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Research Article

Heterosis under aerobic condition in hybrid Rice

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Abstract

An experiment was undertaken to identify heterotic rice hybrids for aerobic condition based on physiological and root characters associated with water stress tolerance in rice. Panicle harvest index, a substitute for spikelet fertility is used as a secondary trait in the selection of drought tolerant genotypes. Deep roots are required to explore the soil profile for effectively absorbing water at deeper layers. A cultivar which partitions more of its dry weight in root can explore more soil volume for extracting water and thus can effectively sustain drought. Four hybrids *viz.,* IR 68885A / IR 73718-3-1-3-3, IR 67684A / CT-6510-24-1- 2, IR 70369A / IR 73718-3-1-3-3 and IR 70372A/ PSBRC 80 exhibited heterotic vigour for yield and maximum number of yield components and showed better adaptability to aerobic conditions. These hybrids can be commercially exploited under aerobic condition.

Key words: Rice hybrids, heterosis, physiological traits, aerobic rice.

Introduction

Under present day condition, growing "Water crisis" threatens the sustainability of irrigated rice productions and ways must be sought to reduce water requirements in rice and increase its productivity. A fundamental approach to reduce water inputs in rice is to grow the crop aerobically like an irrigated upland crop such as wheat and maize. For rice to be successful as an aerobic crop, it should tolerate intermittent water deficits and high soil impedance created due to aerobic conditions (Lafitte and Bonnett, 2002). Hence, specific aerobic rice cultivars with high yield potential and tolerance to water deficit are essential. The success of hybrid rice in breaking the yield barrier under irrigated condition provides an impetus to plant breeders to exploit it under aerobic condition. Keeping this in view, the present study was carried out to identify heterotic hybrids for aerobic conditions based on characters associated with yield and water stress tolerance in rice.

Materials and Methods

An experiment was carried out with forty two rice hybrids under aerobic condition at Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore during *Rabi*, 2005. The experimental material comprising forty two rice hybrids were obtained by crossing six drought tolerant CGMS lines with seven male parents (testers) in Line x Tester design. Well-preserved seeds from the forty two cross combinations were sown in raised nursery beds along with two standard hybrids *viz.,* ADTRH 1, CORH 2 and one aerobic rice variety CT-6510-24-1-2. Twenty-six days old seedlings were transplanted in the main field in a randomized block design (RBD) replicated twice adopting a spacing of 20 cm between rows and 10 cm between plants. Single seedling was transplanted per hill in single row of two-metre length (20 plants per row) in each replication. The transplanted crop was maintained under flooded condition (2-3 cm water layer) for 15 days to ease the establishment of the crop. Thereafter, aerobic condition was imposed by irrigating the crop up to field capacity after it has reached a certain lower threshold (*e.g.,* half way between field capacity and wilting point) as suggested by Bouman (2001). A total of 12 irrigations were given during the crop growth period. Every day soil samples were drawn and the soil moisture content was estimated using gravimetric method. Data were recorded on sixteen traits *viz.,* days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, pollen fertility,

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panicle harvest index, relative water content, membrane integrity (per cent of leakage), catalase, transpiration rate, stomatal conductance, root length, root volume, root dry weight and grain yield in ten plants per replication. Physiological traits were recorded at flowering stage and plants were uprooted at maturity and root traits were recorded. For recording physiological traits like relative water content (Weatherly, 1950), membrane integrity (per cent leakage) and catalase activity (Deshmukh *et al.,* 1991) standard procedures were followed. Transpiration rate and stomatal conductance were measured in the fully expanded flag leaf using Steady State Porometer PMR 5. The over all mean value for each hybrid and standard checks were taken for computation of standard heterosis diii (h) as follows

$$\text{diii(h)} = \frac{\overline{F_1} - \overline{SH}}{\overline{SH}} \text{ x } 100$$

where,

$\overline{F_1}$ = Average performance of the hybrid

$\overline{SH}$ = Average performance of standard checks (CT-6510-24-1-2 or ADTRH 1 or CORH 2)

