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CONTENTS

## PART I : REVIEW ARTICLE



## PART II : PLANT SCIENCES



## PART III : SOCIAL SCIENCE



## PART IV : HOME SCIENCE



## PART V : RESEARCH NOTES

Review Article
The J. Res. PJTSAU 47(1)1-10, 2019

# BREEDING COTTON GENOTYPES FOR HIGH DENSITY PLANTING SYSTEM – A NECESSITY IN THE INDIAN CONTEXT

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## ABSTRACT

High Density Planting System (HDPS) in cotton is one of the alternate production system for enhancing productivity and is being followed in the major cotton growing countries *viz.,* USA, Australia, China, Brazil and Uzbekistan by using compact plant varieties at a plant densities varying from 1.0 lakh to 2.5 lakh plants / ha. On the contrary India farmers are using robust hybrids due to which the plant population seldom exceeds 55,000 plants / ha which may be one of the reasons for low productivity *i.e*., around 500 kg / ha even after the introduction of Bt cotton hybrids. Cotton farmers in India are compelled to adopt HDPS even with Bt cotton hybrids involving high seed rate and cost. However, this practice is proved to be non remunerative as the architecture of the hybrid varieties does not allow any agronomic interventions. Therefore, to improve the productivity levels, development of compact and semi compact plant types with less number of monopodia, more number of short sympodia, medium boll weight (3 gr), 8-14 bolls per plant, earliness and synchronous maturity along with good physiological attributes need to be prioritized. Although efforts are being made in India to develop short compact plant types that are amenable for HDPS, not much progress has been observed so far and hence efforts need to be continued to develop suitable plant types along with good fibre quality to harness better profits from rainfed cotton grown in marginal shallow soils. This review focuses on various studies carried out on the development of compact plant genotypes amenable for HDPS by exploiting heterosis and combining ability along with identification of stable compact plant types.

Cotton (*Gossypium* spp.) popularly called "White Gold" and "King of Fibre Crops" is the most important renewable natural fibre crop of global importance enjoying a premier position among all the commercial crops. It occupies the predominant position in the Indian textile industry, despite stiff competition from the man-made synthetic fibres. It caters to one of the important basic needs of human race *i.e*., clothing, besides meeting various industrial needs of cellulose and medicated absorbent cotton. The seed oil is also edible and can be used for the culinary purpose as refined oil. Cotton is cultivated in 77 countries of the world in an area of 30.92 million ha with a production of 100.22 million bales. India ranks first in area with 10.50 Mha and produces 35.1 million bales (1 bale = 170 kgs of lint) with a productivity of 568 Kg ha$^{-1}$ (www.cotcorp.gov.in). Almost two third of area under cotton cultivation is rain dependent and the productivity got stagnated during the past five years at around 500 kg lint/ha. This could be attributed to the fact that a large area (more than 90 per cent) is being cultivated with Bt cotton hybrids with a plant population of 9000 to 12,000 plants per hectare even under rainfed conditions.

The concept of high density planting system, popularly known as Ultra Narrow Row (UNR) cotton was initiated by Briggs *et. al*. (1967). It is a system that can accommodate a plant population of 2.0 to 2.5 lakh plants / ha against conventional planting system with a plant population of 1.0 lakh plants/ha. The UNR system is popular in the countries like Brazil, Australia, Spain, Uzbekistan, Argentina, USA and Greece (Rossi *et al*., 2004). The UNR cotton plants produce fewer bolls per plant than conventionally planted cotton but retain high percentage of total bolls in the first sympodial position than second sympodial position (Vories and Glover, 2006) besides having better light reception, efficient leaf area development and early canopy exposure which reduce the competition with weeds (Wright *et al*., 2011). The early maturity of the genotypes can make this system ideal for marginal soils under rainfed conditions (Jost and Cothern, 2001). As such, HDPS is considered as an alternative production system having a potential for enhancing the productivity of rainfed cotton besides improving input efficiency, reducing input costs efficient surveillance against pests and diseases (Pradeep and Sumalani, 2005) and minimizing risks associated with present cotton production system.

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Singh et al, (1974) proposed an ideal type for tetraploid (G. *hirsulum* L) and diploid (*G. arboreum* L) cotton under irrigated conditions of North India which include short stature (90-120 cm), compact and sympodial plant habit with unimodal distribution of bolling and high degree of inter plant competitive ability. At present *G. hirsutum* varieties/ hybrids that are cultivated under rainfed situations have low plant population (ranging from 12,345 to 18,520 plants/ ha) which adversely affect the attainment of high yields. These varieties and hybrids do not respond to increased plant population per unit area (Jain *et al*., 1981 and Nahara *et al.,* 1982) which give only 10-15% higher yield than with normal plant population. This is mainly because of the plant canopy of cotton varieties/ hybrids is pyramidal in shape, bearing extended long branches thus requiring wide spacing between rows (Kadapa, 1989). World over during the last three decades, efforts were concentrated to breed varieties with short sympodia, fewer bolls per plant and amenable to HDPS. On the contrary, in India hybrids with high vegetative luxuriance were developed and popularized making HDPS ineffective (Tamilselvam *et al.,* 2013).

HDPS in cotton is commonly followed to obtain high yields with straight varieties across the world, especially in the major cotton growing countries *viz.,* USA, Australia, China, Brazil and Uzbekistan. In these countries suitable plant types were developed to accommodate plant densities ranging from 1.0 lakh to 2.5 lakh plants / ha using narrow and ultra narrow spacing (Gunasekaran *et al*., 2014). However, in India the recommended plant density for cotton seldom exceeds 55000 plants/ha (Venugopalan *et al*., 2013).

The era of hybrids has seen increased productivity coupled with robustness of cotton and thus led to increase in number of pickings. Even though the robust hybrid plant types have contributed to increase in boll number and seed cotton yield, the remunerative value of robust hybrid cotton plant has at times taken a beating because of increase in cost of hybrid seed, plant protection measures against sucking pests, harvesting cost associated with manual picking and lower per day productivity (Patil *et al*., 2014).

Cotton farmers in India were compelled to adopt HDPS in the recent past owing to its cultivation in unfavourable ecologies. Interestingly this system is being followed with Bt hybrids involving high seed rate and seed cost. Preliminary experiments with some of the released semi-compact genotypes under high density planting system with a plant population of around 1,50,000 / ha indicated the possibility of breaking the yield barrier, especially under rainfed ecology. These experiments indicated that productivity of more than 1000 kg lint / ha is possible even in marginal shallow soils under rainfed situation (Manickam *et al*., 2014a).

At CICR, Nagpur thirteen genotypes from diverse agro-climates were evaluated at 3 spacings, 45 x15 cm (1,48,000 plants/ha), 60 x 15 cm (1,11,000 plants/ha) and 90 x 15 cm (74,000 plants/ha) on a shallow black soil under rainfed conditions. The genotypes evaluated include NH 615 and NH 545 from Nanded, ADB 39 and MDLH 1 from Adilabad, Suraj and LRK 516 from Coimbatore, KC 3 from Kovilpatti, RS 875 from Sriganganagar, CSH 3178 from Sirsa, F 2383 from Faridkot, H 6 Bt and H 8 Bt (BG II) from Surat and PKV 081 from Akola. The effect of spacing, genotypes and spacing x genotypes were significant. Across genotypes yield at 45 x 15 cm and 60 x 15 cm were at par and superior to 90 x 15 cm. Genotypes ADB 39 (3000 kg/ha), PKV 081 (3011 kg/ha) and LRK 516 (2814 kg/ha) performed well at 45 x 15 cm spacing whereas genotypes NH 545 (2830 kg/ha), NH 615 (2633 kg/ha), KC 3 (3113 kg/ha) and Suraj (2976 kg/ha) gave highest yield at 60 x 15 cm spacing (Venu Gopalan *et al.,* : 2013).

Preliminary results from the above studies clearly suggest that, HDPS is more relevant to India as cotton is being cultivated under rainfed conditions in about 60% of the area thus resulting in low productivity due to negative effect of low soil moisture on boll formation and retention particularly in shallow soils. The cotton cultivation in newly formed state of Telangana is characterized by large scale cultivation of Bt cotton hybrids in light soils under rainfed conditions. Even though, there is a large area under cotton cultivation in Telangana (12.50 lakh ha), the productivity remains stagnated at 653.0 kg $ha^{-1}$ (www.cotcorp.gov.in) either due to midseason or terminal drought. The productivity of cotton in the state can be improved in light soils with low moisture retention capacity by developing short compact genotypes with early maturity and suitable for HDPS. The obvious advantage of this system is earliness (Rossi *et al*., 2004) since it needs less bolls per plant to achieve the same yield as conventional cotton and the crop does not have to maintain the late formed bolls. The efforts to develop plant types suitable for HDPS have been made across the world for the past three decades and considerable progress was made but there is an urgent need to develop varieties required for HDPS particularly in the countries like India, where more than 60% of the cotton is grown on shallow soils under rainfed conditions.

A systematic breeding programme was initiated in 1996 at ARS, Mudhol/Adilabad through multiple crossing to identify cotton genotypes with short and compact architecture (Pradeep and Sumalini, 2005) possessing short sympodia and lowest or zero monopodia that enable the genotypes to adjust to various agronomic manipulations. As a result, about 30 genotypes were identified from different cross combinations and were evaluated for the traits conferring compact architecture. Finally, half a dozen genotypes were shortlisted for MLT / adoptive trials under HDPS at state and national level. Two early maturing genotypes i.e. ADB-39 and ADB-532 were found promising under 45 x10 cm (2.2 lakh plants /ha) and 45 x 15 cm (1.48 lakh plants/ha) on shallow soils at Nagpur. Besides, ADB-39 ranked second at national level in multilocation trial (IVT-HDPS) during 2011-2013. It is pertinent to mention here that although there were other genotypes such as Suraj, NH615, KC3 and Anjali in addition to the above two which were found promising, their performance under wider row spacing i.e., 60 x 15 cm or 90 x 15 cm was comparatively better suggesting their semi compact plant architecture. This might be because of the fact that these varieties were not bred for closer spacing but were selected from the germplasm. However, concerted efforts on HDPS using a few selected straight varieties were initiated by CICR, Nagpur in 2010 (AICCIP, 2012). Keeping in view of need of the hour to develop varieties suitable for HDPS, it is reviewed here under the breeding efforts that were focussed on development of varieties amenable for HDPS through studies on combining ability, heterosis and stability for productive traits and plant type along with better quality of the fibre.

**Combining ability**

Studies on combining ability are useful to understand the nature of genetic variance. Combining ability helps the breeder to choose suitable parents for developing either hybrids or varieties. The concepts of general and specific combining ability were introduced by Sprague and Tatum (1942) who defined general combining ability (GCA) as the average performance of a line in hybrid combinations, while the specific combining ability (SCA) as the deviation from performance predicted on the basis of GCA. The concept of combining ability provides the scientific basis for formulating efficient breeding strategy for the improvement in yield as well as in any individual desired characters.

General combining ability is the result of additive gene effect, while specific combining ability is considered to be composed of non-allelic interaction (Jinks, 1954).

Sangam *et al*. (2004) reported the importance of non-additive component of variance for plant type traits *viz.,* plant height, number and length of sympodia, number and length of monopodia, angle of sympodia on main stem, leaf area, leaf area index and plant yield. Further the study also revealed the importance of low x low combining parents for breeding compact plant types while evaluating 50 hybrids along with 15 parents at a spacing of 67.5 cm x 60 cm. Verma *et al.* (2004) opined that for most of the yield, quality and yield contributing characters *viz.,* seed cotton yield, plant height, number of monopodia, number of sympodia, boll number per plant, boll weight, ginning out turn, micronaire value, 2.5% span length and bundle strength non additive gene action is important. The testers RS 2013 and LH 1556 and lines namely CISV 31, CISV 48, CISV 12, CISV 6 and CIT 7-2 were found good general combiners for seed cotton yield and on the basis of *sca* effects, the combinations CISV 29 X RS 810, CISV 29 X RS 2013, CISV 47 X H 777, CISV 48 X H 1098, CISV 6 X RS 810, CISV 6 X RS 2013, CIT 7-2 X H 777 and Cit 7-2 X H 1098 exhibited highest magnitude of positive significant effects for seed cotton yield and its components.

Basbag *et al.* (2007) estimated the general combining ability of parents and specific combining ability of hybrids for earliness through a study conducted by crossing three intermediate – early maturing lines with four early maturity testers and evaluated the hybrids along with their parents at a spacing of 70 cm x 15 cm and observed predominance of non-additive gene effects for days to first square, days to first flower and harvested date of first picking. Among the lines, Ersan 92 and Maras 92 and among the testers, Acala Royal were found to be the best general combiners for earliness. Four out of twelve crosses *viz.,* Ersan 92_Chirpan 603, Ersan 92_Acala Maxa, Maras 92_Acala Royal and Nazilli 87_Acala Royal were found to be the best crosses for investigated earliness character. Preetha and Raveendran (2008) crossed eight robust cotton genotypes with four genotypes having compact characters in a Line x Tester mating design and evaluated 32 hybrids along with the parents by adopting a spacing of 75 cm x 30 cm. The study revealed that, 2.5% span length was controlled by additive gene action whereas the traits petiole length, length of sympodia, number of flowers per plant, days to 50% flowering, seeds per locule, ginning outturn, lint index, uniformity ratio and elongation percentage were governed predominantly by non-additive component. The parents *viz.,* MCU 9 for seed cotton yield and 2.5% span length and KC 2 for bundle strength were the best combiners. The cross TCH 1608 X TCH 1002 exhibited significant *sca* effects for the characters *i.e.,* boll number and boll weight. Samreen *et al.* (2008) studied combining ability in 15 $F_1$s obtained by crossing five lines and three testers in a Line x Tester mating design. All the hybrids along with parents were evaluated by adopting a spacing of 75 cm X 30 cm and revealed preponderance of additive gene action for all the traits under study. Further, it was also reported that, the parents *viz.,* CIM-506 and NB-999 were found to be the best general combiners for all the traits where as the crosses *viz.,* CIM-497 X BH-147, FH-901 X BH-147, CIM-499 X NB-999 and CIM-499 X BH-147 were found as best specific combiners for number of bolls per plant, boll weight, seed cotton yield per plant and ginning out turn % respectively.

Karademir *et al.* (2009) crossed seven lines with 3 testers and evaluated 21 $F_1$ hybrids along with their parents at a spacing of 70 cm X 15 cm and reported that, fiber length, fiber fineness and fiber elongation were influenced by additive gene effects where as seed cotton yield, ginning percentage, fiber strength and fiber uniformity were influenced by non-additive gene effects. It was further revealed that, the parents *viz.,* Fiber Max 832, Teks, Stoneville 453 and Maras 92 were found to be good general combiners for seed cotton yield while the parent Askabat 71 was found good for fiber length, fiber strength, fiber fineness and fiber uniformity while most of the parents exhibited significant *gca* effects for ginning percentage. Among the crosses, Fiber Max 832 x Stoneville 453, Tam 94L25 x Maras 92 and Teks x Stoneville 453 had shown significant *sca* effects for yield with acceptable quality. Ashokkumar *et al.* (2010) evaluated eleven genotypes and 28 $F_1$ hybrids obtained by crossing four lines and seven testers by adopting a spacing of 75 cm X 30 cm and found that the parents MCU 12 and F 1561 were good general combiners for the characters such as number of bolls per plant, boll weight, seed cotton yield per plant and seed cotton yield per plant, number of bolls per plant respectively where as the parent SOCC 17 for earliness, surabhi for number of sympodia and TCH 1641 for ginning out turn and lint index. Among the hybrids, MCU 12 X F 1861, SVPR 2 X F 776 and MCU 5 X TCH 1644 showed significant negative *sca* effects for earliness where as significant high *sca* expression was exhibited by the crosses like surabhi X F 1861 for boll weight, MCU 5 X TCH 1644 and MCU 12 X SOCC 11 for lint index, MCU 5 X TCH 1646 for seed index. Basal *et al.* (2011) reported significant GCA and SCA mean squares for all the traits, however, non-additive gene action was predominant. Among the parents, Sahin 2000 and Tamcot-22 were the best general combiners for yield and its components, and Carmen was the best general combiner for improvement in fiber quality. The best specific combinations were S-2000 × SJ-U86 and GSN-12 × NIAB-999 for boll number; BA-119 × DPL90 for boll weight; S-2000 × NIAB-999 for seed cotton yield, GSN-12 × Eva for fiber length; GSN-12 × AZ-31 and BA-119 × Tamcot-22 for fiber strength while evaluating 35 $F_1$ hybrids obtained through crossing five lines and seven testers at a spacing of 70 cm x 20 cm.

Jatoi *et al.* (2011) evaluated 15 $F_1$ upland cotton hybrids at a spacing of 75 cm x 30 cm and reported preponderance of additive gene action. Among the parents NIAB-78 and CRIS-134 were the best general combiners for majority of the characters. The hybrids *viz.,* Chandi – 95 X Shahbaz, CRIS-9 X Shahbaz, Sadori X Shahbaz, NIAB-78 X CRIS-134 and NIAB-78 X Shahbaz were the best specific combiners for the characters *viz.,* number of sympodia per plant, number of bolls per plant, boll weight, seed cotton yield per plant and lint percentage. Alkuddsi *et al.* (2013) studied the performance of 48 $F_1$ hybrids of upland cotton derived from crossing six hirsutum non-Bt robust type lines with eight hirsutum non-Bt compact type testers in a Line x Tester mating design and reported that, dominance variance was predominant for all the characters where as both additive and dominance variances were found to be important for the characters *viz.,* number of monopodia per plant, mean boll weight, days to 50% flowering, seed index and lint index. Baloch *et al*. (2014) evaluated 15 $F_1$ hybrids obtained through crossing five lines and three testers in line x tester design by adopting a spacing of 75 cm x 30 cm and reported that the characters *viz.,*bolls plant$^{-1}$, boll weight, seed cotton yield and lint% were controlled by both additive and dominant genes. Deosarkar *et al.* (2014) studied the performance of 54 $F_1$ hybrids of upland cotton with a spacing of 60 cm x 60 cm and reported the existence of non-additive gene action for the characters *viz.,* days to 50% flowering, plant height, number of monopodia, number of sympodia, number of bolls per plant, boll weight, ginning percentage, seed index, 2.5% span length, micronaire value, fiber strength, uniformity ratio and seed cotton yield. It was further reported that, the cross NH 572 x PH 1009 had shown significant negative *sca* effects for days to 50% flowering and the hybrid L 765 X PH 330 had expressed highest significant negative *sca* effect for number of monopodia per plant.

Kannan and Saravanan (2015) reported that the parents CG 64, CG 67 and CG 45 SB were good general combiners for the seed cotton yield per plant and number of bolls per plant. Further revealed that two crosses CG 64 x CG 45 SB and CG 67 x CG 45 SB registered significant *per se* performance, positive *sca* effects along with significant positive standard heterosis for seed cotton yield and majority of yield components and fiber quality traits through evaluating 21 hybrids along with seven lines and three testers and one check. Sawarkar *et al.* (2015) evaluated eighteen upland cotton hybrids obtained by crossing three lines with six testers along with the parents at a spacing of 60 cm x 60 cm and reported preponderance of non-additive gene action for all the characters under study except plant height, 2.5% span length and oil content. Among the parents, DR-7R was found good general combiner for boll weight and AKH 780 for days to 50% flowering, days to 50% boll bursting and fiber fineness. AK 023 was found as best general combiner for days to 50% flowering, days to 50% boll bursting, 2.5% span length. The hybrids *viz.,* AK 032 X AKH-780 had shown significant and desirable sca effects for days to 50% flowering, days to 50% boll bursting where as AK053 X IET-6 had shown desirable *sca* effects for number of sympodia and boll weight. AK023 X DR-7R had shown highest significant sca effect for number of bolls per plant, boll weight and seed cotton yield per plant. Sivia *et al*. (2017) evaluated 60 F1 hybrids obtained by crossing 15 lines and 4 testers in Line x Tester mating design at a spacing of 67.5 cm x 60 cm and reported preponderance of non-additive gene action for seed cotton yield per plant and majority of its component traits. Among the parents, the parents *viz*., H1156 for days to first flowering, H1471 for plant height, AC726 for monopods per plant, H1464 for boll weight, H476 for seeds per boll and H1470 for seed cotton yield per plant, bolls per plant and sympods per plant were found to exhibit higher general combining ability while the significant SCA effects for seed cotton yield were exhibited by the cross combinations AC726 x H1236, H1476 x H1226, Luxmi PKV X H1226, H1470 X H 1098-I and H1470 X H1236.

Murthy *et al*., (2018) evaluated 42 $F_1$ cross combinations derived by crossing 6 lines and 7 testers that possessed compact plant type characteristics at three different locations by adopting a spacing of 60 cm x 30 cm and revealed preponderance of non-additive gene action for majority of compact plant type features and identified a few lines *viz*., MC 17-6, MC 16-3, MC 4-3 and the testers NH 630 and MC 19-2 as best general combiners for compact plant type characters. Further, it was concluded that the crosses MC 9-1 x NH 630, MC 17-6 x MC 19-2 and MC 4-3 x MC 3-2 were found to be the best specific combiners for compact plant type features *viz*., short stature, earliness, more number of sympodia, high leaf area, medium to high seed cotton yield per plant, number of bolls per plant, high harvest index and boll weight with desirable fiber quality.

**Heterosis**

Estimation of heterosis may be useful in identifying superior hybrids having desirable traits including seed cotton yield and fiber quality. Till date, the research on developing compact cotton hybrids suitable for high density planting system is meager.

Hence, the available literature on exploitation of heterosis for developing compact cotton hybrids is reviewed hereunder

Anuradha (1998) suggested that to develop potential hybrids in cotton it is necessary to exploit genetic diversity available in the form of visible differences in plant type traits and a cross between robust types and compact types can lead to improvement in higher productivity as a result of superimposition of the desirable features of these contrasting plant types in the $F_1$ hybrids. Katanalli *et al*. (2004) evaluated inter and intra plant type crosses involving compact and robust cotton genotypes where in interplant crosses (robust x compact) were developed through line x tester mating design and intraplant (robust x robust) crosses were developed through 7x7 diallel mating design. Comparison of interplant type crosses with intrarobust crosses revealed that, interplant type crosses showed reduction in plant stature and were found more productive and heterotic for seed cotton yield than intrarobust crosses. Potdukhe (2002) evaluated fifteen $F_1$ hybrids along with eight parents by adopting a spacing of 60 cm x 60 cm and reported highest significant heterosis in positive direction for seed cotton yield, number of bolls per plant, number of monopodia, plant height, number of sympodia, lint index, seed index and ginning percentage whereas desirable significant heterosis in negative direction was recorded for days to 50% flowering. The cross Sahana x JLH 168 had exhibited highest heterosis for characters *viz.,* seed cotton yield, bolls per plant, plant height, lint index and seed index.

