ISSN 2395-5945

The J. Res. PJTSAU Vol. XLVIII No.1&2 pp 1- 99, Jan. - June, 2020

THE JOURNAL OF RESEARCH PJTSAU

The J. Res. PJTSAU Vol. XLVIII No.1&2 pp 1-99, Jan. - June, 2020

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

The Journal of Research, PJTSAU

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

SUBSCRIPTION TARIFF

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

Individual (Life) : Rs. 1200/-

Printing Charges : Rs. 100/- per page

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

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Research Article
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ESTIMATION OF HETEROSIS FOR SEED YIELD AND OIL CONTENT IN SUNFLOWER HYBRIDS (*Helianthus annuus* L.)

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Date of Receipt : 23-01-2020 Date of Acceptance : 13-02-2020

ABSTRACT

The experimental material consists of four cytoplasmic male sterile lines and six testers crossed in a line x tester fashion to develop 24 sunflower hybrids during *kharif*, 2017 at Regional Agricultural Research Station, Nandyal. The hybrids and parents along with three checks (NDSH-1012, DRSH-1 and KBSH-44) were evaluated for ten traits during *rabi*, 2018 - 19. The results showed existence of high significant differences among genotypes for all the traits. The extent of heterosis in 24 hybrids over mid parent (MP) ranged from 16.10 to 216.58 percent and over better parent (BP) from -1.05 to 133.81 for seed yield and the standard heterosis indicated that the cross NDLA-4 x NGM-16 exhibited significantly high positive heterosis over DRSH-1 (42.86) and KBSH-44 (65.14) and also the same cross noted to have high positive standard heterosis for NDSH-1012 (24.13). While the extent of heterosis for oil content over mid parent (MP) and better parent (BP) ranged from -0.70 to 18.32 and -5.23 to 9.77 respectively, and regarding the standard heterosis, the cross CMS-30 A x NO-30 expressed significantly high positive heterosis over the standard checks DRSH-1 (5.37) and KBSH-44 (17.45). The best crosses *viz*., NDLA-4 x NGM-16, CMS-17 A x NO-15 and CMS-17 A x NGM-16 were identified as promising for seed yield and its contributing traits based on their heterosis over better parent, *gca, sca* effects and *per se* performance and these better performing hybrids can be used for exploiting hybrid vigour in future breeding programmes.

Sunflower (*Helianthus annuus* L), member of Compositae family is a significant edible oilseed crop. Due to its cross pollinated nature, it offers considerable scope for commercial exploitation of heterosis utilizing cyto-restorer system (Madrap and Makne, 1993; Gangappa *et al*., 1997). A new era opened in sunflower breeding with the discovery of cytoplasmic male sterility by Leclercq (1969) in France and fertility restoration by Kinman (1970) in USA, which provided the required breakthrough heterosis breeding. With the increase in demand for edible oils, there is a need to develop new sunflower hybrids suited to different agro-climatic zones of India with improved seed yield and oil content. In the present era, sunflower growers are giving more importance in the production of hybrids over varietal populations due to their uniform growth and maturity, high productivity, resistance to pests and diseases and also their response to higher level of fertilizer application and irrigation. In view of these advantages, the coverage of area under hybrids is around 95 percent. In India, first sunflower hybrid BSH-1 developed by Seetharam *et.al* (1977), was a turning point in sunflower cultivation. Many biometrical techniques have been developed to generate information on gene action and mode of inheritance of various characters, among which line x tester analysis (Kempthorne, 1957) has been widely used for genetic analysis in large number of crop plants. The present attempt was to evaluate the magnitude of heterosis over mid parent, better parent and standard heterosis against NDSH 1012, DRSH 1 and KBSH 44 hybrids for seed yield and yield contributing traits in sunflower.

MATERIAL AND METHODS

Four CMS lines *viz*., NDLA-3, NDLA-4, CMS-17 A and CMA-30 A were crossed with six restorer lines *viz*., NO-15, R-106, CPI-1, RHA-271, NGM-16 and NO-30 in L x T fashion to generate 24 hybrids during *rabi* 2017-18. The developed hybrids were evaluated along with 10 parents and three standard checks *viz*., NDSH-1012, DRSH-1 and KBSH-44 during *rabi,* 2018-19 at Regional Agricultural Research Station, Nandyal in a Randomized block design with two replications. Each genotype was raised in two rows in a row length of 3 m with a spacing of 60 cm between rows and 30 cm within the row. All the recommended agronomic practices were followed to raise the crop successfully. The observations were recorded on five randomly selected plants from parents

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and crosses for the characters *viz*., plant height, head diameter, 100 seed weight, volume weight, autogamy percentage, seed yield, hull content, oil content and oil yield. While for days to 50 per cent flowering the data was recorded on plot basis.

RESULTS AND DISCUSSION

The results pertaining to heterotic studies of crosses was presented in Tables 1 to 10. Improvement of yield is the ultimate objective of any plant breeding activity owing to its economic importance and the results of heterosis for seed yield over mid parent ranged from 16.10 to 216.58 per cent and majority of the crosses up to 21 out of 24 were observed as significant and positive in their expression. The similar results were observed for better parent for which nineteen crosses manifested significant and positive heterosis. The cross NDLA-4 x NGM-16 recorded the highest heterosis of 133.81 per cent, which was followed by CMS-17 A x NGM-16 and CMS-17 A x NO-15 with 131.06 and 129.35 per cent, respectively. The prevalence of substantial magnitude of heterosis over better parent has also been reported by Neelima and Parameshwarappa (2013), Thakare *et al*. (2015) and Kale *et al*. (2019) for seed yield. Some of the crosses which recorded non-significant or negative sca effects have also recorded high heterosis over better parent indicating that sca alone need not be an index to select heterotic hybrids.

Although, most of the hybrids expressed heterobeltiosis, the standard heterosis over the leading checks assumes importance to decide whether an experimental hybrid is worth consideration for replacement. The results obtained on standard heterosis over three check hybrids reported that none of the hybrids were superior over the best standard check NDSH-1012, but more number of crosses showed significant and positive standard heterosis over the check KBSH-44. The cross NDLA-4 x NGM-16 recorded significant and high positive heterosis over better parent and standard heterosis over DRSH-1 and KBSH-44. At the same time it also showed high positive standard heterosis over the check NDSH-1012. Since, sunflower is an oil seed crop, oil content also has equal importance along with seed yield. The analysis indicated that none of the hybrids possessed significant positive standard heterosis for oil content over the checks NDSH-1012 and DRSH-1, basically these hybrids are known for high oil content. The lack of standard heterosis was also recorded by several workers (Spoorthi and Nadaf 2016, and Lakshman *et al*. 2018). However, out of twenty four hybrids, nine crosses over KBSH-44 (the oil content of this hybrid will be low compared to other hybrids) have shown significant positive standard heterois. The cross CMS-30A x NO-30 had highest significant standard heterosis over DRSH-1 and KBSH-44. Thus, there is a need to look into the oil content of better parental lines for their *per se* performance and nicking ability. The cross CMS-17 A x NO-15 recorded high heterobeltiosis with positive sca effect, but the parents involved were poor combiners for this trait with low x low gca effects indicating the non-additive type of gene action for oil content (Ingle *et al*. 2016; Shamshad *et al*. 2016 and Singh and Kumar 2017).

Early flowering is a desirable attribute in sunflower crop. Therefore, negative heterosis is considered desirable for this trait. A total of twelve hybrids recorded significant negative heterosis over better parent, highest being in NDLA-4 x CPI-1 (-13.33) and NDLA-3 x NGM-16 (-10.19). The presence of both positive and negative heterosis over parents and checks suggests the presence of non-additive gene action for this trait and it was also indicated by Rathi *et al*. (2016) and Lakshman *et al*. (2018). The same cross (NDLA-3 x NGM-16) also exhibited significant negative standard heterosis over the checks *viz*., NDSH-1012, DRSH-1 and KBSH-44. The hybrids with NDLA-3, NDLA-4 and CPI-1 as parental lines presented high significant negative heterosis over standard hybrids indicates utilization of these parental lines results in better heterotic hybrids for early flowering.

For the trait plant height, all the twenty four crosses over mid parent and twenty three crosses over better parent possessed positively significant heterosis (Kanwal *et al*. 2016 and Lakshman *et al*. 2018). The crosses *viz*., CMS 17 A x NO-15, CMS 17 A x R-106 and CMS 17 A x CPI-1 recorded high better parent heterosis with significant positive sca effects.

Capitulum or head diameter is another important yield contributing trait attracting attention of the workers for better head size because large head sizes accommodate more seeds which help to increase production. Out of twenty four hybrids, thirteen hybrids over better parent and seventeen hybrids over mid

Table 1: Percent heterosis over mid parent (MP), better parent (BP) and check hybrids for days to 50 % flowering and plant height (cm) in sunflower (*Helianthus annuus* L.)

S.No	Crosses	Days to 50 % flowering					Plant height (cm)				
		MP	BP	NDSH-1012	DRSH-1	KBSH-44	MP	BP	NDSH-1012	DRSH-1	KBSH-44
1.	NDLA-3 X NO-15	0.00	0.00	1.89 *	-3.57 **	-5.26 **	24.95 **	18.52 **	-21.10 **	-25.00 **	-12.20 **
2.	NDLA-3 X R- 106	4.59**	3.64 **	7.55 **	1.79 *	0.00	38.39 **	31.28 **	-12.60 **	-16.93 **	-2.74
3.	NDLA-3 X CPI-1	-4.76**	-7.41 **	-5.66 **	-10.71 **	-12.28 **	18.88 **	13.99 **	-24.11 **	-27.86 **	-15.55 **
4.	NDLA-3 X RHA-271	-2.75**	-3.64 **	0.00	-5.36 **	-7.02 **	35.38 **	26.75 **	-15.62 **	-19.79 **	-6.10
5.	NDLA-3 X NGM-16	-2.02**	-10.19 **	-8.49 **	-13.39 **	-14.91 **	41.44 **	17.28 **	-21.92 **	-25.78 **	-13.11 **
6.	NDLA-3 X NO- 30	-0.91	-2.68 **	2.83 **	-2.68 **	-4.39 **	29.98 **	18.71 **	-4.38	-9.11 **	6.40
7.	NDLA-4 X NO-15	-3.51**	-8.33 **	3.77 **	-1.79 *	-3.51 **	25.00 **	11.51 **	-15.07 **	-19.27 **	-5.49
8.	NDLA-4 X R- 106	4.35**	0.00	13.21 **	7.14 **	5.26 **	49.60 **	33.45 **	1.64	-3.39	13.11 **
9.	NDLA-4 X CPI-1	-6.31**	-13.33 **	-1.89 *	-7.14 **	-8.77 **	32.93 **	19.78 **	-8.77 **	-13.28 **	1.52
10.	NDLA-4 X RHA-271	-6.09**	-10.00 **	1.89 *	-3.57 **	-5.26 **	26.94 **	11.87 **	-14.79 **	-19.01 **	-5.18
11.	NDLA-4 X NGM-16	2.86**	-10.00 **	1.89 *	-3.57 **	-5.26 **	60.27 **	26.26 **	-3.84	-8.59 **	7.01
12.	NDLA-4 X NO- 30	-3.45**	-6.67 **	5.66 **	0.00	-1.75 *	31.82 **	28.23 **	3.29	-1.82	14.94 **
13.	CMS 17A X NO-15	5.66**	3.70 **	5.66 **	0.00	-1.75 *	58.06 **	52.34 **	-1.92	-6.77 *	9.15 *
14.	CMS 17AX R- 106	4.67**	1.82 *	5.66 **	0.00	-1.75 *	41.72 **	36.60 **	-12.05 **	-16.41 **	-2.13
15.	CMS 17A X CPI-1	2.91**	1.92 *	0.00	-5.36 **	-7.02 **	38.43 **	34.89 **	-13.15 **	-17.45 **	-3.35
16.	CMS 17A X RHA-271	-0.93	-3.64 **	0.00	-5.36 **	-7.02 **	37.81 **	31.06 **	-15.62 **	-19.79 **	-6.10
17.	CMS 17A X NGM-16	7.22**	0.00	-1.89 *	-7.14 **	-8.77 **	44.30 **	21.28 **	-21.92 **	-25.78 **	-13.11 **
18.	CMS 17AX NO- 30	3.70**	0.00	5.66 **	0.00	-1.75 *	36.48 **	22.79 **	-1.10	-5.99 *	10.06 *
19.	CMS 30A X NO-15	0.00	0.00	1.89 *	-3.57 **	-5.26 **	32.12 **	9.70 **	-0.82	-5.73 *	10.37 **
20.	CMS 30AX R- 106	0.92	0.00	3.77 **	-1.79 *	-3.51 **	46.35 **	21.52 **	9.86 **	4.43	22.26 **
21.	CMS 30A X CPI-1	2.86**	0.00	1.89 *	-3.57 **	-5.26 **	35.99 **	13.94 **	3.01	-2.08	14.63 **
22.	CMS 30A X RHA-271	-2.75**	-3.64 **	0.00	-5.36 **	-7.02 **	32.84 **	9.09 **	-1.37	-6.25 *	9.76 *
23.	CMS 30A X NGM-16	7.07**	-1.85 *	0.00	-5.36 **	-7.02 **	39.18 **	3.33	-6.58 *	-11.20 **	3.96
24.	CMS 30A X NO- 30	1.82**	0.00	5.66 **	0.00	-1.75 *	32.05 **	24.85 **	12.88 **	7.29 *	25.61 **

*- Significant at 5% level ** - Significant at 1% level

parent reported significant positive heterosis and are in line with the results reported by (Reddy and Nadaf 2013 and Sapkale *et al*. 2016). The crosses CMS-30 A x NGM-16 and CMS-17 A x NGM-16 recorded high heterobeltiosis values for this trait. Whereas, the standard heterosis indicated that none of the hybrids excelled NDSH-1012 and DRSH-1, while eleven hybrids over KBSH-44 reported significant positive standard heterosis for head diameter. As many as seventeen hybrids recorded significant positive heterosis over better parent indicating that it is possible to combine better parent for head size compared to commercial checks. The *per se* performance of better performing hybrids and significant *sca* effects indicated that the parents (CMS-30 A and NGM-16) involved in this crosses can be used in production of high yielding hybrids with better head diameter.

The trait 100 seed weight is an important yield contributing character. Higher the weight of 100 seeds higher will be the seed yield. The present investigation reported that only five hybrids had significant positive heterosis and the best performing were CMS-17 A x NO-15 (42.86) and CMS-17 A x CPI-1 (34.69) over better parent. The same results were also reported by Habib *et al*. (2006) and Qamar *et al*. (2017). While, the standard heterosis indicates that none of the hybrids exhibited positive and significant heterosis over the checks DRSH-1 and KBSH-44 and eight crosses over NDSH-1012 showed positive and significant standard heterosis.

High volume weight has direct relation to the weight of seed. The crosses *viz*., CMS 30 A x NO-15, CMS 30 A x R-106 and NDLA-4 x R-106 recorded significantly high better parent heterosis with positive sca effect. The results were in accordance with the findings of Rathi *et al*. (2016) and Lakshman *et al*. (2018). The range of standard heterosis over checks was very low, while the cross NDLA-4 x R-106 exhibited significantly high positive heterosis over all the three checks.

The extent of autogamy indicates the limits of selfing that aids in preserving the purity of the genotype. The better parent heterosis indicates that only one hybrid CMS 30 A x CPI-1 had positive heterosis and the same hybrid also recorded significant high and positive standard heterosis over all the three checks (NDSH-1012, DRSH-1 and KBSH-44).

The seed set percentage is one of the limiting factor in sunflower production. So, exploitation of the desirable cross combinations with high seed set percentage is important towards achieving higher yields. Considerable amount of heterosis was observed in the present investigation for seed set percentage. The crosses CMS-17A x CPI-1, CMS-30A x CPI-1 and NDLA-4 x CPI-1 were rated as highly heterotic over better parent. Prevalence of significant heterosis for this trait was in accordance with the studies of Rathi *et al*. (2016), Ingle *et al*. (2016) and Singh and Kumar (2017). Nine hybrids over KBSH-44, six hybrids over DRSH-1 and five hybrids over NDSH-1012 recorded the significant positive heterosis.

Negative association between hull and oil content has been very well established in sunflower. A total of ten hybrids over better parent exhibited significant negative heterosis, highest being in the crosses CMS-30 A x NO-15 (-34.29), NDLA-3 x R-106 (-33.64) and NDLA-3 x CPI-1 (-26.17). The results were in agreement with Kaya (2005), Yamgar *et al*. (2015) and Ingle *et al*. (2016). Among the hybrids, three crosses possessed significant negative heterosis over the check KBSH-44. Not a single cross expressed significant standard heterosis over NDSH-1012 and DRSH-1.

Oil yield is also an important parameter in sunflower in addition to seed yield. The present analysis indicated that more number of hybrids reported positive and significant heterobeltiosis. The crosses *viz*., CMS-17 A x NO-15 (194.61), CMS -17 A x R-106 (154.01) and CMS-17 A x CPI-1 (152.35) recorded the high significant positive heterosis over better parent and the parents involved were poor combiners. These results were in conformation with Reddy and Nadaf (2013), Spoorthi and Nadaf (2016) and Lakshman *et al*. (2018).

The present investigation on the heterotic performance of the developed hybrids revealed that highest magnitude of heterosis was observed for oil yield followed by seed yield and number of seeds per head, however lowest magnitude of heterosis was observed for volume weight. None of the hybrids exhibited positive significant heterosis over NDSH-1012 for seed yield, oil yield, oil content and head diameter.

The hybrids NDLA-4 x NGM-16 and CMS-30 A x R-106 excelled all the check hybrids NDSH-1012, DRSH-1 and KBSH-44 with high positive standard

Table 2. Percent heterosis over mid parent (MP), better parent (BP) and check hybrids for head diameter (cm) and 100 seed weight (g) in sunflower (*Helianthus annuus* L.)

S.No	Crosses	Head Diameter (cm)					100 seed weight (g)				
		MP	BP	NDSH-1012	DRSH-1	KBSH-44	MP	BP	NDSH-1012	DRSH-1	KBSH-44
1.	NDLA-3 X NO-15	10.77	5.88	-7.69	-2.70	16.13	22.71 **	10.43	23.30 *	0.00	-0.78
2.	NDLA-3 X R- 106	5.26	-11.76	-23.08 **	-18.92 *	-3.23	0.00	-26.09 **	-17.48	-33.07 **	-33.59 **
3.	NDLA-3 X CPI-1	20.69 *	2.94	-10.26	-5.41	12.90	16.00	0.87	12.62	-8.66	-9.37
4.	NDLA-3 X RHA-271	36.00 **	0.00	-12.82	-8.11	9.68	37.14 **	4.35	16.50	-5.51	-6.25
5.	NDLA-3 X NGM-16	36.67 **	20.59 *	5.13	10.81	32.26 **	28.57 **	17.39 *	31.07 **	6.30	5.47
6.	NDLA-3 X NO- 30	15.15	11.76	-2.56	2.70	22.58 *	-8.33	-12.00	6.80	-13.39	-14.06
7.	NDLA-4 X NO-15	27.87 **	25.81 *	0.00	5.41	25.81 **	26.04 **	21.00 *	17.48	-4.72	-5.47
8.	NDLA-4 X R- 106	39.62 **	23.33 *	-5.13	0.00	19.35 *	23.87 *	-4.00	-6.80	-24.41 **	-25.00 **
9.	NDLA-4 X CPI-1	33.33 **	20.00	-7.69	-2.70	16.13	32.97 **	23.00 *	19.42	-3.15	-3.91
10.	NDLA-4 X RHA-271	47.83 **	13.33	-12.82	-8.11	9.68	12.50	-10.00	-12.62	-29.13 **	-29.69 **
11.	NDLA-4 X NGM-16	42.86 **	33.33 **	2.56	8.11	29.03 **	-1.54	-4.00	-6.80	-24.41 **	-25.00 **
12.	NDLA-4 X NO- 30	0.00	-3.13	-33.33 **	-29.73 **	-16.13	-13.78	-22.40 **	-5.83	-23.62 **	-24.22 **
13.	CMS 17A X NO-15	12.28	3.23	-17.95 *	-13.51	3.23	47.37 **	42.86 **	35.92 **	10.24	9.38
14.	CMS 17AX R- 106	34.69 **	26.92 *	-15.38 *	-10.81	6.45	20.26	-6.12	-10.68	-27.56 **	-28.12 **
15.	CMS 17A X CPI-1	32.00 **	26.92 *	-17.95 *	-13.51	3.23	44.26 **	34.69 **	28.16 *	3.94	3.13
16.	CMS 17A X RHA-271	61.90 **	30.77 *	-12.82	-8.11	9.68	39.24 **	12.24	6.80	-13.39	-14.06
17.	CMS 17A X NGM-16	38.46 **	38.46 **	-7.69	-2.70	16.13	13.99	12.24	6.80	-13.39	-14.06
18.	CMS 17AX NO- 30	13.79	3.13	-15.38 *	-10.81	6.45	0.45	-10.40	8.74	-11.81	-12.50
19.	CMS 30A X NO-15	29.03 **	29.03 **	2.56	8.11	29.03 **	-0.46	-13.60	4.85	-14.96	-15.62
20.	CMS 30AX R- 106	44.44 **	25.81 *	0.00	5.41	25.81 **	33.33 **	-4.00	16.50	- 5.51	-6.25
21.	CMS 30A X CPI-1	49.09 **	32.26 **	5.13	10.81	32.26 **	19.05 *	0.00	21.36 *	-1.57	-2.34
22.	CMS 30A X RHA-271	61.70 **	22.58 *	-2.56	2.70	22.58 *	37.30 **	1.60	23.30 *	0.00	-0.78
23.	CMS 30A X NGM-16	50.88 **	38.71 **	10.26	16.22	38.71 **	30.00 **	14.40	38.83 **	12.60	11.72
24.	CMS 30A X NO- 30	17.46	15.63	-5.13	0.00	19.35 *	7.20	7.20	30.10 **	5.51	4.69

*- Significant at 5% level   ** - Significant at 1% level

Table 3 : Percent heterosis over mid parent (MP), better parent (BP) and check hybrids for volume weight (g) and autogamy percentage in sunflower (*Helianthus annuus* L.)

S.No	Crosses	Volume weight (g)					Autogamy percentage				
		MP	BP	NDSH-1012	DRSH-1	KBSH-44	MP	BP	NDSH-1012	DRSH-1	KBSH-44
1.	NDLA-3 X NO-15	7.32	-2.22	-2.22	-10.20 **	-2.22	-26.90	-43.01 **	10.42	24.71	-15.20
2.	NDLA-3 X R- 106	1.08 -	2.08	4.44	-4.08	4.44	25.75	-8.70	118.75 **	147.06 **	68.00 **
3.	NDLA-3 X CPI-1	-4.76	-11.11 **	-11.11 **	-18.37 **	-11.11 **	23.14	3.97	63.54 *	84.71 **	25.60
4.	NDLA-3 X RHA-271	7.14	0.00	0.00	-8.16 *	0.00	-32.08 *	-52.81 **	31.25	48.24	0.80
5.	NDLA-3 X NGM-16	1.30	-13.33 **	-13.33 **	-20.41 **	-13.33 **	2.78	-19.57	54.17 *	74.12 *	18.40
6.	NDLA-3 X NO- 30	0.00	-4.44	-4.44	-12.24 **	-4.44	-41.96	-45.83	-32.29	-23.53	-48.00 *
7.	NDLA-4 X NO-15	3.45	-10.00 **	0.00	-8.16 *	0.00	-53.65 **	-56.40 **	-4.17	8.24	-26.40
8.	NDLA-4 X R- 106	10.20 **	8.00 *	20.00 **	10.20 **	20.00 **	-64.63 **	-66.09 **	-18.75	-8.24	-37.60
9.	NDLA-4 X CPI-1	-1.12	-12.00 **	-2.22	-10.20 **	-2.22	-40.88 **	-49.29 **	11.46	25.88	-14.40
10.	NDLA-4 X RHA-271	-1.12	-12.00 **	-2.22	-10.20 **	-2.22	-44.35 **	-50.19 **	38.54	56.47 *	6.40
11.	NDLA-4 X NGM-16	4.88	-14.00 **	-4.44	-12.24 **	-4.44	-29.11 *	-33.65 *	45.83	64.71 *	12.00
12.	NDLA-4 X NO- 30	1.10	-8.00 *	2.22	-6.12	2.22	-16.01	-34.12 *	44.79	63.53 *	11.20
13.	CMS 17A X NO-15	15.00 **	6.98	2.22	-6.12	2.22	-41.15 **	-42.93 **	17.71	32.94	-9.60
14.	CMS 17AX R- 106	5.49	0.00	6.67	-2.04	6.67	-17.76	-23.48	83.33 **	107.06 **	40.80 *
15.	CMS 17A X CPI-1	0.00	-4.65	-8.89 *	-16.33 **	-8.89 *	-16.33	-26.26	52.08 *	71.76 *	16.80
16.	CMS 17A X RHA-271	4.88	0.00	-4.44	-12.24 **	-4.44	-44.52 **	-51.69 **	34.38	51.76	3.20
17.	CMS 17A X NGM-16	12.00 **	-2.33	-6.67	-14.29 **	-6.67	-7.85	-11.11	83.33 **	107.06 **	40.80 *
18.	CMS 17AX NO- 30	4.76	2.33	-2.22	-10.20 **	-2.22	-46.54 **	-57.07 **	-11.46	0.00	-32.00
19.	CMS 30A X NO-15	15.38 **	9.76 *	0.00	-8.16 *	0.00	-30.67 *	-31.22 *	35.42	52.94	4.00
20.	CMS 30AX R- 106	16.85 **	8.33 *	15.56 **	6.12	15.56 **	-12.65	-20.43	90.63 **	115.29 **	46.40 *
21.	CMS 30A X CPI-1	7.50	4.88	-4.44	-12.24 **	-4.44	27.65	14.81	126.04 **	155.29 **	73.60 **
22.	CMS 30A X RHA-271	5.00	2.44	-6.67	-14.29 **	-6.67 -	44.30 **	-52.43 **	32.29	49.41	1.60
23.	CMS 30A X NGM-16	12.33 **	0.00	-8.89 *	-16.33 **	-8.89 *	-20.11	-21.16	55.21 *	75.29 *	19.20
24.	CMS 30A X NO- 30	7.32	7.32	-2.22	-10.20 **	-2.22	14.56	-6.35	84.38 **	108.24 **	41.60 *

- Significant at 5% level** * - Significant at 1% level**

Table 4 : Percent heterosis over mid parent (MP), better parent (BP) and check hybrids for hull content (%) and seed yield (kg ha^{-1}) in sunflower (*Helianthus annuus* L.)

S.No	Crosses	Hull content (%)					Seed yield (kg ha^{-1})				
		MP	BP	NDSH-1012	DRSH-1	KBSH-44	MP	BP	NDSH-1012	DRSH-1	KBSH-44
1.	NDLA-3 X NO-15	-17.92**	-18.69 *	26.09 *	20.83	1.16	95.77 **	45.27 *	-4.83	9.53	26.62
2.	NDLA-3 X R- 106	-22.40**	-33.64 **	2.90	-1.39	-17.44	48.03	-1.05	-35.17 *	-25.39	-13.75
3.	NDLA-3 X CPI-1	-17.28*	-26.17 **	14.49	9.72	-8.14	57.14 *	15.80	-24.13	-12.69	0.93
4.	NDLA-3 X RHA-271	-4.35	-17.76 *	27.54 *	22.22	2.33	120.19 **	37.90	-9.65	3.98	20.19
5.	NDLA-3 X NGM-16	-5.88	-10.28	39.13 **	33.33 **	11.63	92.88 **	53.27 **	0.42	15.57	33.59
6.	NDLA-3 X NO- 30	-3.78	-16.82 *	28.9 *	23.61 *	3.49	43.75 *	42.26 *	-4.83	9.53	26.62
7.	NDLA-4 X NO-15	-9.28	-16.19 *	27.54 *	22.22	2.33	179.11 **	122.92 **	18.35	36.21 *	57.45 **
8.	NDLA-4 X R- 106	-17.58*	-23.60 **	-1.45	-5.56	-20.93 *	162.39 **	85.75 **	-1.39	13.49	31.19
9.	NDLA-4 X CPI-1	-5.20	-7.87	18.84	13.89	-4.65	149.19 **	97.45 **	4.83	20.64	39.46 *
10.	NDLA-4 X RHA-27	1.20	-5.62	21.74	16.67	-2.33	133.71 **	53.28 *	-18.62	-6.34	8.26
11.	NDLA-4 X NGM-16	-9.68	-13.40	21.74	16.67	-2.33	170.73 **	133.81 **	24.13	42.86 *	65.14 **
12.	NDLA-4 X NO- 30	-13.77	-19.10 *	4.35	0.00	-16.28	16.10	4.12	-30.34 *	-19.84	-7.33
13.	CMS 17A X NO-15	--14.13	-24.76 **	14.49	9.72	-8.14	155.84 **	129.35 **	-8.27	5.57	22.04
14.	CMS 17AX R- 106	3.23	1.27	15.94	11.11	-6.98	157.79 **	100.04 **	-19.99	-7.92	6.44
15.	CMS 17A X CPI-1	16.56*	13.10	37.68 **	31.94 **	10.47	152.42 **	124.17 **	-10.34	3.19	19.28
16.	CMS 17A X RHA-271	26.92**	25.32 *	43.48 **	37.50 **	15.12	182.98 **	100.04 **	-19.99	-7.92	6.44
17.	CMS 17A X NGM-16	13.64	3.09	44.93 **	38.89 **	16.28	135.13 **	131.06 **	-7.58	6.36	22.95
18.	CMS 17AX NO- 30	-1.91	-2.53	11.59	6.94	-10.47	36.76	9.26	-26.90	-15.88	-2.75
19.	CMS 30A X NO-15	-17.86*	-34.29 **	0.00	-4.17	-19.77 *	155.77 **	105.26 **	7.60	23.83	43.14 *
20.	CMS 30AX R- 106	-5.04	-13.16	-4.35	-8.33	-23.26 *	216.58 **	124.95 **	6.21	22.24	41.30 *
21.	CMS 30A X CPI-1	7.48	-5.95	14.49	9.72	-8.14	142.91 **	93.38 **	1.37	16.66	34.86
22.	CMS 30A X RHA-271	11.43	1.30	13.04	8.33	-9.30	207.99 **	102.61 **	6.21	22.24	41.30 *
23.	CMS 30A X NGM-16	3.75	-14.43	20.29	15.28	-3.49	120.62 **	91.56 **	0.42	15.57	33.59
24.	CMS 30A X NO- 30	3.55	-6.41	5.80	1.39	-15.12	66.47 **	48.45 *	-0.69	14.30	32.12

*- Significant at 5% level ** - Significant at 1% level

Table 5. Percent heterosis over mid parent (MP), better parent (BP) and check hybrids for oil content (%) and oil yield (kg ha^{-1}) in sunflower (*Helianthus annuus* L.)

S.No	Crosses	Oil content (%)					Oil yield (kg ha^{-1})				
		MP	BP	NDSH-1012	DRSH-1	KBSH-44	MP	BP	NDSH-1012	DRSH-1	KBSH-44
1.	NDLA-3 X NO-15	7.24**	5.99 *	-13.91 **	-8.01 **	2.54	110.30 **	54.78 *	-18.11	0.92	30.23
2.	NDLA-3 X R- 106	7.49**	1.72	-7.45 **	-1.10	10.24 **	64.27 *	13.39	-40.01 **	-26.06	-4.59
3.	NDLA-3 X CPI-1	1.05	-3.52	-21.64 **	-16.26 **	-6.66 *	57.52 *	12.76	-40.34 **	-26.48	-5.13
4.	NDLA-3 X RHA-271	2.40	0.70	-15.40 **	-9.60 **	0.77	129.66 **	44.86 *	-23.36	-5.55	21.88
5.	NDLA-3 X NGM-16	-0.70	-1.17	-18.96 **	-13.41 **	-3.48	92.98 **	53.93 *	-18.56	0.37	29.52
6.	NDLA-3 X NO- 30	5.93*	2.30	-10.79 **	-4.67 *	6.26 *	51.41 **	44.14 *	-15.64	3.97	34.17
7.	NDLA-4 X NO-15	8.60**	7.00 *	-12.54 **	-6.54 **	4.17	202.80 **	138.86 **	3.26	27.26	64.22 **
8.	NDLA-4 X R- 106	8.37**	2.87	-6.40 **	0.01	11.48 **	191.24 **	113.44 **	-7.72	13.72	46.75 *
9.	NDLA-4 X CPI-1	9.39**	4.13	-14.88 **	-9.05 **	1.38	170.15 **	106.42 **	-10.76	9.98	41.92
10.	NDLA-4 X RHA-27	4.61	3.19	-13.31 **	-7.37 **	3.26	147.31 **	63.23 *	-29.43 *	-13.03	12.22
11.	NDLA-4 X NGM-16	6.37*	6.21 *	-12.92 **	-6.95 **	3.72	189.11 **	149.87 **	8.02 ns	33.13 *	71.79 **
12.	NDLA-4 X NO- 30	4.06	0.79	-12.10 **	-6.07 *	4.70	18.57	3.07	-39.67 **	-25.65	-4.05
13.	CMS 17A X NO-15	18.32**	9.77 **	-12.92 **	-6.95 **	3.72	206.91 **	194.61 **	-20.02	-1.43	27.19
14.	CMS 17AX R- 106	8.56**	-5.23 *	-13.77 **	-7.86 **	2.70	191.67 **	154.01 **	-31.05 *	-15.02	9.66
15.	CMS 17A X CPI-1	7.73**	3.34	-23.65 **	-18.42 **	-9.06 **	174.12 **	152.35 **	-31.50 *	-15.57	8.94
16.	CMS 17A X RHA-271	12.09**	1.32	-14.88 **	-9.05 **	1.38	231.56 **	150.28 **	-32.06 *	-16.27	8.05
17.	CMS 17A X NGM-16	5.00	-4.04	-21.32 **	-15.93 **	-6.29 *	147.44 **	130.36 **	-27.45 *	-10.58	15.38
18.	CMS 17AX NO- 30	8.73**	-3.32	-15.69 **	-9.91 **	0.42	43.63	5.12	-38.47 **	-24.17	-2.15
19.	CMS 30A X NO-15	9.01 **	-0.26	-4.65 *	1.89	13.57 **	173.76 **	105.17 **	2.70	26.57	63.33 **
20.	CMS 30AX R- 106	4.85*	2.32	-2.18	4.52	16.51 **	228.31 **	130.19 **	15.22	42.01 *	83.24 **
21.	CMS 30A X CPI-1	10.77**	-1.82	-6.14 **	0.30	11.80 **	160.70 **	89.81 **	-4.99	17.10	51.10 *
22.	CMS 30A X RHA-271	1.64	-4.52	-8.72 **	-2.46	8.72 **	203.40 **	93.63 **	-3.07	19.45	54.14 *
23.	CMS 30A X NGM-16	7.49**	-0.16	-4.55 *	1.99	13.69 **	134.94 **	91.39 **	-4.20	18.07	52.36 *
24.	CMS 30A X NO- 30	7.89**	3.15	-1.39	5.37 *	17.45 **	80.11 **	67.07 *	-2.21	20.52	55.52 *

- Significant at 5% level** * - Significant at 1% level**

Table 6. Superior crosses with heterosis over better parent, *sca* and *gca* effects and mean performance for 10 traits studied in sunflower (*Helianthus annuus* L.)