The significance was tested by using the formula given by Wynne *et al* (1970)

Results and Discussion

Heterosis as per cent increase or decrease over the standard checks of the selected cross combinations for the various yield and water stress tolerant traits under aerobic condition are presented in Table 1 and 2. The nature and magnitude of heterosis revealed that among 42 hybrids, six hybrids exhibited significant negative heterosis for days to 50% flowering over all three standard checks. Among them, the hybrid IR 68885A / IR 73718-3-1-3-3 was found to be superior for earliness under aerobic conditions (Table 1). Early maturing hybrids are desirable under stress as they are more efficient in partitioning carbohydrate to the panicle and producing more yield per day (Lafitte and Courtois, 2002)

Cultivars with high tillering ability are favourable for cultivation under aerobic conditions because proliferic tillering would aid the production of higher leaf areas, higher crop growth rate, and thus, increased sink size under water deficit (Atlin and Lafitte, 2002). The heterosis for number of tillers per plant was found to be significant and positive in the hybrids IR 67684A/CT-6510-24-1-2 and IR 68885A/ R 73718-3-1-3-3 over all the three standard checks (Table 1). Present observations are in conformity with the findings of Souframanien *et al* (1998) under drought condition. Selection based on increased panicle number may be a promising avenue for increasing grain yield under aerobic conditions (Atlin *et al.,* 2004). Significant positive standard heterosis for productive tillers per plant was recorded by three hybrids *viz.,* IR 67684A / CT-6510-24-1-2, IR 70372A / PSBRC 80 and IR 68885A / IR 73718-3-1-3-3 (Table 1). Similiar results were reported by Soni *et al* (2005).

Hybrids with lengthy panicles are desirable, since the number of spikelets would increase proportionally with the enhancement of panicle length (Krishnaveni *et al.,*2005). Out of forty two hybrids studied, two hybrids *viz.,* IR 70372A / PSBRC 80 and IR 68887A / PR-26406-4-B-B-2 showed superior performance over all the three standard checks (Table 1). Higher percentage of pollen fertility is generally associated with more number of filled grains per panicle resulting in higher productivity (Krishnan, 2004). The extent of heterosis for this trait revealed superiority for three hybrids *viz.,* IR 68885A / IR 73718-3-1-3-3, IR 67684A / CT-6510-24-1-2 and IR 70372A / PSBRC 80 over all the three checks (Table 1).

Panicle harvest index, a substitute for spikelet fertility is used as a secondary trait in the selection of drought tolerant genotypes. Highly positive standard heterosis for this trait was exhibited by four hybrids *viz.,* IR 68885A / IR 73718-3-1-3-3 IR 70369A / IR 73718-3-1-3-3, IR 67684A / CT-6510-24-1-2 and IR 70372A / PSBRC 80 over all the three standard checks (Table 1). Positive standard heterosis for panicle harvest index was reported by Sheeba (2005). Maintenance of higher plant water status under drought plays a central role in stabilizing the various plant processes and yield. Relative water content is one of the measures which gives an idea of tissue water status and therefore used as a most meaningful index for identifying genotypes with dehydration tolerance (Kumar and Kajur ,2003).Out of 42 hybrids, two hybrids *viz.,* IR 67684A / CT-6510-24-1-2 and IR 70372A / IR 73718-3-1-3-3 expressed significant positive heterosis over all the three standard checks and are found to be highly tolerant to water stress (Table 2). Hybrids with high relative water content under drought were observed by Souframanien *et al* (1998). Maintenance of membrane integrity and function under water stress was used as a measure of drought tolerance by Malarvizhi (2005). Among 42 hybrids studied, the hybrids IR 68885A / IR 73718-3-1-3-3, IR 70369A / IR 73718-3-1-3-3 and IR 70372A / PSBRC 80 showed significant and positive heterosis over all the three standard checks for membrane integrity (Table 2) .

