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HETROSIS OF SOME AGRONOMIC CHARACTERS IN AROMATIC RICE (*ORYZA SATIVA* L.) VARIETIES AND THEIR F_1 HYBRIDS UNDER LOWLAND AND UPLAND ENVIRONMENTS

A. D. Jarwar[1], Q. D. Dela Cruz[2] and G.S. Junejo[1]

[1]Rice Research Station, Thatta Sindh, Pakistan
[2]Department of Crop Sciences Institute of Graduate studies, Central Luzon State University, Nueva Ecija Philippines

ABSTRACT

Heterotic performance of twenty-one F_1 hybrids and their 10 parents were evaluated in a randomized complete block design with three replications in two environments. Significant differences were observed among parents, hybrids and hybrids versus parents for most of the agronomic characters of hybrids in both environments. Genotype x environment interaction was also significant in most of the traits studied. These differences indicated the presence of variability and heterosis of these traits. Lines (male parents) Rataria, Sugdasi and LR2; testers (female parents) Pandan and Basmati 370 had the highest values under both environments. While, the hybrids Bengalo x Pandan, Sugdasi x Pandan and DR65 x Vertin showed highest average heterotic values under lowland and upland environments. Heterosis breeding may be utilized to improve yield and other traits with dominant gene action. Significant negative heterosis was observed in days to 50% flowering, days to maturity and plant height which is desirable for developing early maturing and medium tall varieties.

Keywords: Aromatic rice, F_1 hybrids, heterosis.

INTRODUCTION

Rice is life for major populations of the world and is deeply embedded in the cultural heritage of societies. Rice is the staple food of nearly one half of the world's population. It contributes over 20% of the total calorie intake of the human population. In Asian population, rice has special position as a source of providing over 75% and more than three billion of worlds population rice meals and represents 50 to 80 percent of their daily calorie intake (Amirjani, 2011). There is a growing concern that current levels of rice production will not meet future demand. Production technology from the green revolution has been exhibiting diminishing returns and 1990s saw a marked decline in yield growth rate, since 2000, annual withdrawals from rice stocks have been necessary to bridge the gap between rice production and demand (Khush, 2000). The challenge of overcoming hunger, poverty and malnutrition in rice-consuming countries while maintaining productivity and protecting the environment will require a coordinated effort. In this regard, increased awareness as well as national, regional and global efforts to secure sustainable rice production is essential. In addition, rice research will play a major role in the efficient utilization of cultivated area, improved rice varieties, and the minimization of loss during milling.

The major focus of rice research in the next decade must be the development of high-yielding and early-maturing varieties in order to ensure food security and efficient use of natural resources (Swain, 2005). Rice, the second most widely-grown cereal crop is the staple food for more than half of the global human population. More than one hundred thousand landraces and improved cultivar collections are available in the rice germplasm world wide and largely contribute to the rich genetic diversity of rice, driven by natural selection of varieties distributed in diverse agro-ecoclimatic conditions coupled with continuous selection

Corresponding address: adjarwar@yahoo.com

by man for diverse in quality and aesthetic preferences, a unique rice varietal group has emerged, which is known as basmati rice, a specialty rice all over the world (Singh *et al*., 2000).

