. The maximum significant SCA effects for grain length was observed in STBN 14 / ADT 43; grain L/B ratio in STBN27 / ADT 37; kernel length and kernel L/B ration in STBN 25 / ADT 37. Similar results were reported by Satheesh Kumar *et al.* (2016), Devi *et al.* (2017) and Saren *et al.* (2018).

Table 1. Analysis of variance for combining ability for seven characters in rice

Source of Variation	df	Grain length	Grain breadth	Grain L/B ratio	Kernel length	Kernel breadth	Kernel L/B ratio	Grain yield plant ⁻¹
Replication	2	0.1739	0.0144	0.0821	0.0236	0.0127	0.1366	6.6521
Hybrid	27	0.9778**	0.0733**	0.1353**	1.1605**	0.0159**	0.2176**	72.3542**
Line	6	1.4832**	0.1455**	0.1539**	3.0346**	0.0270**	0.3300**	80.7432**
Tester	3	1.7120**	0.0749**	0.0685	1.0266**	0.0159*	0.1038	83.4951**
L X T	18	0.6870**	0.0490**	0.1403**	0.5531**	0.0122**	0.1992**	67.7010**
Error	76	0.1449	0.0071	0.0310	0.0596	0.0053	0.0484	5.4573
Estimation of variance								
GCA		0.0065	0.0005	0.0001	0.0135	0.0001	0.0004	2.1034
SCA		0.2050	0.0139	0.0388	0.1628	0.0024	0.0508	20.8391
GCA / SCA		0.0317	0.0359	0.0025	0.0829	0.0416	0.0078	0.1009

*Significant at 5% level ; **Significant at 1% level ; df : degrees of freedom

Table 2. Contribution of lines, testers and their interaction

Contribution	Grain length	Grain breadth	Grain L/B ratio	Kernel length	Kernel breadth	Kernel L/B ratio	Grain yield plant ⁻¹
Lines (%)	33.71	44.09	25.27	58.11	37.65	33.69	24.80
Testers (%)	19.45	11.35	5.62	10.11	11.08	5.30	12.82
Interaction (L X T) (%)	46.84	44.56	69.11	31.78	51.27	61.01	62.38

Table 3. Mean and general combining ability effects of parents for seven characters in rice

Parents		Grain length	Grain breadth	Grain L/B ratio	Kernel length	Kernel breadth	Kernel L/B ratio	Grain yield plant ⁻¹
STBN 14	Mean	9.83**	2.98	3.29	7.29**	2.23**	3.26**	26.20
	gca	0.04	0.04	-0.04	-0.73**	0.01	0.01	-0.29
STBN 15	Mean	9.87**	2.92	3.38	6.59	2.32	2.84	28.40
	gca	-0.57**	-0.19**	0.03	-0.58**	-0.06**	-0.09	-0.36
STBN 25	Mean	9.88**	2.89	3.44*	6.85	2.40	2.85	28.33
	gca	-0.22**	-0.05*	-0.02	-0.04	0.03	-0.16**	1.45**
STBN 26	Mean	9.03	2.55**	3.59**	6.37	2.19**	2.90	32.90**
	gca	-0.22**	0.12**	-0.21**	0.05	0.08**	-0.23**	1.38*
STBN 27	Mean	9.97**	3.01	3.31	7.22**	2.45	2.94	30.28
	gca	0.38**	0.10**	0.01	0.23**	-0.01	0.16*	-5.17**
MTU 1010	Mean	9.08	3.05	2.97	5.99	2.26**	2.65	34.43**
	gca	0.35**	0.06*	0.04	0.45**	-0.01	0.19**	-0.07
RNR 15048	Mean	9.16	3.10	2.95	5.82	2.25**	2.58	28.63
	gca	0.24**	-0.07**	0.17**	0.63**	-0.04**	0.13	3.07**
SE		0.08	0.02	0.44	0.07	0.02	0.06	0.66
Testers								
ADT 37	Mean	9.86**	2.78**	3.54	6.52	2.29*	2.84	23.30
	gca	0.09	0.06**	-0.04	0.15**	0.03*	-0.02	-0.19
ADT 43	Mean	9.93**	3.03	3.27	7.12*	2.48	2.87	26.38
	gca	-0.33	-0.05**	-0.05	-0.23**	-0.03	-0.05	1.55**
CO 41	Mean	10.02**	2.43**	4.12**	7.23	2.32*	2.48	32.62*
	gca	0.34	0.04*	0.07*	0.23**	-0.02	0.10*	-2.75**
IR 64	Mean	10.07**	2.96	3.40	7.05*	2.30**	3.06*	33.03**
	gca	-0.10	-0.05**	0.03	0.15**	0.01	0.04**	1.39**
SE		0.06	0.02	0.03	0.06	0.01	0.12	0.50

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

Table 4. Mean and specific combining ability effects of hybrids for seven characters in rice

Hybrids		Grain length	Grain breadth	Grain L/B ratio	Kernel length	Kernel breadth	Kernel L/B ratio	Grain yield plant ⁻¹
STBN 14 / ADT 37	Mean	9.92**	2.91	3.40	5.50	2.41	2.28	33.78**
	sca	-0.99**	-0.02	-0.31**	-0.31*	0.05**	-0.48**	5.76**
STBN 15 / ADT 37	Mean	9.94**	2.88	3.45	5.76	2.40	2.40	26.54
	sca	-0.58**	0.17**	-0.41**	-0.20	0.03	-0.22	-1.41
STBN 25 / ADT 37	Mean	9.86	2.91	3.38	7.17**	2.27**	3.15**	27.04
	sca	0.57**	0.07	0.11	0.66**	-0.11**	0.46**	-2.72*
STBN 26 / ADT 37	Mean	9.56	2.91	3.28	6.09	2.47	2.46	31.63
	sca	0.27	-0.10*	0.20*	-0.50**	0.04*	-0.01	1.95
STBN 27 / ADT 37	Mean	9.94**	2.97	3.34	7.36**	2.36**	3.11**	22.10
	sca	0.06	-0.03	0.40**	0.59**	0.01	0.01	-1.04
MTU 1010 / ADT 37	Mean	10.02**	2.97	3.73**	6.59	2.32**	2.84*	25.74
	sca	0.16	0.01	0.34**	-0.40**	-0.03	0.46**	-2.50
RNR 15048 / ADT 37	Mean	10.27**	2.72**	3.77**	7.33**	2.31**	3.17**	31.33
	sca	0.52**	-0.10*	0.32**	0.16	0.01	0.19	-0.04
STBN 14 / ADT 43	Mean	9.72	2.87	3.38	5.84	2.35**	2.48	22.99
	sca	0.59**	0.05	0.13	0.41**	0.05**	0.12	-6.77**
STBN 15 / ADT 43	Mean	8.52	2.44**	3.49	5.56	2.39	2.32	31.64
	sca	-0.07	-0.16**	0.19*	-0.02	-0.01	0.01	1.95
STBN 25 / ADT 43	Mean	9.73	2.44**	3.98**	5.71	2.36**	2.41	26.47
	sca	-0.54**	-0.29**	0.17	-0.42**	0.04**	-0.33**	-5.02**
STBN 26 / ADT 43	Mean	9.88*	3.11	3.17	6.16	2.36**	2.61	35.87**
	sca	-0.28	0.21**	-0.32**	-0.05	-0.03	0.02	4.44**
STBN 27 / ADT 43	Mean	9.63	2.92	3.29	6.26	2.30**	2.72	25.33
	sca	0.17	0.04	0.01	-0.13	0.01	0.02	0.46
MTU 1010 / ADT 43	Mean	9.57	2.85	3.35	6.80*	2.21**	3.07**	26.81
	sca	0.13	0.04	0.04	0.19	-0.07	0.10	-3.17*
RNR 15048 / ADT 43	Mean	9.27	2.86	3.24	6.81*	2.25**	3.02**	41.22**
	sca	0.06**	0.15**	0.22**	0.02**	0.02	0.06**	8.11**
STBN 14 / CO 41	Mean	9.74	2.88	3.38	5.47	2.22**	2.46	24.28
	sca	-0.06	-0.03	0.02*	-0.42**	-0.09*	0.16	1.17
STBN 15 / CO 41	Mean	9.77	2.77**	3.52	5.76	2.14**	2.69	25.22
	sca	0.58*	0.08	0.10	-0.28	-0.10*	0.40	-0.17

Contd...41

Contd...from 40

Hybrids		Grain length	Grain breadth	Grain L/B ratio	Kernel length	Kernel breadth	Kernel L/B ratio	Grain yield plant ⁻¹
STBN 25 / CO 41	Mean	9.88*	2.90	3.40	6.96**	2.37	2.93**	30.01
	sca	0.34*	0.08	0.02	0.38*	0.04**	-0.10	1.81
STBN 26 / CO 41	Mean	9.89*	2.90	3.41	7.00**	2.38	2.94**	27.33
	sca	-0.35*	-0.09	-0.03	0.34*	0.00	-0.26*	0.21
STBN 27 / CO 41	Mean	9.92**	2.95	3.36	6.74	2.37	2.84*	23.33
	sca	0.22	-0.02	-0.05	-0.10	0.07**	-0.18	2.76*
MTU 1010 / CO 41	Mean	9.88*	2.91	3.39	7.35**	2.34**	3.14**	24.75
	sca	-0.23	-0.02	-0.05	0.30*	0.05**	0.03	-0.92
RNR 15048 / CO 41	Mean	9.95**	2.80*	3.55*	7.03**	2.37	2.96**	26.30
	sca	-0.06	-0.02	-0.02	-0.21	0.04**	-0.06	-2.51
STBN 14 / IR 64	Mean	9.82	2.82	3.48	5.82	2.32**	2.50	34.06**
	sca	0.46**	0.04	0.16	0.32*	-0.02	0.19	2.18
STBN 15 / IR 64	Mean	9.95**	2.49**	3.99**	6.16	2.33**	2.64	29.17
	sca	0.01	-0.10*	0.12	0.50**	0.07**	-0.18	-0.36
STBN 25 / IR 64	Mean	9.86	2.88	3.42	5.58	2.37	2.35	37.27**
	sca	-0.37*	0.15**	-0.30**	-0.62**	0.02	-0.03	5.93**
STBN 26 / IR 64	Mean	9.48	2.87	3.30	6.49	2.40	2.70	24.27
	sca	0.37*	-0.02	0.15	0.21	0.01	0.24	-6.60**
STBN 27 / IR 64	Mean	9.70	2.89	3.35	6.11	2.23**	2.73	25.53
	sca	-0.09	0.01	-0.01	-0.35*	-0.09*	0.15	-2.18
MTU 1010 / IR 64	Mean	9.61	2.86	3.36	6.59	2.37	2.78	36.40**
	sca	0.06**	0.01	0.03**	0.09**	0.06	0.26**	6.59**
RNR 15048 / IR 64	Mean	9.86	2.66**	3.70**	6.89*	2.25**	3.06**	27.40
	sca	-0.40*	-0.05	-0.08	0.03	-0.03	-0.21	-5.55**
SE		0.15	0.05	0.09	0.15	0.04	0.13	1.31

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

CONCLUSION

The estimates of variances of GCA and SCA revealed that the nature of gene action was predominantly non-additive and in specific combinations exhibited additive type of gene action

for different characters. The crosses RNR 15048 / ADT 43 and MTU 1010 / IR 64 with good *per se* performance and significant SCA effect for yield and four yield components were also found superior for grain length, grain L/B ratio, kernel length, kernel L/B

ratio and grain yield plant¹, may be exploited for better yield and quality either by exploiting them through heterosis breeding or multiple cross breeding programme for obtaining transgressive segregants and broad genetic base population for improvement in quality rice.

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MODIFICATION AND EVALUATION OF SEEDLING PICKING AND RELEASING MECHANISM OF ANNAPURNA RICE TRANSPLANTER

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ABSTRACT

The Laboratory model seedling picking and releasing mechanism has been developed by modifying the mechanism of "Annapurna Rice Transplanter" during 2012-13. Opening of finger is controlled by gap provided between two T-shaped cam plates. Finger assembly has two arms, shorter arm is attached to the fixed L-angle bar and longer arm was hinged to the fixed shaft. Both arms are connected by a spring. Spring is used to close the finger after picking the seedling from the seedling tray. Two channels mounted on the frame are also provided for the smooth movement of finger assembly. One channel has straight path through which finger assembly can be raised or lowered for holding the cluster of seedlings and another is curved path through which finger assembly can be lowered for releasing of seedling. Two roller sets were used to guide the movement of cam during the picking and planting operations. The Laboratory model manual rice transplanter was tested for its picking and releasing operation of seedlings in the laboratory conditions. Opening width of fingers increased linearly with the depth of handle from its reference level allowing smooth operation of opening and closing of fingers while picking and releasing of a cluster of seedlings.

