www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2019; 8(8): 10-15
© 2019 TPI
www.thepharmajournal.com
Received: 06-06-2019
Accepted: 10-07-2019

Anita C Solanke
PhD Scholar, Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Pathik B Patel
Associate Research Scientist, Department of Genetics and Plant Breeding, Main Rice Research Center, Navsari Agricultural University, Navsari, Gujarat, India

Pooja K Patel
PhD Scholar, Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Correspondence
Anita C Solanke
PhD Scholar, Department of Genetics and Plant Breeding, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India

Study of heterosis and inbreeding depression in F_2 generation of aromatic rice

Anita C Solanke, Pathik B Patel and Pooja K Patel

Abstract
A field experiment was conducted during *Kharif*-2017 and *Kharif*-2018 involving seven diversified aromatic and non-aromatic elite lines of rice, four F_1 hybrids and their corresponding F_2 populations to study the inbreeding depression and heterosis for grain yield, yield contributing traits and quality traits. Out of four hybrids studied all the four hybrids exhibited positive and significant heterosis and heterobeltiosis for grain yield per plant. The highest heterosis and heterobeltiosis were exhibited by cross IET-26215 x GNR-2. Out of four hybrids, three hybrids viz., GR-104 x IET-26215, IET-24617 x NWGR-9081 and IET-26214 x GAR-1 showed positive and significant heterosis for productive tillers per plant and 100 seed weight.

Keywords: Aromatic rice, inbreeding depression, heterosis, heterobeltiosis

Introduction
Rice is one of the most important staple food crops of India for more than 2/3rd of the population. The slogan “Rice is life” can be considered appropriate for our country as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households. Rice is one of the world’s largest cereal crop providing the caloric need for millions of people. It is one of the oldest and second most intensively grown cereal crop and ranks third in grain production. Approximately 90 per cent of the world’s rice is grown in the Asian continent and it ranks second in the grain production in India. Rice is placed on position in cereal cultivation around globe and occupies an important position in the economy of India as an export item as well as staple food. India is the largest rice cultivator which accounts for almost 30 percent of the world’s rice area. India is the largest rice growing country, while China is the largest producer of rice.

Aromatic rice is also named as fine rice, scented rice or fragrance rice. Aromatic rices constitute a small but an important sub-group of rice. These are rated best in quality and fetch much higher price than high quality non-aromatic rice in international market. Most of the trade in aromatic rice is from India, Pakistan and Thailand. Although aromatic rices which are popular in world market are long grained, majority of the Indian indigenous aromatic rices are small and medium-grained. A large number of land races of these rices are found in Himalayan Tarai region of the state of UP and Bihar of India, indicating that this region is probably the origin of aromatic rices.

Among quality traits, kernel length, kernel breadth and length/breadth ratio are treated as physical quality traits. Consumers base their concept of quality on grain appearance, size and shape of grain, behavior on cooking, taste, tenderness and flavour of cooked rice. Short and long slender aromatic types normally command high premium in the market. Aromatic rice has got paramount importance in breeding programmes in the countries, which are self sufficient in their production. Preference is given for kernel length, size, shape, appearance and cooking quality characters especially kernel elongation ratio. As such the plant breeders should focus their attention towards the improvement of both Basmati types and aromatic short grain rices for quality and high yield potential. The present investigation was made to identify the promising aromatic rice cross combinations by studying the inbreeding depression, heterosis and residual heterosis.

Material and Methods
The material comprising of seven diversified aromatic and non-aromatic elite lines of rice (GR-104, IET-26215, IET-24617, NWGR-9081, IET-26214, GAR-1 and GNR-2).

The four crosses (GR-104 x IET-26215, IET-24617 x NWGR-9081, IET-26214 x GAR-1 and IET-26215 x GNR-2) obtained by crossing of seven diverse parents during summer 2017 at Main Rice Research Centre, Navsari Agricultural University, Navsari. Selfing of F1s was done in kharif-2017 to get F2s. The evaluation trial was conducted in kharif-2018 at Main Rice Research Centre, Navsari Agricultural University, Navsari. The experimental material consisting of six generations (P_1, P_2, F_1 and F_2) of each of the four crosses were sown during kharif-2018 in compact family block design with three replications. Each plot consisted of one row (10 plants) of parents and F1s and four rows of the F_2 generations of each cross. The recommended package of practices was followed to raise a good crop. Observations were recorded on yield, it's contributing traits and quality traits *viz*., Ten plants from each of the P_1, P_2 and F_1, 40 plants from F_2 and 20 generations were randomly selected per replication and observations were recorded on single plant basis.

