IJ PS INTERNATIONAL JOURNAL OF PLANT SCIENCES
e ISSN-0976-593X Volume **10** | Issue 2 | July, 2015 | 122-129

DOI: 10.15740/HAS/IJPS/10.2/122-129
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RESEARCH ARTICLE

Combining ability analysis of three line hybrids in rice (*Oryza sativa* L.) under aerobic condition

R. SATHYA AND S. JEBARAJ

SUMMARY

Information on the availability of genetic variability and mode of gene action are critically important for choosing effective breeding methods that result in appreciable improvement in performance under drought stress. An investigation in rice (*Oryza sativa* L.) was carried out subjecting six 'lines' and 15 'testers' crossed in a line × tester mating design and the 90 hybrids along with 21 parents were tested for gene action, combining ability for 19 traits under aerobic condition. Three 'lines' *viz*., IR79128A (L_1), IR79156A (L_2) and IR70369A (L_4) and three 'testers' *viz*., IR7925A-428-2-1-1R (T_4), KMP -148 (T_{12}) and BI-33 (T_{15}) were identified as the best general combiners. The genotype IR70369A is suggested for conversion to cytoplasmic male sterility with suitable male sterile source. The parents MAS -26, IR 7925A-428-2-1-1R and KMP-105 are recommended for testing their restorability with suitable CMS source.

Key Words : Additive genetic variance (σ^2A), Dominance genetic variance (σ^2D), General combining ability variance/ effects, Specific combining ability variance/effects, Aerobic rice

How to cite this article : Sathya, R. and Jebaraj, S. (2015). Combining ability analysis of three line hybrids in rice (*Oryza sativa* L.) under aerobic condition. *Internat. J. Plant Sci.*, **10** (2): 122-129.

Article chronicle : Received : 21.01.2015; **Revised :** 09.06.2015; **Accepted :** 18.06.2015

Rice is the staple food for over 70 per cent of Asians, the majority of whom are living below the poverty line. More than 90 per cent of the world's rice is produced and consumed in Asia (Barker *et al.,* 1999) and rice production must be increased by an estimated 56 per cent over the next 30 years to keep up with population growth and income-induced demand for food in most Asian countries where about 75 per cent of total rice production comes from irrigated lowlands (Maclean *et al.,* 2002). Almost 25 per cent of the world's rice is grown under rainfed lowlands and frequently affected by uneven rainfall distribution. Another 13 per cent of the rice area under cultivation is always subjected to water stress during the growing season (Bouman *et al*., 2007). Food security in Asia and the increasing scarcity of fresh water resources for agriculture in many areas are stimulating the development of aerobic rice production system (Tuong *et al*., 2005).

Aerobic rice is high-yielding rice grown under

MEMBERS OF THE RESEARCH FORUM

Author to be contacted :
R. SATHYA, Department of Plant Breeding and Genetics, Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi, COIMBATORE (T.N.) INDIA
Email: sathyapbg@gmail.com

Address of the Co-authors:
S. JEBARAJ, Department of Plant Breeding and Genetics, Agricultural College and Research Institute, MADURAI (T.N.) INDIA

nonflooded conditions in nonpuddled and unsaturated (aerobic) soil. It is responsive to high inputs, can be rainfed or irrigated and tolerates occasional flooding (Maclean *et al.*, 2002). The water use of aerobic rice was about 60 per cent less than that of flooded rice and total water productivity was 1.6 to 1.9 times higher (Vijayakumar *et al*., 2006).