INTRODUCTION

Rice is an important food crop in India. It is sown by broadcasting of pre-germinated seeds in puddled soil and also by transplanting of young seedlings. Other methods such as drilling though tried extensively could not found wide acceptance. Manual transplanting a labour intensive process requires about 250-300 man-h/ha which roughly accounts for 25% of the total labour requirement of the crop (Singh *et al.*, 1985). Mechanical transplanting is an alternative to manual transplanting, in terms of timeliness of operation, reduction of drudgery and low cost of operation. The annual rice transplanters market in India has grown from about 550 in 2008-09 to 1600 units in 2013-14 (Kumar and Naik, 2016). Many models of self-propelled rice transplanters and few models of manually operated rice transplanters are available in India. Indian farmers use root wash type seedlings for transplanting. Adoption of mechanical

transplanting technique leaving the traditional method requires high initial investment cost, precision leveling of the land and expenditures on plastic sheets and mat frame. Transplanter suitable for the cropping practices prevalent in India needs to be developed in order to overcome constraints in the mechanization of rice cultivation.

In an effort, manually operated rice transplanter for root wash type seedlings was developed by Kavitar (2016) and Nirala (2016). However, there is a problem during operation as well as gap filling of missing hills. Commercially available Chinese hand crank rice transplanter was tested by various researchers and reported number of problems associated with the machine (Mehta, 2017). No mechanism has been successful for continuous planting of conventional root-washed seedlings.

Annapurna model manually operated 10 row rice

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transplanter was developed (Mahapatra, 1973) at Orissa for root wash seedlings during the years 1973 (Swain and Maity, 1981). There was problem in the picking and releasing mechanism as well as in the movement of the transplanting arm through the channels for the Annapurna Transplanter (Biswas, 2012). It is very difficult to do both the works at a time. It involves high drudgery, more human stress and high labour requirement. All these limitations of the transplanting system can be overcome by the use of a suitable mechanical transplanter. This will minimize the workers and ensure speedier operation resulting in higher coverage per worker. Considering the above constraints in view, an experiment was undertaken to modify the picking and releasing mechanism and develop a laboratory model rice transplanter suitable for Indian farming conditions.

MATERIAL AND METHODS

Development of Laboratory Model Rice Transplanter

The laboratory model rice transplanter was tested during 2012-13. Finger was made up of hard mild steel. Opening of finger is controlled by gap provided between two T-shaped mild steel plates. Finger assembly has two arms. Shorter arm is attached to the fixed L-angle bar and longer arm was hinged to the fixed shaft. Both the arms are connected by a spring. Spring is used to close the finger after picking the seedling from the seedling tray. Dimension of finger is shown in Fig. 1.

Channels were provided for the smooth movement of finger assembly and mounted on the frame having two types of paths. One was straight path through which finger assembly can be lifted or lowered for holding the cluster of seedlings and

another was curved path through which finger assembly can be lowered for releasing of seedling (Fig. 2). Channels were made up of two T-shaped flats and width of channels was kept as 15 mm.

The required movement of the moveable rod of the finger assembly was 10 mm. There were two T-plates, each of them were welded to flat plate. One flat plate among the two has an oblique edge (Fig. 3), which act as cam and another one has straight edge (Fig. 4), which help in supporting the roller contacts. Cam was used to open finger during picking the seedling from the tray and transplanting it into the soil. In order to provide desired opening of fingers, cam angle of 15° was kept. T-plate is attached to fix L-angle bar with the help of nuts and bolts. The plate with cam was attached to movable shaft by nuts and bolts and follows the path traced by handle. Dimension of T-plates is shown in Fig. 4 and Fig. 5.

Two roller sets were used to guide the movement of cam during the picking and planting operation. Each roller set has two rollers (Fig. 6). One roller set was used during picking of the seedling from the tray and another roller set was used during insertion of the seedling into the puddled soil. Two U-clamps were used to hold the roller sets in their positions. One U-clamp is hinged about the other so that it can lift the whole roller assembly while lifting operation of finger assembly. Dimension of rollers are shown in Fig. 7 and Fig. 8. The two roller sets and T-shaped cams eliminated the need for handle operation for finger actuation.

The handle was connected to finger assembly through a connecting rod made of hollow shaft of 550 mm length and 30 mm diameter. Frame was made of L-angle bar of 3 mm x 25 mm. Two channels were

mounted on the channel for proper movement of finger assembly. Displacement of moving bar was 10 mm and opening width of the finger was 24 mm. Cam

had trapezoidal shape with opposite side widths of 45 mm and 35 mm and length 80 mm.

