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COMBINING ABILITY ANALYSISFOR YIELD, ITS COMPONENTSAND PHYSIOLOGICAL TRAITS IN RICE (*ORYZA SATIVA* L.) UNDER SODICITY

***SURESHKUMAR. M[1], S.K.GANESH[2], M.SAKILA[3], D.DINAKARAN[4] AND T.SENGUTTUVAN[5]**

[1& 2.]DEPARTMENT OF PLANT BREEDING AND GENETICS, ANBIL DHARMALINGAM AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE, TRICHY - 620 009.

[3.]AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE, EACHANKOTTAI - 614 902.

[4.]HORTICULTURAL COLLEGE AND RESEARCH INSTITUTE FOR WOMEN, TRICHY-620 009.

[5.]SOIL AND WATER MANAGEMENT RESEARCH INSTITUTE, THANJAVUR- 613 501.

TAMIL NADU AGRICULTURAL UNIVERSITY, TAMIL NADU, INDIA.

Corresponding author's e-mail: manosuresh967@gmail.com

ABSTRACT:

The present study was conducted to estimate combining ability, gene action and proportional contribution of cross components in rice genotypes under sodicity. Combining ability estimates were worked out through diallel analysis of 30 hybrids developed by crossing six parents to know the genetic architecture of 14 physio-morphological traits *viz.*, days to 50 percent flowering, plant height, number of productive tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility percentage, 100 grain weight, single plant yield, dry root weight, dry shoot weight, root: shoot ratio, Na^{+}: K^{+} ratio, chlorophyll content and proline content under sodic environment. Results of *per se* and *gca* effects of parents revealed that multiple crosses involving FL 478, IW Ponni, BPT 5204, IR 64 and RNR57979 would

be considered as invaluable sources of genetic materials. Considering the hybrids showing non-significant *sca* effects with significant favorable *gca* effects of parents for more than one trait, four hybrids *viz.*, FL 478 / BPT 5204, FL 478 / RNR 57979, BPT 5204 / FL 478 and BPT 5204 / RNR 57979 were found to fulfill with the criteria advocating simple pedigree method of breeding to obtain promising segregants as the traits were governed by additive type of gene action predominantly. An outset on perusal of data for hybrids based on *per se*, *sca* effects and standard heterosis, five hybrids *viz*., FL 478/ IW Ponni, IW Ponni/ IR 64, IW Ponni / BPT 5204, BPT 5204 / FL 478, IW Ponni / FL 478 were found to be suitable for heterosis breeding under sodicity. As there was dominance gene action involved, *inter se*mating followed by recombination breeding might be advocated for improvement of yield, its components and physiological traits under sodicity.

KEY WORDS: *Rice, sodicity, diallel, General Combining Ability (GCA), Specific Combining Ability (SCA), additive, dominance.*

INTRODUCTION:

Rice is cultivated in 114 of the 193 countries of the world. India is capable of producing 134.5 m t of rice over an area of 44.50m ha with productivity of 3.01 t ha^{-1}against 6.23 t $ha^{-1}$of China (Maclean *et al*.,2002). This difference in productivity is due to the slow development of new exploitable hybrids for various abiotic stresses. About 6.5% (831 million ha) of the world's total area (12.78 billion ha) is affected by salt stress (Kinfemichael and Melkamu, 2008). In India, it is considered that the second most important abiotic stress is salinity. The salt affected area is 8.90 million ha area out of which 3.40 million ha under sodicity and rest under salinity.Area under salt stress is on the increase due to many factors including climate change, rise in sea levels,excessive irrigation without proper drainage in inlands,underlying rocks rich in harmful salts etc. Vast areas of land are not utilized due to salinity and alkalinity problems. Rice is rated as an especially salt –sensitive crop (Shannon *et al*.,1998). Breeding rice varieties with in-built salt tolerance is realized as the most promising, less resource consuming, economically viable and socially acceptable approach. Salt tolerance is a multigenic trait that allows plants to grow and maintain economic yield in the presence of non-physiologically high and relatively constant levels of salt(Hurkman,1992). The importance of developing varieties tolerant to sodicity with increased yield is timely felt need. To frame a yield improvement programme in rice, information about *per se*, combining ability effects of parents and hybrids and the magnitude of gene action involved in the inheritance of quantitative traits are very much essential. This prompted the present investigation to estimate the gene action regulating the complex mechanisms involved in rice genotypes under sodicity.