Sangam *et al*. (2004) reported that, compact x medium compact plant type combination had high heterotic hybrids for yield with low to moderate heterosis for plant type traits, indicating the physiological efficiency of the plant type traits in enhancing the yield per se. Karademir *et al.* (2009) crossed seven lines with three testers and evaluated 21 $F_1$ hybrids along with their parents at a spacing of 70 cm X 15 cm and opined that, the crosses Askabat 71 x Stoneville 453 had shown significant positive heterosis for seed cotton yield and fiber length. The crosses *viz.,* Bahr 14 x Stoneville 453, Bahar 14 x Sayar 314 , Bahar 14 x Maras 92 had shown significant positive heterosis for ginning percentage whereas Askabat 71 x Maras 92, Askabat 71 x Sayar 314 and Teks x Stoneville 453 had shown significant negative heterosis for micronaire value. Highest significant positive heterosis for fiber strength, fiber elongation and fiber uniformity were shown by the crosses FiberMax 832 x Stneville 453, Bahar 14 x Sayar 314 and Aksabat 71 x Maras 92 respectively. Ashokkumar *et al.* (2010) observed highly significant negative mid parent heterosis for the characters *viz.,* days to first flowering and days to 50% flowering in a study of 28 $F_1$ hybrids along with eleven parents obtained through Line x Tester mating system at a spacing of 75 cm x 30 cm. Basal *et al.* (2011) evaluated 35 $F_1$ hybrids derived by crossing five lines with seven testers in a line x tester mating design at a spacing of 70 cm x 20 cm and reported that, the highest heterosis was observed for yield, boll number, boll weight and lint % with values of 79.8, 19.8, 35.2, and 5.7%, respectively. Heterosis values for fiber quality parameters were generally lower than that for yield components and 14.1% heterosis was observed for micronaire. The $F_1$ hybrids viz; Sahin-2000 × Tamcot-22, Sahin-2000 × NIAB-999, Carmen × Tamcot-22, and Carmen × NIAB-999 were reported as high yielding hybrids with acceptable fiber quality parameters.

Ranganatha *et al.* (2013a) studied extent of heterosis for seed cotton yield and its attributing traits in 54 inter plant type hybrids of cotton developed by crossing nine robust lines with six compact testers in line × tester mating design and reported that, the hybrids $L_1$ X $T_4$ and $L_5$ X $T_6$ exhibited significant negative heterosis over both the standard checks for interboll distance. The other hybrid *viz.,* $L_9$ X $T_2$ was found to be superior for boll weight and lint index. Tuteja and Agarwal (2014) studied magnitude of heterosis in 52 hybrids derived through crossing 4 lines and 13 testers in line X tester mating design and reported significant economic heterosis for the characters *viz.,* number of bolls per plant, boll weight, ginning percentage, boll weight, 2.5% span length and fiberstrength. The hybrids *viz.,* GMS 17 X EC 138572, GMS 17 X CSH 3129 and GMS 20 X EC 128334 had shown negative economic heterosis for boll number per plant.

Hanif *et al.* (2015) evaluated 15 $F_1$ and their $F_2$ populations developed by crossing eight genotypes in line x tester mating design at high density by adopting a spacing of 75cm x 30 cm and reported that, the $F_1$ hybrids *viz.,* CRIS-121 **×** Tarzan-1, CRIS-129 **×** Tarzan-1 and MNH-886 **×** BT-121 exhibited negative heterosis for number of sympodial branches, number of bolls per plant and seed cotton yield per plant where as the $F_2$ populations from CRIS-121 × MNH-886, CRIS-129 × MNH-886, MNH-886 × Tarzan-1, MNH-886 × FBS-26, BT-121 × Tarzan-1, CRIS-121 × FBS-26, CRIS-121 × BT-121, CRIS-121 × Tarzan-1 and FBS-26 × Tarzan-1 indicated decrease in mean values for the above said characters, showing the possibility of exploitation of heterosis for developing genotypes with compact characters from the segregating generations. Sawarkar *et al.* (2015) evaluated eighteen $F_1$ hybrids along with nine parents at a spacing of 60 cm x 60 cm and reported that, the cross AK 023 X DR-7R had shown maximum heterosis for seed cotton yield per plant over the standard check where as highest significant heterosis in desired direction for fiber strength and number of bolls per plant was recorded in a cross AK 023 x DR-7R followed by AK 023 x AKH-976 over the standard check.

Murthy *et al*., (2017a) reported that, the cross combinations MC 17-6 x MC 19-2, MC 23-2 x MC 17-2, MC 17-6 x MC 17-1, MC 9-1 x NH 630 and MC 4-3 x MC 3-2 were found to exhibit seed cotton yield per plant on par with both the checks along with short compact plant type characteristics besides showing significant standard heterosis for quality traits like ginning outturn, 2.5% span length, uniformity ratio and bundle strength.

**Stability**

According to Finlay and Wilkinson (1963), the stability parameters of a genotype are its phenotypic regression coefficient (bi), a measure of the response of the $i^{th}$ variety to changing environments. A genotype with a unit ‘bi `and higher mean yield (Xi) is said to be stable over a range of environments. As the mean yield decreases, a genotype with high or low slopes is regarded as being specifically adapted to favourable and unfavourable environment respectively. Eberhart and Russel (1966) extended the model of Finlay and Wilkinson (1963) by considering deviations from the regression of $i^{th}$ variety at $j^{th}$ environment (dij) as another important component.

A number of studies have been carried out with hybrids and populations to know G × E interactions and stability of performance over season and locations.

A stable variety is one with a regression slope near to unity, non-significant deviation from regression line and higher mean yield. Perkins and Jinks (1968) proposed that a regression of genotype × environmental interactions on environmental index should be obtained rather than regression of mean performance on the latter as done in the model.

Sreerekha and Pradeep (2015) conducted stability analysis of ten multiple cross derivative lines of cotton through Eberhart and Russell model and reported that, the multiple cross derivatives *viz.,* ADB 159, ADB 160 and ADB 164 were stable and exhibited dwarf stature and found high yielding with high boll weight, possessed less than one monopodia per plant, average number of sympodia and bolls per plant based on mean performance over three fertility levels studied. Further, it was also revealed that their performance was stable even at high fertility level and hence can be amenable for high density planting.

Murthy (2017) studied the stability of 42 cross combinations derived by hybridization between selected multiple cross derivatives that possessed compact plant type characteristics at three different locations and concluded that the cross combination MC 17-6 x MC 3-2 had shown stable performance over different locations for the traits seed cotton yield, length of the sympodia, leaf area, number of bolls, 2.5% span length and bundle strength.

Similarly the same 42 cross combinations were also evaluated to identify hybrid combinations that possessed compact plant type traits with desirable fiber quality and it was concluded that the hybrids with short plant stature (30-35 cm), more number of short sympodial branches (6-8), less or zero monopodia, medium to high number of bolls per plant (8-12), high leaf area, high harvest index (50% and above) with desirable fiber quality may be useful in promotion of compact hybrids under HDPS (Murthy, 2017).

Korekar *et al*., (2017) evaluated 20 $F_1$ hybrids derived through crossing five Bt transgenic lines with four non-Bt lines in a line x tester mating design and reported that the ideotype for high density planting system should have open to semi open plant architecture with determinate growth habit. Further the study has also revealed that to evolve most suitable hybrids for high density planting (HDP) at least one of the parents must be of open plant type with determinant plant growth habit, whereas second parent can be of varied plant type and growth pattern, provided there is nice complementation with the first parent whereas the cross combinations SC1104 X 1205, SC1134 X

1205 and SC1112 X 1205 have been identified as most suitable for high density planting (HDP).

**Conclusion**

The productivity of rainfed cotton in marginal shallow soils can be enhanced by developing plant types suitable for HDPS. From the above review it is clear that although many studies were carried out adopting closer spacings, the suitability of the genotypes to HDPS was not critically evaluated except in a few cases. However, a few genotypes like Suraj, PKV 081, NH-615, KC3, Anjali, F2383 and ADB-39 were identified and evaluated at higher plant densities of 1.5 to 2.2 lakh plants/ha at 45-60 cm row spacing, but still there is a need to develop ideotypes like ADB-39 & 532 with Bt background for faster adoption of the technology. The strategy should be multipronged and aim at exploiting heterosis and combining ability by making hybridization between robust and compact plant types, compact and compact plant types and compact and semi compact plant types. Multiple crossing programme with 1-2 cycles of inter mating in segregating populations would likely to through desirable recombinants by breaking the light linkages. The recent tools like molecular markers and transgenic technology may also be utilized for transfer of traits like resistance to various biotic and abiotic stresses as the system of high-density planting is offering adavantages in terms of enhanced productivity, weed management, better pest surveillance and management and machine harvesting. Further, the genotypes / hybrid combinations identified in different studies could be evaluated under HDPS along with studies on root, biochemical and physiological traits related to drought tolerance to identify plant types suitable for light soils under rainfed conditions at increased plant densities in addition to genetic analysis of the cotton genotypes by using EST-SSR markers for understanding the expression of traits under HDPS. While breeding the genotypes for HDPS, priority should also be given to study the variability for inherent seed dormancy among the genotypes, which could be used for identification of varieties that can avoid germination of seeds due to rains coinciding with maturity stage.

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# SCREENING OF THE RECOMBINANT INBRED LINE MAPPING POPULATION OF RICE DERIVED FROM CROSS WAZUHOPHEK X IMPROVED SAMBA MAHSURI FOR LOW SOIL P TOLERANCE

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## ABSTRACT

Rice (*Oryza sativa* L.) is one of the principal staple food crops, which feeds a major portion of the world's population. Various biotic and abiotic stresses *viz.,* plant diseases, pests, water scarcity, salinity, soil nutrient deficiencies and a rapidly changing climate affects the rice production significantly. In the present study, an effort was made to develop breeding lines in the genetic background of the elite, bacterial blight (BB) resistant, fine-grain type rice variety, Improved Samba Mahsuri (ISM) for tolerance to soil phosphorus (P) deficiency by using the rice line, Wazuhophek (possessing non-*Pup1* type low soil P tolerance), as the donor. Hybridization was made between Wazuhophek and Improved Samba Mahsuri and the derived recombinant inbred line (RIL) mapping population (n = 330; $F_8$ generation) was screened for low soil P tolerance in the low soil P plot (available P < 2 kg $ha^{-1}$) of ICAR-IIRR, Hyderabad, India and also in the normal soil P plot for their resistance against bacterial blight. A total of 191 RILs were tolerant to low soil P condition. Two RILs (KR-100 and KR-295) were identified with higher yield under low P conditions with desirable medium slender grain type. These breeding lines have the potential in saving significant production costs in application of phosphatic fertilizers and increasing profits of farmers.

Rice (*Oryza sativa* L.) is one of the staple and primary food crops that feed a major portion of the world population. Various biotic and abiotic stresses *i.e* plant diseases, water scarcity, soil nutrient deficiency in addition possible adverse effects from climate change affect rice production and productivity. Phosphorus (P) is an essential nutrient to plants as it forms part of several plant structural compounds and also plays key role in numerous key biochemical reactions in plants as its energy currency, i.e. ATP. The overwhelming majority of soils in the rice producing areas, are either P deficient or possess high P-fixing capacity that convert applied P into forms unavailable to the plants, (Vance *et al*., 2003). Low P stress represents a major constraint on plant growth and yield worldwide and Low availability of P in the soils manifests in impeding crop growth leading to yield loss in rice. (Zhang *et al*., 2014). P deficiency in rice will leads to stunted growth with greatly reduced tillers, narrow leaves, spindly stems with reduction in number of leaves, panicles and grains per panicle. P deficiency also delays flowering and maturity by one week or more, when the deficiency is severe, plants may not flower at all and when flowered, large number of empty grains will form with poor grain quality (Dobermann and Fairhurst, 2000). It is pertinent to note that global commercial phosphate reserves are estimated to be depleted in the coming few decades and currently there is no known alternative to substitute inorganic P and it is in the control of only a handful of countries, mainly Morocco, China and the US (Cordell and White, 2011). India is the biggest importer of phosphorus based fertilizers with 90% dependency (Webeck *et al*., 2014). Thus genetic improvement of the tolerance of rice plants to P-limiting is one of the focal areas of research and development in rice in order to minimize the application of phosphatic fertilizers and to enhance sustainable rice production. Various studies has been carried out to study the genetic variation among different crops for low soil P tolerance and have revealed that different phenotypic traits correlate positively and negatively with tolerance to low soil P (Du *et al*., 2008; Islam *et al*., 2008; Krishnamurthy *et al*., 2014; Mukharjee *et al*., 2014; Panigrahy *et al*., 2014; Aluwihare *et al*., 2016; Tian *et al*.,2017; Wang *et al*., 2017). A major QTL/gene associated with tolerance to low available soil P, has been identified on Chr. 12 of rice of an Indian rice variety, Kasalath and it has been named as *Pup1* and has been very well characterized (Wissuwa *et al*., 1998; Wissuwa *et al*., 2002 and Heuer *et al*., 2009). The QTL *Pup1* has since then been fine-mapped, cloned and closely linked markers have been developed (Chin

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*et al.*, 2010; Gamuyao *et al*. 2012). In addition, to *Pup1,* ICAR-IIRR, Hyderabad through a systematic screening in the low soil P plot, has identified several non-*Pup1* type rice lines possessing tolerance to low soil P and one such genotype is Wazuhophek, which has been reported to possess very good level of tolerance for multiple stress tolerance indices (Mahadevaswamy *et al*. 2018).

Bacterial blight (BB), caused by *Xanthomonas oryzae* pv*. oryzae (Xoo)*, is one of the most destructive diseases of rice worldwide and the yield losses can be as high as 50% and significant yield losses have been reported in infected fields, ranging from 20 to 30%, which can reach as high as up to 80% (Noh *et al*., 2007). The rice variety Improved Samba Mahsuri (ISM; also known as RP Bio-226) was developed at ICAR-Indian Institute of Rice Research (ICAR-IIRR) in collaboration with CSIR-Centre for Cellular and Molecular Biology (CSIR-CCMB), Hyderabad by incorporating three bacterial leaf blight (BB) resistance genes (*Xa21, xa13* and *xa5*) into the genetic background of the Indian mega-rice variety, Samba Mahsuri, through MABB (Sundaram *et al*. 2008). It is emerging as the best option for cultivation in the BB endemic areas of country and is presently occupying an area of around 1.3 lakh hectares (Reddy, 2017). However, ISM is susceptible to various abiotic stresses like low soil P.

Earlier, our research group at ICAR-IIRR developed a recombinant inbred line (RIL) mapping population derived from the cross Wazuhophek/ISM ($F_8$ generation) consisting of 330 lines. In the present study, we have analyzed the RIL mapping population for its tolerance towards low soil P conditions and resistance against bacterial blight in the present study.

## MATERIALS AND METHODS

### Development of the mapping population:

Wazuhophek (possessing non-*Pup1* type tolerance to low soil P) was crossed with Improved Samba Mahsuri (possessing high yield, medium slender grain type and high level of resistance against bacterial blight, conferred by *Xa21, xa13* and *xa5*) and the true $F_1$ plants were selfed and advanced through single seed descent method to develop a set of RILs (n = 330; $F_8$ generation). The RIL mapping population was used for screening for low soil P tolerance and bacterial blight resistance along with tolerant checks (Wazuhophek, Swarna and Vandana) and the susceptible check, Improved Samba Mahsuri (ISM) and MTU1010.

### Screening for low P tolerance:

The RIL mapping population mentioned above was screened for low soil P tolerance during *Kharif* 2017 (wet season) in the low soil P plot (available P < 2.5 kg $ha^{-1}$) of ICAR-IIRR, Hyderabad, India (Fig. 1 A and B). All the recommended agronomic practices were followed, except the application of P fertilizers. A total of 33 plants were screened for each of RILs in two replications. The observations for various parameters like days to 50% flowering (DFF), mean plant height (cm), number of productive tillers per plant, flag leaf length (cm), shoot length (cm) , root length (cm) , root volume (ml) , dry shoot weight and dry root weight (g), panicle length (cm) and thousand grain weight were recorded.

## RESULTS AND DISCUSSION

The response of RILs in low soil P condition revealed a normal distribution (Fig. 2 B), indicating that the trait is governed by QTL/genes. Most of the lines were observed to fall in the intermediate category, while some of the lines were as tolerant as Wazuhophek and as sensitive as ISM. Interestingly, the distribution of the RIL population was skewed more towards tolerance, with at least 191 RILs showing good level of tolerance, indicating possible role for major QTLs with respect to the trait phenotype. Based on yield per plant and visual scoring for low soil P tolerance i.e based on plant growth, number of tillers and overall plant structure in comparison of both the parents under field condition and BB resistance, two lines i.e. KR-100 and KR-295 were found to be highly tolerant to low soil P with better root length and root volume in addition to dry root weight and also medium slender grain type.

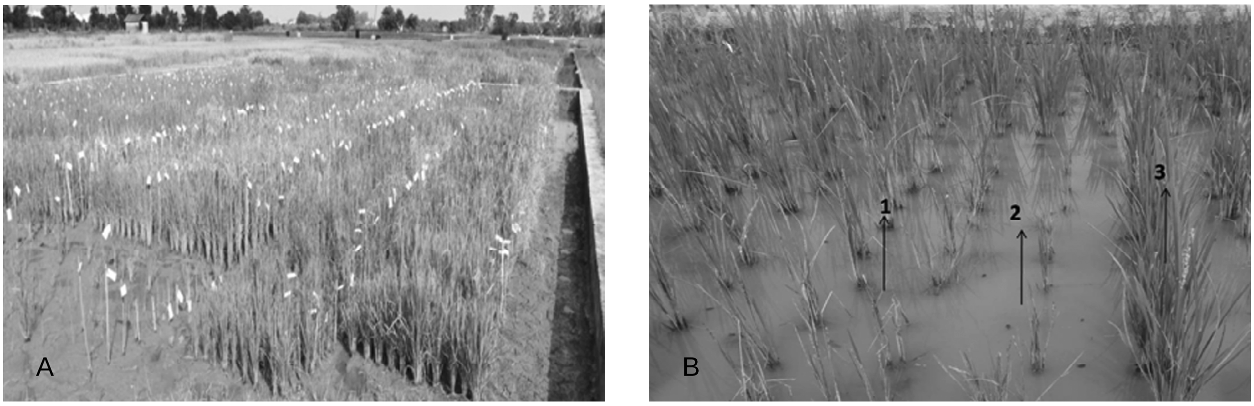


**Fig.1 - Phenotypic screening of recombinant lines along with parents for low soil p tolerance and BB resistance. A. Screening in low soil P plot at IIRR-Hyderabad. B. Indication of low soil P tolerance response with clear difference between recombinant inbred lines (1-lines showing poor survival, 2-lines alomost dead, 3- lines showing good survival)**

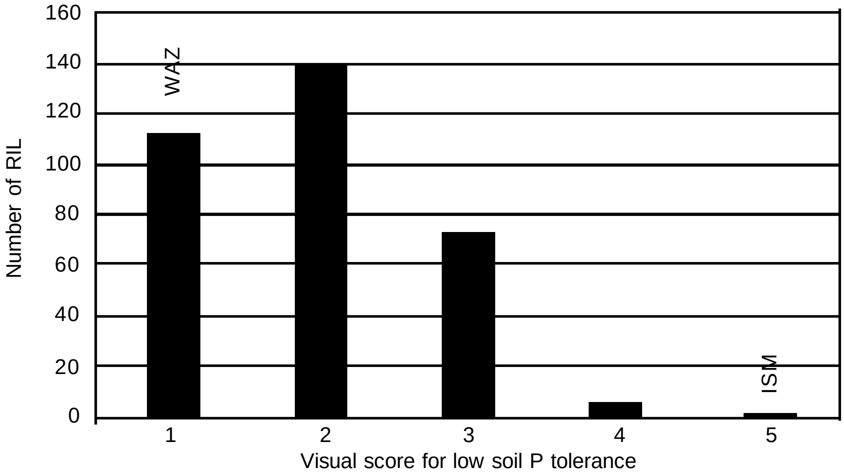


**Fig.2 - Frequency distribution of recombinant inbred lines based on visual screening for low P soil tolerance scoring. Wazuhophek(WAZ), Improved Samba Mahsuri (ISM)**

Improved Samba Mahsuri (ISM; also known as RP Bio 226) is a high yielding, fine-grain type rice variety developed through marker-assisted backcross breeding (MABB), possessing three major bacterial blight (BB) resistance genes, *viz*., *xa13, Xa21* and *xa5* . It is a near-isogenic line of the popular Indian mega-rice variety, Samba Mahsuri (Sundaram *et al*., 2008). ISM has been recently identified to possess a low glycemic index (50.9) and hence is highly suitable for consumption by patients suffering from Type II diabetes. Despite all these advantages, ISM is susceptible to low P soil condition giving very low yields in soils with low level of P (Anila *et al*, 2017). A major quantitative trait locus (QTL) associated with tolerance to low soil P, named *Pup1,* was earlier identified, fine-mapped on Chr. 12 and the candidate gene underlying *Pup1* locus has been cloned (*PSTol kinase*) and characterized (Wissuwa *et al*., 1998; Wissuwa *et al*., 2002; Chin *et al.*, 2010; Gamuyao *et al*. 2012). Analysis of NERICA lines of Africa revealed that there could be genes/QTLs other than *Pup1*, which may encode for low P soil tolerance (Koide *et al*., 2013).

Wauzhophek is a low soil P tolerant rice line from North-eastern part of India and has been reported to be devoid of *Pup1* (Mahadevaswamy *et al*. 2018). In order to improve ISM for its tolerance to soil P-deficiency and to genetically characterize the different loci that are associated with low P soil tolerance, a cross was made by using Wauzhophek as male parent and ISM as female parent to develop a RIL mapping population at ICAR-IIRR, Hyderabad. Mapping population advancement was done through single seed decent method and phenotypic screening for low P soil was done at $F_8$ generation.

Analysis of a few key phenotypic parameters including shoot and root parameters in addition to yield data revealed that the trait of low soil P tolerance in Wazuhophek is polygenic and the skewness of the lines towards tolerance indicates a possibility of identifying one or more major QTLs associated with tolerance. The population will shortly be genotyped using a set of molecular markers for possible identification and characterization of the component loci associated with tolerance. The study has also resulted in identification of some promising RILs that have good level of tolerance to low Soil P. A total of 191 lines recorded very good level of tolerance to low soil P with reasonable yield levels in low soil P, as compared to the sensitive parent, ISM. It was noticed that flowering was delayed under low soil P which also noticed in different crops under low soil P plot (Rodriguez *et. al*., 1998). Phenotypic traits like plant height, tiller number and yield showed drastic reduction in low soil P condition in the sensitive RILs and also in ISM. The reason for reduction of overall plant growth in addition to reduction in yield is the lesser availability of P during crop growth, which affects cell growth and movement of P through the plant for better grain production (Cancellier *et al*., 2012 and Assuero, *et al*., 2004). Dry shoot and dry root weight, root to shoot ratio and root volume was also affected under low soil P. Significant variation was noticed for all these parameters in the RILs and also between Wazhophek and ISM as reported earlier in other studies (Li *et al*., 2009; Chiangmai and Yodmingkhwan, 2011; Aluwihare *et al* ., 2016; and Tian *et al*., 2017). Among the traits analyzed, root architecture and tillering are very important traits serving as key indices for low P soil tolerance (Zhu *et al*., 2005; Nagarajan *et al*., 2016 and Zhang *et al*., 2017). Two RILs, KR-100 and KR-295 also possessed the highly desirable, medium slender grain type like ISM. The two lines showed better root length and root volume in addition to dry root weight and good yield in low soil P and normal conditions as compared to ISM, indicating a key role of these two root associated traits with low soil P tolerance (Table.1). We are advancing these two lines along with other RILs possessing high yield under low soil P for evaluation in larger plots. Cultivation of such lines possessing tolerance to low soil P can enhance the productivity of Samba Mahsuri farmers and reduce their cost of cultivation.