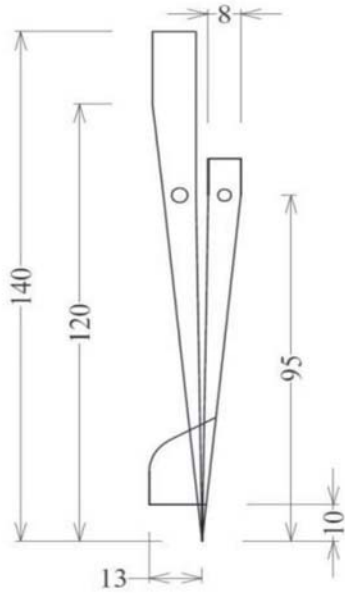


Fig. 1. Finger setup

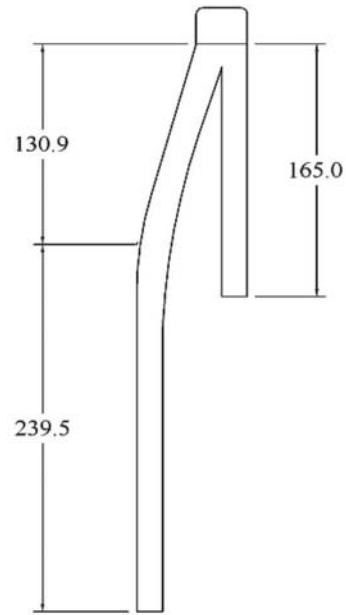


Fig.2. Channel

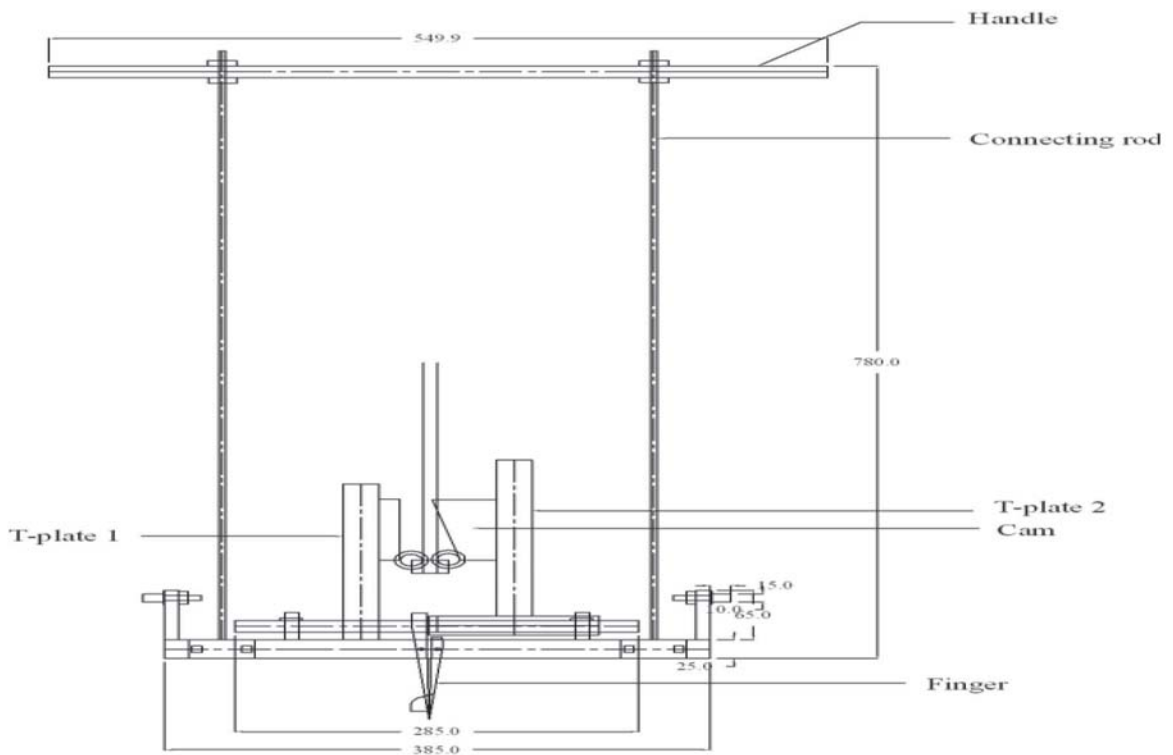


Fig. 3. Laboratory model ricetransplanter

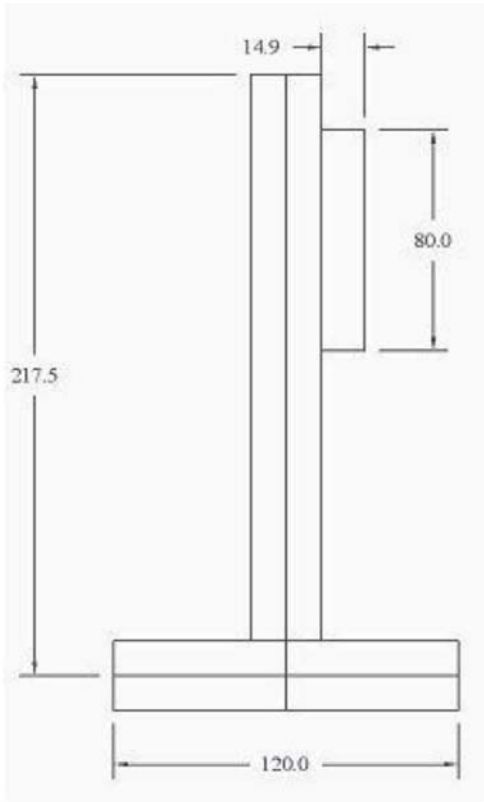


Fig.4. T-plate

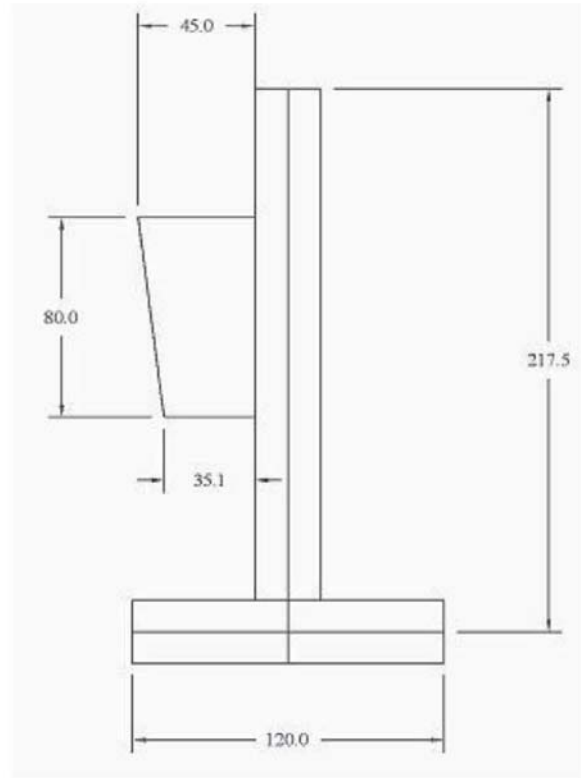


Fig.5.T-plate with a cam attachment

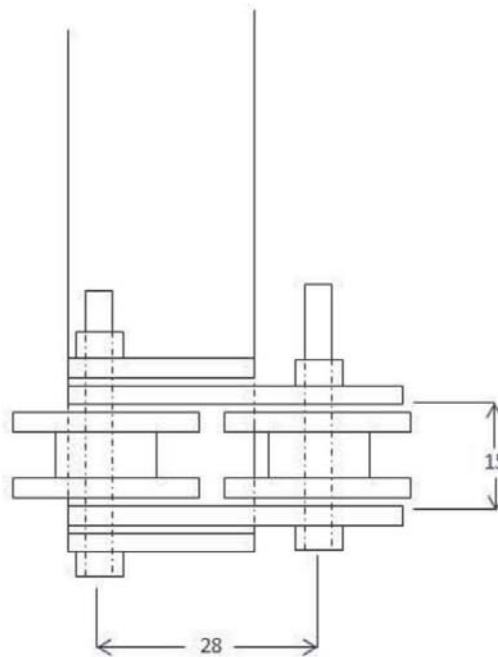


Fig. 6. The roller setup assembly

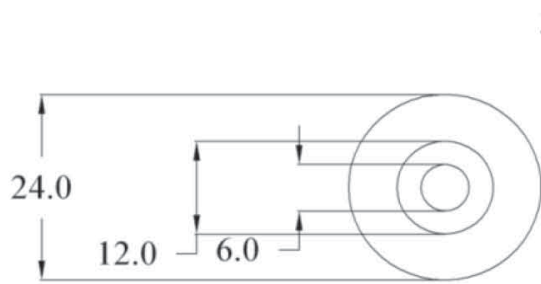


Fig.7. Front view of roller

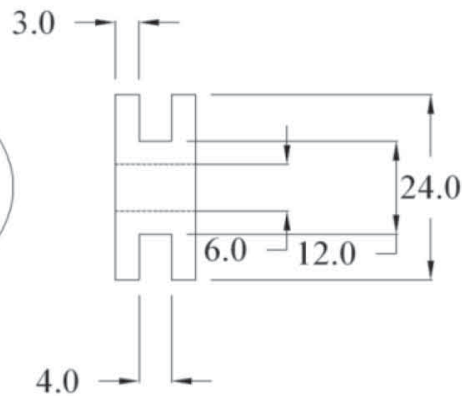


Fig.8. Side view of roller

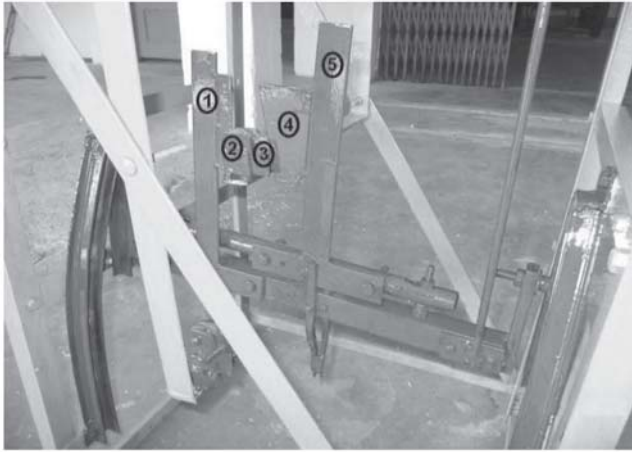
Design of cam and roller

Two identical roller assemblies comprising of two rollers each were attached to the frame. Roller 1 was mounted on the U clam and Roller 2 was in mesh with Roller 1. In the first assembly, U clam was mounted on the frame and hinged about the center of the Roller 1. In second assembly, Roller 2 was attached to L bar, which was hinged about its extreme fiber to the frame. Two T-plates is designed, in which a flat plate of 8 cm was attached to the T-plate 1, where as, a cam of 15° cam profile and 8 cm length was attached to T-plate 2 to facilitate the full opening of finger. The flat plate of T-plate 1 and Cam of T-plate 2 were in mess with the Roller 1 and Roller 2, respectively while in operation. T-plate 1 was mounted on the Fixed bar, whereas, T-plate 2 was mounted on the moving bar (Fig. 9). Fulcrum of the finger is attached to the Fixed bar whereas effort arm of finger was attached to the T-plate 2. When T-plate 2 along with cam follows straight channel to downward direction, due to cam profile, moving bar moves laterally. Lateral movement of Moving bar help in opening of finger as T-plate 2 provide effort on the finger's upper tip so as to collecting seedlings in between the finger tongs. While moving upward

following the channel path opposite series of action takes place, but roller assembly lifted about the center of Roller 1. For inserting the seedling into the soil, T-plates follow the curved channel and come in contact with second roller assembly. Downward movement of T-plates open finger and upward movement lift the whole assembly about the hinged point of the extreme part of L bar.

Testing of laboratory model rice transplanter

Laboratory type manual rice transplanter was tested for its picking and releasing operation of seedling in the laboratory. The laboratory model was kept on a level ground. Rice seedlings from nursery bed were filled in the seedling tray. The machine was then operated and time taken by one entire cycle of picking and releasing of seedling was measured using a stop watch. Height of the handle when finger commences to open was noted and considered it as reference level. Relation was observed between opening width of finger and difference of height of handle from its reference level. The laboratory model rice transplanter during operation is as shown in Fig. 10. Detailed specification of the laboratory model rice transplanter is shown in Table1.



(1) T-plate 1, (2) Roller 1, (3) Roller 2, (4) Cam, and (5) T-plate 2

Fig. 9. Cam and Roller adjustment of laboratory model rice transplanter with finger



Fig. 10. Laboratory model rice transplanter during operation

Table 1. Specifications of developed Laboratory Model Rice Transplanter

S.No.	Description	Specifications
1	Type of machine	Single row laboratory model manually operated rice transplanter
2	Dimensions (Length×Width×Height), mm	300 × 385 × 780
3	Weight, kg	7
4	Type, Size and leaf stage of seedling used	Root washed type, 21-30 days and 3-4 leaf stages
5	Seedling picking and releasing mechanism	Automatic
6	Lever arm	Absent
7	Planting row	
a)	Number	1
b)	Machine width, mm	385

RESULTS AND DISCUSSION

Performance evaluation of Laboratory model rice transplanter

Time requirement per cycle in Annapurna rice transplanter can be reduced by making the following arrangement in the laboratory model rice transplanter:

- i. Proper channel attachment to use the cam in proper way.
- ii. It is expected that the time requirement would be reduced to less than 6.1 sec per cycle.

Observations related to time required per cycle operation and number of seedlings on testing of

Laboratory model rice transplanter is shown in Table 2. Cycle time was calculated from the average time of 30 different videos of 10 different persons. Similarly, cycle time was also calculated as average of manual transplanting by different persons. Table 2 shows that the average time required per cycle operation were found to be 6.55 seconds with 6.27 average numbers of seedlings. Based on independent t-test, statically non-significant difference ($p>0.05$) was observed for complete per cycle operation between laboratory model and Annapurna rice transplanter. Coefficient of variation for time required per cycle and number of seedlings were found 17.22% and 42%, respectively. From the results it was observed that, the number of seedlings per hill in Laboratory model rice transplanter was higher than Annapurna rice transplanter as well as hand transplanting. But statistically non-significant ($p>0.05$) difference was found when laboratory model was compared with Annapurna rice transplanter, whereas, statically

significant ($p<0.05$) difference was found when compared with hand transplanting. The relation between distance of finger from cam end point of working of roller and opening width of finger in laboratory model of rice transplanter is shown in Fig. 11. It shows that opening width of fingers linearly increased with the depth of handle from its reference level. This shows the smooth operation of opening and closing of fingers while picking and releasing of cluster of seedlings. However, in this case time required per cycle was higher than Annapurna rice transplanter. However, works of seedling picking and releasing mechanism in Laboratory model rice transplanter was automatic, whereas, in Annapurna rice transplanter it was manual. The developed model reduces drudgery as well as human stress as lever arm does not require to be pressed to open and close the finger of transplanter.

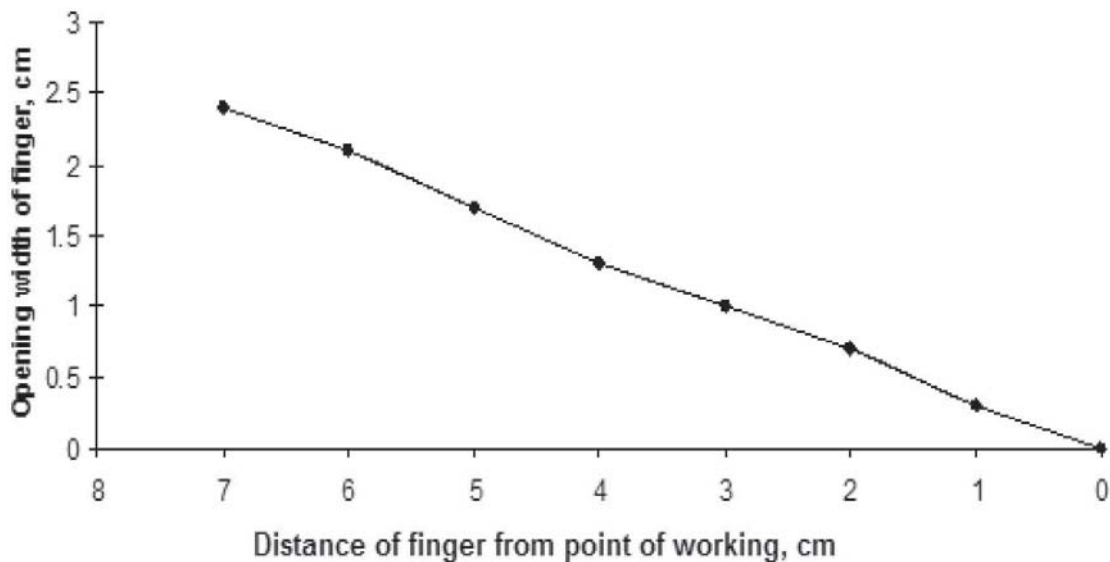


Fig. 11. Relation between distance of finger from point of working and opening width of finger

Table 2. Observation of Laboratory model rice transplanter and Annapurna rice transplanter

S. No.	Laboratory Model Rice Transplanter		Annapurna Rice Transplanter	
	Time required per cycle operation (s)	No of seedlings per hill	Time required per cycle operation (s)	No of seedlings per hill
1	6.14	5	6.08	6
2	8.75	6	4.55	4
3	5.16	8	5.89	3
4	5.87	4	4.02	4
5	7.08	6	8.47	6
6	5.02	7	6.52	7
7	6.15	12	6.17	3
8	7.12	4	5.09	4
9	6.46	6	5.88	11
10	8.01	11	6.31	9
11	6.15	6	6.21	6
12	5.89	4	6.57	9
13	5.46	8	5.77	8
14	5.91	3	5.91	7
15	7.05	8	6.01	3
16	8.01	2	4.68	4
17	5.93	9	5.93	8
18	7.89	4	7.07	4
19	5.68	7	5.48	6
20	6.17	7	6.11	8
21	7.05	12	5.68	3
22	5.88	4	7.25	6
23	6.31	6	9.02	11
24	6.21	9	5.55	2
25	6.57	6	5.77	5
26	5.91	4	4.59	6
27	6.04	2	6.58	6
28	10.54	3	9.01	2
29	5.93	8	4.88	9
30	6.28	7	6.08	4
Average	6.55	6.27	6.10	5.80
SD	1.13	2.63	1.16	2.47
CV%	17.22	42.00	18.99	42.55
p-value	0.069	0.244		

Comparative performance of Laboratory model rice transplanter

Average time required for planting operation of Laboratory model rice transplanter, manually operated Annapurna rice transplanter with hand transplanting is shown in Table 3. Time required for 10 cycles of each machine was recorded. The variations among

different transplanting method were significant ($P < 0.05$) with average time required to complete one cycle. Average time required to complete one cycle with Annapurna rice transplanter and hand transplanting was 6.1 seconds and 1.35 seconds, respectively.

Table 3. Average time required for transplanting through Annapurnatransplanter, Laboratory model rice transplanter and hand transplanting

Parameters	Annapurna Rice Transplanter		Laboratory Model Rice Transplanter		Hand Transplanting			
	Manual observation	Video recording	Manual observation	Video recording	1 st subject	2 nd subject	3 rd subject	4 th subject
Time required to complete one cycle (s)	5.7	6.5	6.2	6.90	1.32	1.68	1.12	1.31
Average time required to complete one cycle(s)	6.1		6.55		1.35*			

Note: * $p < 0.05$

CONCLUSION

The Laboratory model rice transplanter was developed and its movement of fingers during picking and releasing of seedlings works was satisfactory. Cycle time required for laboratory model transplanter was found to be slightly higher than that of Annapurna model. Cycle time may be brought down to a level lesser than Annapurna transplanter cycle time by improving the manufacturing precision of the cam and roller set ups.

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ECO-FRIENDLY PRINTING ON COTTON WITH NATURAL MORDANTS

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ABSTRACT

A study was carried out to print cotton fabric with the marigold flowers as dye source, gum arabic as thickener and eco- friendly mordants such as myrobalan and pomegranate rinds. Paste prepared using marigold flowers, myrobalan and pomegranate rinds with gum arabic as natural thickener was applied for printing on cotton fabric. Colour fastness tests were conducted to assess fastness to sunlight, washing, wet crocking and dry crocking, wet pressing and dry pressing. The printed samples exhibited moderate to good fastness to colour change. The staining test showed very good fastness of all samples. The unique shades and soothing effect created by natural dyes are rewarding than the aesthetic features of chemical dyes. Marigold flowers as a natural dye along with natural mordant and thickener can be successfully used for printing cotton fabric on a larger scale. The effect of natural dye and mordants on print and colour fastness properties were evaluated and found to be good for printing on cotton.

INTRODUCTION

Natural dyes are becoming more popular owing to the growing awareness of environmental problems associated with synthetic dyes. According to the World Bank, 17%-20% of industrial water pollution comes from synthetic textile dyes, and about 40% of synthetic dyes contain known carcinogens (Srivastava and Singh, 2019). From ancient times, textile materials were coloured using natural dyes. People from different regions of India carried out different methods and techniques based on the available local plants, products and sources. People followed different procedures and standards according to the skill and knowledge of the craftsmen. Renewable resources are being considered as alternative raw material for natural dyes (Kannanmarikani *et al.*, 2015).

