



Research Article

Estimation of combining ability and heterosis for drought tolerance in different locations in rice (*Oryza sativa* L.)

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Abstract:

Diallel analysis was carried out in three different environments namely, managed stress, rainfed and dry conditions to study the combining ability and heterosis for 13 yield and drought tolerant traits. Evaluation of parents based on *per se* and *gca* effects, the parents Nootripathu, Mattaikar, Vellaichithiraikar, PMK 3 and NPT 107 were identified as the best genotypes for improvement of yield combined with drought tolerance. The hybrids viz., NPT 107 / MDU 5 for rainfed and dry condition and NPT 107 / Nootripathu for managed stress condition were observed to have parallelism between desirable mean, *sca* effects and standard heterosis for most of the drought tolerant traits besides grain yield and hence these hybrids were recommended for commercial exploitation of heterosis. The hybrids obtained by crossing the good general combiners viz., For the crosses of good general combiners viz., PMK 3 / Vellaichithiraikar, PMK 3 / Nootripathu and Vellaichithiraikar / Nootripathu, can be recommended for the development of high yielding drought tolerant varieties through pedigree method of breeding. For the hybrids of either with one good and one poor combiners viz., PMK 3 / MDU 5, PMK 3 / ASD 16, PMK 3 / Mattaikar, PMK 3 / Norungan, NPT 107 / Nootripathu and ASD 16 / Vellaichithiraikar, the biparental or reciprocal recurrent selection method may be followed to obtain desirable early segregants and for the cross combinations of both poor combiners viz., NPT 107 / MDU 5, MDU 5 / Mattaikar and MDU 5 / Norungan, since they involved non-additive gene action, cyclic method of breeding involving selection of desired recombinants and their *inter se* crossing would be more desirable.

Key words:

Oryza sativa, drought, *per se* performance, combining ability, standard heterosis

Introduction

Rice (*Oryza sativa* L.) is the major food crop of more than half of the global population and will continue to occupy the pivotal place in global food and livelihood security systems. But much of this important crop yield is devastated by drought or diseases (Reddy, 2005). Land races are one of the important components of the germplasm and serve as the donors for the drought tolerance. Local land races are naturally adapted to utilize the natural resource-base better than the introduced modern cultivars (Bhattacharya and Ghosh, 2004). Moreover the land

racess have broad genetic base which provides them wider adaptability and protection from various stresses. Hence, the development of high yielding rice hybrids combined with drought tolerance is highly essential by utilizing the local land races as donors to meet the current demand in rice.

The concept of combining ability helps the breeder to determine the nature of gene action involved in the expression of quantitative traits of economic importance. The choice of suitable breeding method for the improvement of drought tolerance traits primarily depends on the relative importance of GCA and SCA variances. Proper choice of parents on the basis of their combining ability status for putative drought tolerant attributes as well as yield contributing traits and selection in typical target

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environment will help in combining complex traits such as productivity and drought tolerance (Hanamaratti *et al.*, 2004). A hybrid is commercially valuable only when it exhibits significantly high standard heterosis over the best locally adopted variety or hybrid. Apart from high vigour and yield, the hybrids can be a potential genetic source for better root system with higher efficiency to absorb moisture effectively for tolerating drought condition. Existence of heterosis for drought tolerant traits will be a boon to drought tolerance breeding since most of the hybrids developed so far lack of tolerance to abiotic and biotic stresses. With these points in view, the present investigation was carried out to select superior hybrids by studying their *per se* performance, combining ability effects and standard heterosis under three different environmental condition.

Materials and methods

Four cultivars *viz.*, NPT 107, PMK 3, MDU 5 and ASD 16 and four local land races *viz.*, Vellaichithiraikar, Mattaikar, Nootripathu and Norungam were selected and crossed in diallel fashion (Method II; Model I) and resulted 28 hybrids along with parental genotypes were evaluated under three different environments *viz.*, managed stress (E₁-Madurai), rainfed (E₂-Paramakudi) and dry condition (E₃-Ramanathapuram) in Tamil nadu, India.