In conclusion, we have screened a set of 330 RILs of Wazuhophek (a rice line possessing non-*Pup1* type tolerance to low soil P) and Improved Samba Mahsuri (a high-yielding, bacterial blight resistant rice variety possessing medium-slender grain type) for their tolerance to low soil P and resistance against bacterial blight, established polygenic inheritance of tolerance and also identified a few lines possessing tolerance to low P stress and possessing high-yield with medium-slender grain type.

**Table 1 : Comparison between parents and RILs for different trait under low P stress condition**

| Traits | Plant height | No. of productive tiller | Panicle length | Shoot length | Root length | Root Volume | Dry shoot weight | Dry root weight | 1000 seed grain weight | Yield / plant |
|---|---|---|---|---|---|---|---|---|---|---|
| **Entry** | | | | | | | | | | |
| Wauzho-phek | 73.00 | 8.00 | 18.00 | 67.50 | 26.00 | 20.00 | 10.00 | 3.00 | 22.10 | 12.00 |
| ISM | 51.00 | 3.00 | 11.00 | 51.00 | 22.00 | 10.00 | 2.00 | 0.20 | 11.00 | 3.00 |
| KR-100 | 96.33 | 5.67 | 20.33 | 79.00 | 28.50 | 25.00 | 9.40 | 3.75 | 16.50 | 4.93 |
| KR-295 | 84.67 | 6.00 | 22.67 | 70.50 | 23.00 | 12.50 | 4.00 | 3.00 | 15.50 | 7.00 |
| Mean | 76.25 | 5.67 | 18.00 | 67.00 | 24.88 | 16.88 | 6.35 | 2.49 | 16.28 | 6.73 |
| Standard Error | 9.67 | 1.03 | 2.52 | 5.86 | 1.48 | 3.44 | 1.55 | 0.78 | 2.28 | 1.94 |
| Standard Deviation | 19.34 | 2.05 | 5.04 | 11.73 | 2.95 | 6.88 | 3.10 | 1.57 | 4.56 | 3.87 |

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# EFFECT OF *IN SITU* MOISTURE CONSERVATION PRACTICES AND INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON GROWTH AND YIELD OF BT COTTON

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## ABSTRACT

A field experiment was conducted during *kharif* 2015-16 and 2016-17 at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad in strip-plot design with three replications to study the effect of moisture conservation practices (flat bed sowing, ridge and furrow, broad bed and furrow (BBF) and poly mulch on BBF) and integrated nutrient management treatments (Farmer's practice, 100% RDF of 150:60:60 NPK kg ha$^{-1}$, 125% RDF, 100% RDF along with 25% N through FYM or press mud) and their interaction effect on growth, yield attributes and productivity of Bt cotton. Pooled data of two years indicated that poly mulch on BBF increased the growth, yield attributes and yield (2183 kg ha$^{-1}$) followed by ridge and furrow method, BBF and flat bed methods. Among the INM practices, application of 100% RDF along with 25% RDN through press mud improved the growth, yield attributes and yield (2103 kg ha$^{-1}$). Application of 100% RDF along with press mud equivalent to 25% RDN was on par with 100% RDF + 25 % RDN through FYM (2042 kg ha$^{-1}$) and was in turn on par with 125% RDF (1990 kg ha$^{-1}$) followed by farmer's practice (1785 kg ha$^{-1}$) and 100% RDF (1676 kg ha$^{-1}$). Interaction between soil moisture conservation practices and integrated nutrient management practices was found to be significant. Treatment combination involving poly mulch on broad bed and application of 100% RDF along with 25% RDN through pressmud (2370 kgha$^{-1}$) recorded significantly highest mean seed cotton yield and was comparable with poly mulch on broad bed with application of 100% RDF along with 25% RDN through FYM (2346 kgha$^{-1}$) or 125% RDF.

Cotton (*Gossypium hirsutum* L.), the "*white gold or the king of fibers*" is one of the most important commercial crops in India. The productivity of cotton in India is significantly lower (568 kg ha$^{-1}$) as compared to the four major cotton growing countries *i.e* China (1300 kg ha$^{-1}$), USA (900 kg ha$^{-1}$), Pakistan (700 kg ha$^{-1}$) and Brazil (2027 kg ha$^{-1}$) though India ranks first in area with 11.88 m ha$^{-1}$, accounting 30 per cent of world coverage and 22 per cent (351 lakh bales of lint) of the world cotton production (second rank) with a productivity of 568 kg ha$^{-1}$. Telangana ranked third in area (1.65 m.ha) with a production of 5 million bales and productivity of 515 kg ha$^{-1}$ (CICR, 2014).

More than 65% of the cotton in Telangana state is cultivated in red soils although cotton is recommended for black soils. Under rainfed conditions, proper land configuration as per the soil type aids in efficient soil moisture conservation, apart from ensuring better stand, establishment, uniform growth, nutrient use efficiency and yield (Prasad and Sudhakara Babu, 1997). Among various modern and cost effective technologies for efficient utilization of natural resources, effective rain water management as *in situ* moisture conservation comprising of opening of furrow, intercropping, mulching etc prove to be vital for attaining sustainable yields (Gokhale *et al*., 2012). Use of plastic mulch has confirmed water saving to about 40-50 percent in cotton (Nalayini *et al*., 2009).

The other factor for reduced cotton yield is imbalanced use of fertilizers that is resulting in micronutrient deficiencies and making the soil unproductive. Integrated use of chemical fertilizers and organic manures is not only essential for achieving higher yields but also has crucial role in improving soil health. Although FYM is commonly recommended organic manure, its availability is becoming scarce on account of low or negligible maintenance of cattle population in the farm. In this context, alternate organic sources like pressmud is one of the sound option on account of its rich nutrient content (Ghulam *et al*., 2012). Keeping in view the above facts, the present study was initiated to maximize the yield of Bt cotton under different soil moisture conservation techniques and integrated nutrient management practices in red soils.

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## MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2015 and 2016 at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad under rainfed conditions. The soil of the experimental site was sandy loam with soil pH of 7.33, low available N (182 kg $ha^{-1}$), medium in $P_2O_5$ (46.8 kg $ha^{-1}$) and high in $K_2O$ (432 kg $ha^{-1}$). The experiment was laid out in strip plot design with three replications. The size of gross and net plots were 7.2 m x 5.4 m and 5.4 m x 4.2 m respectively. There were twenty treatments comprised of four *in-situ* moisture conservation practices *viz.,* flat method ($M_1$), ridge and furrow ($M_2$) , BBF ($M_3$) and poly mulch on BBF ($M_4$) as main plots and five integrated nutrient management (INM) practices as sub plots were as follows farmer's practice ($S_1$), 100% recommended dose of fertilisers (RDF, $S_2$), 125% RDF ($S_3$), 100% RDF along with 25% N through FYM ($S_4$) and 100% RDF along with 25% RDN through press mud ($S_5$). Neeraja BT-II Bt cotton seeds were dibbled @ 1 seed $hill^{-1}$ on 7th July during 2015 and 2nd July during 2016. The RDF in Telangana state is 150:60:60 NPK kg $ha^{-1}$ . Entire P fertilizer was applied as basal and N and K applied at 20, 40, 60 and 80 days after sowing (DAS) in equal splits. In integrated nutrient management treatments ($S_4$ & $S_5$), 25 per cent nitrogen was applied through organic manures as basal and remaining as that of recommended dose of fertilizers (100 % RDF). Farmers practice of nutrient management was decided after survey of nutrient management in 30 cotton growing farmers fields in Southern Telangana Zone. Farmers are applying 50 kg of DAP at 20-25 DAS, 50 kg of 14-35-14 at 40-45 DAS, 50 kg of urea and 25 kg of muriate of potash at 60-65 DAS, 75 kg urea and potash 25 kg at 80-100 DAS. Based on the above, farmers practice of nutrient management was 3.75 t FYM $ha^{-1}$, 184-101-92 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$.

Pressmud and FYM were analysed for nitrogen content. Pressmud contains 1.92% nitrogen during 2015 and 2.24% during 2016. FYM contains 0.49% during 2015 and 0.72% during 2016. After laying land configurations, during 2015, 1953 kgs of pressmud and 7653 kgs of FYM were applied in $S_5$ and $S_4$ treatment plots. During 2016, 1674 kgs of pressmud and 5208 kgs of FYM were applied in $S_5$ and $S_4$ treatments. In $M_1$ treatment, simple flat bed method of sowing was imposed without any soil moisture conservation treatments as check. In $M_2$ treatment, ridges and furrows were laid at 90 cm apart respectively. While in $M_3$ & $M_4$ broad bed and furrow treatment, beds of 120 cm width and furrows of 60 cm were laid. In $M_4$ treatment, polythene mulch with black (upper) and grey (bottom) having 25 ì thickness was laid before sowing of the crop on the raised (broad) beds (120cm). Before laying the film, small circular holes were made as per the intra row spacing (60 cm) of the crop and the sheet was spread on the raised bed. After that, the sides of the polythene film were covered within the soil. Under all the treatments, sowing was done adopting intra row spacing of 60 cm, thus maintained uniform plant population (18,519 plants $ha^{-1}$). A total rainfall of 375.3 mm was received in 27 rainy days during 2015-16 and 741.1 mm in 37 rainy days during 2016-17, against the decennial average of 616 mm received in 37 rainy days for the corresponding period indicating 2016-17 as comparatively wet year. The crop was sprayed with monocrotophos @ 1 ml $l^{-1}$ against aphids and bollworms and drenching of carbendazim @ 1g $l^{-1}$ of water against wilt. The seed cotton was harvested thrice, when the bolls were fully burst at 100 DAS, 125 DAS and 150 DAS respectively during both the years of experimentation. The crop was finally terminated on 10th December during 2015 and 6th December during 2016. Five plants in each net plot were selected at random and tagged for taking observations on plant height, sympodials, bolls $plant^{-1}$ and boll weight. Destructive sampling for leaf area at 60, 90 and 120 DAS was done in gross plots from the second row on both sides of border rows of the plot. The seed cotton in the net plot was harvested separately. The total seed cotton yield was obtained by adding the weight from each picking and expressed as kg $ha^{-1}$. Statistical analysis of the data of various growth, yield and yield attributes were carried out through analysis of variance technique as described by Panse and Sukhatme (1967).

## RESULTS AND DISCUSSION

### Effect of moisture conservation treatments on growth, yield attributes and yield

Growth, yield attributes and yield were significantly influenced by different moisture conservation treatments (Table 1 to 3). The interaction effect was also significant. Plant height progressively increased

**Table 1: Effect of moisture conservation practices and INM on growth parameters of Bt cotton at harvest (Pooled mean, 2015 & 2016)**

| Treatments | Plant height (cm) | | | | | | Sympodials | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | Mean | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | Mean |
| $M_1$ - Flat bed (control) | 117.2 | 114.5 | 123.0 | 123.2 | 117.4 | 119.1 | 18.6 | 18.0 | 20.0 | 21.0 | 20.9 | 19.7 |
| $M_2$ - Ridge & furrow | 125.0 | 117.4 | 133.5 | 134.6 | 136.3 | 129.4 | 21.0 | 20.3 | 22.9 | 22.0 | 23.9 | 22.0 |
| $M_3$ - BBF | 122.5 | 116.1 | 128.2 | 130.5 | 137.7 | 127.0 | 20.1 | 19.5 | 21.4 | 20.9 | 22.3 | 20.8 |
| $M_4$ - Poly mulch on BBF | 132.1 | 128.7 | 141.3 | 143.0 | 143.1 | 137.6 | 22.7 | 21.9 | 24.0 | 24.5 | 24.3 | 23.5 |
| **Mean** | 124.2 | 119.2 | 131.5 | 132.8 | 133.6 | 128.3 | 20.6 | 19.9 | 22.1 | 22.1 | 22.8 | 21.5 |
| | | **Main** | **Sub** | **MXS** | **SXM** | | | **Main** | **Sub** | **MXS** | **SXM** | |
| **S.Em±** | | 2.0 | 1.2 | 2.1 | 2.6 | | | 0.3 | 0.2 | 0.3 | 0.4 | |
| **C.D at 5%** | | 7.0 | 4.0 | 6.2 | 9.0 | | | 1.2 | 0.7 | 0.8 | 1.4 | |
| **CV** | | 6.1 | | | | | | 6.0 | | | | |

Sub treatments (S) $S_1$: Farmers practice, $S_2$ : 100% RDF, $S_3$ : 125% RDF, $S_4$ : 100% RDF + FYM equivalent to 25% RDN , $S_5$: 100% RDF + Press mud equivalent to 25% RDN

**Table 2: Effect of moisture conservation practices and INM on yield attributes of Bt cotton at harvest (Pooled mean, 2015 & 2016)**

| Treatments | Number of bolls per plant | | | | | | Boll weight (g) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | Mean | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | Mean |
| $M_1$ - Flat bed (control) | 19.7 | 17.6 | 21.3 | 22.0 | 23.0 | 20.7 | 6.0 | 5.5 | 6.2 | 6.2 | 5.8 | 5.9 |
| $M_2$ - Ridge & furrow | 24.1 | 22.9 | 26.2 | 27.0 | 27.5 | 25.5 | 6.7 | 6.5 | 7.4 | 7.4 | 7.6 | 7.1 |
| $M_3$ - BBF | 22.0 | 20.9 | 24.3 | 25.0 | 25.7 | 23.6 | 6.3 | 6.1 | 6.6 | 6.9 | 7.6 | 6.7 |
| $M_4$- Poly mulch on BBF | 27.5 | 26.0 | 29.9 | 30.1 | 30.3 | 28.7 | 7.6 | 7.1 | 7.8 | 7.8 | 8.0 | 7.7 |
| **Mean** | 23.3 | 21.8 | 25.4 | 26.0 | 26.6 | 24.6 | 6.6 | 6.3 | 7.0 | 7.1 | 7.3 | 6.9 |
| | | **Main** | **Sub** | **MXS** | **SXM** | | | **Main** | **Sub** | **MXS** | **SXM** | |
| **S.Em±** | | 0.4 | 0.2 | 0.2 | 0.4 | | | 0.1 | 0.1 | 0.2 | 0.2 | |
| **C.D at 5%** | | 1.4 | 0.7 | 0.4 | 1.5 | | | 0.4 | 0.4 | 0.5 | 0.6 | |
| **CV** | | 7.5 | | | | | | 7.9 | | | | |

Sub treatments (S) $S_1$: Farmers practice, $S_2$ : 100% RDF, $S_3$ : 125% RDF, $S_4$ : 100% RDF + FYM equivalent to 25% RDN , $S_5$: 100% RDF + Press mud equivalent to 25% RDN

**Table 3: Effect of moisture conservation practices and INM on kapas and stalk yield of Bt cotton (Pooled mean, 2015 & 2016)**

| Treatments | Kapas yield (kg $ha^{-1}$) | | | | | | Stalk yield (kg $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | Mean | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | Mean |
| $M_1$ - Flat bed (control) | 1566 | 1447 | 1695 | 1758 | 1843 | 1662 | 3213 | 3103 | 3701 | 3874 | 4099 | 3598 |
| $M_2$ - Ridge & furrow | 1871 | 1779 | 2076 | 2125 | 2195 | 2009 | 4423 | 4170 | 4947 | 5107 | 5316 | 4793 |
| $M_3$ - BBF | 1687 | 1590 | 1898 | 1938 | 2004 | 1823 | 3820 | 3568 | 4335 | 4467 | 4658 | 4170 |
| $M_4$ - Poly mulch on BBF | 2018 | 1888 | 2293 | 2346 | 2370 | 2183 | 4970 | 4612 | 5726 | 5904 | 5979 | 5439 |
| **Mean** | 1785 | 1676 | 1990 | 2042 | 2103 | 1919 | 4107 | 3863 | 4677 | 4838 | 5013 | 4500 |
| | | **Main** | **Sub** | **MXS** | **SXM** | | | **Main** | **Sub** | **MXS** | **SXM** | |
| **S.Em±** | | 26 | 21 | 18 | 29 | | | 59 | 54 | 45 | 68 | |
| **C.D at 5%** | | 89 | 68 | 53 | 100 | | | 203 | 177 | 131 | 235 | |
| **CV** | | 7.2 | | | | | | 5.1 | | | | |

Sub treatments (S) $S_1$: Farmers practice, $S_2$ : 100% RDF, $S_3$ : 125% RDF, $S_4$ : 100% RDF + FYM equivalent to 25% RDN , $S_5$: 100% RDF + Press mud equivalent to 25% RDN

with the age of the crop up to harvest irrespective of the treatments (Table.1). Pooled data of two years 2015 & 2016 indicated that poly mulch on broad bed recorded significantly higher plant height (137.6 cm) compared with other moisture conservation treatments. Bhardwaj (2011) reported that the mulched plants usually grow and mature more uniformly than un mulched plants. Poly mulch on broad bed was followed by ridge & furrow (129.4 cm) which in turn was on par with broad bed and furrow (127.0 cm) and significantly superior over flat bed method. Gaidhane *et al*. (2007), Pore and Bhake (1992) has earlier reported significant effect of land configuration on crop growth and development.

Poly mulch on broad bed method recorded significantly higher sympodials (23.5) compared to rest of the moisture conservation treatments. It was followed by ridge and furrow (22.0), which was comparable with broad bed and furrow (20.8) and significantly superior over flat bed method. Broad bed & furrow method was in turn comparable with flat bed in terms of sympodia $plant^{-1}$. The present result was in conformity with Dilip Kumar *et al.* (1990) who reported that mulch facilitates more retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil and ultimately enhances the growth and yield of crops. Poly mulch on broad bed ($M_4$) recorded significantly higher LAI compared to rest of the moisture conservation treatments. Poly mulch on broad bed ($M_4$) followed by ridge and furrow method ($M_2$), recorded significantly higher LAI as compared to broad bed & furrow and flatbed methods (Fig.1 & Fig.2)

Poly mulch on broad bed has recorded high number of bolls (28.7) and boll weight (7.7 g) than rest of the moisture conservation treatments (Table 2). The increase in the number of bolls $plant^{-1}$ in mulched plot was probably associated with the better partitioning of assimilates towards reproductive parts as the source was not limiting under mulching (Nalayini *et al*., 2009) Mulch on broad bed was followed by ridge and furrow (25.5 and 7.9) has recorded significantly higher bolls and boll weight as compared to broad bed & furrow and flat bed methods. Waghmare *et al*. (2018) revealed that among the land configuration treatments, opening of furrow after each row recorded significantly higher number of bolls $plant^{-1}$(37.06) and boll weight (3.15 g) than flatbed sowing (33.83 and 2.75 g).

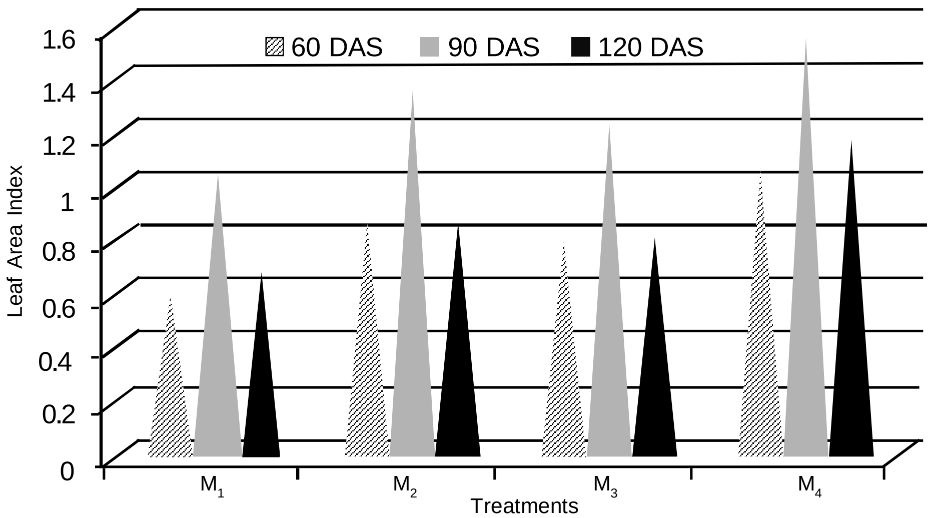


**Fig. 1 : Effect of moisture conservation practices on leaf area index at 60, 90 and 120 DAS of Bt cotton**

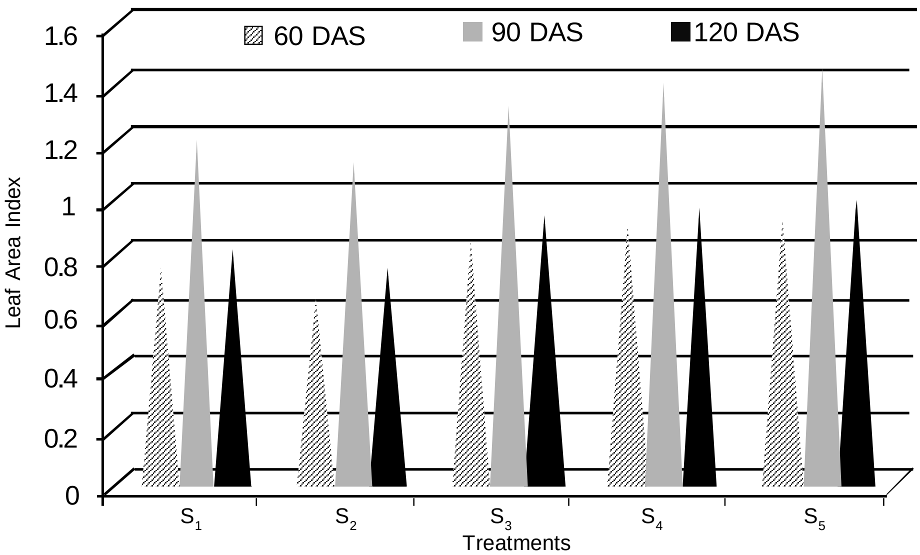


**Fig. 2 : Effect of INM practices on leaf area index at 60, 90 and 120 DAS of Bt cotton**

The data indicated significant effect of moisture conservation treatments on seed cotton yield. Poly mulch on broad bed method ($M_4$) recorded significantly higher seed cotton yield (2183 kg ha$^{-1}$) and stalk yield (5439 kg ha$^{-1}$) compared to other moisture conservation treatments (Table 3). Fortnum *et al*. (2000) reported the beneficial effects of plastic mulch for enhanced water and fertilizer utilization and weed control. Increasing the number of sympodial branches per plant lead to the increase in the number of bolls plant$^{-1}$ consequently higher seed cotton yield. The present result is in conformity with Hugar and Halemani (2010) who also reported improved seed cotton yield under polyethylene mulch to the extent of 11 to 27 per cent over no mulch. The next best treatment was ridge and furrow ($M_2$), which also recorded significantly higher seed cotton yield (2009 kg ha$^{-1}$) and stalk yield (4793 kg ha$^{-1}$) compared to broad bed & furrow (1823 kg ha$^{-1}$ and 4170 kg ha$^{-1}$) and flat bed methods. Hulihalli and Patil (2004) reported that land configuration, a mechanical measure of *in situ* moisture conservation plays an important role in conservation of maximum possible rain water in the soil, so availability of more moisture for longer time boost the yield of cotton.