Heterosis is a phenomenon in which F_1 hybrids derived from diverse parents show superiority over their parents. Two major hypotheses have been proposed to explain the genetic basis of heterosis. The dominance hypothesis (Davenport, 1908) and over dominance hypothesis. Dominance hypothesis states that heterosis is due to the accumulation of favorable dominant genes in a hybrid derived from the two parents. Whereas over dominance hypothesis states that the heterozygote (Aa) is more vigorous and productive than either homozygotes (AA or aa). Studies have shown that heterosis is the result of partial to complete dominance, over dominance, epistasis, and it may be a combination of all these (Comstock and Robinson, 1952). Singh and Kumar (2004) also identified suitable parents through line x tester analysis in rice. In upland rice Alam *et al*. (2004) observed the varying degrees of heterosis for yield and its related traits. For plant height, negative heterosis was desirable but for the rest of the characters, positive heterosis was desirable. Positive heterosis ranged from 1.8-34.8%; 3.8-8.2%; 1.0-15.4%; 5.1-27.7% and 5.6-61.9% for productive tillers/ plant, panicle length, fertility %, 1000-grain weight and yield/ plant. The fine grain Basmati varieties of rice are considered high quality and fetch a high price in the national and international trade. However, yield per unit area of Basmati rice is very low due to tall plant habit and late maturity. So, broadening the genetic base of rice is an essential requirement for rice improvement program. The hybrid rice program depends upon the magnitude of heterosis which also helps in the identification of potential cross combinations to be used in the conventional breeding programs to create wide array of variability in segregating generations. A good hybrid should manifest high heterosis for commercial exploitation. Jelodar (2010) conducted study for combining ability and heterosis on 12 F_1 hybrids. Results revealed significant differences among genotypes, crosses, lines, testers and line x tester interactions for tiller number, plant height, days to 50% flowering, panicle length, number of spikelets per panicle, spikelet fertility and grain yield traits. A hybrid is commercially valuable only when it exhibits significantly high standard heterosis over best locally adopted variety. Breeding strategies based on selection of hybrids require expected level of heterosis as well as specific combining ability. 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. Tiwari *et al*. (2011) conducted an experiment with line x tester mating design and found that the manifestation of heterobeltiosis for grain yield was significantly superior for 43 hybrids ranging from 11.63 to 113.04% and 46 hybrids over standard variety (Sarjoo-52) ranging from 10.48 to 71.56%.

This study was therefore aimed to estimate the combining ability effects and aids in selecting the desirable parents and crosses for the exploitation of heterosis in the introduced Basmati varieties of Indica rice. Generally, this study is aimed at determining the combining ability effect and heterosis in selected parents for the development of aromatic hybrids.

MATERIALS AND METHODS

Ten selected genotypes of which seven were used as lines and three as testers while one was kept as check. Line (males) Local Roosi-2, Sugdasi, Mehak, JJ77, Rataria, DR65, and Bengalo were originated from Pakistan through selection. Whereas Testers (Females) Pandan and Vertin were originated from Philippines and Basmati 370 from India through selection, and variety Basmati 370 from Philippines as check. The material was grown in plastic pails for the production of crosses in the dry/ summer season-2010. Staggard planting was done to synchronize flowering, to obtain the planned crosses. Hybridization was done as soon as the flowering appeared from the parental material.The crosses were attempted in line x tester fashion (Kempthorne, 1957). The pails were filled with garden soil and organic compost in a ratio of 9:1 which was thoroughly mixed. Approximately 10 kg of the medium was used in each pail. Three to five seeds were sown in each pail. The seeds were covered with thin layer of fine soil and kept wet to the point of saturation. Four to five days after emergence watering was done regularly. Fertilizers were applied following the recommended rate into two splits at seedling and at panicle initiation stages. Flowers of female parents were emasculated by cutting the tip of each floret with scissor and the immature anthers were removed with an automatic sucker or by hand with forceps, taking care that stigma is not affected/ damaged. Emasculation was done in the afternoon between 4-6 p.m, one day before the anther is expected to dehisce or mature and the stigma is likely to become fully receptive. The emasculated flowers were then covered with butter paper bags to avoide natural cross pollination. Pollination of emasculated flowers of each floret was done in the morning between 10 and 11 a.m. when the anthers were fully matured and ready to dehisce. Ripe anthers collected from the male parents were used to shed over the female parents (emasculated panicle). After pollination, the panicles were properly covered, again to protect from foreign pollen and were tagged just after bagging. The tags were marked with the date of emasculation, date of pollination, and the names of male and female parents. Seeds of the crossed material were harvested after 21-25 days of pollination and kept in the cold storage. Harvesting of the crossed plants was done 25 days after pollination. Evaluation of crosses along with their parents and a check variety was done in two environments i.e. lowland and upland conditions with three replications, during the dry season in December 2010. Lowland conditions were characterized by continuous presence of water during the growing period, while in the upland condition, the genotypes were grown under controlled irrigation. In each environment, each genotype was planted in a row plot of 1 meter length per row with a distance of 30 cm between rows and 20 cm between plants. The field was prepared thoroughly by alternate plowing and harrowing until the desired soil tilth was attained under lowland environment field, whereas under upland environment field was prepared with disc plowing and harrowing twice. Thirty day old seedlings were pulledout and one seedling/ hill were transplanted in the prepared plots and sprayed with mollusicide at the rate of 1L ha^{-1} right after transplanting in the lowland. Whereas in the upland condition, irrigation was applied in the prepared plots at the time of transplanting. The experimental plots in both the environments were fertilized at the rate of 132-42-42 NPK kg ha^{-1} at 7 days after transplanting, while the remaining rate was applied into two splits at 30 and 45 days after transplanting. During transplanting, water level was maintained at 2-3cm depth until 25-30 DAT, in the lowland condition. Under upland condition, irrigation was applied as alternate dry and wet. Aside from irrigation, weeding and appearance of insect pests and diseases were monitored regularly; no more infestation was observed in the experiments. In the upland condition, manual weeding was used to control the weeds. Harvesting was done when the plants reached maturity. Five plants were randomly selected by cutting the stem close to the soil surface for determining the agronomic traits and yield components. Proper labels were provided for each of the selected plants. The data was recorded on days to flowering, days to maturity**,** plant height (cm), number of productive tillers $plant^{-1}$**,** and number of non productive tillers $plant^{-1}$.