The mean values of F_1s and F_2s along with estimates of inbreeding depression and heterosis are mentioned in Table A and Table B. Inbreeding depression in F_2 generation was estimated using the formula (Kempthorne, 1957) [4].

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

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where,

$\overline{(F_1)}$ = Mean performance of the F1 hybrid

$\overline{(MP)}$ = Mean value of the parents (P1 and P2) of a hybrid

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

$$\text{Inbreeding depression (\%)} = \frac{\overline{F_1} - \overline{\overline{F_2}}}{\overline{\overline{F_1}}} \times 100$$

Where,

$\overline{(F_1)}$ = Mean value of the F1 hybrid

$\overline{(F_2)}$ = Mean value of the F2 generation

Results and Discussion

Out of four hybrids studied, all the four hybrids exhibited positive and significant heterosis for grain yield per plant as presented in Table 1 to Table 3. The highest heterosis of 43.10% and heterobeltiosis of 74.40% were exhibited by cross IET-26215 X GNR-2. Higher positive heterosis for grain yield per plant in rice had been reported by several earlier workers *viz*., Anis *et al.* (2016) [2] Borah *et al.* (2017) [3], Rumanti *et al.* (2017) [8]. Close examination of data on inbreeding depression for grain yield indicated that, in general, crosses showing moderate to high heterotic effect also displayed significant inbreeding depression. Further, the values obtained for relative heterosis was generally greater than the values for inbreeding depression. This was anticipated since the estimates of inbreeding depression, theoretically account for only 50 % of the expected change and consequently they will usually be much less than the estimates of heterosis. The results were in agreement with the findings of kheradanam *et al.* (1975) [5] who reported parallel relationship between heterosis and inbreeding depression. For practical utility, it would be worthwhile to compare the performance of hybrids with the best available pureline.

All four hybrids viz., GR-104 x IET-26215, IET-24617 x NWGR-9081, IET-26214 x GAR-1 and IET-26215 x GNR-2 showed positive and significant heterosis for the important components i.e productive tillers per plant and 100 seed weight. From these results, it is apparent that these hybrids have potentiality for improving yield through adjustment of two vital yield components.

The results on inbreeding depression revealed that high inbreeding depression for grain yield was mainly due to the inbreeding depression for its components. Relationship between heterotic response and inbreeding depression (i.e. crosses showing high heterosis also show high inbreeding depression) suggests the importance of non-additive gene in rice.

In case of days to flowering, only cross-III (IET-26214 x GAR-1) was depicted lowest and negative relative heterosis. These results are in conformity with those obtained by Patil *et al.* (2011) [7] and Soni and Sharma (2011) [9].

The heterosis over mid parent and better parents in desired direction with respect to plant height was low to high. However, all hybrids displayed negative effect with moderate to high heterotic values for tallness. Similar results were reported by Patil *et al.* (2011) [7] and Soni and Sharma (2011) [9].

In case of productive tillers per plant, all four crosses depicted significant and positive relative heterosis and three crosses viz., cross-II (IET-24617 x NWGR-9081), cross-III (IET-26214 x GAR-1) and cross-IV (IET-26215 x GNR-2) depicted significant and positive heterobeltiosis. These results are in conformity with those obtained by Anis *et al.* (2016) [2], Borah *et al.* (2017) [3] and Rumanti *et al.* (2017) [8].

The heterosis for grains per panicle was low to moderate for different crosses. Out of four crosses, only cross-III (IET-26214 x GAR-1) was showed highest positive relative heterosis and heterobeltiosis. The results are in conformity with the findings of Venkanna *et al.* (2014) [10], Anis *et al.* (2016) [2], Borah *et al.* (2017) [3] and Rumanti *et al.* (2017) [8].

Relative heterosis and heterobeltiosis for 100 seed weight was positive and significant in three crosses viz., cross-I (GR-104 x IET-26215), cross-II (IET-24617 x NWGR-9081) and cross-III (IET-26214 x GAR-1). Thus the trait seems to be the control of dominance effect. Out of four only one cross exhibited the positive and significant heterobeltiosis for this trait, which was desirable. Similar results were reported by Venkanna *et al.* (2014) [10], Anis *et al.* (2016) [2], Borah *et al.* (2017) [3], Rumanti *et al.* (2017) [8].

