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COMBINING ABILITY AND HETEROSIS FOR GRAIN YEILD AND ITS COMPONENT TRAITS IN RICE (*ORYZA SATIVA* L.)

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Abstract

Six genotypes of rice namely, ADT36, ADT45, BPT5204, ASD16, ADT37 and ADT39 were mated in half diallel fashion. The resulting fifteen hybrids along with their parents were evaluated for grain yield and its component characters namely, days to 50 percent flowering, plant height, number of productive tillers per plant, panicle length, number of grains per panicle, 100 grain weight, kernel length, kernel breadth and kernel L/B ratio by adopting standard biometric genetic methods. The analysis of variance indicated that the parents and hybrids differed among themselves for all the ten characters studied. The analysis of variance for combining ability indicated the significance of both GCA and SCA variances, illustrating the importance of both additive and non-additive genetic variance in the expression of all the traits. When the parents were assessed for their overall combining ability, the parent namely ADT45 was adjudged as good general combiner followed by ADT39 and ASD16.

Based on overall specific combining ability, the cross combinations *viz*., BPT5204 × ASD16, ADT45 × BPT5204, ASD16 × ADT37, ADT45 × ADT37, ADT45 × ADT39, ASD16 × ADT39, ADT37 × ADT39 and ADT45 × ASD16 were identified as good specific combiners. The cross combination BPT5204 × ASD16 exhibited the maximum standard heterosis (24.65 percent) followed by ADT45 × BPT5204, ASD16 × ADT37, ADT45 × ASD16 and ADT45 × ADT37 for the trait grain yield per plant. The cross combination which showed high commercial heterosis also registered high *per se* performance, significant favorable *sca* effect and had both the parents or at least one of the parent with high *gca* effects. High × High *gca* combinations with high *sca* effects might be due to interallelic interactions like complementary gene action and hence it could be used in heterosis breeding. In case of combinations with high *sca* effects and one of the parents with low *gca* effects, it would throw transgressive segregants for effective selection.

Key words : grain yield, component traits, *Oryza sativa* L., genotypes

Introduction

Rice is the major cereal crop that is consumed almost exclusively by humans. It provides 80 percent of calories for more than two billion people of Asia (Tran, 2003). The population of rice consumers is increasing at the rate of 1.8 percent a year (Khush and Virk, 2000). But the rate of growth in rice production to meet the needs of growing population has slowed down in recent past. So identifying rice genotypes of higher grain yield coupled with grain quality was thus felt important. The planning of any plant breeding programme mostly depends on the genetic architecture of the population handled (Tai, 1979). Identification and selection of flexible parental lines are required to be used in any hybridization programme to produce genetically modified and potentially rewarding genotypes with assembly of fixable gene effects more or less in a homozygous line. Hence, an understanding of combining ability is important before a systematic breeding procedure and it helps in identifying the parents which could be used for hybridization programmes to generate desirable genotypes in the segregating populations. Half diallel analysis is one of the sophisticated forms of progeny testing that is being employed by plant breeders to have a successful selection. This analysis provides information on nature of gene action, interrelationship between the quantitative traits, besides unraveling the combining ability of different parents involved in the crossing programme and of the hybrids produced. An attempt was therefore made to study the genetics of grain yield and yield contributing traits coupled with grain quality components.

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Table 1: Analysis of variance of RBD for parents and hybrids.

Source of vairation	Degrees of freedeom (df)	Days to 50 percent flowering	No. of productive tillers per plant	Plant height	Panicle length	No. of grains per panicle	100 grain weight	Grain yield per plant	Kernel length	Kernel breadth	Kernel L/B ratio
Replication	2	4.09	1.75	2.08	1.94	5.19	0.0002	1.09	0.001	0.003	0.01
Genotype	20	65.54**	50.83**	493.81**	48.21**	892.34**	0.27**	53.65**	0.27**	0.17**	0.29**
Error	40	0.65	0.09	2.22	0.31	3.99	0.003	0.38	0.002	0.002	0.002
SE (d)	-	0.66	0.25	1.22	0.45	1.63	0.04	0.50	0.03	0.03	0.43
CD (5%)	-	1.32	0.50	2.44	0.91	3.28	0.09	1.01	7.54	0.06	8.56
CD (1%)	-	1.76	0.67	3.26	1.21	4.37	0.12	1.34	0.10	8.39	0.11

* Significant at 5 percent level, ** Significant at 1 percent level.