The observations on yield and drought tolerant traits *viz.*, days to 50% flowering, plant height, productive tillers / plant, panicle length, panicle harvest index, filled grains / panicle, spikelet fertility, 100 grain weight, chlorophyll content, root length, dry root weight, root : shoot ratio and single plant yield were recorded. Under managed stress condition (Agricultural College and Research Institute, Madurai), the stress was imposed at active tillering stage. Irrigation was stopped on 59th day after sowing and the stress was imposed for 16 days. During stress period, drought tolerant traits were recorded. After transplanting, irrigation was stopped and maintained under rainfed condition at Agricultural Research Station, Paramakudi and the hybrids and parents were raised under completely dry condition at Coastal Saline Research Centre, Ramanathapuram. The analysis of variance of RBD and their significance for all the characters were worked out in all the three environments (Panse and Sukhatme, 1964). The general and specific combining ability variances were estimated by Method 2 and Model 1 (Griffing, 1956). The diallel

cross data from the all environments were subjected to pooled analysis (Daljit Singh, 1973a, 1973b & 1979). The mean values of hybrids were used for the estimation of standard heterosis per cent *i.e.* the superiority of F₁ over the standard variety MDU 5 (Fonseca and Patterson, 1968).

Results and discussion

Nature of gene action as measured by GCA and SCA variance is of greater importance in deciding the inheritance of a character and thereby selection of suitable breeding programmes. Magnitude of genetic variance for different traits in pooled environment is presented in Table 1. The magnitude of additive variance was higher for the trait plant height in all the environments. Higher magnitude of additive variance suggested the predominance of additive gene action for this trait. This was in agreement with earlier reports (Michael Gomez *et al.*, 2003; Gnanasekaran *et al.*, 2006). For the remaining traits *viz.*, days to 50 per cent flowering, productive tillers/plant, panicle length, panicle harvest index, filled grains/panicle, spikelet fertility, 100 grain weight, chlorophyll content, root length, dry root weight, root:shoot ratio and single plant yield, the non additive genetic variance was greater in magnitude than additive genetic variance in all the environments. Similar results were also reported by earlier workers (Panwar, 2005; Rita Binse and Motiramani, 2005).

The potentiality of a strain to be used as a parent in hybridization, or in a cross to be used as a commercial hybrid, may be judged by comparing the *per se* performance of the parents, the F₁ value (heterosis) and the combining ability effects (Venkateshwaralu and Singh, 1982). The partitioning of cross combinations exhibiting significant *sca* effects and desirable *per se* performance for different traits involved parents with good X good, good X poor, poor X good and poor X poor combining abilities was made. The parents Nootripathu, Vellaichithiraikar and PMK 3 were the good general combiners along with significant *per se* performance for eight, seven and six traits comprising of yield and drought tolerant traits respectively including single plant yield (Table 2). The cross combinations (good X good) of these parents *viz.*, PMK 3 / Vellaichithiraikar, PMK 3 / Nootripathu and Vellaichithiraikar / Nootripathu showed significant *sca* effects and high *per se* performance for some of the yield contributing and drought tolerant traits including single plant yield (Table 3). Hence these parents appear to be worthy of exploitation in varietal

development programme. If these hybrids are utilized in pedigree breeding, there is a possibility of isolating high yielding genotypes along with drought tolerance. This is in accordance with the earlier findings (Manonmani and Faslullah Khan, 2003).