The free radicals produced during water stress cause the lipid peroxidation and membrane deterioration in plants. The free radicals scavenging enzymes such as SOD and catalase cause retardation of lipid peroxidation (Sdychalla and Desborough**,** 1990). The former dismutases the highly reactive superoxide radicals O_2^- produced during stress into H_2O_2 and the later converts H_2O_2 into H_2O and O_2 and there by minimizing damage caused to the membrane under water stress. In the present study, five hybrids IR 70372A / PSBRC 80, IR 70369A / IR73718-3-1-3-3, IR 70372A/ IR 73005-23-1-3-3 ,IR 68281A / PSBRC 80 and IR 68885A / APO (IR55423-01) exhibited higher heterosis over all the standard checks for this trait and found to be highly drought tolerant (Table 2).

Low transpiration rate is a desirable trait, as it is associated with the better conservation of leaf moisture under water stress. In the present investigation, six hybrids *viz.,* IR 68887A/PSBRC80, IR 70369A / IR 73005-23-1-3-3, IR70369A/IR73718-3-1-3-3, IR 70372A / PSBRC 80, IR 67684A / CT-6510-24-1-2 and IR 68885A/ IR 73718-3-1-3-3 showed desirable negative heterosis over the entire three standard checks (Table 2). Low stomatal conductance helps to maintain higher leaf water potential in the genotypes under stress (Blum**,** 1982). Significant negative standard heterosis for stomatal conductance was expressed in two hybrids *viz.,* IR 70369A / IR 73718-3-1-3-3 and IR 68885A / IR 73718-3-1-3-3 over the checks indicating that these hybrids are best suited for aerobic conditions (Table 2).

Deep roots are required to explore the soil profile for effectively absorbing water at deeper layers (Lafitte and Bonnett, 2002). Positive standard heterosis for root length over all the three standard checks was shown by the hybrids IR 70372A / IR 73718-3-1-3-3 and IR 68885A / IR 73718-3-1-3-3 (Table 2). A similar positive heterosis for root length was reported by Michael Gomez (2001). Plants with better root volume can colonize a large soil volume and improve the water uptake under stress (Kanbar, 2004). The hybrids IR 68887A/IR 73718-3-1-3-3, IR 68885A/ IR 73718-3-1-3-3, IR 70369A / IR 73005-23-1-3-3, IR 70369A / IR 73718-3-1-3-3 and IR 67684A / CT-6510-24-1-2 showed high heterosis over all the standard checks indicating their tolerance to water stress (Table 2).

A cultivar which partitions more of its dry weight in root can explore more soil volume for extracting water and thus can effectively sustain drought (Sorte et *al*., 1992). High standard heterosis for root dry weight was found in two hybrids *viz.,* IR 68887A / IR 73005-23-1-3-3 and IR 67684A / CT-6510-24-1-2 over all the three standard checks (Table 2). Significant positive heterosis for grain yield, an economic output of the plant was exhibited by four hybrids *viz* IR 67684A / CT-6510-24-1-2, IR 70369A / IR 73718-3-1-3-3, IR 68885A/ IR 73718-3-1-3-3, and IR 70372A/PSBRC 80 over all the three standard checks (Table 1). Positive heterosis for grain yield was earlier reported by Dalvi and Patel (2005).

On the whole, four heterotic hybrids for yield *viz.,* IR 68885A / IR 73718-3-1-3-3, IR 67684A / CT-6510-24-1- 2, IR 70369A / IR 73718-3-1-3-3 and IR 70372A / PSBRC 80 showed better adaptability to aerobic conditions by exhibiting heterotic vigour for maximum number of yield components and water stress tolerant traits. The hybrid rice seed production techniques of these hybrids have to be standardized for commercial exploitation.