Materials and Methods

Studies on Genetics of grain yield and its component traits in rice were investigated in the plant breeding farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, during 2015-2016. The randomly selected six rice genotypes namely, ADT36, ADT45, BPT5204, ASD16, ADT37 and ADT39 were raised in a crossing block and seedlings were transplanted in the main field adopting 30 cm between the lines and 20 cm within the lines and in between the two genotypes 50 cm spacing was maintained. Crosses were effected in all possible combinations with parental crosses in half diallel mating design of Model I, Method II (Griffing, 1956) by adopting hand emasculation and artificial pollination. A total of 15 cross combinations were obtained. The matured set seeds were collected. The seeds were cleaned, dried and stored carefully for raising the F_1 generation.

All the 15 hybrids (direct crosses) along with their parents were raised in Randomized Block Design (RBD) with three replications during *Kuruvai* (June-September) season. Each genotype was accommodated in a single row of 1.5m length. Single seedling was planted per hill. The spacing adopted was 30cm between rows and 20cm between plants. The recommended agronomic practices were followed. During the flowering period, five competitive plants in each of F_1 hybrid and parent were selected at random and tagged. The data for the traits namely, Days to 50 percent flowering, Number of productive tillers per plant, Plant height (cm), Panicle length (cm), Number of grains per panicle, 100 grain weight (g), Grain yield per plant (g), Kernel length (mm), Kernel breadth (mm) and Kernel L/B Ratio were recorded.

Results and Discussion

The analysis of variance revealed the presence of high genetic variability in the reference population (Table 1). The potentiality of a variety may be judged based on their *per se* performance and *gca* effects. Hence the parents chosen for the present study were assessed based on their *per se* and *gca* effects. Among six parents studied, BPT5204 expressed the maximum grain yield per plant followed by ADT45 and ADT37. Significant favorable superior *gca* effects for seven out of ten traits studied including grain yield per plant was recorded by the parents ADT45 and ADT37 followed by ASD16 for five characters. The other parent BPT5204 is also worth mentioning, since it showed superiority for three traits including grain yield per plant. The parents ADT45 and ADT37 were found to be good general combiners based on overall general combining ability followed by ASD16. Hybridization with these parents will throw better recombinants in the segregating generations. Hence the parents ADT45, ADT37 and BPT5204 (Table 3) which possessed favorable *per se* performance and *gca* effects may be used for further breeding programme. So that

Table 2: Analysis of variance of RBD for parents and hybrids.

Source of vairation	Degrees of freedeom (df)	Mean Sum of Squares									
		Days to 50 percent flowering	No. of productive tillers per plant	Plant height	Panicle length	No. of grains per panicle	100 grain weight	Grain yield per plant	Kernel length	Kernel breadth	Kernel L/B ratio
GCA	5	47.68**	46.15**	350.16**	46.19**	690.92**	0.31**	34.74**	0.20**	0.15**	0.22**
SCA	15	13.24**	7.20**	102.75**	6.03**	166.29**	0.02**	12.2**	0.05**	0.02**	0.05**
Error	40	0.22	0.03	0.74	0.10	1.33	0.001	0.12	0.001	0.001	0.001
GCA/SCA	-	3.60	6.40	3.40	7.66	4.15	15.5	2.84	4.00	7.5	4.4

* Significant at 5 percent level, ** Significant at 1 percent level.

Table 3: Relationship between mean performance and *gca* effects.