Today many manufacturing units both large and small have begun exploring natural sources for

obtaining natural colourants, feasible ways and means of producing eco-friendly products. This will help in producing an eco-friendly textile product and also draw attention of green- minded consumer (Jyothi, 2008). Printing has been a media for value addition on fabrics. Natural dye stuff can produce a wide range of colours by mix and match system. A small variation in the dyeing technique or the use of different mordants with the same dye (polygenetic type natural dye) can shift colours to a wide range or create totally new colours, which are not easily obtainable with synthetic dye stuffs (Srivastava and Singh, 2019). Eco- friendly printed fabrics can even broaden the scope for exports. Though natural dyeing has been increasingly used by many people in India, the use and research on natural dye for printing are little. Though printing can be completed with natural dye the use of chemical mordants, synthetic thickening and binding agents will discharge pollution.

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Hence, natural thickening agent needs to be focused while preparing printing paste. Use of screen printing is common and the major portion of textile printing is carried out by this method globally. To gain importance for eco-textiles, the study was conducted on printing cotton fabric using hand printing methods with natural dyes, thickeners and mordants.

MATERIAL AND METHODS

Selection of Fabric

The study was carried out during 2017-18. Cotton has good weaving qualities, high tensile strength, good absorption, low cost, above all abundant usage. It is the commonly used fabric for most of the textile products and was selected for the study. White cotton fabric was designed by soaking it in water with five per cent detergent solution boiled for 10 minutes, rinsed thoroughly in water and dried and ironed for printing.

Selection of Dye source

Dyes obtained from nature are eco- friendly and have good demand today. Some of the commonly available plant dyes produces good shade and are widely available. Marigold (*Tagetes erecta Linn.*) petals as natural dyes can be used for printing of fabrics (Agarwal *et al.*, 2007). Marigold flowers produce colour and can be used for dyeing cotton fabric (Jyothi, 2008). Hence, Marigold flowers were selected for the study and flowers were collected from the local market, dried in shade, powdered, sieved and collected in a container.

Selection of mordants

Metallic mordants are usually used to produce bright and fast colours but are not always eco-friendly. Different mordant concentration showed a

difference in the shade on the fabric. (Vankar *et al.*, 2008). The type of mordant used, the concentration and the dye used along have a strong influence on wash and light fastness properties (Samantha and Konar, 2009). Tannin is the most widely used mordant. Tannins produce indispensable mordants for the dyeing of vegetable fibres such as cotton and linen (Prabhu and Bhute, 2012). Myrobalan is the most important source of tannin (Khan *et al.*, 2005). Considering their importance, natural mordants namely myrobalan and pomegranate rinds were used along with natural dye as printing paste and alum was used as mordant.

Selection of Thickeners

Gum Arabic is a natural, a dried plant extrude, a high solid content thickening agent used for textile printing. The thickener is prepared by mixing the required amount of gum with cold water and allowed to stand for eight hours during which it was stirred at regular intervals. The floating bits and lumps were filtered and the solution is boiled for an hour by constant stirring, strained and collected to prepare the printing paste.

Preparation of Printing Paste

The paste is prepared by sprinkling the dye powder and the mordant with gum solution gradually until it forms a smooth paste without lumps. Three separate printing pastes were used for printing. One paste consists of a mixture of marigold flower powder and gum arabic, second paste consists of a mixture of marigold flower powder, pomegranate rinds and gum arabic solution, third paste consists of marigold flower powder, myrobalan and gum arabic solution.

Table 1. Nomenclature of the samples

O	Original cotton fabric
D	Marigold dye source
P	Pomegranate rinds
M	Myrobalon
1	Pre mordanting with Alum
2	Post mordanting with Alum

O- original cotton sample, D- fabric printed with marigold flower dye source, DP- fabric printed with paste of dye source and pomegranate rinds, DM- fabric printed with paste of dye source and myrobalon, 1- sample that was pre mordanted with alum, 2- sample that was post mordanted with alum.

Printing on Fabric

Screen printing using natural dye was adopted for the study. The prepared sample was divided into two portions. The first portion was pre treated by boiling it with alum solution for 10 minutes and allowed to stand for two hours. The fabric was then printed with the prepared pastes separately.

The second portion was printed with the three pastes separately and then post mordanting with alum solution was completed. In screen printing, a suitable amount of print paste is poured into the well of the screen frame and transferred through on to the cloth underneath by drawing using a squeeze. Two to four strokes were given to every design for the printing to complete.

After Treatment

The printed samples were then dried, fixed by applying heat and washed in water. The samples were then pressed and evaluated.

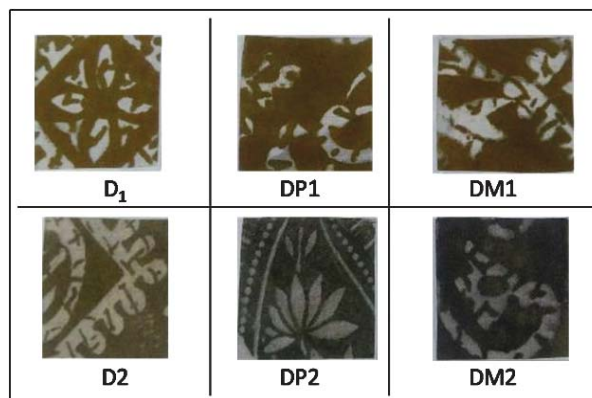


Fig. 1. Cotton samples printed with Marigold flower

Note: D₁- sample printed with marigold flower dye source, DP- fabric printed with paste of dye source and pomegranate rinds, DM- fabric printed with paste of dye source and myrobalon, 1- sample that was pre mordanted with alum, 2- sample that was post mordanted with alum.

RESULTS AND DISCUSSION

The printed samples were tested for tensile strength and elongation, fabric thickness, and colour fastness to washing, sunlight, crocking and pressing.

Tensile Strength

The tensile strength of samples in the warp and weft directions are presented in Table 2 and Table 3, respectively.

Table 2. Tensile Strength - Warp

S. No	Samples	Mean Strength (kg)	Loss in strength over original (kg)	Percentage Loss or gain over original (%)
1	Original	46	-	-
2	D ₁	42	- 4	8.7
3	DP ₁	32	- 14	30.0
4	DM ₁	33	- 13	28.0
5	D ₂	40	- 6	13.0
6	DP ₂	32	- 14	30.0
7	DM ₂	34	- 12	26.0

The strength of the printed samples decreased when compared to the original sample along the warp direction. Samples DP₁ and DP₂ had maximum loss of 30 % followed by samples DM₁, and DM₂.

Table 3. Tensile Strength - Weft

S. No	Samples	Mean Strength (kg)	Loss in strength over original (kg)	Percentage Loss or gain (%)
1	Original	45	-	-
2	D ₁	32	13	29.0
3	DP ₁	33	12	27.0
4	DM ₁	34	11	24.0
5	D ₂	33	12	27.0
6	DP ₂	32	13	29.0
7	DM ₂	33	12	27.0

The tensile strength of printed samples along the weft direction decreased in comparison to the original sample. Samples D₁ and DP₂ had maximum loss of twenty nine per cent.

Fabric Elongation

Table 4. Fabric Elongation - Warp

S. No.	Samples	Mean Value (inches)	Loss over original (inches)	Percentage Loss (%)
1	Original	1.8	-	-
2	D ₁	1.4	0.4	22
3	DP ₁	1.3	0.5	28
4	DM ₁	1.2	0.6	33
5	D ₂	1.2	0.6	33
6	DP ₂	1.3	0.5	28
7	DM ₂	1.3	0.5	28

Fabric elongation of printed sample decreased for all sample along the warp direction. Maximum decrease of 33 percent was found in sample DM₁.

Table 5. Fabric Elongation - Weft

S. No	Samples	Mean Value (in inches)	Loss over original (inches)	Percentage Loss
1	Original	1.4	-	-
2	D ₁	1.2	0.2	14
3	DP ₁	1.2	0.2	14
4	DM ₁	1.1	0.3	21
5	D ₂	1.1	0.3	21
6	DP ₂	1.0	0.4	29
7	DM ₂	1.1	0.3	21

The elongation of printed samples along weft direction also decreased with maximum difference of twenty nine percent in DP₂.

Fabric Thickness

Table 6. Fabric Thickness

S. No.	Samples	Mean value (mm)	Loss over original (mm)	Percentage Loss (%)
1	Original	0.40	-	-
2	D ₁	0.36	0.04	10
3	DP ₁	0.34	0.06	15
4	DM ₁	0.35	0.05	13
5	D ₂	0.29	0.11	28
6	DP ₂	0.30	0.10	25
7	DM ₂	0.30	0.10	25

It is evident that the thickness of all samples decreased irrespective of the nature of mordant and the stage of mordanting. Thickness of samples DP₂ and DM₂ decreased of twenty- five percent and D₁ had a minimum difference of ten percent.

Colour Fastness

Colour fastness tests were conducted to assess fastness to sunlight, washing, wet and dry crocking, wet and dry pressing (Table 7).

Table 7. Colour fastness of printed samples

S. No	Samples	Sunlight colour change	Washing		Pressing				Croaking			
			Colour change	Staining	Wet		Dry		Wet		Dry	
					Colour change	Staining	Colour change	Staining	Colour change	Staining	Colour change	Staining
1	D ₁	3	¾	¾	4/5	3	4/5	4/5	4	4	4	4/5
2	DP ₁	¾	¾	¾	4	2/3	5	4/5	4	4	4/5	4
3	DM ₁	3	¾	3	3/4	3	5	4/5	4	4	4	4
4	D ₂	¾	¾	3	4	2/3	4/5	4/5	4/5	4	4/5	4/5
5	DP ₂	3	3	3	4	3	4/5	4/5	4	4	4	4
6	DM ₂	3	3	3	3/4	2/3	4/5	4/5	4	4	4	4

Note: ½ - 2 – Poor; 1 - Very poor; 3/4 - Fair; 2/3 - 3 - Moderate; 4 – Good; 4/5- Very good; 5 - Excellent

In case of the colour fastness test against sun light, printed sample DP₁ was under fair fastness category and other samples were under moderate category. With regard to wash fastness of cotton samples, almost all samples were fair to moderate fastness both in colour change and staining tests. Regarding colour fastness to wet pressing samples, D₁ had very good fastness, samples DP₁, D₂ and DP₂ were good, samples DM₁ and DM₂ were moderate fast to colour change. The staining test proved to have fair to moderate fastness. In case of dry pressing, almost all samples had excellent to very good fastness in colour change. The staining test showed very good fastness of all samples. Croaking tests revealed that sample D₂ had very fastness and other samples had good fastness to wet croaking. Staining test showed that all samples had good fastness. With respect to dry croaking, samples, DP₁ and D₂ had very good fastness and other samples were good to colour change. D₁ and D₂ samples were categorized as very good and other samples were categorized as good to staining tests.

CONCLUSION

Marigold flowers as a natural dye along with natural mordant and thickener was found to be good and can be successfully used for printing cotton fabric.

Acknowledgement

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IMPACT ASSESSMENT OF KONANKI WATERSHED PROJECT IN PRAKASAM DISTRICT ON BIO-PHYSICAL, ENVIRONMENTAL AND SOCIO-ECONOMIC ASPECTS

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ABSTRACT

Konanki mega watershed project was sanctioned in the year 2010-11 and implemented in Prakasam district till March 2018. Impact study was conducted on environmental and socio-economic indicators by physical visit to the project area and through bio-physical measurable characteristics by remote sensing and GIS techniques to assess the outcomes and impact on the watershed community. The total geographical area of the project is 10,574 ha having undulating terrain with net treatable area of 4,773 ha encompassing seven micro watersheds. The impact of watershed management interventions were observed in terms of sustaining the productivity of crops under drought conditions, development of waste lands and current fallow lands, increase in cultivated area, improvement in agri-vegetation and vigour, expansion of water bodies, soil moisture in the profile as a result of the effective in-situ soil conservation and water conservation activities, increase in milk productivity, etc. The water productivity also found improved through conservation measures and judicious use of available water resources. Watershed interventions helped in enhancement of family income especially of the marginal farmers (37.1 % rise), small farmers (15% rise) and landless poor (76.1% rise) of watershed community.

INTRODUCTION

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) has watershed development as one of the component to treat ridge area and drainage line, soil moisture conservation, rain water harvesting and other watershed interventions. Andhra Pradesh is one of the top 10 states in India receiving maximum central share for watershed development programs. Watershed projects in A.P. are sanctioned in batches and year wise. Konanki project was sanctioned in the year 2010-11 and is implemented in Prakasam district till March, 2018.

Konanki watershed project

Konanki PMKSY watershed is located in

santhamaguluru DPAP block of Martur mandal, Prakasam district. The mega watershed is located at an elevation of 99 m above the MSL, between the latitudes N15° 54' 25.95" and longitude E 80° 04' 58.68" at ridge point and between latitude N 15° 53' 45.32" and longitude E 80° 03' 03.64" at valley point. The total geographical area of the watershed project is 10,574 ha having undulating terrain with net treatable area encompassing seven micro watersheds namely Valaparla, Konanki, Kolalapudi, Jonnathali, Darsi, Chimmiribanda, Martur is 4,773 ha with a total project cost of 572.76 Lakhs. (Govt. of A.P. Glance Reports, 2018.). The total population of this watershed cluster is 47,804. The location and topographical maps of Konanki watershed project are shown in Fig.1a & Fig. 1b.