The hybrids PMK 3 / MDU 5, PMK 3 / ASD 16, PMK 3 / Mattaikar, PMK 3 / Norungan, NPT 107 / Nootripathu and ASD 16 / Vellaichithiraikar recorded significant *sca* effects with desirable *per se* performance for more traits including single plant yield (Table 3) involved either with one good and one poor combiners (good X poor or poor X good) (Table 2). This suggests that high *sca* effect of any cross combination does not necessarily depend upon the *gca* effects of the parent lines involved. This is in agreement with the earlier findings (Sarsar *et al.*, 1986; Ram *et al.*, 1998). These hybrids can be utilized for the identification of transgressive segregants in the later generations. To obtain desirable early segregants the appropriate breeding method would be biparental mating or reciprocal recurrent selection method (Wilfred Manuel and Palanisamy, 1989). The crosses of both poor combiners (poor X poor) *viz.*, NPT 107 / MDU 5, MDU 5 / Mattaikar and MDU 5 / Norungan showed significant *sca* and desirable *per se* performance for single plant yield and some of the yield and drought tolerant traits (Table 3). For these combinations, since most of the traits involved were shown non-additive gene action, cyclic method of selection of desired recombinants and their *inter se* crossing would be more desirable (Sankarapandian, 1986).

The superiority of *sca* effects obtained by crossing the poor *gca* effect parents may be due to complementary type of gene action or involvement of non-allelic interaction of fixable and non-fixable genetic variance. The crosses involved at least one parent with good general combining ability which indicated the presence of additive X additive or additive X dominance genetic interaction, while, remaining crosses involved poor combiners suggesting the epistatic gene action, which could be mainly due to genetic diversity in the form of heterozygous loci (Ram *et al.*, 1998).

Only the high *sca* effects may not be the appropriate choice for heterosis exploitation because hybrid with low mean values may also possess high *sca* effects. Further more, heterosis value alone may also mislead the identity of superior hybrids. Exploitation of hybrids for heterosis breeding is best judged by *per*

se, *sca* effects and magnitude of heterosis. Based on these three criteria, the hybrid NPT 107 / Nootripathu was suitable for heterosis breeding under managed stress condition, since it exhibited desirable mean, *sca* effects and standard heterosis for eight traits including three yield contributing traits *viz.*, productive tillers / plant, panicle harvest index and filled grains / panicle and four drought tolerant traits *viz.*, spikelet fertility, root length, dry root weight and root: shoot ratio with single plant yield (Table 3). Under rainfed condition, the hybrid NPT 107 / MDU 5 performed well by possessing favourable mean, *sca* effects and standard heterosis for nine traits including single plant yield (Table 3). The same hybrid showed parallelism between high mean, *sca* effects and standard heterosis for eight traits under dry conditions (Table 3). It is concluded that, the above said hybrids are highly suitable for commercial exploitation of heterosis under drought situations.

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References :

- Bhattacharya, S., and Ghosh, S. K. 2004. Association among yield related traits of twenty-four diverse land races of rice. *Crop Res.*, **27**(1): 90-93.
- Daljit Singh. 1973a. Diallel analysis over different environments-I. *Indian J. Genet.*, **33**(2): 127-136.
- Daljit Singh. 1973b. Diallel analysis for combining ability over several environments-II. *Indian J. Genet.*, **33**(3): 469-481.
- Daljit Singh. 1979. Diallel analysis for combining ability over environments. *Indian J. Genet.*, **39**(3): 383-386.
- Fonseca, S., and Patterson, F. L. 1968. Hybrid vigour in seven parent diallel cross in common wheat (*Triticum aestivum* L.). *Crop Sci.*, **2**: 85-88.
- Gnanasekaran, M., Vivekanandan, P., and Muthuramu, S. 2006. Combining ability and heterosis for yield and grain quality in two line rice (*Oryza sativa* L.) hybrids. *Indian J. Genet.*, **66**(1): 6-9.
- Griffing, B. 1956. Concepts of general and specific combining ability in relation to diallel crossing systems. *Australian J. Biol. Sci.*, **9**: 463-493.
- Hanamaratti, N. G., Salimath, P.M., Mohankumar, H.D., and Shailaja Hittalmani. 2004. Genetic and physiological basis of breeding productive and drought tolerant genotypes in upland rice. In: *Proc. workshop on resilient crops for water limited environments*. Cuernavaca, Mexico. Pp. 100-101.