S.No.	Character	Crosses with high heterotic performance over better parent	Heterosis over better parent	*sca* effect	*gca* status		Mean performance
					Female	Male	
1.	Days to 50 % flowering	NDLA-4 x CPI-1	-13.33 **	-1.29 **		L	H52
		NDLA-3 x NGM-16	-10.19 **	-2.08 **		L	H49
		NDLA-4 x RHA-271	-10.00 **	-0.29	L	L	55
		NDLA-4 x NGM-16	-10.00 **	1.08 **		L	H54
2.	Plant height (cm)	CMS 17A x NO-15	52.34 **	20.10 **		L	L 179
		CMS 17A x R-106	36.60 **	-10.15 *		L	H161
		CMS 17A x CPI-1	34.89 **	1.48	L	L	159
3.	Head diameter (cm)	CMS 30A x NGM-16	38.71 **	-0.21	H	H	22
		CMS 17A x NGM-16	38.46 **	-0.63	L	H	18
		NDLA-4 x NGM-16	33.33 **	0.04	L	H	22
4.	100 seed weight (g)	CMS 17A x NO-15	42.86 **	0.77	L	H	7.00
		CMS 17A x CPI-1	34.69 **	0.37	L	H	6.60
5.	Volume weight (g/100ml)	CMS 30A x NO-15	9.76 *	-0.13	L	L	45
		CMS 30A x R-106	8.33 *	1.63	H	H	52
		NDLA-4 x R-106	8.00 *	2.13	H	H	54
6.	Autogamy (%)	CMS 30A x CPI-1	14.81	17.15	H	H	109
7.	Hull content (%)	CMS 30A x NO-15	-34.29 **	-2.25	H	L	35
		NDLA-3 x R-106	-33.64 **	-1.67	L	H	36
8.	Seed yield (kg ha^{-1})	NDLA-4 x NGM-16	133.81 **	483.27	L	H	4167
		CMS 17A x NGM-16	131.06 **	-77.56	L	H	3102
		CMS 17A x NO-15	129.35 **	-62.56	L	H	3079
9.	Oil content (%)	CMS 17A x NO-15	9.77 **	1.21	L	L	34.56
		CMS 17A x NO-16	7.00 *	-0.63	L	L	34.71
		CMS 17A x NGM-16	6.21 *	0.58	L	L	34.56
10.	Oil yield (kg ha^{-1})	CMS-17A x NO-15	194.61 **	14.20	L	H	1066
		CMS-17A x R-106	154.01 **	-28.35	L	L	920
		CMS 17A X CPI-1	152.35 **	45.77	L	L	913

and better parent heterosis values for seed yield and oil yield, respectively and are worth for testing over locations. Considering hybrids with significant heterosis over better parent, *gca, sca* effects and *per se* performance, the crosses *viz*., NDLA-4 x NGM-16, CMS-17 A x NO-15 and CMS-17 A x NGM-16 have significant positive heterosis for seed yield and its contributing traits. NDLA-3, NDLA-4 and CPI-1 parental lines involved crosses resulted in better heterotic hybrids for early flowering. NDLA-4 and NGM-16 parental combinations can be used for the development of high yielding hybrids as their cross combinations reported high number of seeds per head. However, majority of the hybrid combinations involving NDLA-4, CMS-17 A and CMS-30 A as female parents and NGM-16, NO-15 as male parents recorded the high heterotic effects with L x L or L x H or H x L *gca* effects indicating a gene interaction of additive and non-additive type.

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Research Article
The J. Res. PJTSAU 48 (1&2) 12-20, 2020

PHENOTYPIC DIVERSITY OF RICE GERMPLASM FOR YIELD TRAITS UNDER AEROBIC CULTIVATION

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Date of Receipt : 21-05-2020 Date of Acceptance : 05-06-2020

ABSTRACT

Rice is central in the food consumption of more than half of global population and also holds a very major share in water used for agriculture. The rapid depletion of water resources is making it a difficult task for the farmers to cultivate rice under flooded condition thus emphasizing the need to shift to aerobic cultivation. As the genetic basis of material suitable for aerobic cultivation is narrow, the present study aims at understanding the performance of germplasm collected from various parts of country under aerobic cultivation. In the present study, one hundred and ten germplasm lines collected from Cuttack, Tamilnadu, Andhra Pradesh, Telangana and Karnataka were evaluated for two seasons. Data was collected on ten yield attributing traits *viz.*, seedling vigour index, days to 50% flowering, plant height, panicle length, total tillers per plant, productive tillers per plant, filled grains per panicle, thousand grain weight, percentage spikelet fertility and grain yield per plant. The results revealed that a significant number of lines had values with desirable range for each trait. Correlation analysis revealed a significant positive correlation between the traits such as productive tillers and thousand grain weight (0.74), plant height with panicle length (0.73) and seedling vigour index (0.56) and panicle length and filled grains per panicle (0.55). The diversity analysis resulted in two major clusters (I and II) with 63 and 47 lines respectively, which further branched into two sub-clusters each (Ia, Ib and IIa, IIb). The cluster I predominantly had lines from Tamilnadu, Andhra Pradesh, Telangana and Karnataka and four national checks for water stress tolerance, while cluster II was dominated by germplasm collected from Cuttack. The present study thus formed a basis to understand the performance of rice germplasm under aerobic cultivation. Lines with desirable agronomic traits can be chosen from both the clusters and exploited in future research towards aerobic rice breeding.

Rice is an important staple food crop and at the same time it is also a voracious consumer of water. On an average 4500-5000 litres of water is required (in transplanted rice system) to produce 1kg of rice (Bouman, 2009). The present surge in water usage has led to depletion of water resources at a faster pace, which in near future would lead to unavailability of sufficient water for agriculture. So, rather than following the age old practice of growing rice in a continuously flooded field condition, the usage of water can be reduced by adopting certain water management techniques crucial in the present situation of water crisis (Bouman, 2001). The best among the available techniques is cultivation of aerobic rice. The concept of aerobic rice was first developed in China (Bouman and Tuong 2001). The term “Aerobic Rice” was coined recently by IRRI (Bouman *et al* ., 2002). It involves growing of rice in aerobic soil, under non-flooded and non-puddled conditions with the use of external inputs such as supplementary irrigation and fertilizers and aiming at high yields (Wang *et al* ., 2002).This method of growing rice requires almost 73% less water during land preparation and 56% less during crop growth as compared to lowland system (Castaneda *et al* ., 2004). But, intermittent water limitation in this cultivation approach results in yield reduction ranging between 15 and 40% which is not acceptable (George *et al*. 2002).

The success of aerobic rice cultivation is majorly decided by selection of appropriate cultivars (Wang *et al* ., 2002). Under such requirements, genetic diversity present among the genotypes acts as a very powerful tool in the process of selection of good genotypes for breeding program. Joshi and Dhawan (1966) reported that genetic diversity was a very important factor for any hybridization program aiming at genetic improvement of yield especially in self-pollinated crops. The aerobic rice breeding program when compared with lowland rice breeding is extremely small and the genetic basis is very narrow. Moreover, so far only a very few studies have been conducted to understand the diversity present among rice germplasm that can be exploited for breeding cultivars suitable under aerobic conditions (Mall *et al* ., 2013; Ramanjaneyulu *et al* ., 2014; Kumari *et al* ., 2016 and Behera *et al* ., 2017). Moreover, all these studies were conducted only

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with a handful of genotypes (10 to 36 entries) and this number is not sufficient to understand the variation present across diverse agro-climatic and geographical regions.

This implies the necessity of understanding performance of more and more entries of rice germplasm under aerobic cultivation, which would help breeders in broadening the genetic base for future breeding programmes. Hence, in the present study we have evaluated about 110 rice germplasm lines collected from different parts of India and recorded yield attributing traits to assess the diversity present among them and understand their performance under aerobic conditions.

MATERIAL AND METHODS

Plant material

The experimental material used for this study comprised of 110 germplasm lines of rice collected from NRRI (National Rice Research Institute, Cuttack, 60 lines), Tamilnadu (30 lines), Andhra Pradesh (8 lines), Telangana (6 lines), and Karnataka (2 lines) and national checks for water stress tolerance (4 lines).

Phenotyping and statistical analysis

The germplasm lines were sown in the field through direct seeding in RBD with two replications for two seasons (*Kharif* 2018 and *Kharif* 2019), with a spacing of 15 cm x 15 cm with six plants per row and six rows per entry. Data were recorded on ten yield attributing traits i.e., Seedling Vigour Index (SVI), Days to 50% Flowering (DFF-days), Plant Height (PHT-cm), Panicle Length (PL-cm), Total Tillers per plant (TT), Productive Tillers per plant (PT), Filled Grains per Panicle (FGP), Thousand Grain Weight (TGW-g), Percentage spikelet Fertility (PFER-%) and Grain Yield per Plant (GYP-g) on 5 healthy plants from each of the germplasm lines. All the traits except SVI were recorded as per the standard evaluation system of rice given by IRRI (IRRI, 2013).

To calculate SVI, 20 healthy seeds from each line were sown in germination towels in two replications and the towels were rolled and placed vertically in a tub with one end dipped in water. On third day after sowing, number of seeds that have germinated were counted thus giving us the germination percentage. Seven days after recording the germination percentage i.e., ten days after sowing, five healthy seedlings per entry were taken from each replication and their root and shoot lengths were measured and averaged. Seedling vigour index values were obtained using the following formula:

SVI = Germination percentage (Root length + Shoot length)

Descriptive statistical parameters like mean, minimum, maximum, kurtosis and skewness were calculated to understand the distribution pattern of the individuals for different traits and also frequency distribution and correlation analysis was done using data analysis package in MS Excel.

Diversity analysis:

The phenotypic diversity analysis of population was done using the software DARwin ver. 6.0 (Perrier *et al* ., 2003). The analysis was carried out with the help of recorded phenotypic data to construct an unweighted neighbour joining tree.

RESULTS AND DISCUSSION

Phenotypic characterization of germplasm lines:

Descriptive statistical parameters like minimum, maximum, mean, skewness and kurtosis are given in Table 1 and frequency distribution of germplasm for various traits is presented in Fig. 1. Trait wise results of the germplasm lines under study are presented here under.

1. **Seedling Vigour Index (SVI):** The seedling vigour index values ranged from 1329.8 to 3362 with a mean index of 2513.1. Both kurtosis and skewness values for this trait were -0.4. The frequency distribution graph showed that around 15 lines had an index of greater than 3000, which is considered desirable.
2. **Days to 50% Flowering (DFF):** The time taken by the germplasm lines to reach 50% flowering ranged from 76 days to 126 days and the mean was 97 days. Kurtosis and skewness values were obtained as 0.5 and 0.3 respectively. The frequency distribution graph depicted that as many as 58 lines had a DFF value of d" 95 days. Similar results for this trait were obtained by Rawte and Saxena (2018) where the days to 50% flowering in their experimental material of 100 lines ranged from 69.5 to 128 days with a mean of 97.92 days.
3. **Plant Height (PHT):** This was one of the most diverse traits in the germplasm wherein the minimum and maximum height recorded was 48 cm and 117.6 cm respectively and the mean was 82 cm.

The skewness value for this trait is 0 which implies that the population followed normal distribution. The histogram for this trait showed that around 90 lines possessed a plant height of d" 100 cm, which is desirable for the crop. In another study conducted by Roy *et al*. (2016) the mean value obtained for plant height was 81.11cm, which is almost equal to the mean value obtained in the present study, while the minimum and maximum values were recorded as 32 cm and 122.2 cm respectively.

4. **Panicle Length (PL):** The length of the panicles in germplasm varied from 14.6 cm to 26.3 cm with an average panicle length of 20.4 cm. The kurtosis and skewness for panicle lenth is 0.0 and 0.1 respectively. Twenty four lines had panicles measuring greater than 22 cm. Nearly similar result for panicle length was obtained by Chakrabarthy *et al*., 2012 who reported panicle length in a range of 17.0 – 29.6 cm with a mean of 22.05 cm. Yet another study carried out by Mall *et al*. (2013) under aerobic conditions gave almost similar result and the panicle length ranged between 17.05 cm to 28.88 cm while the mean was 23.87 cm. Variation for panicle length in the germplasm lines is presented Fig.2a.

5. **Total Tillers per plant (TT):** The minimum and maximum value for this trait was 6 and 46 respectively and the mean number of tillers was 13 per plant. The kurtosis value was obtained as 8.8 and this implied that the curve had a higher peak and most of the lines were scattered closer to the mean while the skewness value (2.7) suggested that the curve was skewed to the left and around 24 lines had more than 14 tillers per plant. In another study carried out by Ramanjaneyulu *et al*. (2014) under aerobic cultivation a similar mean of 13.05 tillers per plant was obtained while the readings in the experimental material ranged from 11.24 to 15.04 tillers. Roel *et al*., 2014 also reported similar result where the culm number ranged from 5.2 to 32.8 and the mean value was 16.3.

6. **Productive Tillers per plant (PT):** The values for number of productive tillers per plant ranged from 5 to 33 with a mean value of 11 tillers. The kurtosis (6.5) and skewness (2.4) values clearly implied that the distribution curve had a higher peak with many individuals lying closer to the mean and also the curve was skewed to the left. The frequency distribution showed that around 23 entries among the population could produce more than 12 productive tillers per plant. Similarly in another study carried out by Nandan *et al*., 2010 the data recorded for number of productive tillers per plant showed a similar mean of 11.12 tillers with the values ranging between 10.46 to 12.06 tillers.

7. **Filled Grains per Panicle (FGP):** The number of filled grains per panicle ranged from 25 to 227 grains with a mean value of 103. The kurtosis and skewness values for this trait were 1.2 and 0.8 respectively. Out of 110 lines, 9 lines had greater than 150 filled grains per panicle. Variation for number of grains per panicle in the germplasm lines is presented Fig.2b.

8. **Thousand Grain Weight (TGW):** The weight of thousand grains of germplasm lines ranged from 7.62 g to 35.0 g and the mean weight recorded was 17.3 g. Skewness value for this trait (-0.3) fell in the normal range but the kurtosis value (4.3) implied a higher peak with most of the lines having a TGW value closer to mean and around 26 lines exhibited a TGW value greater than 20 g. In another study carried out by Chakrabarthy *et al*. (2012) the thousand grain weight of the experimental material ranged from 8.4 g to 27.9 g with a mean value of 18.71 g. In yet another study carried out by Ramanjaneyulu *et al*. (2014) under aerobic cultivation the thousand grain weight ranged from 12.06 g to 21.46 g and a mean value of 16.25 g was observed.

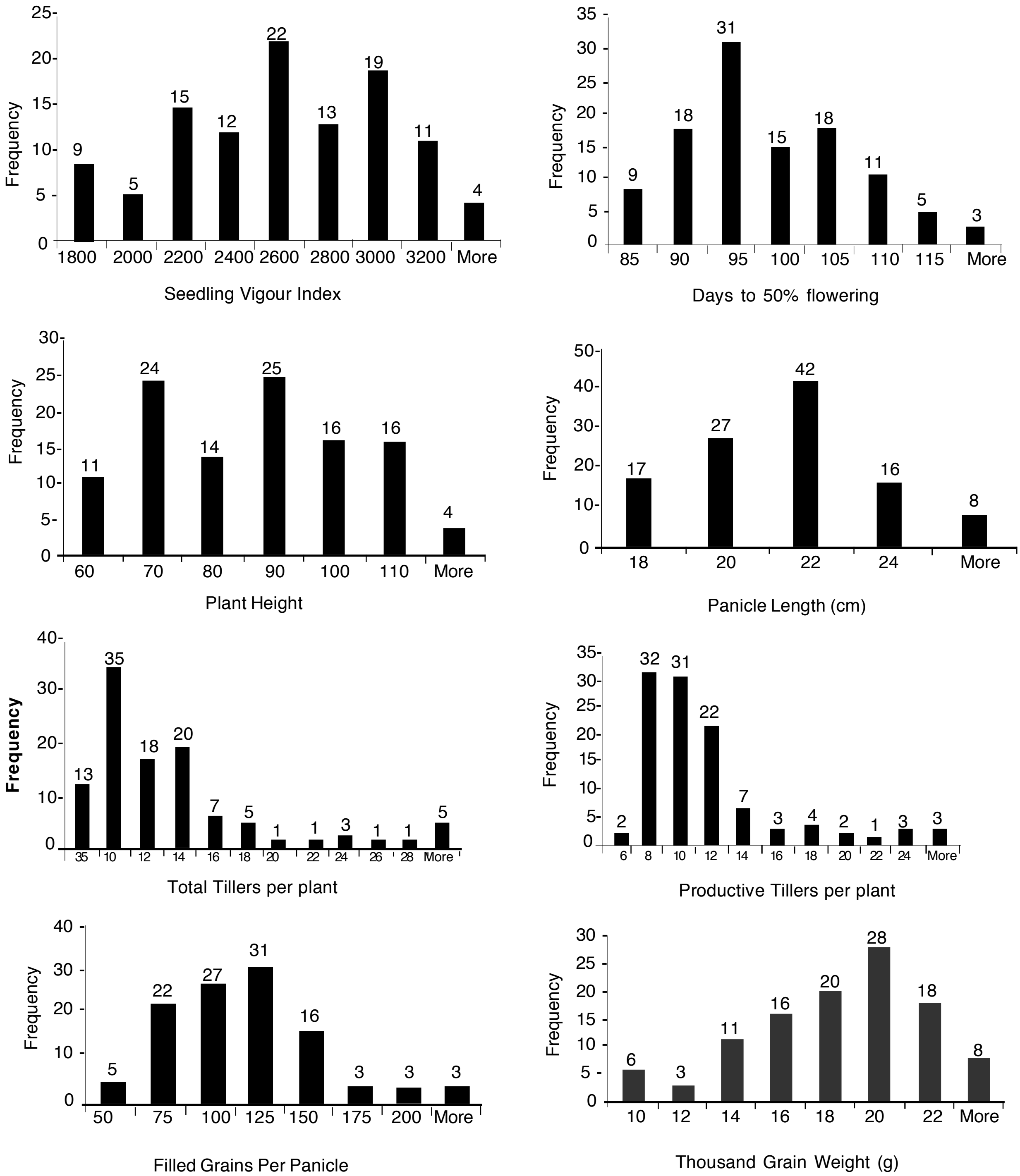
9. **Percentage spikelet Fertility (PFER):** Fertility of the germplasm lines ranged from 45.9% to 96.6% while the mean fertility percentage was recorded as 81.9%. The kurtosis (1.5) and skewness (-1.4) values showed that the curve is partially skewed towards right. In the population, around 30 lines have a fertility percentage of greater than 90%. Similar result was obtained by Yadav *et al.*, 2013 where the mean spikelet fertility was recorded as 81.06% and the range was 38.2% - 96.7%.

10. **Grain Yield per Plant (GYP):** Total grain yield from a single plant ranged from 2.82 g to 21.3 g with a mean yield of 9.3 g. The skewness value (0.7) fell within the normal range while kurtosis value (2.2) showed that a significant number of lines produced a yield closer to the mean value. Around 15 entries in the population gave greater than 12 g yield per plant.

Table 1. Summarized descriptive statistics of the germplasm material

	SVI	DFF	PHT	PL	TT	PT	FGP	TGW	PFER	GYP
Minimum	1329.8	76	48.0	14.6	6	5	25	7.62	45.9	2.82
Maximum	3362.0	126	117.6	26.3	46	33	227	35.0	96.6	21.3
Mean	2513.1	97	82.0	20.4	13	11	103	17.3	81.9	9.3
Kurtosis	-0.4	0.5	-0.9	0.0	8.8	6.5	1.2	4.3	1.5	2.2
Skewness	-0.4	0.3	0.0	0.1	2.7	2.4	0.8	-0.3	-1.4	0.7

Fig. 1. Trait wise histograms showing frequency distribution of the germplasm for ten phenotypic traits



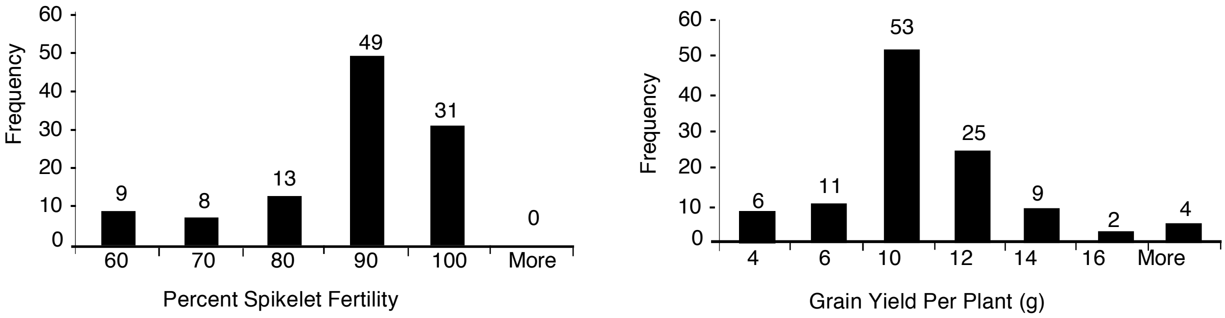
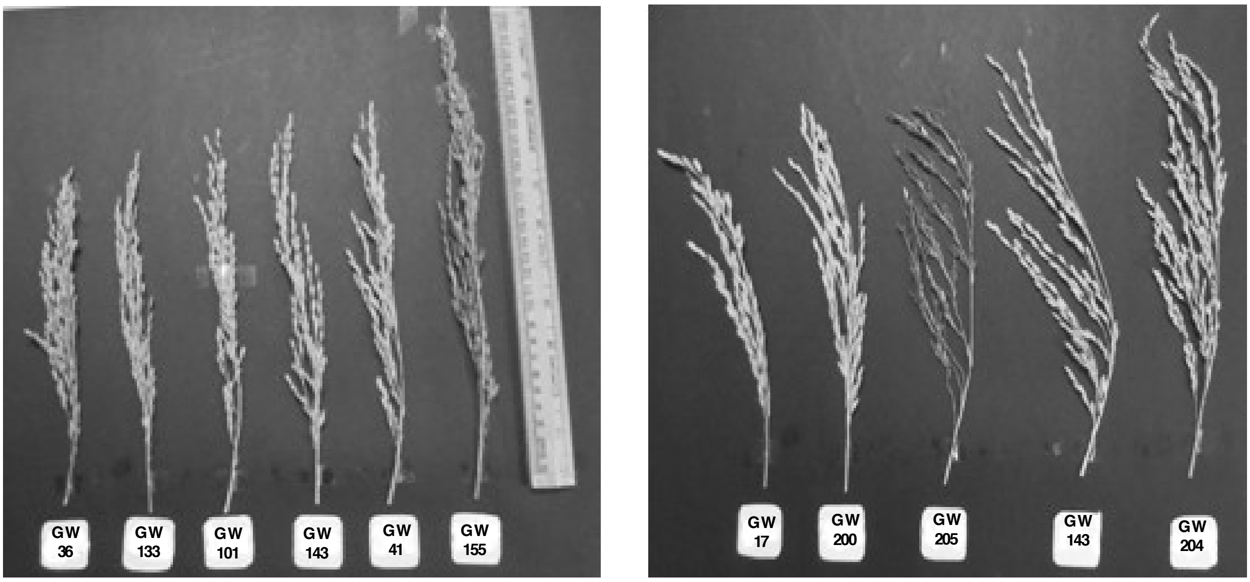


Fig. 2. Variation for panicle length (a) and grain number per panicle (b) in the germplasm



(a) (b)

Correlation analysis

Phenotypic correlation between yield and its component traits are presented in Table 2. Highly significant positive correlation was observed between two pairs of traits i.e., panicle length and plant height (0.73) and thousand grain weight and productive tillers per plant (0.74). Similar results were observed in three other studies carried out by Lakshmi *et al* . (2014), Ramanjaneyulu *et al* . (2014) and Rawte and Saxena (2018) where a weak to moderate positive correlation was present between panicle length and plant height (0.47, 0.31 and 0.44 respectively). Yet another study conducted by Behera *et al.* (2017) specifically in aerobic rice also reported existence of moderate positive correlation between plant height and panicle length (0.42). Similar work done by Dindin *et al.* (2019) suggested the existence of moderate positive correlation between hundred grain weight and productive tiller number (0.47). On the other hand, significant negative correlation is recorded between Number of productive tillers and percent spikelet fertility (-0.63). A moderate positive correlation was seen to exist between plant height and seedling vigour index (0.56) and filled grains per panicle and panicle length (0.55). Nandan *et al.*, 2010 also reported moderate positive correlation between filled grains per panicle and panicle length (0.39). Moderate negative correlation was recorded between total tillers per plant and filled grains per panicle (-0.45) and total tillers per plant and percent spikelet fertility (-0.43). Productive tillers per plant exhibited a moderate negative correlation with traits seedling vigour index (-0.43) and panicle length (-0.44). In a similar study carried out by Lakshmi *et al.* (2014) a weak negative correlation was reported to exist between productive tiller number and panicle length (-0.25).

Diversity analysis

Phenotypic diversity of 110 germplasm lines based on yield and yield attributing traits is presented in the form of Unweighted Neighbour Joining Tree (Fig.3).

Table 2. Correlation analysis of the germplasm

	SVI	DFF	PH	PL	TT	PT	FGP	TGW	PSF	GYP
SVI	1.00									
DFF	0-2.8	1.00								
PH	0.56	-0.23	1.00							
PL	0.32	-0.12	0.73	1.00						
TT	0.02	-0.31	0.18	-0.38	1.00					
PT	-0.43	-0.03	-0.38	-0.44	0.34	1.00				
FGP	-0.21	-0.07	0.22	-0.55	-0.45	-0.16	1.00			
TGW	-0.27	-0.12	-0.28	0.27	0.02	0.74	-0.12	1.00		
PSF	0.24	-0.25	0.33	0.38	-0.43	-0.63	0.33	-0.36	1.00	
GYP	0.19	-0.22	0.20	0.24	-0.20	-0.20	0.12	0.29	0.32	1.00

*Significant values have been highlighted.

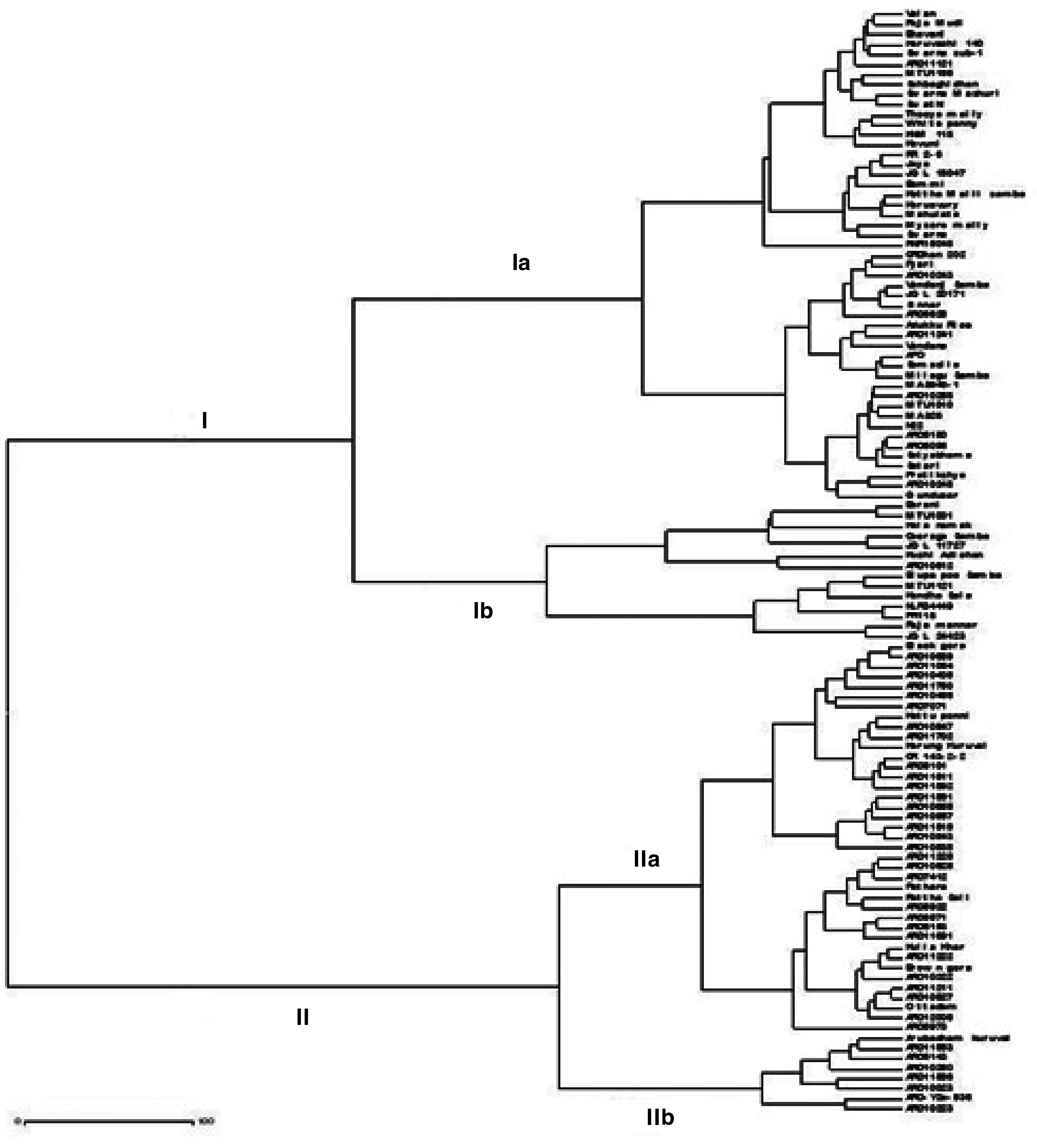
The total germplasm lines were grouped into two major clusters (I and II) which further branched into two sub-clusters each (Ia, Ib and IIa, IIb). The clusters Ia and Ib had 49 and 14 lines respectively (total 63 lines) while the clusters IIa and IIb had 39 and 8 lines respectively (total 47 lines). The cluster I predominantly had landraces from Tamilnadu followed by varieties released from Andhra Pradesh, Telangana and Karnataka. The national checks for water stress tolerance included in this study were also present in cluster I. Majority of the lines in cluster I belonged to southern India implying that these lines are related in terms of agronomic traits due to the geographical and meteorological similarities. On the other hand, cluster II was dominated by germplasm collected from Cuttack, i.e., ARC lines (Assam Rice Collection). This again clearly indicated that the reason behind relatedness of these lines is their origin. Detailed cluster information is given in Table 3.

Similar clustering of rice germplasm for agro-morphological traits was performed by Chakrabarty *et al*. (2012) for farmers' varieties from Southern parts of West Bengal with a sample size of 91 varieties. A total of fifty two plant morphological and grain characteristic traits were recorded for two years at IARI, New Delhi. The varieties having considerable diversity in quantitative traits were grouped into four clusters. Though these varieties were from the same geographical location, the diversity and clustering was based on the variation present in the quantitative traits.

In another study carried out by Sharma *et al*. (2013) 2142 rice accessions from North-west India were tested for ten agro-morphological traits at CSSRI, Karnal, Haryana. The diversity analysis resulted in formation of eight clusters where the majority of variation was due to traits such as plant height, days to 50% flowering and maturity, productive tillers and grain size. Mall *et al*., (2013) evaluated a set of 36 promising rice genotypes for one season under both irrigated and aerobic situations for eight quantitative traits and were grouped into six distinct clusters based on the variation present. Interestingly, the genotypes originated in one region were distributed into different clusters suggesting the absence of correlation between genetic and geographic diversity.

Similarly, Kumari *et al.* (2016) conducted diversity analysis with 24 rice genotypes under aerobic situation for 13 quantitative characters. Varietal composition of five clusters revealed that genotypes did not follow their geographical distribution as varieties from diverse sources were grouped into same cluster. None of the clusters contained genotypes with all desirable traits. The study suggested that hybridization between genotypes of different clusters is necessary for development of desirable genotypes. In another recent study taken up by Dindin *et al.* (2019) a set of twenty seven tidal swamp rice cultivars from South Kalimantan, Indonesia were grown to record fourteen qualitative and fifteen quantitative traits. The germplasm had unique diversity in phenotypic traits. Correlation analysis confirmed that plant height was strongly correlated to culm diameter, number of tillers and grain ratio. The cultivars were grouped in four clusters according to PCA, where the first group was influenced by grain weight and plant height, second group by flag leaf altitude, number of productive tillers and panicle

Fig. 3. Unweighted neighbour joining tree depicting the phenotypic diversity among germplasm



length, third group by grain ratio and plant age, and the last group by culm diameter. All these research studies portray the importance of phenotypic data and how it influences the diversity and variability in cultivars.

CONCLUSION

The present study gives a comprehensive picture about the performance of rice germplasm under aerobic cultivation. Lines with desirable agronomic traits can be chosen from both the clusters and used as parents in future breeding programs to develop mapping populations and new varieties suitable for aerobic cultivation. On the other hand, the same set of material can be used to carry out genome wide association studies using the data from molecular markers that would help capture the genomic regions associated with yield attributing traits under aerobic cultivation. The regions once mapped and validated can directly be used in marker assisted gene

Table 3. Detailed cluster information of the dendrogram

Cluster	Sub-cluster	No. of entries	Names of entries
Cluster I	Cluster Ia	49	ARC6096, ARC6180, ARC6628, ARC10243, ARC10248, ARC10258, ARC11121, ARC11241, Pyari, Swarna sub-1, Mahulata, Vandana, Jaya, Pratikshya, Satari, Satyabhama, RR 2-6, MAS26, MAS946-1, Somasila, Swathi, Swarna, MTU1010, JGL 20171, JGL 18047, KNM 118, Sahbaghidhan, N22, APO, CRDhan 202, Adukku Rice, Bommi, Gunducar, Kavuni, Karuavury, Kottha Malli samba, Milagu Samba, Raja Mudi, Swarna Mashuri, Valan, Vandanj Samba, MTU1156,RNR15048, Bhavani, White ponny, Karuvachi 140, Mysore mally, Sinnar, Thooya mally
	Cluster Ib	14	ARC10612, PR118, NLR34449, MTU1001, JGL 11727, JGL 24423, Barani, Kandha Sala, Kala namak, Kuzhi Adichan, MTU1121, Ceeraga Samba, Elupa poo Samba, Raja mannar
Cluster II	Cluster IIa	39	ARC5922, ARC5973, ARC6101, ARC6153, ARC6571, ARC7071, ARC7412, ARC10222, ARC10405, ARC10455, ARC10625, ARC10655, ARC10689, ARC10827, ARC10838, ARC10843, ARC10847, ARC10957, ARC11064, ARC11211, ARC11222, ARC11225, ARC11515, ARC11611, ARC11691, ARC11702, ARC11750, ARC11861, ARC11892, ARC12006, Brown gora, Pathara, CR 143-2-2, Black gora, Kattu ponni, Karung Kuruvai, Kulla Khar, Ottadam, Rattha Sali
	Cluster IIb	8	ARC6143, ARC10023, ARC10223, ARC10260, ARC-Y2a-536, ARC11553, ARC11566, Arubadham kuruvai

introgression and gene pyramiding, thus enabling the lowland varieties to perform better under aerobic situations too.

Acknowledgements

The authors sincerely acknowledge NRRI (National Rice Research Institute) Cuttack for providing necessary plant material and PJTSAU for providing financial support to first author and facilities to carry out the field experiments.

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Research Article
The J. Res. PJTSAU 48 (1&2) 21-27, 2020

EFFECT OF TEMPERATURE AND CULTURE MEDIA ON MYCELIAL GROWTH AND SPORULATION OF *Botryotinia ricini* CAUSING GRAY MOLD OF CASTOR

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Date of Receipt : 29-05-2020 Date of Acceptance : 20-06-2020

ABSTRACT

Gray mold diseases of castor caused by the fungus *Botryotinia ricini* is responsible for disease epidemics and heavy yield losses in castor growing regions of Telangana state. A laboratory experiment was conducted to study the mycelial growth rate, colony character and sporulation pattern of *Botryotinia ricini* on ten different culture media *viz*., corn meal agar, pikovskayas agar, carrot agar, potato carrot agar, glucose agar, oat meal agar, potato dextrose agar, czapek'sdox agar, soybean meal agar and water agar. The mycelial colony diameter, culture characteristics (texture, pigmentation, and pattern) and sporulation of *B.ricini* were greatly influenced across the culture media tested. OMA and PDA evinced higher mycelial growth and sporulation of *B. ricini*, whereas remaining eight media revealed low sporulation. Colony colour varied from grayish-white to brown across the culture media tested. Findings revealed that oat meal agar was the most suitable culture medium for growth and sporulation of *B. ricini*. The optimum temperature for its growth and sporulation was found to be 22^{o}C under *in vitro* conditions.

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop cultivated throughout tropical and sub-tropical regions, which has several industrial and medicinal applications. Gray mold of castor caused by the fungus *Botryotinia ricini* (Godfrey) Whetzel is one of the most destructive diseases of castor which is responsible for disease epidemics and yield losses in Telangana state of India. *B. ricini* fungus causes infection during inflorescence and raceme development stage (Dange *et al.,* 2005, Soares, 2012 and Prasad *et al*., 2016). Prasad and Kumaraswamy (2017) reported that infected raceme shows characteristic grayish coloured growth of the fungus under high humid conditions. The diversity in cultural characters of *B.ricini* was studied on six different growth media. Radial growth was higher on oat meal agar medium and enhanced sporulation was observed on oat meal enriched medium by Yamuna *et al*. (2015) and Prasad and Bhuvaneswari (2014). Knowledge on nutritional requirements influencing the growth of fungi help in understanding the host-pathogen relationship (Krishna *et al*. 2018). Hence not much importance has been given on cultural studies of *B. ricini* which leads to clear understanding of influence of culture media and temperature on the development of the fungus isolated from gray mold infected castor racemes. Therefore, the present experiment was conducted to study the cultural characteristics of the pathogen infecting castor and this information helps to develop suitable management strategies against the disease.