References

Atlin, G.N. and H.R. Lafitte. 2002. Developing and testing rice varieties for water saving systems in the tropics. In: Water Wise Rice Production. Proceedings of the International Workshop on Water-wise Rice Production, 8-11 April (Eds. Bouman, B.A.M., H. Hengsdijk, B. Hardy, P.S. Bindraban, J.P. Tuong and J.K. Ladha), IRRI, Los Banos, Philippines, pp. 275-283.

Atlin, G.N., M. Laza, M. Amante and H.R. Lafitte. 2004. Agronomic performance of tropical aerobic, irrigated and traditional upland rice varieties in three hydrological environments at IRRI. In: Fourth International Crop Science Congress, IRRI, Los Banos, Philippines (www.regional.org), p.1439.

Blum, A. 1982. Evidence for genetic variability in drought resistance and its implications in plant breeding. In: Drought Resistance in Crops with Emphasis on Rice. IRRI, Manila, Philippines, pp.53-68.

Bouman, B.A.M. 2001. Water efficient management strategies in rice production. Int. Rice Res. Notes, 26: 17-22.

Dalvi, V.V. and D.V. Patel. 2005. Heterosis for yield and its components. In: National seminar on "Rice and Rice Based Systems for Sustainable Productivity, Extended summaries, ICAR Research Complex for Goa", 18-19th October, 2005, pp.34-35.

Deshmukh, P.S., R.F. Sairam and D.S. Shukla. 1991. Measurement of ion leakage as a screening technique for drought resistance in wheat genotypes. Indian J. Plant Physiol., 34: 89-91.

Krishnan, V. 2004. Studies on the development of improved grain quality hybrids through three line breeding in rice (*Oryza sativa* L.). Unpub. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore, India.

Krishnaveni, B., N. Shobha Rani and A.S.R. Prasad. 2005. Heterosis for yield components and key quality traits in Basmati rice. Oryza, 42: 97-102.

Kumar, R and R. Kajur. 2003. Role of secondary traits in improving the drought tolerance during flowering stage in rice. Indian J. Plant Physiol., 8: 236-240.

Lafitte, H.R and J. Bonnett. 2002. Requirements for aerobic rice: physiological and molecular considerations. In: Water Wise Rice Production. Proceedings of the International Workshop on Water-wise Rice Production, 8-11 April (Eds. Bouman, B.A.M., H. Hengsdijk, B. Hardy, P.S. Bindraban, J.P. Twong and J.K. Ladha), IRRI, Los Banos, Philippines, pp.259-271.

Lafitte, H.R and B. Courtois. 2002. Interpreting cultivar x environment interactions for yield in upland rice: Assigning value to drought adaptive traits. Crop Sci., 42: 1409-1420.

Malarvizhi, D. 2005. Genetic studies on development of rice hybrids for aerobic cultivation. Unpub. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore, India.

Michael Gomez, M.S. 2001. Identification of gene action for drought resistance traits in rice (*Oryza sativa* L.). Unpub. M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore, India.

Sdychalla, J.P and S.L. Desborough. 1990. Superoxide dismutase, catalase and tocopherol contents of stored potato tubers. Plant Physiol., 94: 1214-1218.

Sheeba, A. 2005. Genetic studies on drought tolerance and stability of Temperature sensitive genic male sterility (TGMS) based rice hybrids. Unpub. Ph.D. Thesis, Tamil Nadu Agric. Univ., Madurai, India.

Soni, D.K., A. Kumar, N. Sunil and Lakeswar Sahu. 2005. Study of heterosis by utilizing cytoplasmic genic male sterility system in rice (*Oryza sativa* L.). Plant Archives, 5: 617-621.

Sorte, N.V., R.D. Deotale, M.N. Patankar. A.H. Narkhede, V.J. Golliwar and. B.D. Katole. 1992. Root and shoot physiology as influenced by short term water stress in upland paddy. J. Soils and Crops, 2: 86-91.

Souframanien, S., P. Rangasamy, P. Vaidyanathan, and M. Thangaraj. 1998. Heterosis and combining ability for drought resistance characters in hybrid rice (*Oryza sativa* L.). Indian J. Agric. Sci., 68: 687-689.