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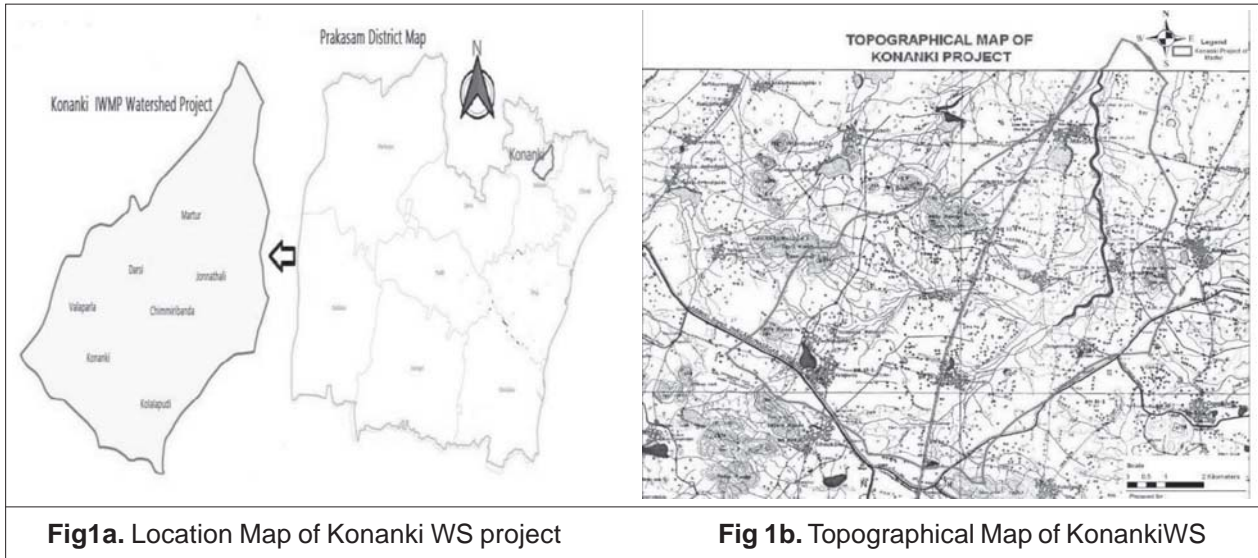


Fig1a. Location Map of Konanki WS project

Fig 1b. Topographical Map of KonankiWS

NABARD Consultancy Services (NABCONS) as a Monitoring, Evaluation, Learning & Documentation (MEL&D) agency for Prakasam district has undertaken the final impact study of konanaki watershed project on environmental & socio-economic indicators and bio-physical measurable characteristics through remote sensing & GIS techniques.

The study mainly focused on bio-physical, environmental and socio-economic impacts of different watershed interventions such as soil conservation and moisture conservation measures, drainage line treatments, rain water harvesting and afforestation on surface and groundwater resources, land use and land cover, crop productivity and cropping pattern, changes in household incomes of watershed community.

MATERIAL AND METHODS

Methodology for bio-physical study using remote sensing and GIS

The bio-physical indicators were studied using remote sensing and GIS techniques using ERDAS

Imagine and ArcGIS software to prepare the final maps. Satellite imageries of LISS IV (5.8 meters resolution) were procured from NRSC Portal for image interpretation. Date of satellite pass was 2nd September, 2012 for pre project period and 31st August, 2017 for post- project period. The topography of the area was studied using the Survey of India Toposheet.

Digital image processing was carried out to delineate various land use/land cover categories in the study area *viz.*, built up area, crop area, forests, scrub forests, land with or without scrubs and water bodies by assigning necessary training sets, which were identified based on tone, texture, size, shape pattern and location information. NDVI was calculated for confirming Vegetation Indexing(VI).

Remote Sensing and GIS data analysis was completed by satellite data processing and land use/ land cover classification and mapping techniques. The classified images having different land use/ land cover categories pertaining to pre and post treatment period were compared to derive information on changes. Ground truth was undertaken in conjunction

with the use of multi-resolution remote sensing data to assess the changes in land use with the implementation of watershed programme.

In order to monitor the vegetation condition/vigour and assess the biomass productivity, normalized difference vegetation index (NDVI) was computed using the infrared and red bands of satellite data.

$$\text{NDVI} = (\text{IR} - \text{R}) / (\text{IR} + \text{R})$$

Similarly, another index, normalized difference water index (NDWI) was used for remote sensing of vegetation liquid water from space. They sense similar depths through vegetation canopies and NDWI is sensitive to changes in liquid water content of vegetation canopies.

$$\text{NDWI} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR})$$

Based on NDWI values ranging from maximum (+1) for maximum soil moisture in comparatively deep soils to minimum (-1) for dry lands, the soil moisture is grouped into four soil moisture classes- Good soil moisture (>0.14), Medium soil moisture (-0.08 to 0.13), Less soil moisture (-0.11 to -0.09) and Very less and dry soil (< -0.12). The total area under each soil moisture class based on RS image is expressed in per cent against the total watershed area.

Methodology for environmental and socio-economic study

The field study was conducted in September and October months of 2018 as per the tool designed for the household Survey and Focus Group Discussions (FGDs), covering all seven micro watersheds of Konanki project. Sample households were randomly selected from watershed community including OC, BC, SC, ST, landless households,

marginal farmers, small and big farmers representing all villages in each micro watershed (MWS). The socio-economic study covered 5% of households in each micro watershed for household survey to collect information. The total number of households were 9,612 from seven micro watersheds and 483 households are surveyed for the study.

Interview schedule developed was used to collect household data (sample size of 5% households in each micro watershed) through household survey, organized Focus Group Discussions (FGDs) involving various stakeholders of watershed community and collected primary and secondary data. The information related to pre-project period was collected from Detailed Project Reports (Govt. of A.P., 2018) of each MWS. The gross income per annum for each household at the start and the end of project period was computed based on income from agriculture, milk and wage income. The data collected from primary and secondary sources was tabulated and analysed using various statistical tools.

RESULTS AND DISCUSSION

A. Bio-physical impacts

Land use and land cover

Land use change modelling tools support timely and effective monitoring of natural resources through spatio-temporal land use/land cover change detection (Anurag *et al.*, 2018; Aspinall, 2004). Land Use and land cover changes as observed from satellite imageries of LISS IV data for the year 2012 (pre - project period), and 2017 (post-project period) are presented in Table 1 and shown in Fig.2a & Fig.2b. The study results show that land use for agriculture crops increased by 10.5 % from 4242 ha to 4688 ha;

agriculture plantations area also increased by 416.4 ha; water body coverage increased by 30.6 % and waste land decreased by 44.9 % in August 2017. Shift from annual crops to perennial crops

(plantations) was observed mostly by converting the wastelands to plantations and growth is observed in about 416.4 ha (88.7%). Soil erosion is not identified in either of the satellite imageries of LISS IV.

Table 1. Satellite Imagery Based Land Use/ Land Cover Details

S.No	Land Use/Land Cover Class	Pre- Project Area (ha) (Sept. 2012)	Post Project Area (ha) (August, 2017)	Change in Area (ha)	% Change
1	Built up Land	354	358.5	4.4	1.3
2	Industrial Establishment	167.8	185.3	17.4	10.4
3	Agriculture Crops	4242.4	4687.8	445.4	10.5
4	Vegetation (Ag Plantation)	469.4	885.7	416.4	88.7
5	Waste Land	2109	1162.9	-946	-44.9
6	Water Body	203.9	266.3	62.5	30.6
Total (ha)		7546.53	7546.5		

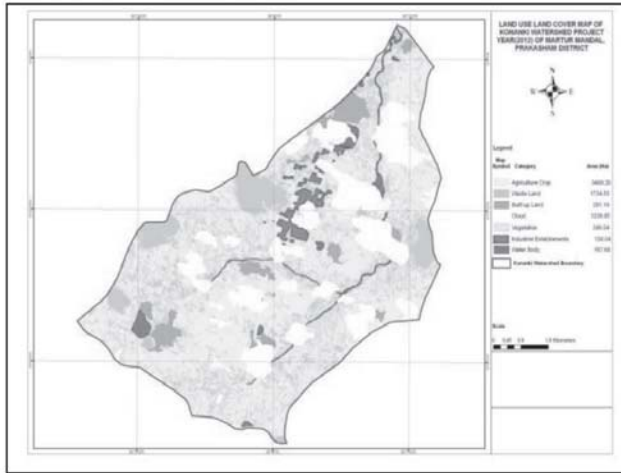


Fig 2a. Land use/ Land cover map in September 2012

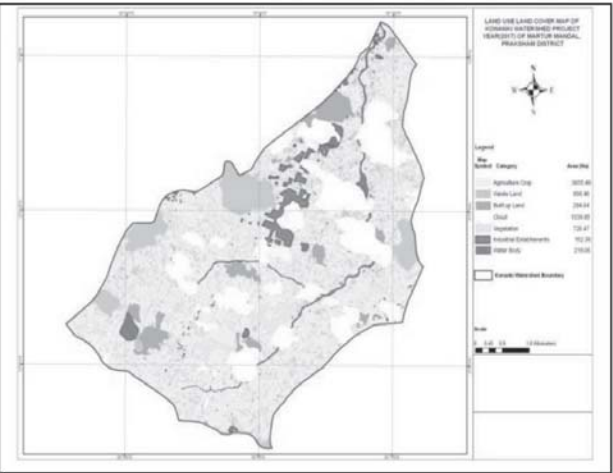


Fig 2b. Land use/ Land cover map in August 2017

Vegetation cover

Spatial and temporal changes in vegetation cover measured through Normalized Difference Vegetation Index (NDVI) are presented in Table 2. NDVI is the suitable index for vegetation studies to extract the extent of cropped area from study region

(Vani and Pavan Kumar, 2018; Vani and Mandla, 2017). NDVI is most widely used index for vegetation health condition and spread area (Miura *et al.*, 2006). In the year 2012, dense vegetation covered 1% of the total watershed area, open vegetation and sparse vegetation covered 47% and 31%, respectively of the

watershed area. No vegetation cover including the built up land, barren land constituted significant area of the watershed. However, during the year 2017, the dense vegetation cover occupied 16% of the area followed by 40% of open vegetation, 26% of sparse vegetation and 18% without any vegetation.

Compared to the Pre-project period (Year-2012), the dense vegetation cover increased by 1177 ha and the open vegetation cover & sparse vegetation cover and no vegetation cover decreased by 574 ha, 339 ha and 264 ha, respectively in the year 2017.

Table 2. Change in vegetation cover

S. No.	Vegetation Cover Type	Pre Treatment Area (ha)	Post Treatment Area, ha	Change	
				Area (ha)	%
1	Dense Vegetation	62	1239	1177	1890.4
2	Open Vegetation	3568	2994	-574	-16.1
3	Sparse Vegetation	2331	1993	-338	-14.5
4	Water Body, Built up, Barren Land	1585	1320	-265	-16.7
	Total (ha)	7546	7546		

Adoption of soil and water conservation practices increased the vegetation cover in the watershed area, while the area under no vegetation

cover declined. The maps depicting the different types of vegetation cover in the pre project and post project period is shown in Fig. 3a & Fig. 3b.