MATERIAL AND METHODS

Isolation of *Botryotinia ricini*

In the present study, infected castor raceme samples were collected from experimental fields of Indian Institute of Oilseeds Research, Hyderabad, India and the pathogen *Botryotinia ricini* Whetzel was isolated and maintained using Oat Meal Agar (OMA) enriched medium developed by Prasad and Bhuvaneswari (2014).

Effect of culture media on growth and sporulation of *B. ricini*

A laboratory study with different culture media was carried out during 2019 in ICAR-IIOR and Department of Plant Pathology, PJTSAU. Ten different culture media, *viz*., potato dextrose agar (peeled potato 200 g + dextrose 20 g + agar-agar 20 g), corn meal agar (corn-meal 20 g + glucose 20 g + agar-agar 20 g), pikovskaya (glucose 10 g + $Ca_3(PO_4)_2$ 5 g + $(NH_4)_2SO_4$ 0.5 g + NaCl 0.2 g + $MgSO_4{\cdot}7H_2O$ 0.1 g + KCl, 0.2 g+ yeast extract 0.5 g + $MnSO_4{\cdot}H_2O$ 0.002 g

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and $FeSO_4 \cdot 7H_2O$ 0.002 g), potato carrot agar (carrot 200 g + potatoes 250 g + agar 15 g), carrot agar (carrot 200 g+ agar 17 g), oat meal agar (rolled oats 30 g + agar 15 g), glucose agar (tryptone 2 g + glucose 10 g + sodium chloride 5 g + yeast extract 1 g + potassium hydrogen phosphate 0.3 g + bromothymol blue 0.08 g and agar 20 g), soybean meal agar (soybean meal 5 g and agar 15 g), czapek's medium (sucrose 30 g + sodium nitrate 2 g + potassium dihydrogen phosphate 1.0 g + magnesium sulphate 0.5 g + potassium chloride 0.5 g + ferrous sulphate 0.01 g + agar-agar 20 g), and water agar medium (agar-agar 20 g) were prepared with their respective compositions / 1000ml sterilized distilled water using standard procedures. The entire media were autoclaved for 15 minutes at 15 lbs pressure and poured in sterile petri-plates separately and a 5 mm disc of *B. ricni* was aseptically transferred onto the different media and incubated at 23±2°C. Observations on mycelial growth, colony character and sporulation of the fungus at 48, 72, 96, 120 and 144 hours after incubation were recorded. The observations at 6^{th} day (144 hours) after inoculation (DAI) were considered for evaluation.

Effect of temperature on growth and sporulation of *B. ricini*

Experiments were conducted to find out, the effect of temperature on radial mycelial growth and sporulation of *B. ricini* on best suitable culture medium (OMA). As OMA was found to be the best suitable culture media in the above study the sterilized petriplates with OMA were inoculated with seven day old 5 mm culture disc of the *B. ricini.* The petriplates were incubated at 10, 15, 18, 20, 22, 23, 25, 28 and 30°C temperature. Four replications were maintained for each treatment and observation on *B. ricini* mycelial growth and sporulation was recorded after seven day of inoculation. Sporulation was determined under the microscope by counting 4 samples (0.1 ml each) per replication. Number of spores were counted and measured using the haemacytometer slide under an optical microscope field of vision (10x eyepiece and 40x objective).

Statistical Analysis

The experiments were carried out with four replications under controlled laboratory condition.The data recorded were analyzed by following factorial completely randomized design (CRD).

RESULTS AND DISCUSSION

Effect of culture media on growth and sporulation of *Botryotinia ricini*

A total of ten solid culture media incubated at 23±2°C were tested to assess their effect on mycleial growth, cultural characters and sporulation of *B. ricini* and results are presented in Table 1. The results revealed that extensive mycelial growth and sporulation of *B. rinci* were observed in culture media. Mean colony diameter recorded on culture media ranged from 15 mm (soybean meal agar) to 85 mm (OMA). However, it was significantly higher on OMA and PDA followed by czapek's dox agar and pikovskaya's agar. Least mycelial growth was observed on soymeal agar and water agar media. The colony growth produced on culture media was mostly regular with cottony or cushiony to carpet like mycelial mat (Plate 1). Colony colour varied from grayish-white to brown. The culture media exhibited a wide range of sporulation. However, OMA exhibited excellent sporulation and was good on PDA; fair on corn meal agar and pikovskaya's agar; whereas, it was with poor growth on carrot agar and glucose agar.

Several studies have documented the effect of culture media on the mycelial growth and sporulation of *B. ricini.* For instance, Whitney (1986) isolated *Amphobotrys ricini* causing the stem canker disease on Texas weed [*Caperonia palustis*(L) St. Hill] on PDA medium by placing surface sterilized sclerotia obtained from the stem tissue of dead plants. Bheemaraju (1999) isolated castor gray rot pathogen on PDA medium from infected capsules. Whereas, Aswani Kumar (2001) used V8 juice agar medium for isolation of *B. ricini* from naturally infected castor capsules. Prasad and Bhuvaneswari (2014) isolated gray rot pathogen on OMA medium enriched with gallic acid, L-aspargine and castor pericarp extract. The medium has been developed for improved sporulation of castor gray mold pathogen *Botryotinia ricini.* The enriched OMA medium supported higher sporulation compared to the normal OMA medium which was commonly used for *B. ricini.*

Effect of temperature on growth and sporulation of *B. ricini*

Mycelial growth and sporulation of *B. ricini* was studied from 10 to 30°C temperature on OMA culture medium and the results are presented in Table 2. It was observed that there was a large difference in

Table 1. Growth, sporulation and colony characters of *B. ricini* on different culture media

S.No	Culture medium	Radial colony growth (mm)*					Mycelial texture	Pigmentation	Colony Pattern	Degree of Sporulation
		48 h	72 h	96 h	120 h	144 h				
1.	Corn meal agar	25.0 (29.9) **	35.0 (35.6) **	44.0 (41.5) **	50.0 (44.5) **	54.0(47.4) **	Appressed	Grey	Regular	++
2.	Pikovskaya's Agar	23.0 (27.9) **	37.0 (36.4) **	52.0 (46.1) **	60.0 (50.7) **	71.0(56.5) **	Fluffy	White	Irregular	+
3.	Carrot Agar	24.0 (28.8) **	33.0 (34.8) **	36.0 (35.4) **	40.0 (39.0) **	46.0(42.8) **	Appressed	Brown	Regular	-
4.	Potato carrot agar	12.0 (12.9) **	12.0 (18.1) **	12.0 (20.2) **	12.0 (20.2) **	12.0(20.2) **	Fluffy	Grey	Regular	+
5.	Glucose agar	10.0 (18.7) **	15.0 (23.5) **	17.0 (25.3) **	20.0 (27.2) **	23.0(28.8) **	Fluffy	White	Regular	-
6.	Oat meal agar	35.0 (36.4) **	61.0 (51.1) **	76.0 (58.6) **	82.0 (65.8) **	85.0(67.1) **	Fluffy	Grey	Regular	++++
7.	Potato dextrose agar	35.0 (36.2) **	56.0 (49.3) **	70.0 (54.7) **	80.0 (61.3) **	85.0(65.6) **	Fluffy	Grey	Regular	+++
8.	Czapek Dox agar	22.0 (26.5) **	51.0 (43.4) **	58.0 (46.5) **	61.0 (50.7) **	73.0(57.7) **	Fluffy	White	Irregular	-
9.	Soybean meal agar	5.0(12.9) **	7.0(15.6) **	10.0 (19.3) **	12.0 (20.5) **	15.0(21.0) **	Appressed	Grey	Irregular	+
10.	Water agar	5.0(12.9) **	10.0 (13.3) **	13.0 (17.4) **	15.0 (19.9) **	18.0(25.0) **	Appressed	Grey	Irregular	+
	Factors	**SE(d)**			**C.D.**					
	Media (A)	0.41			0.83					
	Time interval (B)	0.28			0.56					
	Interaction (A X B)	0.93			1.86					

mycelial growth of *B. ricini* at different temperatures after six days of inoculation. The maximum mycelial growth was recorded at 22°C followed by 23°C temperature, while low mycelial growth was recorded at 10 and 30°C (Figure 2). Temperatures from 20 to 23°C were most favorable for the mycelial growth and sporulation of *B. ricini* pathogen. The highest mycelial growth of *B. ricini* pathogen was recorded at 22°C with higher sporulation (3.61 $x10^6$ spores ml^{-1}) count.

Dik and Wubben (2004) reported that *Bortytis* species can thrive under a range of temperatures from 15 to 25°C to develop both infection and colonization processes. Godfrey (1923) mentioned that temperatures around 25°C and high relative humidity are highly congenial for gray mold development. Such results have been comprehensively repeated in research publications over the last decades by Goncalves (1936), Lima and Soares (1990), Batista *et al.* (1998) and Araujo *et al.* (2003). According to Godfrey (1923) the minimum and maximum temperatures required for mycelial growth of *B. ricini* was 12°C and 35°C respectively. Some complementary studies have confirmed that temperatures around 25°C are favourable to *Botrytis* growth and disease development (Araujo *et al.* 2003, Suassuna *et al.* 2003 and Sussel, 2008). The gray mold pathogen has exhibited less growth at below 20°C temperatures and highly dependent on relative humidity for longer periods (Sussel, 2008).

Though *B. ricini* was found capable to grow on almost all the media tested with different growth patterns at 23±2°C under *in vitro* conditions, OMA was proved to be the best suitable medium for the growth of *B. ricini* under *in vitro* conditions. It was also evident from the study that the effect of temperature strongly influenced mycelial growth and sporulation of *B. ricini* and thereby the development of gray mold in castor. However, temperature at 22°C was found to be the optimum for mycelial growth and sporulation of *B. ricini* under *in vitro* conditions.

Table 2. Effect of different temperatures on mycelial growth and sporulation of *B. ricini* on Oat meal agar medium

Temperature (°C)	**Mean mycelial growth (mm)***	**Sporulation ($x 10^6$ spores ml^{-1})**
10	33.2 (35.1) **	-
15	72.7 (58.5) **	0.4×10^6
18	70.0 (56.8) **	1.6×10^6
20	70.7 (57.2) **	$2.14 x10^6$
22	84.7 (67.0) **	$3.61 x10^6$
23	74.2 (59.4) **	$2.42 x10^6$
25	49.5 (44.6) **	$2.35 x10^6$
28	58.2 (49.7) **	$0.64 x10^6$
30	36.2 (37.0) **	$0.17 x10^6$
C.D.	1.75	
SE(d)	0.86	
C.V.	2.63	

*Mean of four replications, ** Data in parentheses are arcsine transformed values

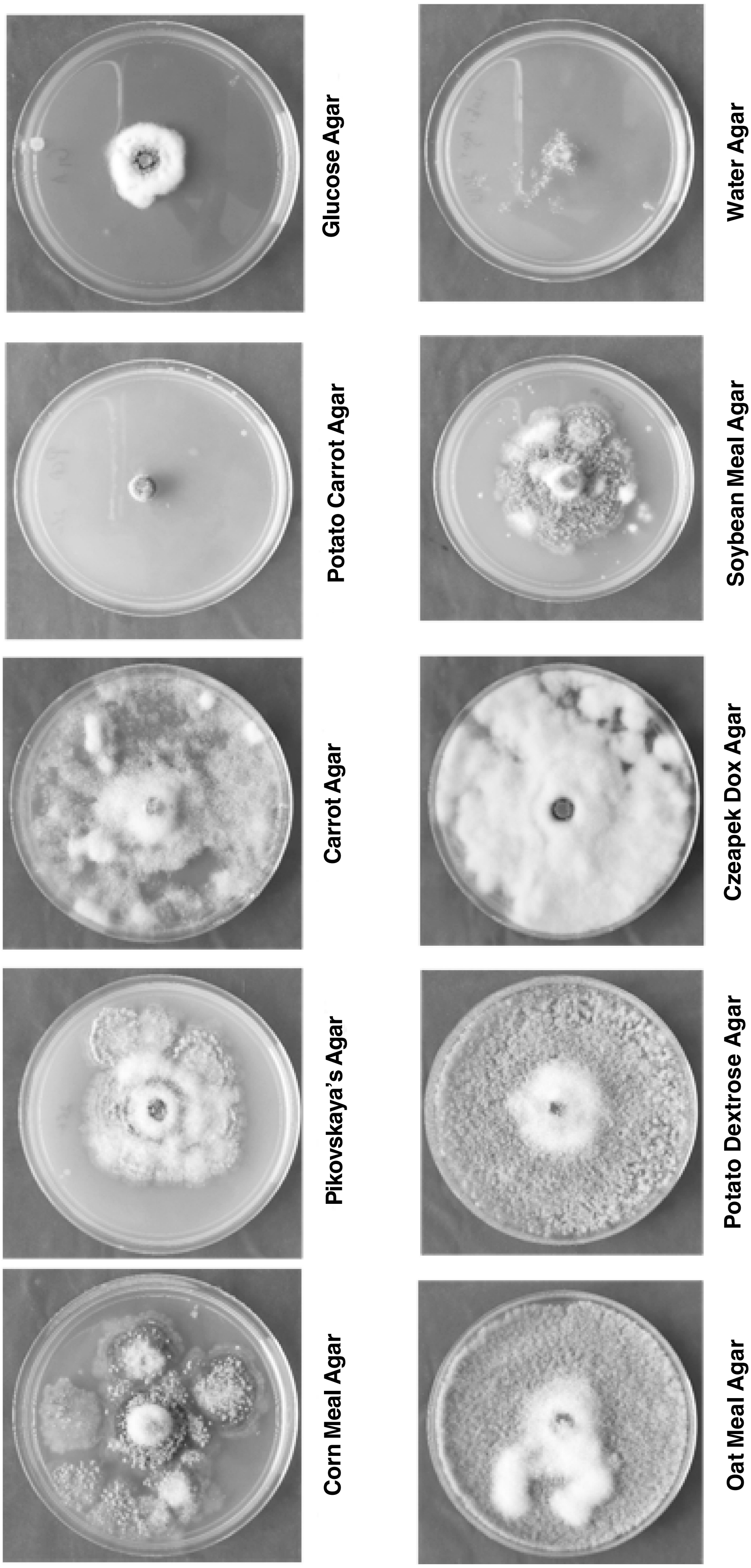
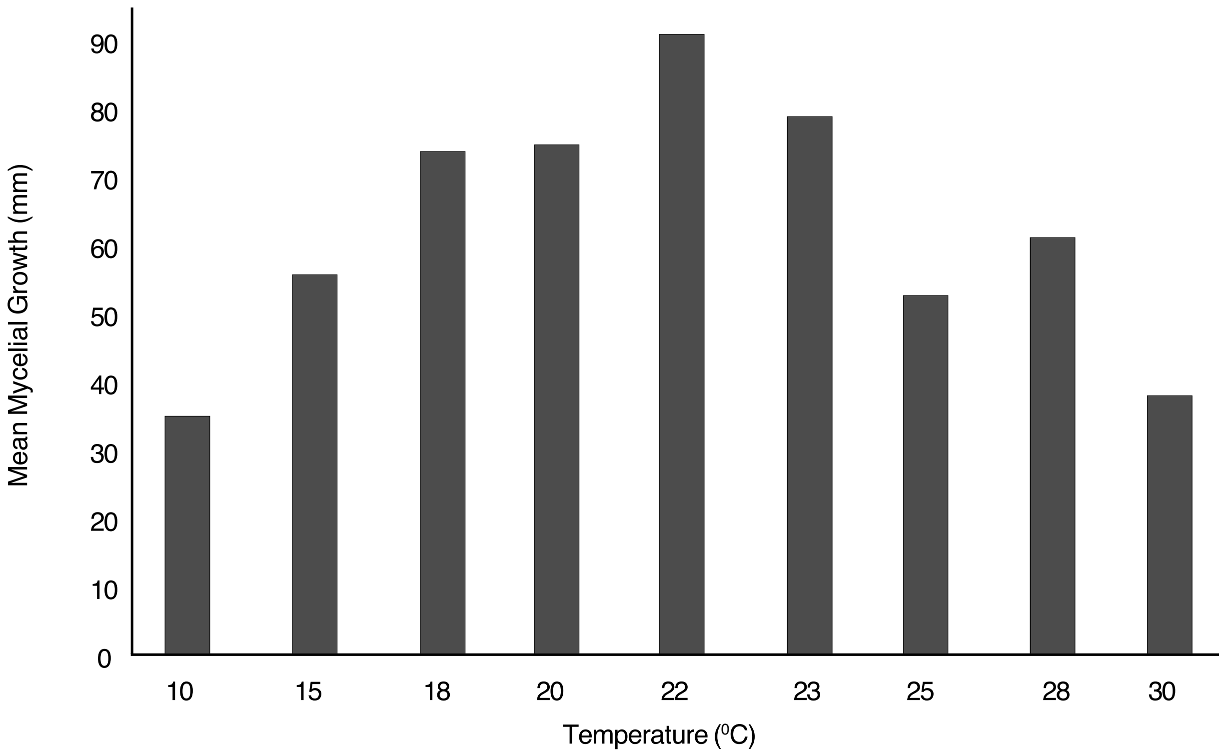


Plate 1. Effect of culture media on mycelial growth and sporulation of *B. ricini*

Figure 1. Effect of different temperatures on mycelial growth of *B. ricini* on Oat meal agar medium



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Research Article
The J. Res. PJTSAU 48 (1&2) 28-38, 2020

HETEROSIS FOR GRAIN YIELD, RANCIDITY AND ASSOCIATED CHARACTERS IN PEARL MILLET (*Pennisetum glaucum* L.)

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Date of Receipt : 28-02-2020 Date of Acceptance : 19-03-2020

ABSTRACT

Heterosis for grain yield, rancidity and associated characters was studied in pearl millet in line × tester design. Thirty two crosses were generated using eight CMS lines and four testers and evaluated along with parental lines and two checks to estimate heterosis for ten characters in pearl millet. Non-additive gene action was predominant for all the characters under study except effective tillers per plant. None of the hybrids showed significant heterosis over the check 86 M 86 for grain yield, while hybrids 92777A × R22, 97111A × R39 and 04999A × 08222R showed significantly positive heterosis of 254.81, 230.28 and 214.98 respectively over the check HHB 67. The hybrids 03666A × 08222R, 05444A × 08222R and 98222A × 08222R exhibited significantly lower negative standard heterosis over the check 86 M 86 for alcoholic acididty at 5th day of storage indicating higher longevity in these lines.

Pearl millet is a nutritionally rich cereal extensively cultivated in arid and semi arid regions in the world. Pearl millet accounts for half of the global millet production and developing countries of Asia and Africa contribute 93 % of total millet production in the world. It is a staple food grain crop in India and Africa due to its wide adaptability and high nutritive value. Pearl millet is the sixth most important cereal crop in the world and fourth in India after Rice, Wheat and Maize. In India pearl millet is extensively cultivated in Gujarat, Rajasthan, Maharashtra and Uttar Pradesh and also in the states of Karnataka, Andhra Pradesh, Telangana and Tamilnadu. It is cultivated in an area of 7.5 m ha with a production of 9.8 million tones and productivity of 1311 kg per ha. The major problem associated with pearl millet for low acceptance by the food industry and consumers inspite of high nutrient value is the development of off flavor with a mousy acidic odour within few hours of grinding.

Pearl millet is highly heterozygous because of its cross pollination nature. Hence conventional breeding procedures like hybridization followed by selection was adopted in pearl millet for development of composites, synthetics and hybrids. Heterosis is an outstanding genetic tool in pearl millet to enhance its yield. The availability of cytoplasmic genetic male sterile lines in the crop has made it feasible to exploit heterosis commercially. Rawat and Tyagi (1989) and Ugale *et al.* (1989) also found high levels of heterosis for grain yield in pearl millet. Hence this investigation was carried out to study the extent of heterosis for grain yield, rancidity and associated characters.

MATERIAL AND METHODS

In the present investigation eight CMS lines (97111A, 08666A, 03666A, 05444A, 04999A, 98222A, 92777A, 94444A) were crossed with four restorer lines (08222R, R22, R39 and 07444R) in L × T mating design during summer 2018 at Indian Institute of Millets Research, Rajendranagar, Hyderabad. The 32 crosses obtained were evaluated along with 12 parental lines and two checks (HHB 67 and 86 M 86) during *kharif* 2018 at Agricultural Research Station, Madhira in a randomized block design with three replications. Each entry was sown in two rows of 4 m length at spacing of 45 cm between the rows and 15 cm between the plants. The recommended dose of N, P and K were applied @ 80:40:30 kg ha^{-1}. The entire P and K and half the dose of Nitrogen were applied as basal, while remaining Nitrogen was applied at 30 days after sowing. Intercultural operations and irrigation schedules were followed as and when necessary. Need based plant protection measures were adopted to raise a healthy crop.

The observations for plant height, effective tillers per plant, ear length, ear width and grain yield per plant were recorded on five randomly selected competitive plants of each genotype in each replication and the

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Table 1. Analysis of variance for grain yield, rancidity and its component characters in Pearl millet

Source	df	Days to 50% flowering	Plant height (cm)	Effective tillers per plant	Ear length (cm)	Ear width (cm)	1000 seed weight (g)	Grain yield per plant (g)	Seed diameter (mm)	Fat content (%)	Alcho-holic Acidity
Replication	2	3.93	4912.79	25.95 **	100.17 **	2.08 **	17.97**	161.86**	0.021	0.02	0.04
Genotypes	43	62.35**	7913.53**	2.29	15.99 *	0.45 *	7.17**	66.39**	0.09 **	1.37 **	0.08 **
Parents	11	24.54**	17850.83**	1.17	20.05 *	0.15	8.49**	61.98**	0.05 **	0.75 **	0.02 **
Parents vs Crosses	1	1753.62**	1658.96	2.41	49.22 *	0.12	2.74*	1402.32**	0.10 *	5.77 **	2.76 **
Crosses	31	21.22**	426.84	2.68	13.48	0.56 **	6.84**	24.85	0.10 **	1.45 **	0.01 **
Lines	7	28.57**	2465.67	4.11 *	21.14 *	0.46	3.60**	25.39	0.02	1.79 **	0.002
Testers	3	10.45*	2456.09	9.88 **	10.59	1.74 **	13.70**	19.03	0.22 **	0.99 **	0.06 **
Line x tester	21	20.304**	5601.71	1.18	11.33	0.43	6.95**	25.51	0.11 **	1.4 **	0.006
Error	86	3.23	4784.69	1.70	8.91	0.27	0.55	21.20	0.01	0.028	0.005
$\sigma^2 gca$		0.04	2.84	0.32	0.25	0.04	0.09	-0.18	0.0005	-0.0006	0.0001
$\sigma^2 sca$		6.06	56	-0.23	0.65	0.04	2.15	0.02	0.03	0.455	0.0002
$\sigma^2 gca / \sigma^2 sca$		0.01	0.05	-1.39	0.38	1.00	0.04	-9.00	0.02	-0.001	0.50

mean of five plants was taken for statistical analysis, while days to 50% flowering was recorded on plot basis. For 1000 seed weight a random sample of 200 seeds of each entry was recorded for weight and multiplied by a factor of 5 to find 1000-seed weight in grams, while for seed diameter five seeds at random were selected and diameter was measured with the help of screw guage and expressed in millimeters and the mean of five seeds is used for statistical analysis. The fat content in the flour was determined by AOAC method (1999) with slight modifications for which the fat from flour was extracted in hexane by using SOCS PLUS system (Pelican Equipments). Alcoholic acidity method was used to measure rancidity of pearl millet flour as per IS 12711:1989 Method of Determination of Alcoholic Acidity. For this 5 g of pearl millet flour was soaked in 50 ml of neutral ethyl alcohol (90%) and allowed to stand for 24 hours with occasional swirling. Ten ml of filtered alcohol extract was titrated with 0.05 N standard sodium hydroxide solution using phenolphthalein indicator.

RESULTS AND DISCUSSION

The analysis of variance (Table 1) showed a significant variation among genotypes for all the characters which indicates sufficient amount of variability in the material under study. The parents showed significant variation for all the characters except effective tillers per plant and ear width, while crosses showed significant variation for all the characters except plant height, effective tillers per plant, ear length and grain yield per plant. The estimates for parents vs crosses was significant for all the characters except plant height, effective tillers per plant and ear width indicating that selection of diverse parental lines results in high mean heterosis. The magnitude of variance due to *sca* (σ^2 *sca*) was higher than variance due to *gca* (σ^2*gca)* for all the characters except effective tillers per plant indicating predominance of non-additive gene action. The ratio of *gca* to *sca* variance is less than unity for most of the characters which may be due to diversity in genetic material under study. High *sca* variances and ratio of *gca* to *sca* variance less than unity for days to 50 % flowering, plant height, days to maturity, grain yield per plant, 1000 seed weight was earlier reported by Vagadiya *et al* (2010a), Lakshmana *et al.(*2010) and Reshma Krishnan *et al* (2019).

A significant negative standard heterosis over 86 M 86 was reported in 29 hybrids for days to 50 % flowering. The better parent (BP) heterosis for days to 50% flowering ranged from -28.66 (cross 16, 05444A × 07444R) to -9.36 (cross 8, 08666A × 07444R). None of the hybrids had significant negative standard heterosis over HHB 67, while lowest standard heterosis over 86 M 86 was reported in cross 16 (05444A × 07444R, -23.27). Earliness in days to 50% flowering is a desirable character as it helps in escaping terminal drought if any and will also be ideal to fit into any cropping system. Significant negative heterosis for days to 50% flowering in pearl millet was also reported by Athoni *et al*., (2016) and Karad & Harer (2004). The better parent (BP) heterosis for plant height was found to be significant and positive in 17 hybrids and ranged from -62.13 in cross 15 (05444A × R39) to 36.45 in cross 3 (97111A × R39). Standard heterosis over HHB 67 for plant height ranged from -14.06 in cross 7 (08666A × R39) to 21.36 in cross 24 (98222A × 07444R), while none of the hybrids showed significant positive standard heterosis for plant height over 86 M 86. Six hybrids showed significant positive standard heterosis over HHB 67. High magnitude of heterosis for plant height was also reported by Nanadaniya *et al*. (2016), Patel *et al*. (2016) and Vetrivethan *et al* (2008). A significant positive better parent heterosis was reported in one hybrid for effective tillers per plant in cross 28 (92777A × 07444R) showing maximum positive heterosis (47.42). A significant positive standard heterosis over the checks HHB 67 and 86 M 86 was reported in 2 and 8 hybrids respectively. The standard heterosis for effective tillers per plant over HHB 67 was maximum in the cross 12 (03666A × 07444R, 90.48), while 169.43 over the check 86 M 86 was also observed in the same cross. Rafiq *et al*. (2016) also reported high heterosis for productive tillers per plant. The medium magnitude of heterobeltiosis and standard heterosis for number of effective tillers per plant were also reported by Ramamoorthi and Govindarasu (2006), Aruselvi *et al*., (2006), Jethva *et al*., (2012) and Patel (2014).

The better parent heterosis for ear length among the hybrids tested ranged from -26.10 in cross 6 (08666A × R22) to 30.38 in cross 24 (98222A × 07444R). The standard heterosis over HHB 67 ranged from -11.60 in cross 6 (08666A × R22) to 38.31 in cross 24 (98222A × 07444R), while over the check

Table 2. Better parent and Standard Heterosis for grain yield, rancidity and component characters in Pearl millet

S.No	Crosses	Days to 50 % Flowering			Plant Height (cm)			Effective tillers per plant			Ear length (cm)		
		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis	
			HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86
1.	97111A × 08222R	-23.16 **	13.33 **	-14.47**	28.86**	19.71*	8.08	-31.37	-14.53	20.90	4.94	25.23 **	13.16
2.	97111A × R22	-15.21 **	20.83 **	-8.81 *	5.00	8.40	-2.14	17.65	46.52 **	107.25 **	-1.00	18.42 *	7.01
3.	97111A × R39	-21.26 **	14.17 **	-13.84**	36.45**	19.94*	8.28	-43.14**	-29.18	0.17	5.78	27.99 **	15.66 *
4.	97111A × 07444R	-15.79 **	20.00 **	-9.43**	15.59*	6.57	-3.79	-13.73	7.45	51.99 **	-8.51	-2.95 -	12.30
5.	08666A × 08222R	-16.95 **	22.50 **	-7.55*	21.49**	12.87	1.90	11.77	39.19	96.89 **	-3.86	14.73 *	3.68
6.	08666A × R22	-20.47 **	13.33 **	-14.47**	-13.13**	-10.32	-19.04 *	-44.00**	-48.72 **	-27.46	-26.10 *	-11.60	-20.12 **
7.	08666A × R39	-11.49 **	28.33 **	-3.14	-3.51	-14.06	-22.41 **	-55.56*	-60.93 **	-44.73	-6.55	13.08	2.18
8.	08666A × 07444R	-9.36 **	29.17 **	-2.52	26.54**	16.66*	5.32	-12.77	0.12	41.62	8.53	26.52 *	14.33 *
9.	03666A × 08222R	-23.16 **	13.33 **	-14.47**	19.18*	10.72	-0.04	-45.00**	-19.41	13.99	-9.88	7.55	-2.81
10.	03666A × R22	-20.47 **	13.33 **	-14.47**	6.68	10.13	-0.58	-46.67**	-21.86	10.54	-15.17 *	1.47	-8.30
11.	03666A × R39	-10.92 **	29.17 **	-2.47	36.14**	19.67*	11.94	-53.33**	-31.62	-1.96	3.50	25.23 **	12.62
12.	03666A × 07444R	-25.73 **	5.83	-20.13**	15.15*	6.16	-4.16	30.00	90.48 **	169.43 **	10.42	17.13	5.84
13.	05444A × 08222R	-25.42 **	10.00 **	-16.98**	-59.68**	7.57	-2.88	-14.71	6.23	50.26 **	-0.93	18.23 **	6.84
14.	05444A × R22	-14.62 **	21.67 **	-8.18**	-59.86**	7.09	-3.32	17.33	7.45	51.99 **	-9.93	7.73	-2.65
15.	05444A × R39	-20.12 **	15.83 **	-12.58**	-62.13**	1.05	-8.78	29.17	13.55	60.62 **	-7.61	11.79	1.02
16.	05444A × 07444R	-28.66 **	1.67	-23.27**	-60.57**	5.20	-5.03	-27.66	-16.97	17.44	5.69	23.20 **	11.33
17.	04999A × 08222R	-18.64 **	20.00 **	-9.43**	9.70*	13.78	2.72	-11.77	9.89	55.44 **	3.62	26.52 **	14.33
18.	04999A × R22	-16.96 **	18.33 **	-10.69**	8.87	12.91	1.94	-21.51	-10.87	26.08	11.31	35.91 **	22.82 **
19.	04999A × R39	-18.39 **	18.33 **	-10.69**	-2.00	1.64	-8.24	-9.68	2.56	45.08	-0.15	21.92 **	10.17
20.	04999A × 07444R	-18.13 **	16.67 **	-11.95**	14.32**	18.57*	7.05	12.77	29.43	83.07	6.94	30.57 **	17.99
21.	98222A × 08222R	-24.86 **	10.83 **	-16.35**	11.91*	3.97	-6.14	-33.33	-16.97	17.44	-0.31	18.97 **	7.51
22.	98222A × R22	-15.21 **	20.83 **	-8.81 **	8.44	11.96	1.07	5.13	0.12	41.62	14.09 *	36.46 **	23.32

S.No	Crosses	Days to 50 % Flowering			Plant Height (cm)			Effective tillers per plant			Ear length (cm)		
		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis	
			HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86
23.	98222A × R39	-16.09 **	21.67 **	-8.18 **	8.38	0.09	-9.64	-20.51	-24.30	7.08	-4.41	15.65 *	4.51
24.	98222A × 07444R	-19.88 **	14.17 **	-13.84 **	31.41 **	21.36 **	9.56	-12.77	0.12	41.62	30.38 **	38.31 **	24.98 **
25.	92777A × 08222R	-18.08 **	20.83 **	-8.81 **	15.30 *	7.12	-3.30	-68.63 **	-60.93	-44.73	2.32	22.10	10.33
26.	92777A × R22	-21.64 **	11.67 **	-15.72 **	-5.73	-2.67	-12.13	19.59	41.64	100.35	-18.40 **	-2.39	-11.80
27.	92777A × R39	-21.26 **	14.17 **	-13.84 **	24.56 **	9.49	-1.15	5.16	28.21	81.35	-6.39	13.26	2.35
28.	92777A × 07444R	-14.62 **	21.67 **	-8.18 **	14.68	5.73	-4.55	47.42 **	74.60	146.98	-0.72	14.64	3.59
29.	94444A × 08222R	-19.77 **	18.33 **	-10.69 **	15.50 *	7.30	-3.13	-52.63 **	-34.07	-6.74	-1.70	17.31	6.01
30.	94444A × R 22	-23.98 **	8.33 **	-18.24 **	-1.50	1.69	-8.20	-28.07	0.12	41.62	-12.09	5.16	-4.98
31.	94444A × R39	-25.86 **	7.50 **	-18.87 **	24.92 **	9.81	-0.87	-15.79	17.22	65.80	-8.37	10.87	0.18
32.	94444A × 07444R	-23.98 **	8.33 **	-18.24 **	14.21 *	5.29	-4.94	-52.63 **	-34.07	-6.74	1.39	7.55	-2.81
	Range	-28.66 - -9.36	1.67 - 29.17	-23.27 - -2.47	-62.13 - 36.45	-14.06 - 21.36	-22.41- 11.94	-68.63 - 47.42	-60.93- 90.48	-44.73 - 169.43	-26.10 - 30.38	-11.60- 38.31	-20.12 - 24.98

Table 2. contd..

S.No	Crosses	Ear width (cm)			1000 seed weight (g)			Grain yield per plant (g)		
		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis	
			HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86
1.	97111A × 08222R	-6.76	15.58	-11.54	-24.04 **	-21.65 **	-9.85 *	22.03	195.11 **	-14.02
2.	97111A × R22	-15.41	4.86	-19.74	3.04	8.70	22.29 **	0.03	140.88 **	-29.52 **
3.	97111A × R39	34.32 **	66.50 **	27.44 *	-31.94 **	-11.42	10.65 **	36.30 *	230.28 **	-3.97
4.	97111A × 07444R	-29.73 **	-12.90	-33.33 **	15.64 **	17.67 *	37.23 **	-13.86	106.63 **	-39.31 **
5.	08666A × 08222R	11.94	25.63 *	-3.85	-23.51 **	-27.09 **	-8.27	19.28	106.82 **	-39.26 **
6.	08666A × R22	-23.94 *	-9.55	-30.77 *	2.24	3.67	22.62 **	20.23	169.93 **	-21.22
7.	08666A × R39	-6.94	12.23	-14.10	-20.79 **	-1.39	28.77 **	101.72 **	178.02 **	-18.91
8.	08666A × 07444R	-16.42	-6.20	-28.21 **	-12.53 **	-10.30	4.91	-15.55	89.80 **	-44.12 **

S.No	Crosses	Ear width (cm)			1000 seed weight (g)			Grain yield per plant (g)		
		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis	
			HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86
9.	03666A × 08222R	1.52	12.23	-14.10	11.19 **	9.59	28.21 **	64.25 **	186.93 **	-16.36
10.	03666A × R22	-7.04	10.55	-15.38	8.48 *	2.30	25.09 **	-7.13	107.22 **	-39.15 **
11.	03666A × R39	-6.94	12.23	-16.18	-5.12	24.68 **	54.25 **	34.59	76.41 **	-47.95 **
12.	03666A × 07444R	22.73	35.68 **	3.85	-12.10 **	-17.42 *	1.35	-40.69 *	40.73 **	-60.76 **
13.	05444A × 08222R	29.23 *	40.70 **	7.69	-1.66	-31.05 **	-8.21	14.94	99.08 **	-41.47 **
14.	05444A × R22	-18.31	-2.85	-25.64 *	15.82 **	-3.38	12.15 **	18.26	165.43 **	-22.51
15.	05444A × R39	12.50	35.68 **	3.85	-34.17 **	- 18.14 *	7.02	95.82 **	159.26 **	-24.27 **
16.	05444A × 07444R	18.49	30.99 *	0.26	0.78	-9.03	11.25 **	12.84	155.51 **	-25.34 **
17.	04999A × 08222R	-22.22	-6.20	-28.21 **	-0.95	-28.17 **	-9.55 **	79.99 **	214.98 **	-8.35
18.	04999A × R22	14.44	38.02 **	5.64	0.79	-25.29 **	-2.40	15.79	159.76 **	-24.13 **
19.	04999A × R39	17.50	41.71 **	8.46	-50.19 **	-40.07 **	- 19.01 **	71.34 *	126.13 **	-33.74 **
20.	04999A × 07444R	-23.61 *	-7.87	-29.49 **	43.16 **	31.58 **	58.03 **	32.91	201.96 **	-12.06
21.	98222A × 08222R	-6.73	37.02 **	4.87	34.53 **	-1.23	23.16 **	33.95	132.95 **	-31.79 **
22.	98222A × R22	-28.16 *	5.53	-19.23	-3.49	-23.90 **	-6.54	13.35	154.16 **	-25.73 **
23.	98222A × R39	7.64	58.12 **	21.03	-27.96 **	-11.80	17.12 **	104.84 **	171.47 **	-20.78
24.	98222A × 07444R	0.34	47.40 **	12.82	14.51 **	1.88	26.41 **	-19.43	80.81 *	-46.69 **
25.	92777A × 08222R	-2.35	11.22	-14.87	-0.38	-13.97 *	5.75	19.32	106.88 **	-39.24 **
26.	92777A × R22	1.69	20.94	-7.44	5.56	-10.22	12.05 **	57.25 **	254.81 **	3.04
27.	92777A × R39	23.61 *	49.08 **	14.10	-36.54 **	-17.96 **	3.17	81.63 **	140.06 **	-29.76 **
28.	92777A × 07444R	12.21	27.81 *	-2.18	17.18 **	3.94	29.35 **	25.62	185.09 **	-16.89
29.	94444A × 08222R	6.15	15.58	-11.54	-17.89 **	-25.33 **	-4.24	18.36	105.19 **	-39.73 **
30.	94444A × R 22	-9.86	7.20	-17.95	-33.09 **	-33.40 **	-21.97 **	-0.88	121.55 **	-35.05 **
31.	94444A × R39	16.11	40.03 **	7.18	-20.98 **	9.48	28.46 **	120.68 **	192.89 **	-14.66
32.	94444A × 07444R	-22.73	-14.57	-34.62 **	7.21	3.92	25.04 **	18.50	168.60 **	-21.60
	Range	-29.73 - 34.32	-14.57 - 66.50	-34.62- 27.44	-50.19 - 43.16	-40.07 - 31.58	-19.01 - 58.03	-40.69 - 120.68	40.73 - 254.81	-60.76 - 3.04

Table 2. contd..

