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RESEARCH PAPER

Heterosis for phenological and root morphological traits in rice (*Oryza sativa* L.) under moisture stress

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***Abstract* :** Rice is one of the important food security crop of world. Drought is the major yield destabilizing factor in irrigated rice cultivation. To maintain rice production stable there is need to develop drought tolerant genotypes with better root characters like increased root growth, increased number of roots and volume/mass. The material for the present study comprised of four cytoplasmic sterile lines and eight testers are crossed in line X tester design to produce F_1 hybrids during *Kharif* 2009 Z.A.R.S, V. C. Farm, Mandya. Lines, testers and hybrids were grown in PVC pipes and low moisture stress was imposed for15 days at vegetative stage during summer 2010 under green house condition at GKVK, UAS, Bengaluru. Observations were recorded and statistical analysis was done using standared methods. Analysis of variance showed significant variation in in all seven characters studied. IR68897B, IR 58025B, MAS 868, qRT(1+7)-8 and MAS 25 exhibited largest root length, total number of roots, root volume under stress. These lines and testers can be used for development of hybrids for moisture stress and aerobic condition. Among hybrids IR68888A/OYR-128, IR68897A/OYR-128 and IR79156A/OYR-128 showed high per cent of heterosis over better parent. These hybrids can be further evaluated for yield under varied moisture condition and superior hybrids can be proposed for commercial cultivation under drought condition. The heterosis of root traits is the one of the major cause for increased drought tolerance of hybrids over parents which can be exploited with high yield under drought situation to stabilize rice yields.

***Key Words* :** Heterosis, Drought, Moisture stress, Rice, Root characters

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INTRODUCTION

Rice (*Oryza sativa* L.) is the staple crop for more than two thirds of the world population and gives 35-60 per cent of calories requirement (Khush, 2005). Drought is the most important abiotic constraint that reduces yield in rainfed areas. Limited water availability due to inadequate and erratic rainfall has contributed 15 per cent loss in rice production (Dey and Upadhaya, 1996). Drought tolerance is a complex trait, depends on several expressed and constitutive traits. Root characteristics are the one of the important traits in phenotyping of drought as root is the first organ that comes in contact drought stress (Adanan *et al.,* 2004). Increased root growth, increased number of roots and volume/mass and its ability to grow deep during moisture stress to withstand water deficit situation is important for a genotype (Ganapathy and Ganesh, 2008). Even though there are several varieties developed for aerobic and drought stress conditions many of them have to be complimented to break the ceiling of yield and exhibit vigour for higher production with limited water available (Naresh Babu *et al.,* 2011). Hybrids play a great role to increase yield due to heterosis (Virmani and Edwards, 1983). In some of the cases the hybrids attain yields 100 per cent higher than varieties. There is need to breed a genotype for better root characteristics along with higher grain yield and recovery after drought spell and these genotypes can be used in heterosis breeding. The objective of this study was to identify genotypes and hybrids having heterosis for better root characteristics to thrive well under moisture stress. This will provide insight into the development of high yielding drought tolerant hybrid rice cultivars with good root characters.

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MATERIALS AND METHODS

The material for the present study comprised of four cytoplasmic sterile lines *viz.,* IR 68888 A, IR 68897 A, IR 58025 A and IR 79156 A and eight tester namely MAS 26, MAS 868, OYT 58, OYR 128, HPR 14 and IET 21574. These lines and testers were crossed in line X tester design to produce F_1 hybrids during *Kharif* 2009 Z.A.R.S, V. C. Farm, Mandya.

Lines, testers and hybrids were sown in PVC pipes measuring 1m in length and 18 cm diameter during summer 2010 under green house condition at GKVK, UAS, Bengaluru. The design followed was RCBD design with two replications. The pipes were filled with a mixture of sandy clay loam and FYM in 4:1 proportion. The soil was fertilized according to the recommended package of practices for aerobic rice (Anonymous, 2007). One seedling was transplanted in each PVC pipe and five pipes for each genotype in each replication. Low-moisture stress was imposed on genotypes by withholding irrigation between 60 and 75 days after sowing (DAS) and rainout shelter was provided during imposition of low-moisture stress. Roots were sampled on 76th day and fallowing observations were recorded in three randomly selected from each genotype in each replication. The observations were recorded on plant height (cm), number of tillers, maximum root length (cm), total root number, root volume (cc), root fresh weight (g) and root dry weight (g). ANOVA was done based Panse and Sukathme (1967) and heterosis over mid parent (relative heterosis) and better paresnt (heterobeltiosis) were calculated according to Fonseca and Petterson(1968) using mean values.