To formulate an efficient breeding program for developing drought tolerant varieties, it is essential to understand the mode of inheritance, the magnitude of gene effects and their mode of action (Farshadfar *et al*., 2008). Due to their quantitative nature, drought related traits cannot be studied in simpler way. Specialized biometrical techniques are required to work out the type of genetic variability associated with the traits. These biometrical techniques are dependent on different mating designs such as diallel, line × tester, North Carolina design and generation mean analysis for the estimation of type of genetic variability. In breeding high yielding varieties of crop plants, the breeders often face with the problems of selecting parents and crosses. Combining ability analysis is one of the powerful tools available to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis. The line × tester analysis provides information about general combining ability (*gca*) of parents and specific combining ability (*sca*) effects of crosses and is helpful in estimating various types of gene actions. Zhang *et al.* (2002) studied the heterosis and combining ability of hybrid rice. The genetic improvement of rice for aerobic environments has not been understood well and major efforts in this front are lacking.

Significant yield advantage gained through the adoption and spread of hybrid rice technology had helped China to add about 350 million tonnes of extra rice to its food basket during 1976-1998 and enabled it to divert some of their rice areas to other commercial crops. Hybrid rice technology had also shown increased yield, farmer profitability and better adaptability to stress environments such as water scarce and aerobic conditions. Development of rice hybrids with high yield potential for aerobic conditions would be one of the exciting researches to be carried out to overcome the existing water crisis in India. Breeding strategies based on selection of hybrids require expected level of heterosis as well as the specific combining ability.

MATERIAL AND METHODS

Site description :

The present investigation was carried out in the Research Farm of the Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Madurai, Tamil Nadu, India during 2009-2011.

Hybridization programme :

The 21 parental seed materials [six Lines and 15 Testers (Testers = eight R lines and seven aerobic rice varieties)] were sown in a raised nursery bed during the month of June, 2009. Recommended package of practices and need based plant protection measures were adopted. Crosses were effected in a 'line × tester' mating design (Kempthorne, 1957). The hybrid seeds of 90 cross combinations and selfed seeds from all the 21 parents were collected after maturity. The seeds were dried at 12 per cent moisture and preserved at room temperature (28±1^{o}C).

Evaluation of F_1 hybrids and parents for yield traits under aerobic condition :

Ninety hybrids along with six lines, 15 testers and one check were raised in a Randomized Block Design (RBD) with three replications under non-puddled and non-flooded aerobic soil, during *Rabi*, 2010. The hybrids along with their parents were maintained under irrigated condition upto 55 days. From the 56th day onwards the treatment plot was maintained under aerobic condition. Five plants were selected at random and tagged. Data were recorded at panicle initiation (75 – 80 days), flowering and maturity stages for physiological and quantitative traits. Observations of B lines were recorded for the corresponding A lines.

Characters studied :

Observations were recorded for the drought tolerant, yield and its component traits *viz*., days to 50 per cent flowering (DF), plant height (PH), number of productive tillers per plant (PT), number of panicles per plant (PP), panicle length (PL), filled grains per panicle (FG), spikelet fertility (SF), hundred grain weight (HGW), proline content (PC), SPAD chlorophyll meter reading (SCMR), chlorophyll stability index (CSI), relative water content (RWC), biomass yield (BMY), dry shoot weight (DSW), dry root weight (DRW), root / shoot ratio (RS), root length (RL), harvest index (HI), single plant yield (YLD) under water stress and fully irrigated (control) conditions as per the Standard Evaluation System (1996).

Statistical analysis :

The mean values of all the above observations recorded on five randomly selected plants were utilized for statistical analysis. Lines, testers and hybrids were tested for their significance based on their respective means.

Line × tester analysis :

Analysis of variance :

The analysis of variance of Randomized Block Design and their significance for all the characters were worked out as suggested by Panse and Sukhatme (1967).

Analysis of combining ability and gene action :

Line × tester analysis was carried out to test parents and hybrids with respect to their general and specific combining ability, respectively. The line × tester analysis of combining ability gives useful information regarding the choice of parents and elucidates the nature and magnitude of various types of gene action for the expression of yield and yield attributing characters.

The data on the hybrids and parents were subjected to L × T analysis. The assumption of Null hypothesis was tested for differences among the genotypes as detailed by Panse and Sukhatme (1967). The general combining ability effects of the parents and specific combining ability effects of the crosses were worked out as suggested by Kempthorne (1957).