S.No	Crosses	Seed diameter (mm)			Fat content (%)			Alcoholic acidity on 5th day		
		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis	
			HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86
1.	97111A × 08222R	-16.10 **	-10.48 **	2.87	-0.64	2.49	3.28	-51.41 **	-23.14 **	-29.97 **
2.	97111A × R22	6.83 *	4.29	19.85 *	-5.65 **	-2.67	-1.92	-47.02 **	-16.19	-23.64 **
3.	97111A × R39	-17.26 **	-15.32 **	-2.69	-7.10 **	0.46	1.24	-46.78 **	-9.11	-17.19 *
4.	97111A × 07444R	0.13	-2.24	12.34 *	-17.02 **	-14.41 **	-13.74 **	-45.36 **	4.33	-4.94
5.	08666A × 08222R	-12.11 **	-6.22	7.77	19.56 **	8.93 *	9.78 *	-56.37 **	-33.14 **	-39.08 **
6.	08666A × R22	-18.14 **	-19.71 **	-7.73	47.36 **	39.32 **	40.40 **	-51.33 **	-25.46 **	-32.09 **
7.	08666A × R39	0.03	2.37	17.64 *	-14.27 **	-7.29	-6.57 *	-47.60 **	-10.51	-18.47 *
8.	08666A × 07444R	-9.28 **	-11.03 *	2.25	-2.05	-10.75 **	-10.06 **	-38.96 **	16.55	6.19
9.	03666A × 08222R	-2.55	3.97	19.48 **	-13.39 **	-15.47 **	-14.81 **	-67.88 **	-41.13 **	-46.36 **
10.	03666A × R22	3.61	2.02	17.24 **	-16.40 **	-18.41 **	-17.77 **	-50.74 **	-9.74	-17.76 *
11.	03666A × R39	-10.02 **	-7.92	4.98	-7.18 **	0.37	1.25	-51.77 **	-11.62	-12.74
12.	03666A × 07444R	-9.44 *	-10.83 *	2.47	-5.08 **	-7.36 *	-6.64 *	-52.67 **	-9.62	-17.65
13.	05444A × 08222R	-18.80 **	-13.37 **	-0.44	-10.92 **	-11.09 **	-10.40 **	-65.82 **	-36.79 **	-42.41 **
14.	05444A × R22	3.09	-6.92	6.96	16.27 **	16.05 **	16.95 **	-55.46 **	-17.63 *	-24.96 **
15.	05444A × R39	0.09	2.44	17.72 **	-13.26 **	-6.20 *	-5.47	-51.69 **	-10.66	-18.60 *
16.	05444A × 07444R	8.24 *	-2.28	12.30 *	24.28 **	24.05 **	25.01 **	-46.15 **	2.83	-6.31
17.	04999A × 08222R	-32.38 **	-27.85 **	-17.09 **	32.61 **	16.65 **	17.55 **	-46.12 **	-17.43 **	-24.77 **
18.	04999A × R22	-3.85	-14.33 **	-1.55	7.10 **	1.26	2.05	-36.76 **	-3.14	-11.75 *
19.	04999A × R39	6.58 *	9.07	25.34 **	-9.05 **	-1.65	-0.89	-48.16 **	-11.47	-19.34 **
20.	04999A × 07444R	9.66 **	-2.82	11.68 *	5.74 **	-6.98 *	-6.26 *	-56.21 **	-16.39 **	-23.82 **
21.	98222A × 08222R	-21.78 **	-16.54	-4.09	36.32 **	21.29 **	22.23 **	-64.07 **	-34.53 **	-40.35 **
22.	98222A × R22	-4.69	-2.24	12.34 *	13.06 **	6.89 *	7.72 *	-43.61 **	2.76	-6.38

S.No	Crosses	Seed diameter (mm)			Fat content (%)			Alcoholic acidity on 5th day		
		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis		BP Heterosis	Standard Heterosis	
			HHB 67	86 M 86		HHB 67	86 M 86		HHB 67	86 M 86
23.	98222A × R39	0.00	2.56	17.86**	-2.56	5.37 *	6.19 *	-48.93 **	- 6.94	-15.21 *
24.	98222A × 07444R	-8.03 *	-5.67	8.40	12.20 **	-0.17	0.61	-46.22 **	2.70	-6.43
25.	92777A × 08222R	-21.21 **	-15.93 **	-3.39	2.77	-5.60 *	-4.87	-61.74 **	-35.82 **	-41.52 **
26.	92777A × R22	-4.98	-3.30	11.12 *	27.20 **	20.25 **	21.19 **	-42.78 **	-4.02	-12.56 *
27.	92777A × R39	-14.75 **	-12.76 *	0.26	8.07 **	16.86 **	17.77 **	-40.41 **	1.77	-7.28
28.	92777A × 07444R	5.01	6.86	22.80 **	34.19 **	23.26 **	24.22 **	-47.81 **	-0.35	-9.21
29.	94444A × 08222R	-22.35 **	-17.15 **	-4.79	-8.03 **	0.22	1.00	-48.03 **	-4.69	-13.16 **
30.	94444A × R 22	-7.87 *	-12.21 *	0.88	1.65	10.77 **	11.63 **	-58.48 **	-23.86 **	-30.63 **
31.	94444A × R39	-10.87 **	-8.78	4.83	-3.32 *	5.36 **	6.18 *	-53.05 **	-13.89 **	-21.54 **
32.	94444A × 07444R	9.62 **	4.46	20.04 **	-10.92 **	-2.93	-2.17	-43.40 **	8.07	-1.54
	Range	-32.38 - 9.66	-27.85- 9.07	-17.09- 25.34	-17.02- 47.36	-18.41- 39.32	-17.77- 40.4	-67.88 - 36.76	-41.13- 16.55	-46.36 - 6.19

86 M 86 was -20.12 in cross 6 (08666A × R22) to 24.98 in cross 24 (98222A × 07444R). A significant positive BP heterosis for ear length was found in two hybrids, while 16 hybrids had standard heterosis over HHB 67 and 4 hybrids over 86 M 86. The medium magnitude of heterobeltiosis and standard heterosis were noticed for ear head length by Zeal *et al* (2017), Ramamoorthi and Govindarasu (2006), Aruselvi *et al*., (2006), Jethva *et al*., (2012), and Patel (2014). A significant positive better parent heterosis for ear width was reported in three hybrids with the hybrid 3 (97111A × R39, 34.32) recording maximum heterosis, while cross 4 (97111A × 07444R, -29.73) recording minimum BP heterosis. The standard heterosis for ear width over HHB 67 ranged from -14.57 to 66.50, while in 86 M 86 it ranged from -34.62 to 27.44 with minimum heterosis in cross 32 (94444A × 07444R) and maximum heterosis in cross 3 (97111A × R39) for both checks. A significant positive standard heterosis for ear width over HHB 67 and 86 M 86 was reported in 14 and one hybrid respectively. Moderate amount of heterosis for ear girth was also reported by Lakshmana *et al* (2010). In contrast Patel *et al* (2016) reported that none of the hybrids showed significant positive heterosis for ear girth.

The better parent heterosis for 1000 seed weight ranged from -50.19 in cross 19 (04999A × R39) to 43.16 in cross 20 (04999A × 07444R) with eight hybrids recording significant positive BP heterosis. The standard heterosis for 1000 seed weight ranged from - 40.07 in cross 19 (04999A × R39) to 31.58 in cross 20 (04999A × 07444R) over the check HHB 67, while it was -19.01 in cross 19 (04999A × R39) to 58.03 in cross 20 (04999A × 07444R) over the check 86 M 86. A significant positive standard heterosis for 1000 seed weight over check HHB 67 and 86 M 86 was observed in 3 and 18 hybrids respectively. Test weight is an important yield attributing character and heterosis for 1000 seed weight was also observed by Chotaliya *et al*., (2010) and Vagadiya *et al*., (2010a). A significant positive better parent heterosis for grain yield per plant was reported in 10 hybrids, while none of the hybrids showed significant positive standard heterosis over the check 86 M 86. On the contrary all the hybrids had significantly positive standard heterosis over HHB 67. The better parent heterosis for grain yield per plant ranged -40.69 in cross 12 (03666A × 07444R) to 120.68 in cross 31 (94444A × R39). The cross 26 (92777A × R22, 254.81) recorded maximum standard heterosis for grain yield per plant over the check HHB 67. A high magnitude of heterobeltiosis was also observed for grain yield per plant in pearl millet by Zeal *et al*. (2017), Aruselvi *et al*., (2006), Umaretiya (2006), Patel *et al*., (2008), Vetriventhan *et al*., (2008), Vagadiya *et al*., (2010a), Patel *et al*., (2016), Jethva *et al*., (2012) and Patel (2014). The better parent heterosis for seed diameter among the hybrids tested ranged from -32.38 in cross 17 (04999A X 08222R) to 9.66 in cross 20 (04999A X 07444R), while standard heterosis over HHB 67 ranged from - 27.85 in cross 17 (04999A X 08222R) to 9.07 cross 19 (04999A X R39) and over 86 M 86 was in the range -17.09 in cross 17 (04999A X 08222R) to 25.34 in cross 19 (04999A X R39). Seed diameter had significant positive correlation with 1000 seed weight which is a yield attributing character hence selection for seed diameter may in turn contribute to enhanced grain yield.

A significant positive better parent heterosis for fat content was found in 12 hybrids and it ranged from -17.02 in cross 4 (97111A × 07444R) to 47.36 in cross 6 (08666A × R22). The standard heterosis for fat content over HHB 67 ranged from -18.41 in cross 10 (03666A × R22) to 39.32 in cross 6 (08666A × R22), while it ranged from -17.77 in cross 10 (03666A × R22) to 40.40 in cross 6 (08666A × R22) over 86 M 86. A significant positive standard heterosis over HHB 67 and 86 M 86 for fat content was reported in 13 hybrids. The alcoholic acidity recorded a better parent heterosis ranging from -67.88 in cross 9 (03666A × 08222R) to -36.76 in cross 18 (04999A × R22) on fifth day of storage, while standard heterosis over the check HHB 67 ranged from -41.13 in cross 9 (03666A × 08222R) to 16.55 in cross 8 (08666A × 07444R) and -46.36 (03666A × 08222R) to 6.19 (08666A × 07444R) over the check 86 M 86. A significant negative BP heterosis was observed in 32 hybrids and standard heterosis in 12 and 22 hybrids over the checks HHB 67 and 86 M 86 respectively on fifth day of storage. A lower value for alcoholic acidity is desirable as it indicates an increase in the shelf life of the pearl millet flour which is desirable for use of pearl millet flour in the bakery and food industry.

The list of best performing hybrids is enlisted in Table: 3. The estimates of standard heterosis and standard heterosis over the check 86 M 86. The hybrids 92777A × R22, 97111A × R39, 04999A × 08222R,

Table 3. Superior cross combinations for yield, rancidity and associated characters

S.No	Character	Hybrid	Better Parent Heterosis	Standard Heterosis		Mean performance	*sca* effect
				HHB 67	86 M 86		
1.	Days to 50 % Flowering	05444A × 07444R	-28.66**	1.67	-23.27**	40.67	-3.57**
2.	Plant height (cm)	98222A × 07444R	31.41**	21.36 **	9.56	177.27	13.59**
3.	Effective tillers per plant	03666A × 07444R	30.00	90.48 **	169.43**	5.20	1.83**
4.	Ear Length (cm)	98222A × 07444R	30.38**	38.31 **	24.98**	25.03	1.51
5.	Ear Width (cm)	97111A × R39	34.32**	66.50 **	27.44**	3.31	0.57**
6.	1000 seed weight (g)	04999A × 07444R	43.16**	31.58 **	58.03**	12.36	3.11**
7.	Grain Yield per plant (g)	92777A × R22	57.25**	254.81 **	3.04	21.13	4.18**
8.	Seed diameter (mm)	04999A × R39	6.58*	9.07	25.34**	2.27	0.31**
9.	Fat content (%)	08666A × R22	47.36**	39.32 **	40.40**	7.23	1.35**
10.	Alcoholic acidity on 5th Day	03666A × 08222R	-67.88**	-41.13 **	-46.36**	0.22	-0.03

04999A × 07444R and 97111A × 08222R gave significantly positive standard heterosis for grain yield over the check HHB 67 and better parent heterosis. The hybrids 03666A × 08222R, 05444A × 08222R, 92777A × 08222R, 98222A × 08222R and 08666A × 08222R showed significantly negative standard heterosis over the check 86 M 86 at 5th day of storage. These hybrids identified in this study can be further evaluated for grain yield and rancidity for commercial use in future.

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Research Article
The J. Res. PJTSAU 48 (1&2) 39-47, 2020

EFFECT OF WATER MANAGEMENT PRACTICES AND NITROGEN SOURCES ON SPAD, N CONTENT AND UPTAKE IN RICE (*Oryza sativa L.*)

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Date of Receipt : 05-05-2020 Date of Acceptance : 21-06-2020

ABSTRACT

A field study was carried out for two years on clay loam soil during *Rabi* 2015-16 and 2016-17 at college farm, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India with a view to study the relationship between SPAD value, plant nitrogen content and uptake. The experiment was laid out in a Split plot design under two types of water management practices *i.e.*, Continuous flooding (CF) and alternate wetting and drying (AWD) with five treatments *viz.*, T_1- N_0:P_2O_5 @ 60 kg ha^{-1}: K_2O @ 60 kg ha^{-1} (Control); T_2- Nitrogen @ 120 kg ha^{-1}(Prilled Urea): P_2O_5 @ 60 kg ha^{-1}: K_2O @ 60 kg ha^{-1} T_3- Soil test based fertiliser application; T_4- Nitrogen @ 60 kg ha^{-1}+ 60 kg ha^{-1} through green manure and T_5-Nitrification inhibitor Coated Urea. MTU-1010 variety was cultivated and recommended management practices were followed.In continuous flooding plots always 5 cm level of water was maintained, while in alternate wetting and drying, when hairline crack appeared on surface of soil, irrigation was given. Significantly higher SPAD values, N content and N uptake was recorded in the crop raised under continuous flooding over alternate drying at all crop growth stages. Among different nitrogen sources, higher SPAD and N uptake was observed with Soil test crop response (STCR) treatment. High N content was observed with green manure treated plot followed by coated urea and STCR treatment. Interaction effect of water management methods and nitrogen sources on SPAD, N content and N uptake was significant. Strong relationship between SPAD and plant N content was observed at flowering stage, whereas for SPAD and N uptake, a good correlation was noticed at harvest.

Rice is the most important staple food for a large part of the world's human population (about 3 billion) and supplies as much as half of the daily calories of the world population (Abbasi *et al.*, 2011). In India, 43.79 M ha of area was under rice cultivation in 2017-18 (Indiastat, 2018). Conventionally, it is mainly grown under continuous flooded conditions. Nitrogen is one of the key inputs for increasing agricultural productivity and it is most limiting nutrients in rice in tropics and adequate N supply is needed throughout the active growing period of rice. Thus proper N management is very crucial for successful rice production

Prilled urea is the popular source of nitrogenous fertilizer applied to the soil in Indian sub-continent (Prasad, 1998). Urea, when applied to soil is hydrolysed by urease to from NH_4^+-N and this is subsequently converted to nitrate (NO_3 - N) during nitrification either by the nitrifying bacteria in aerobic soil condition or denitrifying bacteria under anaerobic soil conditions (Kiran and Patra, 2003).Therefore, to reduce the nitrogen losses from paddy fields, best nitrogen management practices in combination with water management methods to improve the productivity of paddy for growing population and with limiting water sources is required.

MATERIAL AND METHODS

The experiment was laid out in a split plot design with two types of water management methods *i.e.*, continuous flooding and alternate drying with five treatments *viz.*, T_1- N_0:P_2O_5 @ 60 kg ha^{-1}: K_2O @ 60 kg ha^{-1} (Control); T_2- Nitrogen @ 120 kg ha^{-1}(Prilled Urea): P_2O_5 @ 60 kg ha^{-1}: K_2O @ 60 kg ha^{-1}; T_3- Soil test based fertiliser application; T_4- Nitrogen @ 60 kg ha^{-1} + 60 kg ha^{-1} through green manure and T_5-Nitrification inhibitor coated urea @ 120 kg $ha^{-1}$and were replicated thrice.The soil of the experimental site was a clay loam in texture, slightly alkaline in reaction (7.72), normal in electrical conductivity (1.56 dS m-$^{-1}$), low in organic carbon (0.49 %), low in available nitrogen (243 kg N ha^{-1}), medium in available phosphorus (19.26 kg P_2O_5 ha^{-1}) and potassium (520.05 kg K_2O ha^{-1}).

Note: 60 kg P_2O_5: 60 kg K_2O ha^{-1} common for all treatments. Nitrogen applied as basal dose and two

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Table 1. Treatments with different water management and nitrogen sources.

Treatment details	
Main plot treatments	
A) Continuous flooding	
B) Alternate wetting and drying	
Subplot treatment	
T_1	N_0:P_2O_5 @ 60 kg ha^{-1}: K_2O @ 60 kg ha^{-1} (Control)
T_2	Nitrogen @ 120 kg ha^{-1}(Prilled Urea): P_2O_5 @ 60 kg ha^{-1}: K_2O @ 60 kg ha^{-1}
T_3	Soil test based fertiliser application
T_4	Nitrogen @ 60 kg ha^{-1} + 60 kg ha^{-1} through green manure
T_5	Coated Urea@ 120 kg ha^{-1}

split doses. Phosphorus and potassium applied as basal dose at the time of transplantation.

SPAD (Soil Plant Analytical Development) chlorophyll meter readings (SPAD 502; Minolta company Ltd) measures the greenness or relative chlorophyll content of the leaves. SPAD value is a reflection of the leaf chlorophyll content and in turn reflects crop N status. The chlorophyll (SPAD) meter provides an instantaneous, non-destructive indication of leaf chlorophyll or N concentration in the crop.

SPAD chlorophyll meter reading (SCMR) was taken at maximum tillering, flowering and at harvest of the crop. The third leaf from the top was used for measuring SCMR, which was taken on one side of leaf blade, midway between the leaf base and tip. The readings were taken between 10.00 and 12.00 hours of the day. The plant samples were collected for N content analysis at maximum tillering, flowering and at harvest from the respective treatments and were oven dried and finely ground and used for chemical analysis. Nitrogen content was estimated by Micro Kjeldhal's method as outlined by Jackson (1973) and expressed in percentage. Plant N uptake was computed and expressed in kg ha^{-1} as follows.

$$\text{N uptake (kg ha}^{-1}\text{)} = \frac{\text{N content (\%) x straw yield (kg ha}^{-1}\text{)}}{100}$$

The data on various parameters studied during the course of investigation were statistically analyzed as suggested by Panse and Sukhatme (1985). The significance was tested by F test (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

SPAD

SPAD values were recorded at maximum tillering, flowering and at harvest of the crop. Significant variation in SPAD values were observed with water management practices in both the years (Table 2). In 2015-16, among the water management methods, continuous flooding resulted in significantly higher SPAD values (33.10 and 34.15) than alternate wetting and drying(31.50 and 32.70) at maximum tillering and flowering stage respectively. However, at harvest SPAD values were not significant between two water management practices.Similar trend was observed in 2016-17 for SPAD values. Significantly higher SPAD values were observed in continuous flooding (38.44 and 39.36) than in in alternate wetting and drying (35.76 and 36.89) at maximum tillering and flowering stages respectively, whereas SPAD values were non-significant at harvest of the crop. Zhang *et al.*, 2012 also reported significantly higher SPAD values in continuous flooding than in alternate wetting and drying.

Significant difference in SPAD values were observed among varied N sources. In 2015-16, STCR nitrogen applied plot registered significantly highest SPAD value *i.e.,* 35.11, 36.38 and 30.33 at maximum tillering, flowering stage and at harvest respectively. However, the SPAD values of all other N treatments at all stages of plant growth were at par (Table 2). Similar trend was observed during 2016-17 at all stages of the crop growth. SPAD value is an index of chlorophyll content of leaf and it may in turn result in higher grain yield and dry matter production in STCR treatment (Cabangon *et al.*, 2011).

The interaction effect between water management methods and nitrogen sources was also significant during both the years of study at different stages (Table 2a and 2b).

In continuous flooding at flowering stage, treatment with soil test based fertiliser has shown significantly higher SPAD value (39.40 and 46.50) followed by treatment receiving urea coated with nitrification inhibitor (36.56 and 41.70) during 2015-16 and 2016-17, respectively and lowest being in control (27.43 and 33.43). Among water management methods, continuous flooding registered high SPAD values with treatment receiving STCR (33.20 and 40.10) followed by Urea coated with nitrification inhibitor (30.40 and 35.70) at harvesting stage in 2015-16 and 2016-17, respectively.

N content (%)

The data pertaining to N content by rice was depicted in Table 3 shows that N content was significantly influenced by water management methods, nitrogen sources at different stages in both the years.

Among water management methods, continuous flooded rice showed significantly higher N content at all growing stages of rice crop in both the years of study. In 2015-16, results revealed that continuous flooded rice recorded higher N content of 2.086 %, 1.273 % and 0.503% at maximum tillering, flowering, at harvest over alternate drying. During 2016-17 also similar trend was observed with continuous flooding treatment in which N contents were 1.955 %, 1.359 % and 0.493 % at maximum tillering, flowering and at harvest respectively over that of alternate drying. Growing rice under AWD could consequently lead to a greater loss of applied fertilizer N and soil N compared with that under continuous flooding conditions (Peng *et al.*, 2006). Hence, N content in plant may be lower in alternate drying compared to continuous flooding. The results were in line with that of Somaweera *et al.*, 2015. Significant difference was observed in N content at all stages of crop growth (Table 3). At maximum tillering highest N content was noticed in green manure applied treatment (2.355 %) followed by both coated urea (2.173 %) and STCR treatment (2.147 %) which were at par during 2015-16. Similar results were observed during 2016-17 also. However, in 2016 -17 significant difference was observed between green manure applied plot (2.157%) and coated urea treatment (2.010 %). At flowering stage, N content in green manure applied treatment (1.338)was at par with STCR applied plot (1.335 %)and both treatments pocessed significantly higher N than coated urea plot in 2015-16. During second year of study, green manure applied treatment (1.410 %), coated urea treatment (1.395 %) and STCR

Table 2. Effect of water management and nitrogen sources on SPAD values at different stages of rice

Treatments	SPAD (2015-2016)			SPAD (2016-2017)		
	Maximum tillering	Flowering	At Harvest	Maximum tillering	Flowering	At Harvest
M1	33.10	34.153	28.04	38.44	39.36	33.14
M2	31.50	32.70	26.71	35.76	36.89	31.04
SEm ±	0.219	0.209	0.257	0.078	0.169	0.385
CD (p=0.05)	1.352	1.294	NS	0.484	1.047	NS
T_1	26.08	27.14	21.28	32.35	33.40	26.38
T_2	32.26	33.33	27.28	34.50	35.40	29.95
T_3	35.11	36.38	30.33	40.13	41.23	35.15
T_4	33.75	34.60	28.63	39.13	40.01	34.41
T_5	34.31	35.40	29.35	39.41	40.60	34.56
SEm ±	0.354	0.394	0.393	0.288	0.292	0.372
CD (p=0.05)	1.062	1.182	1.179	0.864	0.876	1.116

treatment (1.382 %) were at par. At harvest, similar trend was observed .However, at all stages of crop growth, significantly lower N content was noticed in control (without N application) during both years of study.

The interaction between water management methods and nitrogen sources was also significant in both the years of study (Table 3a, 3b and 3c). During 2015-16, at maximum tillering stage, with continuous flooding in STCR (2.517 %) and coated urea treatment (2.423 %) and green manure applied plot (2.420 %) were comparable each other. Whereas, green manure treatment under alternate drying has shown higher N content (2.290 % and 2.117 % respectively during two years). Second year of study also showed similar trend with STCR (2.487 %) and coated urea treatment (2.370 %) which were comparable with each other.

N uptake (kg ha^{-1})

Data represented in Table 5, showed that water management methods and nitrogen sources significantly influenced the N uptake over control (T_1 treatment). The nitrogen uptake was more in continuous flooding than in alternate drying at all the stages of rice. In 2015-16, significantly highest N uptake was observed with continuous flooding over alternate drying flooding. The highest values observed were 39.87 kg ha^{-1}, 50.91 kg ha^{-1} and 28.74 kg ha^{-1} at maximum tillering, flowering and at harvest respectively. Similar trend of N uptake was observed in the second year of study. Significantly highest N uptake registered in continuous flooding with 39.95 kg ha^{-1}, 47.59 kg ha^{-1}, and 30.77 kg ha^{-1} at maximum tillering, flowering and at harvest respectively over alternate drying. Higher nitrogen uptake (109.8 kg ha^{-1}) was reported in puddled rice than intermittently drained rice (79.2 kg ha^{-1}) by Banerjee *et al.* (2002).

The percent increase in N uptake with continuous flooding was 17 %, 11 % and 25 % over alternate drying at maximum tillering, flowering and at harvest respectively in 2015-16. Whereas in second year of study, in continuous flooding percent increase in N uptake was 21%, 16.8 % and 20 % over alternate drying at maximum tillering, flowering and at harvest respectively. Under conditions of water stress, roots are unable to take up many nutrients from the soil due to a lack of root activity as well as slow ion diffusion and water movement rates (Dubey and Pessarakli, 2001). Moreover, the mineralization process depends on micro-organisms and enzyme activity, which may be affected by water stress (Mengel and Kirkby, 2001).

Different sources of nitrogen exerted considerable influence on N uptake of rice at different crop growth stages. In 2015-16, significantly highest N uptake recorded with green manure applied plot (44.24 kg ha^{-1} and 54.60 kg ha^{-1}) over STCR applied treatment (43.07 kg ha^{-1} and 53.79 kg ha^{-1}) at maximum tillering and flowering stage respectively. At harvest, STCR treatment (30.81 kg ha^{-1}) recorded significantly high N uptake followed by neem coated urea treatment (28.91 kg ha^{-1}). In second year of study (2016-17), at

Table 2a. Interaction between water management and nitrogen sources on SPAD at flowering in rice

Treatments	2015-2016			2016-2017		
	M1	M2	Mean	M1	M2	Mean
T_1	27.43	27.40	27.41	33.43	33.36	33.40
T_2	32.46	33.36	32.91	34.76	35.96	35.36
T_3	39.40	34.30	36.85	46.50	39.60	43.05
T_4	34.90	34.20	34.55	40.43	36.03	38.23
T_5	36.56	34.23	35.40	41.70	39.50	40.60
Mean	34.15	32.70		39.36	36.89	
	C.D (0.05)		S.Em±	C.D (0.05)		S.Em±
Factor N at same levels of M	1.982		0.469	1.504		0.380
Factor M at same levels of N	1.922		0.541	1.481		0.407

Table 2b. Interaction between water management and nitrogen sources on SPAD readings at harvesting stage in rice

Treatments	2015-2016			2016-2017		
	M1	M2	Mean	M1	M2	Mean
T_1	21.36	21.20	21.28	26.66	26.10	26.38
T_2	26.53	27.46	27.00	28.56	30.20	29.38
T_3	33.20	28.56	30.88	40.10	34.16	37.13
T_4	28.70	28.03	28.36	34.66	31.33	33.00
T_5	30.40	28.30	29.35	35.70	33.43	34.56
Mean	28.04	26.71		33.14	31.04	
	C.D (0.05)		S.Em±	C.D (0.05)		S.Em±
Factor N at same levels of M	2.09		0.57	2.33		0.86
Factor M at same levels of N	2.11		0.56	2.69		0.60

maximum tillering stage and at harvest highest N uptake was registered with STCR treatment (43.31 and 34.07 kg ha^{-1}) At flowering stage N uptake was observed in STCR treatment and green manure applied plot were at par and superior over control (43.31kg ha^{-1} and 43.16 kg ha^{-1}).

The interaction effects between water management methods and nitrogen sources were significant during both the years of study (Table 5a). In 2015-16, among water management methods continuous flooding recorded significantly highest N uptake at different crop growth stages. At maximum tillering stage, continuous flooding with STCR treatment (55.78 kg ha^{-1} and 58.40 kg ha^{1}) recorded significantly higher value N uptake over alternate drying with STCR treatment (30.366 kg ha^{-1} and 28.224 kg ha^{-1}) followed by green manure applied treatment (46.046 kg ha^{-1} and 44.179 kg ha^{-1}) in both the years respectively. Whereas at flowering and harvesting, similar trend was followed. Significantly high N uptake was recorded with STCR applied treatment (63.417 kg ha^{-1} and 64.881 kg ha^{-1}) in continuous flooding, whereas in alternate drying, receiving green manure shown high N uptake (53.057 kg ha^{-1} and 48.279 kg ha^{-1}) over the other treatments. STCR treatment (40.59 kg ha^{-1} and 44.66 kg ha^{-1}) recorded highest N uptake at harvest and superior over other treatments in both the years. Grigg *et al.* (2000) reported that reduced N uptake from intermittent irrigated compared to flooding of rice and attributed partly to N losses from denitrification in AWD practice. Growing rice under AWD could consequently lead to a greater loss of applied fertilizer N and soil N compared with that under continuous flooding conditions (Peng *et al.*, 2006).

Relationship between SPAD value, N content and N uptake

SPAD values were correlated with plant N content, N uptake and significantly related to each other (Table. 4). Among all stages of crop growth, strong correlation between SPAD and N content was observed at flowering stage (Fig 1 and 2). Whereas at harvest good correlation was observed between SPAD and N uptake. Hence it may be concluded that N content is strongly related to SPAD values as N application must have maintained leaf N concentration and there by increased levels of chlorophyll, photosynthesis, carbohydrate at have maintained leaf N concentration and there by increased levels of chlorophyll, photosynthesis, carbohydrate accumulation. The results were in line with that of Islam *et al.*, 2009. Suresh *et al.*, 2017 also observed strong correlation between N content and SPAD values at 45, 55 and 65 days after transplanting of rice.The relationship between SPAD and N content in this study confirms the possibility of management of N fertilizer in the crop with SPAD values.