MATERIALS AND METHODS:

The present investigation was carried out at the Research farm of Department of Plant Breeding and Genetics, Anbil Dharmalingam Agricultural College and Research Institute, Trichy, where the soil is found to be sodic in nature with a pH of 9.5 and ESP of 23.The water used for irrigating the experimental field was taken from the bore well with pH ≥9.0 and RSC is 10meq/l. The experimental materials consisted of two high yielding, two sheath blight resistant, one fine grain and one sodicity tolerant parental genotypes *viz.*, BPT 5204, IR 64,RNR 57979,TETEP,IW Ponni and FL 478 respectively to produce 30 hybrids through full diallel mating design(Griffings, 1958).The experiment was laid out in randomized bock design with three replications adopting a recommended spacing of 20 x15 cm in field during 2013 to 2014. Recommended package of practices were followed to establish the crop. Five plants were selected at random from each entry in each replication to record data on 14 physio-morphological traits *viz.*, days to 50 percent flowering, plant height, number of productive tillers per plant, panicle length, number of filled grains per panicle, spikelet fertility percentage, 100 grain weight, single plant yield, dry root weight, dry shoot weight, root: shoot ratio, Na^+: K^+ ratio, chlorophyll content and proline content. The biometrical observations were recorded for yield and its component traits under sodicity as per the Standard Evaluation System for rice (SES, 1996). The mean data were subjected to ANOVA and to estimate combining ability variances and effects.

RESULTS AND DISCUSSION:

Analysis of variance

The analysis of variance for all the traits recorded in 30 hybrids and six parents revealed that the genotypes taken for study registered significant differences among all traits investigated. Since, all traits showed significant differences among genotypes, the combining ability analysis was carried out (Tables 1 and 2).

Combining ability effects of parents and hybrids

Combining ability effect is one of the important parameters commonly used by breeders to evaluate the genetic potential of materials handled. Dhillon (1975) revealed that the combining ability of parents provides useful information on the choice of parents in terms of expected performance of their hybrids and progenies. The attraction of combining abilities is that they provide an empirical summary of complex observations and a reasonable basis for forecasting the performance of yet untested cross but yet make no genetical assumption.

General combining ability effects of parents and specific combining ability effects of hybrids for different traits were presented in Tables 3 to 6.

General combining ability effects

The *gca* effect is considered as intrinsic genetic value of the parent for a trait, which is due to additive gene effects and it is fixable (Simmonds, 1979). Singh and Singh (1985) suggested that parents with high *gca* would produce transgressive segregants in F_2 or later generations. Gravois and New (1993) reported that if additive gene action is predominant in a self-pollinated species such as rice, the breeder can effectively select at various levels of breeding, because additive effects are readily transmissible from one generation to another. Parents that had negative and significant *gca* were considered for days to 50 percent flowering, plant height and Na^+: K^+ ratio, while, significant positive *gca* effects were taken into consideration for the remaining traits in the present set of materials.

In the present study, the parents FL 478 and RNR 57979 were adjusted as the best general combiners, since they expressed significant *gca* effects for most of the traits *viz.*, days to 50 percent flowering, plant height, number of filled grains per panicle, spikelet fertility percentage, dry shoot weight and chlorophyll content for the former and days to 50 percent flowering, plant height, spikelet fertility percentage, single plant yield, dry root weight, root: shoot ratio and proline content for the latter. This was followed by BPT 5204, which was found to be a good combiner for six traits *viz*., days to 50 percent flowering, plant height, spikelet fertility percentage, dry root weight, root: shoot ratio and proline content. The parent IR 64, which was found to be a good combiner for six traits *viz*., plant height, panicle length, spikelet fertility percentage, 100 grain weight, dry shoot weight and Na^+: K^+ ratio. These results were in conformity with earlier findings of Geetha *et al*. (2006), Kumar *et al.* (2010), Shanthi *et al*. (2011) and Gopikannan and Ganesh (2013).

From the above discussion, it was inferred that FL 478, BPT 5204, IR 64 and RNR 57979 were found to be good general combiners, since they expressed desirable *gca* effects for majority of the traits including sodicity tolerant and yield contributing traits. As *gca* is primarily due to the function of additive genetic component and fixable, those parents could serve as useful donors in the crossing programme to isolate promising sodicity / salinity tolerant segregants in later generations. If epistasis is present, *gca* also includes additive x additive type of non-allelic interaction (Singh and Narayanan, 2004).