Characters	High Mean performance	High *gca*	Common parent
Days to 50 percent flowering	ADT37 (69.93) ADT39 (72.48) ADT45 (73.19)	ASD16 ADT37 ADT45 ADT 39	ADT37 ADT45 ADT39
Number of productive tillers per plant	ADT45 (23.94) ADT36 (19.97) BPT5204 (17.74)	ADT45 BPT5204	ADT 45 BPT5204
Plant height	ASD16 (81.47) ADT45 (81.87) ADT36 (84.24)	ADT45 ASD16 ADT37	ADT45 ASD16
Panicle length	BPT5204 (28.43) ADT45 (24.57) ADT36 (22.20)	BPT5204 ADT39 ADT45	BPT5204 ADT45
Number of grains per panicle	ADT37 (143.10) ADT45 (132.13) ADT36 (117.81)	ADT37 ADT45 ASD16	ADT37 ADT45
100 grain weight	ADT37 (2.45) ADT39 (2.26) BPT5204 (1.89)	ADT37 ADT39 ASD16	ADT37 ADT39
Grain yield per plant	BPT5204 (27.76) ADT45 (25.67) ADT39 (23.67)	BPT5204 ADT45 ASD16	BPT5204 ADT45
Kernel length	ADT36 (6.18) ADT45 (6.06) BPT5204 (5.53)	ADT45 ADT36	ADT45 ADT36
Kernel breadth	ADT37 (1.59) ADT36(2.08) ADT39 (2.12)	ADT36 ADT37	ADT37 ADT39
Kernel L/B ratio	ADT37 (3.27) ADT36 (2.97) ASD16 (2.55)	ADT37 ADT36	ADT37 ADT36

desirable segregants could be obtained for most of the traits including grain yield per plant through recombination of favorable genes.

Many researchers stressed that the *per se* performance is a useful index to evaluate and to select the hybrids. Among fifteen hybrids studied, five hybrids namely, BPT5204 × ASD16, ADT45 × BPT5204, ASD16 × ADT37, ADT45 × ASD16 and ADT45 × ADT37 exhibited maximum significant grain yield per plant and also recorded more than 30g of grain yield per plant. Superior crosses were obtained either from high × high or high × low or low × high performing parents for all the characters studied. Similar observations were also reported by Gilbert, 1958 and Singh and Hari Singh, (1985). From the foregoing discussion, it could be concluded that the performance of hybrids was independent of the performance of their parents. High significant specific combining ability effects represent predominance of non-additive gene action. The favorable *sca* effects indicated that the hybrid BPT5204 × ASD16 alone was best in respect of all the ten characters studied. The cross combinations namely, ADT45 × BPT 5204 (+7), ASD16 × ADT37 (+7), ADT45 × ADT37 (+4), ADT45 × ADT39 (+4), ASD16 × ADT39 (+4) ADT37 × ADT39 (+4) and ADT45 × ASD16 (+2) were identified as good specific combiners based on over all specific combining ability effects.

The hybrids which displayed high mean grain yield per plant *viz*., BPT5204 × ASD16, ADT 45 × BPT5204, ASD16 × ADT37, ADT45 × ASD16 and ADT45 × ADT37 were also found to possess high *sca* effects for many of the traits investigated including grain yield per plant. Similar observations were also reported by Dwivedi *et al.,* (2012).

In the present study, the hybrids were evaluated based on standard heterosis over the standard variety BPT5204

Table 4: Performance of best five crosses selected for grain yield per plant based on standard heterosis (diii), for other traits in percent.

Traits \ CROSSES	BPT5204 × ASD16 (24.65**)	ADT45 × BPT5204 (19.97**)	ASD16 × ADT37 (18.65**)	ADT45 × ASD16 (17.45**)	ADT45 × ADT37 (14.33**)
Days to 50 per cent flowering	-13.77**	-13.24**	-8.61**	-11.24**	-5.81**
Number of productive tillers per plant	30.75**	47.66**	14.75**	36.20**	34.89**
Plant height	-32.83**	-34.31**	-33.72**	-30.85**	-26.70**
Panicle length	7.15**	14.65**	-17.23**	-2.46	-9.26**
Number of grains per panicle	26.62**	28.74**	38.76**	34.21**	29.65**
100 grain weight	15.52**	1.76	22.57**	13.76**	23.46**
Kernel length	5.55**	1.93**	5.01**	5.25**	6.94**
Kernel breadth	-13.28**	-10.65**	-23.37**	-4.29**	-28.22**
Kernel L/B ratio	21.66**	14.10**	37.06**	10.61**	48.98**

* Significant at 5 percent level, ** Significant at 1 percentlevel.