### Effect of integrated nutrient management on growth, yield attributes and yield

Significantly taller plants (133.6 cm) were recorded with 100% RDF + 25 % RDN through press mud treatment, which was on par with 100% RDF + 25% RDN through FYM (132.8 cm) and 125% RDF (131.5 cm). These treatments were followed by farmers practice (124.2 cm), which was on par with 100% RDF (119.2 cm). Higher number of sympodials (22.8) were recorded with application of 100% RDF + 25% RDN through press mud treatment, which was on par with 100% RDF + 25% RDN through FYM (22.1) and 125 % RDF (22.1). This was followed by farmers practice (20.6) and 100% RDF (19.9) and these two treatments in turn were comparable with each other. Significantly higher LAI at 60 DAS was recorded with application of 100% RDF along with 25% RDN through press mud treatment ($S_5$) followed by application of 100% RDF + 25% RDN through FYM ($S_4$) and was in turn on par with application of 125 % RDF ($S_3$). The treatment consisting of application of 125 % RDF was followed by Farmers practice ($S_1$) and application of 100% RDF ($S_2$) respectively. Similar trend was followed in terms of LAI at 90 and 120 DAS (Fig.1 & Fig.2). The positive effects of organic manures on growth, yield attributes and yield of cotton could be attributed to the fact that the organic manures were instrumental in supplying available nutrients directly to the plants and also these sources had solubility effect on fixed form of nutrients in soil (Sinha *et al*., 1981).

Significantly higher number of bolls (26.6) were recorded with 100% RDF + Press mud equivalent to 25 % RDN) and was on par with 100% RDF + FYM (26.0). Application of 100% RDF + FYM was in turn on par with 125% RDF (25.4) followed by farmers' practice (23.3 ) and 100% RDF (21.8). Pressmud after decomposition releases major and micro nutrients, which become available through out crop growth period that lead to more number of bolls plant$^{-1}$. Heavier bolls (7.3 g) were observed with 100% RDF + 25 % RDN through pressmud treatment and was on par with 100% RDF + 25 % RDN through FYM (7.1 g) and 125% RDF (7.0 g). Seed cotton yield (2103 kg ha$^{-1}$) was significantly higher in 100% RDF + 25 % RDN through Press mud ($S_5$) treatment and was on par with 100% RDF + FYM (2042 kg ha$^{-1}$). Application of 100% RDF + 25 % RDN through FYM was in turn on par with 125% RDF (1990 kg ha$^{-1}$) followed by Farmers practice (1785 kg ha$^{-1}$ ) and ($S_2$) 100% RDF (1676 kg ha$^{-1}$). The higher seed cotton yield with different INM practices may be attributed to the various yield components viz., number of sympodial branches per plant, number of bolls per plant and boll weight. Juwarkar *et al*. (1993) reported that application of 20 t ha$^{-1}$ pressmud and addition of NPK equivalent to 75% of RDF to each crop through fertilizers were found to be beneficial and resulted 21-43% higher crop yield. Stalk yield (5013 kg ha$^{-1}$) was significantly higher in 100% RDF + 25 % RDN through pressmud treatment and was on par with 100% RDF + FYM (4838 kg ha$^{-1}$) and the later was in turn on par with 125% RDF (4677 kg ha$^{-1}$) followed by farmers practice (4107 kg ha$^{-1}$ ) and 100% RDF (3863 kg ha$^{-1}$). Joga Rao *et al.*(2017) observed that application of 100% RDF (90:45:45 kg NPK ha$^{-1}$) + FYM @ 10 t ha$^{-1}$ recorded highest seed cotton yield of 2181 kg ha$^{-1}$and it was on par with 150% RDF.

**Interaction between soil moisture conservation practices and integrated nutrient management**

Interaction between soil moisture conservation practices and integrated nutrient management practices was found to be significant influence on plant height, sympodial branches, yield attributes and yield at harvest. The pooled data of two years indicated that combination of poly mulch on broad bed and the application of RDF along with pressmud ($M_4S_5$) recorded significantly higher values. This was found on par with ($M_4S_4$) poly mulch on broad bed and application of RDF along with FYM and ($M_4S_3$) 125% RDF.

Application of poly mulch on broad bed and application of 100% RDF along with 25% RDN through pressmud ($M_4S_5$) recorded significantly higher bolls (30.3) and boll weight (8.0 g) than rest of treatments and this was comparable with poly mulch on broad bed and application of 100% RDF along with 25% RDN through FYM.

Treatment combination involving poly mulch on broad bed and application of RDF along with 25% RDN through press mud ($M_4S_5$) recorded significantly higher mean seed cotton yield (2370 kgha$^{-1}$) than rest of the treatment combinations. This treatment was comparable with ($M_4S_4$) poly mulch on broad bed and application of RDF along with 25% RDN through FYM (2346 kgha$^{-1}$). $M_4S_5$ and $M_4S_4$ treatments were in turn on par with poly mulch on broad bed and application of 125% RDF ( $M_4S_3$) indicating that poly mulch was more effective when RDF was applied either with press mud or FYM equivalent to 25% RDN or with 125% RDF alone. Increased seed cotton yield under broad bed and furrow with poly mulch was due to the sufficient soil moisture in the root zone and the extended retention of moisture lead to higher uptake of nutrients for proper growth and development of plant which resulted in higher yield. These results are in accordance with those of Patel *et al*. (2015), who reported improved yield on treatments consisting of positive effect of press mud and FYM on seed cotton yield. Higher fertilizer (125% RDF) might have increased growth parameters and higher drymatter accumulation in reproductive parts.

**Conclusion**

Based on above results, it can be concluded that maximum growth, yield attributes and yield from Bt. cotton can be obtained by application of pressmud or FYM equivalent to 25% RDN along with 100 % RDN or 125% RDF with *in situ* moisture conservation practice of poly mulch on broad bed in red soils of Telangana

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# EVALUATION OF DIFFERENT NITROGEN MANAGEMENT PRACTICES FOR IMPROVEMENT OF YIELD AND YIELD ATTRIBUTES OF RICE UNDER DIFFERENT ESTABLISHMENT METHODS

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## ABSTRACT

A field experiment was conducted during *kharif* 2017 and 2018 at ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad to study the effect of different nitrogen management practices on the yield and yield attributes of rice under different establishment methods. The experiment was laid out in split plot design with two establishment methods [Normal transplanting ($M_1$) and mechanized SRI ($M_2$)] in main plots and six nitrogen management practices [$N_1$- Nutrient Expert based recommendation of nitrogen with neem coated urea, $N_2$- Nutrient Expert based recommendation of nitrogen with neem coated urea (75%) + vermicompost (25%), $N_3$- Recommended dose of nitrogen with neem coated urea, $N_4$- Recommended dose of nitrogen with neem coated urea (75%) + vermicompost (25%), $N_5$- N omission, $N_6$- Absolute control (No N, P and K fertilizer application)] in sub-plots with three replications. The results revealed that yield and yield attributes of rice did not vary significantly due to establishment methods. Among nitrogen management practices, application of nitrogen as per recommendation of Nutrient Expert with neem coated urea (75%) + vermicompost (25%) ($N_2$) recorded significantly higher yield and yield attributes (Number of panicles $m^{-2}$, panicle length, panicle weight and test weight) as compared to that of nitrogen omission ($N_5$) treatment and absolute control ($N_6$) where as it was found at par with all other nitrogen management practices ($N_1$, $N_3$ and $N_4$).

Rice (*Oryza sativa* L.) is the most important staple food crop for more than half of the global population. In India, rice production has increased more than five-fold from about 20 million tonnes (mt) in 1950-51 to more than 111 mt in 2018-19. This increase in production was mainly attributed to the development of fertilizer responsive high yielding varieties. Fertilizer consumption, which contributes to nearly 50% of rice varietal yield potential, showed a phenomenal increase during this period [69,800 t in 1950-51 to 25.6 mt by 2017-18 (FAI, 2018)]. Telangana State contributes 2.09 million ha area annually with a production of 6.62 million tonnes, with an average productivity of 3295 kg $ha^{-1}$ during 2018-2019 (Season and Crop report Telangana, 2018-19).

Method of establishment is one of the cultural practices, which influences the rice crop through its effect on growth and development (Gopi *et al*., 2006). Manual transplanting is the most common practice of rice cultivation in south and south-east Asia. Non availability of irrigation water and shortage of labour during peak periods, increased labour wages make transplanting and manual weeding costly, invariably causing delays in farm operations. The manual method of rice transplanting gives the desired result but that involves enormous drudgery, more human stress and also high labour requirement. It combined with labour intensive operations like nursery rising, uprooting of the seedlings, transporting and transplanting in the main field requiring about 250-300 man-h/ha which is approximately 25% of the total labour requirement of crop (Chaudhary and Varshney, 2003). In spite of huge labour requirement, plant to plant and row to row spacing are not achieved which make mechanical weeding difficult. Moreover, with the onset of industrialization, employment opportunities have increased and acute shortage of labours is often experienced during transplanting season.

The system of rice intensification (SRI) which was developed in Madagascar in 1983 by Father Henri Laulanie, is one among the scientific management tools for utilizing irrigation water based on soil and climatic condition to achieve maximum crop production per unit of water applied per unit area per unit time. The system of rice intensification (SRI) is an improved technology for production of rice. SRI is considered to be a

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disembodied technological breakthrough in paddy cultivation. SRI increases rice production and raises the productivity of land, labour, water and capital through different practices of management. This system also provides better growing conditions for rice. Even though the new system has promised less water and other recourses the major problem among the rice growers is labour scarcity. To solve this problem, IFFCO joined hands with agricultural department and made efforts to reduce the labour drudgery by introducing mechanization in all operations of SRI technology.

Nitrogen is the key nutrient element required in large quantities by rice. In modern agro ecosystems, it was estimated that the removal of as much as 300 kg N $ha^{-1}$ $year^{-1}$ in the above ground portions of the harvested produce requires substantial inputs of N either through fertilizers, manure, or N-fixation to maintain the productivity levels (Cassman *et al*., 2002). Higher loss of N from urea necessitates an innovative application technique for increasing the nitrogen use efficiency (NUE). Proper management of N is essential for achieving higher productivity, maximizing N use efficiency (NUE) and improving environmental safety by ensuring minimal losses of applied N. However, efficiency of applied N fertilizer primarily depends on the form of N applied and the ecosystem in which they are used.

Nutrient Expert (NE) is a new computer-based decision support tool that helps crop advisors to formulate fertilizer guidelines based on SSNM principle. NE considers the most important factors affecting nutrient management recommendations in a particular location and enables crop advisors to provide farmers with fertilizer guidelines that are suited to their farming conditions.

For improving rice productivity, nitrogen need to be applied in desired quantities and according to the crop needs. Therefore, application of nitrogen to be made by right source (neem coated urea and vermicompost), right time (Basal, panicle initiation and at heading stage by using Nutrient Expert) and in right amount (Nutrient Expert). Keeping these points in consideration, the experiment entitled “Evaluation of different nitrogen management practices for improvement of yield and yield attributes of rice under different establishment methods” was carried out.

## MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2017 and 2018 at ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, located in the Southern Telangana agro-climatic zone of Telangana state. Geographically, it lies at $17^0$ 19' N latitude, $78^0$ 23' E longitude with an altitude of 542.3 m above mean sea level (MSL). During the crop growth period, a total rainfall of 861.4 mm was received in 43 rainy days during *kharif* 2017 and 333.8 mm in 21 rainy days during *kharif* 2018. The daily mean bright sunshine during crop growth period ranged from 2.1 to 8.8 hours with an average of 5.1 hours during *kharif* 2017 and 0.6 to 8.1 hours with an average of 5.1 hours during *kharif* 2018. The daily mean evaporation (mm) during the crop growth period was 3.9 mm and 4.6 mm during *kharif* 2017 and *kharif* 2018, respectively.

The analysis of soil sample revealed that soil was clay loam in texture having low organic carbon and available nitrogen, high in available phosphorus and available potassium contents with moderate alkaline in reaction. Rice variety RNR-15048 (Telangana Sona) is tested in the experiment. The experiment was laid out in split plot design with two establishment methods [Normal transplanting ($M_1$) and mechanized SRI ($M_2$)] in main plots and six nitrogen management practices [$N_1$- Nutrient Expert based recommendation of nitrogen with neem coated urea, $N_2$- Nutrient Expert based recommendation of nitrogen with neem coated urea (75%) + vermicompost (25%), $N_3$- Recommended dose of nitrogen with neem coated urea, $N_4$- Recommended dose of nitrogen with neem coated urea (75%) + vermicompost (25%), $N_5$- N omission, $N_6$- Absolute control (No N, P and K fertilizer application)] in sub-plots with three replications. The recommended dose of fertilizer (RDF) for rice is 120, 60 and 40 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$, respectively. Nutrient expert based recommendation for rice is 125, 34 and 55 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$, respectively. Nitrogen was applied in three equal split doses i.e. basal, 60 DAS and 90 DAS. Full dose of P, and K were applied as basal dose. The nutrients N, $P_2O_5$ and $K_2O$ were supplied through urea, single super phosphate and muriate of potash, respectively. Seedlings were transplanted at spacing of 20 cm x 15 cm under normal transplanting and 23.5 cm x 15 cm under mechanized

SRI. For transplanting, 25 and 18 days old seedlings were used under normal transplanting and mechanized SRI, respectively. Soil was kept wet with thin film of water during the first one week under normal transplanting. Depth of irrigation was increased to 2.5 cm progressively along the crop age. Provided adequate drainage facilities to drain excess water. In case of mechanized SRI, the soil was kept saturated and standing water was avoided until the seedling establishment. Thereafter, the field was kept saturated by supplementing irrigation whenever there was insufficient rainfall. The excess rain or irrigation water was drain from the field. Last irrigation was given 15 days ahead of harvest in both the methods of establishment. Gross plot size was same (42 $m^2$) under both the establishment methods while net plot size was 33.48 $m^2$ under normal transplanting 32.72 $m^2$ under mechanized SRI.

At harvest, plant samples from each plot were harvested to record the yield-attributing characteristics, such as the number of panicles $m^{-2}$, panicle length, panicle weight, test weight and grain yield. The data recorded on various parameters of the crop during the course of investigation was statistically analyzed following the analysis of variance for split plot design given by Gomez and Gomez (1984).

## RESULTS AND DISCUSSION

### Yield attributes

There was no significant difference in number of panicles $m^{-2}$ due to different establishment methods, however comparatively higher values of number of panicles $m^{-2}$ were recorded under mechanized system of rice intensification (MSRI) ($M_2$) (262.0, 255.2 and 258.6) as compared to normal transplanting ($M_1$) (236.6, 231.7 and 234.1) during 2017, 2018 and in pooled means, respectively (Table 1). The per cent increase in number of panicles $m^{-2}$ under mechanized SRI ($M_2$) was 10.74, 10.14 and 10.44% higher than normal transplanting ($M_1$) during 2017, 2018 and in pooled means, respectively. Higher number of panicles $m^{-2}$ under mechanized SRI ($M_2$) was due to more number of seedlings per hill and tillers per unit area as compared to normal transplanting ($M_1$). These results are also supported by Anbumani *et al.* (2004), Singh *et al.* (2009) and Sangeetha (2013).

Other yield attributes (Panicle length, panicle weight and test weight) also did not vary significantly due to different establishment methods however comparatively higher values of panicle length, panicle weight and test weight were recorded under mechanized system of rice intensification (MSRI) ($M_2$) (Table 1).

Nutrient Expert based recommendation of nitrogen with neem coated urea (NCU) (75%) + vermicompost (VC) (25%) ($N_2$) recorded significantly higher number of panicles $m^{-2}$ as compared to nitrogen omission ($N_5$) and absolute control ($N_6$), however it did not show any significant variation from all the all other nitrogen management practices (Table 1). These results are in accordance with findings of Sheoran *et al* (2007), Sathiya and Ramesh (2009), Damodaran *et al* (2012) and Kandeshwari *et al* (2012).

Nitrogen omission ($N_5$) recorded significantly higher number of panicles $m^{-2}$ (174.0, 167.1 and 170.5) as compared to absolute control ($N_6$) (145.1, 138.4 and 141.7) during 2017, 2018 and pooled mean, respectively. It indicated that application of P and K fertilizer to the rice crop resulted in 19.92, 20.74 and 20.35% increase in number of panicles $m^{-2}$ over absolute control during 2017, 2018 and in pooled means, respectively.

Nutrient Expert based recommendation of nitrogen with NCU (75%) and VC (25%) ($N_2$) recorded significantly higher yield attributes such as panicle length (cm), panicle weight (g) and test weight (g) as compared to nitrogen omission ($N_5$) and absolute control ($N_6$) and all other nitrogen management practices ($N_1$, $N_3$ and $N_4$) were statistically at par with $N_2$ during both the years of study.

### Grain yield

Mean grain yield of rice was 4951, 4777 and 4864 kg $ha^{-1}$ during 2017, 2018 and in pooled means, respectively. In spite of the treatment differences, higher grain yield was recorded during *kharif* 2017 than *kharif* 2018 (Table 2). It may attributed to congenial weather parameters (rainfall, solar radiation and temperature) and yield attributes during *kharif* 2017 whereas less rainfall, number of rainy days and high wind velocity, evaporative demand and temperature at reproductive stage might have affected pollen fertility and grain filling resulted reduction in yield and yield attributes during *kharif* 2018.

**Table 1: Yield attributes of rice as influenced by establishment methods and nitrogen management practices during *kharif* 2017 and 2018**

| Treatments | No. of panicles $m^{-2}$ | | | Panicle length (cm) | | | Panicle weight (g) | | | Test weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| **Methods of establishment (M)** | | | | | | | | | | | | |
| $M_1$- Normal Transplanted Rice (NTP) | 236.6 | 231.7 | 234.1 | 23.93 | 22.75 | 23.34 | 3.58 | 3.49 | 3.54 | 12.12 | 11.98 | 12.05 |
| $M_2$- Mechanised SRI (MSRI) | 262.0 | 255.2 | 258.6 | 25.30 | 23.86 | 24.58 | 3.83 | 3.70 | 3.76 | 12.46 | 12.21 | 12.34 |
| SEm± | 5.31 | 5.50 | 5.30 | 0.43 | 0.46 | 0.44 | 0.07 | 0.08 | 0.07 | 0.19 | 0.23 | 0.18 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Nitrogen management practices (N)** | | | | | | | | | | | | |
| $N_1$- NE based recommendation of N with NCU | 289.4 | 285.0 | 287.2 | 25.51 | 23.85 | 24.68 | 3.90 | 3.75 | 3.83 | 12.88 | 12.52 | 12.70 |
| $N_2$- NE based recommendation of N with NCU (75%) + VC (25%) | 306.2 | 298.1 | 302.1 | 26.25 | 24.83 | 25.54 | 4.07 | 3.96 | 4.01 | 13.17 | 13.08 | 13.13 |
| $N_3$- RDN with NCU | 282.8 | 278.0 | 280.4 | 25.41 | 23.68 | 24.54 | 3.83 | 3.71 | 3.77 | 12.75 | 12.47 | 12.61 |
| $N_4$- RDN with NCU (75%) + VC (25%) | 298.4 | 293.9 | 296.2 | 26.02 | 23.97 | 24.99 | 4.00 | 3.88 | 3.94 | 13.02 | 12.80 | 12.91 |
| $N_5$- N omission | 174.0 | 167.1 | 170.5 | 23.13 | 22.38 | 22.76 | 3.35 | 3.28 | 3.31 | 11.21 | 11.07 | 11.14 |
| $N_6$- Absolute control (No N, P, and K fertilizer application) | 145.1 | 138.4 | 141.7 | 21.36 | 21.10 | 21.23 | 3.08 | 2.99 | 3.04 | 10.73 | 10.65 | 10.69 |
| SEm± | 8.04 | 8.02 | 8.11 | 0.59 | 0.43 | 0.45 | 0.10 | 0.09 | 0.09 | 0.22 | 0.31 | 0.29 |
| CD (p=0.05) | 23.73 | 23.66 | 23.92 | 1.74 | 1.26 | 1.32 | 0.29 | 0.27 | 0.26 | 0.64 | 0.91 | 0.86 |
| **Interactions (M x N)** | | | | | | | | | | | | |
| **Nitrogen management practices at same level of establishment method** | | | | | | | | | | | | |
| SEm± | 11.37 | 11.34 | 11.47 | 0.83 | 0.61 | 0.63 | 0.14 | 0.13 | 0.12 | 0.31 | 0.43 | 0.41 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Establishment method at same or different level of nitrogen management practices** | | | | | | | | | | | | |
| SEm± | 11.66 | 11.72 | 11.73 | 0.87 | 0.72 | 0.73 | 0.15 | 0.14 | 0.13 | 0.34 | 0.46 | 0.42 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| General Mean | 249.3 | 243.4 | 246.4 | 24.61 | 23.30 | 23.96 | 3.71 | 3.59 | 3.65 | 12.29 | 12.10 | 12.19 |
| CV (%) | 9.0 | 9.6 | 9.1 | 7.4 | 8.3 | 7.9 | 8.5 | 8.9 | 7.6 | 6.6 | 8.2 | 6.4 |

**NE- Nutrient Expert; NCU- Neem coated urea; VC- Vermicompost; RDN- Recommended dose of nitrogen**

**Table 2: Grain yield, straw yield and harvest index of rice as influenced by establishment methods and nitrogen management practices during *kharif* 2017 and 2018**

| Treatments | Grain yield (kg $ha^{-1}$) | | | Straw yield (kg $ha^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled | 2017 | 2018 | Pooled |
| **Methods of establishment (M)** | | | | | | | | | |
| $M_1$- Normal Transplanted Rice (NTP) | 4744 | 4548 | 4646 | 5955 | 5872 | 5914 | 43.81 | 43.64 | 43.72 |
| $M_2$- Mechanised SRI (MSRI) | 5159 | 5006 | 5083 | 6490 | 6200 | 6345 | 44.12 | 43.96 | 44.04 |
| SEm± | 86.18 | 96.73 | 109 | 113.28 | 119.41 | 108 | 0.57 | 0.60 | 0.71 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Nitrogen management practices (N)** | | | | | | | | | |
| $N_1$- NE based recommendation of N with NCU | 6046 | 5823 | 5934 | 7487 | 7246 | 7367 | 44.71 | 44.54 | 44.63 |
| $N_2$- NE based recommendation of N with NCU (75%) + VC (25%) | 6322 | 6114 | 6218 | 7756 | 7553 | 7654 | 44.93 | 44.74 | 44.83 |
| $N_3$- RDN with NCU | 5991 | 5755 | 5873 | 7448 | 7188 | 7318 | 44.59 | 44.45 | 44.52 |
| $N_4$- RDN with NCU (75%) + VC (25%) | 6205 | 6018 | 6112 | 7624 | 7438 | 7531 | 44.89 | 44.73 | 44.81 |
| $N_5$- N omission | 2766 | 2690 | 2728 | 3752 | 3674 | 3713 | 42.47 | 42.26 | 42.36 |
| $N_6$- Absolute control (No N, P, and K fertilizer application) | 2378 | 2265 | 2321 | 3268 | 3118 | 3193 | 42.19 | 42.09 | 42.14 |
| SEm± | 129.15 | 139.44 | 118 | 116.51 | 183.87 | 115 | 0.60 | 0.27 | 0.77 |
| CD (p=0.05) | 380.99 | 411.35 | 347 | 343.72 | 542.42 | 340 | 1.78 | 0.79 | 2.26 |
| **Interactions (M x N)** | | | | | | | | | |
| **Nitrogen management practices at same level of establishment method** | | | | | | | | | |
| SEm± | 183 | 197 | 167 | 165 | 260 | 163 | 0.85 | 0.38 | 1.09 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Establishment method at same or different level of nitrogen management practices** | | | | | | | | | |
| SEm± | 188 | 204 | 187 | 188 | 266 | 184 | 0.97 | 0.70 | 1.22 |
| CD (p=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| General Mean | 4951 | 4777 | 4864 | 6222 | 6036 | 6129 | 43.96 | 43.8 | 43.88 |
| CV (%) | 7.4 | 8.6 | 9.5 | 7.7 | 8.4 | 7.5 | 5.5 | 5.8 | 6.9 |

**NE- Nutrient Expert; NCU- Neem coated urea; VC- Vermicompost; RDN- Recommended dose of nitrogen**

Establishment methods failed to bring any significant variation in grain yield but comparatively higher value of grain yield recorded in mechanized system of rice intensification (MSRI) ($M_2$) (5159, 5006 and 5083 kg ha$^{-1}$) as compared to normal transplanting ($M_1$) (4744, 4548 and 4646 kg ha$^{-1}$) during 2017, 2018 and in pooled means, respectively. The per cent increase in grain yield under mechanized SRI ($M_2$) was 8.75, 10.07 and 9.41% over normal transplanting ($M_1$) during 2017, 2018 and in pooled means, respectively.