Statistical analysis

The data collected from the experiment were subjected to statistical analysis for analysis of variance appropriate for RCBD. Mean squares were tested against error variance by the usual “F” test. The standard error of the difference in comparing two genotype means were estimated by $\sqrt{2EMS/r}$ where MS is the estimate of EMS. The least significant difference (LSD) was computed by multiplying the standard error of the difference with “t” values for (r-1) (t-1) degree of freedom at 5% and 1% level of significance. Heterosis was expressed as the percent deviation of the hybrids (F_1) from each of the relative parent that is increased or decreased vigor of the F_1 hybrids over the mid parent value.

$$\text{Mid-parent (\%)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where :$\overline{\mathbf{F_1}}$ = Mean performance of F_1 hybrids

$\overline{\mathbf{MP}} = \frac{\mathbf{p_1 - p_2}}{\mathbf{2}}\ \mathbf{x\ 100}$ = Mean value of the two corresponding parents

P_1 = mean performance of male parent, P_2 = mean performance of female parent

Estimates of heterosis was tested for their significance by the following formula:

$$\mathbf{S.E.\ for\ the\ heterosis\ of\ individual\ hybrid} = \sqrt{\mathbf{3\ EMS/2r}}$$

The least significant difference (LSD) was computed by multiplying the standard error of the difference with the respective “t” value for error degree of freedom at 5% and 1% levels of significance.

RESULTS AND DISCUSSION

One of the essential factors needed in hybrid development is the high magnitude of heterosis in specific combinations. In the present study, heterosis was calculated as deviation of hybrids from mid parental values of each of the crosses for yield and its components. In the present study, the parents of diverse origin were used which indicate a variable heterosis from higher to lower degrees in their F_1 hybrids under lowland and upland environments. The heterotic effect of the crosses for different agronomic traits, for two environments studied are presented in Table 1.