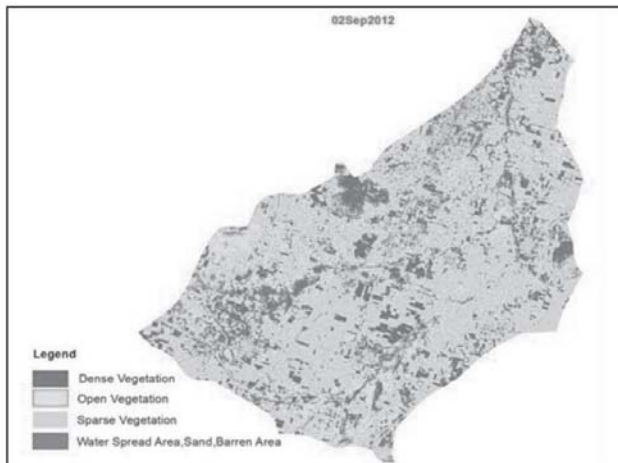


Fig 3a. Normalized Difference Vegetation Index (NDVI) map in 2012

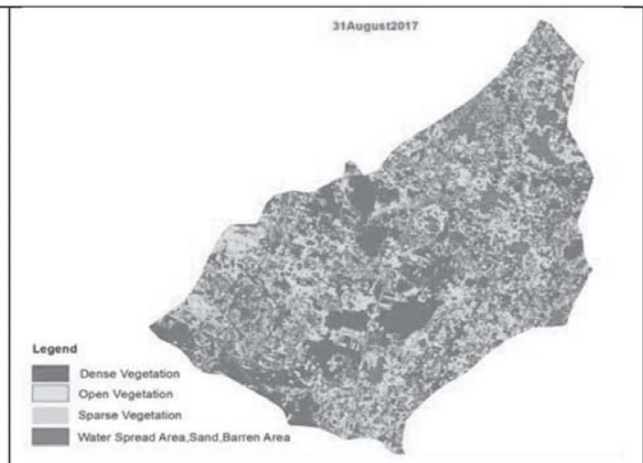


Fig 3b. Normalized Difference Vegetation Index (NDVI) map in 2017

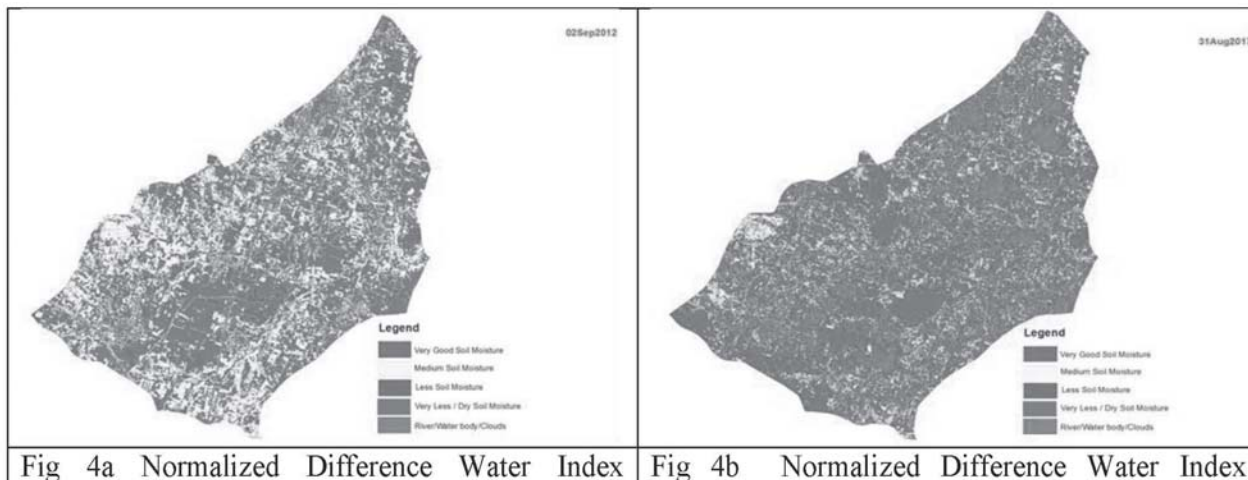
Soil moisture

Soil moisture availability through wetness indicators was assessed by Normalized Difference

Water Index (NDWI). NDWI is being used for change detection analysis of water cover areas in the study region (Gao, 1996; Krishna Das, 2017). Based on computed NDWI as shown in Fig.4a & Fig.4b, there

was an increase in soil moisture of the watershed areas as a result of the watershed activities. At the end of project period, the area with very good soil moisture increased from 35% of watershed area to 45 % of the watershed area; while the area under

medium soil moisture reduced from 25% to 15% of the watershed area. However, the area under less soil moisture and very less/no soil moisture remained same.



B. Environmental Impacts

Natural resource management

Natural Resource Management (NRM) is the major thrust area of watershed program for the works such as land, soil moisture conservation, water harvesting structures and afforestation etc.,. The details of physical and financial achievements under

NRM component are furnished in Table 3. In all, 425 works are executed with an expenditure of 267.8 lakhs, which is 46.8 % of the project cost. Effective management of natural resources (soil, water and vegetation) supported by other interventions of watershed project resulted in increased cultivation of field crops and plantations.

Table 3. NRM category wise physical and financial achievements

S. No.	Name of the Activity	Physical (No.)	Financial (Rs. in Lakhs)
1	Land Development Works	12	4.7
2	Soil Moisture Conservation Works	15	15.7
3	Water harvesting structures	126	220.6
4	Afforestation Works	266	25.7
5	Livestock related works	6	1.1
6	Total no. of NRM works & expenditure	425	267.8
7	Total project cost (Lakh Rs.)	-	572.8
8	% of NRM expenditure	-	46.8

(Source: IWMP AP NRM MIS report R: 2.1)

Rainfall, ground water and irrigation

I. Rainfall

Annual rainfall (actual and normal) data given in Table 4 shows that there was deficit rainfall in five

of the seven years of project implementation period. The deficit rainfall was recorded for four successive years from 2014 onwards. The percent deficiency of normal rainfall from that of actual rainfall varied from as high as -43 in 2014 to -27.2 in 2015.

Table 4. Annual Rainfall during the project period

S. No.	Year	Total Rainfall in mm (Jan.-Dec.)	
		Actual (mm)	% deficit over normal rainfall of 871.5 mm
1	2011	570	-34.6
2	2012	886.4	1.7
3	2013	986.2	13.1
4	2014	497.1	-43
5	2015	634.1	-27.2
6	2016	549.5	-37
7	2017	615.2	-29.4

(Source:Gol, 2019)

II. Irrigation

As a result of rainfall shortage and excess tapping of ground water, despite better conservation of soil moisture and recharging and rainwater harvesting through soil moisture conservation (SMC) measures, the ground water table dropped by 3.2 m from 6.9 m to 10.1 m. Apart from all the constraints, the irrigated area increased by 3.3% by tapping ground water from deeper depth scoupled with increased awareness on better water management practices, growing water efficient crops and short duration crop varieties.

Crops and cropping pattern

I. Crop area

Change in land use was observed in the watershed (WS) program with an increase in cropped area under agriculture and horticulture crops. The area under agriculture crops increased from 3947 ha to 4450 ha and horticulture crops from 65 ha to 91 ha in post treatment period. The waste land decreased by 69.6 % from 761 ha to 231 ha at the end of project period (Table 5). Watershed interventions such as soil and moisture conservation measures, harvesting of rain water and recycling, development of waste lands and fallow lands resulted in such a change in land use.

Table 5. Change in land use and area under agriculture and horticulture

SI. No	Particulars	Land Use(ha)		
		Pre Project	Post project	% of change
1	Agriculture	3947	4450	12.7
2	Horticulture	65	92	40
3	Waste land	761	231	(-) 69.6
Total (ha)		4773	4773	

II. Crop yield

Watershed developmental activities have made significant positive impacts on crop production and productivity (Palanisami and Suresh Kumar, 2009). The per hectare economic yield of all the major crops in the post project period was higher due to growing of high yielding crop varieties, adoption of recommended package of practices, effectively conserving and utilizing the soil moisture and rainfall. In convergence with agriculture department, the farmers are supplied quality seed, farm equipment's and technical knowhow, judicious utilization of available irrigation, timely credit supply and other

production system improvement (PSI) activities. Besides, the farmers are involved in capacity building (CB) programs such as trainings, field demonstrations and exposure visits.

The yield of crops such as rice, red gram, chillies, cotton, blackgram and subabul increased ranging from 2.3 per cent in chilli to 20 per cent in pigeon pea (Table 6). Black gram is a short duration crop, which enabled the crop to escape terminal drought at the end of crop season. Yield increase was higher in pulses followed by cotton.

Table 6. Crop Yield of Major Crops

S. No	Crop	Crop Yield(kg ha ⁻¹)		
		Pre project period	Post project period	% Change
1	Rice	5290	5420	2.6
2	Cotton	2210	2600	17.6
3	Pigeonpea	1230	1470	20
4	Black gram	1000	1200	19.5
5	Chilli	4840	4950	2.3
6	Subabul	54300	55600	2.4

III. Cropping pattern

Cropping pattern during the project period did not differ much (Fig.5). Subabul is the major crop occupying 47 % to 48 % of the cultivated area, followed by cotton (22%-24%), black gram (12%-13%), chillies (6%-9%), pigeonpea (4%-5%) and rice

(5%). In focused group discussions, the stakeholders informed that the area under crops such as subabul and cotton is higher due to better income and their ability to withstand moisture stress conditions better in drought years.

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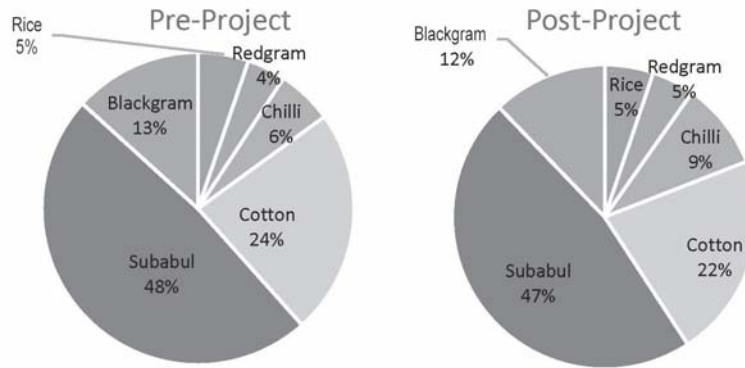


Fig. 5. Cropping Pattern in Pre project and Post Project Periods

Milch cattle, milk production and productivity

The number of milch cattle decreased by 47.3 % from 5893 to 3104 (Table 7) due to shortage of open grazing lands and successive drought conditions. The total milk production per year decreased by 3.6 % in the watershed project with reduced number of milch cattle in each micro watershed. However, the milk productivity of milch

animals improved by 7.3 % during the project period, mainly with improved breeds, artificial insemination, improved hygiene & health management, clean milk production, etc and balanced nutrition in convergence with animal husbandry (AH) department. The farmers who own milch cattle have secured income to meet the family expenditure, even during drought years.

Table 7. Milch cattle, milk production and productivity

Sl. No	Indicator	Pre project	Post project	% Change
1	Milch Cattle (No.)	5893	3104	(-) 47.3
2	Milk Production (KL/year)	4349	4193	(-) 3.6
3	Milk Productivity (L/day)	4.1	4.4	7.3

B. Socio-economic impact

Agriculture and allied activities are the predominant livelihood activities in watershed area, as 69 per cent of households are still depending on agriculture during the project implementation period. Average size of farm holding of households studied is 1.66 ha during project period. The participation of watershed community in various group activities such as Self Help Groups (SHGs), User Groups (UGs), and watershed committees increased from 88 % to

94 % after the initiation of the project, indicating the people's participation in the programme.

Gross income of total households

The gross returns per annum of household from farming, dairying and wage labour is calculated and presented in Table 8. The Gross Income of total households increased by 23.4 % from Rs.1,34,320 in the pre project period to Rs.1,65,797/- at the end of project period.

Table 8. Gross income of households

Sl. No	Indicator	Pre project (Rs./Yr/HH)	Post project (Rs./Yr/HH)	% Change
1	Total Houeholds	1,34,320	1,65,797	23.4
2	Marginal Farmers	73,191	1,00,355	37.1
3	Small Farmers	1,84,918	2,12,714	15
4	Big Farmers	3,38,427	3,70,775	9.6
5	Landless HHs	60,790	1,07,044	76.1

The annual gross income of all households irrespective of size of land holding (including landless households) increased after the project period in the watershed area. The annual household's income of marginal farmers after the project period is Rs.1,00,355 (increased by 37.1% over the pre-project period). The annual gross income of small farmers increased by 15% over the pre-project period raising to Rs.2,12,714 and the gross income of large landholders increased by 9.6% over the pre-project period reaching Rs.3,70,775. The annual gross income of landless households from subsidiary activities such as rearing of milch animals and wage income from agriculture and non-agricultural activities increased to Rs.1,07,044 in the post-project period showing an increase of 76.1%.

CONCLUSION

The impact of watershed management interventions was observed in sustaining the productivity of crops under drought conditions, development of waste lands and fallow lands, increase in the area of cultivation, development in agri-vegetation, expansion of water bodies, better soil moisture in the soil profile, increase in milk productivity, etc. Water productivity was also improved through conservation measures and judicious use of

available water resources. There is an overall socio-economic development of marginal farmers, small farmers and landless poor of watershed community.

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Research Note

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ESTIMATION OF HETEROSIS FOR PHYSIOLOGICAL, GROWTH, BIOCHEMICAL, SEED YIELD AND ITS COMPONENT CHARACTERS IN SESAME (*Sesamum indicum* L.)

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Sesame is one of the edible oilseed crop, which contain about 45%-58%oil. Similar to other crops, in sesame too, the yield is a complex character and the lower productivity could be attributed to the interplay of different yield related, biochemical, growth and morphological characters. In the past decades, the sesame improvement was solely based on the selection of morphological characters and less importance was given to physiological characters. An insight into the genetics of physiological, growth, biochemical traits would be the best prospects for breeding for higher yield. However, little is known about the physiological, growth and biochemical characters that appear highly promising in improving the performance of this crop (so far has been mostly confined to single plant selection).

Heterosis plays a predominant role in accelerating the agricultural production and heterosis breeding opens up tremendous potential among the crops for quantitative improvement. The manifestation of heterosis and its utilisation as a means of maximizing the yield of crops has been one of the most important in plant breeding.