Higher row to row and plant to plant spacing under mechanized SRI cause less inter plant competition and provide more opportunity for efficient utilization of available resources than normal transplanting. Higher grain yield under mechanized SRI is mainly attributed to better vegetative growth, more dry matter accumulation and effective partitioning to panicles resulted in more number of panicles per unit area, higher panicle length, panicle weight and test weight as compared to normal transplanting. An increase in yield of 10-12% were reported in farmer fields with the use of self-propelled rice transplanter than manual transplanting due to uniform plant population and healthy crop environment in line planted crop (*Anon*ymous, 2016). Singh and Vatsa (2006) also found that seedlings were transplanted at uniform depth and spacing with mechanical transplanter thereby establishment of seedlings is faster and producing more number of tillers which resulted in 30-35 per cent higher yield compared to that of manual transplanting.

Application of nitrogen as per recommendation of Nutrient Expert with NCU (75%) + VC (25%) ($N_2$) gave significantly higher grain yield compared to nitrogen omission ($N_5$) treatment and absolute control ($N_6$) and all the other nitrogen management practices ($N_1$, $N_3$ and $N_4$) were statistically at par with $N_2$ during both the years of study (Table 2). This treatment($N_2$) recorded 128.56, 127.29 and 127.93% higher grain yield than nitrogen omission ($N_5$) treatment and 165.85, 169.93 and 167.90% higher than absolute control ($N_6$) during 2017, 2018 and in pooled means, respectively.

The greater grain yield under Nutrient Expert based recommendation with NCU (75%) + VC (25%) ($N_2$) was the result of supply of right dose of nutrients at right time with right source which mainly attributed to more number of panicles per unit area, higher panicle length, panicle weight and test weight as compared to nitrogen omission ($N_5$) treatment and absolute control ($N_6$). Integrated use of nitrogen through inorganic and organic (Vermicompost) sources promote positive soil biological processes and enhance the availability of nutrients over a longer period that led to better growth and grain yield (Wijebandara *et al*., 2009 and Kumar *et al*., 2013).

Nitrogen omission ($N_5$) recorded significantly higher grain yield (2766, 2690 and 2728 kg ha$^{-1}$) as compared to absolute control ($N_6$) (2378, 2265 and 2321 kg ha$^{-1}$) during 2017, 2018 and in pooled means, respectively. It indicated that application of P and K fertilizer to the rice crop resulted in 16.32, 18.76 and 17.54% increase in grain yield over absolute control ($N_6$) during 2017, 2018 and in pooled means, respectively.

**Straw yield**

There was no significant difference in straw yield due to different establishment methods however comparatively higher values of straw yield recorded under mechanized system of rice intensification (MSRI) (6490, 6200 and 6345 kg ha$^{-1}$) over normal transplanted rice (5955, 5872 and 5914 kg ha$^{-1}$) during 2017, 2018 and in pooled mean, respectively (Table 2). These results are in agreement with findings of Prasad *et al.* (2001), Manjappa and Kataraki (2004), Anbumani *et al.* (2004), Singh *et al*. (2006), Jayadeeva and Shetty (2008) and Sangeetha (2013).

Application of nitrogen as per recommendation of Nutrient Expert with NCU (75%) + VC (25%) ($N_2$) recorded significantly higher straw yield of rice as compared to nitrogen omission ($N_5$) and absolute control ($N_6$) and all the other nitrogen management practices ($N_1$, $N_3$ and $N_4$) were statistically at par with $N_2$ during both the years of study (Table 2).

**Harvest index (%)**

Harvest index did not vary significantly due to different establishment methods but comparatively higher values were recorded under mechanized system of rice intensification (MSRI) ($M_2$) (Table 2). Higher harvest index was due to higher economic yield under mechanized SRI ($M_2$) as compared to normal transplanting ($M_1$).

Application of nitrogen as per recommendation of Nutrient Expert with NCU (75%) + VC (25%) ($N_2$) recorded significantly higher harvest index of rice (44.93, 44.74 and 44.83% during 2017, 2018 and in pooled means, respectively) as compared to nitrogen omission ($N_5$) (42.47, 42.26 and 42.36% during 2017, 2018 and in pooled means, respectively) and absolute control ($N_6$) (42.19, 42.09 and 42.14% during 2017, 2018 and in pooled means, respectively) and all the other nitrogen management practices ($N_1$, $N_3$ and $N_4$) were statistically at par with $N_2$ during both the years of study.

## Conclusion

The study revealed that mechanized SRI could be an option for rice cultivation as normal transplanting required more labour and water and delayed maturity as compared to mechanized SRI. Nutrient Expert based recommendation of nitrogen with NCU and VC was found superior to other nitrogen management approaches in terms of yield and yield attributes. It was also concluded that production of more grain yield with less phosphorus application can be obtained in Nutrient Expert based fertilizer application compared to the absolute control and other nitrogen management practices.

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Research Article
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# CONSTRAINTS AND SUGGESTIONS AS PERCEIVED BY THE RED GRAM FARMERS IN KARNATAKA STATE OF INDIA

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## ABSTRACT

An ex-post-facto research design was adopted to study the constraints faced by the Red gram farmers and the probable suggestions provided by them to overcome the constraints. Data were collected from 150 farmers. Weighted mean score (WMS) estimation of constraints showed that majority of the farmers faced problems with respect to labour shortage/ costly wages, lack of technical guidance about cultivation and untimely, costly and poor quality inputs. However, frequency estimations of suggestions represented a requirement of effective labour policies and the provision of subsidized inputs to overcome the above constraints.

Red gram is grown in the area of 3.56 lakh hectares and 57,570 hectares in Gulbarga and Bidar districts contributes over 60 per cent of the state's Red gram production[1]. The crop is cultivated on marginal land by resource poor farmers, who commonly grow traditional medium and long-duration (5–11 months) landraces. Short duration pigeon peas (3–4 months) suitable for multiple cropping have recently been developed. Traditionally, the use of inputs such as fertilizers, weeding, irrigation, and pesticides is minimal, so present yield levels are low (average = 700 kg/ha) and the farmers are also facing problems such as unawareness about the recommended cultivation practices of Red gram, over-exploitation by the middlemen and low price realization by the growers. Hence to enhance the production and productivity of Red gram cultivation there is a need to study the major problems faced by the farmers of the area. Therefore an attempt has been made to analyze the present status of lacunae in production and marketing of Red gram cultivation as well as the suggestions for their improvement are extracted from farmers of Bidar and Kalaburagi districts of Karnataka, India.

## MATERIALS AND METHODS

The ex-post facto research design was employed in the present study. The state of Karnataka was purposively selected and Bidar and Kalaburgi districts were selected because of their dominance in area and production of Red gram cultivation. Basavakalyan and Bhalki taluks of Bidar district and Kalaburagi, Aland and Sedam taluks from Kalaburagi district were randomly selected. Thirty Red gram cultivators from each taluk were randomly selected, thus making a total of 150 respondents for the study. Primary data were collected using a pre-tested interview schedule. To analyze the constraints, major problems observed by farmers were put before sample farmers and asked to give a score/weights based on 3 point continuum of most serious (3), serious (2) and not so serious (1) and analyzed using weighted mean score method. The formula used was

$$\bar{X}_w = \Sigma w_i X_i / \Sigma w_i$$

where $\bar{X}_w$ = weighted mean score, $w_i$=weight of $i^{th}$ item and $X_i$ =value of the $i^{th}$ item X. Whereas the suggestions were analyzed using frequency and percentage. The constraints and suggestions were ranked by arranging them in descending order.

## RESULTS AND DISCUSSION

The results in the table 1 indicated that labour shortage/ costly wages (75.00), lack of technical guidance about cultivation (72.50), untimely, costly and poor quality inputs (70.00), lack of proper infrastructure facilities such as implements, irrigation facilities, power and electricity etc. (65.33), high incidence of diseases and pests, crop failure (63.00) and lack of financial support (55.16) were the major technical constraints. Due to lack of effective labour policies, inadequate extension personnel the farmers were deprived of technical guidance related to Red gram cultivation. The results were in agreement with the findings of, Shashikant *et al.* (2012),Chodavadia, *et al.* (2013), and Ahire *et al.* (2015).

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**Table 1: Technical and operational constraints of Red gram cultivation as perceived by the respondents**

| S. No | Constraint | Farmers [N=150] | |
|---|---|---|---|
| | | WMS | Rank |
| 1. | Untimely, costly and poor quality inputs | 70.00 | III |
| 2. | Lack of proper infrastructure (implements, irrigation facilities, power, and electricity) | 65.33 | IV |
| 3. | High incidence of diseases and pests, crop failure | 63.00 | V |
| 4. | Labour shortage/ Costly wages | 75.00 | I |
| 5. | Lack of financial support | 55.16 | VI |
| 6. | Lack of technical guidance about cultivation | 72.50 | II |

**Table 2: Marketing constraints with respect to Red gram cultivation as perceived by the respondents**

| S. No | Constraint | Farmers [N=150] | |
|---|---|---|---|
| | | WMS | Rank |
| 1. | Price fluctuation | 74.16 | I |
| 2. | Lack of market awareness | 72.66 | V |
| 3. | Too many intermediaries in non-FPO based supply chain | 73.00 | IV |
| 4. | Distant market and the high cost of transportation | 71.66 | VIII |
| 5. | Exploitation by middlemen and traders | 73.16 | III |
| 6. | Delayed payment | 72.00 | VII |
| 7. | Illiteracy and Lack of unity among members | 72.50 | VI |
| 8. | Lack of well-developed storage facilities | 70.00 | IX |
| 9. | Lack of well-developed processing facilities | 66.83 | X |
| 10. | Lack of assured procurement facilities | 73.67 | II |

In case of marketing constraints, findings of the table 2 showed price fluctuation (74.16) was the most serious constraint followed by lack of well-developed procurement facilities (73.67), Exploitation by middlemen and traders (73.16), Too many intermediaries in non-FPO based supply chain (73.00), Distant market and the high cost of transportation (71.66), Lack of well-developed storage facilities (70.00), Lack of well-developed processing facilities (66.83). The results were in agreement with the findings of, Shashikant *et al.* (2012), Chodavadia, *et al.* (2013), and Ahire *et al.* (2015).

**Table 3: Suggestions given by the respondents for overcoming technical and operational constraints of Red gram cultivation**

| S. No | Suggestions | Farmers [N=150] | | |
|---|---|---|---|---|
| | | Frequency | % | Rank |
| 1. | Provision of inputs at subsidized rates | 150 | 100.00 | I |
| 2. | Provision of infrastructure [implements, irrigation facilities, power, and electricity] | 150 | 100.00 | I |
| 3. | Providing technical guidance | 113 | 75.33 | II |
| 4. | Provision of credit facilities | 95 | 63.33 | III |
| 5. | Regular demonstrations for controlling pests and diseases | 150 | 100.00 | I |

**Table 4: Suggestions given by the respondents for overcoming marketing constraints of Red gram cultivation practices**

| Sl. No | Suggestions | Farmers [n=150] | |
|---|---|---|---|
| | | Frequency | % |
| 1. | Regular procurement of products every year by the government | 150 | 100.00 |
| 2. | Provision of storage and processing facilities | 150 | 100.00 |
| 3. | Establishing an organized supply chain without many intermediaries in non-FPO based supply chain | 150 | 100.00 |
| 4. | MSPs should be strictly enacted in all the supply chain systems | 150 | 100.00 |
| 5. | Establishment of procurement centers at every village (Gram panchayats) | 150 | 100.00 |
| 6. | Ensure immediate payments through the direct benefit transfer system | 150 | 100.00 |
| 7. | Providing market awareness at every crop season | 150 | 100.00 |

To overcome the constraints the farmers provided the following suggestions. Table 3 indicated that cent per cent of them urged for the provision of inputs at subsidized rates, providing infrastructure facilities and regular demonstrations of cultivation practices for the control of pests and diseases followed by provision of technical guidance (75.33 %) about recommended cultivation practices like seed treatment, nipping practice, use of growth regulators, procedure of use plant protection chemicals, etc. The farmers were spending a major portion of their costs on purchasing pesticides, growth regulators, etc. hence they were commending for providing them at subsidized rates.

In case of mitigation of marketing constraints Table: 4 showed that cent per cent of the farmers felt that their products should be procured every year by the government otherwise the government should ensure all the supply chains to procure at not less than MSP. They also urged for the establishment of an organized supply chain without many intermediaries so that they escape from the exploitation of middlemen and traders. Similar results were observed in the study of Shashikant *et al.*(2012).

## CONCLUSION

Understanding about the problems and suggestions from the farmers would help the change agencies to develop effective strategies for improving the ways of providing awareness thus help in adoption of recommended practices. There is a need for the district level agencies like ATMA and KVKs to encourage for the collectivization of Red gram growers into Farmers Producer Organizations (FPOs) and coordinate and streamline the efforts of stakeholders like NGOs, Private agencies, line departments of agriculture, State agricultural universities, etc. to provide adequate forward and backward linkages for improving the production and productivity of Red gram cultivation in Bidar and Kalaburagi districts of Karnataka.

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# EFFECT OF TRAINING PROGRAMMES ON KNOWLEDGE LEVELS OF PADDY AND COTTON FARMERS IN PRAKASAM DISTRICT OF ANDHRA PRADESH

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## ABSTRACT

To assess the effect of the training programmes organized by District Agricultural Advisory and Transfer of Technology Centre (DAATTC), Ongole, an investigation was carried out in Prakasam district of Andhra Pradesh during the year 2016-17. Training programmes organized for thirty paddy farmers and thirty two cotton farmers and the trainees of the training programme were the sample for the study purpose. The effectiveness of the training programme was assessed by studying knowledge levels of the farmers before and after participating in training programmes. Majority of the paddy farmers were in middle age group, with high school education, medium farming experience, farm size, extension contact, innovativeness, trainings undergone and mass media exposure. Sixty per cent of the paddy farmers were with low knowledge in pre test followed by one third with medium and almost seven per cent with high knowledge. With respect to post knowledge test fifty three per cent of the paddy farmers were in high knowledge group followed by forty per cent in medium and almost seven per cent with low knowledge. Regarding knowledge gain of the farmers sixty per cent were with high knowledge gain followed by medium (30.00%) and low (10.00%) categories. Majority of the cotton farmers were in middle age group, functionally literate and with high farming experience, medium and low farm size, medium extension contact, innovativeness, trainings undergone and mass media exposure Forty seven per cent (46.88%) of the cotton farmers were with low knowledge followed by 43.75 per cent in medium and 9.37 per cent in high knowledge groups in pre test. Whereas fifty six per cent of the farmers were with medium knowledge followed by high (40.63%) and low (3.13%) knowledge groups in post knowledge test. Almost half the cotton farmers were found with high knowledge gain followed by medium (40.63%) and low (12.50%) categories. Education, mass media use, extension contact and trainings undergone by the paddy farmers were found to have significant positive relation with their knowledge gain. Extension contact, innovativeness, mass media use and trainings undergone had significant positive relation with their knowledge gain with respect to cotton farmers.

Investing in human capital is one of the most effective means of reducing poverty and ensuring sustainable development in rural areas of our country. Available agricultural technology does not serve its purpose till it reaches and adopted by its ultimate users, the farmers. Technology transfer refers to the spread of new ideas from originating sources to ultimate users (Prasad *et al. 1987*). Capacity building of the farmers to face the impending challenges of globalization and liberalization further necessitated the need for a strong and innovative extension system.

Training is an empowerment process of creating awareness, imparting knowledge and capacity building leading to greater participation for greater decision making (Punia *et al*., 2007).In this direction, training programs can bring about tremendous desirable change in knowledge, skill, attitudes and behavior of the farmers enabling them not only to become well acquainted with the recent technologies but also to enhance their skills, competencies and efficiency in a desired manner.

One of the major mandatory activities of District Agricultural Advisory and Transfer of Technology Centre (DAATTC) is to provide training to farmers and improve the level of knowledge of the trainees about the improved farm practices, because knowledge is cognitive component of individual's mind and plays an important role in covert as well as overt behaviour and individuals with a greater knowledge of technical nature of improved practices would lead to a high adoption possibly because knowledge is not inert. Once knowledge is acquired and retained, it undergoes and produces changes in the thinking process and of mental alchemy. Paddy and cotton were the two important crops cultivated in Prakasam district with an area of 44,000 ha and 54,393 ha respectively. Hence, DAATTC Ongole had organized training programmes to farmers on paddy and cotton cultivation aspects during the year 2015-16. The advantage of assessing knowledge, attitude and practice after training of farmers on a given agro technology is one of the tools for information on the effectiveness of training (Adhikarya,1996).With this background pre- and post-evaluation has been conducted to know the knowledge of the trainees before and after the training to understand how the training programmes have changed the knowledge of the trainees.

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## MATERIALS AND METHODS

The present evaluation study was conducted at the DAATTC, Ongole, Prakasam district of Andhra Pradesh state. The major crops of the district include paddy, redgram, cotton and groundnut. Two training programmes for two batches of 30 paddy farmers and 32 cotton farmers were organized by DAATTC, Ongole during the year 2015-16. The socio economic profile characteristics of the paddy and cotton farmers were studied using structured schedule. To understand the level of knowledge on different aspects of paddy and cotton improved agricultural technologies of the participants before and after the training programme, a pretested schedule was used and the data collected was pooled from both the batches and analyzed using statistical tools. The scores obtained by the participants in both the tests were recorded and analyzed to evaluate the knowledge gain. Correlation analysis was carried out to assess the relationship between profile characteristics of farmers and their knowledge gain through training.

## RESULTS AND DISCUSSION

### Profile Characteristics of Paddy farmers

Data pertaining to profile characteristics of paddy farmers is presented in Table 1. It could be inferred from the table that majority of the paddy farmers were in middle age group (40.00%) followed by old age (36.67%) and young age (23.33%) groups. They had high school education (26.67%), followed by functionally literate and with primary school education (20.00%). Majority of the paddy farmers were found with medium farming experience and farm size (43.33%), extension contact (43.33), innovativeness (56.67%), trainings undergone (50.00%) and mass media exposure (60.00%).

**Table 1: Profile Characteristics of Paddy farmers**

n=30

| S.No | Socio-Economic characteristics | Fre quency | Per centage |
|---|---|---|---|
| 1. | Age | | |
| | i. Young age | 7 | 23.33 |
| | ii. Middle age | 12 | 40.00 |
| | iii. Old age | 11 | 36.67 |
| | | 30 | 100.00 |
| 2 | Education | | |
| | i. Illiterate | 4 | 13.33 |
| | ii. Functionally literate | 6 | 20.00 |
| | iii. Primary school | 6 | 20.00 |
| | iv. Middle school | 3 | 10.00 |
| | v. High school | 8 | 26.67 |
| | vi. PUC | 3 | 10.00 |
| | vii. Graduate and above | 0 | 0.00 |
| | | 30 | 100.00 |
| 3 | Farming experience | | |
| | i. Low | 5 | 16.67 |
| | ii. Medium | 13 | 43.33 |
| | iii. High | 12 | 40.00 |
| | | 30 | 100.00 |
| 4 | Farm size | | |
| | i. Low | 8 | 26.67 |
| | ii. Medium | 13 | 43.33 |
| | iii. High | 9 | 30.00 |
| | | 30 | 100.00 |
| 5 | Extension contact | | |
| | i. Low | 7 | 23.33 |
| | ii. Medium | 13 | 43.33 |
| | iii. High | 10 | 33.34 |
| | | 30 | 100.00 |
| 6 | Innovativeness | | |
| | i. Low | 4 | 13.33 |
| | ii. Medium | 17 | 56.67 |
| | iii. High | 9 | 30.00 |
| | | 30 | 100.00 |
| 7 | Trainings undergone | | |
| | i. Low | 8 | 26.67 |
| | ii. Medium | 15 | 50.00 |
| | iii. High | 7 | 23.33 |
| | | 30 | |
| 8 | Mass media exposure | | |
| | i. Low | 6 | 20.00 |
| | ii. Medium | 18 | 60.00 |
| | iii. High | 6 | 20.00 |
| | | 30 | 100.00 |

**Knowledge levels of the paddy farmers before and after conducting training programme**

Findings regarding the knowledge levels of the farmers before and after participation in training programme is presented in Table 2 & 3. In pre knowledge test sixty per cent of the paddy farmers were with low knowledge followed by one third in medium and only 6.67 per cent in high category. After participating in training programme on paddy cultivation more than fifty per cent (53.33%) of the trainees were with high knowledge followed by forty per cent in medium and very meager per cent (6.67%) in low knowledge categories. Regarding knowledge gain of the farmers, sixty per cent of the farmers gained high knowledge followed by thirty per cent in medium and ten per cent in low knowledge gain categories. Low knowledge of Paddy farmers during pre test is attributed to their insufficient knowledge with respect to recommended cultivation practices in paddy in general and pest and disease management, fertilizer management, weed management and irrigation management in particular.

Data in Table 3 depicts that in the pre knowledge test majority of the paddy farmers had incorrect knowledge on irrigation management (90.00%) followed by seed treatment (83.33%), sowing and nursery management (76.67%), disease management (73.33%), fertilizer management (70.00%), pest management (66.67%) and weed management (53.33%). The effect of the training programme is depicted in the post test by the correct knowledge gained by the paddy farmers on fertilizer management (80.00%) followed by weed management (76.67%), pest management (70.00%), seed treatment (66.67%),

**Table 2. Knowledge levels of the paddy farmers before and after conducting training programmes**

n=30

| Category | Pre test | | | Post test | | | Knowledge gain | | |
|---|---|---|---|---|---|---|---|---|---|
| | Range | Freq. | % | Range | Freq | % | Range | Freq. | % |
| **Low** | <3.163 | 18 | 60.00 | <7.36 | 2 | 6.67 | <1.56 | 3 | 10.00 |
| **Medium** | 3.163 -7.087 | 10 | 33.33 | 7.36-10.14 | 12 | 40.00 | 1.56-5.56 | 9 | 30.00 |
| **High** | >7.087 | 2 | 6.67 | >10.14 | 16 | 53.33 | >5.56 | 18 | 60.00 |
| **Total** | | 30 | 100.00 | | 30 | 100.00 | | 30 | 100.00 |
| | Mean=5.125 SD= 1.962 | | | Mean= 8.75 SD= 1.390 | | | Mean=3.5625 SD= 1.998 | | |

**Table 3: Item analysis in knowledge of the farmers on paddy production technologies**

n=30

| S.No | Aspects of training | Pre test | | | | Post test | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Correct knowledge | | Incorrect knowledge | | Correct knowledge | | Incorrect knowledge | |
| | | Freq | % | Freq | % | Freq | % | Freq | % |
| 1. | Seed treatment | 5 | 16.67 | 25 | 83.33 | 20 | 66.67 | 10 | 33.33 |
| 2. | Sowing and nursery management | 7 | 23.33 | 23 | 76.67 | 19 | 63.33 | 11 | 36.67 |
| 3. | Fertilizer management | 9 | 30.00 | 21 | 70.00 | 24 | 80.00 | 6 | 20.00 |
| 4. | Irrigation management | 3 | 10.00 | 27 | 90.00 | 18 | 60.00 | 12 | 40.00 |
| 5. | Weed management | 14 | 46.67 | 16 | 53.33 | 23 | 76.67 | 7 | 23.33 |
| 6. | Pest management | 10 | 33.33 | 20 | 66.67 | 21 | 70.00 | 9 | 30.00 |
| 7. | Disease management | 8 | 26.67 | 22 | 73.33 | 19 | 63.33 | 11 | 36.67 |

sowing and nursery management and disease management (63.33%) and irrigation management (60.00%). Farmers used to believe that the seed provided by the Department of Agriculture and private agencies will be treated for all pest and diseases. But only after getting trained they came to know different types of seed treatments and seed treatment chemicals. Paddy farmers were lacking knowledge on fertilizer management and recent recommended pest and disease management chemicals, due to which their knowledge score was low on these aspects. During training programme they were able to gain knowledge on compatibility of pesticides and fungicides. These results emphasize the importance of training in the knowledge improvement of the farmers which in turn helps in adoption of technologies learnt in the training programmes. This is in conformity with the study of Singh *et al*., (2010) and Shankara *et al.,* (2014).