Estimation of combining ability effects :

General combining ability effects (*gca*) of parents and specific combining ability effects (*sca*) of hybrids of ijkth observation were arrived at using the mathematical model given below :

$$X_{ij} = \mu + \hat{g}_i + \hat{g}_j + \hat{s}_{ij} + \hat{e}_{ijk}$$

where,

X_{ijk} = value of ijkth observation

μ = population mean

$\hat{g}_i$ = *gca* of ith line

$\hat{g}_j$ = *gca* of jth tester

$\hat{s}_{ij}$ = *sca* of ijth hybrid

$\hat{e}_{ijk}$ = error associated with ijkth observation

i = number of lines

j = number of testers

k = number of replications

$$\text{Mean } (\mu) = \frac{X...}{rlt}$$

where,

X…= total of all hybrids

r = number of replications

l = number of lines

t = number of testers

General combining ability effects :

The individual *gca* effects were estimated as follows:

$$gca \text{ effect of lines } (g_i) = \frac{X_{i..}}{rt} - \frac{X...}{rlt}$$

$$gca \text{ effect of testers } (g_i) = \frac{X.j.}{rl} - \frac{X...}{rlt}$$

where,

X_i.. = Total of ith line over ‘t’ testers and ‘r’ replications

X.$_j$. = Total of jth tester over ‘l’ lines and ‘r’ replications

X… = Total of all hybrids

Specific combining ability effects :

The individual *sca* effects were estimated as follows:

$$sca \text{ effects of hybrid } (s_{ij}) = \frac{X_{ij}.}{r} - \frac{X_{i}..}{rt} - \frac{X.j.}{rl} + \frac{X...}{rlt}$$

where,

X_{ij}. = Total of the hybrid between ith line and jth tester over ‘r’ replications.

Test of significance of combining ability effects :

The standard error pertaining to *gca* effects of lines and testers and *sca* effects of hybrids were calculated as follows :

$$\text{S.E. of } gca \text{ of lines} = \sqrt{\frac{EMS}{rt}}$$

$$\text{S.E. of } gca \text{ of testers} = \sqrt{\frac{EMS}{rl}}$$

$$\text{S.E. of } sca \text{ of hybrids} = \sqrt{\frac{EMS}{r}}$$

where,

S.E. = Standard error

EMS = Error mean square

$$'t' = \frac{\text{Parameter}}{\text{S.E.}}$$

The calculated 't' value was compared with table't' value at error degrees of freedom to test the significance.

The significance of *gca* effect of lines, *gca* effect of testers and *sca* effects of hybrids was tested against twice the standard error at five per cent level and one per cent level.

The ratio of $\sigma^2A/\ \sigma^2D$ was worked out for each character to find out predominance of additive or non-additive gene action, assuming the simple additive dominance model.

Estimation of heterosis :

The term heterosis was coined by Shull in 1914. It refers to the superiority of F_1 hybrid over its parents. In other words, heterosis refers to increase in fitness and vigour of F_1 over the parental values. While heterosis refers to the phenomenon (cause), hybrid vigour is the phenotypic expression (effect) of the genetical phenomenon.

The mean values of hybrids and their respective parents were used for estimation of heterosis per cent under three categories. The magnitude of heterosis in hybrids was expressed as percentage of increase or decrease of a character over mid parent (d_i), better parent (d_{ii}) and standard hybrid (d_{iii}) and was estimated by following the formula of Fonseca and Patterson (1968).

Heterobeltiosis (d_{ii}) :

The superiority of F_1 over better parent was estimated as follows :

$$dii = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where,

$\overline{F_1}$ = Mean value of hybrid

$\overline{BP}$ = Mean value of better parent

Standard heterosis (d_{iii}) :

The superiority of F_1 hybrid over the standard commercial variety or hybrid is known as standard heterosis. The term useful heterosis was used by Meredith and Bridge (1972). It is also called as economical heterosis. This type of heterosis is of direct practical value in plant breeding. It is estimated as follows:

$$dii = \frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$$

where,

$\overline{F_1}$ = Mean value of hybrid

$\overline{SV}$ = Mean value of standard variety

The variety IR 6888 was used as standard variety for yield components and drought tolerant traits in the present study.