Table 3. Effect of water management and nitrogen sources on N content (%) at different stages of rice

Treatments	N Content (2015-2016)			N Content (2016-2017)		
	Maximum tillering	Flowering	At Harvest	Maximum tillering	Flowering	At Harvest
M1	2.086	1.273	0.503	1.955	1.359	0.493
M2	1.894	1.218	0.425	1.659	1.236	0.422
SEm ±	0.011	0.007	0.011	0.023	0.007	0.004
CD (p=0.05)	0.070	0.046	0.075	0.148	0.045	0.027
T_1	1.412	1.002	0.337	1.263	1.098	0.363
T_2	1.863	1.235	0.485	1.593	1.202	0.413
T_3	2.147	1.335	0.502	2.010	1.382	0.513
T_4	2.355	1.338	0.498	2.157	1.410	0.500
T_5	2.173	1.318	0.498	2.010	1.395	0.497
SEm ±	0.020	0.012	0.010	0.030	0.015	0.009
CD (p=0.05)	0.060	0.036	0.030	0.090	0.045	0.026

Table 3a. Interaction between water management and nitrogen sources on N content (%) at maximum tillering

Treatments	2015-2016			2016-2017		
	M1	M2	Mean	M1	M2	Mean
T_1	1.463	1.360	1.412	1.337	1.190	1.263
T_2	1.607	2.120	1.863	1.383	1.803	1.593
T_3	2.517	1.771	2.147	2.487	1.533	2.010
T_4	2.420	2.290	2.355	2.197	2.117	2.157
T_5	2.432	1.923	2.173	2.370	1.650	2.010
Mean	2.086	1.894		1.955	1.659	
	C.D (0.05)		S.Em±	C.D (0.05)		S.Em±
Factor N at same levels of M	0.100		0.024	0.167		0.051
Factor M at same levels of N	0.097		0.027	0.174		0.044

Table 4. Correlation between SPAD, N content and N uptake of rice at different stages

S.No	Stage of the crop	r^2 value (SPAD and N content)	r^2 value (SPAD and N uptake)
1.	Maximum tillering	0.33	0.44
2.	Flowering	0.66	0.29
3.	At harvest	0.51	0.58

Table 5. Effect of water management and Nitrogen sources on N uptake (kg ha^{-1}) at different stages of rice

Treatments	N Uptake (2015-16)			N Uptake (2016-17)		
	Maximum tillering	Flowering	At Harvest	Maximum tillering	Flowering	At Harvest
M_1	39.87	50.91	28.746	39.95	47.59	30.771
M_2	33.22	45.33	21.468	31.65	39.63	24.582
SEm ±	0.20	0.32	0.705	0.41	0.23	0.194
CD (p=0.05)	1.32	2.11	4.621	2.690	1.485	1.272
T_1	23.06	35.08	13.349	22.55	32.35	15.783
T_2	35.08	49.95	25.01	32.63	42.83	24.202
T_3	43.07	53.79	30.81	43.31	50.19	34.507
T_4	44.24	54.60	27.43	43.16	50.27	31.739
T_5	37.28	47.19	28.91	37.34	42.43	32.152
SEm ±	0.35	0.54	0.585	0.58	0.47	0.600
CD (p=0.05)	1.06	1.62	1.770	1.74	1.41	1.813

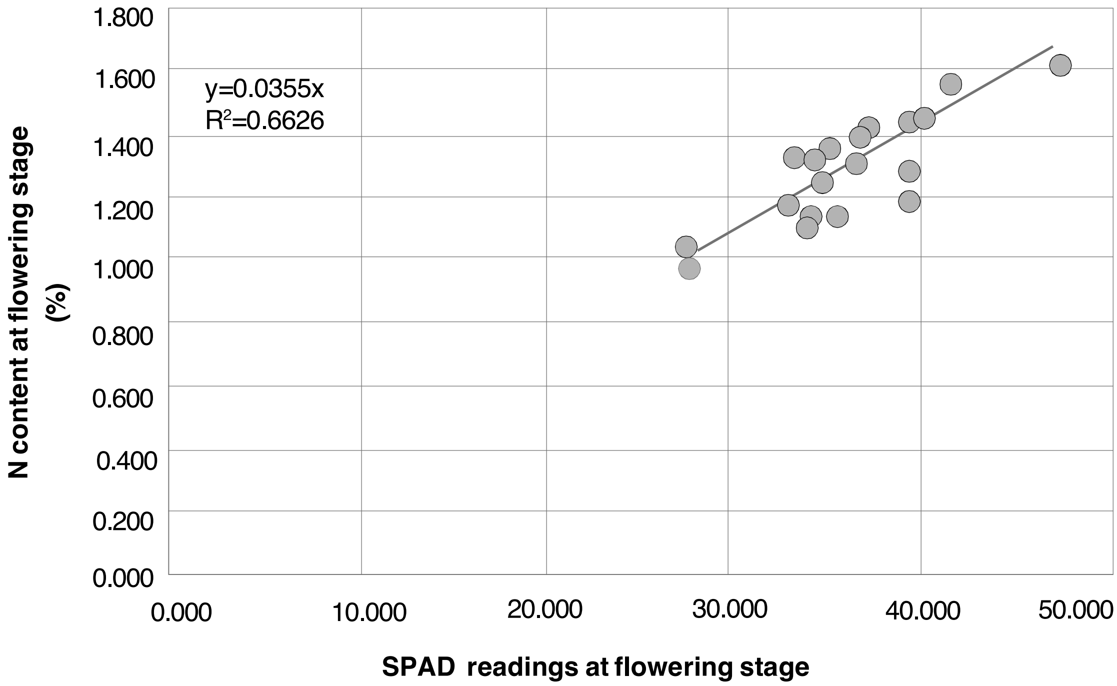
Table 5a. Interaction between water management and nitrogen sources on N uptake (kg ha^{-1}) of rice at maximum tillering

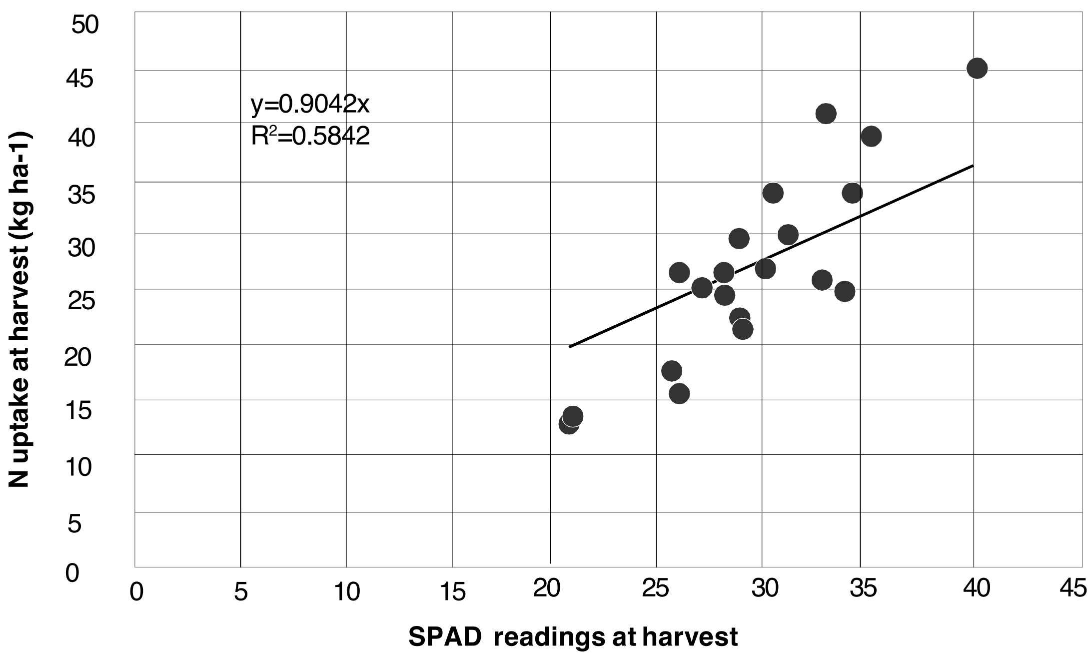
Treatments	2015-2016			2016-2017		
	M1	M2	Mean	M1	M2	Mean
T_1	24.04	22.07	23.06	23.96	21.14	22.55
T_2	32.69	37.47	35.05	30.17	35.10	32.63
T_3	55.79	30.37	43.08	58.40	28.22	43.31
T_4	46.05	42.45	44.25	44.18	42.14	43.16
T_5	40.82	33.76	37.29	43.05	31.64	37.34
Mean	39.88	33.22		39.95	31.65	
	C.D (0.05)		S.Em±	C.D (0.05)		S.Em±
Factor N at same levels of M	1.81		0.45	3.152		0.92
Factor M at same levels of N	1.78		0.49	3.24		0.84

CONCLUSION

For same amount of nitrogen applied continuous flooding showed higher SPAD values and N uptake than in alternate wetting and drying practice i.e., in turn reflects in more chlorophyll content. Strong relationship between SPAD and plant N content was observed at flowering stage. The relationship between SPAD values and N content gives the possibility of N fertilizer management with SPAD observations.

Figure 1. Regression of SPAD values on N content of rice at flowering stage





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Research Article
The J. Res. PJTSAU 48 (1&2) 48-54, 2020

PATH ANALYSIS FOR GRAIN YIELD IN RICE

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Date of Receipt : 20-05-2020 Date of Acceptance : 19-06-2020

ABSTRACT

The present study was carried out to estimate the direct and indirect influence of yield related traits on single plant yield in rice. A total of 150 genotypes were evaluated for 19 traits including 14 yield and yield related traits and 5 grain quality traits. Path coefficient analysis revealed that biomass was an important component trait of grain yield because it had relatively large positive direct effect on grain yield, which was strengthened through positive indirect effect via harvest index, total number of tillers, kernel length and gel consistency. The trait harvest index was next to the biomass as it had next highest direct effect on grain yield followed by kernel length and total number of tillers. Therefore direct selection of biomass, harvest index and total number of tillers would be highly effective for improvement of grain yield.

In trait improvement programmes plant breeders have to deal with correlated variables while practicing selections. In rice grain yield is a complex trait and influenced by many component characters. Hence rapid improvement in yield is expected to result if selection is practiced for component traits. Rate of improvement can be rapid if selection criteria are based on component traits. Selection criteria can be laid out based on degree of influence of component traits on grain yield. Path coefficient analysis developed by Wright (1921) is an efficient statistical method in measuring the degree of influence of one variable on other variables. First time this method was employed in plants by Dewey and Lu (1959) to know the direct and indirect effects of component traits of seed yield in crested wheat-grass.Correlation does not provide the true contribution of the characters towards the yield, the genotypic correlations can be partitioned into direct and indirect effects through path coefficient analysis for better interpretation of cause and effect relationship (Babu *et al*., 2012). Path analysis enables plant breeders to extract the direct and indirect effects of yield related traits. Based on these effects, differential emphasis can be laid on component traits during selection.Taking in to account of advantages of path coefficient analysis, the present study was taken up to study the direct and indirect effects of yield related traits on overall grain yield in rice.

MATERIAL AND METHODS

A total of 150 rice genotypes were evaluated during *kharif* 2018 at research farm Indian Council of Agricultural Research-Indian Institute of Rice Research (ICAR-IIRR), Hyderabad using Alpha Lattice Design with three replications. Seeds of 150 genotypes sown on nursery beds and 30 days seedlings were transplanted in main field with spacing of 20 x 15 cm and 25 hills per row were maintained. Data recorded on various yield and yield related traits *viz.,*days to 50% flowering, days to maturity, plant height (cm), panicle length (cm), number of productive tillers, total number of tillers, number of filled grains, number of unfilled grains, spikelet fertility (%), 1000 grain weight (g), single plant yield (g), biomass (g), harvest index and per day productivity and 5 grain quality traits namely amylose content, gel consistency, kernel length, kernel breadth and kernel L/B ratio were recorded. The recorded data was subjected to path coefficient analysis as suggested Dewey and Lu (1959).

RESULTS AND DISCUSSION

Data recorded on 150 genotypes were first subjected to correlation analysis and then correlation coefficients were partitioned into direct and indirect effects through path coefficient analysis. Estimates of direct and indirect effects are furnished Table 1 and Figure 1.Trait wise direct and indirect effects and

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correlation with grain yield presented and discussed here under. Days to maturity were calculated by adding 30 days to days to 50 % flowering and hence the direct and indirect effects were similar for both traits. Days to 50 % flowering and days to maturity had negative direct effect (-0.0602) on grain yield and it showed positive non-significant association with grain yield (0.12). This may be resulted due to the positive indirect effect through plant height (0.0003), panicle length (0.0006), spikelet fertility (0.0072), thousand grain weight (0.0276), biomass (0.2475), harvest index (0.0507), gel consistency (0.0029) and kernel breadth (0.1287). Negative indirect effects on grain yield via productive tillers (-0.0083), total number of tillers (-0.0021), filled grains (-0.0075), unfilled grains (-0.0040), per day productivity (-0.0563), amylose content (-0.0089), kernel length (-0.0410), kernel L/B ratio (-0.1164). Similar results were reported by Muthuramu and Sakthivel, 2016 and Bagudam *et al.* (2018) negative direct effect on grain yield whereas Priya *et al.* (2017) for positive direct effect of days to 50 % flowering on grain yield and positive indirect effect via plant height, thousand grain weight, and kernel breadth however Srijan *et al.* (2018), Islam *et al.* (2019), Katiyar *et al.*(2019) and Saha *et al.*(2019) reported positive direct effect of days to 50 % flowering on grain yield.

Plant height had shown negative direct effect (-0.0078) on grain yield while plant height had positive significant correlation with grain yield (0.17*). This positive correlation may be due to the positive indirect effects registered through days to 50 % flowering (0.0025), productive tillers (0.0470), filled grains (0.0065), unfilled grains (0.0057), biomass (0.3701), amylose content (0.0005), kernel length (0.0068) and kernel L/B ratio (0.2749). Among positive indirect effects, biomass and kernel L/B ratio had maximum indirect influence on grain yield remaining traits had negligible effect. Negative indirect effects on grain yield via panicle length (-0.0147), total number of tillers (-0.0637), spikelet fertility (-0.0179), thousand grain weight (-0.0401), harvest index (-0.0545), per day productivity (-0.1459) and kernel breadth (-0.2242). Present results were in accordance with Srijan *et al.* (2018), Dhavaleshvar *et al.* (2019), Katiyar *et al.*(2019) and Saha *et al.*(2019) for negative direct effect of plant height on grain yield whereas Kalyan *et al.* (2017) and Sudeepthi *et al.*(2017) observed positive direct effect on grain yield.

Panicle length exhibited a genotypic negative direct effect (-0.0239) on grain yield while correlation analysis showed significant positive association (0.20*) with grain yield. This positive association may be due to positive indirect effects through days to 50 % flowering (0.0015), productive tillers (0.0595), filled grains (0.0122), unfilled grains (0.0042), biomass (0.2784), harvest index (0.1697), gel consistency (0.0041) and kernel length (0.1890). Negative indirect effects of panicle length on grain yield through plant height (-0.0048), total number of tillers (-0.0818), spikelet fertility per cent (-0.0042), thousand grain weight (-0.0481), per day productivity (-0.1942), amylose content (-0.0007), kernel breadth (-0.1254) and kernel L/B ratio (-0.0327). Similar results were reported by Sudeepthi *et al.*(2017), Srijan *et al.* (2018) and Islam *et al.* (2019) for negative direct effect of panicle length on grain yield whereas positive direct effect reported by Bagudam *et al.* (2018), Dhavaleshvar *et al.*(2019) and Saha *et al.*(2019).

Productive tillers registered negative direct effect (-0.2698) on grain yield while correlation with grain yield was found to be positive significant (0.36**). This positive association may be due to the positive indirect effects expressed through total number of tillers (0.2439), thousand grain weight (0.0453), biomass (0.6257), harvest index (0.1105), gel consistency (0.0091) and kernel breadth (0.2494). Present results were in conformity with the results of Seyoum *et al.* (2012), Nikhil *et al.* (2014) and Srijan *et al.* (2018) for negative direct effects of productive tillers on grain yield.

Total number of tillers expressed positive direct effect (0.2486) as well as significant positive association with grain yield (0.31**). Hence direct selection of this trait would be effective for improvement of single plant yield. Total number of tillers registered positive indirect effect on grain yield via days to 50 % flowering (0.0005), plant height (0.0020), panicle length (0.0079), thousand grain weight (0.0438), biomass (0.5289), harvest index (0.1479), gel consistency (0.0077) and kernel breadth (0.2472). Similar results reported by Gangashetty *et al.* (2013) and Hossain *et al.*(2018) for positive direct effect on grain yield.

Filled grains exhibited negative direct effect (-0.0428) on grain yield and its correlation with grain yield was positive non-significant (0.11). It had positive indirect effect through plant height (0.0012), panicle length (0.0068), total number of tillers (0.0351), spikelet

Table: 1 Estimates of direct and indirect effects of various yield and yield related traits

	DFF	DM	PH	PL	PT	TT	FG	UFG	SF%	TGW	BM	HI	PDP	AC	GC	KL	KB	LB	SPY
DFF	**-0.0602**	0.0000	0.0003	0.0006	-0.0083	-0.0021	-0.0075	-0.0040	0.0072	0.0276	0.2475	0.0507	-0.0563	-0.0089	0.0029	-0.0410	0.1287	-0.1164	0.12
DM	-0.0602	0.0000	0.0003	0.0006	-0.0083	-0.0021	-0.0075	-0.0040	0.0072	0.0276	0.2475	0.0507	-0.0563	-0.0089	0.0029	-0.0410	0.1287	-0.1164	0.12
PH	0.0025	0.0000	-0.0078	-0.0147	0.0470	-0.0637	0.0065	0.0057	-0.0179	-0.0401	0.3701	-0.0545	-0.1459	0.0005	0.0000	0.0068	-0.2242	0.2749	0.17 *
PL	0.0015	0.0000	-0.0048	-0.0239	0.0595	-0.0818	0.0122	0.0042	-0.0042	-0.0481	0.2784	0.1697	-0.1942	-0.0007	0.0041	0.1890	-0.1254	-0.0327	0.20 *
PT	-0.0018	0.0000	0.0014	0.0053	-0.2698	0.2439	-0.0070	-0.0029	-0.0002	0.0453	0.6257	0.1105	-0.3275	-0.0124	0.0091	-0.1257	0.2494	-0.1730	0.36 **
TT	0.0005	0.0000	0.0020	0.0079	-0.2647	0.2486	-0.0060	-0.0023	-0.0009	0.0438	0.5289	0.1479	-0.3118	-0.0134	0.0077	-0.1311	0.2472	-0.1596	0.31 **
FG	-0.0105	0.0000	0.0012	0.0068	-0.0440	0.0351	-0.0428	-0.0097	0.0070	0.0812	0.2129	0.0112	-0.0748	-0.0006	-0.0032	-0.2449	0.2605	-0.0752	0.11
UFG	-0.0135	0.0000	0.0025	0.0056	-0.0443	0.0318	-0.0234	-0.0178	0.0459	0.0706	0.0857	-0.0154	-0.0087	-0.0021	-0.0018	-0.1826	0.2859	-0.1755	0.04
SF%	0.0081	0.0000	-0.0026	-0.0019	-0.0010	0.0040	0.0056	0.0153	-0.0534	-0.0352	0.0645	0.0543	-0.0606	0.0026	0.0001	0.0289	-0.1744	0.1935	0.03
TGW	0.0121	0.0000	-0.0023	-0.0084	0.0893	-0.0797	0.0254	0.0092	-0.0137	-0.1368	0.1432	0.1138	-0.1447	-0.0023	0.0039	0.4259	-0.4682	0.1648	0.11
BM	-0.0117	0.0000	-0.0023	-0.0052	-0.1325	0.1032	-0.0072	-0.0012	-0.0027	-0.0154	1.2743	0.5526	-0.8338	-0.0100	0.0054	0.0999	-0.0381	-0.0356	0.90 **
HI	-0.0037	0.0000	0.0005	-0.0049	-0.0364	0.0448	-0.0006	0.0003	-0.0035	-0.0190	0.8583	0.8205	-0.8008	0.0031	0.0013	0.1388	-0.0651	-0.0545	0.75 **
PDP	-0.0038	0.0000	-0.0013	-0.0052	-0.0983	0.0862	-0.0036	-0.0002	-0.0036	-0.0220	1.1817	0.7307	-0.8992	-0.0042	0.0041	0.1345	-0.0820	-0.0184	0.99 **
AC	-0.0128	0.0000	0.0001	-0.0004	-0.0798	0.0796	-0.0006	-0.0009	0.0034	-0.0076	0.3044	-0.0601	-0.0908	-0.0419	0.0161	0.0493	-0.0291	-0.0027	0.12
GC	0.0047	0.0000	0.0000	0.0027	0.0669	-0.0524	-0.0037	-0.0009	0.0001	0.0146	-0.1874	-0.0282	0.1004	0.0184	-0.0365	-0.0840	0.0620	0.0067	-0.1
KL	0.0033	0.0000	-0.0001	-0.0061	0.0460	-0.0442	0.0142	0.0044	-0.0021	-0.0790	0.1727	0.1544	-0.1640	-0.0028	0.0042	0.7373	-0.2666	-0.4069	0.15
KB	0.0134	0.0000	-0.0030	-0.0052	0.1162	-0.1061	0.0193	0.0088	-0.0161	-0.1105	0.0839	0.0922	-0.1273	-0.0021	0.0039	0.3392	-0.5794	0.3741	0.07
LB	-0.0093	0.0000	0.0028	-0.0010	-0.0618	0.0525	-0.0043	-0.0041	0.0137	0.0299	0.0601	0.0593	-0.0219	-0.0001	0.0003	0.3973	0.2871	**-0.7551**	0.05

Genotypic residual level=0.0690; Bold values-direct effects; Normal values- Indirect effects; * Level of significance at 5% ; ** Level of significance at 1%; DFF, Days to 50% flowering; DM, Days to maturity; PH, Plant height; PL, Panicle length; NPT, Number of productive tillers; TT, Total number of tillers; NFG, Number of filled grains; NUFG, Number of unfilled grains; SF%, Spikelet fertility percent; TGW, thousand grain weight; BM- Biomass; HI, Harvest index; PDP, Per day productivity; AC, Amylose content; GC, Gel consistency; KL, Kernel length; KB, Kernel breadth; LB, Kernel L/B ratio; SPY Single plant yield.

fertility (0.0070), thousand grain weight (0.0812), biomass (0.2129), harvest index (0.0112) and kernel breadth (0.2605). Negative indirect effect through days to 50 % flowering (-0.0105), productive tillers (-0.044), unfilled grains (-0.0097), per day productivity (-0.0748), amylose content (-0.0006), gel consistency (-0.0032), kernel length (-0.2449) and kernel L/B ratio (-0.0752). Oladosu *et al.* 2018 reported similar kind of result for number of filled grains. Contrary to the above result was reported by Bhadru *et al.* (2011), Seyoum *et al.* (2012), Patel *et al.* (2014) and Srijan *et al.* (2016) where they observed positive direct effect on grain yield.

Number of unfilled grains had negative direct effect (-0.0178) on grain yield and its correlation with grain yield was positive non-significant (0.04). This small positive association may be resulted through minimum positive indirect effects on grain yield via plant height (0.0025), panicle length (0.0056), total number of tillers (0.0318), spikelet fertility (0.0459), thousand grain weight (0.0706), biomass (0.0857) and kernel breadth (0.2859). Oladosu *et al.* 2018 observed positive direct effect of unfilled grains on grain yield.

Spikelet fertility had shown negative direct effect on grain yield. Its correlation with grain yield was positive non-significant (0.03). This small positive association may be because of positive indirect effects through days to 50 % flowering (0.0081), total number of tillers (0.0040), filled grains (0.0056), unfilled grains (0.0153), biomass (0.0645), harvest index (0.0543), amylose content (0.0026), gel consistency (0.0001), kernel length (0.0289) and kernel breadth (0.1935) while it had negative indirect effect through plant height (-0.0026), panicle length (-0.0019), productive tillers (-0.0010), thousand grain weight (-0.0352), per day productivity (-0.0606) and kernel breadth (-0.1744). Similar results observed by Srijan *et al.* (2018) and Dhavaleshvar *et al.*(2019) for negative direct effect on grain yield.

Thousand grain weight registered genotypic negative direct effect (-0.1368) on grain yield while its correlation with grain yield was positive non-significant (0.11). It had exhibited positive direct effects through days to 50 % flowering (0.0121), productive tillers (0.0893), filled grains (0.0254), unfilled grains (0.0092), biomass (0.1432), harvest index (0.1138), gel consistency (0.0039), kernel length (0.4259) and kernel L/B ratio (0.1648). Patel *et al.* (2014) and Katiyar *et al.*(2019) also reported negative direct effect on grain yield. Similar results reported by Dhavaleshvar *et al.*(2019) and Sreedhar and Uma reddy (2019) for positive indirect effects on days to 50 % flowering, Srijan *et al.* (2018) for productive tillers.

Biomass had positive direct effect (1.2743) on grain yield while its correlation with grain yield was also positive significant (0.90**). Hence it was revealed that biomass was an important trait for yield improvement. Biomass exhibited positive indirect effects through total number of tillers (0.1032), harvest index (0.5526), gel consistency (0.0054) and kernel length (0.0999) whereas negative indirect effects through days to 50 % flowering (-0.0117), plant height (-0.0023), panicle length (-0.0052), productive tillers (-0.1325), filled grains (-0.0072), unfilled grains (-0.0012), spikelet fertility (-0.0027), thousand grain weight (-0.0154), per day productivity (-0.08338), amylose content (-0.0100), kernel breadth (-0.0381) and kernel L/B ratio (-0.0356). Nikhil *et al.* (2014), Kishore *et al.* (2018) and Katiyar *et al.*(2019) reported similar results for positive direct effect of biomass on grain yield.

Harvest index had positive direct effect (0.8205) on grain yield, while its correlation was also positive significant (0.75**). Therefore direct selection through this trait would be effective for yield enhancement. Kishore *et al.* (2018), Dhavaleshvar *et al.* (2019) and Katiyar *et al.*(2019) also observed positive direct effect on grain yield.

Per day productivity registered negative direct effect (-0.8992) on grain yield. Its correlation with grain yield was highly significant positive (0.99**). In this case positive indirect effects seem to be the cause of positive association. Positive indirect effect via total number of tillers (0.0862), biomass (1.1817), harvest index (0.7307), gel consistency (0.0041) and kernel length (0.1345).Srijan *et al.*, 2018 has also observed positive direct effect on grain yield.

Amylose content had negative direct effect (-0.0419) on grain yield and its correlation was positive non-significant (0.12). Positive indirect effects via plant height (0.0001), total number of tillers (0.0796), spikelet fertility % (0.0034), biomass (0.3044), gel consistency (0.0161), kernel length (0.0493). Gel consistency exhibited negative direct effect (-0.0365) on grain yield and correlation with grain yield was also negative non-significant (-0.1). Kernel length had positive direct effect (0.7373) on grain yield and its correlation was positive

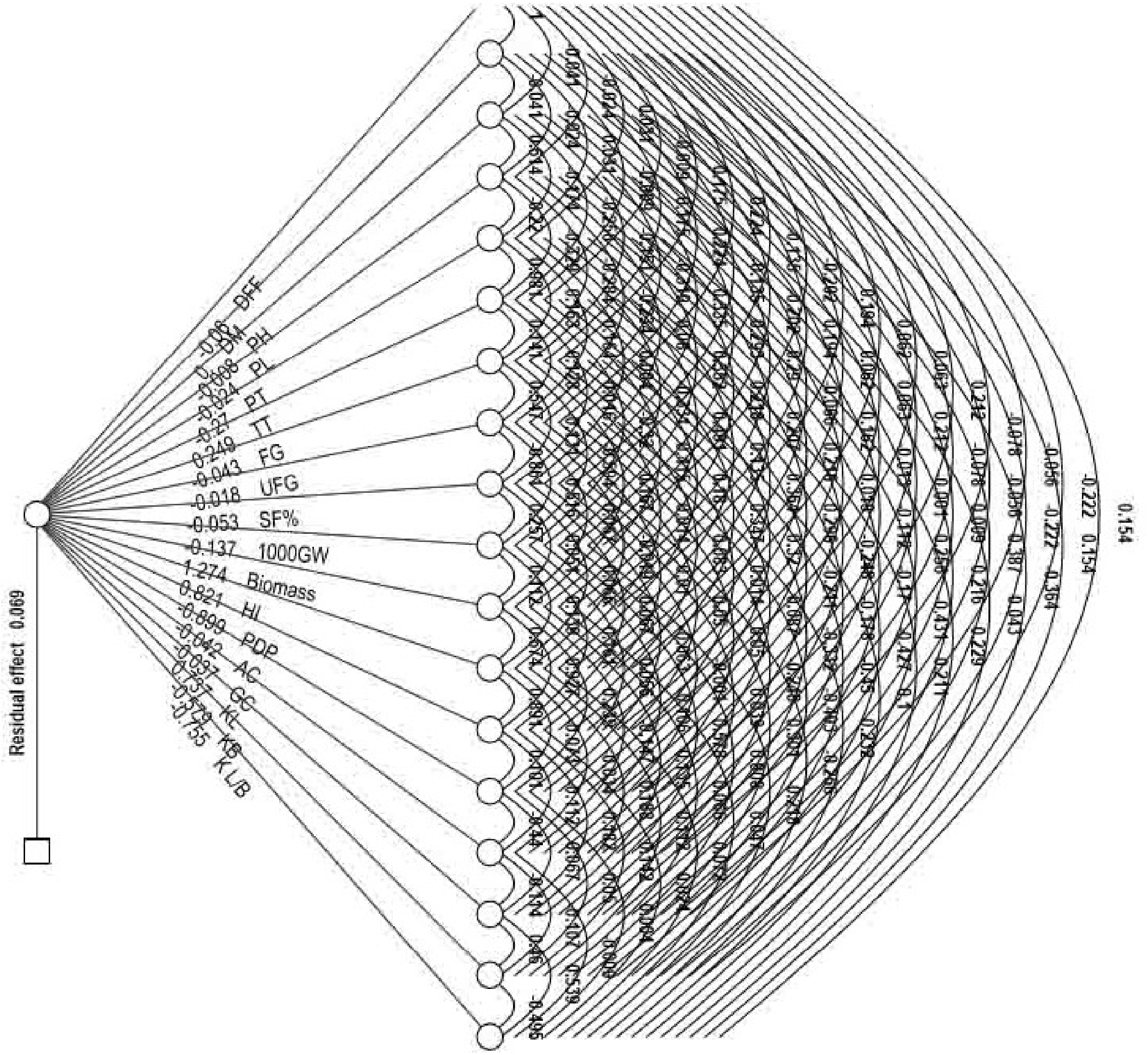

Fig.1 Genotypical path diagram for single plant yield

non-significant (0.15). It had positive indirect effect through days to 50 % flowering (0.0033), productive tillers (0.0460), number of filled grains (0.0142), number of unfilled grains (0.0044), biomass (0.1727), harvest index (0.1544) and gel consistency (0.0042). Similar result was observed by Islam *et al.* (2019) for negative direct effect on grain yield.Kernel breadth had negative direct effect (-0.5794) on grain yield while its correlation with grain yield was positive non-significant (0.07). Positive indirect effects on grain yield through days to 50 % flowering (0.0134), productive tillers (0.1162), number of filled grains (0.0193) and number of unfilled grains (0.0088), biomass (0.0839), harvest index (0.0922), gel consistency (0.0039), kernel length (0.3392) and kernel L/B ratio (0.3741). Similar result was observed by Islam *et al.* (2019) for negative direct effect on grain yield. Kernel L/B ratio had negative direct effect (-0.7551) on grain yield while its correlation with grain yield was positive non-significant (0.05). It had positive indirect effect through plant height (0.0028), total number of tillers (0.0525), spikelet fertility % (0.0137), thousand grain weight (0.0299), biomass (0.0601), harvest index (0.0593), gel consistency (0.0003), kernel length (0.3973) and kernel breadth (0.2871) and negative indirect effects through days to 50 % flowering (-0.0093), panicle length (-0.0010), productive tillers (-0.0618), number of filled grains (-0.0043), number of unfilled grains (-0.0041), per day productivity (-0.0219) and amylose content (-0.0001).

In the current study, path analysis has been done by considering single plant yield as dependent variable. Path analysis has revealed that biomass had highest positive direct effect on single plant yield followed by harvest index, kernel length and total number of tillers (Table 1). Correlation analysis revealed that significant positive association of single plant yield with biomass, harvest index and total number of tillers and positive non-significant association with kernel length. Biomass, harvest index and total number of tillers had positive direct effect and expressed significant positive association with grain yield which indicates true relationship among all these traits. Therefore direct selection of biomass, harvest index and total number of tillers would be highly effective for improvement of grain yield.

In the present study the correlation was significant positive between grain yield and plant height, panicle length, productive tillers and per day productivity however the direct effect of plant height, panicle length productive tillers and per day productivity was negative on grain yield. In this case positive indirect effects via various other traits may be the reason for positive significant correlation.

Total 18 traits under study explained 99.52 % of the variability in the single plant yield and the residual effect was only 0.0690 indicating that the characters are sufficient to account for the variability in the grain yield. Per day productivity had highest negative direct effect on grain yield and high positive indirect effect via biomass, harvest index, kernel length and total number of tillers and gel consistency which finally resulted in high positive significant association with grain yield. Path analysis results indicating that selection would be effective if it is based on biomass, harvest index and total number of tillers as these traits had high positive direct effect towards single plant yield.

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Research Article
The J. Res. PJTSAU 48 (1&2) 55-60, 2020

EFFECT OF DIFFERENT SOURCES AND LEVELS OF SILICON APPLICATION ON GROWTH, YIELD ATTRIBUTES AND YIELD OF RICE (*Oryza sativa* L.)

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Date of Receipt : 28-05-2020 Date of Acceptance : 25-06-2020

ABSTRACT

A field experiment was conducted to study the effect of different sources and levels of silicon fertilization on growth, yield and yield attributes of rice during *kharif* and *rabi* season of 2018 at College Farm, College of Agriculture, Rajendranagar. Experiment was laid out in randomized block design with fourteen treatments and three replications consisting of four silica sources and three levels of silicon fertilizers along with one RDF(100:40:40 NPK) and one absolute control. Results showed that application of silica through different sources with different levels significantly increased grain and straw yield as well as yield attributing parameters such as plant height, number of panicles hill^{-1}, length of panicle (cm), number of filled grains panicle^{-1} and 1000 grain weight (g). The application of RDF + FYM + 450 kg silicon per hectare through diatomaceous earth recorded significantly higher grain and straw yield of 8547 kg ha^{-1}and 10204 kg ha^{-1} respectively.Higher grain and straw yield under this particular treatment was mainly attributed to higher growth and yield parameters like higher plant height (87.50 cm), number of panicles hill^{-1} (19.44), length of panicle (23.47 cm), number of grains panicle^{-1} (269.30), and 1000 grain weight (13.67 g) at harvest.

Rice is an important staple food crop for more than two-thirds of the population of India and plays a vital role in national food security and a means of livelihood for millions of people. Population in our country is expected to reach 1.4 and 1.6 billion by 2025 and 2050,requiring annually 380 and 450 million tonnes of food grains respectively (Pati *et al.*,2016).Continuous paddy growing regions showing evidence of soil nutrient depletion, imbalances and low nutrient use efficiency necessitating improvement in the production and productivity of crops in a sustainable manner. Hence improving the yields of crops without deteriorating the environment and soil health is a big challenge to the farmers and scientists. Therefore, adequate nutrient management is essential to enhance productivity of rice as it is an exhaustive feeder crop (Thind *et al.*, 2012).

Si is the second most abundant element in soils after oxygen and is available to plants in the form of silicic acid (H_4SiO_4). Although Si is abundant in the earth's crust, its availability in soil is very low because of its low solubility from soil source. Monocotyledons in general and Poaceae species such as rice in particular are clearly favored due to an enhanced supply of Si (Epstein 1999; Ma *et al.,*2007). In modern agriculture, silicon has already been recognized as a functional nutrient for a number of crops, particularly rice, maize and sugarcane, and plays an important role in the growth and development of crops, especially Gramineae crops. Plants vary in their ability to absorb silicon. Plants that can absorb and accumulate silicon in their tissues are known as silicon accumulators. Rice exhibits the greatest uptake of silicic acid in the grass family. Information on the importance of Si in Indian rice farming system is limited (Prakash *et al.*, 2011). Since yield responses of rice to Si application are related to available Si in soils and the Si content of rice plants. This is evident from the fact that most of the traditional rice fields of the world are low in plant available Si and addition of Si is reported to improve the rice yield. Rice being a largest silicon accumulator, information on use of different sources of silicon, extent of their usage, standard dosages of Si, their effects on growth and yield of wetland paddy is limited. A rice crop producing 5 t ha^{-1} grain yields in soils of India has been found to remove 300 - 450 kg Si ha^{-1} (Korndorfer*et al.*, 2001). In this view a suitable field which was low in soil available silicon status was selected for the field

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experiment to evaluate various indigenous sources of silicon *viz* rice husk ash (RHA), fly ash (FA) along with diatomaceous earth (DE) and silica gel (SG) with low, medium and high silicon doses. With this background the present investigation was undertaken to know the effect of sources and levels of silica application on performance of low land rice.

MATERIAL AND METHODS

A field experiment was carried out at College Farm, College of agriculture, Rajendranagar during *kharif* and *rabi* season of 2018 in same field. It is located between 17^0 21' N latitude and 78^0 25' E longitude and 543.2 meters above mean sea level. The soil was sandy loam in texture with slightly alkaline reaction (pH = 7.64), electrical conductivity was 1.36 dSm^{-1} and organic carbon content was medium (0.63%). The soil was medium in available nitrogen (422.1 kg ha^{-1}), high in available phosphorus (93 kg ha^{-1}), and high in exchangeable potassium (320.6.4 kg ha^{-1}), with high available sulphur (48.12 mg kg^{-1}) and low available silicon content (91 kg ha^{-1}/ 40.62 ppm). The available silicon content in the soil was estimated by 0.5 M acetic acid method and availability ranges of silica is < 50 ppm for sandy soils having < 15 % clay, 65 ppm for soils having 16 to 35% of clay and < 100 ppm for clay soils having > 35% clay as per Korndorfer*et al.*, (2001).

The experiment was laid out in Randomized Block Design (RBD) with fourteen treatments and three replications. The treatment combinations consisting of four sources of silicon fertilizers (*viz.* diatomaceous earth, rice husk ash, flyash and silica gel) and three levels of silicon (150, 300 and 450 kg silicon ha^{-1}) from each source along with one absolute control and recommended dose of fertilizers. Here 150, 300 and 450 kg silicon ha^{-1} was fixed mainly because for the production of 5 t ha^{-1} of grain yield of rice it is estimated to remove about 300-450 kg elemental silicon from soil, depending upon soil and plant factors (Korndorfer*et al.*, 2001) and based on this one low, medium and high levels of silicon was taken in the experiment. Recommended quantity of FYM at the rate of 10 t ha^{-1} was applied for both the seasons and mixed into the soil two weeks before transplanting. As per the treatments fifty percent of nitrogen was applied as basal dose and entire quantity of phosphorus (DAP), potassium (MOP), and silicon were supplied at the time of transplanting as a basal dose to each plot and remaining fifty percent of nitrogen was applied as top dress at 30 days after transplanting.

Table 1. Characteristics of the Si sources used in experiment analyzed by XRD and XRF (CSIR-Indian Institute of Chemical Technology, Hyderabad)

S.No.	Parameter	Diatomaceous earth	Rice husk	Fly ash	Silica gel
1.	Solubility (1:10)	Easily soluble	Fairly	Slightly good	Good
2.	Forms of silica	Amorphous	Amorphous	Crystalline	Amorphous
3.	SiO_2 (%)	72	34.4	30.02	99.01
4.	pH (1:2.5)	8.02	7.14	8.94	7.81
5.	EC (dS m^{-1})	0.74	0.05	1.84	0.14
6.	Al_2O_3 (%)	16.4	0.34	20.23	0.12
7.	CaO (%)	2.25	0.18	2.64	1.16
8.	Fe_2O_3 (%)	4.2	0.10	4.80	0.42
9.	K_2O (%)	0.4	0.10	0.20	0.10
10.	MgO (%)	2.8	0.19	3.60	0.24
11.	MnO (%)	00	0.10	0.12	0.10
12.	Na_2O (%)	1.1	0.14	1.36	0.21
13.	P_2O_5 (%)	0.1	0.1	0.23	0.10
14.	SO_3	0.43	0.12	0.62	0.20

The quantity of bioavailable silicon contributed from the each source (Table.1) was estimated by UV visible spectrophotometry using aminonaphthol sulphonic acid (ANSA) as reducing agent (Ma and Takahashi.,2002) prior to their applications in the main field. As per the treatment wise 150 kg, 300 kg and 450 kg of silicon levels were maintained by weighing accurately from the required known quantity of silica sources. These silicon sources with different levels are then mixed thoroughly with the other NPK (100:40:40 kg N: P: K respectively per hectare) fertilizers at the time of transplanting and applied entire silica to the root zone of the transplanted rice. Soluble silicon concentration available for plant (PAS) was determined by soil extraction using 0.5 M acetic acid and Si was measured using UV visible spectrophotometry.