**Profile Characteristics of cotton farmers**

It could be noticed from Table 4 that majority of the cotton farmers were middle aged (56.25%), followed by old age (31.25%) and young age groups. One fourth of the farmers were with functional literacy and high school education. Half of the cotton farmers had high farming experience followed by thirty one per cent with medium experience. Equal per cent (37.50%) of the farmers had low and medium farm size followed by twenty five per cent farmers in high group. Majority of the trainees were with medium extension contact (43.75%), innovativeness, mass media exposure (56.25%) and trainings undergone (46.87%).

**Table 4:Socio-Economic Characteristics of Cotton farmers**

n=32

| S.No | Socio-Economic characteristics | Freq | % |
|---|---|---|---|
| 1. | Age | | |
| | i. Young age | 4 | 12.50 |
| | ii. Middle age | 18 | 56.25 |
| | iii. Old age | 10 | 31.25 |
| | | 32 | 100.00 |
| 2 | Education | | |
| | i. Illiterate | 5 | 15.63 |
| | ii. Functionally literate | 8 | 25.00 |
| | iii. Primary school | 2 | 6.25 |
| | iv. Middle school | 4 | 12.50 |
| | v. High school | 8 | 25.00 |
| | vi. PUC | 4 | 12.50 |
| | vii. Graduate and above | 1 | 3.12 |
| | | 32 | 100.00 |
| 3 | Farming experience | | |
| | i. Low | 6 | 18.75 |
| | ii. Medium | 10 | 31.25 |
| | iii. High | 16 | 50.00 |
| | | 32 | 100.00 |
| 4 | Farm size | | |
| | i. Low | 12 | 37.50 |
| | ii. Medium | 12 | 37.50 |
| | iii. High | 8 | 25.00 |
| | | 32 | 100.00 |
| 5 | Extension contact | | |
| | i. Low | 10 | 31.25 |
| | ii. Medium | 14 | 43.75 |
| | iii. High | 8 | 25.00 |
| | | 32 | 100.00 |
| 6 | Innovativeness | | |
| | i. Low | 4 | 12.50 |
| | ii. Medium | 18 | 56.25 |
| | iii. High | 10 | 31.25 |
| | | 32 | 100.00 |
| 7 | Trainings undergone | | |
| | i. Low | 7 | 21.88 |
| | ii. Medium | 15 | 46.87 |
| | iii. High | 10 | 31.25 |
| | | 32 | 100.00 |
| 8 | Mass media exposure | | |
| | i. Low | 6 | 18.75 |
| | ii. Medium | 18 | 56.25 |
| | iii. High | 8 | 25.00 |
| | | 32 | 100.00 |

**Knowledge levels of the cotton farmers before and after conducting training programme**

The findings presented in Table 5 indicated that, 46.88 per cent of the farmers were in low knowledge group followed by 43.75 per cent in medium and 9.37 per cent in high categories during pre knowledge test. Whereas, in post knowledge test 56.25 per cent of the farmers were with medium knowledge followed by 40.63 per cent in high and very meager per cent (3.13%) were in low knowledge category. Almost half (46.88%) of the cotton farmers gained high knowledge followed by 40.63 per cent in medium gain category followed by 12.50 per cent in low knowledge through training on cotton cultivation aspects.

knowledge test. Enhanced knowledge levels of cotton farmers was reflected in terms of their correct knowledge on pest management (73.33%), drought management (65.63%), fertilizer management (62.50%), disease management (59.38%), non Bt refugee crop (56.25%), weed management (53.13%) and micronutrient management (50.00%) in post test. These results clearly indicated the effect of training programme on knowledge levels of the farmers. But still half the cotton farmers were with incorrect knowledge on micronutrient management. This may be because of their inability to differentiate disease symptoms with that of micro nutrient deficiency symptoms. The probable reason for their confusion might be similar symptoms like yellowing and drying of the leaves at final stages of micronutrient deficiency, severe pest and disease incidence. Hence diagnosis at early stages will help farmers to plan and implement effective crop management practices.

**Table 5: Knowledge levels of the cotton farmers before and after conducting training programmes**

n=32

| Category | Pre test | | | Post test | | | Knowledge gain | | |
|---|---|---|---|---|---|---|---|---|---|
| | Range | Freq. | % | Range | Freq. | % | Range | Freq. | % |
| **Low** | <2.76 | 15 | 46.88 | <7.64 | 1 | 3.125 | <3.1216 | 4 | 12.50 |
| **Medium** | 2.76 -5.96 | 14 | 43.75 | 7.64-9.36 | 18 | 56.25 | 3.12-5.17 | 13 | 40.63 |
| **High** | >5.96 | 3 | 9.37 | >9.36 | 13 | 40.625 | >5.17 | 15 | 46.88 |
| **Total** | | 32 | 100.00 | | 32 | 100.00 | | 32 | 100.00 |
| | Mean=4.36 SD= 1.6 | | | Mean= 8.5 SD= 0.85 | | | Mean=4.14 SD= 1.03 | | |

Item analysis in knowledge of the farmers depicted in Table 6 revealed that majority of the cotton farmers had incorrect knowledge levels on growing non Bt refugee crop (87.50%) followed by fertilizer management (81.25%), drought management (75.00%), micronutrient management (71.87%), weed management (68.75%), disease management (62.50%) and pest management (56.25%) in pre

**Table 6: Item analysis in knowledge of the farmers on cotton production technologies**

n=32

| S.No | Aspects of training | Pre test | | | | Post test | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Correct knowledge | | Incorrect knowledge | | Correct knowledge | | Incorrect knowledge | |
| | | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| 1. | Refugee crop | 4 | 12.5 | 28 | 87.50 | 18 | 56.25 | 14 | 37.50 |
| 2. | Fertilizer management | 6 | 18.75 | 26 | 81.25 | 20 | 62.50 | 12 | 37.50 |
| 3. | Drought management | 8 | 25.00 | 24 | 75.00 | 21 | 65.63 | 11 | 34.37 |
| 4. | Weed management | 10 | 31.25 | 22 | 68.75 | 17 | 53.13 | 15 | 46.87 |
| 5. | Micro nutrient management | 9 | 28.13 | 23 | 71.87 | 16 | 50.00 | 16 | 50.00 |
| 6. | Pest management | 14 | 43.75 | 18 | 56.25 | 22 | 73.33 | 10 | 31.25 |
| 7. | Disease management | 12 | 37.50 | 20 | 62.50 | 19 | 59.38 | 13 | 40.62 |

**Relationship between profile characteristic of paddy farmers and their knowledge gain through training programme.**

It is evident from table 7 that education and mass media use had significant positive relation with knowledge gained by the paddy farmers at 0.05% level of significance. Trainings undergone and extension contact were the variables having significant positive relation at 0.01% level. Education is the variable which facilitates the farmers to get acquainted with the recent technologies. Mass media use and extension contact were the factors which contributed towards their knowledge because of their exposure to the new technologies. It implies that with the increase in mass media use and extension contact there is increase in knowledge gained by the farmers. A positive and significant association with training undergone implies that farmers who have attended more number of trainings have gained more knowledge on the improved cultivation practices of the paddy crop. It is in line with the findings of Parvinder Sharma *et al* (2013) .

**Table 7: Relationship between profile characteristics of paddy farmers and their knowledge gain**

n=30

| S.No | Variable | Correlation coefficient (r) |
|---|---|---|
| 1. | Age | 0.283 NS |
| 2. | Education | 0.410 * |
| 3. | Farming Experience | 0.025 NS |
| 4. | Farm size | 0.110 NS |
| 5. | Extension contact | 0.517 * * |
| 6. | Innovativeness | 0.261 NS |
| 7. | Trainings undergone | 0.87 * * |
| 8. | Mass media use | 0.450 * |

*- significant at 0.05% level , ** - significant at 0.01% level

**Relationship between profile characteristic of cotton farmers and their knowledge gain through training programme.**

It could be noticed from table 8 that, at 0.05% level of significance extension contact and at 0.01% level of significance mass media use, innovativeness and trainings undergone had significant positive relationship with knowledge gain of the cotton farmers. This may be because more the extension contact more will be the possibility of exposure to recent developments in the field of agriculture. Mass media use was the another factor that helps the farmers to gain knowledge on cotton cultivation aspects. More the innovativeness of the farmers more will be the efforts to gain knowledge hence innovativeness had strong positive relation with the knowledge gained by the farmers. Training programmes were the major sources to update the knowledge levels of the farmers and to convince them for further adoption.

Lack of correct and inadequate knowledge leads to under or over adoption of technologies which proves fatal to the farming. Results revealed that majority of the paddy and cotton farmers gained good knowledge on production aspects. There is observed difference between pre and post test scores regarding their knowledge levels. We, therefore, conclude that after participation in training programmes they had greater knowledge on improved production technologies of paddy and cotton than prior to participation in training programmes. Regular training programmes need to be organized in order to enhance the knowledge levels of the farmers. Farmers should be encouraged and persuaded to take advantage and participate actively in such training programmes in order to increase their productivity and income for escaping poverty.

**Table 8: Relationship between profile characteristics of cotton farmers and their knowledge gain**

n=32

| S.No | Variable | Correlation coefficient (r) |
|---|---|---|
| 1. | Age | 0.128NS |
| 2. | Education | 0.244NS |
| 3. | Farming Experience | 0.015NS |
| 4. | Farm size | 0.265NS |
| 5. | Extension contact | 0. 431* |
| 6. | Innovativeness | 0.63** |
| 7. | Trainings undergone | 0.703** |
| 8. | Mass media use | 0.542** |

*- significant at 0.05% level , ** - significant at 0.01% level

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# CELLULAR STRUCTURE FORMATION IN PUFFED RICE CAKES USING SEM ANALYSIS

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## ABSTRACT

The increase in the trend of breakfast cereal and convenience food has raised the stage for several innovations to serve the need. Puffing is a very traditional and old practice of processing cereal grains that form light, fluffy, crispy product that are highly consumer-acceptable. Puffed rice cakes are novel food products that have been recently added to breakfast cereals. There is accumulation of individually puffed grains to form a disc or biscuit like shape. The novelty of this product is that the disc shape is maintained by the grain without addition of any binding agents. Puffing is an instantaneous process which occur in few seconds at high temperatures to form light, fluffy expanded product that is crunchy and have good consumer acceptance. During the formation, puffing of grains occur upon rapid heating of the platens of mould due to which the unbound moisture gets evaporated and nucleates to form small gas cells. These gas cells increase in size as the temperature increases the volume till the vapour pressure is nullified by the pressure exerted by solid matrix. The SEM analysis showed the microstructural changes occurred in the rice cakes during the formation. It showed struts and nodes with closed air pockets. The changes in the rice cake during formation were observed at every 0.5 second from 1 to 4 seconds which showed the formation of bubbles and the air cells.


Rice is one of the most widely consumed cereal by majority of population of South and South-east Asia, where about 90% of the production occurs. It has been traditionally used as staple food, and also as breakfast cereal and snack. In South-Asia apart from table rice, the puffed, popped and flaked rice are also very prominent for subsidiary consumption (Bhattacharya, 2011). Production of subsidiary products from rice like puffed rice, rice flour, vermicelli, semolina etc., from the by-products of rice during processing like large brokens ensure reduction of post-harvest losses as well as increase the income generation from the crop (Samaddar *et al*., 2017). Puffing can be explained as a process of expansion of kernel of a grain as such, without distortion to the shape. Puffing is a traditional process of cereal processing in South Asian countries, and is widely consumed as a light-snack.The puffing of material is achieved by subjecting to ultra-high temperatures, causing the moisture present in it to undergo flash vaporisation (Chandrasekhar & Chattopadhyay, 1991). The phenomenon of puffing can be compared with formation of blow plastics like polystyrene in which a gas-generating blowing agent would be introduced into a polymer at molten state. The expansion of the blowing agent causes the polymer melt to expand and yield to form the puffed structure (Elshereef, Vlachopoulos, & Elkamel, 2010). In case of puffed rice, the blowing agent is internally generated due to high temperatures by evaporation of moisture present in the grain and the polymer melt can be compared with the starch present in the rice grains that tend to come to amorphous state from glassy state due to elevation in temperature.

Puffed rice cakes are relatively novel products from rice. They are puffed products in disc shape and are one of the popular ready-to-eat convenience foods made of rice. Puffed rice cakes, also called as rice thins, are a low-calorie cereal substitute and a convenience food. The rice thins have a unique characteristic that no binder is required to bind the puffed grains into disc shaped form. They are formed from the tempered, pre-conditioned rice which is puffed and fused to form disc-like shape simultaneously during puffing (Hsieh*et al*., 1989). The puffed rice cakes were formed using compression-mould technique which uses flash vaporization and pressure-drop to cause puffing and formation of disc simultaneously. The equipment consists of a metal mould made up of two different platens that fuse to form the mould. The two platens, one adjustable and one fixed, get fixed in a ring-shaped side piece into which the two platens sit to form a complete mould. The mould had been pre-heated to

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200°C to 260°C. When tempered and conditioned grain gets placed on the pre-heated mould, the movable upper platen lowers on to the sample and apply minute pressure to spread the rice in bottom of mould, during which the grain starts to get heated from all sides. This causes increase in the grain temperature, which generates water vapour to be formed inside the kernel, which do not have an escape. The pressure build-up in the kernels of grain occurs due to accumulation of water vapour in it. The high temperatures would also cause phase change in the starch present in the grain, causing it to form a gelatinised solid. The upper platen suddenly lifts to a pre-set height after few seconds providing space for the grain to expand. A pressure gradient is created in the mould and in the grain due to the sudden lifting of the upper platen of the mould. The formed water vapour in the grain suddenly escapes through the gelatinised mass of starch causing to yield and form a matrix like network spontaneously. Also, since the expansion of grain occurs in a closed mould, the pressure with which the expansion of grains occur makes them adhere to each other forming disc-like structure (Hsieh *et al*., 1989; Sharma, 2012). The formation of cakes is very rapid and is achieved within 3 to 10 seconds, which makes studying of structural formation difficult.

## MATERIALS AND METHODS

### Procurement of sample

Paddy (CR 1009 variety) which was harvested in January 2018, was obtained from Soil and Water Management Research Institute (Kattuthottam, Tamilnadu, India). The proximate analysis of sample, CR 1009 rice was performed using standard methodology (AACC, 2000).

### Differential Scanning Calorimetry

The Differential scanning calorimeter (NETZSCH- DSC214 Polyma, Model No. DSC21400A-0470-L) with DSC 214 Corona sensor available at SASTRA University, Thanjavur was used to determine the thermal properties like gelatinization temperature between the rice cultivar. The peak temperature was taken as the gelatinization temperature and the area under curve was used to calculate the differences in enthalpy. Rice flour (8±0.5 mg) was taken in priorly weighed aluminium pan (Concavus Pan Al) which was hermetically sealed after addition of 8 µL of deionised water using a micro-syringe. The aluminium pans were equilibrated at room temperature for 1 hour after which they were scanned from 20°C to 200°C by rising temperature at rate of 10° C/min against empty pierced aluminium pan as reference. The outer atmosphere of the chamber was purged with nitrogen gas at rate of 40 ml/min. to avoid condensation (Bhattacharya, 2011). The sample CR 1009 was analysed twice for DSC, first with normal moisture content present in the flour and second by increasing the moisture content to 18% to simulate the conditions in production of puffed rice cakes to find the changes in glass transition that occurs.

### Preparation of Puffed rice cakes

The dry paddy was exposed to steam for 10 minutes and allowed to condition for 1 hour. The steamed, tempered grain was dried to moisture content of 12%. The steam-parboiled paddy was subjected to de-husking in Satake Testing Rice De-husker (Model: 1012260, Make: Satake Corporation, Japan). The de-husked rice was adjusted to moisture of 16-18% and conditioning for 1 hour. The conditioned grain was made into rice cakes in puffed rice caking machine at air pressure, 6 psu; cooking time 3.5 sec; setting time 1.5 sec; clearance between two platens 0.47 cm.; mould temperature 260°C. To understand the structural formation in rice cakes, the rice cakes were taken out of the mould at intervals of 0.5 seconds from 1 to 4 seconds.

### Scanning Electron Microscopy

The puffed rice cake samples were observed under Scanning electron microscope (Model: TE-SCAN VEGA 3 SEM) to analyse the sequence of changes in the surface morphology and microstructure (cross-section) during the process of formation of the final product. The puffed rice cake samples were removed from the mould at different cooking time i.e. 1, 1.5, 2, 2.5, 3, 3.5, 4.0 seconds (Sharma, 2012). The puffed rice cakes were resized using a surgical blade to a 1x1 cm. size for convenience. The samples were mounted on an aluminium stub using double-sided conductive tapes for sputter-coating with gold for 30 seconds (Model: JEOL JFC 1600). The gold coated samples were viewed under SEM at different magnifications and angles.

## RESULTS AND DISCUSSION

### Properties of rice

The whole rice flour contained 10.46% moisture,11.74% protein,1.53% ash,1.74% fat and amylose-amylopectin ratio of 0.08:1.Water absorption capacity of brown rice was 180.31% and alkali degradation score was 2. The paddy had pasting properties, peak viscosity of 1441±166.8cp and final viscosity of 5340±472.3cp, with pasting temperature of 72.28±1.15°C. The milled brown rice was used in preparation of puffed rice cakes.

**Table 1: DSC analysis of CR 1009**

| Parameter | CR 1009 with 11% moisture | CR 1009 with 18% moisture |
|---|---|---|
| Onset ($T_o$) | 100.2 °C | 110.5 °C |
| Mid ($T_m$) | 129.2 °C | 116.3 °C |
| Inflection ($T_i$) | 99.8 °C | 114.3 °C |
| End ($T_c$) | 150.6 °C | 122.7 °C |
| Peak ($T_p$) | 92.8 °C | 100.3 °C |
| Final ($T_f$) | 28.0 °C | 129.5 °C |
| $\Delta C_p$ | 5.168 J/ (g °K) | 7.718 J/ (g °K) |

The DSC analysis of the CR 1009 sample was performed with added moisture to understand the changes in glass transition due to added moisture. The moisture content of 18% was selected to simulate the conditions of the production of puffed rice cakes. The sample with increased moisture showed a considerable rise of 10 °C in onset temperature and the peak temperature raised by about 8 °C (Table 1). There was also a considerable increase in the change in specific heat by 2.55 J/ (g °K). However, the end temperature has dropped to 122.7 °C from 150.6 °C after addition of moisture to the sample.

The reason for increase in glass transition and enthalpy might be due to greater moisture which takes more heat energy to raise the temperature of the sample. The moisture needs to attain the temperature after which the starch granules would be able to receive the heat energy for transition. The peak formed also had a sharp tip smooth edges and minimal deflections in the curve.

### Preparation of rice cake

The rice with less than 15% moisture content formed rice cakes that did not have shape holding after unmoulding, due to less moisture availability for evaporation, showing more hardness and less formability. As the amount of available moisture for expansion is less, it forms relatively smaller air pockets in 3-dimensional gelatinous starch matrix, resulting in less cellularity. Similarly, the moisture content more than 18% resulted in excessive puffing of rice kernels, thus making it unable to hold its disc shape. Also, greater moisture content of rice showed puffed rice kernels shooting out of the mould individually, when the mould lifts up for 0.47 cm for creating pressure drop.Previous studies have shown that the rate of expansion and specific volume of rice cakes increased with increase in tempering moisture level (Huff, HsiehF., & Peng, 1992), which was on par with the studies of Hsieh et al., (1989). It has been shown that rice at optimum moisture content, tempered for shorter time resulted in rice cakes with greater specific volume (Sharma *et al*., 2010).

The processing of rice grains typically involves heating of grain to a temperature at which the starch granules present in the grain gets manipulated. The increase in heat to reach the glass transition causes the crystalline matrix of starch to melt and form a paste like amorphous melt. Further increase in temperature causes the moisture content in grain to evaporate and increase in volume. The water vapour nucleates and forms bubbles that expand with temperature till the vapour pressure and shear strength of the starch matrix nullifies each other at which expansion ceases forming a 3-dimensional network with closed air pockets.

### Formation of rice cake

The process of puffing is instantaneous in which the small amount of moisture present in grain acts as driving force for the grain to increase in volume and puff. The preliminary trials have suggested that the puffing process in formation of puffed rice cakes occurred only for 3.5 to 4 seconds after which the expanded partially gelatinised starch started scorching and exhibited gradual discolouration as the time increased. The puffed rice cakes formed at intervals of 1, 1.5, 2, 2.5, 3, 3.5 and 4 seconds were observed in Scanning electron microscope to observe the changes occurring to the grain at microstructural level. The occurrence of heterogeneity in the rice cakes might be affected by several factors like pressure of water vapour, process parameters variations, occurrence of cracks and intergranular spaces in the grain endosperm, presence of bran and chalkiness and arrangement and composition of starch granules (Sharma, 2012). It has been observed from the SEM that the expansion of grain is higher at the periphery of the grain showing larger but a smaller number of air cells, whereas the central portion had very small numerous air cells.

At 1 second (Fig 1(a)), the rice sample started to swell on the outer side which is touching the mould surface since the heat transfer starts to occur initially. The top surface of grain showed many creases and abrasions that might be occurred due to uneven heat transfer in the initial period which causes the starch granules to swell and puff in an asymmetrical pattern causing the bumpy texture. It was observed that minute micropores started to form on the surface of grain facilitating the water vapour that is formed due to high temperatures to escape out. The space between the grains was found to be very minute and the grains were found to be twisting and inter-locking with each other during puffing. The surface of the grains started to show the patterns that look like yielding of the material for expansion.

The rice surface started smoothening once the puffing has started in Fig 1(b), at 1.5 seconds. The grain surface also showed patterns like yielding and filling of the cracks in the grain due to expansion. At 2 seconds, the surface of the grain is seen with many pin holes and pores since the increase in time caused greater evaporation of moisture in the air cells formed (Fig 1(c)). The greater evaporation builds up higher pressure that causes formation of pin holes to escape. The expansion of grain was also comparatively higher. The expanded grain was seen to compress and curl inter-twining with each other since there is restriction on volume expansion due to the presence of mould. The grain surface also showed tearing of the surface layers which might be to facilitate expansion of grain.