Days to 50% flowering

Under lowland condition, results revealed that most of the crosses showed significant negative and positive heterosis, except two, JJ77 x Pandan and DR65 x Basmati 370, which showed non significant negative (-0.59) and positive (1.10) heterosis, respectively. Heterotic values ranged from -8.38 to 19.38%. Hybrid Mehak x Vertin manifested highest significant positive heterosis (19.38%) which indicates that this cross is late flowering. Among the negative significant heterosis cross of LR2 x Pandan showed the highest negative value (-8.38%), followed by Rataria x Vertin (-8.27%). These crosses also showed earliness in flowering in the average performance. The significant negative heterosis indicates that the crosses are early flowering than their mid parents. Under upland condition, heterotic values ranged from -12.56 to 19.03%. Out of 21 crosses eleven crosses, exhibited significant negative heterosis. Heterotic values ranging from -12.56 to -2.18%. Hybrid Bengalo x Basmati 370 manifested highest significant negative heterosis (-12.56%), followed by Sugdasi x Pandan (-11.75%) and Sugdasi x Vertin (-9.44%) which indicates that these hybrids are earlier in maturity. The average of two environments showed that the mean values of hybrids ranged from -9.70 to 15.32%.The average negative heterosis, are combinations Sugdasi x Pandan, LR2 x Pandan, and Rataria x Vertin had highest values (-9.70, -8.45% and -8.41%, respectively). The lowest average value was found in hybrid Mehak x Pandan (-0.96%).

Table 1. Heterotic effects for different agronomic characters under two environments of F_1 hybrids in aromatic rice.

F_1 hybrids	Days to 50% flowering			Days to maturity			Plant height (cm)		
	Low land	Upland	Mean	Low land	Upland	Mean	Low land	Upland	Mean
LR2 x Pandan	-8.38**	-8.53**	-8.45	-5.84**	-2.15	-3.99	-5.88**	18.49**	6.30
LR2 x Basmati 370	-4.34**	-6.17**	-5.25	-2.61*	-2.63	-2.62	0.80	-14.88**	-7.04
LR2 x Vertin	7.59**	4.78*	6.14	5.65**	2.11	3.88	-9.48**	-18.16**	-13.82
Sugdasi x Pandan	-7.65**	-11.75**	-9.70	-5.26**	0.65	-2.30	-6.84**	-8.08**	-7.46
Sugdasi x Basmati 370	7.52**	17.02**	12.27	4.62**	1.92	3.27	-5.80**	9.29**	1.74
Sugdasi x Vertin	-5.34**	-9.44**	-7.39	-2.77*	-3.03	-2.90	7.58**	3.16	5.37
Mehak x Pandan	-2.49**	0.57	-0.96	0.17	-0.75	-0.29	-7.57**	-15.69**	-11.63
Mehak x Basmati 370	-4.77**	-5.06**	-4.91	-2.92**	-0.93	-1.92	-7.83**	5.05	-1.39
Mehak x Vertin	19.38**	11.27**	15.32	11.31**	7.96**	9.63	-1.20	1.39	0.09
J J 77 x Pandan	-0.59	-2.18	-1.38	-1.62	4.41*	1.39	5.21**	9.55**	7.38
J J 77 x Basmati 370	-3.07**	-7.08**	-5.07	-1.63	-4.84*	-3.23	-0.13	21.16**	10.51
J J 77 x Vertin	-3.39**	-3.83*	-3.61	-3.33**	0.14	-1.59	-1.19	-2.64	-1.91
Rataria x Pandan	-4.26**	-7.26**	-5.76	-0.79	2.19	0.70	14.26**	-5.29	4.48
Rataria x Basmati 370	6.01**	12.05**	9.03	3.61**	-1.55	1.03	0.51	-11.83**	-5.66
Rataria x Vertin	-8.27**	-8.56**	-8.41	-5.9**	-4.80*	-5.35	-6.28**	9.80**	1.76
Bengalo x Pandan	4.49**	9.61**	7.05	1.12	1.51	1.31	1.84	-2.89	-0.52
Bengalo x Basmati 370	1.78*	-12.56**	-5.39	0.44	3.62**	2.03	2.73	-13.91**	-5.59
Bengalo x Vertin	2.43**	19.03**	10.73	1.79	-1.26	0.26	4.79**	22.96**	13.87
DR 65 x Pandan	-2.17**	-5.57**	-3.87	-1.94	-7.43**	-4.68	-3.29	-0.38	-1.83
DR 65 x Basmati 370	1.10	6.03**	3.56	-1.63	6.25**	2.31	-1.76	-18.17**	-9.96
DR 65 x Vertin	5.69**	4.18*	4.93	6.46**	-1.68	2.39	16.47**	21.16**	18.81
S.E	0.68	1.78	-	1.06	1.98	-	1.67	2.94	-
L.S.D. at 0.5	1.38	3.59	-	2.14	4.01	-	3.38	5.95	-