Weatherly, P.E. 1950. Studies in the water relations of the cotton plant. I. The field measurement of water deficits in leaves. New Phytol., 49: 81-97.

Wynne J.C., D.A. Emery and P.W. Rice. 1970. Combinining ability estimates in *Arachis hypogea L*. II. Field performance of a F_1 hybrids. Crop Sci., 10 :713-715.

Table 1. Standard heterosis for yield and yield components in hybrid rice

Hybrids		DFF	TILL	PT	PL	PF	PHI	GY
IR 67684A / CT-6510-24-1-2	A	8.20**	59.09**	57.78**	1.68	7.30**	3.62**	61.51**
	B	8.20**	42.89**	32.09**	4.30	3.53*	5.91**	45.53**
	C	7.03**	48.94**	42.00**	3.19	11.70**	8.29**	29.74**
IR 68281A / PSBRC 80	A	0.02	-14.55*	-4.44	-11.53**	-6.40**	-9.80**	-20.37**
	B	0.02	-23.27**	-20.00**	-9.25**	-12.32**	-7.81**	-28.25**
	C	-1.08	-20.00**	-14.00	-10.21**	-2.57	-5.74**	-36.05**
IR 68885A / PR-26406-4-B-B-2	A	-9.29**	-38.18**	-38.89--	1.01	-89.38**	-66.79**	-83.22**
	B	-9.29**	-44.19**	-48.84**	3.66	-90.05**	-66.05**	-84.88**
	C	-10.27**	-42.13**	-45.00**	2.55	-88.95**	-65.29**	-86.52**
IR 68885A / APO (IR55423-01)	A	6.01**	-4.55	-21.11*	-11.95**	-88.03**	-71.42**	-83.43**
	B	6.01**	-14.29*	-33.95**	-9.68**	-88.79**	-70.78**	-85.07**
	C	4.86**	-10.64	-29.00**	-10.64**	-87.54**	-70.13**	-86.69**
IR 68885A / IR 73718-3-1-3-3	A	-10.93**	20.00*	27.78**	3.77	7.75**	5.02**	51.51**
	B	-10.93**	14.90*	18.37*	6.45*	6.52**	7.34**	36.52**
	C	-11.89**	19.36**	19.00*	5.32	12.13**	9.76**	21.70**
IR 68887A / PSBRC 80	A	-10.38**	-20.00**	-9.28	0.42	-13.60**	-5.10**	-20.86**
	B	10.38**	-28.16**	-24.05**	3.01	-19.30**	-3.00*	-28.69**
	C	-11.35**	-25.11**	-18.35*	1.91	-10.06**	-0.82	-36.43**
IR 68887A / PR-26406-4-B-B-2	A	-8.20**	-36.36**	-23.33*	6.29*	-87.13**	-75.99**	-85.14**
	B	-8.20**	-42.86**	-35.81**	9.03**	-87.95**	-75.46**	-86.61**
	C	-9.19**	-40.43**	-31.00**	7.87**	-86.61**	-74.91**	-88.07**
IR 68887A / IR 73005-23-1-3-3	A	-3.28**	-11.36	-8.33	0.42*	3.37*	-0.29	28.53**
	B	-3.28**	-20.41**	-23.26**	3.01	-3.06*	1.92	15.81*
	C	-4.32**	-17.02*	-17.50*	1.91	7.60**	4.21**	3.25
IR 68887A / IR 73718-3-1-3-3	A	-1.90	-24.82**	-8.56	-6.92*	-5.06**	-2.85*	-27.71**
	B	-1.09	-29.80**	-23.44**	-4.52	-11.05**	-0.70	-29.46
	C	-2.16*	-26.81**	-17.50*	-5.53	-1.17	1.53	-37.11**
IR 70369A / IR 73005-23-1-3-3	A	1.09	-11.82	-3.33	-11.11**	4.21**	1.25	13.88
	B	1.09	-20.85**	-19.07*	-8.82**	-2.37	3.49*	2.61
	C	0.05	-17.45*	-13.00	-9.79**	8.48**	5.82**	-8.52
IR 70369A / IR 73718-3-1-3-3	A	-1.09	2.27	16.67	0.21	5.62**	3.82**	58.73**
	B	-1.09	-8.16	-2.33	2.80	-1.05	6.12**	43.03**
	C	-2.16*	-4.26	5.00	1.70	9.94**	8.51**	27.51**
IR 70372A / PSBRC 80	A	2.19*	13.64	29.44**	7.95**	6.52**	2.92*	41.96**
	B	2.19*	2.04	18.98*	10.99**	3.18*	5.19**	27.91**
	C	1.08	6.38	21.00*	8.93**	10.88**	7.59**	14.03*