Test of significance :

The significance of magnitude of heterobeltiosis and standard heterosis was tested at error degrees of freedom by the formula as suggested by Turner (1953) :

$$\text{'t' for heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\sqrt{\frac{2EMS}{r}}}$$

$$\text{'t' for standard heterosis} = \frac{\overline{F_1} - \overline{SV}}{\sqrt{\frac{2EMS}{r}}}$$

where,

EMS = Error mean square

r = Number of replication

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Variability studies :

Progress in any crop improvement venture depends mainly on the variability existing in the metric traits of the base population. Genetic variability studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop. The variability for 19 traits was estimated on the basis of phenotypic and genotypic co-efficient of variations. The PCV value was found to be higher in all the 19 characters studied than the GCV. The differences between PCV and GCV for the 19 characters were very less indicating less environmental influence on those characters (Table 1). Similar findings were reported by Muhammad Rashid *et al*. (2007).

Selection of biometrical techniques :

The analysis of variance for combining ability indicated that the lines and testers differed significantly among themselves for all the traits under aerobic condition. Further, the analysis of GCA/SCA variances indicated that the nature of gene action was non-additive due to dominance with non-fixable genetic variation for all the characters studied. The results are in accordance with the earlier reports of Babu *et al*. (2001).

The presence of greater magnitude of non-additive gene action offers scope for exploiting hybrid vigour through heterosis breeding and hence, these parents can be exploited for production of commercial hybrids. Similar results were also reported by Banumathy (2001). The proportional contribution to total genetic variance by the lines was found to be higher for 100 grain weight. For other characters contribution from line × tester interaction was higher. These results indicate the predominance of non-additive gene action. This is in accordance with the earlier reports of Muhammad Yussouf Saleem *et al*. (2010) and Malathi (2010).

Evaluation of parents based on mean performance:

As said by Gilbert (1958) and Nadarajan (1986) that the parents with high mean performance would result in good performing offspring, the lines IR79128A (L_1), IR79156A (L_2), COMS14A (L_5) and COMS24A (L_6) and the testers, IR 80286-22-3-6-1R (T_3), IR7925A-428-2-1-1R (T_4) and KMP -148 (T_{12}) were adjudged as the best parents as it had significantly desirable mean values for drought and yield traits (Fig. 1).

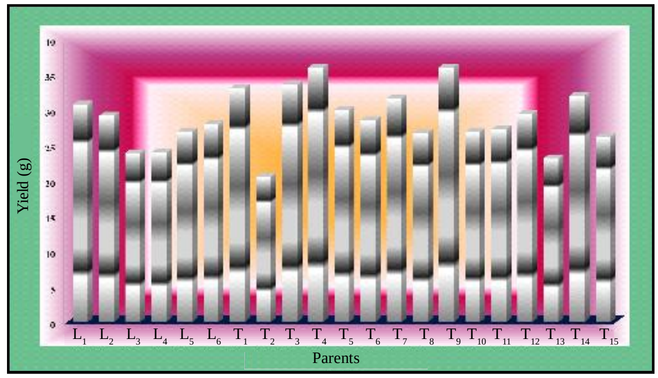


Fig. 1: Mean performance of parents for single plant

Evaluation of parents based on general combining ability :

Since the combining ability effect is one of the most important parameters commonly used by plant breeders to evaluate the genetic potential of the materials handled, IR79128A (L_1), IR70369A (L_4) and IR79156A (L_2) among lines and BI-33 (T_{15}), IR79582-21-2-2-1R (T_5), KMP-105 (T_{11}), T_1 (IR 69726-29-1-2-2R) and MAS-946-1 (T_9) (Fig. 2) among testers were found to be the best general combiners as earlier reported by Simmonds (1979) emphasizing that *gca* effect gives the intrinsic