The experiment was conducted at Plant Breeding Farm, Annamalai University, during 2016-2017. Sesame genotypes namely VRI 1, VRI 2, TMV 3, TMV 4, TMV6 and CO1 were selected and were procured from Regional Research Station, Vridhachalam. Six parents were crossed in all possible combinations and the resulting thirty cross

combinations inclusive of reciprocal crosses along with the parents form an effective complete diallel set were used for the present study. Thirty hybrids along with six parents were sown in rows with a spacing of 30 cm X 30 cm. In each cross, 20 plants were maintained. A randomized block design replicated thrice was laid. Recommended fertilizer schedule, cultural operations and plant protection measures were carried out. The observations were recorded on 10 plants in parents and hybrids for the following traits viz., days to first senescence, leaf area index, dry matter production, harvest index, total chlorophyll content, soluble protein content, number of capsules plant⁻¹, number of seeds per capsule, 1000 seed weight and seed yield plant⁻¹. The heterosis for individual crosses was calculated and the significance of heterosis was tested using the formula as suggested by Wynne *et al.* (1970).

The results of the analysis of variance showed that all the characters studied were significant except 1000 seed weight which indicated the genetic diversity of the parents selected for the study (Table 1). The main aim of the estimation of heterosis was to find out the superior combinations of parents giving the high degree of useful heterosis for yield and its contributing characters. The estimation of relative heterosis, heterobeltiosis and standard heterosis were presented in Table 2 to Table 6. The results revealed that the hybrids VRI 2 x TMV 3 (6.33 per cent) for leaf area index, VRI 1 x TMV 3 (15.83) for dry matter

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Table 1. Analysis of variance for physiological, growth, biochemical, seed yield and its component characters in sesame

Source	Df	Mean sum of squares									
		Days to first senescence	Leaf area index	Dry matter production	Harvest index	Total chlorophyll content	Soluble protein content	Number of capsules plant ⁻¹	Number of seeds per capsule	1000 seed weight	Seed yield plant ⁻¹
Replication	2	32.76	0.01	4.95	0.65	0.01	1.35	15.18	5.80	0.23	0.73
Genotypes	35	34.49**	0.02**	14.58**	31.51**	0.01**	2.31**	187.40**	22.41**	0.017	3.11**
Error	70	5.54	0.01	3.98	4.49	0.01	0.79	7.22	3.94	0.02	0.43

** - Significant at 1% level

Table 2. Estimation of heterosis for days to first senescence and leaf area index (per cent)

S. No.	Hybrids	Relative heterosis		Heterobeltiosis		Standard heterosis		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal
1.	VRI 1 × VRI 2	-0.73	-0.43	-1.96	-1.66	-7.99**	-7.72**	1.20	-0.10	-5.08*	-6.30*	-9.04**	-10.21**
2.	VRI 1 × TMV 3	-0.77	0.67	-2.22	-0.79	-7.83**	-6.49**	4.67*	-2.77	-0.22	-7.31	-7.63**	-14.19**
3.	VRI 1 × TMV 4	-7.24*	0.68	-11.40**	-3.84**	-10.93**	-3.33**	-1.50	1.57	-4.59	-1.62	-14.56**	-11.90**
4.	VRI 1 × TMV 6	-7.64**	2.58**	-12.18**	-2.46**	-10.87*	-1.01*	4.91*	-4.95	-2.34*	-11.52*	-4.89**	13.83**
5.	VRI 1 × CO 1	-7.35**	4.44**	-11.28*	0.01*	-11.28*	0.01*	4.73*	-4.23	-3.68**	-11.92**	-3.68**	-11.92
6.	VRI 2 × TMV 3	-5.50	-0.59	-5.71	-0.81	-11.13**	-6.51**	6.33*	-3.93	4.52*	-5.57	0.16	-9.50
7.	VRI 2 × TMV 4	0.18	3.55**	-3.15	0.11	-2.64	0.64	-2.89	-1.82	-6.07*	-5.04*	-9.99**	-9.00**
8.	VRI 2 × TMV 6	1.46**	-5.51	-2.36*	-9.07*	-0.90	-7.72	0.14	-4.76	-0.66	-5.52	-3.26*	-7.99*
9.	VRI 2 × CO 1	-1.73	6.96**	-4.76	3.66	-4.76	3.66	4.92*	-2.91	2.74	-4.93	2.74	-4.93
10.	TMV 3 × TMV 4	-7.95**	-3.64**	-10.82**	-6.64**	-10.35**	-6.15**	-4.49	6.30*	-6.05	4.57*	13.03**	-3.20**
11.	TMV 3 × TMV 6	-1.64	1.30	-5.15	-2.31	-3.73	-0.86	1.43	4.31	-1.08	1.74	-3.66	-0.93
12.	TMV 3 × CO 1	-1.80	2.82**	-4.62	-0.13	-4.62	-0.13	0.51	3.94	-3.22	0.08	-3.22	0.08
13.	TMV 4 × TMV 6	-1.59	1.11	-2.06	0.63	-0.59	2.14	2.85	-3.20	-1.28	-7.09	-3.87*	-9.52*
14.	TMV 4 × CO 1	-5.14	-0.59	-5.39	-0.85	-4.89	-0.33	3.98	-1.26	-1.45	-6.42	-1.45	-6.42
15.	TMV 6 × CO 1	0.39	-0.15	-0.35	-0.89	1.14	0.59	2.88	0.84	1.53	-0.48	1.53	-0.48

*- Significant at 5% level**- Significant at 1% level CO 1 - Standard variety

Table 3. Estimation of heterosis for dry matter production and harvest index (per cent)

S. No.	Hybrids	Relative heterosis		Heterobeltiosis		Standard heterosis		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal
1.	VRI 1 × VRI 2	13.23*	12.02*	9.89	8.72	-10.08*	-11.04*	5.77	9.18	2.55	5.86	-13.01*	-10.29
2.	VRI 1 × TMV 3	15.83*	-12.00	10.84	-15.79	-0.75*	-24.59*	31.43**	12.83**	30.01**	11.62**	10.29	-5.32
3.	VRI 1 × TMV 4	0.94	4.76	-3.44	0.21	-13.48*	10.21*	1.20	6.51	-4.03	1.01	-9.21	-4.44
4.	VRI 1 × TMV 6	8.58	4.28	4.27	0.15	-7.32*	-10.99*	24.60**	6.34**	21.12*	3.37*	8.82	-7.13
5.	VRI 1 × CO 1	0.95	-6.48	8.22*	14.98*	-8.22*	-14.98*	21.38	-1.70	12.17	-9.16	12.17	-9.16
6.	VRI 2 × TMV 3	10.01*	4.89	2.30	-2.46	-8.39*	-12.66*	26.80**	31.62**	24.26**	28.98**	3.13	7.05
7.	VRI 2 × TMV 4	3.47	5.49	-3.80	-1.92	-13.81**	-12.13**	16.09**	26.32**	6.93*	16.36*	1.15	10.07
8.	VRI 2 × TMV 6	15.49*	-2.81	7.77	-9.31	-4.22*	-19.39*	12.44**	22.87**	6.07	15.91	-4.70	4.14
9.	VRI 2 × CO 1	10.51*	10.53*	-2.20	-2.18	-2.20*	-2.18*	33.65**	22.42**	20.06**	9.98**	20.06**	9.98**
10.	TMV 3 × TMV 4	-10.45	6.19	-10.48	6.16	-19.79*	-4.88*	13.28**	19.84**	6.34	12.49	0.59	6.42
11.	TMV 3 × TMV 6	5.00	6.39	4.61	6.00	-6.33*	-5.08*	27.41**	25.31**	22.56**	20.53**	10.11	8.29
12.	TMV 3 × CO 1	7.42	2.60	1.80	-2.76	1.80	-2.76	21.91**	19.08**	11.55	8.96	11.55	8.96
13.	TMV 4 × TMV 6	-4.01	9.64	-4.39	9.20	-14.34*	-2.16*	3.64	12.91	1.03	10.07	-4.42	4.13
14.	TMV 4 × CO 1	3.28	-2.95	-2.09	-8.00	-2.09*	-8.00*	17.30*	3.42*	14.13	0.62	14.13	0.62
15.	TMV 6 × CO 1	2.74	1.94	-2.97	-3.73	-2.97*	-3.73*	18.88**	18.72**	12.84*	12.69*	12.84*	12.69*

* - Significant at 5% level

** - Significant at 1% level

CO 1 - Standard variety

Table 4. Estimation of heterosis for total chlorophyll content and soluble protein content (per cent)

S. No.	Hybrids	Relative heterosis		Heterobeltiosis		Standard heterosis		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal
1.	VRI 1 × VRI 2	6.36*	4.25*	2.11	0.09	3.44	1.39	15.46*	-1.41	13.75	-2.88	4.71	-10.59*
2.	VRI 1 × TMV 3	9.29	-8.41*	7.60	-9.83*	12.48	-5.74*	24.27**	7.10**	24.07*	6.94*	11.18**	-4.18*
3.	VRI 1 × TMV 4	-1.04	-1.48	-3.06	-3.48	-1.80	-2.23	7.33	1.50	-0.48	-5.89	4.04	-1.62
4.	VRI 1 × TMV 6	2.35	-4.26	1.28	-5.26	2.60	-4.03	13.17	6.22	6.34	-0.19	8.03	1.39
5.	VRI 1 × CO 1	4.11	-2.32	3.44	-2.95	4.78	-1.69	18.59*	-4.52	12.26	-9.62*	12.26	-9.62*
6.	VRI 2 × TMV 3	7.64*	1.97*	1.81	-3.55	6.42	0.82	19.94**	17.40**	18.35*	15.82*	8.95	6.63
7.	VRI 2 × TMV 4	-0.96	5.89	-2.98	3.73	-5.72*	0.80	1.90	7.74	-4.19*	1.31	0.17	5.91
8.	VRI 2 × TMV 6	4.78**	9.28**	1.63	5.99	0.80	5.12	2.27	2.07	-2.52	-2.72	-0.98	-1.17
9.	VRI 2 × CO 1	10.63**	10.87**	6.88**	7.11**	6.88**	7.11**	13.54*	8.23*	9.03	3.93	9.03	3.93
10.	TMV 3 × TMV 4	-1.89	5.72	-5.34*	2.00	-1.05	6.63	12.52*	12.40*	4.48	4.37	9.23*	9.11*
11.	TMV 3 × TMV 6	1.22*	9.49*	-1.37	6.69	3.10**	11.52	8.19	10.70	1.81	4.17	3.43	5.82
12.	TMV 3 × CO 1	4.18**	14.60**	1.92**	12.11**	6.54**	17.19**	18.15**	11.01**	12.01**	5.24**	12.01**	5.24**
13.	TMV 4 × TMV 6	8.95*	2.06*	7.85	1.03	6.97	0.20	3.98	6.87	2.51	5.36	7.16	10.14
14.	TMV 4 × CO 1	6.98**	8.71**	5.47*	7.17*	5.47*	7.17*	12.66	-0.29	10.21	-2.45	15.22*	1.98
15.	TMV 6 × CO 1	8.14**	6.47**	7.70**	6.04**	7.70**	6.04**	12.46**	15.03**	11.58*	14.13*	13.35*	15.94*

* - Significant at 5% level

** - Significant at 1% level

CO 1 - Standard variety

Table 5. Estimation of heterosis for number of capsules plant⁻¹ and number of seeds per capsule (per cent)

S. No.	Hybrids	Relative heterosis		Heterobeltiosis		Standard heterosis		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal	Direct	Reci-procal
1.	VRI 1 × VRI 2	17.74**	5.93**	10.77	-0.34	11.10	-0.04	-1.46	-0.56	-2.50	-1.60	-19.14**	-18.39**
2.	VRI 1 × TMV 3	19.04**	-3.20**	14.73	-6.70**	15.08	-6.42	5.30	-6.06	0.09	-10.71	7.87**	-17.81**
3.	VRI 1 × TMV 4	1.88**	21.92**	-1.00**	18.47**	-0.70**	18.83**	3.83	4.12	2.03	2.31	-12.34**	-12.10**
4.	VRI 1 × TMV 6	-0.55	-0.99	-0.87	-1.30	-0.57	-1.00	-12.10*	-4.06*	-16.59**	-8.97**	22.95**	15.91**
5.	VRI 1 × CO 1	19.89**	12.17**	19.71**	12.00**	20.08**	12.34**	3.26	1.54	-5.55	-7.13	-5.55	-7.13
6.	VRI 2 × TMV 3	28.64**	12.52**	25.45**	9.73**	16.72**	2.09**	8.85*	10.86*	2.43	4.32	-5.72	-3.98
7.	VRI 2 × TMV 4	11.49	-9.30	7.83	-12.27	2.05*	-16.98*	9.47*	9.77*	6.46	6.75*	-8.83*	-8.29*
8.	VRI 2 × TMV 6	9.28*	4.29*	3.12	-1.59	2.77	-1.93	6.92*	8.35*	0.45	1.79	-7.21	-5.97
9.	VRI 2 × CO 1	27.59**	7.80**	20.20**	1.56**	20.20**	1.56**	5.53*	12.67*	-4.39	2.07	-4.39	2.07
10.	TMV 3 × TMV 4	17.98**	18.92**	16.99**	17.92**	10.71**	11.59**	4.56*	8.47*	1.08	4.86*	-6.96	-3.48
11.	TMV 3 × TMV 6	-11.39*	23.64*	-14.33	19.54	-14.62	19.13	-0.99	2.96	-1.17	2.78	-8.70	-5.05
12.	TMV 3 × CO 1	-0.73	11.11	-4.19	7.24	-4.19	7.24	0.95	8.54*	-3.07	4.23	-3.07	4.23
13.	TMV 4 × TMV 6	17.93**	12.27**	14.96**	9.44**	14.57**	9.07**	-2.23	-1.30	-5.65	-4.75	-12.84**	-12.01**
14.	TMV 4 × CO 1	23.71**	22.36**	20.39**	19.08**	19.08**	20.39**	3.12	1.16	-4.14	-5.97	-4.14	-5.97
15.	TMV 6 × CO 1	9.29**	26.26**	9.10**	26.04**	9.10**	26.04**	10.25*	3.70	6.05*	-0.25	6.05	-0.25