RESULTS AND DISCUSSION

Drought is the one of the important yield constraint in rice production due to intermittent and uneven distribution of rainfall and changing climate. The drought tolerant genotype should posses better root characters to drag water from lower depths under low moisture condition (Kumar *et al.,* 2008).

Analysis of variance:

The analysis of variance carried out for seven traits in rice is presented in Table 1. The mean sum of squares due to treatments which included both parents and hybrids were highly significant for all the characters. The sum of squares due to the entries were further partitioned orthogonally into components attributable to i) parents, ii) crosses, and iii) parents v/s crosses. The mean sum of squares due to parents and crosses were highly significant for all the characters indicating significant differences among parents as well as hybrids. Similarly, the mean sum of squares due to parents v/s crosses was also highly significant for all the characters indicated that presence of heterosis. The mean sum of squares due to lines and testers was non significant for all character and highly significant mean sum of squares due line X testers indicated there is a operation of dominance type of gene action for all characters studied in the present study. The highly significant mean sum of squares due to lines v/s testers for all characters indicating lines differ significantly from testers.

Mean performance of lines, testers and hybrids under stress:

In present study analysis of variance showed significant variation in in all seven characters studied. Among root characters root volume and root length are important traits in determining the drought tolerant capacity of genotypes (Kumar *et al.,* 2008) under stress. IR68897B and IR 58025B exhibited largest root length, total number of roots, root volume under stress. These lines can be used as females for development of hybrids for moisture stress and aerobic condition. Among lines MAS 868, MAS 25 and qRT(1+7)-8 shown better root characters and these can be used as males in test cross nursery of hybrid rice breeding.

Heterosis of phenological and root morphological traits:

Hybrids play a major role in higher rice production per unit of water used. Hybrid rice is practically feasible and readily adoptable genetic option to increase rice production has been amply demonstrated in China and in India. Root characters

Table 1 : Analysis of variance for phenological and root morphological traits under stress in rice

Sr. No.	Source of variation	D.F	Plant height (cm)	Number of tillers	Max root length (cm)	Total no of roots	Root volume (cc)	Root fresh weight(g)	Root dry weight (g)
1.	Replication	1	24.78	0.0	4.82	23.22	0.00	0.31	0.04
2.	Genotype	43	323.37**	35.72**	178.91**	897.41**	42.257**	96.7253**	10.8715**
3.	Parent	11	296.83**	8.28**	117.92**	228.21**	6.7038**	47.1167**	3.1701**
4.	Cross	31	243.90**	35.56**	168.79**	960.68**	41.4674**	97.9248**	12.8152**
5.	Lines	3	249.84	113.66*	190.14	2241.90	22.58	197.93	19.26
6.	Testers	7	355.02	13.0	170.58	435.36	48.32	74.15	9.80
7.	Line x Tester	21	206.03**	31.92**	165.15**	952.75**	41.88**	91.56**	12.90**
8.	Cross vs parents	1	3078.83**	342.65**	1163.23*	6297.29**	457.82**	605.23**	35.33**
9.	Error	43	12.64	0.1	1.92	6.96	0.12	0.46	0.01

* and ** indicate significance of values at P=0.05 and 0.01,respectively

Table 2 : Mid parent and better parent heterosis of phonological and root morphological traits under stress in rice