Table 1 : Details of parents

Sr. No.	Symbol	Genotypes	Source
Lines			
1.	L_1	IR 79128A	IRRI, Phillipines
2.	L_2	IR79156A	IRRI, Phillipines
3.	L_3	IR73328A	IRRI, Phillipines
4.	L_4	IR70369A	IRRI, Phillipines
5.	L_5	CO MS- 14A	TNAU, Coimbatore
6.	L_6	CO MS 24A	TNAU, Coimbatore
Testers			
1. .	T_1	IR 69726-29-1-2-2R	IRRI, Phillipines
2.	T_2	IR 81178-2T-2-2-3R	IRRI, Phillipines
3.	T_3	IR 80286-22-3-6-1R	IRRI, Phillipines
4.	T_4	IR 7925A-428-2-1-1R	IRRI, Phillipines
5.	T_5	IR 79582-21-2-2-1R	IRRI, Phillipines
6.	T_6	IR 79200-45-2-2-1R	IRRI, Phillipines
7.	T_7	IR 80402-88-3-1-3R	IRRI, Phillipines
8.	T_8	IR05 N496R	IRRI, Phillipines
9.	T_9	MAS- 946-1	UAS, Bangalore
10.	T_{10}	MAS -26	UAS, Bangalore
11.	T_{11}	KMP-105	UAS, Bangalore
12.	T_{12}	KMP -148	UAS, Bangalore
13.	T_{13}	KMP -149	UAS, Bangalore
14.	T_{14}	BR -2655	UAS, Bangalore
15.	T_{15}	BI-33	UAS, Bangalore

genetic value of the parent for a trait. High *gca* effects show presence of favourable genes with additive type of gene action. Therefore, a multiple crossing programme involving good general combiners isolated in the present study is recommended to identify superior genotypes as suggested by Nadarajan and Gunasekaran (2005).

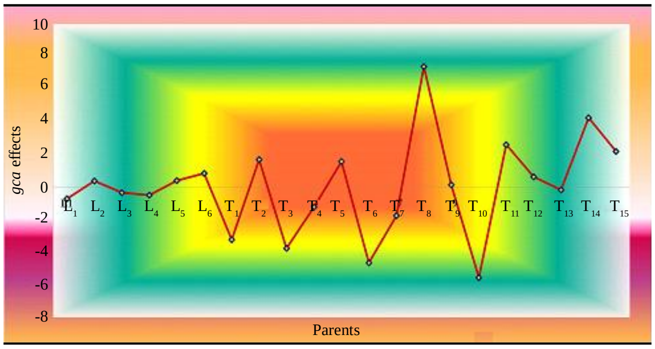


Fig. 2: General combining ability of parents for single plant yield

Evaluation of parents based on *per se* performance and *gca* effects :

Evaluation of parents based on *per se* performance and *gca* effects separately might lead to contradiction in selection of promising parents since *per se* performance of parents was not always associated with high *gca* effects. IR79128A (L_1), IR79156A (L_2) and IR70369A (L_4) among lines and IR7925A-428-2-1-1R (T_{11}), KMP -148 (T_{12}) and BI-33 (T_{15}) among testers were the best parents for most of the traits since they had high *per se* performance and *gca* effects. Earlier studies also indicated that the parallelism between *per se* performance and *gca* effects did not always exist (Selvaraj *et al*., 2006).

Evaluation of hybrids :

Hybridization is the most important method of crop improvement. The basic idea of hybridization is to combine favourable genes present in different parents into a single genotype.

Evaluation of hybrids based on mean performance:

The hybrids IR79156A / KMP-105 ($L_2 \times T_{11}$), IR70369A / MAS -26 ($L_4 \times T_{10}$), IR79156A / IR05 N496 ($L_2 \times T_8$), IR79156A / BI-33 ($L_2 \times T_{15}$) and CO MS- 14A / BR -2655 ($L_5 \times T_{14}$) exhibited significantly desirable mean performance for most of the characters which included drought tolerant, yield and yield components under aerobic condition. These results are in conformity with the earlier findings of Sabesan *et al*. (2009) and Saravanan *et al*. (2006).