L.S.D. at 0.1	1.85	4.82	-	2.86	5.36	-	4.52	7.96	-

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F_1 hybrids	Number of productive tillers plant^{-1}			Number of non productive tillers plant^{-1}		
	Lowland	Upland	Mean	Lowland	Upland	Mean
LR2 x Pandan	-16.67**	2.85	-6.91	-6.66**	-13.58**	-10.12
LR2 x Basmati370	-7.39**	-3.45*	-5.42	-6.66**	0.00	-3.33
LR2 x Vertin	-15.25**	-5.57**	-10.41	-5.41**	-6.67**	-6.04
Sugdasi x Pandan	2.64*	4.13**	3.38	7.01**	-11.32**	-2.15
Sugdasi x Basmati 370	-16.17**	-1.99	-9.08	-10.83**	1.29*	-4.77
Sugdasi x Vertin	-1.77	-0.09	-0.93	-0.65	10.94**	5.14
Mehak x Pandan	3.58**	-8.29	-2.35	-3.35**	-12.49**	-7.92
Mehak x Basmati 370	6.19**	4.22**	5.20	5.44**	15.38**	10.41
Mehak x Vertin	-15.45**	-0.09	-7.77	-2.12**	1.68**	-0.22
J J 77 x Pandan	-7.82**	-3.78*	-5.80	1.00**	8.49**	4.74
J J 77 x Basmati 370	6.79**	-5.88**	0.45	1.00**	5.00**	3.00
J J 77 x Vertin	0.05	4.34**	2.19	10.75**	-0.91	4.92
Rataria x Pandan	13.19**	1.46	7.32	-4.74**	20.92**	8.09
Rataria x Basmati 370	-4.05**	-9.11**	-6.58	12.58**	-14.28**	-0.85
Rataria x Vertin	-2.66*	-0.79	-1.72	-3.55**	-4.91**	-4.23
Bengalo x Pandan	7.40**	8.60**	8.00	-0.43	6.23**	2.90
Bengalo x Basmati 370	0.27	-1.27	-0.50	-0.43	2.63**	1.10
Bengalo x Vertin	9.49**	4.42**	6.95	-8.29**	-11.66**	-9.97
DR 65 x Pandan	8.95	-10.26**	-0.65	9.42**	-11.32**	-0.95
DR 65 x Basmati 370	9.55**	11.68**	10.61	1.00**	1.29*	1.14
DR 65 x Vertin	9.14**	7.39**	8.26	2.23**	10.94**	6.58
S.E	1.11	1.47	-	0.37	0.59	-
L.S.D. at 0.5	2.24	2.97		0.74	1.19	-
L.S.D. at 0.1	3.00	3.98	-	0.99	1.61	-

** = Significant at1% level

* = Significant at 5% level

Days to maturity

Results of lowland condition showed that out of 21 crosses five crosses, exhibited significant positive heterotic effects, while six crosses showed significant negative effects. heterotic values ranged from -5.90 to 11.31%. The highest negative heterosis was exhibited by Rataria x Vertin (-5.9%). This was followed by LR2 x Pandan (-5.84%) and Sugdasi x Pandan (-5.26%). The negative heterosis of the crosses indicates dominance over their early maturing parents. The highest positive heterosis was exhibited by Mehak x Vertin (11.31%), followed by DR65 x Vertin (6.46%) and LR2 x Vertin (5.65%). Hybrid with negative heterosis indicates early maturity while the positive heterosis indicates that the hybrids matured later. Under upland condition, heterosis values ranged from-7.43 to 7.96%. Out of 21 F_1 hybrids only three hybrids such as DR65 x Pandan (-7.43%), JJ77 x Basmati 370 (-4.84%) and Rataria x Vertin (-4.80%), showed significant negative heterosis while four had significant positive heterosis. Hybrid Mehak x Vertin showed highest significant positive heterosis (7.96%), followed by DR65 x Basmati 370 (6.25%). The highest value was observed from crosses Rataria x vertin (-5.35) followed by DR65 x Pandan (-4.68%). All the cross combinations with negative heterotic effects indicated early maturity in two varying environments.