Sr. No.	Hybrid	Plant height		Number of tillers		Root length		Total root number	
		MP	BP	MP	BP	MP	BP	MP	BP
1.	IR 68888 A × MAS 25	118.95 **	56.71 **	298.74 **	168.64 **	109.52 **	104.65 **	269.54 **	267.68 **
2.	IR 68888 A × MAS 868	32.90 **	25.61 **	48.43 **	0	106.04 **	74.42 **	39.34 **	4.08
3.	IR 68888 A × CR1(24) 1	50.12 **	30.86 **	111.06 **	77.97 **	49.09 **	22.39 **	36.59 **	16.38 *
4.	IR 68888 A × CR1(14) 8	41.29 **	33.54 **	128.31 **	111.86 **	83.94 **	51.86 **	88.56 **	81.63 **
5.	IR 68888 A × OYT 58	26.30 **	4.68	122.12 **	104.24 **	34.49 **	16.98 *	54.88 **	54.25 **
6.	IR 68888 A × OYR 128	53.03 **	21.20 **	80.74 **	60.53 **	35.60 **	28.54 **	57.38 **	31.51 **
7.	IR 68888 A × IIPR 14	40.96 **	15.61 *	122.45 **	84.75 **	24.87 **	12.09	127.02 **	83.47 **
8.	IR 68888 A × IET 21574	65.95 **	54.24 **	77.29 **	56.13 **	45.94 **	40.00 **	283.64 **	245.90 **
9.	IR 68897 A × MAS 25	114.19 **	50.91 **	263.93 **	174.07 **	220.66 **	136.59 **	113.26 **	94.95 **
10.	IR 68897 A × MAS 868	67.92 **	62.80 **	165.57 **	100.00 **	161.26 **	116.11 **	195.09 **	134.63 **
11.	IR 68897 A × CR1(24) 1	46.35 **	30.55 **	148.15 **	148.15 **	61.39 **	4.18	71.79 **	36.49 **
12.	IR 68897 A × CR1(14) 8	15.47	11.95	34.07 **	20.79 **	9.89	6.79	19.91	14.1
13.	IR 68897 A × OYT 58	26.60 **	7.21	8.89	17.17 **	84.80 **	49.06 **	78.10 **	62.96 **
14.	IR 68897 A × OYR 128	20.30 **	2.8	100.86 **	53.95 **	62.96 **	14.58 *	107.02 **	61.64 **
15.	IR 68897 A × IIPR 14	48.69 **	24.56 **	214.47 **	208.64 **	129.05 **	79.82 **	267.98 **	219.51 **
16.	IR 68897 A × IET 21574	46.91 **	40.00 **	166.95 **	103.23 **	66.10 **	24.05 **	200.00 **	150.82 **
17.	IR 58025 A × MAS25	91.98 **	26.78 **	188.56 **	81.25 **	9.54 *	14.13 **	68.40 **	58.36 **
18.	IR 58025 A × MAS 868	45.39 **	33.40 **	327.86 **	168.75 **	27.45 **	9.97 *	350.25 **	222.06 **
19.	IR 58025 A × CR1(24) 1	9.98 NS	9.98	80.91 **	36.25 **	39.66 **	41.83 **	98.73 **	79.60 **
20.	IR 58025 A × CR1(14) 8	19.31 **	9.47	24.14 **	1.25	65.67 **	14.96 **	67.32 **	51.25 **
21.	IR 58025 A × OYT 58	11.28	4.86	42.08 **	15.00 **	22.31 **	44.04 **	144.32 **	129.54 **
22.	IR 58025 A × OYR 128	11.11 *	0.8	33.33 **	30.00 **	11.48 **	7.2	0.62	10.96
23.	IR 58025 A × IIPR 14	4.62	2.63	2.52	23.75 **	1.5	25.21 **	109.49 **	61.03 **
24.	IR 58025 A × IET 21574	8.08	0.81	2.86	1.25	35.18 **	49.86 **	38.23 **	40.66 **
25.	IR 79156 A × MAS 25	40.53 **	60.99 **	23.93 **	49.18 **	16.67 **	18.60 **	44.34 **	59.05 **
26.	IR 79156 A × MAS 868	32.79 **	20.30 **	98.77 **	32.79 **	78.57 **	51.16 **	21.05 **	51.43 **
27.	IR 79156 A × CR1(24) 1	5.92	4.46	41.87 **	18.03 **	7.27	23.88 **	21.42 **	0.95
28.	IR 79156 A × CR1(14) 8	20.22 **	27.72 **	63.23 **	66.39 **	65.63 **	71.63 **	59.84 **	71.24 **
29.	IR 79156 A × OYT 58	11.79 *	6.76	97.29 **	78.69 **	100.53 **	74.42 **	11.4	34.86 **
30.	IR 79156 A × OYR 128	29.20 **	16.80 **	10.95 **	19.74 **	60.88 **	52.50 **	45.62 **	53.90 **
31.	IR 79156 A × IIPR 14	14.05 *	18.95 **	0	18.03 **	3.89	6.74	5.33	39.05 **
32.	IR 79156 A × IET 21574	60.75 **	48.02 **	56.68 **	61.29 **	11.03	6.51	41.57 **	53.81 **
	S.E.	3.08	3.56	1.2	1.39	0.3	0.35	0.08	0.09

Contd...... Table 2

Table 2 contd.....