* - Significant at 5% level

** - Significant at 1% level

CO 1 - Standard variety

Table 6. Estimation of heterosis for 1000 seed weight and seed yield plant⁻¹ (per cent)

S. No.	Hybrids	Relative heterosis		Heterobeltiosis		Standard heterosis		Relative heterosis		Heterobeltiosis		Standard heterosis	
		Direct	Reci procal	Direct	Reci procal	Direct	Reci procal	Direct	Reci procal	Direct	Reci procal	Direct	Reci procal
1.	VRI 1 × VRI 2	5.28*	-1.53	3.41*	-3.27	-0.39	-6.83	31.68**	18.87**	29.33*	16.74*	16.23**	24.38**
2.	VRI 1 × TMV 3	6.09*	-2.45	4.99*	-3.46	-0.39	-8.41**	35.76**	-10.59	32.15*	-12.97	-9.59**	40.46**
3.	VRI 1 × TMV 4	1.84	2.69	1.70	2.55	-5.52**	-4.73	9.05*	27.45*	7.11	25.18*	28.06**	15.93**
4.	VRI 1 × TMV 6	10.42*	0.97	8.46*	-0.82	4.47**	-4.47	19.45*	-3.31	7.00	-13.39	-12.44**	29.12**
5.	VRI 1 × CO 1	3.13	1.09	-0.53	-2.50	-0.53	-2.50	22.99*	4.35*	1.33	-14.03	1.33	-14.03
6.	VRI 2 × TMV 3	-1.99	-1.31	-2.73	-2.05	-6.31	-5.65**	32.72**	19.27**	26.94*	14.08*	-13.16**	21.96**
7.	VRI 2 × TMV 4	-0.56	0.56	-2.46	-1.36	-6.04	-4.99	20.19**	-6.09	15.98**	-9.37	22.11**	39.14**
8.	VRI 2 × TMV 6	3.27	-4.91	3.27	-4.91**	-0.53	-8.41**	18.11**	-1.18	4.12	-12.88	-14.79**	28.71**
9.	VRI 2 × CO 1	2.95	-1.07	1.05	-2.89	1.05	-2.89	20.40*	6.30*	-2.20	-13.65	-2.20	-13.65
10.	TMV 3 × TMV 4	3.43	1.19	2.22	-0.00	-3.02	-5.12	24.70**	27.27**	23.56**	26.11**	-15.47*	-13.73*
11.	TMV 3 × TMV 6	-3.37	3.23	-4.09	2.46	-7.62	-1.31	12.97**	25.24**	3.71	14.97*	-15.13	-5.92
12.	TMV 3 × CO 1	-0.74	-0.61	-3.29	-3.15	-3.29	-3.15	4.12	11.64**	-12.12	-5.99	-12.32	-5.99
13.	TMV 4 × TMV 6	-2.09	4.31*	-3.96	2.32	-7.49*	-1.45	15.14**	7.05	4.82	-2.55	-14.22**	-20.25**
14.	TMV 4 × CO 1	2.18	0.68	-1.58	-3.02	-1.58	-3.02	14.61	9.53	-4.21	-8.46	-4.21	-8.46
15.	TMV 6 × CO 1	0.67	-2.14	-1.18	-3.94	-1.18	-3.94	9.91	4.44	-0.08	-5.04	-0.08	-5.04

* - Significant at 5% level; ** - Significant at 1% level; CO1- Standard variety

production, VRI 2 x CO 1 (33.65 per cent) for harvest index, CO 1 x TMV 3 (14.60 per cent) for total chlorophyll content, VRI 1 x TMV 3 (24.27 percent for soluble protein content, VRI 2 x TMV 3 (28.64 per cent) for number of capsules plant⁻¹, CO 1 x VRI 2 (12.62 per cent) for number of seeds per capsule, VRI 1 x TMV 6 (10.42 %) for 1000 seed weight and VRI 1 x TMV 3 (35.76 %) for seed yield plant⁻¹ exhibited positive and significant relative heterosis indicating for these traits the genes with positive effect were dominant. A perusal of performance of hybrids over better parent revealed that ten hybrids exhibited significant positive heterobeltiosis for seed yield plant⁻¹ and maximum value was observed in the hybrid VRI 1 X TMV 3 (32.15 %). Heterobeltiosis was maximum, negative and significant in the hybrid VRI 1 X TMV 6 (-12.18 %) for days to first senescence. The hybrid VRI 1 X TMV 3 (30.01 %) recorded maximum, positive and significant heterobeltiosis for harvest index, VRI 1 X TMV 3 (24.07 %) for soluble protein content, CO 1 X TMV 6 (26.04 per cent) for number of capsules plant⁻¹ and VRI 1 X TMV 3 (32.15 %) for seed yield plant⁻¹.

The hybrid TMV 3 X VRI 1 (40.46 %) had significant positive standard heterosis for seed yield plant⁻¹. The hybrid VRI 1 X TMV 6 possessed significant positive value for 1000 seed weight. Maximum significant positive standard heterosis was observed by the hybrids TMV 6 X CO 1 for harvest index, total chlorophyll content and soluble protein content. In general, heterosis for days to first senescence was required in the negative direction, hence, the crosses TMV 6 X CO 1 and VRI 1 X CO 1 could be used in future crop improvement programme for development of early maturing varieties. Highest positive and significant standard heterosis was observed by the hybrid CO 1 X TMV 6 for soluble protein content and number of capsules plant⁻¹. These findings are in consonance with Pawar and Aher,

(2016); Nayak *et al.* (2017); Karande *et al.* (2018). Positive standard heterosis for harvest index and leaf area index was reported by Backiyarani *et al.* (1998).

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Research Note

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IMPACT OF PMKSY – WATERSHED ON LANDLESS, SMALL AND MARGINAL FARMERS OF SRIKAKULAM DISTRICT OF ANDHRA PRADESH

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India is basically an agrarian society where agriculture alone provides employment to more than 50% of the total population of the country and its contribution to the country's Gross Domestic Product (GDP) is less due to issues of degradation of natural resources, rainwater runoff, soil erosion, floods, frequent droughts and desertification, reduced forest cover, low agricultural productivity, low water availability and poor quality, and poor access to land and related resources. To address these above issues, an integrated watershed management approach is found to be an appropriate solution world over. (Paul Bhaskar *et al.*, 2014). In India, the Department of Land Resources (DoLR), under the Ministry of Rural Development (MoRD), has been implementing the Integrated Watershed Management Programme (IWMP) since 2009. In Andhra Pradesh, the Department of Rural Development through the State Level Nodal Agency (SLNA) is implementing 372 watershed projects with an outlay of Rs.1985.16 crores covering an extent of 15.83 lakh ha in five batches from 2009-10 to 2013-2014.

In Andhra Pradesh, Batch II (2010-11) Projects of PMKSY – watersheds have completed more than seven years period and now the projects are on the verge of consolidation and withdrawal phase. Hence, the study was undertaken during 2018 for assessment

of the Batch II watersheds and to find out the extent of the impact of these projects on the beneficiaries. The objective was to analyse the changes in cropping pattern, cropping intensity, changes in yield and income of the households and to document the impact on the beneficiaries.

Srikakulam District of Andhra Pradesh was purposively selected for the study as this is the only district in the north coastal area where Batch II (2011-11) projects of *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) watershed programmes have been implemented. Further, one project area out of five, namely Vajrapukotturu was selected purposively which is located at a distance of 20 km from its Mandal head-quarters and 110 km from the district head-quarters. The average annual rainfall in the area is 1130 mm. The temperatures in the area are in the range between 36 °C during summer and 26.6 °C during winter. There are 13 micro-watersheds in the project area with a total geographical area of 4777 ha. The project is being operated at the district level by the District Watershed Management Agency (DWMA), Srikakulam.

Selection of Households: Households were selected randomly and categorized into landless, marginal (< 1 ha) and small farmers (1 ha - 2 ha) based on their land holdings as PMKSY-watersheds

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projects majorly cater to the needs of the landless and small farmers. The total number of households in each category was 20, thus, the sample size was 60. Matching sample of 30 households, ten in each category was selected outside the non-project area for comparison purpose which forms control group/non-beneficiaries. Thus, the total sample size was 90.

The primary data was collected for both the pre-project (2010-11) and post-project (2017-18) periods after pre-testing the questionnaire by recall techniques through cross-checking questions to ascertain the reliability and validity of data. The secondary data was obtained from the available records and reports available at the watershed computer centre.

Average size of family and literacy levels

At the end of the project, landless families either purchased or converted forest lands to cultivable land and started cultivating the land. The literacy percentage (2% rise in landless, 4 % rise in marginal farmers and 6 % rise in small farmers) and holding size of land increased (nil to 0.18 acres in case of landless; 1.38 acres to 1.62 acres in case of marginal farmers and 2.81 acres to 3.83 acres in case of small farmers) from pre to post periods, though average family size decreased (5 no. to 4 no.) during the same period among the beneficiaries category.

Crops grown

The major crops grown both by beneficiaries and non-beneficiaries were rice, groundnut and pulses besides cashew nut. However, during post-project,

the respondents were growing rice, groundnut, pulses, maize and up to some extent sugarcane, due to water storage in tanks, ponds, check-dams available in the selected areas after implementation of the watershed project. Project implementation resulted in an increase in area under irrigation leading to increase in productivity. Similar cropping pattern was observed in case of non - beneficiaries in both the periods.

Cropping Intensity

Cropping intensity was more in the project area for marginal and small farmers *i.e.* 1.56% and 1.37%, respectively as compared to 1.07% and 1.06%, respectively of non-project area for similar category of farmers considering pre-project and post- project periods. This might be due to the availability of water and adoption of new technologies in addition to bringing uncultivable area and wastelands under cultivation.

Productivity of important crops

Incremental differences in crop productivity to the tune of 966 kg ha⁻¹ was observed especially in paddy during *Rabi* season among the beneficiaries compared to pre-project *rabi* grown paddy. Similar observations were recorded in *Kharif* rice (665 kg ha⁻¹) and pulses (207 kg ha⁻¹). This might be due to the availability of irrigation water during *Rabi* season as a result of project implementation.

Income from all sources

The major source of income for marginal and small farmers was agriculture, contributing to more than 30% of the total income during the pre-project period followed by wages from agriculture and Mahatma Gandhi National Rural Employment

Guarantee Scheme (Act) (MGNREGA). A similar trend was noticed in post-project period among the marginal (40%) and small farmers (46%). However, for landless households wages from agriculture and MGNREGA / Watershed formed a major share (around 80%) in the total income. The increase in agriculture income from pre to post for marginal and small farmers was due to the irrigation sources generated by PMKSY-Watersheds project. Also, the income of landless respondents has increased from pre-project to post-project as the result of the implementation of Watershed / MGNREGA programme in the project area. A similar trend was also observed for non-beneficiary respondents, but not to the extent of project households because of the spill-over effects of the watershed programme and existence of other State and Central Govt. Rural Development programmes.

Perceptions of respondents regarding PMKSY-watersheds

The perceptions of the respondents regarding PMKSY-Watersheds programme was documented while conducting focused group discussions at various meetings. The perceptions were ranked by using Garrett's Table based on the mean scores. "Identification and implementation of Entry Point Activities" programme secured the highest rank (around 99%) among all the activities followed by "Conducting of PRA tools" (83%) and "Quality of NRM works" (80%). It is evident that the project implementing agency has taken all the precautions and conducted a situation analysis of the villages in identification of entry point activities. It was opined that the project also created necessary community assets which led to the increase in employment man-

days (61%) and income generation (58%).

The analysis revealed that there was an increase in literacy levels, average size of holding, cropping intensity, crop productivity and income among the selected respondents from pre to post-project periods due to the implementation of PMKSY-Watershed programme in the study area. A similar trend was observed even in non-beneficiaries because of the spill-over effects of the watershed programme as well as the existence of other State and Central Government rural development programmes in the selected area. Nevertheless, the impact was more among the beneficiaries compared to non-beneficiaries which could be attributed to the project. Further, it was perceived that the project created community assets which led to the enhancement of direct and indirect employment, thus, augmenting their income.

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