Plant height

Under lowland condition, results revealed that out of 21 cross combinations, only seven crosses showed significant negative heterosis. Among the significant negative heterosis, cross of LR2 x Vertin (-9.48%) was the highest, followed by cross Mehak x Basmati 370 (-7.83%). Five cross combinations showed significant positive heterosis indicating dominance over taller parents. However, the highest positive heterosis value was found in hybrid DR65 x Vertin (16.47%), which was followed by Ratria x Pandan (14.26%). The negative heterotic effects indicating that the hybrids were shorter than their mid parents and positive heterotic effects showed that hybrids were taller with their mid parents. Under upland condition, the heterosis values ranged from -18.17 to 22.96% for plant height. Out of 21 hybrids, seven hybrids showed significant negative heterosis and seven significant positive heterosis, others were found non-significant in both (positive and negative). The highest significant negative value was observed in cross combination DR 65 x Basmati 370 (-18.17%) was followed by LR2 x Vertin (-18.16%) and Mehak x Pandan (-15.69%). The significant negative attribute shows the dwarfness of theses hybrids over their mid parents. The short plant height in basmati rice is also an important aspect for the improvement of basmati rice breeding through heterosis. However, hybrids Bengalo x Vertin, JJ77 x Basmati 370 and DR65 x Vertin exhibited highest significant positive heterosis (22.96 and 21.16%, respectively).The mean values of two environments ranged from -11.63 to 18.8%1. The highest negative mean value was observed in the cross LR2 x Vertin (-13.82%), followed by Mehak x Pandan (-11.63). In cross combination, Bengalo x Pandan showed the lowest negative value (-0.52). Results showed that F1 hybrids are generally taller than their shorter parents, but shorter than their taller parents indicating partial dominance in this trait. Earlier, Alam *et al*. (2004) reported that for plant height, negative heterosis was desirable. One of the desirable traits in Basmati inbred is medium plant height because most of the Basmati varieties are known to have tall and weak stem, hence, susceptible to lodging. As such, medium plant height, row spacing and plant density can be manipulated. Thus, the occurrence of negative heterosis in cross combinations indicates the possibility of producing hybrids with short medium height.

Number of productive tillers

Under lowland environment, heterotic values for this trait ranged from -16.67 to 13.19%. Out of 21crosses, nine showed significant negative heterosis ranging from -2.66 to -16.67. Nine showed significant positive heterosis range from 2.64 to 13.19. Hybrids such as Sugdasi x Pandan, Mehak x Pandan, Mehak x Basmati 370, JJ77 x Basmati 370, Rataria x Pandan, Bengalo x Pandan, Bengalo x Vertin, DR65 x Basmati 370 and DR65 x Vertin exhibited significant positive heterosis indicating additive gene action. Under upland environment, heterotic values for this trait ranged from -10.26 to 11.68%. Cross combination LR2 x Pandan showed highest negative heterosis value (-16.675) and DR65 x Basmati 370 showed highest positive heterosis value (11.68). Among all cross combinations six crosses showed significant positive heterosis. The lowest value was in cross of Sugdasi x Pandan (4.13%), while six hybrids showed significant negative heterosis. The significant positive heterotic effects indicate more number of productive tillers in the crosses. In both environments, mean heterotic values ranged from -9.08 to 10.6%. Out of 21 hybrids, nine hybrids showed positive heterotic effects, indicating that these crosses had more productive tillers. Cross combination, DR65 x Basmati 370, showed highest value (10.61%), followed by crosses DR65 x Vertin (8.26%) and Bengalo x Pandan (8.00), while the lowest value was observed in hybrid JJ77 x Basmati 370 (0.45%). Result found by Sreedhar *et al.* (2011) agreed with present findings. They reported that, substantial portion of genotype x environment interaction was significant for number of productive tillers. These results agreed with the results of Alam *et al*. (2004) who noted positive heterosis range from 1.8 to 34.8% for this character. Jelodar (2010) observed highest heterosis in some crosses.