The mineralogical composition and forms of silica sources were determined by X-ray diffraction (XRD) on powdered samples using a Philips MPD 3710 (Co anti–cathode) X-ray diffractometer. The oxides of minerals present in different silica sources was quantified by energy-dispersive X-ray diffractometer spectroscopy (EDS- Quantax) with a Si-Li detector (Table.1). Twenty one days old seedlings was transplanted with spacing of 30 cm × 10 cm as inter and intra row spacing. Irrigation was given as per requirement. Usually every 4 to 5 days once irrigation was given based on the moisture prevailing in the field and two hand weeding was done to keep the plots free from weeds at 25 and 45 DAT. The plant growth and yield parameters *viz.* number of panicles hill^{-1}, length of panicle (cm), number of filled grains panicle^{-1} and 1000 grain weight were recorded. Biomass yields of straw and grain were also recorded at harvest from each plot in both the seasons and mean of data is presented.

RESULTS AND DISCUSSION

Plant height is a direct index to measure the growth and vigour of the plant. Plant height was significantly influenced by various levels and sources of silicon application. Among the different treatments RDF + FYM + 450 kg silicon per hectare through diatomaceous earth (T_5 treatment) recorded higher plant height of 87.50 cm compare to other treatments, however absolute control recorded lower plant height of 71.80 cm. The superiority of diatomaceous earth could be attributed to agronomic efficiency of fertilizer, where plants were able to utilize maximum nutrients. These results were in harmony with Pati *et al.* (2016) with diatomaceous earth.

The yield and yield attributes of rice was significantly influenced by application of different sources and levels of silica. Significantly more number of panicles (19.44 hill^{-1}), higher panicle length (23.47 cm), and higher number of grains per panicle (269.30) was recorded under RDF +FYM+ 450 kg silicon per hectare through diatomaceous earth. However the 1000 grain weight was significantly higher with RDF + FYM+ 450 kg silicon per hectare through diatomaceous earth and it was at par with all other treatments except the absolute control (T_1 treatment) and recommended dose of fertilizers + FYM (T_2 treatment). Application of silica made the leaves to become more erect, thus reducing the leaf shading, increased light penetration, increased number of panicles and increasing the photosynthetic rate which in turn increased their dry matter and grain yield. These results are in accordance with Pati *et al.* (2016); Sandhya *et al.* (2018); Arthanari *et al.* (2007) and Jan *et al.* (2018).

The grain and straw yield of rice as influenced by different sources and levels of silicon is presented in Table 3, significantly higher straw yield (10204 kg ha^{-1}) was recorded with RDF + 450 kg silicon per hectare through diatomaceous earth and was at par with all other treatments except the RDF+FYM+ 150 kg Si ha^{-1} through rice husk ash (T_6), absolute control (T_1) and RDF+FYM (T_2) treatments. However, absolute control recorded the lowest straw yield of 6873 kg ha^{-1}. Grain yield of rice significantly increased with increased doses of silicon treatments, indicating the beneficial role of silica in improving the rice yield. Among the different treatments RDF+FYM+450 kg silicon per hectare through diatomaceous earth recorded significantly higher grain yield (8547 kg ha^{-1}) which is 36.03 % over the control and was at par with RDF+FYM+300 kg Si ha^{-1} (diatomaceous earth), RDF+FYM+450 kg Si ha^{-1} (Silica gel) and RDF+FYM+150 kg Si ha^{-1} (diatomaceous earth) treatments. However lowest grain yield was recorded under absolute control (5467 kg ha^{-1}). Prakash *et al.*(2011) also reported 40 % of increased grain yield by soil application of silicon. The grain and straw yield in any crop is dependent upon the photosynthetic source it can build up. A sound performance in terms

Table 2. Effect of different sources and levels of silicon application on plant growth and yield parameters of rice

Treatments	Plant height (cm)			No of panicles hill^{-1}			Length of panicle (cm)			No of grains panicle^{-1}			Test weight (g)		
	Kharif	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean	*Kharif*	*Rabi*	Mean
Absolute control	75.80	67.80	71.80	11.53	9.20	10.37	18.01	16.22	17.12	249.47	235.53	242.50	12.13	12.00	12.07
RDF+FYM	79.27	71.33	75.30	12.87	11.07	11.97	20.62	18.62	19.62	258.60	244.53	251.57	12.77	12.63	12.70
RDF+FYM +150 kg Si ha^{-1} (DE)	86.53	77.73	82.13	18.07	15.33	16.70	22.51	21.34	21.93	268.67	259.07	263.87	13.43	13.23	13.33
RDF+FYM + 300 kg Si ha^{-1} (DE)	88.87	79.80	84.34	19.47	16.13	17.80	23.08	22.67	22.88	272.60	261.53	267.07	13.53	13.23	13.38
RDF+FYM + 450 kg Si ha^{-1} (DE)	92.07	82.93	87.50	20.67	18.20	19.44	23.51	23.43	23.47	275.07	263.53	269.30	13.73	13.60	13.67
RDF+FYM +150 kg Si ha^{-1} (RHA)	81.27	74.00	77.64	15.47	11.80	13.64	21.15	19.76	20.46	262.00	248.60	255.30	13.13	13.07	13.10
RDF+FYM + 300 kg Si ha^{-1} (RHA)	83.87	77.40	80.64	15.80	12.60	14.20	21.39	19.93	20.66	265.60	251.67	258.64	13.17	13.13	13.15
RDF+FYM + 450 kg Si ha^{-1} (RHA)	85.80	78.60	82.20	17.73	13.80	15.77	22.12	20.78	21.45	266.13	254.13	260.13	13.27	13.20	13.24
RDF+FYM +150 kg Si ha^{-1} (FA)	82.67	75.87	79.27	16.53	12.53	14.53	22.04	20.31	21.18	262.87	249.40	256.14	13.20	13.17	13.19
RDF+FYM + 300 kg Si ha^{-1} (FA)	83.87	76.33	80.10	17.20	12.93	15.07	22.15	20.91	21.53	265.13	251.87	258.50	13.33	13.27	13.30
RDF+FYM + 450 kg Si ha^{-1} (FA)	84.53	77.87	81.20	18.00	13.93	15.97	22.76	21.28	22.02	265.40	254.33	259.87	13.40	13.33	13.37
RDF+FYM + 150 kg Si ha^{-1} (SG)	83.80	76.27	80.04	17.27	14.87	16.07	21.97	20.94	21.46	265.13	252.47	258.80	13.27	13.13	13.20
RDF+FYM + 300 kg Si ha^{-1} (SG)	86.60	77.60	82.10	19.00	15.13	17.07	22.20	21.51	21.86	268.73	257.00	262.87	13.33	13.23	13.28
RDF+FYM + 450 kg Si ha^{-1} (SG)	87.87	79.00	83.44	19.60	15.87	17.74	23.05	21.95	22.50	269.93	259.60	264.77	13.50	13.27	13.39
SEm±	0.38	0.59	0.49	0.28	0.42	0.35	0.25	0.20	0.23	0.72	0.79	0.76	0.28	0.26	0.27
CD (p=0.05)	1.11	1.71	1.41	0.80	1.21	1.01	0.74	0.58	0.66	2.08	2.31	2.20	0.81	0.74	0.78

Table 3. Straw yield and Grain yield of rice as influenced by different sources and levels of silicon application

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	Kharif	***Rabi***	**Mean**	***Kharif***	***Rabi***	**Mean**
Absolute control	5676	5258	5467	7131	6614	6873
RDF+FYM	6622	6173	6397	8077	7614	7846
RDF+FYM +150 kg Si ha^{-1} (DE)	8552	7777	8165	10128	9722	9925
RDF+FYM + 300 kg Si ha^{-1} (DE)	8674	8153	8414	10250	9863	10057
RDF+FYM + 450 kg Si ha^{-1} (DE)	8757	8338	8547	10333	10076	10204
RDF+FYM +150 kg Si ha^{-1} (RHA)	6698	6265	6481	8796	8617	8707
RDF+FYM + 300 kg Si ha^{-1} (RHA)	7206	6936	7071	9304	9104	9204
RDF+FYM + 450 kg Si ha^{-1} (RHA)	7587	7158	7373	10479	9096	9788
RDF+FYM +150 kg Si ha^{-1} (FA)	7250	6909	7080	9336	8906	9121
RDF+FYM + 300 kg Si ha^{-1} (FA)	7641	7207	7424	9726	9069	9398
RDF+FYM + 450 kg Si ha^{-1} (FA)	7825	7453	7639	9401	9169	9285
RDF+FYM +150 kg Si ha^{-1} (SG)	7907	7523	7715	9873	9076	9474
RDF+FYM + 300 kg Si ha^{-1} (SG)	7873	7650	7761	9904	9438	9671
RDF+FYM + 450 kg Si ha^{-1} (SG)	8241	7917	8079	10339	9819	10079
SEm±	207.60	174.41	191.01	457.82	337.93	397.88
CD (p=0.05)	603.49	507.00	555.25	1330.86	982.36	1156.61

DE- Diatomaceous earth; RHA- Rice husk ash; FY- Fly ash; SG- Silica gel

of plant height, number of panicles hill^{-1}, length of panicle, number of grains panicle^{-1} and the 1000 grains weight were logically able to improve the sources and increase the total dry matter and later lead to higher grain yield. In the effect among silicon sources, diatomaceous earth followed by Silica gel had a significant influence and relatively better than other sources. The superiority of diatomaceous earth over the other sources of silicon is mainly due to the agronomic efficiency of the fertilizer *viz.,* Solubility, chemical composition,addition of some micronutrients by diatomaceous earth besides the beneficial effect of silicon to the plant and forms of silica that is present in applied fertilizer. Of all the silicon sources, solubility was in the order of diatomaceous earth > silicagel > fly ash > rice husk Ash. Poor performance of the rice husk ash over the others is due to its solubility nature though it's having plant available forms of silica (amorphous). Ashique, (2014) also reported that diatomaceous earth application will facilitate better plant growth by providing better soil environment, providing additional nutrient supply and increasing plant available silicon in soil, that have resulted in better root growth and thereby nutrient uptake ultimately lead to better yield production. Results of Sandhya *et al.* (2018) and Pati *et al*, (2016) also support for that diatomaceous earth as the most efficient source of silicon to paddy, which outperformed in all growth attributing characters of paddy.

The performance of the silicon fertilization was varied with crop growth periods and it is beneficially good in *kharif* season than over *rabi,* it might be due the favourable climatic factors for crop during *kharif* with good rain fall and sunlight intensity hours. Among the different sources diatomaceous earth is good source for silica supplement followed by silica gel and crop yields increased with increments in silica application.

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Research Article
The J. Res. PJTSAU 48 (1&2) 61-69, 2020

PROFILE CHARACTERISTICS OF THE SELECTED FARMERS OF SEED VILLAGE PROGRAMME (SVP) WITH REFERENCE TO RICE CROP

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Date of Receipt : 11-05-2020 Date of Acceptance : 16-06-2020

ABSTRACT

Seed is the critical input in sustainable development of agriculture for enhancing production and productivity. As seed quality is one of the key contributors to crop productivity and food production a robust seed system is most significant for food security in India. The present investigation was carried out in Telangana State. Ex-post facto research design was followed selecting 120 respondents at random from three districts, three mandals and three villages of the mandal. The profile characteristics of respondents of SVP practicing seed production in rice crop was studied on adopting Ex-post facto research design. Salient findings of the study are, most of the respondents were middle aged (67.50%), had high school level education (34.16%), with marginal land holding (49.16%), low farming experience (46.66%), medium extension contact (42.50%), medium mass media utilization (45.00%), medium storage facilities (56.66%), medium market orientation (42.5%), medium innovativeness (59.16%), medium aspirational level (52.50%), high economic motivation (42.50%) and medium risk orientation (51.66%).

The demand for rice is expected to grow faster than the production in most countries. How the current level of annual production of 524 million tonnes could be increased to 700 million tonnes by the year 2025 using less land, less water, less manpower and fewer agro-chemicals is a big question (Papademetriou, M.K., 2016). One of the alternative ways to meet the above challenge can be with the quality seed production. Use of quality seed is the first and foremost way of realizing the yield potential with recommended technology. Enhancement of productivity depend mainly on the quality of the seeds and the management practices adopted. A superior quality seed not only increases productivity per unit area, but it also ensures proper germination, crop stands, free from seed borne pests and diseases and helps producing uniform crops without any admixtures important for obtaining high prices in the market. Besides it is recognized in general, that quality seed ensures 10 to 15 percent higher yields under the same set of crop management practices (Varsha More, 2016). The Indian seed sector has evolved gradually into a multi-faceted system with more importance given to research and development activities with the concern to develop quality seed of improved varieties. And this developed quality seed of improved varieties needs to be always readily available to the farmers. Unfortunately, in most countries sufficient quantities of certified seed are not readily available to the farmers from all the seed sources put together and there are several issues associated with quality of seed obtained. Further the government has come up with proper legislation for the seed industry to prosper with the support of many decentralized seed production and distribution programmes and schemes to strengthen the seed sector in the country. (Papademetriou, M.K., 2016)

Despite implementation of the organized seed programme since the mid-60s, the seed replacement rate has only reached the level of 15%, 85% of the seeds used are farm saved seed. There is always some uncertainty regarding the ability possessed by the farmers to produce quality seed (e.g., with high genetic purity, vigour, freedom from off types, pathogens and other inert material), with questions raised about farmer skills and capabilities in production, utilization and marketing of their own quality seed and it is necessary to improve the stock of farm saved seeds for enhancing crop production/productivity besides enhancing the self-sufficient of seed in the country. To address this limitation, "Seed Village Programme (SVP)" has been implemented. It is proposed to provide financial assistance for distribution of foundation/certified

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seed at 50% cost of the seed of crops for production of certified /quality seed and to provide training on seed production and technology to the farmers. With the potential to provide information regarding best practices and having a set of people dedicated to guide them at every step, the farmers can achieve much better yields, higher profits and improve their conditions. This SVP initiative was from central sector under "Development and Strengthening of Infrastructure Facilities for Production and Distribution of Quality Seeds" from the year 2005-06 with the objective to develop and strengthen the existing infrastructure for the production and distribution of certified /quality seeds to farmers. "Seed Village Scheme (or) Seed Village Programme (SVP)" is one of the component from 10 other components of the programme for developing and strengthening of quality seed production in India (http://www.seednet.gov.in).

The seed produced in these seed villages will have to be preserved till the next sowing season. In order to encourage farmers to develop storage capacity of appropriate quality, assistance was given to farmers for procuring of Pusa Bin/Mud bin/Bin made from paper pulp for storing of seed produced by the farmers on their farms.

A village, where in trained group of farmers are involved in production of seed of various crops to cater to the needs of themselves, fellow farmers of the village and farmers of the neighbouring village in appropriate time and at affordable cost is called "A Seed Village" (http://www.seednet.gov.in).

The implementing agencies will be State Department of Agriculture, State Agriculture Universities, *Krishi Vigyan Kendras*, State Seed Corporation, National Seed Corporation, State Farms Corporation of India (SFCI), State Seed Certification Agencies, and Department of Seed Certification. The programme offers 50% subsidy on seed for half an acre unit area. The area for one unit is 10.00 ha. covering minimum of 50 farmers. Trainings are given to the farmers on crucial crop stages; There are 10 Seed Farms in the Telangana state with 536 hectares of cultivable area. The main objective of the intervention is to produce foundation seed and supply them under Seed Village Scheme (http://www.seednet.gov.in).

In the year 2014, new state called Telangana was formed after its bifurcation from Andhra Pradesh. From 2014-15 onwards the Seed Village Programme (SVP) became one of the most important components of the Sub-mission on Seeds and Planting Materials (SMSP) under Nation Mission on Agriculture Extension and Technology (NMAET) being implemented by Government of India (Sai santhosh *et al*, 2017). Next to that year, in 2015, 29th October 8th National Seed Congress held in Hyderabad, was organized in association with Telangana. The theme of the congress was "Quality Seed for Farmer's Prosperity". This geared up the seed development in newly formed Telangana. Hence, the present study was taken to study the profile characteristics of respondents under the SVP programme with reference to the rice crop

MATERIAL AND METHODS

Ex-post facto research design was used in the present investigation. The state of Telangana was chosen as the locale of the study and three districts namely Nizamabad, Nalgonda and Warangal was purposively selected based on highest number of SVP units allotted under the programme and one mandal each from three districts were selected randomly. From each mandal one village was selected randomly, accordingly from each village forty rice seed production farmers' respondents were selected randomly, thus constituting 120 respondents for the study.

Data was collected using interview schedule developed for the study. Based on obtained scores the respondents were grouped into low, medium and high knowledge categories according to equal interval method. The collected data was analysed using appropriate statistical tools like frequency and percentage and class interval.

RESULTS AND DISCUSSION

Age

From the Table 1 it is found that, most of (67.50%) the respondents belonged to middle age followed by young (25.0%) and old (7.5%) age categories.

One of the possible reasons for this might be that, the middle-aged farmers are enthusiastic in getting information related to advanced practices in agriculture

Table 1. Distribution of respondents according to their Age

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Young age (upto 35)	30	25.00
2.	Middle age (36-55)	81	67.50
3.	Old age(>55)	09	7.50

and tend to take risk involved in new practices mainly seed production in this case. Hence, they tend to move towards seed production for seed self-sufficiency. The other reason for the above trend might be due to the fact that old age farmers still don't change their agricultural practices from crop production to seed production as they are resistant to change while young people are inclining towards migration to towns and cities for higher education and business. The above two reasons account for low percent of young and old age group farmers.

These results are in confirmation with the findings reported by Deshmukh *et al.* (2007) and Adamu *et al.* (2013).

Education

From the Table 2 it is found that most of the farmers were educated up to high school level (34.16%) followed by primary school (26.66%), inter (20.00%), degree (5.83%), post graduate (0.00%) and 3.33 percent of farmers were found to be illiterate.

Table 2. Distribution of respondents according to their Education

S.No.	Category	Scores	Respondents (n=120)	
			Frequency	Percentage
1.	Illiterate	0	4	3.33
2.	Functional literate	1	12	10.00
3.	Primary School	2	32	26.66
4.	High School	3	41	34.16
5.	Intermediate	4	24	20.00
6.	Undergraduate	5	7	5.83
7.	Post-Graduation and above	6	00	0.00

It is inferring that, education plays a key role in molding and bringing desirable changes. Generally, in the present scenario, almost everybody has minimum education due to the awareness brought by the government on the importance of education. In the present study, the respondents have access to schools and able to pursue formal education. Hence, majority of them are in high school followed by primary school education. As they had formal education, they were able to gather knowledge on recent programmes and schemes through different sources.

This finding is in conformity with the findings of Adhikari (2007) and Sharma (2007).

Caste

The respondents from different castes were identified as participants under Seed Village Programme. However majority (Table 3) of the respondents (40.83%) belong to other backward caste followed by 32.50 percent OC and 26.66 percent SC or ST. Our society is mostly caste structured. In the present system caste structure also decides the relative position of a person in the society. Thus, it may be inferred from the data that maximum percentage of beneficiaries (40.83%) belonged to other background caste (OBC). The findings of this study corroborated with the findings of Joshi (2001) and Tomar (2006) Ghodeswar (2012) and Hoshale (2015)

Farming Experience

It could be indicated from the Table 4 that majority i.e. 46.66 percent of the respondents were grouped

Table 3. Distribution of respondents according to their Caste

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	OC	39	32.50
2.	Other back ward caste (OBC)	49	40.83
3.	SC/ST	32	26.66

under low experience in the farming, followed by medium (39.16%) and high experience in farming (14.16%).

This trend could be attributed to their higher percentage of middle age. Definitely the farming experience is an important factor which influences the respondents to accept and involve in the programme. The prevailing medium followed by young age among the respondents has even reflected in terms of their farm experience. Whereas, the old age people may not be interested to go for new skills in farming and resistant to change with present generation. But the richness of farming experience is more important than quantity. Hence, to improve the quality and richness of experience of the respondents, the extension agencies have to conduct extension activities like trainings,

Table 4. Distribution of respondents according to their Farming experience

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (3-15)	56	46.66
2.	Medium (15-27)	47	39.16
3.	High (27-39)	17	14.16

demonstrations, meetings, visits etc. This finding is in the line with the finding of Nagendra babu (2016).

Annual income

From the Table 5 it was known out of total Seed Village Programme beneficiaries majority (51.66%) ofthe respondents are under medium income category followed by high income (39.16%) group and then low-income category are 9.16 percent.

Table 5. Distribution of respondents according to their Annual income

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (Up to Rs. 33,750)	11	9.16
2.	Medium (Rs. 33,751-1,44,000)	62	51.66
3.	High (>Rs. 1,44,000)	47	39.16

Income of a family greatly influences the decision-making, aspiration and goals of an individual. In this study the respondents are motivated by the Seed Village Programme and able to increase the income by selling and reusing the seed produced by them for future seasons. The findings of this study corroborated with the findings of Mane (2012), Hoshale (2015) and Varsha More (2016).

Irrigation source

It could be observed from the Table 6 that majority i.e. 64.16 percent of the respondents are utilizing borewell/ open well as their irrigation source followed by 35.83 percent of respondents under canal irrigation whereas under river as their source of irrigation for and any other source of irrigation were of 00.00 percent.

Table 6. Distribution of respondents based on their Irrigation source

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Bore well	77	64.16
2.	Canal	43	35.83
3.	River	00	00.00
4.	Others	00	00.00

It may be due to the fact that irrigation is essential for the production of quality seed mainly in rice. Probably due to abundance of borewells these are highly used as source of irrigation. Generally for quality seed production, field should be irrigated from an assured irrigation source and abundance of bore well may be the probable reason to use them for irrigation. Therefore this might be one of the reasons for having the above results. The results are in the line with the results of Dalsaniya (2010) and Mavani (2012) by members (15.83) and no office bearer were found under sample area.

The study revealed that majority of the respondents among all the categories 60.83 percent were members under village panchayat category. The reason might be that respondents are persons both within and outside this social system are educated and are eager to adopt new technology and want to expose to new schemes and programmes.

Social participation

Table 7. Distribution of respondents based on their Social participation

S.No.	Category	Nature of participation		
		Office bearer	Member	Non – member
1.	Village panchayat	11 (9.16)	73 (60.83)	36(30.00)
2.	Agricultural cooperative society	10 (8.33)	78 (65)	32 (26.66)
3.	Religious groups	14 (11.66)	41 (34.1)	65 (54.16)
4.	*Raithu Mithra* groups	0 (00)	30 (25)	90 (75)
5.	Farmer producer organizations	14 (11.66)	60 (50)	46 (38.33)
6.	Mandal panchayat	3 (2.50)	13 (10.83)	104 (86.66)
7.	Education management committee	0 (00)	19 (15.83)	101 (84.16)

Table 7 shows us that as far as participation in social organizations was concerned 60.83 percent were member in village panchayat, 30.00 percent were non- member and 9.16 percent were office bearer of the village panchayat. In case of agricultural cooperatives society 65 percent were member and 26.66 percent were non-members and 8.33 percent of respondents were as office bearers. Under religious groups, 54.16 percent were non- members, 34.1 per cent were members and 11.66 percent of the respondents were office bearer. In case of *Raithu Mithra* groups, 75 percent were still the non – member, 25 percent were just the member and no office bearers. In Farmer producer organization 50 percent were member, 38.33 per cent were still non – members and 11.66 percent of beneficiaries were office bearer of farmers organizations. As regard to mandal panchayat, 86.66 percent were non – member, 10.83 percent were members and 2.50 percent were office bearer and Under education management committee, majority of them were non-members (84.16) followed

Storage facilities

Table 8. Distribution of respondents based on their Storage facilities

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (0-1)	46	38.33
2.	Medium (1-2)	68	56.66
3.	High (2-3)	6	5.00

It was observed from the Table 8 that majority of the respondents i.e. 56.66 percent of them had medium storage facilities followed by low storage facilities (38.33 %) and 5.00 percent of them are under high storage facilities in the study area

This result might be due to the fact that as soon as the respondents produce the grain or seed in the field they immediately sell in the market. Hence, they didn't develop much storage facilities and hence medium storage facilities are observed in the study.

Innovativeness

Table 9. Distribution of respondents based on their Innovativeness

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (2-4)	22	18.33
2.	Medium (4-6)	71	59.16
3.	High (6-8)	27	22.50

It was observed from the Table 9 that majority of the respondents i.e. 59.16 percent of them had medium innovativeness followed by high (22.50 %) and 18.33 of them are under low innovativeness.

The medium innovativeness of the respondents (Table 9) may be attributed to marginal and small holdings of this respondents in this study who cannot afford to take risk by practicing innovations. Same time the high school level of education followed by primary level helped them to try new technologies which were disseminated through trainings under the programme. Further, because of abundance of bore well as irrigation source,they might be interested to try new innovations to increase their income. Hence, farmers normally inclined towards the SVP programme which disseminated the technology and supplied quality seed, which fetch them higher income. The activities executed under the programme from time to time might have ignited the process of thinking and applying seed production practices among the respondents in a more rationale and innovative way. Hence this kind of result might have been revealed in this study. The results were in line with findings of Mavani (2012).

Economic motivation

Table 10. Distribution of respondents based on their Economic motivation

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (14-18)	28	23.33
2.	Medium (18-22)	41	34.16
3.	High (22-26)	51	42.50

It was observed from the Table 10 that majority of the respondents i.e. 42.50 percent of them had high economic motivation followed by medium (34.16%) and 23.33 percent of them are under low economic motivation

The above results obtained might be due to that the respondents,middle aged and high school educated farmers urge to participate in the schemes and programmes organized by the government with an expectation that with change in time the respondents may alleviate into high income level from medium to low level. The findings of this study are in close conformity with the findings reported by Hoshale (2015) and Varsha More (2016)

Market orientation

Table 11. Distribution of respondents based on their Market orientation

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (4-6)	48	40.00
2.	Medium (6-8)	51	42.50
3.	High (8-10)	21	17.50

It was observed from the Table 11 that majority of the respondents i.e. 42.50 percent of them had medium market orientation followed by low (40.00%) and 17.5 percent of them are under high market orientation.

Data pertaining to market orientation revealed that majority of beneficiaries are with medium market orientation for their products, the reason being the poor infrastructure facilities, as well as proximity of the co-operative markets and other market yards which are generally located only in the towns. Therefore, marketing facilities should be created for a cluster of villages, especially in remote areas where transportation facilities are meager. More farming groups should be formed to empower the farmers to market their products. The finding are coordinating with finding of Tiwari (2006).

Aspirational level

It was observed from the Table 12 that majority of the respondents i.e. 52.50 percent of them had medium aspiration level followed by high (25.83%) and 21.66 percent of them are under low aspiration level.

Majority of the respondents under SVP had medium aspirational level. This trend might be due to the reason that aspiration level is the basic character which motivates and helps an individual to do anything.

Table 12. Distribution of respondents based on their Aspirational level

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (6-9)	26	21.66
2.	Medium (9-12)	63	52.50
3.	High (12-15)	31	25.83

It is the condition which drives an individual to aspire for higher level of earning and living. Here, the trend was medium to high aspiration level by the respondents, generally the farmers who have tendency of aspiration will go for commercialization of farm than just production for grain purpose like in case of paddy. This finding is in conformity with the findings of Meshram (2003).

Mass media utilization

Table 13. Distribution of respondents based on their Mass media utilization

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (10-15)	32	26.66
2.	Medium (15-20)	54	45.00
3.	High (20-25)	34	28.33

It was observed from the Table 13 that majority of the respondents i.e. 45 percent of them had medium mass media utilization followed by high (28.33%) and 26.66 percent of them are under low mass media utilization

The medium level of mass media utilization of respondents might be due to the fact that majority of respondents were small farmers with meager facilities of exposure to television made of education but at the same time due to their high school education, high level of economic orientation and medium to high level of aspiration. This shall drive these beneficiaries to seek information from diversified sources. Hence, the trend of medium level of mass media exposure can be seen in the study. The finding is coordinating with finding of Adhikari (2007) and Ghodeswar (2012)

Extension contact

Table 14. Distribution of respondents according to their Extension contact

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (14-19)	48	40.00
2.	Medium (19-24)	51	42.50
3.	High (24-29)	21	17.50

It was observed from the Table 14 that majority of the respondents i.e. 42.50 percent of them had medium extension contact followed by low (40.00%) and 17.50 percent of them are under high extension contact.

The small farm sizes coupled with medium level of innovativeness and aspirational level might have lead them to fall under medium level of extension contact. In some of the areas in three districts, the respondents were not aware about extension activities like visits, meetings, exhibitions conducted on different technological aspects. Lack of established institutional arrangements and accessible extension personnel to be approached to guide the farmers on various aspects of agricultural and allied aspects. But there are respondents who frequently contact the officials to participate actively in various extension activities. These findings were in concurrence with the findings of Bandgar *et.al* and (2002), Khandare (2002)

Risk orientation

It was observed from the Table 15 that majority of the respondents i.e. 51.66 percent of them had medium risk orientation followed by low (35.00%) and 13.33 percent of them are under high risk orientation.

Table 15. Distribution of respondents according to their Risk orientation

S.No.	Category	Respondents (n=120)	
		Frequency	Percentage
1.	Low (6-8)	42	35.00
2.	Medium (8-10)	62	51.66
3.	High (10-12)	16	13.33

The result might be due to the reason that majority of respondents had primary school to high school education and maintain medium extension contact, which enabled them to take risk in the farming. As most of the farmers in the study are small and marginal with medium level income. Extension workers should maintain closer rapport by organizing demonstrations and exposure visits. They should also help them to overcome the problems in adoption and suggest alternatives and induce confidence. As a result, unwanted confusion prevailing in the farmers can be eliminated and they can be made to easily adopt any new technology. These results were in conformity with the findings of Mane (2012).

CONCLUSION

Above results concluded that most of the respondents were middle aged, had high school education, low farming experience with marginal land holdings, and had medium level of market orientation, innovativeness, aspirational level, medium extension contact and showing medium risk orientation besides having high economic motivation. These finding implies that success in agriculture depends upon, how well the farmer process, manage and implement the information he got through different means. Here the task is to gain knowledge through exposure and develop self-confidence to adopt the different production practices or activities. Need to contact more diversified extension agents or information sources. The state Department of Agriculture, KVKs and research centers need to provide training facilities on seed production practices besides frequent visits to farmers fields for effective seed as well as farm management.

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Research Article
The J. Res. PJTSAU 48 (1&2) 70-74, 2020

OPINIONS AND CONSTRAINTS FACED BY FARMERS IN MAINTENANCE OF TANKS UNDER MISSION KAKATIYA

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Date of Receipt : 23-04-2020 Date of Acceptance : 10-06-2020

ABSTRACT

The objective of the study was to record and document the opinions of the sample farmers on advantages and disadvantages of Mission Kakatiya, and factors that influence their participation and non-participation in tank maintenance activities after restoration. In Telangana state one tank each in Warangal and Nalgonda districts i.e a total of two tanks where in all the activities of Mission Kakatiya were completed were purposively selected for the present study. A total of 720 households (360 from each district) were considered. Descriptive analysis and Garrett ranking technique were used to analyse the present study. The study revealed that,100 percent of sample farmers opined that the yield was increased and FYM usage was reduced after application of silt in their fields. 86.19 percent of silt applied sample farmers opined that the number of irrigations were reduced. Cent percent of the tank area farmers opined that the major advantages of Mission Kakatiya are increased ground water level, water availability for irrigation, birds and livestock, increased animal grazing hours and crop yields. Cent percent of the farmers opined that there were no disadvantages of Mission Kakatiya and felt that the restored tank has to be conserved. Availability of irrigation water was found to be the most important factor influencing sample farmers to participate in tank maintenance activities, ranked first. The most important reason for factors influencing non-participation in tank maintenance activities is expecting government to do repairs and maintenance was ranked first. The opinion on benefits of restoration of tanks by sample farmers in non-tank areas was found to be increase in ground water recharge (first rank).

Water is an essential and precious resource upon which our ecosystems and agricultural production depend. However, water a natural resource of the world constitutes, 1,384 million cubic kilometers of which around 97.39 percent (i.e.1,348 million cubic kilometers) of water is in the oceans, which is salty in nature. Another 2.61 percent (i.e., 36 million km^3) is fresh water of this 77.23 percent (27.82 million km^3) is in the polar ice caps, icebergs and glaciers. Only small fraction of water resources (0.59% or 8.2 million km^3) of the earth present on the ground, lakes, rivers and atmosphere and is useful to mankind. Whereas, more than 99 per cent of water present on the earth is not useful to mankind (Anonymous, 2013).

The per capita water availability in the country is reducing progressively due to increase in population. The average annual per capita availability of water in the country, taking into consideration the population of the country as per the 2001 census, was 1816 cubic meters which reduced to 1545 cubic meters as per the 2011 census. (Government of India, 2015).

Irrigation tanks are one of the oldest and most important common property water resources in the resource poor regions especially in South India. Construction of tanks in Telangana has been an age old activity since pre Satavahana era. During the Kakatiya era, the construction of tanks was carried out with utmost technical expertise. Tanks such as Ramappa, Pakhala, Laknavaram, Ghanapuram, Bayyaram which were built by Kakatiyas resemble seas and they greatly helped agriculture and overall development and prosperity of the Kakatiya kingdom.

Understanding the importance of reclamation of tanks for growth in the state, the Government of Telangana State has taken up the programme of restoring the minor irrigation sources under the title "Mission Kakatiya" (*Mana Ooru – Mana Cheruvu*) in 2014. The mission aims at retrieving the lost glory of minor irrigation in the state with community participation for ensuring sustainable water security.

As per survey 46,531 number of M.I, Small tanks, Percolation tanks, Private Kuntas and Small tanks (built by Forest Department) were distinguished for restoration. The irrigation department has planned to restore all the 46,531 minor irrigation sources in the state in next five years in five phases, taking up 20%

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of the tanks in each phase i.e., 9306 per year (https://www.missionkakatiya.cgg.gov.in).

The main objective of this mission is to enhance the development of agriculture based income for small and marginal farmers by accelerating the development of minor irrigation infrastructure, strengthening community based irrigation management and adopting a comprehensive programme for restoration of tanks.

Inadequate maintenance, reduction in storage capacity, heavy seepage losses in the delivery system and poor water management techniques are the major deficiencies that influence the sustainability. There is a pressing need to evolve and implement appropriate strategies that must be sound on technical, social, institutional, and economical dimensions for sustainable development and management of tank systems. (Arumugam *et al.,* 1997).

MATERIAL AND METHODS

Ex-post facto research design was adopted for the study, since the variables chosen for the study have already occurred.Telangana was selected purposively for the study, in Telangana state Warangal and Nalgonda districts, where more number of tanks was selected for restoration under Mission Kakatiya in the year 2014-15 was purposively selected for the present study. One tank in each district i.e Ooracheruvu tank from Kundaram village in Warangal district and Peddacheruvu tank from Chandupatla village in Nalgonda district, total of two tanks where in all the activities of Mission Kakatiya were completed, those tanks were purposively selected for the study.

The respondents are selected using random sampling technique. A sample of 180 beneficiary households were selected from each restored tank in each district and 180 non beneficiary households who are not covered under Mission Kakatiya were selected. Thus, a total of 720 households (360 from each district) were considered.

Descriptive analysis was done by working out simple averages, percentages of characteristics of sample farm households such as age, education status and size of operational holding, benefits from tank renovation, opinions and constraints faced by the farmers. The percentages and averages were computed and compared to draw meaningful inferences.

Garrett ranking technique was used to rank the problems or factors influencing the tank maintenance activities. In the Garrett's scoring technique, the respondents were asked to rank the factors or problems and these ranks were converted into percent position by using the formula

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

Where,

R_{ij} = Ranking given to the i^{th} attribute by the j^{th} individual

N_j = Number of attributes ranked by the j^{th} individual.