Specific combining ability effects

The second most important criterion for the evaluation of hybrids is the specific combining ability effects. According to Peng and Virmani (1990), *sca* effect is the index to determine the usefulness of a particular cross combination for exploitation of heterosis. The specific combining ability effects are due to non-additive and epistatic gene action (Sprague and Tatum, 1942). The *sca* effects of the hybrids have also been attributed to the combination of favorable genes from different parents or may be due to the presence of linkage in repulsion phase (Sarsar *et al*., 1986). Hence, selection of hybrids based on *sca* effects would excel in their heterotic effect. Hybrids with significant favorable *sca* effects in the present investigation are discussed hereunder:

In the present investigation, as regards to hybrids, negative *sca* effects were taken into consideration for days to 50 percent flowering, plant height and Na^+: K^+ ratio, while, for the remaining traits positive and significant *sca* effects were taken into account.

For days to 50 percent flowering significant *sca* effects were pronounced in six hybrids *viz*., FL 478 / TETEP, IW Ponni /IR 64, IR 64 / IW Ponni, RNR 57979 / IW Ponni, TETEP / FL 478 and TETEP / IW Ponni. None of the *per se* performed hybrids exhibited significant *sca* effects. There was no association between *per se* and *sca* for the trait among hybrids. All hybrids had parents of either one poor combiner or both poor combiners indicating the importance of non- additive type of gene action. For exploiting this type of gene action, inter- mating among the segregating populations to accumulate favorable alleles and at the same time maintaining heterozygousity for exploiting dominance gene effects would be the ideal method of breeding for the improvement of this trait. Kumar *et al*. (2010), Kannan (2011) and Gopikannan and Ganesh (2013) reported similar findings for this trait improvement.

For plant height, seven hybrids *viz*., FL 478 / IW Ponni, IW Ponni / BPT 5204, IW Ponni / RNR 57979, BPT 5204 / FL 478, IR 64 / IW Ponni, IR 64 / BPT 5204 and TETEP / IR 64 recorded negative and significant *sca* effects. Among seven hybrids, only two hybrids *viz*., FL 478 / IW Ponni and IW Ponni / RNR 57979 showed good association for both *per se* performance and *sca* effect indicating *per se* itself could be taken as the criteria for the selection of the trait in those hybrids. It was observed that parents of other hybrids had either one poor or one good combiner indicating the importance of dominance gene action. This was further evidenced through greater estimates of SCA variances for this trait. As predominance of dominance gene action governed the inheritance of the trait, heterosis breeding was advocated for the improvement. Those crosses would throw desirable segregants in latter generations. These results were in accordance with findings of Thirumeni *et al*. (2000).

The measure of *sca* effect for number of productive tillers per plant indicated the positive and significant for three hybrids *viz*., FL 478 / RNR 57979, IW Ponni / IR 64 and IR 64 / IW Ponni. There was no association between *per se* and *sca* effect for the trait in those hybrids showing the importance of harnessing dominant type of gene action. This was further evidenced through high estimate of SCA over GCA. None of the parents in the crosses was of good combiner. In these combinations, bi- parental approach would enhance the variability by breaking the genetical ceiling of the parents. The exploitation of this variability might offer the chance of selecting the segregants with more number of productive tillers. Alternatively, postponement of selection to later generations might also be helpful in harnessing the dominant gene action. This finding was in good accordance with earlier reports of Senthilkumar (2012) and Gopikannan and Ganesh (2013).

For panicle length, none of the hybrids recorded positive and significant *sca* effect. The *per se* performed hybrid, TETEP / RNR 57979 did not possess desirable *sca* effect for this trait. For number of filled grains per panicle, seven hybrids *viz*., FL 478 / IW Ponni, BPT 5204 / IW Ponni, BPT 5204 / IR 64, BPT 5204 / RNR 57979, RNR 57979 / TETEP, TETEP / FL478 and TETEP / IW Ponni recorded positive and significant *sca* effects. There was a linear relationship between *per se* and *sca* effect for only one hybrid *viz*., FL 478 / IW Ponni showing *per se* itself could be adjudged as the indicator for the improvement of the trait. All hybrids had parents of either one good combiner or both poor combiners indicating the importance of dominant gene action. This was further evidenced through higher estimate of SCA variance than GCA variance for the trait studied. Hence, bi-parental mating followed by recurrent selection in the segregating generations would help to break undesirable linkages and allow accumulation of desirable genes in those crosses for the improvement of the trait. Similar results were reported by Kannan (2011) and Gopikannan and Ganesh (2013).