Evaluation of hybrids based on *sca* effects :

The second important criterion for the evaluation of hybrids is the specific combining ability effects which could be related with hybrid vigour. The *sca* effects signify the role of non-additive gene action in character expression (Sprague and Tatum, 1942). The hybrids IR70369A / IR 7925A-428-2-1-1R ($L_4 \times T_4$), IR 79128A / BR -2655 ($L_1 \times T_{14}$) and IR70369A / KMP-105 ($L_4 \times T_{11}$) expressed superior *sca* effects for majority of drought tolerant and yield attributing characters including single plant yield.

Evaluation of hybrids based on heterosis :

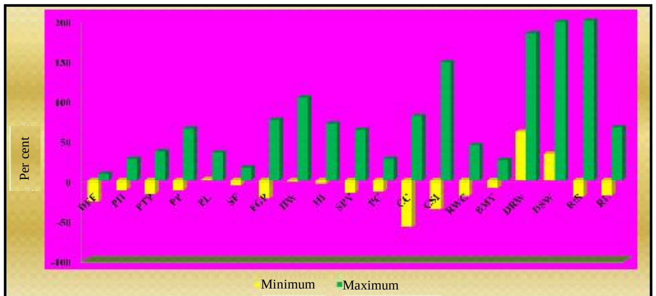
Significant standard heterosis over check IR6888 was observed in IR79156A / IR 79582-21-2-2-1R ($L_2 \times T_5$) for 16 traits except plant height, 100 grain weight and root: shoot ratio. Similar results have been reported by Khoyumthem *et al*. (2005) and Soni *et al*. (2005).

Selection of best parents and hybrids for utilization in plant breeding programme :

The utilization of hybrids directly for commercial seed production mainly depends on the genetic constitution of hybrids. The genetic constitution from the parameter like mean performance, *sca* effects and extent of heterosis. The hybrids IR70369A / IR 7925A-428-2-1-1R ($L_4 \times T_4$) and IR70369A / KMP-105 are suitable for heterosis breeding (Plate 1) under aerobic condition (Fig. 3). This is in accordance with the reports of Malarvizhi *et al*. (2010).

$L_4 \times T_4$ – IR70369A × IR7925A-428-2-1-1R

Plate 1: Hybrid recommended for heterosis breeding



DFF-Days to 50 per cent flowering	HW-Hundred grain weight	RWC-Relative water content
PH-Plant height	HI-Harvest index	BMY-Biomass yield
PTP-Productive tillers per plant	SPY-Single plant yield	DRW-Dry root weight
PP-Panicles per plant	PC-Proline content	DSW-Dry shoot weight
PL-Panicle length	CC-SPAD chlorophyll meter reading	R:S-Root : Shoot
SF-Spikelet fertility	CSI-Chlorophyll stability index	RL-Root length
FGP-Filled grains per panicle		

Fig. 3: Range of standard heterosis for different traits

Considering the hybrids showing non-significant *sca* effects with significantly favourable *gca* effects of parents for more than one character, the hybrid IR70369A / MAS -26 ($L_4 \times T_{10}$) is suitable for recombination breeding to get desirable segregants in early segregating generations for drought tolerant and yield attributes (Plate 2). These results are supported by the findings of Utharasu (2007) and Sheeba *et al.* (2010).