At 2.5 seconds, the grain surface was seen to be patchy and uneven again which might be due to insufficient space for volume expansion which causes uneven structure of the grain. The surface of the grain has been shown to have several folds and creases and it has been seen to interlock with each other (Fig 1(d)). There was a thin spider web like network on the surface of the grains which might be

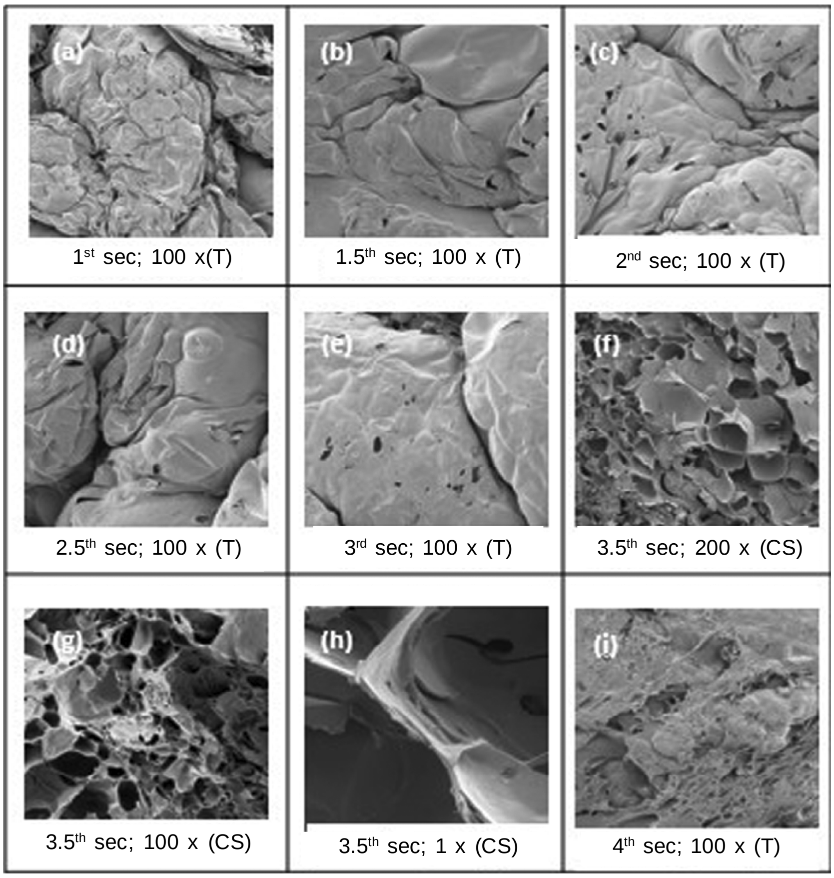


**Fig 1 : SEM images of puffed rice cakes at different time intervals (T-Top view ; CS- Cross - sectional view)**

the amylose leached from the starch granules during partial glass transition and gelatinisation. The rice cake formed at 3 seconds showed similar pinholes, creases and surface abrasion like sample at 2.5 seconds (Fig 1(e)). The tearing of surface layers showed the bottom layers beneath the surface.

At 3.5 seconds, the surface of grains showed comparatively lesser abrasion and pores. the air cells looked to be partly spherical in shape (Fig 1(f)). Some of the air cells showed damage in the struts due to tension and strain during expansion. There appears uneven breakage of the sides of the structure, which is due to the brittleness of the network (Fig 1(g)). The air cell matrix appeared to be heterogenous with uneven cell sizes and shapes. Also, some of the cells fused with adjacent cells to form larger cells. Some struts exhibited pinholes and cracks. Most of the nodes were observed to be formed at the junction of 3 struts with very rare occurrence of nodes with 4 struts (Fig 1(h)) which was similar to the results of previous researches (Mariotti, Alamprese, Pagani, & Lucisano, 2006). At 4 seconds, the surface of the grains has shown considerate amount of etching with lot of patterns that looks like tearing up of the top layers (Fig 1(i)). There had been no considerable change in volume and compactness of the grain, but the grain surface was smooth in places etching was not observed.

**Cellular structure**

The starch present in the rice grains is the key factor for formation of the puffed rice cakes. At low moisture content, when heat energy is applied to the grains, at glass transition temperature the starches present in the grain start to transform from glassy state to rubbery, amorphous state. During this transition, the moisture content present along with the starches also get heated up and show an increase in temperature. After the water molecules reach the boiling point, it starts to form small bubbles of water vapour in the viscous starch solution. The initial small bubbles expand as the time passes and the expansion causes it to draw the energy from the amorphous starches for latent heat of vaporisation (Soykeabkaew, Thanomsilp, & Suwantong, 2015). Thus, the expansion of each cell reduces the temperature of adjacent viscous starch solution. The pressure exerted by the water vapour formed will continue till it reaches to an equilibrium with the visco-elastic forces exerted by the viscous starch solution at which point both the pressures nullify each other causing the expansion to cease (Sharma, 2012).

The puffed rice cakes can be expressed as a cellular solid or a brittle starch foam based on the microstructural characteristics observed in the Scanning electron microscope. The edible solid foams are interesting type of solids due to their biphasic nature. They are made by dispersing gas into a biopolymeric matrix by means of a blowing agent that is released into the matrix by changing temperature or pressure or often both (Van der Sman, 2016). In case of the puffed rice cakes, the water vapour formed due to increase in temperature acts as the blowing agent. Also, the puffed rice cakes are different type of cellular solids or brittle foams because the grains are separately puffed to form a miniature cellular solid and all the grains fuse together due to pressure and interlocking to form a compact cellular solid. It means that the puffed rice cake is a compaction of individual cellular solids.

The puffed rice cakes make a light food and a very good breakfast cereal. The major advantages of the puffed rice cakes are its low-calorie value per serving, it adds variety to diet and it does not contain any allergens that are generally present in wheat and other millets. Though the technology for production of puffed rice cakes and automated equipment for production have been patented in 1980s, this product has been least explored.The puffed rice cakes can be added to the list of potential value-added products from rice and open a large scope for marketability.

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# ECO FRIENDLY PRINTING ON COTTON FABRIC WITH SYNTHESIZED *Azardirachta indica* LEAF DYE EXTRACT

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## ABSTRACT

A*zadirachta indica* (commonly known as neem, nimtree and Indian lilac) belongs to the family Meliaceae. This tree is drought resistant and is native to the Indian subcontinent; it typically grows in tropical and semi-tropical regions. Its fruits, leaves and seeds have many medicinal and therapeutic values. In India, it is called as sacred tree and in villages serves as a pharmacy for many diseases. In the present study, natural dye was extracted from neem leaves through aqueous method which was used as colouring pigment in print paste for screen printing. Nanoparticles were prepared from neem leaves and these were mixed in the printing paste in different percentages to identify the difference in colour fastness and wash fastness along with colour improvement.

*Azadirachta indica* has been known and is used in India for over two million years for different medicinal properties. This tree is considered as sacred tree in almost all the villages and is also commonly called as Heal all, Village Pharmacy and Panacea for all diseases. The phytochemicals present in this source are Azadirachtin, saponins, and triterpene (in seeds). Parts of neem tree like leaves, fruits, flowers and bark are well known for their anti-fungal, antibacterial, anthelmintic, anti-diabetic, contraceptive and antiviral properties. Neem leaf extracts were also used as mosquito repellent, insect repellents and to control nematodes in many tribal practices. The leaves were placed in woollens and books as well as rice sacks to protect them against pests. On the other hand, natural dyes are gaining market place and people have become aware and showing their interest towards natural dyed and printed garments and products. Natural dyes which were obtained from different mineral, animal and plant sources have been used since pre-historic times in colouring different materials like leather, food and different natural fibres. Most of the fibres have no substantivity to natural dyes, hence require a mordant as a link or bridge between fibre and the natural dye molecule to form complex bonds. Natural dyes are eco-friendly and are biodegradable when used along with natural fibres which results in increased compatibility with the environment. Deo and Desai (1999) have used commercially available tea as substrate to natural dyes, and have dyed cotton and jute fabrics with pre, meta and post mordanting methods. Despite of their inferior fastness properties, natural dyed and printed fabrics are attracting nature loving or environment conscious people. Bahtiyari *et al.* (2013) used madder, buckthorn, walnut bark and indigo as natural dye in printing of fabrics. In natural Dyeprinting, a natural gum source like gum arabica is generally used as a binding agent to fix the dye stuff on the textile material.

## MATERIALS AND METHODS

| | |
|---|---|
| Source | : *Azardiracta indica* leaves |
| Nano particles | : Nano particles extracted from *Azardiracta indica* leaves |
| Textile substrate | : Cotton fabric |
| Mordants | : Copper sulphate |
| Gum | : Cassia tora gum |

### Scouring and Pre-treatment

In the present study, 100 percent pure cotton fabric was scoured with 2 per cent NaOH and 1 per cent neutral soap solution for 3 hours using M: L: R of 1:20 at boiling temperatures. Desized fabric was treated using myrobalan solution which was prepared by soaking 20g of myrobalan powder for every 100 grams of the fabric for 4 hrs with a material to liquor ratio of 1: 30. The solution was filtered, and the fabric was soaked overnight. Later the fabric was squeezed gently and dried in direct sunlight. The side exposed to sun was used for printing.

### Preparation of Nano particles

For preparation of nanoparticles, Aqueous extraction was employed using freshly collected leaves

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of *Azardirachta indica* using distilled water at $60^0$ C for 1 hrs with MLR of 1: 5. This extract was filtered through Whatman no.41 filter paper into conical flask and used for further experiment. One molarity of Titanium dioxide (precursor) was dissolved in 100 ml distilled water and stirred on a magnetic stirrer, to obtain homogenous dispersion for half an hour. Under constant stirring, 40 ml plant extract was added drop wise and was allowed to stir continuously for 4 hrs. The whole mixture was allowed to settle overnight and was filtered using Whatman filter paper no.1 or centrifugated to remove the by-products. The collected wet cake/ slurry was dried in hot air oven at $70^0$ C for 12 hrs to obtain nanoparticles in powder form (pre-calcinated nanoparticles). The obtained powder was further calcinated at $200^0$ C for 2 hrs in a muffle furnace, to later acquire calcinated nanoparticles at Department of Nano science and Technology, JNTU, Hyderabad using Green synthesis technique.The prepared nanoparticles when analysed for SEM portrayed a particle size of 113 nm - 146 nm for pre-calcinated and 60 nm - 93 nm for calcinated nanoparticles.

**Extraction of Dye**

The neem leaves were weighed, washed, soaked overnight and boiled for 45 minutes in water with M:L:R of 1: 50 at $80^0$C. Then the extract was filtered and condensed to 40% (w/w) aqueous extract, which was further used for printing

**Preparation of Gum**

Dried seeds of cassia were milled into flour and used for preparation of binding agent with M:L:R of 1:20. The prepared solution was boiled until it reached the consistency of a thick paste suitable for screen printing. It was further filtered and used in the preparation of a print paste.

**Selection of Mordant**

Most natural dyes require a chemical in the form of metallic salt to create an affinity between the fibre and pigment. Copper sulphate was selected as mordant and was used at a concentration of 0.8 gm/100 gms of print paste.

**Preparation of Print Paste**

Printing paste was prepared by adding extracted dye to gum in 4:3 ratio to which copper sulphate was added according to the weight to give an earthy green colour. Two types of printing pastes were prepared with before and after calcinated neem nanoparticles in two per cents (1.5 and 3) based on volume of print paste.

**Type of printing**

Screen printing method was employed to carry out the research.

**After-treatment of the printed samples**

The printed samples were shade dried and steamed for a period of 1 hour. Steamed samples were given after treatment with 20 percent Sodium chloride for half an hour with MLR of 1: 20, which was followed by rinsing with 2 gpl neutral detergent solution to remove excess dye and nanoparticles on the surface of the printed sample.

**Assessment of wash and Sunlight Fastness**

The after treated samples were assessed for colour fastness properties using the standard procedures laid down by the Bureau of Indian Standard Test Series IS 768-1976 for colour change and IS 769-1956 for colour staining:

- Wash fastness -Launder-O-Meter (IS: 3361-1979)
- Sunlight fastness– Sunlight cabinet (IS: 686-1985)
- Rub fastness – Crockmeter (IS 766-1956)
- Fastness to perspiration – Perspirometer (IS 971-1956)

**Subjective evaluation**

All the printed samples were subjected to physical evaluation by 30 members for depth of the colour and sharpness of print. The results were analysed through Weighted Mean Scores.

**RESULTS AND DISCUSSION**

In this study it was aimed to show that with the use of nanoparticles, colour fastness can be improved in natural printing. During printing, it was observed that dye extract when mixed with copper sulphate as mordant produced khaki green colour and adding of nano particles to the dye extract produced little darker shade compared to normal dye extract. Colour fastness for the samples printed with direct dye source, before calcinated nano particles and after calcinated nano particles in two percentages viz. 1.5% and 3% was observed. Differences in shades can be witnessed from the figure 1.

$CuSO_4$ + DE (Control) | $CuSO_4$ + DE + BCN 1.5% | $CuSO_4$ + DE + BCN 3.0% | $CuSO_4$ + DE + ACN 1.5% | $CuSO_4$ + DE + ACN 3.0%

**Figure 1. Swatches printed with the neem leaves dye extract, nano particles in different percentages**

* $CuSO_4$ = Copper Sulphate; DE = Dye Extract; BCN = Nano particles Before Calcination; ACN = Nano particles After Calcination

**Colourfastness properties**

Colour fastness is the term given to the property of printed/dyed textile materials for retaining its original hue without fading, running or changing its colour when wetted, washed, cleaned, rubbed and exposed to light under normal conditions. While doing the testing process, the concurrent plain fabric to the test sample may get stained and this is called colour stain.

The table 1 have a glimpse on colour fastness rating for wash, light, rub and perspiration. The ratings of them are described in qualitative terms. Wash fastness of printed samples was tested for colour change and colour stain. Based on the wash fastness grading scale, the samples printed with 3 percent before and after calcinated nanoparticles have scored grade 5, which portrays an excellent fastness to washing that is no colour change or colour stain was observed.

**Table 1. Colour fastness properties of the test samples**

| Parameters | Wash Fastness | | Sun Light Fastness | Rub/Crock Fastness | | | | Fastness to Perspiration | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry | | Wet | | Acidic | | Alkaline | |
| Fabric Samples | CC | CS | | CC | CS | CC | CS | CC | CS | CC | CS |
| $CuSO_4$ + DE (control) | 4 | 4 | 5 | 4/5 | 4/5 | 4 | 4 | 3 | 3 | 3 | 3 |
| $CuSO_4$ + DE + BCN 1.5% | 4/5 | 4/5 | 6 | 5 | 5 | 5 | 5 | ¾ | ¾ | 4 | 4 |
| $CuSO_4$ + DE + BCN 3.0% | 5 | 5 | 7 | 4/5 | 4/5 | 4 | 4 | 4 | 4 | 4 | 4 |
| $CuSO_4$ + DE + ACN 1.5% | 4/5 | 4/5 | 6 | 5 | 5 | 5 | 4/5 | 4/5 | 4/5 | 4/5 | 4 |
| $CuSO_4$ + DE + ACN 3.0% | 5 | 5 | 7 | 4 | 4 | 3/4 | 4/5 | 4/5 | 4/5 | 4/5 | 4 |

* $CuSO_4$ = Copper Sulphate; DE = Dye Extract; BCN = Nano particles Before Calcination;ACN = Nano particles After Calcination; CC = Colour Change and CS = Colour Stain

Where in fabric treated with 1.5 percent before and after calcinated nanoparticles showed 4/5 grade on fastness rating scale indicating very good to excellent wash fastness to colour change and colour stain. Control has revealed very good wash fastness with a rating of 4, which suggest slight colour change and colour stain on the adjacent material.

The colour fastness to dry and wet rubbing for all the samples was found to have very good to excellent fastness. No colour staining was observed for sample printed with 1.5 percent before and after calcinated nanoparticles. Fabric printed with 3 percent for before calcinated nanoparticles and control sample have exhibited very good to excellent rub fastness in dry condition. Whereas, the same sample in wet condition was very good to crock fastness for colour change and colour stain. Very good fastness to dry crocking was observed with samples treated with 3 percent after calcinated nanoparticles.

The colour fastness to wet rubbing was observed to be excellent to very good for all the samples in both the cases of colour stain and colour change. Samples coated with 1.5 percent before calcinated nanoparticles exhibited excellent fastness to wet rubbing. Wherein the samples coated with 1.5 percent after calcinated nanoparticles presented excellent fastness to wet rub i.e., no colour change was observed when compared to colour stain which was rated as very good to excellent.Control sample and sample coated with 3 percent before calcinated nanoparticles executed very good fastness for both colour change and colour stain when wet.

Light fastness is the property which explains how the printed fabric is resistant to fading when exposed to sunlight. Light fastness of printed fabric is influenced by chemical and physical state; concentration of dye; nature of the fibres and mordant type. According to light fastness grading, the samples treated with 3 percent before and after calcinated Nano particles are having grade 7, which suggests an excellent fastness to light with very slight fading, where control sample stands at grade 5 with moderate fading. At the same time samples treated with 1.5 per cent Nano particles irrespective to the type of nano particles have shown grading 6 with slight fading.

Colour fastness to perspiration is the test conducted to find the effect of dye/colour due to human perspiration which varies for different individuals and conditions. In order to forecast such effects of perspiration under different conditions, this test was conducted in acid and alkaline medium. The samples were rated as per grey scale, samples coated with after calcinated nanoparticles in both the percentages have shown slight change to negligible change in colour when exposed to acidic and alkaline conditions. Very slight colour stain was observed on the sample's concealed fabric under acidic conditions and very good fastness to perspiration was observed in alkaline condition. On the contrary, slight change in colour and slight colour stain was observed for samples coated with 3 percent before calcinated nanoparticles. Good to very good fastness to colour change and stain was observed for samples treated with 1.5 percent before calcinated nanoparticles in acidic medium. Whereas, slight colour changes and slight staining was observed with 1.5 percent before calcinated samples. Fabrics treated with 3 percent nanoparticles after calcination were observed with good to very good fastness in case of colour change when wet and very good to excellent fastness of colour stain. Noticeable colour changes and colour stain was observed with control samples in both acidic and alkaline conditions.

**Subjective analysis**

All the printed samples were subjected to visual evaluation called subjective analysis in terms of depth of the colour and sharpness of the print.

Test swatches have shown dark green hue from the Neem leaf extract, as shown in figure 1. From the table 2 it is evident that control sample have gained fair acceptance in terms of depth of colour. However,

**Table 2. Weighted Mean Scores of the Printed Samples for the Subjective Analysis (N=30)**

| Parameters | $CuSO_4$ + DE (control) | $CuSO_4$ + DE +BCN 1.5% | $CuSO_4$ + DE + BCN 3.0% | $CuSO_4$ + DE + ACN 1.5 % | $CuSO_4$ + DE + ACN 3.0% |
|---|---|---|---|---|---|
| **Depth of the colour** | 3 | 5 | 5 | 5 | 4 |
| **Sharpness of print** | 3 | 5 | 4 | 5 | 4 |

Rating for Weighted Mean Scores (WMS) 5 = v. good, 4 = good, 3 = fair, 2 = poor and 1= v. poor samples printed with nano particles (both 1.5 and 3 per cent) have shown very good acceptability for the same. This is owing to Nano-particles that improved the colour depth of the printed samples by deeply penetrating the dye stuff into the samples. Among the test samples, the sharpness of the print for control is fair, where 1.5 per cent nano particle printed samples have shown very good finish at design edges. Samples printed with 3 per cent nano particles have shown good design sharpness. However, samples printed with 1.5 per cent nano particles were chosen than its counterpart.

**Conclusion**

Today the market for natural dyes is growing because of the increased interest of people towards environment. This interest in use of natural dyes has given scope for development of new techniques in preparation of natural dyes. On the contrary, natural dyes have few downsides like poor fastness properties especially light fastness where mordant as a metal ion is a must in dyeing process. Use of natural dyes in printing is not common. But, natural dyes in ancient history have stood as a source of many colours. These dyes stood as an environmental friendly and can be used as substitute to synthetic dyes. Hence, the present study focused on the neem leaf extract as natural dye for textiles printing, where cassia tora, a natural gum source was used as binding agent. From the research, it was observed that the source has good dye potential along with good colour fastness to wash, rub/crock, sun light and perspiration. Samples printed with nano particles have shown more intense fastness properties than control. The samples printed with 1.5 per cent nanoparticle in both types of calcination methods, when analysed for the sample's subjective evaluation, have got good acceptance than the 3 per cent nanoparticles printed samples.

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# STUDIES ON GENETIC PARAMETERS FOR ANAEROBIC GERMINATION TRAITS, YIELD AND ITS CONTRIBUTING CHARACTERS IN RICE (*Oryza sativa* L.)

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Rice is the most important cereal crop, which is the staple food for more than half of the world's population. It has shaped the cultures, diets and economies of billions of people living in Asia where it has a long history of cultivation and is deeply ingrained in the daily lives of Asian people.

The recent developments in rice production technology and the new economic trends are encouraging farmers to shift from traditional transplanting to direct seeding. Transplanting is basically labor-intensive, constrained by manpower availability and higher cost. Direct seeding also reduces production risks by allowing farmers to respond to varying rainfall and drought incidences during planting time. As compared with transplanting, direct seeding sometimes promotes increase in yield of rice, particularly in cases of terminal drought. Amidst the advantages of the method, direct seeding has also its disadvantages. From sowing to seedling establishment, potential losses can occur due to physical factors such as heavy rains, water stress, lodging at maturity and high weed infestation can also hinder direct seeding.

Early flooding can reduce the oxygen content of the seed environment, which impairs seedling root and shoot growth. Moreover, the seeds in standing water cannot form roots. Both anchorage problems and lower initial growth rate cause poor rice seedling establishment and encourages growth of weeds. Poor seedling stand establishment may somehow offset the weed-suppressing characteristic of early flooding. It is then important to develop rice varieties capable of growing vigorously in hypoxic or oxygen-deficient conditions to alleviate these constraints. Several studies revealed that rice has enormous exploitable variation in tolerance of flooding during germination, while very little progress was made in understanding the basis of tolerance.

Genetic improvement for any character requires heritable variation coupled with high magnitude of genetic advance. The information on these parameters with respect to anaerobic germination and yield components will help in formulating effective breeding programme for breeding rice cultivars suitable for direct seeding.

Keeping in view the importance of aforesaid aspects, the present investigation was undertaken to study the genetic variability, heritability and genetic advance among the genotypes (hybrids, parents and checks) of rice for anaerobic germination traits, yield and its component traits.

The field experiment was conducted during *kharif,* 2016 at ICAR-Indian Institute of Rice Research Farm, ICRISAT campus, Patancheru, Hyderabad, India, situated at $17.53^0$ N latitude, $78.27^0$ E longitude and altitude of 545 m above mean sea level. Twenty five $F_1$ hybrids of rice along with their ten parents and three standard checks were sown separately in raised bed nursery. Thirty days old seedlings of each genotype were transplanted in 5 rows of 3 m length by adopting a spacing of 20 cm between rows and 15 cm between plants within a row in Randomized Block Design replicated thrice. All the necessary precautions were taken to maintain uniform plant population of each genotype per replication. All the recommended package of practices was adopted besides providing necessary prophylactic plant protection measures to raise a good crop.