The severe inhibitory effects of salts on fertility may be due to differential competition in carbohydrate supply between vegetative growth and constrained supply of these to the developing panicles (Murty and Murty, 1982). While considering the *sca* effects of hybrids for spikelet fertility percentage, there seemed to be positive and significant *sca* effects for two crosses *viz*., BPT 5204 / TETEP and TETEP / BPT 5204. None of the crosses showed a close relationship between *per se* and *sca* effects for the trait. Both hybrids *viz*., BPT 5204 / TETEP and TETEP / BPT 5204 possessed parents with one good and one poor combiner. This indicated the predominance of dominant gene action for spikelet fertility percentage. Hence, selection in early segregating generation would not be sufficient to yield desirable segregants. This might possibly overcome by delaying selection to later generations when dominance gene effects disappear as well as resorting inter-mating of segregants in F_2 generation followed by recurrent selection. The result was in accordance with Sankar *et al*. (2008) and Verma *et al*. (2010).

For 100 grain weight, nine hybrids *viz*., FL 478 / IW Ponni, FL 478 / BPT 5204, IW Ponni / FL 478, IW Ponni / IR 64, BPT 5204 / IR 64, IR 64 / RNR 57979, RNR 57979 /FL 478, RNR 57979 / IR 64 and RNR 57979 / TETEP recorded positive and significant *sca* effects. Out of nine crosses, only in four hybrids *viz*., FL 478 / IW Ponni, IW Ponni / IR 64, BPT 5204 / IR 64, IR 64 / RNR 57979, there was a good association between *per se* performance and *sca* effects indicating the importance of *per se* value for excising selection. It was observed that parents of all hybrids had either one good or one poor combiner or both poor combiners showing the presence of dominance gene action in the inheritance of the trait. As predominance of non- additive gene action governed the inheritance of the trait, heterosis breeding was advocated for the improvement. These crosses would throw desirable segregants in later generations. Alternatively, one or two cycles of inter- mating followed by pedigree method of breeding might be useful for improvement of this trait. These results were in accordance with findings of Thirumeni *et al*. (2000).

Yield is the complex phenomenon and also is the end product of multiplicative interaction between various yield components. High and significant *sca* effects were recorded in six hybrids *viz*., IW Ponni / FL 478, IW Ponni / BPT 5204, BPT 5204 / IW Ponni, IR 64 /IW Ponni, IR 64 / BPT 5204 and TETEP / IW Ponni for single plant yield suggesting the role of non- additive gene action. It was obvious to note that there was close correspondence between *sca* effect and *per se* performance for only one hybrid *viz.*, IW Ponni / BPT 5204. None of the hybrids possessed parents of good combiners. As the trait was under the control of non- additive gene action in those hybrids, the conventional breeding technology needs some modification for capitalizing the genetic effects. Instead of continuous selfing for a number of generations prior to selection, alternative inter-mating and selfing might be adopted to increase the span of selections. This would enhance the frequency of potential transgressive segregants in such materials. These results were in conformity with earlier findings of Karthikeyan and Anbuselvam (2006), Kannan (2011) and Gopikannan and Ganesh (2013).

With increase in salinity, reduction in dry weight of root and shoot was observed by Roy *et al.* (2002) and the similar findings were also reported by Govindaraju and Balakrishnan (2002). For dry root weight, seven hybrids *viz*., FL 478 / IR 64, FL 478 / RNR 57979, IR 64 / TETEP, TETEP / FL 478, TETEP / IW Ponni, TETEP / IR 64 and TETEP / RNR 57979 registered significant *sca* effects. There was absolutely no association between *per se* and *sca* effect for this trait in those hybrids. Moreover, no hybrid possessed parents of good combiners. To harness non - additive gene action, a modified method through adoption of bi- parental mating followed by recurrent selection could be suggested for the improvement of this trait. But, Robin (1997) and Nilakanta Pillai (1998) observed additive type of gene action governing the inheritance of the trait. For dry shoot weight, 13 hybrids *viz*., FL478 / IW Ponni, IW Ponni / FL 478, BPT 5204 / FL 478, BPT 5204 / IW Ponni, IR 64 / FL 478, IR 64 / IW Ponni, RNR 57979 / FL 478, RNR 57979 / IW Ponni, RNR 57979 / BPT 5204, RNR 57979 / IR 64, TETEP / FL 478, TETEP / IW Ponni and TETEP / IR 64 registered significant *sca* effects. It was paramount importance to note that both *per se* and *sca* effects had close correspondence in two hybrids *viz.*, FL 478 / IW Ponni, and its reciprocal cross of IW Ponni / FL 478. In the remaining hybrids, there was no such association. The *per se* performed hybrids *viz*., FL478 / IW Ponni and IW Ponni / FL 478 had both parents of good combiners. The other hybrids possessed parents of either one good or one poor combiner or both poor combiners suggesting the importance of dominant gene action. To harness additive as well as non- additive gene actions present in those hybrids, a modified method through adoption of bi-parental mating followed by recurrent selection could be suggested for the improvement of this trait.