Table 5: Relationship between *Per se*, Standard heterosis, *sca* and *gca* effects.

Traits \ Crosses	High Mean performance	High (diii)	*sca*	*gca*
Days to 50 per cent flowering	ASDI6 × ADT39	ASD16 × ADT39	+1	+1 × +1
	BPT5204 × ASD16	BPY5204 × ASD16	+1	0 × +1
	ADT45 × BPT5204	ADT45 × BPT5204	+1	+1 × 0
	ADT45 × ASD16	ADT45 × ASD16	+1	+1 × +1
	ADT37 × ADT39	ADT37×ADT39	+1	+1 × +1
Number of productive tillers per plant	ADT45 × BPT5204	ADT45 × BPT5204	+1	+1 × +1
	ADT45 × ASD16	ADT45 × ASD16	+1	+1 × -1
	ADT45 × ADT37	ADT45 × ADT37	+1	+1 × –1
	BPT5204 × ASD16	BPT5204 × ASD16	+1	+1 × -1
	ADT45 × ADT39	APT45 × APT39	+1	+1 × -1
Plant height	ADT45 × BPT5204	ADT45 × BPT5204	+1	+1 × -1
	ASD16 × ADT37	ASD16 × ADT37	+1	+ 1 × +1
	BPT5204 × ASD16	BPT5204 × ASD16	+1	-1 × +1
	ADT45 × ASD16	ADT45 × ASD16	-1	-1 × +1
	ADT36 × ADT37	ADT36 × ADT37	+1	+1 × +1
Panicle length	ADT45 × BPT5204	ADT45 × BPT5204	+1	+1 × +1
	BPT5204 × ASD16	BPT5204 × ASD16	+1	+1 × -1
	ADT45 × ASD16	ADT45 × ASD16	+1	+1 × -1
	BPT5204 × ADT39	BPT5204 × ADT39	-1	+1 × -1
	BPT5204 × ADT37	BPT5204 × ADT37	+1	+1 × -1
Number of grains per panicle	ASD16 × ADT37	ASD16 × ADT37	+1	+1 × +1
	ADT45 × ASD16	ADT45 × ASD16	+1	+1 × +1
	ADT37 × ADT39	ADT37 × ADT39	+1	+1 × -1
	ADT45 × ADT37	ADT45 × ADT37	-1	+1 × +1
	ADT4 5 × BPT5204	ADT45 × BPT5204	+1	+1 × -1
100 grain weight	ADT37 × ADT39	ADT37 × ADT39	+1	+1 × +1
	ADT45 × ADT37	ADT45 × ADT37	+1	-1 × +1
	ASD16 × ADT37	ASD16 × ADT37	+1	+1 × +1
	ADT45 × ADT39	ADT45 × ADT39	+1	-1 × +1
	BPT5204 × ASD16	BPT5204 × ASD16	+1	+1 × 0
Grain yield per plant	BPT5204 × ASD16	BPT5204 × ASD16	+1	+1 × +1
	ADT45 × BPT5204	ADT45 × BPT5204	+1	+1 × +1
	ASD16 × ADT37	ASD16 × ADT37	+1	+1 × +1
	ADT45 × ASD16	ADT45 × ASD16	+1	+1 × +1
	ADT45 × ADT37	ADT45 × ADT37	+1	+1 × +1
Kernel length	ADT45 × ADT39	ADT45 × ADT39	+1	+1 × -1
	ADT36 × ADT45	ADT36 × ADT45	0	+1 × +1
	ADT36 × BPT5204	ADT36 × BPT5204	+1	+1 × 0
	BPT5204 × ADT39	BPT5204 × ADT39	+1	0 × -1
	ADT45 × ADT37	ADT45 × ADT37	+1	+1 × -1
Kernel breadth	ADT45 × ADT37	ADT45 × ADT37	+1	0 × +1
	BPT5204 × ADT37	BPT5204 × ADT37	+1	-1×+1
	ADT36 × ADT37	ADT36 × ADT37	0	0 × +1
	ASD16 × ADT37	ASD16 × ADT37	0	0 ×+ 0
	ADT36 ×ASD16	ADT36 × ASD16	+1	0 × 0
Kernel L/B ratio	ADT45 × ADT37	ADT45 × ADT37	+1	-1 × +1
	ASD16 × ADT37	ASD16 × ADT37	+1	-1 × +1
	ADT36 × ADT37	ADT36 × ADT37	-1	+1 × +1
	BPT5204 × ADT37	BPT5204 × ADT37	+1	-1 × +1
	BPT5204 × ADT39	BPT5204 × ADT39	+1	-1 × -1