Evaluation for anaerobic germination traits was done under lab conditions at ICAR-IIRR. Direct dry seeding in germination trays with a shallow layer of field soil was done for the genotypes under study. The trays containing the germination sheets wherein rice seed were placed and covered with thin layer of soil were immersed in larger zinc trays where 40 cm depth

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of water was maintained for 15 days without any disturbance. Recording of observation on a three metric traits *viz.,* anaerobic germination percentage, seedling length and vigour index was done on 15$^{th}$ day after seeding as per the standard procedure given by ICAR-IIRR (Suneetha *et al*., 2012).

Data were recorded on twelve metric characters. Among them seven characters *viz.,* plant height, total number of tillers per hill, number of productive tillers per hill, panicle length, total number of grains per panicle, spikelet fertility and single plant yield were recorded on five randomly selected plants in each plot. Days to 50 % flowering was recorded on plot basis. 1000-grain weight was recorded per replication in each genotype. While three anaerobic germination traits were *viz.,* anaerobic germination percentage (%), seedling length (cm) and seedling vigour index I recorded as per the standard procedure given by ICAR-IIRR (Suneetha *et al*., 2012). The data collected on all the characters were subjected to standard methods of analysis of variance (Panse and Sukhatme, 1985). Phenotypic and genotypic coefficient of variation was calculated as suggested by Falconer (1981). Heritability (broad sense) (Johnson *et al*., 1955), genetic advance (Burton, 1952) and genetic advance as a percent of mean (Johnson *et al*., 1955) were also estimated.

The analysis of variance revealed the existence of significant differences among the genotypes for all the traits (Table 1), indicating the presence of considerable genetic variability among the experimental material under study. Thus there is ample scope for improvement of all the traits through selection. The mean values, genotypic and phenotypic coefficient of variation, heritability, genetic advance and genetic advance as per cent of mean (Table 2) of 38 genotypes which includes $F_1$ hybrids, along with their parents and standard checks were calculated for anaerobic germination traits, yield and its contributing traits.

For all the characters under study, phenotypic coefficient of variation values are slightly higher than the genotypic coefficient of variation values indicating that the characters were less influenced by the environment. Therefore, response to direct selection may be effective in improving these traits.

**Table 1: ANOVA for anaerobic germination traits, yield and its contributing characters in rice (*Oryza sativa* L.)**

| S.No. | Character | Mean sum of squares | | |
|---|---|---|---|---|
| | | Replication (d.f. = 2) | Genotypes (d.f. = 37) | Error (d.f. = 74) |
| 1. | Anaerobic germination percentage (%) | 1.533 | 2679.137** | 1.810 |
| 2. | Seedling length (cm) | 1.896 | 571.186** | 2.242 |
| 3. | Seed vigour index I | 0.132 | 561.840** | 1.545 |
| 4. | Days to 50 % flowering | 0.430 | 185.166** | 2.520 |
| 5. | Plant height (cm) | 1.405 | 945.840** | 2.567 |
| 6. | Number of tillers/hill | 0.092 | 18.537** | 0.688 |
| 7. | Number of productive tillers/ hill | 0.596 | 15.829** | 0.688 |
| 8. | Panicle length (cm) | 0.771 | 21.856** | 0.560 |
| 9. | Number of grains/panicle | 2.381 | 2404.546** | 10.039 |
| 10. | Spikelet fertility (%) | 1.851 | 66.221** | 1.674 |
| 11. | 1000-grain weight (g) | 0.907 | 24.453** | 0.326 |
| 12. | Single plant yield (g) | 0.667 | 91.649** | 1.023 |

*Significant at 5 per cent level, **Significant at 1 per cent level

**Table 2: Estimation of variability, heritability and genetic advance for anaerobic germination traits, yield and its contributing characters of rice**

| S.No | Character | Mean | Range | | Phenotypic variance | Genotypic variance | PCV (%) | GCV (%) | Heritability in broad sense ($h^2$) (%) | GA (5 %) | GA as percent of mean(5 %) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | | | | | |
| 1. | Anaerobic germination (%) | 60.82 | 8.07 | 100.00 | 894.25 | 892.44 | 49.17 | 47.12 | 95.83 | 55.48 | 91.21 |
| 2. | Seedling length (cm) | 32.45 | 6.03 | 51.22 | 191.89 | 189.65 | 42.69 | 42.44 | 98.80 | 28.20 | 86.91 |
| 3. | Seedling vigour index I | 22.15 | 0.49 | 43.52 | 188.31 | 186.77 | 61.97 | 60.71 | 97.90 | 20.04 | 90.47 |
| 4. | Days to 50 % flowering | 94.52 | 81.67 | 109.67 | 63.40 | 60.88 | 8.42 | 8.26 | 96.00 | 15.75 | 16.67 |
| 5. | Plant height (cm) | 107.39 | 80.07 | 156.67 | 316.99 | 314.42 | 16.58 | 16.51 | 99.20 | 36.38 | 33.88 |
| 6. | No. of tillers/hill | 14.43 | 8.60 | 20.57 | 6.64 | 5.95 | 17.85 | 16.90 | 89.60 | 4.76 | 32.97 |
| 7. | No. of productive tillers/hill | 13.26 | 7.90 | 18.77 | 5.74 | 5.05 | 18.06 | 16.94 | 88.00 | 4.34 | 32.74 |
| 8. | Panicle length (cm) | 24.09 | 18.37 | 29.83 | 7.66 | 7.10 | 11.49 | 11.06 | 92.70 | 5.28 | 21.94 |
| 9. | Number of grains/panicle | 174.76 | 106.40 | 216.67 | 808.21 | 798.17 | 16.27 | 16.17 | 98.80 | 57.84 | 33.10 |
| 10. | Spikelet fertility (%) | 84.73 | 73.58 | 94.61 | 23.19 | 21.52 | 5.68 | 5.48 | 92.80 | 9.20 | 10.86 |
| 11. | 1000-grain weight (g) | 22.08 | 16.29 | 26.71 | 8.37 | 8.04 | 13.10 | 12.84 | 96.10 | 5.73 | 25.94 |
| 12. | Single plant yield (g) | 27.68 | 15.18 | 35.88 | 31.23 | 30.21 | 20.19 | 19.86 | 96.70 | 11.14 | 40.24 |

Min.-Minimum, Max.-Maximum
PCV- Phenotypic Coefficient of Variation; GCV- Genotypic Coefficient of Variation; GA-Genetic Advance

The characters studied in the present investigation exhibited low (less than 10 %), moderate (10-20 %) and high (more than 20 %) phenotypic and genotypic coefficients of variation. High phenotypic and genotypic coefficients variations were observed for three traits namely seedling vigour index I (61.97/60.71), anaerobic germination percentage (49.17/47.12) and seedling length (42.69/42.44). These results are in confirmity with the findings of Okelola *et al*. (2007) for seedling vigour index I and anaerobic germination percentage. The estimates of phenotypic and genotypic coefficients of variation were low for days to 50 % flowering (8.42/8.26) and spikelet fertility (5.68/5.48). These findings are in accordance with those of Harsh *et al*. (2015), Konate *et al.* (2016) and Rashid *et al*. (2017) for days to 50 % flowering and Rohit *et al.* (2017) and Umarani *et al.* (2017) for spikelet fertility.

Phenotypic and genotypic coefficients of variation were moderate for number of productive tillers per hill (18.06/16.94), number of tillers per hill (17.85/ 16.90), plant height (16.58/16.51), number of grain per panicle (16.27/16.17), 1000-grain weight (13.10/12.84) and panicle length (11.49/11.06).These results are in trend with the findings of, Konate *et al.* (2016) and Rohit *et al.* (2017) for number of productive tillers per hill, Kumar *et al.* (2013) and Umarani *et al.* (2017) for number of tillers per hill and panicle length, Gokulakrishnan *et al.* (2014) and Harsh *et al.* (2015) for plant height and number of grains per panicle and Kishore *et al.* (2015) and Rashid *et al.* (2017) for 1000-grain weight. However, single plant yield recorded higher PCV (20.19) and moderate GCV (19.86) values. Similar results were observed by Bhati *et al.* (2015) and Tiwari (2017) for single plant yield.

All the characters under investigation expressed high estimates of heritability in broad sense ranging from 88.00 to 99.20%. Among all the characters, highest heritability was recorded for plant height (99.20 %) followed by total number of grains per panicle and seedling length (98.8%). High heritability for quantitative characters indicates the scope of genetic improvement of these characters through selection and also revealed that these characters are less influenced by environment and there could be greater correspondence between phenotypic and breeding values.

Genetic advance as a per cent of mean is classified as low (less than 10 %), moderate (10-20 %) and high (more than 20 %). Among the metric characters, days to 50 % flowering (16.67 %) and spikelet fertility (10.86 %) exhibited moderate genetic advance as per cent of mean. Remaining all the traits exhibited high estimates of genetic advance as per cent of mean, among them anaerobic germination percentage acquired highest value (91.21 %) followed by seedling vigour index I (90.47 %).

Among all the characters studied, days to 50 % flowering and spikelet fertility expressed high heritability coupled with moderate genetic advance as per cent of mean, which is in accordance with the reports of Patel *et al*. (2014) and Devi *et al*. (2017) for days to 50 % flowering and Sankar *et al*. (2006) for spikelet fertility. High heritability coupled with moderate genetic advance as per cent of mean, suggested that the expression of this trait was mostly influenced by additive type of gene action. Hence its response to selection would be effective in improving the seed yield.

All the remaining metric characters expressed high heritability coupled with high genetic advance, indicating the preponderance of additive gene action in controlling the traits. Hence direct selection of such characters would be effective in improving the yield. Similar results were observed by Srilakshmi (2017) for anaerobic germination percentage, seedling length, seedling vigour index I; Gangashetty *et al*. (2013) and Umarani *et al*. (2017) for plant height, number of tillers per hill and productive tillers per plant; Kumar *et al.* (2013) and Umarani *et al*. (2017) for total number of grains per panicle and 1000-grain weight; and Lakshmi *et al*. (2017) for single plant yield.

A perusal of genetic parameters *viz.,* phenotypic and genotypic coefficients of variation revealed less influence of environment on the characters under study. Therefore, response to direct selection may be effective in improving these traits. All the characters under study except days to 50 % flowering and spikelet fertility exhibited high heritability coupled with high genetic advance as per cent of mean which indicated the preponderance of additive gene action in controlling these traits. Hence direct selection of these characters would be effective in improving the anaerobic germination traits as well as seed yield. Days to 50 %

flowering and spikelet fertility had high heritability coupled with moderate genetic advance as per cent mean suggesting that the expression of this trait was mostly influenced by additive type of gene action. Hence its response to selection would be effective in improving the seed yield.

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Research Note
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# PARENTAL POLYMORPHISM SURVEY BETWEEN DONOR RICE LINE WITH DROUGHT QTL AND ELITE RECIPIENT VARIETY USING SSR MARKERS

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Rice is very important food crop for Asian countries. Among different biotic, abiotic stresses, drought is a major limiting factor for rice crop production. Plants are most susceptible to drought stress at the reproductive stage. Drastic grain yield reduction occurs if drought stress coincides with reproductive stage. So drought resistance at reproductive stage is very important trait (Yue *et al* 2006).The development of molecular techniques for genetic analysis has led to a great increase in our knowledge of cereal genetics and our understanding of the structure and behavior of cereal genomes. These molecular techniques, such as molecular markers, have been used to monitor DNA sequence variation in and among the species and create new sources of genetic variation by introducing new and favorable traits from land races and related grass species.

From last few decades, utilization of molecular markers has played an increasing role in rice breeding. Among all the molecular markers, microsatellites have been utilized extensively (Miah *et al* 2013). The term micro satellite was first coined by Litt and Luty.1989. Microsatellites are also known as simple sequence repeats (SSRs). They are having more advantages than other markers because they can be amplified by PCR, create large amount of allelic variation at each locus, abundance in availability, distributed throughout the genome, highly polymorphic, co-dominant and species-specific. Identification of quantitative trait loci (QTLs) for grain yield under reproductive stage and its use in developing drought tolerant varieties through marker assisted selection (MAS) is very effective strategy. Several QTLs for grain yield under drought have been identified in rice. DTY1.1 and qDTY12.1 having major and consistent effect under reproductive stage drought Stress situations were identified (Vikram *et al* 2011, Mishra *et al* 2013). In the present study, parental polymorphism of donor and recipient parent was analyzed using SSR markers. The polymorphic markers identified in the present study were used for identification of QTLs responsible for yield under drought in the RIL population developed using the donor (IR91648-B-117-B-1-1) and recipient (MTU1010) parents. Identified QTLs will aid in selection of drought tolerant rice varieties through marker assisted breeding.

MTU1010 and IR91648-B-117-B-1-1 were used as parent in current study. MTU1010 is a semi-dwarf high-yielding medium-duration variety developed from the Regional Agricultural Research Station, Maruteru, Andhra Pradesh targeted for in irrigated ecosystem. It is susceptible to reproductive stage drought stress. IR91648-B-117-B-1-1 was developed from IRRI for reproductive stage drought stress tolerance. For current study, 940 random microsatellite (RM) markers distributed across 12 chromosomes were used for polymorphic survey. Seeds were germinated in petriplates and after 10-15 days, leaf samples were collected and stored at -20$^{0}$C for further use.

Freeze-dried leaf samples were cut into pieces in eppendorf tubes and ground through a GENO grinder. TPS buffer was used to extract the genomic DNA. Compared with cetyl trimethyl ammonium bromide (CTAB) this is superior as it uses fewer reagents and is simpler, faster and less expensive. Then to quantify the isolated DNA 0.8% agarose gel was used. DNA samples were then diluted to 50 ng/ µ l for further PCR analysis. Nine hundred and forty SSRs were selected based on earlier reports from Supplementary Table - 18 (www.gramene.org) to study the polymorphism between the parents. MTU1010 and IR91648-B-117-B-1-1. PCR amplification was done with a 10 µ l master

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mix having 50 ng DNA, 10× PCR buffer, 2 mM dNTPs, 10 pmol/μl primers, and 1 unit Taq polymerase enzyme. Then PCR was run with PCR conditions of Initial denaturation at 94°C for 8 minutes, denaturation at 94°C for 40 seconds, annealing at 57°C keeping touchdown option for 45 seconds, primer extension at 72° for 45 seconds for 35 cycles. Final extension was done at 72°C for 7 minutes. To resolve the PCR products, 3.5% agarose gel were used. Polymorphism was recorded based on difference between base pair size of both the parents. Polymorphic % was calculated by using the following formula.

$$\text{Polymorphism \%} = \frac{\text{Number of polymorphism markers identified per chromosome}}{\text{Total Number of markers used per chromosome}} \times 100$$

GGT software was used to locate the polymorphic markers on chromosomes.

**Table 1: List Polymorphic percentage information**

| Chromo some | Total | Polymorphic Markers | Polymorphic % |
|---|---|---|---|
| 1 | 132 | 12 | 9 |
| 2 | 100 | 17 | 17 |
| 3 | 98 | 11 | 11 |
| 4 | 78 | 10 | 13 |
| 5 | 77 | 7 | 9 |
| 6 | 79 | 2 | 3 |
| 7 | 53 | 6 | 11 |
| 8 | 77 | 6 | 8 |
| 9 | 71 | 12 | 17 |
| 10 | 56 | 9 | 16 |
| 11 | 75 | 9 | 12 |
| 12 | 44 | 9 | 20 |
| **TOTAL** | **940** | **110** | |

Polymorphic markers between donor (IR91648-B-117-B-1-1) and recipient (MTU1010) parents were essential for construction of linkage map and effective identification of QTLs linked to the traits under study. In order to identify the grain yield QTLs for reproductive drought tolerance, the genomic DNA isolated from15 days old seedlings, gave instance and clear band on 0.8% agarose gel indicating that the isolated genomic DNA is reliable. Nine hundred and forty SSR markers distributed on all the 12 chromosomes from Supplementary Table-18 (www.gramene.org) were selected for this study. Among these, 110 markers (Table 1) were found polymorphic and produced distinct reproducible amplification patterns. Similar kind of results was also reported by Vikram et al (2011). In a cross between N22/MTU1010 in which 125 polymorphic markers were identified.

Polymorphic percentage ranged between 3-20% (Table 1) in the current study. Highest polymorphic percentage was observed on chromosome 12 (20%) and least on chromosome 6 (3%). Dixit *et al.* (2018) and Yerva *et al*.( 2018) reported 4-24% and 7-34% polymorphism respectively in rice between the parents used in their study. Among the 110 Polymorphic markers, di-nucleotide primers (78) were maximum followed by tri-nucleotide primers (17), tetra -nucleotide primers (4) and compound repeat primers (10).

Maximum number of polymorphic markers (17) were observed on chromosome 2 (table 1) and minimum (2) on chromosome 6. It indicates that genetic variability for two parents was more on 2nd chromosome and very less on 6th chromosome. Thirty six Polymorphic markers Out of 110 polymorphic markers identified in this study, were also reported as polymorphic in other studies (Table 2). RM212 and RM511 were found as robust markers since their usage was high in many drought studies in rice. Less number of polymorphic markers were found in the current study were due to the fact that both the parents are *indica* genotypes, which was also noticed in previous studies by Xu *et al* (2002) and Biradar *et al* (2004). The identified polymorphic markers across 12 chromosomes were used in subsequent linkage map construction and QTL mapping of grain yield under drought.

**Table 2: List of identified polymorphic marker used in other drought studies in rice.**

| S.No | Marker name | chr | Trait | Reference |
|---|---|---|---|---|
| 1. | RM212 | 1 | Yield | Vikram *et al.*2012, Ghimire *et al.*2012, Verma *et al.*2014 |
| | | 1 | Relative water content | Kamoshita *et al.*2008 |
| | | 1 | Different traits | Babu *et al.*2010 |
| | | 1 | Drought resistance | Kanagaraj *et al.* 2010 |
| | | 1 | Plant height | Gomez *et al.*2006, Sellamuthua *et al.* 2011, Prince *et al.*2015 |
| | | 1 | Dry root weight | Lang *et al.* 2013 |
| 2. | RM237 | 1 | Relative no of spikelet's per panicle (%), Leaf-drying | Yue *et al.* 2005 |
| | | 1 | Filled grains per panicle, yield, Panicle no. | Wang *et al.* 2013 |
| | | 1 | Yield | Lang *et al.* 2013,Venuprasad *et al*. 2012 |
| 3. | RM246 | 1 | Yield | Palanog *et al.* 2014 |
| | | 1 | Plant height | Lin *et al.* 2007 |
| 4. | RM5 | 1 | Filled grains per panicle, Seed fertility, yield | Wang *et al.*2013 |
| | | 1 | Yield | Verma *et al* .2014 |
| 5. | RM449 | 1 | Yield | Verma *et al.* 2014 |
| 6. | RM572 | 1 | Yield | Verma *et al.* 2014, Palanog *et al.* 2014 |
| 7. | RM488 | 1 | Yield | Venuprasad *et al.* 2012 |
| 8. | RM530 | 2 | Yield | Vikram *et al.* 2011 |
| | | 2 | Flowering | Tiwari *et al.* 2014 |
| 9. | RM555 | 2 | Leaf-drying score | Yue *et al.* 2005 |
| | | 2 | Yield | Dixit *et al*. 2012 |
| 10. | RM208 | 2 | Stress recovery | Prince *et al.* 2015 |
| | | 2 | Biomass | Dixit *et al.* 2012a |
| 11. | RM211 | 2 | Yield | Palanog *et al.* 2014, Kumar *et al.* 2014 |
| | | 2 | Flowering | Sandhu *et al.* 2014 |
| 12. | RM3549 | 2 | Yield | Dixit *et al.* 2012 |
| 13. | RM154 | 2 | Yield | Shamsudin, *et al* . 2016 |
| 14. | RM6374 | 2 | Yield | Sandhu *et al.* 2017 |
| 15. | RM520 | 3 | Relative yield per plant (%), Leaf-drying score. | Yue *et al.* 2005 |
| | | 3 | Yield | Venuprasad *et al.* 2009, Kumar *et al.*2014 |
| 16. | RM7332 | 3 | Yield | Dixit *et al.* 2012a |
| 17. | RM426 | 3 | Panicle water potential | Liu *et al.* 2010 |

| S.No | Marker name | chr | Trait | Reference |
|---|---|---|---|---|
| 18. | RM518 | 4 | Yield | Palanog *et al.* 2014 |
| | | 4 | leaf rolling | Lin *et al.* 2007 |
| 19. | RM273 | 4 | Drought tolerance | Lang *et al.* 2013 |
| 20. | RM252 | 4 | Total spikelet number | Lanceras *et al.* 2014 |
| 21. | RM18 | 7 | Plant height | Man-yuan *et al.* 2011 |
| | | 7 | Yield | Ghimire *et al.* 2012 |
| 22. | RM25 | 8 | Days to flowering | Tiwari *et al.* 2014 |
| | | 8 | Yield | Venuprasad *et al.* 2012 |
| | | 8 | Seed fertility | Wang *et al.* 2013 |
| 23. | RM210 | 8 | Panicle number, Percent spikelet sterility, Grain yield | Kamoshita *et al.* 2008 |
| | | 8 | Yield | Ghimire *et al.* 2012,Vikram *et al.* 2012 |
| | | 8 | Panicle number | Lanceras *et al.* 2014 |
| 24. | RM257 | 9 | Leaf-drying score | Yue *et al.* 2005 |
| | | 9 | Thousand-grain weight | Wang *et al.* .2013 |
| 25. | RM566 | 9 | Yield | Dixit *et al*. 2012 |
| 26. | RM304 | 10 | Yield | Vikram *et al.* 2012, Dixit *et al.* 2014 |
| | | 10 | Flowering | Vikram *et al.* 2011 |
| 27. | RM269 | 10 | Yield | Kumar *et al.* 2014 |
| 28. | RM286 | 11 | Maximum root depth under drought (cm) | Yue *et al.* 2005 |
| | | 11 | Yield | Venuprasad *et al.* 2012 |
| | | 11 | Filled grains per panicle | Wang *et al.* 2013 |
| 29. | RM206 | 11 | Yield | Venuprasad *et al.* 2012, Tiwari *et al.* 2014 |
| | | 11 | Panicle number | Man-yuan *et al.* 2011 |
| | | 11 | Effective Tillers, Yield | Tiwari *et al.* 2014 |
| 30. | RM21 | 11 | Yield | Verma *et al.* 2014 |
| | | 11 | Root pulling force QTL | Zhang *et al.* 2001 |
| 31. | RM224 | 11 | Yield | Man-yuan *et al.* 2011, Verma *et al.* 2014 |
| 32. | RM287 | 11 | Root growth rate in volume (ml/day) | Yue *et al.* 2005 |
| 33. | RM511 | 12 | Yield | Babu *et al.* .2010, Dixit *et al.* 2012, Dixit *et al.* 2012a, |
| | | | | Venuprasad et al.2012, Mishra *et al.* 2013 |
| | | 12 | Days to flowering | Lang *et al.* 2013 |
| 34. | RM28089 | 12 | Yield | Mishra et al.2013 |
| 35. | RM1261 | 12 | Yield | Dixit *et al.* 2012, Dixit *et al.* 2012a |
| 36. | RM28166 | 12 | Yield | Dixit *et al.* 2012, Mishra *et al.* 2013, Kumar *et al.* 2014 |

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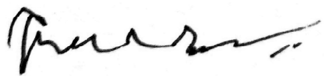

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