Ali *et al.* (2004) emphasized the importance of root- shoot ratio while screening the rice germplasm against salinity as the lines with higher root shoot ratio recorded lower visual score of 4-5. For root: shoot ratio, seven hybrids *viz*., IW Ponni / TETEP, BPT 5204 / IR 64, BPT 5204 / RNR 57979, IR 64 / BPT 5204, IR 64 / RNR 57979, RNR 57979 / TETEP and TETEP / RNR 57979 registered significant *sca* effects. Three *per se* performed hybrids *viz.*, BPT 5204 / IR 64, BPT 5204 / RNR 57979 and RNR 57979 / TETEP had significant *sca* effects for this trait. Out of three hybrids, only one hybrid *viz.*, BPT 5204 / RNR 57979 had parents of both good combiners. The result indicated that BPT 5204 / RNR 57979 hybrid would serve as immense valuable material for the improvement of the trait. As additive and non-additive gene actions might govern the inheritance of the trait, a modification of conventional selection would be an ideal approach i.e., inter-mating of selected segregants in F_2 generation followed by simple selection in advanced generations could be advocated in order to break any undesirable linkages and also to allow accumulation of favorable alleles for the improvement of this important physiological trait contributing tolerance to sodicity. The remaining six hybrids either possessed parents of one good combiner or both poor combiners showing the preponderance of non –additive gene action. To harness as non- additive gene action, a modified method through adoption of bi-parental mating followed by recurrent selection or, alternatively, the selection would be postponed to later generations until attaining homozygousity could be suggested for the improvement of this trait.

For Na^+: K^+ ratio, four hybrids *viz*., IW Ponni / TETEP, BPT 5204 / IW Ponni, IR 64 / FL 478 and IR 64 / IW Ponni registered significant *sca* effects. None of the hybrids exhibited a linear relationship between *per se* and *sca* effect. All hybrids had either both parents were of poor combiners or one parent with good combiner indicating the importance of harnessing dominant gene action. To harness the dominant gene action *inter se* mating could be practiced among selected segregants to break any undesirable linkages for the accumulation of favorable alleles for the improvement of Na^+: K^+ ratio. These results were in accordance with findings of Kannan (2011), Senthilkumar (2012) and Gopikannan and Ganesh (2013).

One of the most notable effects of salt stress is the alteration of photosynthetic pigment biosynthesis (Maxwell and Johnson, 2000). The decrease in chlorophyll content under salt stress is a commonly reported phenomenon and in various studies and the chlorophyll concentration is used as a sensitive indicator of the cellular metabolic state (Chutipaijit *et al*., 2011). Reduction in leaf chlorophyll under salinity is attributed to the destruction of pigments and instability of pigment protein complexes (Levitt, 1980). While considering the *sca* effects of hybrids for chlorophyll content, there was positive and significant *sca* effects pronounced in eight crosses *viz*., FL 478 / BPT 5204, FL 478 / IR 64, BPT 5204 / FL 478, BPT 5204 / IW Ponni, IR 64 / BPT 5204, RNR 57979 / FL 478, RNR 57979 / TETEP and TETEP / BPT 5204. Except for the cross, FL 478 / BPT 5204, all hybrids exhibited poor association between *per se* and *sca* effect for the trait. The parents of all hybrids were also found to be either poor combiners or one good combiner and one poor combiner suggesting the role of dominance gene action in governing this trait. This was further evidenced through higher estimate of SCA variance when compared to GCA variance for the trait studied. Hence, selection in advanced generations might be advocated for the improvement of chlorophyll content. This finding was in good accordance with earlier reports of Shanthi *et al*. (2011), Senthilkumar (2012) and Gopikannan and Ganesh (2013).

The measure of *sca* effects for proline content indicated the significance in six hybrids *viz*., FL 478 / RNR 57979, IW Ponni / FL 478, IW Ponni / IR 64, IR 64 / FL 478, IR 64 / IW Ponni and RNR 57979 / FL 478. Two *per se* performed hybrids *viz*., FL 478 / RNR 57979 and IW Ponni / IR 64 had also significant *sca* effect for the trait indicating *per se* could be taken as indicator for the improvement. All hybrids possessed parents of one good and one poor combiner or both poor combiners indicating the preponderance of dominance gene action. Hence in those crosses, postponement of selections to later generations to tag promising segregants possessing tolerance to sodicity would be of ideal method. This finding was in good accordance with earlier reports of Babu *et al*. (2005) and Gopikannan and Ganesh (2013).