Sr. No.	Hybrid	Root volume		Root fresh weight		Root dry weight	
		MP	BP	MP	BP	MP	BP
1.	IR 68888 A \ MAS 25	576.06 **	313.79 **	674.19 **	492.59 **	1174.82 **	1130.56 **
2.	IR 68888 A \ MAS 868	184.06 **	68.97 **	130.00 **	70.37 **	250.40 **	226.87 **
3.	IR 68888 A \ qRT(2-7) 1	96.52 **	201.72 **	3.73	37.66 **	46.09 **	71.16 **
4.	IR 68888 A \ qRT(1-7) 8	134.69 **	98.28 **	207.26 **	180.61 **	473.00 **	330.83 **
5.	IR 68888 A \ OYT 58	69.75 **	74.14 **	123.08 **	101.80 **	85.15 **	38.52 **
6.	IR 68888 A \ OYR 128	46.76 **	75.86 **	321.82 **	233.81 **	519.13 **	336.81 **
7.	IR 68888 A \ HPR 14	297.18 **	143.10 **	217.14 **	174.07 **	325.84 **	300.48 **
8.	IR 68888 A \ IET 21574	426.45 **	251.72 **	190.41 **	130.43 **	306.90 **	164.57 **
9.	IR 68897 A \ MAS 25	2164.71 **	563.79 **	534.29 **	437.10 **	1063.93 **	886.11 **
10.	IR 68897 A \ MAS 868	1056.25 **	218.97 **	498.02 **	387.10 **	696.30 **	641.38 **
11.	IR 68897 A \ qRT(2-7) 1	186.32 **	248.28 **	4.1	44.64 **	50.74 **	74.09 **
12.	IR 68897 A \ qRT(1-7) 8	152.46 **	32.76 **	22.5	0	74.86 **	20.3
13.	IR 68897 A \ OYT 58	97.56 **	39.66 **	25.85	1.9	40.54 *	3.7
14.	IR 68897 A \ OYR 128	145.10 **	115.52 **	140.80 **	74.10 **	191.08 **	90.18 **
15.	IR 68897 A \ HPR 14	970.59 **	213.79 **	392.56 **	380.65 **	711.21 **	661.40 **
16.	IR 68897 A \ IET 21574	680.25 **	172.41 **	235.00 **	142.75 **	308.79 **	150.22 **
17.	IR 58025 A \ MAS25	420.75 **	137.93 **	190.07 **	83.92 **	423.81 **	280.50 **
18.	IR 58025 A \ MAS 868	1547.06 **	624.14 **	672.32 **	380.05 **	2093.55 **	1396.86 **
19.	IR 58025 A \ qRT(2-7) 1	16.30 *	15.52	7.59	24.69 **	32.97 **	60.92 **
20.	IR 58025 A \ qRT(1-7) 8	395.00 **	241.38 **	66.41 **	34.04 **	61.64 **	48.43 **
21.	IR 58025 A \ OYT 58	195.05 **	156.90 **	41.27 **	14.71	125.17 **	108.18 **
22.	IR 58025 A \ OYR 128	95.04 **	103.45 **	45.62 **	35.91 **	119.25 **	116.56 **
23.	IR 58025 A \ HPR 14	360.38 **	110.34 **	47.68 **	1	128.70 **	55.35 **
24.	IR 58025 A \ IET 21574	175.63 **	41.38 **	18.23 *	23.94 **	16.75 *	28.70 **
25.	IR 79156 A \ MAS 25	9.73	6.9	1.09	34.04 **	74.80 **	54.17 *
26.	IR 79156 A \ MAS 868	263.96 **	248.28 **	57.78 **	0.71	351.33 **	339.66 **
27.	IR 79156 A \ qRT(2-7) 1	192.59 **	455.17 **	25.46 **	49.63 **	30.04 **	63.01 **
28.	IR 79156 A \ qRT(1-7) 8	68.57 **	62.07 **	65.69 **	70.92 **	2.13	30.83 *
29.	IR 79156 A \ OYT 58	76.40 **	144.83 **	80.84 **	54.61 **	235.79 **	136.30 **
30.	IR 79156 A \ OYR 128	9.39	41.38 **	0.71	0	27.52	14.72
31.	IR 79156 A \ HPR 14	7.96	5.17	60.00 **	13.48	219.64 **	214.04 **
32.	IR 79156 A \ IET 21574	0.42	3.45	13.98	14.89	5.04	34.53 **
	S.E.	0.27	0.31	2.29	2.64	0.59	0.68