- Manonmani, S., and Faslullah Khan, A. K. 2003. Studies on combining ability and heterosis in rice. *Madras Agric. J.*, **90**(4-6): 228-231.
- Michael Gomez, S, Rangasamy, P., and Nadarajan, N. 2003. Assessing the best combiners in rice (*Oryza sativa* L.) suitable for drought prone areas of Tamil Nadu. *Res. on Crops.*, **4**(1): 79-84.
- Panse, V. G., and Sukhatme, P. V. 1964. *Statistical methods for agricultural research workers*, ICAR, New Delhi.
- Panwar, L.L. 2005. Line x Tester analysis of combining ability in rice (*Oryza sativa* L.). *Indian J. Genet.*, **65**(1): 51-52.
- Ram, T., Singh, J., and Singh, R.M. 1998. Combining ability for yield and its components in rice. *Oryza*, **30**: 33-37.
- Reddy, C.S. 2005. Disease management in rice. *In: Proc. National seminar on Rice and Rice based system for Sustainable Productivity*, Goa. Pp. 188-191.
- Rita Binse and Motiramani, N. K. 2005. Study on gene action and combining ability in rice. *Oryza*, **42**(2): 153-155.
- Sankarapandian, R. 1986. Heterosis and combining ability analysis in sorghum (*Sorghum bicolor* L. Moench). M.Sc (Ag.) Thesis, TNAU, Coimbatore.
- Sarsar, S. M., Patil, R. A., and Bhatda, S. S. 1986. Heterosis and combining ability in upland cotton. *Indian J. Agric. Sci.*, **42**:11-14.
- Venkateshwaralu, S., and Singh, R. B. 1982. Combining ability in Pigeonpea. *Indian J. Genet.*, **42**:11-14.
- Wilfred Manuel, W. and Palanisamy, S. 1989. Line x tester analysis for combining ability in rice. *Oryza*, **29**: 15-18.



Table1. Magnitude of genetic variance for different traits in pooled environment

S. No	Character	σ^2A	σ^2D	σ^2A / σ^2D
1.	Days to 50 % flowering	55.57	120.39	0.46
2.	Plant height	775.80	581.92	1.33
3.	Productive tillers / plant	6.02	19.44	0.31
4.	Panicle length	3.18	15.17	0.21
5.	Panicle Harvest Index	-0.53	10.73	-0.05
6.	Filled grains / Panicle	172.02	951.24	0.18
7.	100 grain weight	0.02	0.11	0.19
8.	Spikelet fertility	-11.78	182.69	-0.06
9.	Chlorophyll content	1.12	29.12	0.04
10.	Root length	11.39	21.11	0.54
11.	Dry root weight	0.59	1.32	0.45
12.	Root : Shoot ratio	0.00004	0.0004	0.11
13.	Single plant yield	-5.97	55.85	-0.11



Table2. *per se* performance and *gca* of parents for yield and drought tolerant traits in pooled environment