In the present study, the hybrid IR 64 / IW Ponni recorded significant*sca* effects for seven traits *viz*.,days to 50 percent flowering, plant height, number of productive tillers per plant, single plant yield, dry shoot weight, Na^{+}: K^{+} ratio and proline content. The hybrid TETEP / IW Ponni was the next best specific combiner for five traits, *viz*., days to 50 percent flowering, number of filled grains per panicle, single plant yield, dry root weight and dry shoot weight. The cross, BPT 5204 / IW Ponni had desirable *sca* effect for number of filled grains per panicle, single plant yield, dry shoot weight, Na^{+}: K^{+} ratio and chlorophyll content. The crosses FL 478 / IW Ponni and IW Ponni / IR 64 were the next best specific combiners for four traits each. The former FL 478 / IW Ponni expressed significant *sca* effects for plant height, number of filled grains per panicle, 100 grain weight and dry shoot weight. The later IW Ponni / IR 64 recorded desirable *sca*effects for days to 50 percent flowering, number of productive tillers per plant, 100 grain weight and proline content.

In general, among 30 hybrids evaluated, four hybrids *viz*.,IR 64 / IW Ponni, TETEP / IW Ponni, BPT 5204 / IW Ponni , FL 478 / IW Ponni and IW Ponni / IR 64 were the best specific combiners for majority of sodicity tolerant and yield and its contributing traits and considered as promising. As non- additive type of gene action might govern the inheritance of most of the traits studied, either the selection could be postponed to later generations or *inter se* matings among selected segregants might be advocated to break any undesirable linkages and to allow accumulation of favorable genes for improvement of yield in rice under salinity / sodicity.

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Table 1.Analysis of variance of combining ability for different biometrical traits

Source of variation	df	Days to 50 per cent flowering	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of filled grains per panicle	Spikelet fertility (%)	100 grain weight (gm)	Single plant yield (gm)
GCA	5	25.13**	996.45**	0.10	8.58**	81.13**	401.78**	0.0394**	18.24**
SCA	15	3.66**	44.47**	0.87*	4.58**	122.66**	13.17**	0.0069**	3.41*
Reciprocal	15	2.77**	10.81**	0.63	1.95**	173.90**	6.94*	0.0122**	33.06**
Error	70	0.39	0.70	0.39	0.58	6.19	2.95	0.0007	1.83
GCA : SCA	0.33	6.86	22.40	0.11	1.87	0.66	30.50	6.5000	5.34

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

Table 2. Analysis of variance of combining ability for different physiological traits

Source of variation	df	Dry root weight (mg)	Dry shoot weight (mg)	Root: shoot ratio	Na^+:K^+ ratio	Chlorophyll content	Proline content (μgg^{-1})
GCA	5	2.20**	11.50**	0.070**	0.08**	6.81*	24809.32**
SCA	15	0.34*	1.91**	0.010**	0.02*	14.86**	5956.90*
Reciprocal	15	0.48**	6.35**	0.030**	0.06**	6.50**	29127.42**
Error	70	0.15	0.04	0.001	0.01	1.52	2459.79
GCA : SCA	0.33	6.47	6.02	7.000	4.00	0.45	4.16

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

Table 3. General combining ability effects of parents for different biometrical traits

Parent/trait	Days to 50 per cent flowering	Plant height (cm)	Number of productive tillers per plant	Panicle length (cm)	Number of filled grains per panicle	Spikelet fertility (%)	100grain weight (gm)	Single plant yield (gm)
FL 478	-0.680*	-3.585*	0.020	-0.394	4.704*	2.893*	0.011	0.314
IW Ponni	0.698*	1.070*	0.043	-0.739*	-0.296	0.043	0.004	0.515
BPT 5204	-0.702*	-3.730*	-0.152	-0.317	-2.846*	2.831*	0.007	-0.024
IR 64	-0.319	-4.085*	0.098	0.561*	-1.807*	3.048*	0.060*	0.111
RNR 57979	-1.552*	-7.430*	-0.074	- 0.572*	-0.191	2.765*	-1.109*	1.386*
TETEP	2.554*	17.759*	0.065	1.461*	0.437	- 11.580*	0.027*	-2.303*
S.E	0.16	0.22	0.16	0.20	0.65	0.45	0.007	0.35