By referring to the Garrett's table, the percent positions estimated were converted into scores. Thus, for each factor the scores of the various respondents were added and the mean values were estimated. The mean values thus obtained for each of the attributes were arranged in descending order. The attributes with the highest mean value was considered as the most important one and the others followed in that order.

RESULTS AND DISCUSSION

The socio economic characteristics of the sample farmers are presented in the table 1, revealed that, majority number of respondents belonged to middle age (36-55 years) in both tank and non-tank areas accounting for 69.17 and 51.94 percent respectively followed by old age group (>55 years) i.e., 23.89 percent in tank area and 35 percent in non-tank area.It is confirmed that majority of the sample farmers in both the areas belong to middle age group.

The educational level of sample farmers in the case of tank area was higher than the non-tank area. About 23.61 percent of farmers in tank area were illiterates, whereas about 55.83 percent of farmers in case of non-tank area were illiterates. It was found that 41.94 percent and 26.11 percent of the farmers were educated up to primary level in case of tank and non-tank areas respectively.

The average land holding was 0.44 ha and 1.36 ha in areas with and without tanks, respectively. Majority of the farmers selected under tanks were marginal (56.11%), followed by small (30.83%), medium (7.78%) and large (5.28%) categories. In non-tank area

41.11 percent of farmers were marginal, while 36.11, 10 and 6.67 per cent farmers were small, medium and large farmers' respectively.The continuous subdivision and fragmentation of land among the legal heirs of farmers in the study area may be the reason for prevalence of more number of small and marginal farms in the study area.

The majority of the sample respondents in both tank (65.28 %) and non-tank (63.33%) areas belong to OBC category, followed by SC and ST category in tank (25.56 %) and non-tank (21.67 %) areas. The percentage of sample farmers fall under OC category both in tank and non-tank areas were 9.17 and 15 percent respectively.

All the farmers in case of tank area have tube well irrigation under tank ayacut, because purposively selected farmers under tank ayacut as sample units for the study. However, majority (81.11%) of the selected farmers in non- tank area have tube wells as main source of irrigation followed by open well (17.22%) and other sources (1.67%) for farming.

Particulars presented in Table 2 represent the impact of silt application as opined by sample farmers.Out of 720 sample farmers 268 farmers applied silt in their field. All of them (100%) opined that the yield was increased and FYM usage was reduced after application of silt in their fields. 86.19 percent of silt applied sample farmers opined that the number of irrigations were reduced, while the remaining (13.81%) said that there was no change in the number of irrigations given to crops after silt application. Similarly, 79.85 and 20.15 percent of the farmers opined that usage of fertilizers in the fields decreased and no change in fertilizer usage respectively. 42.91 percent of the sample farmers opined that pesticide application decreased and 57.09 percent felt there was no change in the application of pesticides after application of silt in their fields. From the above results, it could be concluded that the application of silt in the fields has positive impact in different ways. As opined by sample farmers it may be due to the improvement in the soil condition and increase in water retention capacity.

Advantages of Mission Kakatiya as opined by sample farmers in tank area is presented in Table 3.Total 360 sample farmers opined that the major advantages of Mission Kakatiya were increased ground water level, water availability for irrigation, birds and livestock, increased animal grazing hours and crop yields. These results indicated that, restoration of tanks under Mission Kakatiya has many advantages leading to improvement in rural economy in terms of higher yields and income.

The particulars regarding factors influencing participation of sample farmers in tank maintenance activities are presented in Table 4. Availability of irrigation water was found to be the most important factor influencing sample farmers to participate in tank maintenance activities, ranked first with mean score of 78.89. This was followed by water availability for domestic use with mean score of 60.56. Water availability for livestock drinking and increased grazing hours was ranked third with mean score of 58.66. Whereas, fourth, fifth and sixth ranks were given to factors like small size of land holdings, support from local organization and past experience / success stories of tank restoration respectively with mean scores of 48.06, 45.38 and 39.58.These opinions of sample farmers were also clearly reflecting the increased water availability for different uses made them to participate in tank restoration and maintenance activities taken up under Mission Kakatiya.

The factors influencing non-participation in tank maintenance activities by sample farmers are presented in the Table 5. The most important reason i.e., expecting government to do repairs and maintenance was ranked first with 77.62 mean score. The poor income levels of the sample farmers, lack of cooperation among the farmers, labour scarcity and far away from the tank were ranked second, third, fourth and fifth with mean scores of 73.53, 69.64, 66.11 and 54.02 respectively. Non-participation behaviour of the sample farmers in tank maintenance may be decreased by making it as responsibility of the tank users only. These results were similar with findings of Desai (2005).

Apart from the tank beneficiaries, the opinion on benefits of restoration of tanks was obtained from sample farmers in non-tank areas also and presented in Table 6. As revealed from the data in the table, the major benefit of tank ecosystem was found to be increase in ground water recharge (first rank) with mean score of 78.99. This was followed by availability of irrigation water (second rank) with mean score of 75.10.

Table 1. Socio-economic characteristics of the sample farmers

Category	Tank area (n=360)		Non-tank area (n=360)	
	Number	Percent	Number	Percent
Young age (up to 35)	25	6.94	47	13.06
Middle age (36-55)	249	69.17	187	51.94
Old age(>55years)	86	23.89	126	35.00
Illiterates	85	23.61	201	55.83
Primary	151	41.94	94	26.11
Secondary	117	32.50	34	9.44
College	7	1.94	31	8.61
Marginal farmers (upto 1 ha)	202	56.11	148	41.11
Small farmers (1 – 2 ha)	111	30.83	152	36.11
Medium farmers (2 - 4 ha)	28	7.78	36	10.00
Large farmers (Above 4 ha)	19	5.28	24	6.67
OC	33	9.17	54	15.00
OBC	235	65.28	228	63.33
SC and ST	92	25.56	78	21.67
Tank + Tube well	360	100	-	-
Tube well	-	-	292	81.11
Open well	-	-	62	17.22
Other sources	-	-	6	1.67

Table 2. Impact of silt application as opined by sample farmers

S.No	Particulars	Sample farmers response (in number)			
		Increased	Decreased	No change	Total
1.	Yield	268 (100)	0	0	268 (100)
2.	Number of Irrigations	0	231(86.19)	37 (13.81)	268 (100)
3.	Fertilizers	0	214 (79.85)	54 (20.15)	268 (100)
4.	Pesticides	0	115 (42.91)	153 (57.09)	268 (100)
5.	FYM	0	268 (100)	0	268 (100)

Note: Figures in parenthesis are percentages to their respective totals

Table 3. Advantages of Mission Kakatiya as opined by sample farmers in tank area

S.No	Particulars	Sample farmers response (in number)		
		Increased	Decreased	Total
1.	Ground water level	360 (100)	0	360 (100)
2.	Water availability for irrigation	360 (100)	0	360 (100)
3.	Water availability for birds and livestock	360 (100)	0	360 (100)
4.	Animal grazing hours	360 (100)	0	360 (100)
5.	Crop yields	360 (100)	0	360 (100)

Note: Figures in parenthesis are percentages to their respective totals

Table 4. Factors influencing participation of sample farmers in tank maintenance activities

S. No	Particulars	Garrett Score	Rank
1.	Water availability for irrigation	78.89	I
2.	Water availability for domestic use	60.56	II
3.	Water availability for livestock drinking and increased grazing hours	58.66	III
4.	Small size of land holding	48.06	IV
5.	Huge initial investment on wells	33.59	VIII
6.	Water scarcity	35.36	VII
7.	Support from local organization	45.38	V
8.	Past experience/success stories	39.58	VI

Table 5. Factors influencing non-participation in tank maintenance activities by sample farmers

S. No	Particulars	Garrett Score	Rank
1.	Non availability of water in tank	48.92	VI
2.	Lack of cooperation among the farmers	69.64	III
3.	Far away from the tank/tail end location	54.02	V
4.	Illiteracy	42.91	VIII
5.	Sufficient water availability in owned land	46.75	VII
6.	Expecting government to do repairs and maintenance	77.62	I
7.	Poor income	73.53	II
8.	Labour scarcity	66.11	IV

Table 6. Perceived benefits of tank ecosystem by sample farmers in non- tank areas

S. No	Particulars	Garrett Score	Rank
1.	Irrigation	75.10	II
2.	Fish source	71.16	IV
3.	Domestic use	72.49	III
4.	Livestock use	62.63	V
5.	Nutrient deposition	52.34	VI
6.	Ground water recharge	78.99	I
7.	Protection from natural calamity	48.05	VII
8.	Bird's resting place	38.84	VIII
9.	No benefits	32.81	IX

Similarly, other benefits that were ranked as third, fourth and fifth include water availability for domestic use, increase in profitable fish farming and use of tank water for livestock with mean scores of 72.49, 71.16 and 62.63 respectively. With these reasons farmers who were not beneficiaries of Mission Kakatiya are also very much interested to conserve their ecosystem.

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Research Note
The J. Res. PJTSAU 48 (1&2) 75-78, 2020

ECONOMICAL EFFICACY OF DIURON AS A WEED CONTROL OPTION IN RAINFED COTTON

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Date of Receipt : 11-05-2020 Date of Acceptance : 16-06-2020

Cotton, popularly known as "King of fibre" and "White gold" is the most important fibre and commercial crop of India. The contribution of India to global cotton fibre and edible oil production is 44 and 10%, respectively. Though India has the largest area (26%) of cotton in the world, due to its lower productivity the share to the total world cotton production is only 12%. Weeds consume 5 to 6 times of N, 5 to 12 times of P and 2 to 5 times of K more than cotton crop and thus reduced the cotton yield from 54 to 85% (Jain *et al.* 1981). Cotton is very sensitive to crop-weed competition due to slow growth during early stage and wider spacing.Weed infestation in cotton has been reported to offer severe competition causing yield reduction to an extent of 74 percent (Shelke and Bhosle, 1990), 50 to 85 percent (Sharma, 2008) depending upon the nature and intensity of weeds. The critical period of weed competition in cotton was found to be 15 to 60 days (Sharma, 2008). Weed management options should prevent weed interference, be economical and sustainable, reduce weed seed bank in soil, prevent weed resistance and neither cause phytotoxicity to cotton nor reduce the cotton lint quality. Manual weeding has traditionally been a labour intensive operation and hence there is no other alternative rather than use of post emergence herbicides for control of weeds in cotton. Herbicide is an economic alternative when labour is a problem or in abnormal weather situation where fields are not accessible for mechanical weeding.

Pre-emergence herbicides like alachlor and pendimethalin are most widely used and registered herbicides to give initial weed control in cotton but the crop being a long duration one, the late emerging weeds need to be controlled mechanically or by using post emergence herbicides. As alachlor is being phased out for use by 2020, pendimethalin will be the only PE herbicide for cotton. Using the same herbicide over long period will result in poor bioefficacy and development of resistance in weeds.Diuron which belongs to substituted urea group has a prolonged soil residual life (80-230 days) and hence proves to be a good herbicide for cotton crop. In an experimental study conducted in PJTSAU, significant reduction in plant population in black soil was noticed with preemergence application of diuron 80% WP at 1.0 kg ha^{-1}.Hence there is a need to evaluate the economical efficiency of diuron for pre-emergence use, keeping in view the safe practice of rotating herbicides with different modes of action in both red and black soils.

A field experiment was conducted at College farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State during *kharif*, 2017. The experiment was conducted in red and black soil and laid out in a randomised block design with three replications. The treatments under test included three doses of diuron (0.5, 0.75 and 1.0 kg ha^{-1}), pendimethalin 38.7% CS at 677 g ha^{-1} as PE followed by sequential application of pyrithiobac sodium 10% EC 62.5 g ha^{-1} + quizalofop p ethyl 5% EC 50 g ha^{-1}, intercropping of cotton with green manure crop (sunhemp), mechanical weeding thrice at 20, 40 and 60 DAS (weed free), polymulch and unweeded control.

Mallika *Bt* variety of cotton with a seed rate of 2.5 kg ha^{-1} was sown for the experiment. One-two seeds per hill were sown at a spacing of 75cm X 75 cm to facilitate the use of power weeder in both directions in case of mechanical weeding. Diuron 80% W.P. at 0.5 kg ha^{-1}, diuron 80% W.P. at 0.75 kg ha^{-1}, diuron 80% WP 1.0 kg ha^{-1}, pendimethalin 38.7% CS 677 g ha^{-1} were sprayed on the third day, pyrithiobac sodium 10% EC 62.5 g ha^{-1}+ quizalofop p ethyl 5%

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EC 50 g ha^{-1} were sprayed at 2-3 leaf stage of the weeds. In the intercropping treatment the intercrop sunhemp was sown along with cotton. Polymulch was spread 8 DAS after emergence of the seedling. Mechanical weeding at 20, 40, 60 DAS was done with power weeder and an unweeded check was maintained.

The weed species associated with *Bt* Cotton crop in the experimental area were recorded at 30, 60 and 90 DAS. At each picking, seed cotton obtained from the net plot was weighed. The cumulative yield from three pickings (127, 142 and 167) in plots in each treatment was expressed as yield in kg ha^{-1}.The cotton stalk was uprooted from net plot area of treatment and sun dried for one week and the weight was recorded. The stalk yield (kg ha^{-1}) was worked out. Economics in terms of cost of cultivation, gross returns, net returns and B: C ratio were calculated as per existing market prices.

Polymulch treatment incurred higher cost of cultivation due to the investment required for poly sheet of 25 micron thickness. The purchase of the polymulch was needed in both years as the polythene was damaged due to crop growth, various biotic and abiotic factors. Then the next treatment which required higher investment was mechanical weeding which included the cost of diesel required to operate the power weeder and also the charges for skilled operator. It was then followed by the chemical methods and the least cost of cultivation was incurred with unweeded control as there was no money or energy spent for weed management while other cultural operations remained same for all the treatments.

In red soil, polymulch (2425 kg ha^{-1}) registered significantly highest yield which was on par with mechanical weeding thrice (2108 kg ha^{-1}). In case of chemical treatments, diuron 1.0 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE (2046 kg ha^{-1}) was statistically comparable to mechanical weeding and significantly superior to the other herbicidal treatments. While in black soil, significantly higher yield was achieved in polymulch (3464 kg ha^{-1}) treatment and was followed by mechanical weeding thrice (2749 kg ha^{-1}). Diuron 0.75 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE (2655 kg ha^{-1}) recorded the highest yield among the chemical weed control practices and was comparable to mechanical weeding treatment in contrast to red soils. While the higher dose of 1.0 kg ha^{-1} of diuron did not result in higher yields due to the reduced plant stand by phytotoxic effect of the chemical.

Considering the gross returns in red soil, polymulch treatment (Rs.104741 ha^{-1}) received significantly highest gross returns which was comparable to mechanical weeding thrice (Rs. 91079 ha^{-1}) due to the higher yields obtained. Among the chemical weed control practices, diuron 1.0 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE (Rs. 79304 ha^{-1})was statistically on par with mechanical weeding thrice at 20, 40, 60 DAS and the best among the chemical treatments which was followed by other doses of diuron, pendimethalin and inter crop with sunhemp. While in case of black soil, polymulch (Rs.149630 ha^{-1}) recorded highest gross returns and was significantly superior to the mechanical weeding thrice (Rs.118780 ha^{-1}). Unlike the red soils, the treatment diuron 0.75 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE (Rs.106332 ha^{-1}) recorded the highest gross returns among the chemical weed control practices and was on par with that of mechanical weeding treatment, while the higher dose of 1.0 kg ha^{-1}of diuron did not result in higher gross returns but however was on par with former treatment. Diuron 0.5 kg ha^{-1} as PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE, pendimethalin as PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE and inter crop with sunhemp which were comparable to each other. These results are in accordance with the findings of Singh *et al.* (2016), and Yadahalli (2013).

In red soils, mechanical weeding thrice (Rs.46763 ha^{-1}) gave maximum net returns which was comparable to polymulch (Rs.43725 ha^{-1}) and diuron 1.0 kg ha^{-1} as PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE (Rs.41840 ha^{-1}) and these treatments were significantly superior over other treatments. Diuron 0.75 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE was on par with diuron 1.0 kg ha^{-1} and polymulch and also with diuron 0.5 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE. While negative returns were observed with intercrop with sunhemp and unweeded control.

And in black soils, significantly higher net returns were reported by polymulch (Rs.88614 ha^{-1}) which was on par with mechanical weeding thrice

Table 1. Economics in cotton as influenced by weed control options adopted

Treatments	Red soil					Black soil				
	Kapas yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio	Kapas yield (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Diuron 80% WP 0.5 kg ha^{-1} *fb* pyrithiobac sodium 10% EC 62.5 g ha^{-1} + quizalofop p ethyl 5% EC 50 g ha^{-1}	1,409	36857	65203	28345	1.77	1,552	36857	67040	30183	1.82
Diuron 80% WP 0.75 kg ha^{-1} *fb* pyrithiobac sodium 10% EC 62.5 g ha^{-1} + quizalofop ethyl 5% EC 50 g ha^{-1}	1,622	37161	74680	37519	2.01	2,655	37161	106332	69171	2.86
Diuron 80% WP 1.0 kg ha^{-1} *fb* pyrithiobac sodium 10% EC 62.5 g ha^{-1} + quizalofop p ethyl 5% EC 50 g ha^{-1}	2,046	37464	79304	41840	2.12	2,040	37464	88114	50650	2.35
Pendimethalin 38.7% CS at 677 g ha^{-1} *fb* pyrithiobac sodium 10% EC 62.5 g ha^{-1} + quizalofop p ethyl 5% EC 50 g ha^{-1}	1,389	37756	59984	22228	1.59	1,498	37756	64694	26938	1.71
Cotton + sunhemp	648	32816	27993	-6073	0.85	1,032	32816	44582	10516	1.36
Mechanical weeding at 20, 40, 60 DAS	2,108	44316	91079	46763	2.06	2,749	44316	118780	74464	2.68
Control (unweeded)	83	31016	3600	-27416	0.12	102	31016	4393	-26623	0.14
Polymulch of 0.25 mm thickness	2,425	61016	104741	43,725	1.72	3,464	61016	149630	88614	2.45
SE(m)±	121.6	-	4,659.8	4,659.8	-	211.6	-	9039.1	9,039.1	-
C.D. (p=0.05)	372.4	-	14271.1	14,271.0	-	648.1	-	27683.0	27,683.0	-

(Rs.74464 ha^{-1}) and diuron 0.75 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE (Rs.69171 ha^{-1}). Diuron 1.0 kg ha^{-1} as PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE was on par with diuron at 0.75 kg ha^{-1} and also with diuron 80% WP a 0.5 kg ha^{-1} and pendimethalin as PE *fb* pyrithiobac sodium + quizalofop p ethyl as PoE. Negative returns were obtained with unweeded control (Rs.-26623 ha^{-1}). Here in black soils polymulch reported higher net returns due to the greater increase in yield and higher net returns were reported in diuron 0.75 kg ha^{-1} than 1.0 kg ha^{-1} which might be due to the reduced yield in diuron 1.0 kg ha^{-1} treatment by phytotoxicity observed on plant stand. The results are in accordance with Prabhu *et al.* (2012), Singh and Katti (1972) and Nayak *et al.* (2016).

The perusal of data on B: C ratio in red soil indicated that diuron 1.0 kg ha^{-1} as PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE recorded highest B:C ratio (2.12) which was *fb* mechanical weeding thrice (2.06), diuron 0.75 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl POE (2.01) and polymulch (1.72).Diuron 0.75 kg ha^{-1} PE *fb* pyrithiobac sodium + quizalofop p ethyl PoE registered highest B: C ratio (2.86) *fb* mechanical weeding thrice at 20, 40, 60 DAS (2.68) and polymulch (2.45) in black soil. Similar findings were reported by Hanumanth (2017), and Prabhu *et al.* (2011).

From this study, it can be concluded that higher gross and net returns were realised with polymulch which is comparable to mechanical weeding thrice at 20, 40, 60 DAS, diuron at 1.0 kg ha^{-1} PE *fb* pyrithiobacsodium+ quizalofop p ethyl PoE in red soil and diuron at 0.75 kg ha^{-1} PE *fb* pyrithiobacsodium+ quizalofop p ethyl PoE in black soil. Maximum B:C ratio was obtained with diuron at 1.0 kg ha^{-1} PE *fb* pyrithiobacsodium+ quizalofop p ethyl PoE in red soil and diuron at 0.75 kg ha^{-1} PE *fb* pyrithiobacsodium+ quizalofop p ethyl PoE in black soil.

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Research Note
The J. Res. PJTSAU 48 (1&2) 79-84, 2020

A STUDY ON PRICE BEHAVIOUR OF IMPORTANT VEGETABLES IN HYDERABAD

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Agriculture plays a vital role in Indian economy. India is the second largest producer of vegetables, next to China with annual production of 184 million tonnes in the year 2017-18 accounting for nearly 12 percent of world production of vegetables.Uttar Pradesh and West Bengal are the largest vegetable producing states in India with annual production of nearly 29 and 28 million tonnes accounting for 15.4 and 15.04 percent of total vegetables production respectively. Telangana state accounts for only 1.4 percent of total vegetables production in india with annual production of 2.7 million tonnes in 2017-18.

Prices play an important role in Indian agriculture as it directly influences the decision making of farmers and consumers. The price of vegetables fluctuates mainly due to their seasonality and perishability in nature. The knowledge of the nature and magnitude of price movements is utmost important to the policy makers and those who engaged at various levels of their production and marketing. The market imperfections are also providing disincentive to the growers in increasing vegetable production. Thus, the price behaviour of vegetables, spatial or temporal, has a definite bearing upon the rationality of the decisions by the growers as well as traders. Therefore, the price behaviour of major vegetables needs to be studied from time to time. Hence, the present study was undertaken to study the price behaviour of important vegetables in Hyderabad. The study is based on secondary data collected from major markets of Hyderabad namely Gudimalkapur and Bowenpally markets for tomato, potato, brinjal and bhendi and Gudimalkapur and Malakpet market for onion based on maximum arrivals. The monthly modal prices and arrivals were collected for the period from 2009 to 2018. The study was confined to the major vegetables namely Tomato (29.80%), Onion (12.99%), Brinjal (8.10%), Bhendi (8.74%) and Potato (2.41%) considering their share in total area of Telangana state under vegetables and based on their importance in day-to-day consumption. To study the secular trend, simple linear trend line method was employed. Twelve months ratio to moving average method was used for estimating seasonal indices

TREND ANALYSIS

Analysis of trend enables us to indicate the general direction of movement in prices in different markets over the years from 2009 to 2018.The result shows that for tomato (Table1) there was an increasing trend in the arrivals and prices in the selected markets. With regard to arrivals, the monthly increase was high in Bowenpally market (468 qtls) compared to Gudimalkapur market (233 qtls). As observed in tomato, there was an increasing trend in the prices and arrivals of potato, onion, brinjal and bhendi in the selected markets. The monthly increase in potato prices was found to be highest in Bowenpally market (Rs 4.53/ qtl) and lowest in Gudimalkapur market (Rs.2.97/qtl). Similarly for arrivals, the monthly increase was highest in Bowenpally market (629 qtls) and lowest in Gudimalkapur market (199 qtls).,(Table2)

For onion, (Table3) Malakpet market had the highest monthly increase in prices at Rs.4.19 /qtl and Gudimalkapur market lowest monthly increase in prices at Rs.3.20 /qtl. Similarly for arrivals, the monthly increase was highest in Malakpet market (100 qtls) and lowest in Gudimalkapur market (50 qtls). The monthly increase in the brinjal prices (Table 4) was found to be highest in Bowenpally market (Rs.9 /qtl) and lowest in Gudimalkapur market (Rs.4.75/qtl). Similarly, the monthly increase in arrivals was highest in Bowenpally market (31 qtls) and lowest in Gudimalkapur market 18 qtls) respectively.

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Table 1. Trends in the prices and arrivals of Tomato in the selected markets from 2009 to 2018

Market		Equation	R^2	t
Gudimalkapur	Prices	733.90+2.9t	0.21	4.62**
	Arrivals	5109.77+233.37t	0.10	3.65**
Bowenpally	Prices	621.5+2.01t	0.10	3.65**
	Arrivals	14605.02+468t	0.58	12.89**

** Significant at 1% level

Table 2. Trends in the prices and arrivals of Potato in the selected markets from 2009 to 2018

Market		Equation	R^2	t
Gudimalkapur	Prices	770.90+2.97t	0.17	3.13**
	Arrivals	3203.77+199.37t	0.52	11.42**
Bowenpally	Prices	846.78+4.531t	0.13	4.20**
	Arrivals	12218.02+629t	0.76	19.68**

** Significant at 1% level

Table 3. Trends in the prices and arrivals of Onion in the selected markets from 2009 to 2018

Market		Equation	R^2	t
Gudimalkapur	Prices	754.54+3.20t	0.13	4.14**
	Arrivals	1366+50.33t	0.38	8.25**
Malakpet	Prices	775.21+4.19t	0.05	2.51**
	Arrivals	2460.95+100.7t	0.30	7.20**

** Significant at 1% level

Table 4. Trends in the prices and arrivals of Brinjal in the selected markets from 2009 to 2018

Market		Equation	R^2	t
Gudimalkapur	Prices	465.48+4.75t	0.17	4.94**
	Arrivals	537.08+18.29t	0.67	13.74**
Bowenpally	Prices	406.54+9.00t	0.40	8.87**
	Arrivals	1411.02+31.72t	0.59	13.17**

** Significant at 1% level

The monthly increase in bhendi price (Table 5) was found to be highest in Gudimalkapur market (Rs. 2.87 /qtl) and lowest in Bowenpally market (Rs.1.21 /qtl) while the monthly increase in arrivals was highest in Bowenpally market (43 qtls) and lowest in Gudimalkapur market (36 qtls). Thus the results show that for tomato, potato, onion, brinjal and bhendi, there was positive and increasing trend for both the arrivals and prices in the selected markets. The coefficients obtained were statistically significant at 1 percent level of significance. This suggests that there was significant increase in prices and arrivals of selected vegetables over the study period in both the markets. The long term increasing trend in arrivals may be due to factors

Table 5. Trends in the prices and arrivals of Bhendi in the selected markets from 2009 to 2018

Market		Equation	R^2	t
Gudimalkapur	Prices	1043+2.87t	0.20	3.32**
	Arrivals	554.23+36.05t	0.75	19.28**
Bowenpally	Prices	1182.04+1.21t	0.18	3.36**
	Arrivals	1411.02+43.36t	0.36	8.25**

** Significant at 1% level

like increase in cultivated area, technological improvements, improvement in production and productivity and the long term increasing trend in prices may be due to growth in real per capita income levels and population. However, the long term increasing trend in both arrivals and prices implies the scope for expansion of vegetable cultivation in the future but little care has to be taken that supply do not exceed the demand in the market so that vegetables can be marketed sustainably and profitably by sellers.Mishra and Kumar (2012) also found positive increasing trend in prices of tomato in the hill region of Nepal during the study period from 2000 to 2010 which indicated that irrespective of increase in supply, the price also increased, due to faster rate of growth in demand than supply.

SEASONAL VARIATIONS

Tomato

The harvesting period for tomato is mainly from August to September month (*kharif*) and December to February month (*Rabi*). The season arrivals were almost similar in both markets with higher arrivals coinciding with *kharif* and *rabi* harvesting season and lower arrival index during the off- season (Table 6). High price indices were found in lean month of arrivals while, low price indices were observed in post-harvest months. Due to perishable nature of tomato, it is usually marketed immediately during the post-harvest period creating a glut in the markets. These results are in line with Khunt *et.al* (2006).He reported an inverse relationship between the prices and arrival index of tomato with higher arrivals during post-harvest season

Table 6. Seasonal indices of Tomato prices and arrivals in selected markets from 2009 to 2018

Month	Gudimalkapur		Bowenpally	
	Prices	Arrivals	Prices	Arrivals
Jan	56.33	105.49	68.62	102.06
Feb	46.63	103.95	47.03	76.20
Mar	55.19	87.65	46.69	75.79
Apr	68.44	77.16	67.73	73.81
May	111.58	90.14	105.47	83.64
Jun	157.37	90.83	167.78	84.99
Jul	211.54	96.84	194.07	91.67
Aug	105.53	112.16	108.01	109.25
Sep	81.47	115.81	76.12	120.09
Oct	101.99	113.63	103.80	145.74
Nov	116.90	112.91	135.25	129.53
Dec	87.02	103.42	79.43	117.23
CV (%)	47.15	12.41	46.08	23.12

and lower arrival index during lean season in the selected markets in Gujarat.

Potato

In both the markets, the arrival indices were high when the prices indices were high and vice versa indicating a positive correlation between the arrivals and prices of potato (Table 7). Potato is mostly grown as *Rabi* crop on northern plains with the sowing period from mid-September to November and the harvesting period from December to March. Due to adequate cold storage facilities and semi-perishable nature of potato, sellers can adjust their supply to the variation in prices, making it less seasonal in nature.Similar results were observed by Dhiraj *et.al* (2017) in their study on potato in the markets of Uttar Pradesh. They found that market price index for potato was higher during October-November months and lowest in the month of February.

Table 7. Seasonal indices of potato prices and arrivals in selected markets from 2009 to 2018

Month	Gudimalkapur		Bowenpally	
	Prices	Arrivals	Prices	Arrivals
Jan	79.17	67.73	74.01	86.09
Feb	70.27	65.82	71.86	67.29
Mar	79.20	94.34	82.59	96.92
Apr	92.34	100.40	98.72	101.41
May	103.48	110.45	102.82	106.66
Jun	104.74	111.80	108.58	89.41
Jul	108.14	120.20	106.97	102.29
Aug	109.72	114.14	109.26	108.97
Sep	113.32	106.80	109.53	108.07
Oct	117.47	114.67	114.06	111.35
Nov	120.26	109.16	120.32	114.90
Dec	101.88	84.49	101.26	106.62
CV (%)	16.24	18.30	15.64	13.00

Onion

The harvesting periods for Onion are September to October (*kharif*), January to March (late *Kharif)* and from March to May (*Rabi*) Onion is mainly grown as rabi crop in major producing states. Nearly 70 percent of total arrivals were during *rabi* post-harvest periods in both the selected markets where price indices were also ruled low (Table 8). The higher price index was observed in the lean period of arrivals during August to October months.

In both the markets the price indices were higher during August to January months while lower during February to July months.However, the arrival index was exactly opposite with higher indices during January to June months and lower indices during the August to December months.

Brinjal

Though brinjal can be grown as round the year crop, the peak harvesting season was October to December and January to April months. Both the markets had almost similar seasonal arrivals with higher arrival index coinciding with the peak harvesting season and low arrival index coinciding with the off- season (Table 9). High price indices were found in lean period of arrivals and low price indices during the high arrivals periods. The same trend was also observed in Bowenpally market. These results are on par with the results of Khunt *et.al* (2006) who also found that the low price index was during high arrivals period and high price index during low arrivals period in Gujarat.

Table 8. Seasonal indices of Onion prices and arrivals in selected markets from 2009 to 2018

Month	Gudimalkapur		Malakpet	
	Prices	Arrivals	Prices	Arrivals
Jan	122.09	111.64	116.13	99.40
Feb	91.72	108.74	93.30	96.27
Mar	73.23	121.08	75.10	135.23
Apr	64.20	106.11	62.59	119.58
May	55.21	105.33	64.44	105.81
Jun	78.18	88.48	88.19	107.23
Jul	97.83	84.88	94.90	54.40
Aug	133.00	80.62	119.21	57.53
Sep	126.13	85.88	132.47	91.13
Oct	117.86	90.94	113.05	101.41
Nov	128.36	101.76	117.82	123.03
Dec	112.14	114.53	122.80	108.98
CV (%)	27.53	13.85	23.71	23.92

Table 9. Seasonal indices of Brinjal prices and arrivals in selected markets from 2009 to 2018

Month	Gudimalkapur		Bowenpally	
	Prices	Arrivals	Prices	Arrivals
Jan	78.45	84.95	86.66	82.15
Feb	70.93	95.02	80.94	101.15
Mar	72.17	112.59	70.85	101.60
Apr	71.45	101.88	74.58	84.92
May	99.21	97.15	85.92	81.91
Jun	114.63	96.47	114.05	76.85
Jul	103.31	97.78	104.55	81.57
Aug	130.90	92.32	119.77	102.03
Sep	130.53	91.59	114.73	112.06
Oct	117.44	100.44	133.09	104.96
Nov	127.34	116.00	129.99	147.68
Dec	83.66	113.81	84.89	123.12
CV (%)	23.99	9.61	21.91	20.74

Bhendi

The lowest price index and highest arrival index was found during the *kharif* harvesting season in both the markets from July to September as bhendi was mainly grown in June to July rainy season (Table 10). Mukesh and Bhogal (2003) also revealed this kind of well-marked seasonality in the price and arrival index of bhendi in Uttar Pradesh.

The relationship between wholesale price and market arrival of all the selected vegetables except potato was negative mainly due to seasonal production, perishable nature and lack of storage facilities. Selling the vegetables in the post-harvest period by producers is creating a glut in the market and thus slump in prices. In case of potato, there is positive relationship between arrivals and prices reflecting the seller's decision to sell the produce during higher prices in the market due to its semi-perishable nature and adequate storage facilities available.

The foregoing analysis of results showed an increasing trend in prices and arrivals of all the major vegetables indicating the scope for further expansion in vegetable cultivation and production as Telangana state accounts for only 1.4 percent of total vegetable production in India.

There is seasonality in arrivals and prices of all the major vegetables in the markets. This indicates the need for adequate cold storage facilities, quick transportation, processing facilities, improved market information system and suitable post-harvest market intervention policies to reduce the price fluctuations within the year and meet the interests of producer and consumers.

Table 10. Seasonal indices of Bhendi prices and arrivals in selected markets from 2009 to 2018

Month	Gudimalkapur		Bowenpally	
	Prices	Arrivals	Prices	Arrivals
Jan	109.07	100.68	102.78	91.76
Feb	112.92	93.768	97.12	90.79
Mar	114.96	107.83	107.85	110.83
Apr	92.14	91.00	83.52	109.80
May	103.45	77.53	92.84	88.73
Jun	114.51	77.24	112.97	79.69
Jul	81.58	109.54	90.33	115.27
Aug	80.23	113.02	84.98	132.75
Sep	80.00	115.91	82.91	118.45
Oct	91.33	104.30	100.44	98.56
Nov	108.92	103.39	122.33	87.55
Dec	110.90	105.73	121.92	75.81
CV (%)	14.02	12.73	14.01	17.30

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Research Note
The J. Res. PJTSAU 48 (1&2) 85-88, 2020

UTILIZATION OF INFORMATION SOURCES BY PROGRESSIVE AND NON-PROGRESSIVE FARMERS OF KARNATAKA STATE

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Date of Receipt : 29-02-2020 Date of Acceptance : 04-06-2020

Information sources are the various means by which a piece of information is recorded for use by an individual. It is how a person is informed about something or knowledge is availed to someone or a group of people. Patel *et al.*, (1993) have suggested that in a developing country like India, dissemination of agricultural information and improved technology through the use of latest communication technology can play a great role in agricultural development. Knowledge derived from formal research, or developed in other localities, can stimulate new thinking and practices (Figueroa *et al.*, 2002). So it is evident that proper dissemination of information is highly necessary for agriculture development.

Indian Agriculture is on the threshold of a second revolution. It is becoming increasingly clear that the next leap will come from the information and the knowledge transfer to the agricultural sector together with other traditional inputs and interventions. Information sources play a vital role in agriculture and rural development (Garforth *et al.*, 2003). It serves as an important resource in modern agriculture.

The result of farmers adopting any technology also depends on the type of information source they utilized.Hence the source should be relevant and should provide true information then only it helps the end-users. Choo (2012) affirmed that people use the information to create knowledge, but not just in the sense of data and facts but the form of representations that provide meaning and the context for purposive action.

The flow of information should be understandable, well interpreted, accepted and liked by the users and also be as fast as possible. Information sources have a vital role to carry the messages of improved practices from sources to the ultimate users. Farmers usually receive information from various sources to accomplish their farming needs. The preferences of information sources vary from farmer to farmer. But most of the extension organizations have limited scope and time to research how the preference of different information sources influence the dissemination of new improved technologies. The present study was conducted with the following objectives: (i)To identify the information sources used by progressive and non-progressive farmers in receiving farm information; (ii) To examine the overall use of information sources by the progressive and non-progressive farmers.