Parents	Productive tillers / plant	Panicle length (cm)	Panicle harvest index (%)	Filled grains / Panicle	100 grain weight (g)	Spikelet fertility (%)	Chlorophyll content (lux)	Root length (cm)	Dry root weight (g)	Root : Shoot ratio	Single plant yield (g)
NPT 107	8.82	23.83*	86.16*	98.42	2.07	71.43	38.60*	16.42	1.55	0.05	9.71
	-0.85**	0.49**	0.50**	7.39**	-0.12	0.67**	0.57**	0.10	-0.29**	0.00	-0.36*
PMK 3	10.47*	25.00*	84.41	108.20*	2.24	66.73	31.23	18.12	2.23*	0.05	12.92*
	1.03**	0.66**	-0.66**	13.21**	-0.04	-4.02**	-2.02**	-0.23*	0.10**	0.00	1.63**
MDU 5	6.75	18.50	82.83	85.07	2.16	59.51	36.42*	14.38	1.27	0.04	8.49
	-1.19**	-0.98**	-0.02	-7.19**	-0.05	-1.08**	0.15	-1.29**	-0.47**	0.00	-0.28
ASD 16	7.48	21.55	83.41	107.31*	2.56	71.46	33.17	13.90	2.04	0.05	10.63
	-1.46**	-2.14**	-0.73**	-8.57**	0.05	0.53**	-0.51**	-3.06**	-0.51**	0.00	-1.31**
Vellaichithiraikar	9.77*	24.24*	82.03	79.93	2.78	83.27*	35.73*	21.07*	2.57*	0.05	9.83
	0.52**	0.28**	0.10	-3.46**	0.08	2.73**	1.32**	1.09**	0.49**	0.00	0.48**
Mattaikar	9.68	21.43	84.47	99.92*	2.21	81.74*	29.57	21.48*	2.40*	0.05	10.21
	0.92**	0.60**	0.59**	4.10**	-0.08	1.59**	-0.83**	2.31**	0.37**	0.00	-0.84**
Nootripathu	9.58	25.39*	85.97*	107.61*	2.47	76.56*	34.31	22.35*	2.55*	0.05	13.08*
	2.03**	0.40**	0.54**	0.79	0.05	-1.01**	0.94**	0.70**	0.13**	0.01**	0.78**
Norungan	10.77*	25.65*	85.28*	89.90	2.88	75.57*	32.15	17.33	2.42*	0.05	14.90*
	-1.00**	0.68**	-0.31	-6.27**	0.12	0.59**	0.38**	0.38**	0.19**	0.00	-0.09
Grand mean	9.17	23.20	84.32	97.05	2.42	73.28	33.90	18.13	2.13	0.05	11.22
SEd	0.28	0.13	0.41	1.22	1.22	0.04	0.29	0.29	0.04	0.003	0.44
CD (5 %)	0.57	0.26	0.83	2.48	2.48	0.08	0.59	0.59	0.08	0.01	0.89
SE	0.10	0.04	0.16	0.44	0.44	0.01	0.11	0.10	0.01	0.001	0.16

* and **significantly superior at 5 % and 1% level respectively; please note that *gca* is italicized



Table3. *per se* performance and *sca* of important hybrids for yield and drought tolerant traits in pooled environment and standard heterosis of best hybrids for different traits in their concerned environment