*Significantat 5 per cent level

Table 4. General combining ability effects of parents for different physiological traits

Parent/trait	Dry root weight (mg)	Dry shoot weight (mg)	Root: shoot ratio	Na^+:K^+ ratio	Chlorophyll content	Proline content (μgg^{-1})
FL 478	-0.285*	1.237*	-0.086*	-0.012	1.425*	-55.682*
IW Ponni	-0.078	0.987*	-0.084*	0.042	-0.334	-24.331
BPT 5204	0.442*	-0.602*	0.076*	0.001	0.215	43.969*
IR 64	0.100	0.226*	-0.015	0.121*	-0.221	-18.054
RNR 57979	0.462*	-1.214*	0.099*	-0.015	-0.465	65.274*
TETEP	-0.643*	-0.634*	0.011	-0.137*	-0.620	-11.176
S.E	0.10	0.05	0.01	0.02	0.32	13.06

*Significantat 5 per cent level

Table 5.Specific combiningability effects of hybrids for different biometrical traits

Hybrid	DFF	PHT	NPT	PL	NFGP	SFP	HGW	SPY
FL 478 / IW Ponni	-0.30	-5.16**	0.44	0.19	7.60**	1.63	0.06**	0.88
FL 478 / BPT 5204	-0.60	-0.49	0.30	-1.12*	-0.28	-0.99	0.04**	-0.09
FL 478 / IR 64	0.60	-0.54	-0.14	-0.30	-5.52**	-0.70	-0.004	-1.02
FL 478 / RNR 57979	0.37	-0.29	0.79*	0.06	-5.60**	-0.02	0.006	0.51
FL 478 /TETEP	-1.39**	3.01**	0.25	-1.03*	-0.03	-3.08**	-0.04**	-0.92
IW Ponni / FL 478	0.06	0.53	-0.50	- 1.30**	-0.16	-0.33	0.065**	2.10*
IW Ponni / BPT 5204	-0.25	-1.95**	-0.62	-0.65	- 10.24**	1.75	0.002	2.20**
IW Ponni / IR 64	-0.87*	-0.39	0.89*	-0.61	-9.42**	1.47	0.065**	-0.66
IW Ponni / RNR 57979	1.39**	-7.82**	0.06	-0.62	-5.33**	0.91	-0.09**	0.17
IW Ponni / TETEP	1.99**	-0.30	-0.03	- 1.42**	-8.36**	-1.59	0.01	-0.10
BPT 5204 / FL 478	0.16	-1.00*	-0.23	-0.93*	-6.60**	0.96	-0.10**	- 6.67**
BPT 5204 / IW Ponni	0.43	3.86**	-0.86*	-0.53	13.83**	-0.60	0.00	8.51**
BPT5204 / IR 64	-0.60	-0.06	-0.10	-0.08	4.13**	-2.14*	0.04**	-0.17
BPT 5204 / RNR 57979	0.56	2.51**	0.63	-0.21	4.41**	-1.79	-0.08**	0.73
BPT 5204 / TETEP	0.05	2.62**	0.49	-0.78	2.85	3.01**	-0.02*	-1.61

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

Table 5. Specific combining ability effects of hybrids for different biometrical traits (Contd…)

Hybrid	DFF	PHT	NPT	PL	NFGP	SFP	HGW	SPY
IR 64 / FL 478	0.90*	-0.33	-0.90*	-1.36**	1.60	0.66	-0.07**	-3.92**
IR 64 / IW Ponni	-0.80*	-2.13**	1.30**	-1.00*	-4.10**	0.13	0.01	5.88**
IR 64 / BPT 5204	0.86*	-2.80**	-0.50	0.40	-3.36*	1.96	-0.003	2.48**
IR 64 / RNR 57979	0.74*	0.13	0.38	0.43	-0.59	1.31	0.02*	-0.24
IR 64 / TETEP	-0.42	1.64**	-0.09	-2.16**	1.88	-1.47	0.000	-0.70
RNR 57979 / FL 478	0.03	2.16**	-0.46	-1.40**	2.60	-0.80	0.09**	-0.30
RNR 57979 / IW Ponni	-0.96*	4.10**	-0.03	0.23	-3.80*	0.70	-0.04**	-4.41**
RNR 57979 / BPT 5204	-0.40	-0.10	0.26	0.06	-2.60	-3.30**	-0.03**	-5.85**
RNR 57979 / IR 64	0.16	5.10**	-0.46	-0.73	-0.90	-0.96	0.10**	-0.92
RNR 57979 /	1.37**	4.35**	-0.35	0.83	8.03**	-3.65**	0.05**	0.63