* and ** indicate significance of values at P=0.05 and 0.01, respectively

are important for drought tolerant genotypes especially root length and root volume to uptake water under water limited condition. Range of heterosis for root length over mid parent was 220.66 per cent (IR 68897A/ MAS 25) to -65.63 per cent (IR 79156A/ qRT(1+7)-8). Twenty seven out of thirty two hybrids found significant of which twenty one were positively significant and remaining were negatively significant. Range of better parent heterosis from 136.59 per cent (IR 38897A/ MAS 25) to -71.63 (IR 79156A/qRT(1+7)-8). The range of heterosis for root number over mid parent 283.64 per cent (IR68888A/ IET 21574)to -59.84 per cent (IR 79156AqRT(1+7)-8) and over better parent heterosis 245.90 per cent (IR 68888A/ IET 21574) to -71.245 per cent (IR79156A/qRT(1+7)-8). There were about twenty one hybrids found positively significant over both better parent and mid parent. For root volume all most all hybrids had shown very high per cent of heterosis over both mid parent and better parent. Among all hybrids IR 58025A/ MAS 868 (1574%) shown highest volume of roots followed by IR 58025A/MAS 25 (420%), IR 58025A/qRT(1+7)-8 over mid parent and better parent. IR 68897 A \MAS 25, IR 68897 A \ qRT(2+7)-1, IR68897A \ qRT(1+7)-8, IR68897 A \ OYR128, IR68897 A \ IET 21574, , IR79156 A \ qRT(2+7)-1, IR 58025 A \ MAS 868, and IR 79156 A \ MAS 868 (Table 2) found positively significant over both better parent and mid parent for most of the root morphological traits under moisture stress.

Among 32 hybrids three new fertile hybrids (Naresh Babu N, 2010) are IR68888A/OYR-128, IR68897A/OYR-128 and IR79156A/OYR-128 exhibited high per cent of heterosis for root morphological traits. IR68888A/OYR-12 showed 828.5 per cent, 31.51 per cent, 75.86 per cent for root length, root number, and root volume, respectively over better parent. IR68897A/OYR-128 recorded 14.58 per cent 61.64 per cent and 115.52 per cent for root length, root number, and root volume, respectively over better parent. IR 79156A/OYR-128 recorded heterosis for root length (52.5 %), root number (-53.90%) and root volume (41.38%). The result revealed that these crosses perform better under aerobic condition due to high root volume (Boumen *et.al.* 2002). IR79156A/OYR-128 recorded high percentage of heterosis for root length and suited for stress condition. The results of heterosis for root traits are in agreement with Ganapathy and Ganesh (2008). The heterosis of root traits is the one of the major cause for increased drought tolerance of hybrids over parents (Adanan *et al.,* 2004).

The overall result suggested that the lines IR68897B and IR 58025B and testers MAS 868 and qRT(1+7)-8 are high suitable genotypes development of drought tolerant hybrid rice breeding due their better root characteristics. Among hybrids IR68888A/OYR-128, IR68897A/OYR-128 and IR79156A/OYR-128 are shown high per cent of heterosis over better parent but these also fertile combination. Since these are fertile still there is need to evaluate under varied moisture condition and then cobinations can be selected for commercial purpose under drought condition. Other hybrids showed high degree of heterosis for most of root traits but their restoration behaviour need to be studied, if they show fertile, they can be used for production of F_1hybrid and if sterile, they can be used for development of CMS specific to drought condition. Since root study is destructive sampling there is need for screening of genotypes with better root characteristic under field condition mainly to study their yielding capacity under stress. Genotypes with good root characters may or may not perform better performers under field conditions as reflected by their yield under moisture stress.

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