IR 70372A / IR 73005-23-1-3-3	A	18.58**	-13.18*	-3.33	-4.82	0.01	0.42	4.82
	B	18.58**	-22.04**	-19.07	-2.37	-6.32**	2.64	-5.55
	C	17.30**	-18.72**	-13.00	-3.40	4.09*	4.92**	-15.80**
IR 70372A / IR 73718-3-1-3-3	A	13.66**	7.27	6.67	4.98	4.48**	0.10	34.37**
	B	13.66**	-16.73*	-10.70	6.67*	-2.11	2.32	21.07**
	C	12.43**	-13.19*	-4.00	5.95*	8.77**	4.62**	7.93

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

A: standard heterosis over CT-6510-24-1-2, B: standard heterosis over ADTRH 1,C: standard heterosis over CORH 2

DFF: Days to 50 % flowering, TILL: Number of tillers per plant, PT: No. of productive tillers per plant
PL: Panicle length in cm, PF: Pollen fertility in %, PHI: Panicle harvest index in %: GY: Single plant yield in grams

Table 2. Standard heterosis for water stress tolerant traits in hybrid rice

Hybrids		RWC	MI	CAT	TR	SC	RL	RV	RDW
IR 67684A / CT-6510-24-1-2	A	4.00*	9.10*	2.52	-45.83**	-4.80	-9.20**	13.64**	16.30*
	B	4.77**	1.48	9.96*	-50.94**	-12.15	0.05	30.89**	43.90**
	C	5.30**	-2.53	5.11	-60.00**	-13.37*	2.60	20.16**	23.94**
IR 68281A / PSBRC 80	A	-4.92**	5.51	9.58*	25.00	-6.50	-8.20**	-13.02**	-16.30*
	B	-4.22**	-1.86	17.53**	13.21	-13.71*	1.01	0.18	3.56
	C	-3.74*	-5.54	12.35**	-7.29	-14.91*	3.64	-8.03	-10.80
IR 68885A / PR-26406-4-B-B-2	A	-0.12	24.30**	-1.31	87.50**	134.63**	-6.90*	-63.41**	-85.89**
	B	0.62	15.62**	5.85	69.81**	116.53**	2.53	-57.86**	82.54**
	C	1.12	11.05**	1.19	38.46**	113.52**	5.19	-61.31**	-84.96**
IR 68885A / APO (IR55423-01)	A	-9.42**	26.33**	8.27*	91.67**	16.50*	-16.87**	-6.98	9.59
	B	-8.74**	17.50**	16.13**	73.59**	7.50	-8.46**	7.14	35.42**
	C	-8.29**	12.87**	11.01**	41.54**	6.02	-6.08*	-1.64	16.64*
IR 68885A / IR 73718-3-1-3-3	A	1.85	-7.18*	4.59	-43.75**	-16.01*	5.75*	18.60**	4.79
	B	2.60	-8.25*	12.18**	-49.06**	-18.61**	8.86**	96.61**	29.66**
	C	3.12*	-11.87**	7.24	-58.46**	-19.74**	11.69**	25.41**	11.68
IR 68887A / PSBRC 80	A	0.09	17.82**	-74.07**	-58.33**	-7.74	-8.05**	-10.85**	-20.82**
	B	0.84	9.59**	-72.19**	-62.26**	-14.86*	1.27	2.68	-2.03
	C	1.34	5.26	-73.12**	-69.23**	-16.04*	3.90	-5.74	-15.62
IR 68887A / PR-26406-4-B-B-2	A	-8.40**	22.56**	-10.79**	83.33**	93.50**	-48.94**	-27.91**	-78.36**
	B	-7.72**	14.00**	-4.32	66.04**	78.57**	-43.77**	-16.96**	-73.22**