TETEP								
TETEP / FL 478	-2.10**	-0.73	-0.13	-2.06**	27.73**	-0.20	-0.13**	-0.41
TETEP / IW Ponni	-3.00**	-0.13	-0.17	0.13	10.73**	-1.03	-0.06**	2.39**
TETEP / BPT 5204	1.73**	0.20	0.06	-0.73	-4.40*	2.76**	-0.10**	-2.98**
TETEP / IR 64	0.76*	-2.06**	-0.40	-0.16	0.20	-2.70*	0.01	0.98
TETEP / RNR 57979	-0.53	0.03	0.50	-1.16	-10.30**	-4.16**	-0.12**	-0.05
S.E	**0.37**	**0.50**	**0.37**	**0.45**	**1.49**	**1.03**	**0.01**	**0.81**

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

Table 6.Specific combining ability effects of hybrids for different physiological traits

Hybrid	DRW	DSW	RSR	$Na^+:K^+$	CC	PC
FL 478 / IW Ponni	-0.37	0.39**	-0.06**	0.07	-2.81**	-1.66
FL 478 / BPT 5204	0.25	-0.45**	0.004	-0.10	3.93**	4.29
FL 478 / IR 64	0.51*	0.02	0.010	0.13	2.27**	-74.04*
FL 478 / RNR 57979	0.59*	-0.11	0.02	0.15*	-0.54	91.49**
FL 478 /TETEP	0.04	0.05	-0.008	0.05	-0.98	-70.82*
IW Ponni / FL 478	-0.91**	0.48**	-0.05*	-0.09	-2.12**	82.86**
IW Ponni / BPT 5204	0.32	-0.34**	0.03	-0.03	-2.30**	43.24
IW Ponni / IR 64	0.10	-0.13	0.003	-0.04	-2.89**	65.03*
IW Ponni / RNR 57979	-0.68**	-0.33**	0.004	0.10	-0.74	-83.15**
IW Ponni / TETEP	0.014	-0.15	0.06**	-0.66**	-1.09	37.95
BPT 5204 / FL 478	0.02	2.91**	-0.17**	0.03	2.72**	-40.66
BPT 5204 / IW Ponni	-0.25	2.13**	-0.16**	-0.17**	3.66**	39.83
BPT5204 / IR 64	-0.41	-0.53**	0.04*	0.08	-0.35	5.63
BPT 5204 / RNR 57979	-0.51*	-0.82**	0.07**	0.03	-1.60*	-17.85
BPT 5204 / TETEP	-0.34	-0.69**	-0.01	0.06	-1.40	20.42

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

Table 6.Specific combining ability effects of hybrids for different physiological traits (Contd…)

Hybrid	DRW	DSW	RSR	$Na^+:K^+$	CC	PC
IR 64 / FL 478	-0.27	1.48**	-0.10**	-0.26**	-0.94	135.90**
IR 64 / IW Ponni	-0.75**	0.91**	-0.08**	-0.30**	0.76	239.06**
IR 64 / BPT 5204	0.06	-1.28**	0.15**	-0.01	3.03**	-5.90
IR 64 / RNR 57979	0.25	-0.51**	0.08**	0.03	-1.11	5.06
IR 64 / TETEP	0.48*	-0.35**	0.02	-0.11	-0.61	53.81
RNR 57979 / FL 478	0.20	3.06**	-0.20**	-0.04	2.12*	64.36*

RNR 57979 / IW Ponni	-0.30	2.61**	-0.23**	-0.06	0.86	-17.60
RNR 57979 / BPT 5204	0.003	0.54**	-0.07**	-0.09	1.16	-126.53**
RNR 57979 / IR 64	0.07	1.62**	-0.14**	0.08	-0.92	-117.43**
RNR 57979 / TETEP	0.15	-0.90**	0.06**	0.01	2.63**	9.15
TETEP / FL 478	0.50*	2.39**	-0.09**	0.21**	1.16	-57.20
TETEP / IW Ponni	0.75**	1.93**	0.008	0.13*	-0.35	-3.46
TETEP / BPT 5204	0.21	-0.24*	0.03	0.24**	1.90*	-256.70**
TETEP / IR 64	0.61*	0.91**	-0.02	0.27**	-0.40	41.26
TETEP / RNR 57979	0.84**	-0.36**	0.14**	0.23**	0.24	-166.00**
S.E	**0.23**	**0.12**	**0.02**	**0.06**	**0.74**	**29.80**

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