Number of non-productive tillers

Results under lowland environment showed that most of the crosses had significant negative heterotic effect for this trait, which indicates that crosses posses less number of non-productive tillers. The heterosis values ranged from -10.83 to 12.58. The highest negative heterotic value was shown by cross Sugdasi x Basmati 370 (-10.83%), followed by Bengalo x Vertin (-8.29), while the lowest negative heterosis was found in hybrid Mehak x Vertin (-2.12). Whereas under upland environment heterotic values ranged from -14.28 to 20.92%. Out of 21 cross combinations, eleven crosses showed significant positive heterosis while eight showed significant negative heterosis. The negative heterosis is important showing the less number of non-productive tillers plant^{-1}. The highest significant negative heterosis was observed by cross Rataria x Basmati 370 (-14.28%), followed by cross combinations LR2 x Pandan (-13.58%), Mehak x Pandan (-12.49) and Bengalo x Vertin (-11.66%). Under both environments results showed that out of 21 F_1 hybrids, 11 had negative mean heterotic effects while the rest had positive values. The average values for this trait ranged from -10.12 to 10.41. The highest negative mean values (-10.12) was observed on cross LR2 x Pandan, followed by Bengalo x Vertin (-9.97%) and Mehak x Pandan (-7.92). The lowest mean heterotic value was the cross Mehak x Vertin (-0.22%).

CONCLUSION

It can be concluded from the study that heterosis breeding can be utilized for the successful improvement of yield and other related traits, with dominant gene action.

REFERENCES

Amirjani, M. R. 2011. Effect of salinity stress on growth, sugar content, pigments and enzyme activity of rice. Int. J. Bot., (7): 73-81.
Alam, M. F., M. R. Khan, M. Nuruzzaman, S. Parvez, A. M. Swaraz, I. Alam and N. Ahsan. 2004. Genetic basis of heterosis and inbreeding depression in rice (*Oryza sativa* L.). J. ZJU. Sci., 5 (4): 406-411.

Comstock, R. E. and H. F. Robinson. 1952. Estimation of average dominance of genes. In: Heterosis. Ames, Iowa (USA): Iowa State College Press. pp. 494-516.

Davenport, C. B. 1908. Degeneration, albinism and inbreeding. Sci., 28: 454-455.

Jelodar, N. B. 2010. Heterosis and combining ability analysis for yield and related-yield traits in hybrid rice. Int. J. Biology, (2) 2: 222-231.

Jinks, J. L. 1983. Biometrical genetics of heterosis. *In:* Frankel R, editor. Heterosis: reappraisal of Theory and practice. Berlin (Germany): Springer-Verlag.

Kempthorne, O. 1957. An introduction of genetic statistics. John Willey & Sons Inc. New York, USA, pp. 468-473.

Khush, G. S. 2005. What it will take to feed 5.0 billion rice consumers in 2030. Plant Mol. Biol. 59: 1-6.

Roy, B. and A. B. Mandal. 2001. Combining ability of some quantitative traits in rice. Ind. J. Genet., 61 (2): 162-164.

Singh, R. K., V. S. Singh and G. S. Singh. 2000. Aromatic rice. New Delh: Oxford and IBH Publishing Co. Pvt. Ltd.

Singh, N. K. and A. Kumar, 2004. Combining ability analysis to identify suitable parents for heterotic rice hybrid breeding. IRRN, 29 (1): 21-22.

Swain, D. 2005. Rainfed lowland and flood–prone rice a critical review on ecology and management technology for improving the productivity in Asia: Role of Water Sci; in Transboundary River Basin Mangmnt., Thailand.

Tiwari, D. K., P. Pandey, S. P. Giri and J. L. Dwivedi. 2011. Heterosis studies for yield and its components in rice hybrids using cms system. Asian J. of Plant Sci., 10: 29-42.

Vanaja, T. and L. C. Babu. 2004. Heterosis for yield and yield components in rice (*Oryza sativa* L.). J. Trop. Agri., 42 (2): 43-44

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