$L_4 \times T_{10}$ – IR70369A × MAS-26

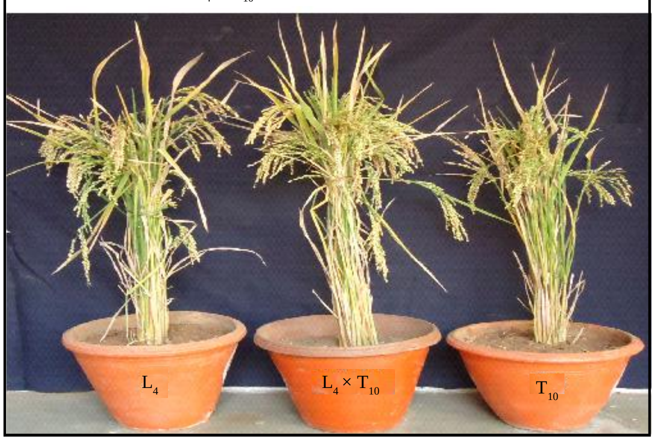


Plate 2: Hybrid recommended for recombination breeding

Acknowledgement :

We are very much grateful to The Pioneer Hibred International, Inc., for providing me Pioneer Hibred International Scholarship of $15000 to carry out this doctoral programme successfully.

REFERENCES

Babu, S., Nguyen, B.D., Sarkarung, S., Blum, A. and Nguyen, H.T. (2001). Locating genomic regions associated with components of drought resistance in rice: comparative mapping within and across species. *Theor. Appl. Genet.*, **103**(1) : 19-29.

Banumathy, S. (2001). Development and evaluation of hybrids with better grain and cooking qualities using CGMS system in rice (*Oryza sativa* L.). *Trop. Agric. J.*, **86** (1-3): 7-9.

Barker, M.G., Brimage, L.J. and Smart, K.A. (1999). Effect of Cu, Zn superoxide dismutase disruption mutation on replicative senescence in Saccharomyces cerevisiae. *FEMS Microbiol. Lett.*, **177**(2) :199-204.

Bouman, B.A.M., Lampayan, R.M. and Tuong, T.P. (2007). Water management in irrigated rice: coping with water scarcity. Los Baños (Philippines) : International Rice Research Institute. 54 p.

Farshadfar, E., Sabaghpour, S.H. and Khaksar, N. (2008). Inheritance of drought tolerance in chickpea (*Cicer arietinum* L.) using joint scaling test. *J. Appl. Sci.*, **8** (21) : 3931-3937.

Fonseca, S. and Patterson, F.L. (1968). Hybrid vigour in seven parent diallel cross in common wheat (*Triticum aestivum* L.). *Crop Sci.*, **8**(1) : 85-88.

Gilbert, N.E.G. (1958). Diallel cross in plant breeding. *Heredity*, **12** : 477-498.

Khoyumthem, P., Sharma, P.R., Singh, N.B. and Singh, M.R.K. (2005). Heterosis for grain yield and its component characters in rice (*Oryza sativa* L.). *Environ. & Eco.*, **23** (4) : 687-691.

Kempthorne, O. (1957). *An introduction to genetic studies*. John Wiley and Sons Inc., New York. pp. 265-270.

Maclean, J.L., Dawe, D.C., Hardy, B. and Hettel, G.P. (2002). Rice Almanac. IRRI, Los Banos, Philippines.

Malarvizhi, D., Thiyagarajan, K., Vijayalakshmi, C. and Manonmani, S. (2010). Genetic analysis to assess the physiological efficiency of parental lines in rice (*Oryza sativa* L.). *Electr. J. Pl. Breed.*, **1**(2) : 100-113.

Malathi, D. (2010). Genetic analysis for yield and yield component traits in aerobic rice (*Oryza sativa* L.). M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Madurai, T.N. (INDIA).

Meredith, W.R., Jr. and Bridge, R.R. (1972). Heterosis and gene action in cotton (*Gossypium hirsutum* L.). *Crop Sci.*, **12**(3) : 304-310.

Muhammad Rashid, Akbar Ali Cheema and Muhammad Ashraf (2007). Clustering of basmati rice mutants by metroglyph analysis. *Pak. J. Bot.*, **39**(6) : 2043-2049.