The study was conducted in Karnataka State. A purposive sample of 200 respondents was selected for the study, of which 100 respondents were selected purposively from the database of awardees, achievers and innovative farmers from University of Agricultural Sciences, Dharwad, University of Agricultural Sciences, Bangalore, University of Agricultural Sciences, Raichur, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka State Department of Agriculture and other sources like NGOs, Societies, etc, who considered as progressive farmers for their achievements in farming. While the rest of 100 respondents were considered as non-progressive farmers.The respondents were personally interviewed by the investigator by administering the interview schedule. A list of various information sources viz., formal, informal and mass media was prepared and the responses were obtained on three-point continuum *viz.,* regularly, occasionally and never. With the weightage of 3, 2 and 1 respectively. The maximum and minimum possible scores ranged between 63 and 21, whereas obtained scores were 60 and 24 respectively. For better understanding of the use of

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information sources, Weighted mean score was used. It is calculated by assigning weights *viz.,* 3 to regularly, 2 to occasionally and 1 to never. On the basis of frequency of ratings for each information source, weighted mean scores have been calculated with the help of following formula:

$$\text{WMS} = \frac{\text{Rwurx3} + \text{Rwuox2} + \text{Rwnux}}{\text{Sum of weights}}$$

Where, Rwur = Respondents who used regularly; Rwuo = Respondents who used occasionally; Rwnu = Respondents who never used.

Each information source score was measured according to the use by the respondents. Then the information sources were ranked in a sequential order considering their WMS.

Table 1. Distribution of respondents according to their use of information sources

(N=200)

S.No	Name of Source	Use of Information									
		Progressive farmers					Non-progressive farmers				
		R	O	N	WMS	Rank	R	O	N	WMS	Rank
		Frequency					Frequency				
Formal sources											
1.	State department officials (AAO, AO, ADA)	48	35	17	38.50	IX	41	30	29	35.33	V
2.	Agriculture Scientist	59	23	18	40.17	V	27	34	39	31.33	XIII
3.	*Krishi Vigyan Kendra* (KVK)	59	30	11	41.33	IV	34	36	30	34.00	X
4.	Kisan Call Centre (KCC)	43	38	19	37.33	X	38	35	27	35.17	VI
5.	Veterinary Doctor	28	43	29	33.17	XV	22	31	47	29.17	XV
6.	NGO's	25	29	46	29.83	XVII	19	24	57	27.00	XVIII
Informal sources											
1.	Neighbours	24	39	37	31.17	XVI	58	26	16	40.33	II
2.	Relatives and Friends	38	41	21	36.17	XII	52	41	07	40.83	I
3.	Input dealers	46	31	23	37.17	XI	41	37	22	36.50	III
4.	Progressive farmers	62	48	-	47.00	I	44	25	31	35.50	IV
5.	Local leaders	08	15	77	21.83	XIX	29	45	26	33.83	XI
Mass Media											
1.	Radio	12	29	59	25.50	XVIII	16	32	52	27.33	XVII
2.	Television	63	27	10	42.17	II	31	49	19	35.00	VII
3.	Newspapers	44	51	05	39.83	VII	35	39	26	34.83	VIII
4.	Printed literature	41	31	28	35.50	XIV	13	31	56	26.17	XIX
5.	Exhibition	34	47	18	35.67	XIII	32	32	36	32.67	XII
6.	Agricultural fair	56	28	16	40.00	VI	39	28	33	34.33	IX
7.	Access to mobile alerts	52	33	15	39.50	VIII	24	33	43	30.17	XIV
8.	Access to Internet (Social media)	67	17	16	41.83	III	21	29	49	28.33	XVI

Note: R=Regularly, O=Occasionally, N=Never, WMS=Weighted Mean Score

The results in Table 1 indicated that progressive farmers highly preferred other progressive farmers for getting information compared to other sources of information. This might be due to their feeling that the progressive farmers are really practicing the innovation and it is better to collect information from a person who is actually practicing i.e. credibility of the source. Majority of the progressive farmers are innovative and they are successful in their profession. So the farmers act as a good source of information for the needy. As the locality has electricity facility so television is very common in most of the houses. So, they can watch different agriculture and allied sector programs to get information. Sometimes television acts as a good source of information on getting emergency information especially when natural disasters occur. Even warning of disease outbreak, weather forecast, market price are shown on television. Social media also acts as good information sources for those using smartphones. They are creating groups and sharing useful news in the group. They also opted to *Krishi Vigyan Kendra*, agriculture scientists and agricultural fairs for getting information as the official sources. Local leaders got the least preference for getting information as they opine progressive farmers generally had more knowledge than the local leaders. Radio is the second least used information source. This might be due to the penetration of the use of mobile phones in rural areas which makes the radio outdated nowadays.

It could be observed from Table 1 that non-progressive farmers preferred informal sources of information more than the progressive farmers. Among the informal sources they mostly preferred relatives, friends and neighbours for getting information compared to other sources of information. This might be due to their relative credibility and empathetic proximity with relatives and friends in the society and their availability on the time of information need. Input dealers are next used source of information. This might be due to agri-input dealers in rural domain are very close to farmers in providing extension service to the farmers, and they are easily accessible. There are many places in India where there is no reach of any extension worker or government agencies but Agri-input dealers are doing the extension services. An agri-input dealer plays a multiple role at a time, by providing seeds, fertilizers or pesticides in advance without taking cash, it acts like a financing body. Also provide information about new technology, new variety and about various control measures. Printed literature got the least preference for getting information as non-progressive farmers are not highly educated in the area. So they cannot read and understand the literature clearly. NGO is the second least used information source. Due to their abstaining to the NGO's, Contact with NGO workers is very less.

Table 2. Distribution of respondents according to their overall use of information sources

(N=200)

S.No.	Category	Progressive farmers	Non-progressive farmers
		Frequency & Percentage	Frequency & Percentage
1.	Low (24-36)	18	32
2.	Medium (36-48)	53	57
3.	High (48-60)	29	11
	Total	**100**	**100**
	Mean	**42.85**	**38.16**
	S.D.	**80.10**	**7.25**

The results depicted in Table 2 clearly showed that majority (82.00%) of the progressive farmers fell in medium to high category of use of information sources and only 18 percent of the progressive farmers belonged to the low category of use of information sources. Among non-progressive farmers, the great majority (89.00%) of the farmers fell in medium to low category of use of information sources and only 11 per cent of the non-progressive farmers belonged to the high category of use of information sources. This indicates that progressive farmers had good exposure to the information sources, on the other hand, non-progressive farmers had limited exposure to the information sources.

The study shows that there is enough scope to improve the utilization of the information sources. There is a gap between progressive and non-progressive farmers in terms of information utilization. Non-progressive farmers, still prefer local sources which are something not so authentic. Scientific information sources were less preferred by non-progressive farmers.The field level extension workers of the Department of Agriculture (DoA) should be well acquainted with the local problems and needs so that they can satisfy the information need of the non-progressive farmers. Besides, mass media like television and newspaper should be used more to disseminate emergency information as well as new information. On the other hand, there is an extensive scope to improve the present condition of farmer's information source management through comprehensive campaigns by involving the State Department officials and NGOs as well.

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Research Note
The J. Res. PJTSAU 48 (1&2) 89-93, 2020

GENETIC VARIATION FOR YIELD TRAITS IN MAGIC *INDICA* PLUS POPULATION AND INDIAN RICE GERMPLASM

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Date of Receipt : 19-05-2020 Date of Acceptance : 26-06-2020

Genetic diversity represents the heritable variation within and between populations of accessions. The success of plant breeding depends on the available genetic variability both indigenous as well as exotic to cater to the need of various farming situations of rice. Higher grain production is the primary trait targeted for the improvement of rice productivity in both favourable and unfavourable environments from its present level. Knowledge of the genetic architecture of genotypes is necessary to formulate efficient breeding methodology. It is essential to find out the relative magnitude of additive and non additive genetic variances, heritability, and genetic gain about the characters of concern to the breeder. The crop improvement program generally involves generation of genetic variability, selection, and yield evaluation trails to evolve promising varieties. The large spectrum of genetic variability in segregating populations depends on the level of genetic diversity among genotypes that are chosen for hybridisation. Besides, heritability and genetic advance are other important selection parameters. The evaluation of heritability helps the plant breeder in determining the character for which selection would be rewarding. The breeders are interested in the selection of superior genotypes based on their phenotypic expression. The major function of heritability estimates is to provide information on the transmission of characters from the parents to the progeny. Heritability estimates along with genetic advance are normally helpful in predicting the gain under selection than heritability estimates alone. Keeping in view the importance of the subject, an attempt was made to estimate genetic variability in rice MAGIC *indica* plus lines along with rice accessions and four checks.

The experiment was conducted with 102 MAGIC *indica* plus lines, 106 Indian rice accessions along with 4 checks at the College farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during *kharif*, 2017. The Experiment was planted in Alpha Lattice Design with 3 replications. Each replication was divided into 4 incomplete blocks with 53 plots each. Each entry was planted in 4 rows with a spacing of 15 x 15 cm^2. Observations were recorded on five plants at random in each replication for eight quantitative characters, plant height (PH), number of productive tillers per plant (NPT), panicle length (PL), number of filled grains per panicle (NFG), number of grains per panicle (NG), spikelet fertility (SF), thousand-grain weight (TGW), grain yield per plant (GY). Phenological data on days to fifty percent flowering (DFF) was recorded on whole plot basis.

The analysis of variance for the alpha lattice design was done according to the procedure developed by Patterson and Williams (1976) using R-3.6.3 software, alpha design (agricolae package). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated according to the formula given by Burton and De Vane (1953) and Singh and Chaudhury (1985). Heritability in a broad sense was estimated by the formula given by Allard (1960). Genetic advance was calculated in accordance to the method suggested by Johnson *et al.* (1955).

The mean sum of squares due to genotypes showed significant differences (*pd" 0.01*) for the nine yield traits studied (Table 2), indicating the presence of high genetic variability among the MAGIC lines and germplasm accessions. Non-significant differences for

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replication and replication within blocks indicated elimination of error due to soil heterogeneity resulting in smaller error variance and adjusting genotypes means for block effects.

The mean value and range for nine quantitative characters were presented in Table 3. The average grain yield per plant was 26.42 g with the range varying from 11- 62 g. Indian rice accession GSR IR-1-DQ157-R6-D1 (62.02 g) showed higher mean performance for grain yield per plant followed by GSR IR-1-DQ112-Y1-D2 (51.02 g) and HUANGHUZHAN (47.19 g) than the best check RNR2465 (33.85 g). Among MAGIC *indica* plus lines, MIB-5753 (38.45 g) and MIB-5829 (38.36 g) had higher grain yield per plant than the check RNR2465 (33.85 g). The higher yield of these lines was mostly due to more number of grains per panicle and longer panicle length (Table 1). The estimates days to 50% flowering ranged from 78 to 118 days with a mean of 103 days and most of the accessions were mid-early to medium duration. The range for panicle length across genotypes was between 18-29 cm with an average of 22.54 cm. Genotypes KASTURI had the highest mean performance followed by GSR IR-1-DQ157-R6-D1 and MIB-5995. All the best performing genotypes had 1000 grain weight between 21-25 g. MAGIC *indica* plus line MIB-5829 recorded highest thousand grain weight. Based on mean performance across genotypes on grain yield, days to 50% flowering, thousand grain weight and panicle length, GSR IR-1-DQ157-R6-D1, GSR IR-1-DQ112-Y1-D2, MIB-5753 and MIB-5829 were found to be superior genotypes with early and mid-early duration.

The genetic variability parameters revealed that there was tremendous amount of variation among the genotypes for different characters (Table 3) studied. The difference between the genotypic and phenotypic coefficient of variation was less for all characters except for productive tillers per plant suggesting influence of the environment on these traits. Similar results were also reported by Seyoum *et al.* (2012), Dhanwani *et al.* (2013), Asante *et al.* (2019) and Adjah *et al.* (2020). The high percent of GCV and PCV were recorded for grain yield per plant (30.90 and 29.78), number of filled grains per panicle (28.25 and 26.49), number of grains per panicle (25.67 and 24.16) and number of productive tillers per plant (22.44 and 19.59) (Fig 1-A, B & C). Dhanwani *et al.* (2013), Roy and Shil, (2020) reported high GCV and PCV for most of the yield attributing traits. The moderate genotypic and phenotypic coefficient of variation was recorded for thousand-grain weight (13.77 and 12.88). The low genotypic and phenotypic coefficients of variation were registered in plant height (9.46 and 9.37), panicle length (9.17 and 7.60), days to 50 percent flowering (7.67 and 7.02) and spikelet fertility (6.25 and 5.64). The results were in accordance with the findings of Singh *et al.* (2011), Ram *et al.* (2017), Sreedhar, (2018), Asante *et al.* (2019), Adjah *et al.* (2020).

High heritability helps in the effective selection of the character. Heritability in broad sense was calculated for all the characters and presented in Table 3. High estimates of heritability were exhibited by all the traits and highest was recorded by plant height (98) followed by grain yield per plant (93), number of grains per panicle (89), number of filled grains per panicle (88), thousand-grain weight (87), days to 50 percent flowering (84), spikelet fertility (81), number of productive tillers per plant (76) and panicle length (69) (Fig. 2-A). High heritability values for these traits indicate that they are less influenced by the environment and controlled by additive gene action. The plant breeder, therefore, can adopt phenotypic selection to improve these traits. Similar results were also quoted by Subbaiah *et al.* (2011), Sumanth *et al.* (2017), Sreedhar, (2018), Htwe *et al.* (2019), Roy and Shil, (2020), Adjah *et al.* (2020).

Genetic advance denotes the improvement in the genotypic value of the new population over the original population. Estimates of genetic advance were presented in Table 3. The genetic advance as a percentage of mean was highest for grain yield per plant (59.10) followed by the number of filled grains per panicle (51.17), number of grains per panicle (46.82), number of productive tillers per plant (35.23) and thousand-grain weight (24.80). Moderate values were observed for plant height (19.10), while days to 50 percent flowering (13.22), panicle length (12.96) and spikelet fertility (10.49) showed lower values (Fig. 2-B). Broad sense heritability includes both additive and epistatic effects. Heritability estimates along with genetic advances are more reliable than heritability alone in predicting the effectiveness of selection (Johnson *et al.* 1955). The characters that showed high heritability associated with high genetic advance are grain yield per plant, number of filled grains per panicle, number of grains per panicle, number of productive tillers per plant and thousand-grain weight (Fig. 2-C) suggesting that these can be improved by direct phenotypic selection. These results are in accordance with the finding of Subbaiah *et al.* (2011), Seyoum *et al.* (2012), Sreedhar, (2018), Htwe *et al.* (2019), Roy and Shil, 2020).

Analysis of variance revealed highly significant differences among the accessions for all the parameters studied. PCV and GCV estimates were found to be high for grain yield per plant, number of filled grains per panicle, number of grains per panicle and number of productive tillers per plant while, moderate GCV and PCV were noticed for thousand-grain weight. Plant height and panicle length exhibited least phenotypic and genotypic coefficient of variation. The heritability estimates were found to be high for all the characters. The traits *viz.*, grain yield per plant, number of filled grains per panicle, number of grains per panicle, number of productive tillers per plant and thousand-grain weight exhibited high heritability coupled with a high genetic advance representing that simple selection scheme would be good enough for these traits to enhance genetic improvement in desired direction. Indian rice accessions GSR IR-1-DQ157-R6-D1 and GSR IR-1-DQ112-Y1-D2 and among MAGIC *indica* plus lines, MIB-5753 and MIB-5829 were identified as

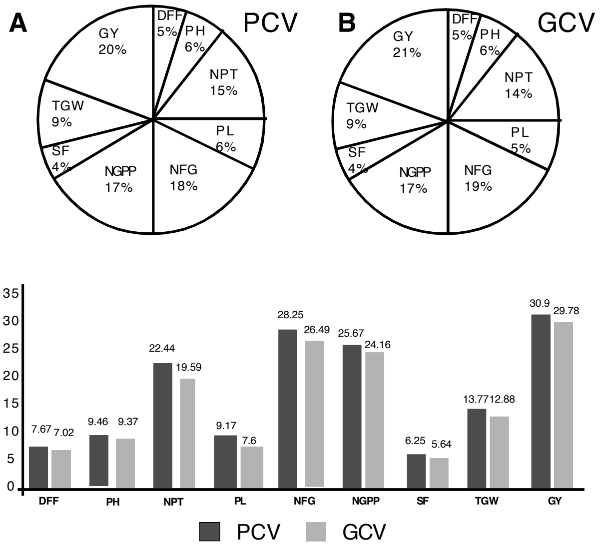

Figure 1. **A.** Percentage contribution of different traits to Phenotypic coefficients of variation (PCV). **B:** Percentage contribution of different traits to Genotypic coefficients of variation (GCV). **C:** Comparison between PCV and GCV

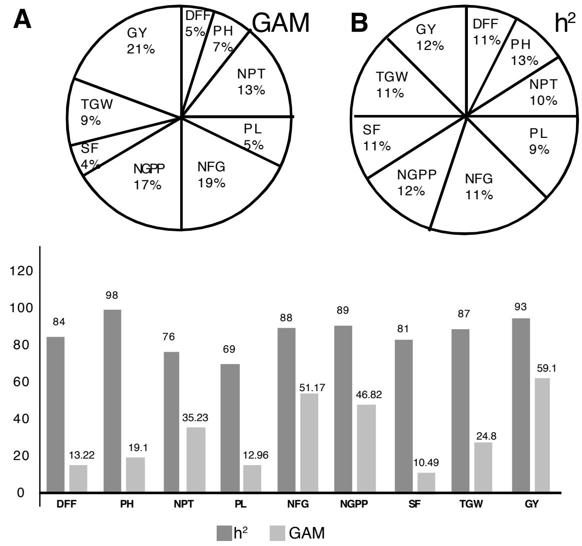

Figure 2. A. Heritability (h^2) percentage of different traits. **B:** Genetic advance as per cent of mean (GAM) percentage of different traits. **C:** Comparison between h^2 and GAM.

Table 1. Agronomic performance of rice genotypes

S.No.	Genotypes	DFF	PH	PL	NFG	TGW	SPY
1.	GSR IR-1-DQ157-R6-D1	98	91.5	27.58	301.33	25.85	62.02
2.	GSR IR-1-DQ112-Y1-D2	95	84.5	25.58	227.17	22.35	51.02
3.	HUANGHUZHAN	102	88.5	23.92	219.17	22.01	47.19
4.	GSR IR-1-DQ139-R1-D1	106	90.5	21.67	178.50	22.95	46.77
5.	GSR IR-1-DQ186-Y2-D1	102	84.5	23.58	188.17	23.14	46.06
6.	GSR IR-1-DQ122-D2-D1	98	93	22.42	176.50	25.25	44.94
7.	GSR IR-1-DQ136-Y8-Y1	96	86.5	22.58	153.67	25.34	43.81
8.	GSR IR2-1-Y16-S1-R2	101	90.5	21.25	180.83	25.23	42.85
9.	GSR IR2-5-L10-U1-R2	104	83	21.75	187.33	27.60	40.51

S.No.	Genotypes	DFF	PH	PL	NFG	TGW	SPY
10.	GSR IR2-17-R14-L1-L2	100	83.5	22.5	210.67	25.72	40.13
11.	GSR IR2-19-Y14-L2-L2	101	82.5	22.08	193.67	27.46	39.25
12.	MIB-5753	106	104.5	22.96	187.33	21.52	38.45
13.	MIB-5829	107	95.5	20.83	187.67	27.5	38.36
14.	GSR IR-1-DQ136-Y3-Y2	106	86	20.75	133.00	26.17	37.99
15.	GSR IR-1-DQ62-D7-D1	99	83.5	20.00	150.17	25.02	37.88
16.	MIB-5678	106	95.5	23.75	83.17	21.00	37.63
17.	GSR IR2-1-R5-N1-Y3	100	84.5	21.83	187.67	25.04	37.44
18.	MIB-5995	111	94.5	26.5	118.00	26.39	37.18
19.	GSR IR-1-DQ125-R4-Y1	102	87.5	22.08	203.50	22.6	37.08
20.	GSR IR-1-DQ130-Y5-Y1	100	89	21.75	138.167	24.49	37.00
21.	GSR IR2-11-R9-Y1-L2	100	84.5	21.16	171.67	28.44	36.95
22.	MIB-5687	110	95	21.88	104.00	25.00	36.94
23.	RNR2465	102	101	25.5	193.89	24.6	33.85

DFF- Days to 50% flowering, PH-Plant height, PL-Panicle length, NFG- Number of filled grains/panicle, TGW-Thousand grain weight, SPY-Single plant yield

Table 2. Analysis of variance for 9 quantitative characters in 212 rice accessions

Source of variation	df	DFF	PH	NPT	PL	NFG	NGP	SF	TGW	GY
Replication	1	3.03	3.23	0.002	1.48	28.34	33.57	0.02	1.44	0.29
Treatment (unadjusted)	211	115.1**	146.7**	12.91**	7.33**	2608.1**	2915.3*	51.8**	21.31**	128.5**
Block/replication	3	1.1	3.22	4.98	0.97	205.31	229.85	4.49	0.86	9.74
Residual	208	10.34	1.47	1.69	1.23	166.01	176.16	5.22	1.41	4.73

** Significance at 0.01% probability

DFF- Days to 50% flowering, PH-Plant height, NPT-Number of productive tillers/plant, PL-Panicle length, NFG- Number of filled grains/panicle, NGP- Number of grains/panicle, SF-Spikelet fertility, TGW-Thousand grain weight, GY- Grain yield

Table 3. Genetic parameters for 9 quantitative characters in 212 rice accessions

Character	Mean	Range		PCV (%)	GCV (%)	h^2 (%)	GAM (%)
		Minimum	Maximum				
Days to 50 % flowering	103.23	78	118	7.67	7.02	84	13.22
Plant height (cm)	91.04	74	108	9.46	9.37	98	19.10
Number of productive tillers/plant	12.08	8	18	22.44	19.59	76	35.23
Panicle length (cm)	22.54	18	29	9.17	7.60	69	12.96
Number of filled grains / panicle	131.83	59	301	28.25	26.49	88	51.17
Number of grains/ panicle	153.18	73	325	25.67	24.16	89	46.82
Spikelet fertility (%)	85.63	68	96	6.25	5.64	81	10.49
Thousand grain weight (g)	24.46	15	34.50	13.77	12.88	87	24.80
Grain yield/plant (g)	26.42	11	62	30.90	29.78	93	59.10

high yielding lines with early and mid-early duration. These accessions can be exploited further for the development of high yielding rice cultivars.

ACKNOWLEDGEMENTS

The authors would like to thank the Director IBT, Chairman and members for their support on conducting research activities, ICAR for PhD seat, Ministry of Tribal affairs for fellowship, and PJTSAU, Telangana for providing the facilities and encouragement.

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Research Note
The J. Res. PJTSAU 48 (1&2) 94-97, 2020

GROWTH AND YIELD OF MACHINE TRANSPLANTED RICE AS INFLUENCED BY WEED MANAGEMENT PRACTICES

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Date of Receipt : 22-01-2020 Date of Acceptance : 20-02-2020

Rice (*Oryza sativa* L.) is considered as the "global grain" and is the staple food for Asia and for more than half of the global population. In India, it contributes to about 40 percent of the total food grain production. Several factors are responsible for reducing the yield of transplanted rice. However, weed infestation is the major threat to productivity of transplanted rice and causes 45-51% loss in rice yields in India (Veeraputhiran and Bala subramanian, 2013). Transplanted rice in the country encounters diverse type of weed flora consisting of grasses, broad-leaf weeds and sedges. Weeds, by virtue of their high adaptability and faster growth, dominate the crop habitat and reduce the crop yield. Under machine transplanting inter row spacing of 30 cm allows severe weed infestation in the field and finally resulting in significant yield loss. Thus, weed management is an essential practice of machine transplanted rice and farmers are looking for better weed management options in machine transplanting.

The present investigation entitled "Weed management in machine transplanted rice'' was conducted during *kharif*, 2019 at ARI Farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The soil of the experimental site was sandy loam in texture, slightly alkaline, medium in organic carbon and available nitrogen and potassium, high in available phosphorus.

Experiment was laid out in Randomized Block Design (RBD) consisting of eight treatments *viz*., pretilachlor @ 625 g *a.i* ha^{-1} as PE@3DAT + cono weeder at 15, 30 & 45 DAT (T_1), pretilachlor @ 625 g *a.i* ha^{-1} as PE at 3 DAT + power weeder at 15, 30 & 45 DAT (T_2), flucetosulfuron 10 % WG @ 25 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (T_3), penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (T_4), penoxsulam 0.97% W/W + butachlor 38.8% W/W @ 820 g ha^{-1} at 7 DAT + power weeder at 30-40 DAT (T_5), bentazone @ 960 g *a.i* ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 – 40 DAT (T_6), weedy check (T_7) and hand weeding at 20, 40 DAT (T_8). The recommended dose of fertilizers 120-60-40 kg NPK ha^{-1} in the form of diammonium phosphate, urea and muriate of potash was applied to all treatments.

Paddy mat nursery was sown on July 11th 2019 (Telangana sona variety) and 22 days old seedlings were used for transplanting in main field with self propelled 6 row paddy transplanter at a spacing of 30 cm x 12 cm in a plot size of 7.5 m X 4.0 m. The pre emergence herbicide pretilachlor was applied at 3 DAT as sand mix broadcast using 50 kg sand ha^{-1}, penoxsulam + butachlor (pre mix) was applied at 7 DAT and the post emergence herbicides were applied at 2-3 leaf stage of weeds (15 DAT) as spray using knapsack sprayer with flat fan nozzle in a spray volume of 300 litres ha^{-1}.Quadrant of 50 cm x 50 cm was used to record tillers during crop growth. Need based plant protection measures for the control of insect pests were taken during the season and crop was harvested on November 14th, 2019.

Growth parameters of rice were significantly influenced by weed management practices of machine transplanted crop. Hand weeding at 20, 40 DAT recorded significantly taller (109.0 cm) plants at harvest and was at par with penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (T_4) (105.4 cm) followed by T_3 i.e. flucetosulfuron 10% WG @ 25 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (102.4 cm) while, lowest plant

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height was observed with weedy check treatment (79.5 cm). These results corroborate with Manjunatha *et al.* (2013) and Khare *et al.* (2014).

Number of tillers at harvest were significantly more with hand weeding at 20, 40 DAT (392.6 m^{-2}) and was statistically at par with penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (377.5 m^{-2}). Lowest number of tillers of rice crop were noticed with weedy check treatment (211.9 m^{-2}). Reduction in weed growth with herbicides application and hand weeding allowed the crop to absorb adequate nutrients resulting in better assimilation of photosynthates and thus increasing tiller production. These findings were in conformity with Sangeetha *et al.* (2009).

Higher dry matter production at harvest was recorded with T_8 i.e. hand weeding at 20, 40 DAT (14715 kg ha^{-1}) and it was statistically at par with that of T_4 (penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT) (14315 kg ha^{-1}) followed by T_3 i.e. flucetosulfuron 10% WG @ 25 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (13952 kg ha^{-1}) and lowest crop dry matter was accumulated with weedy check plot (8796 kg ha^{-1}). Reduction in weed growth with herbicidal application and mechanical weeding might have allowed the crop to absorb adequate nutrients, resulting in better accumulation of photosynthates and thus increased growth parameters of the crop. These results are in consonance with findings of Hossain and Mondal (2014).

Table 1. Growth parameters of machine transplanted rice as influenced by weed management practices

Treatment	Plant height at harvest (cm)	Tillers at harvest (No. m^{-2})	LAI at 60 DAT	Dry matter production at harvest (kg ha^{-1})
T_1 - Pretilachlor @ 625 g *a.i* ha^{-1} as PE at 3 DAT + cono weeder at 15, 30 & 45 DAT	92.8	312.1	4.26	12867
T_2 - Pretilachlor @ 625 g *a.i* ha^{-1} as PE at 3 DAT + power weeder at 15, 30 & 45 DAT	94.3	325.0	4.37	13086
T_3 - Flucetosulfuron 10 % WG @ 25 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 - 40 DAT	102.4	367.2	4.73	13952
T_4 - Penoxsulam 1.02 % W/W + cyhalofop- p-butyl 5.1 % W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 - 40 DAT	105.4	377.5	4.87	14315
T_5 - Penoxsulam 0.97 % W/W + butachlor 38.8 % W/W @ 820 g ha^{-1} at 7 DAT + power weeder at 30 - 40 DAT	101.0	356.1	4.67	13467
T_6 - Bentazone @ 960 g *a.i* ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 - 40 DAT	86.2	262.5	3.84	11641
T_7 - Weedy check (control)	79.5	211.9	3.51	8796
T_8 - Hand weeding at 20, 40 DAT.	109.0	392.6	5.01	14715
SEm±	1.82	6.14	0.06	193.4
CD	5.57	18.30	0.18	592.6

Table 2. Grain yield, straw yield and Harvest index of machine transplanted rice influenced by weed management practices

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 - Pretilachlor @ 625 g *a.i* ha^{-1} as PE at 3 DAT + cono weeder at 15, 30 & 45 DAT	5884	6582	47.2
T_2 - Pretilachlor @ 625 g *a.i* ha^{-1} as PE at 3 DAT + power weeder at 15, 30 & 45 DAT	5991	6660	47.4
T_3 - Flucetosulfuron 10 % WG @ 25 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 - 40 DAT	6415	7173	47.2
T_4 - Penoxsulam 1.02 % W/W + cyhalofop-p- butyl 5.1 % W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 - 40 DAT	6732	7474	47.6
T_5 - Penoxsulam 0.97 % W/W + butachlor 38.8 % W/W @ 820 g ha^{-1} at 7 DAT + power weeder at 30 - 40 DAT	6253	6817	47.8
T_6 - Bentazone @ 960 g *a.i* ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30 - 40 DAT	5486	5991	47.8
T_7 - Weedy check (control).	3795	4685	44.8
T_8 - Hand weeding at 20, 40 DAT.	6922	7661	47.5
SEm±	133.9	150.9	0.74
CD	410.5	462.5	NS

The leaves of the plants are normally the main organs of photosynthesis and total area of leaves per unit ground area is leaf area index (LAI). LAI is a useful indicator of crop photosynthetic activity and responded positively to a reduction in weed pressure. Machine transplanted rice crop at 60 DAT recorded significantly higher LAI with T_8 i.e. hand weeding at 20, 40 DAT (5.01) over other treatments except T_4 (penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT) (4.87) treatment. Lowest leaf area index of 3.51 was observed with weedy check treatment due to shading of lower leaves of the crop by the weeds and thus caused their senescence and death. These results corroborate with Shan *et al.* (2012).

Among the different weed control treatments, hand weeding at 20, 40 DAT produced significantly higher grain and straw yield (6922 kg ha^{-1} & 7661 kg ha^{-1} respectively) and remained at par with that of application of penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT (6732 kg ha^{-1} & 7474 kg ha^{-1}) followed by T_3 treatment (6415 kg ha^{-1} & 7173 kg ha^{-1}) i.e. flucetosulfuron 10% WG @ 25 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT. Weedy check recorded lowest grain and straw yield (3795 kg ha^{-1} & 4685 kg ha^{-1}). These enhanced yields might be due to effective control of weeds and thus less competition to the crop (Prakash *et al.* 2013). Harvest index was not significantly influenced by weed management practices in machine transplanted rice. The results are in conformity with Patra *et al.* (2011).

Based on the results obtained, it can be concluded that among the different herbicidal treatments, application of penoxsulam 1.02% W/W + cyhalofop-p-butyl 5.1% W/W @ 153 g ha^{-1} at 2-3 leaf stage of weeds + power weeder at 30-40 DAT was found to be an effective weed management practice in machine transplanted rice.

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Research Note
The J. Res. PJTSAU 48 (1&2) 98 -99, 2020

INFLUENCE OF TEMPERATURE ON DEVELOPMENT OF PINK BOLLWORM, *Pectinophora gossypiella* (Saunders) LARVAE

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Date of Receipt : 10-06-2020 Date of Acceptance : 24-06-2020

Pink bollworm, *Pectinophora gossypiella* (Saunders) a pest of cotton having national importance, recently became serious on BG II cotton hybrids, causing damage from flowering stage onwards by feeding on anthers and pollen and living in a sort of web. Such flowers are characteristically twisted in the form of rose called as rosette flower. Later the larvae bore into the green bolls, and further burrow into mature bolls through the lint penetrating deep into seeds. When one seed is destroyed, the larvae tunnel and enters through the developing lint and migrates to another seed and similarly to locules. The affected bolls rot and shed, while those retained on plants open prematurely resulting in stained immature fibre, causing 80 percent reduction in seed cotton yield and quality of lint (Henneberry and Clayton 1986). Pupation of PBW occurs in flimsy cocoon in the boll, often in seed hollowed out by larva or in soil. Pink bollworm has a tendency to enter into facultative diapause in some temperate and tropical regions of the world. Induction and termination of diapause depends on the seasonal changes such as temperature, photoperiod, availability of food etc. Present study was conducted to define the influence of temperature on development of pink bollworm**.**

The study was conducted at Central Instrumentation Cell, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during August 2018. To know the influence of temperature on induction of diapause of pink bollworm, fourth instar larvae were incubated at 10±1, 13±1, 16±1, 19±1°C in BOD and at room temperature 25±2°C for 120 days. The larvae were placed in plastic cups covered with muslin cloth and each cup consisted of ten larvae. Five such cups were placed in each cabinet from November 2018 to February 2019 in BOD. Data on percent pupation, days to last pupal formation and percent adult emergence was recorded at 7 days interval by counting the number of pupae formed and number of adult moths emerged.

Results revealed that at a temperature of 10 and 13°C, the larvae of PBW remained in diapause for 120 days though the larvae spun a loose cocoon around their body termed as hibernacula indicating beginning of larvae entering into diapause. However, at 13°C, only one percent of the larvae could be able to pupate which was considered as threshold temperature for larval development. These results were in close conformity with the findings of Watson *et al.* (1973) who reported larvae of PBW failing to pupate and continued to be in diapause condition when the temperature was maintained below 13.9°C.

At 16°C, 40 percent pupation was recorded during third week and maximum of 100 per cent by fifth week. At 19°C, 50 percent pupation was recorded after first week and 100 percent by second week. At 25°C, 100 percent pupation was recorded in the first week itself, indicating the range from 16°C to 25°C as optimum temperature for larval development. Present findings are in line with Raina and Bell (1974) who compared incidence of diapause in Arizona and South Indian strain of pink bollworm, by subjecting to 19°C for 11-12-hour photoperiod. They revealed that Arizona strain entered into diapause, but South Indian strain failed to undergo diapause under similar conditions. However, present results are deviating from the findings of Kiranamaya Pradhan *et al.* (2020) who quoted that diapause inducing daily temperature and photoperiod were 20°C and 12 h, respectively where hibernaculum was spun by larvae.

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Table 1. Effect of Temperature on Diapause of Pink bollworm

Weeks	Percent Pupation					Percent Adult emergence				
	Temperature in °C					Temperature in °C				
	10	13	16	19	25	10	13	16	19	25
1	0	0	0	50	100	0	0	0	0	0
2	0	0	0	100	-	0	0	0	0	0
3	0	0	40	-	-	0	0	0	0	100
4	0	0	70	-	-	0	0	0	0	-
5	0	0	100	-	-	0	0	0	80	-
6	0	1	-	-	-	0	0	0	100	-
7	0	0	-	-	-	0	0	0	-	-
8	0	0	-	-	-	0	0	2	-	-
9	0	0	-	-	-	0	0	0	-	-
10	0	0	-	-	-	0	0	0	-	-
11	0	0	-	-	-	0	0	0	-	-
12	0	0	-	-	-	0	0	0	-	-
13	0	0	-	-	-	0	0	0	-	-
Days to last pupa /adult	-	-	35	14	7	-	-	-	42	21

Total number of larvae are N=50

No adult emergence was recorded at 10 and 13°C and it was only 2.0 percent at 16°C after eight weeks which could be considered as threshold temperature for adult emergence and further increase in temperature reduced the duration for adult emergence. At 19^0 and 25°C, 100 percent adult emergence was recorded by sixth and third week, respectively, indicating the range from 19°C to 25°C as optimum temperature for adult emergence. Present findings are in concurrence with the findings of Watson et al. (1973) who couldn't observe adult emergence at 13.9°C and only small percent at 15.6°C and considered these temperatures as unfavourable for adult emergence of pink bollworm.

CONCLUSION

Temperature plays an important role in induction and termination of diapause, 13°C temperature was found to be the threshold for larval development below which larvae of pink bollworm remained in diapause and 16°C to 25°C indicated as optimum temperature for larval development. Whereas 16°C as threshold temperature for adult emergence and 16°C to 19°C indicated as optimum temperature for adult emergence.

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