Hybrids	Productive tillers / plant	Panicle length (cm)	Panicle harvest index (%)	Filled grains / Panicle	100 grain weight (g)	Spikelet fertility (%)	Chlorophyll content (lux)	Root length (cm)	Dry root weight (g)	Root : Shoot ratio	Single plant yield (g)
NPT 107 / MDU 5	11.80*	26.95*	87.42*	135.98*	2.62	83.93*	29.22	22.22*	2.65*	0.05	21.42*
	3.60**	4.69**	1.31*	25.69**	0.28	10.10**	-2.74**	3.43**	1.03*	-0.01**	6.23**
E2 - Rainfed	<i>19.00**</i>	<i>0.95**</i>	<i>7.37**</i>	<i>26.55**</i>	<i>17.19**</i>	<i>25.90**</i>	<i>3.76**</i>	<i>24.64**</i>	<i>23.64*</i>	<i>0.00</i>	<i>60.30**</i>
E3 - Dry	<i>10.16**</i>	<i>-0.39</i>	<i>1.39**</i>	<i>28.93**</i>	<i>15.49**</i>	<i>28.92**</i>	<i>-1.80**</i>	<i>18.28**</i>	<i>26.32*</i>	<i>0.00</i>	<i>69.08**</i>
NPT 107 / Nootripathu	12.87*	21.09	87.27*	120.83*	2.23	75.37*	29.70	24.73*	2.74*	0.07	19.75*
	1.45**	-2.55**	0.61*	2.56	-0.21	1.46**	-3.04**	3.96**	0.52*	0.01**	3.50**
E1 – Managed stress	<i>20.75**</i>	<i>-1.75**</i>	<i>6.35**</i>	<i>10.83**</i>	<i>0.00</i>	<i>11.07**</i>	<i>-19.12**</i>	<i>38.92**</i>	<i>26.36*</i>	<i>60.00**</i>	<i>41.82**</i>
PMK 3 / MDU 5	12.78*	19.32	85.02	136.82*	2.19	74.34	25.73	22.32*	2.33	0.06	18.87*
	2.70**	-3.11**	0.07	20.70**	-0.23	5.20**	-3.65**	3.86**	0.31*	0.01**	1.69**
PMK 3 / ASD 16	6.55	21.18	84.58	127.70*	2.70	65.27	27.75	17.38	1.62	0.04	19.05*
	-3.26**	-0.09	0.33	12.96**	0.19	-5.48**	-0.96**	0.69*	-0.35*	-0.01**	2.91**
PMK 3 / Vellaichithiraikar	15.88*	23.72*	84.24	104.95	2.63	72.10	25.09	21.45*	3.36*	0.06	23.57*
	4.09**	0.03	-0.84	-14.91**	0.08	-0.86**	-5.45**	0.61	0.39*	0.01**	5.63**
PMK 3 / Mattaikar	15.17*	25.10*	85.86	135.77*	2.48	64.39	28.43	21.30*	4.10*	0.06	18.32*
	2.97**	1.10**	0.30	8.35**	0.09	-7.42**	0.04	-0.76*	1.25*	0.01**	1.70**
PMK 3 / Nootripathu	10.18	25.38*	85.70	144.73*	2.56	72.80	30.32	20.02	2.04	0.07	21.26*
	-3.12**	1.58**	0.19	20.64**	0.05	3.59**	0.15	-0.43	-0.57*	0.01**	3.02**
PMK 3 / Norungan	10.57	22.97*	83.33	114.42	2.72	70.99	29.55	19.85	2.85*	0.05	18.89*
	0.29	-1.12**	-1.32*	-2.62	0.13	0.17**	-0.06	-0.28	0.18*	-0.01**	1.52**
MDU 5 / Mattaikar	10.82	21.16	86.40	109.79	2.37	80.38*	31.68*	19.88	2.66*	0.06	19.73*
	0.84*	-1.20**	0.21	2.78*	-0.01	5.63**	1.12**	-1.11**	0.37*	0.01**	5.01**
MDU 5 / Norungan	7.00	23.78*	87.61*	81.72	2.65	73.89	29.36	16.75	1.71	0.06	21.91*
	-1.05**	1.34**	2.30**	-14.92**	0.08	0.14**	-2.41**	-2.32**	-0.40*	0.01**	6.45**
ASD 16 / Vellaichithiraikar	11.00	20.91	88.39*	99.32	2.63	90.20*	30.63	16.58	1.81	0.04	20.55*
	1.70**	0.02	3.37**	1.25	0.00	12.70**	-1.41**	-1.43**	-0.56*	-0.01**	5.56**
Vellaichithiraikar / Nootripathu	16.38*	21.37	87.12*	91.53	2.43	54.47	33.44*	19.27	4.33*	0.07	24.43*
	3.59**	-2.06**	0.85	-15.89**	-0.20	-21.49**	-0.06	-2.50**	1.32*	0.01**	7.34**
Grand mean	10.55	22.61	86.01	113.83	2.53	74.51	30.48	20.51	2.46	0.06	17.15
SEd	0.28	0.13	0.41	1.22	1.22	0.04	0.29	0.29	0.04	0.003	0.44
CD (5 %)	0.57	0.26	0.83	2.48	2.48	0.08	0.59	0.59	0.08	0.01	0.89
SE	0.31	0.13	0.49	1.36	1.36	0.04	0.33	0.31	0.04	0.003	0.48

*and**significantly superior at 5 % and 1%level respectively; please note that mean values in bold and standard heterosis in italicHeterosis values are not given for all the hybrids it was given with only top two hybrids