Muhammad Yussouf Saleem, Javed Iqbal Mirza and Muhammad Ahsanul Haq. (2010). Combining ability analysis for yield and related traits in basmati rice (*Oryza sativa* L.). *Pak. J. Bot.,* **42**(1) : 627-637.

Nadarajan, N. (1986). Genetic analysis of fibre characters in cotton (*Gossypium hirsutum* L.). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, T.N. (INDIA).

Nadarajan, N. and Gunasekaran, M. (2005). *Quantitative genetics and biometrical techniques in plant breeding*. Kalyani Publ., New Delhi. 135 pp.

Panse, V.G. and Sukhatme, P.V. (1967). *Statistical methods for agricultural workers.* ICAR, New Delhi. 287 pp.

Sabesan, T., Suresh, R. and Saravanan, K. (2009). Genetic variability and correlation for yield and grain quality characters of rice grown in coastal saline low land of Tamil Nadu. *Electr. J. Pl. Breed.,* **1** (1) : 56-59.

Saravanan, K. and Sabesan, T. (2009). Association analysis and path analysis for yield and its contributing traits in rice (*Oryza sativa* L.). *Internat. J. Pl. Sci.,* **4** (1) : 27-29.

Saravanan, K., Ramya, B., Satheeshkumar, P., and Sabesan, T. (2006). Combining ability for yield and yield characters in rice (*Oryza sativa* L.). *Oryza,* **43**(4) : 274-277.

Selvaraj, C.I., Nagarajan, P. and Das, L.D.V. (2006). Heterotic expression and combining ability analysis for qualitative and quantitative traits in inbreds of maize (*Zea mays* L.). *Crop Res.,* **32** (1) : 77-85.

Sheeba, A., Vivekanandan, P., Banumathy, S., Manimaran, R. and Ramasubramanian, G.V. (2010). Role of secondary and putative traits for improvement of upland rice. *Electr. J. Pl. Breed.,* **1**(4) : 903-907.

Simmonds, N.W. (1979). *Principles of crop improvement*. Long Man Group Ltd., London, pp. 110-116.

Soni, D.K., Kumar, Arvind, Nag, Sunil and Sahu, Lakeswar (2005). Study of heterosis by utilizing cytoplasmic genetic male sterility system in rice (*Oryza sativa* L.). *Pl. Arch.,* **5** (2) : 617-621.

Sprague, G.F. and Tatum, L.A. (1942). General vs. specific combining ability in single crosses of corn. *J. Amer. Soc. Agron.,* **34** : 923-932.

Tuong, T.P. and Bouman, B.A.M. (2002). Rice production in water scarce environments. In: Proceedings of the Water Productivity Workshop, 12-14 November 2001, Colombo, Sri Lanka.

Tuong, T.P., Bouman, B.A.M. and Mortimer, M. (2005). More rice, less water-integrated approaches for increasing water productivity in irrigated rice-based systems in Asia. *Plant Prod. Sci.,* **8** : 231-241.

Turner, A.G.L. (1953). Some old english passages relating to the episcopal manor of Taunton. *Proceedings Somerset Natural History & Archaeological Soc.,* **98** : 118-126.

Utharasu, S. (2007). Genetic analysis for yield and yield components involving in aerobic rice cultivars (*Oryza sativa* L.). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Madurai, T.N. (INDIA).

Vijayakumar, C.H.M., Volefi, S.R., Rao, K.V., Ramesha, M.S., Viratamath, B.C. and Mishra, B. (2006). Breeding for high yielding rice (*Oryza sativa* L.) varieties and hybrids adapted to aerobic (non-flooded, irrigated) conditions-I. Preliminary evaluation of a large number of improved germplasm lines. *Indian J. Genet.,* **66**(2): 113-118.

Zhang, R., Ming, J.S., Xu, C.W., Yang, L.S., Bai, Y.S., Sun, C.Q. and Wanc, X.K. (2002). Heterosis and combining ability of hybrid rice and its relation to Japonica-index of parents. *Theor. Appl. Genet.,* **45** : 26-30.

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