and promising hybrids were selected based on standard heterosis. The hybrid BPT5204 × ASD16 recorded the maximum standard heterosis followed by ADT45 × BPT5204, ASD16 × ADT37, ADT45 × ASD16 and ADT45 × ADT37 (Table 4) for the trait grain yield per plant. Heterotic vigor achieved in F_1 generation of the above cross combinations should be given due consideration in self pollinated crops like rice as heterotic crosses may give transgressive segregants in the later generation.

Best five crosses were selected for *per se* performance for all the traits. All the crosses which endowed with high *per se* exhibited the high standard heterosis (Table 5). The cross combination which showed high commercial heterosis also registered with significant favorable *sca* effects for almost all the traits. Raghavaiah and Joshi, (1986) suggested that for the improvement of self pollinated crops, *sca* effects for a particular combination could be useful if it is accompanied by high *gca* effects of the respective parents. In the present study, the number of hybrids obtained from parents with different type of *gca* effects and their corresponding *sca* effects are presented in table 2. The relationship between *gca* and *sca* effects evidenced that most of the cross combinations which exhibited high *sca* effects had both the parents or at least one of the parent with high *gca* effects. This is in harmony with the findings of Peng and Virmani, (1990).

It is also noticed that the cross combinations ADT45 × ADT37 and ADT36 × ADT45 with non-significant *sca* effects had parents with significant *gca* effects for number of grains per panicle and kernel length, respectively. It indicated that the parents with high *gca* need not be good specific combiners. If both the parents of a specific cross combination showed high *gca* effect, it revealed the presence of additive × additive gene action and hence high yielding segregants would be isolated from the segregating generations (Shinde and Kulkarni, 1984). In case of combinations with high sca effects and one of the parents with low *gca* effects, it would threw transgressive segregants for effective selection (Langhum, 1961). On the other hand, high × high *gca* combinations with high *sca* effects might be due to inter allelic interactions like complementary gene action and hence it could be used in heterosis breeding. Hence, for the improvement of self pollinated crop like rice, *sca* effects of a particular cross will be useful if it is coupled with high *gca* effects of both the parents or at least one of the parent as suggested by Ragavaiah and Joshi, (1986).

The mean sum of square for combining ability revealed that the GCA variance was significant for all the characters studied (Table 2). This indicated the presence of additive genetic variance for all the ten characters studied. The SCA variances were also significant for all the ten traits studied. This implied the presence of dominance and non-additive genetic variance in the inheritance of these traits. The results amply revealed the importance of both additive and non additive genetic variance for all the ten traits. However the ratio of GCA/SCA was more than unity for all the traits including grain yield per plant. This indicated the preponderance of additive genetic variance in the improvement of the traits of interest. This was in conformity with the findings of Thirugnana kumar *et al.,* (2008), Veeresha *et al.,* (2013) and Upadhyay *et al.,* (2015).

Present study revealed the importance of both additive and non-additive gene action in the improvement of grain yield traits. In such case, simple pure line selection or modified pedigree selection may not be possible. Hence improvement can be expected by delaying the selection to later segregating generations, when the dominance and epistatic interactions disappear and resorting to inter mating of superior segregants followed by recurrent selection (Frey, 1984, Hallaure, 1986, Delogu *et al.,* 1988). Diallel selective mating system can also be adopted (Jenson, 1970). In the presence of over dominance, the best scheme to develop hybrids would be reciprocal recurrent selection.

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