	C	-7.26**	9.50**	-8.53*	35.38**	76.09**	-42.31**	-23.77**	-76.93**
	A	-2.28	7.10	-0.17	20.83	-5.71	-9.20**	-19*.40**	22.19**
IR 68887A / IR 73005-23-1-3-3	B	-1.55	-0.38	7.07	9.43	-12.98*	0.01	-7.16	51.18**
	C	-1.06	-4.32	2.35	-10.77	-14.19*	2.60	-14.77**	30.22**
	A	-4.00*	23.71**	-41.14**	-23.17	-8.76	-4.94	27.13**	-28.22**
IR 68887A / IR 73718-3-1-3-3	B	-3.29*	15.01**	-36.86**	-35.85*	-15.75*	4.68	46.43**	-11.19
	C	-2.80	10.53**	-39.65**	-47.69**	-16.92**	7.40*	34.43**	-23.50**
	A	-4.31**	14.67**	-14.62**	-37.50*	-3.95	-6.55*	16.28**	2.47
IR 70369A / IR 73005-23-1-3-3	B	-3.60*	6.66	-8.53*	-43.40**	-11.37	2.91	33.93**	26.78**
	C	-3.12*	2.45	-12.56**	-53.85**	-12.90*	5.58	22.96**	9.20
	A	0.62	-7.86*	12.35**	-58.33**	-18.76**	-3.45	16.28**	9.45
IR 70369A / IR 73718-3-1-3-3	B	1.36	-11.51**	20.50**	-62.26**	-25.03**	6.33*	33.93**	35.59**
	C	1.87	-15.00*	15.19**	-69.23**	-26.07**	9.09**	22.96**	16.79*
	A	2.15	-9.54**	13.14**	-52.08**	-0.11	-24.48**	-29.46**	12.33
IR 70372A / PSBRC 80	B	2.91	-15.86**	21.35**	-56.60**	-7.82	-16.84**	-18.75**	38.98**
	C	3.43*	-19.18	16.00*	-64.62**	-9.10	-14.68**	-25.41**	19.71*
	A	-4.00*	21.50**	11.21**	10.83	-11.81	-18.39**	3.88	-9.04
IR 70372A / IR 73005-23-1-3-3	B	-3.29*	13.01**	19.28**	0.38	-16.48*	-10.13**	19.64**	12.24
	C	-2.80	8.55*	14.03**	-18.15	-17.63**	-7.79**	9.84*	-3.07
	A	3.38*	-1.35	-35.88**	25.00	-8.70	11.49**	3.88	11.94
IR 70372A / IR 73718-3-1-3-3	B	4.15**	-7.89*	-31.22**	13.21	-15.75*	22.78**	19.64**	38.14**
	C	4.67**	-10.18**	-34.25**	-7.69	-16.92**	25.97**	9.84*	18.98*

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

A: standard heterosis over CT-6510-24-1-2, B: standard heterosis over ADTRH 1,C: standard heterosis over CORH 2

RWC: Relative water content at flowering in %, MI: Membrane integrity (% of leakage) at flowering,

CAT: Catalase at flowering (µg/g/minute)

TR: Transpiration rate at flowering in(mmol/m^2/sec),SC: Stomatal conductance at flowering in(mmol/m^2/sec),

RL: Root length in cm

RV: Root volume in cc: RDW: Root dry weight in grams