For kernel length and kernel L/B ratio, only one cross i.e., GR-104 x IET-26215 had positive and highly significant relative heterosis. This cross also showed positive and highly significant heterobeltiosis for kernel length. The remaining three crosses exhibited negative and significant heterobeltiosis for kernel length. Thus, the trait seems to be the control of dominance effect. Similar results were reported by Venkanna *et al.* (2014) [10].

Negative direction of heterosis for kernel breadth was considered to be desirable. For kernel breadth, only one cross GR-104 x IET-26215 had negative and significant relative heterosis and cross IET-26214 x GNR-2 had negative and significant heterobeltiosis. Similar results were reported by Venkanna *et al.* (2014) [10].

For straw yield per plant, only two crosses GR-104 x IET-

26215 and cross IET-26214 x GAR-1 had positive and significant relative heterosis and the crosses GR-104 x IET-26215, IET-26214 x GAR-1 and IET-26214 x GNR-2 exhibited positive and significant heterobeltiosis. These results are in agreement with those obtained by Rumanti *et al*. (2017) [8].

For harvest index, only one cross IET-26214 x GNR-2 had positive and highly significant relative heterosis and heterobeltiosis. These results are in agreement with those obtained by Borah *et al.* (2017) [3], Rumanti *et al.* (2017) [8].

Out of four crosses, two crosses IET-24617 x NWGR-9081 and IET-26214 x GNR-2 exhibited the positive and significant relative heterosis and heterobeltiosis for protein content. These results are in accordance with the findings of Adilakshmi and Reddy (2011) [1], Patil *et al.* (2011) [7] and Nagesh *et al.* (2012) [6]. For amylose content all four crosses depicted negatively significant relative heterosis and heterobeltiosis. The heterosis for milling (%) was low for all crosses. All the crosses exhibited the positive and highly significant heterosis except cross IET-26214 x GAR-1 and all crosses exhibited the positive and highly significant heterobeltiosis for this trait. Soni and Sharma (2011) [9] were observed similar results. The heterosis for hulling (%) was low for all crosses. Two crosses GR-104 x IET-26215 and IET-26214 x GAR-1 exhibited the positive relative heterosis and cross GR-104 x IET-26215 positive significant heterobeltiosis for this trait. All the crosses exhibited the positive and highly significant relative heterosis and heterobeltiosis for head rice recovery (%). Soni and Sharma (2011) [9] were observed similar results.

Out of four crosses, only two crosses GR-104 x IET-26215 and IET-24617 x NWGR-9081 exhibited significant inbreeding depression in respect of grain yield per plant. However, GR-104 x IET-26215 expressed significant inbreeding depression for grains per panicle, 100 seed weight, kernel length, kernel breadth, kernel L/B ratio, straw yield per plant, amylose content, milling (%) and head rice recovery (%), whereas IET-24617 x NWGR-9081 expressed significant inbreeding depression for productive tiller per plant, grains per panicle, 100 seed weight, kernel length, kernel breadth, harvest index, protein content, milling (%), hulling (%) and head rice recovery (%). Out of four crosses, all crosses showed significant inbreeding depression for milling (%) and head rice recovery (%). IET-26214 x GAR-1 showed significant inbreeding depression for productive tiller per plant, grains per panicle, 100 seed weight, kernel breadth, protein content, amylose content, milling (%), and head rice recovery (%).While cross IET-26214 x GNR-2 expressed significant inbreeding depression for productive tiller per plant, grains per panicle, kernel length, kernel breadth, kernel L/B ratio, straw yield per plant, amylose content, milling (%) hulling (%) and head rice recovery (%). The results are matching with the results of Adilakshmi and Reddy (2011) [1] and Venkanna *et al.* (2014) [10].

Significant negative inbreeding depression in respect of days to flowering was recorded in cross (IET-26214 x GNR-2) indicating that F2s were late flowering than their F1s. For plant height, all crosses showed significantly negative inbreeding depression.

In general, most of the crosses, those who exhibited positive inbreeding depression for yield components like productive tillers per plant, 100 seed weight and grains per panicle also exhibited positive inbreeding depression for grain yield per plant, which revealed that the expression of heterosis and inbreeding depression for grain yield per plant was dependent on its attributing traits.

Significant positive heterosis for grain yield per plant and its related traits followed by significant inbreeding depression indicated major role of non-additive gene actions in the inheritance of grain yield per plant and its attributes. Crosses with higher and positive estimates of heterosis for grain yield and its related traits exhibited negative heterosis for nutritional quality traits like protein and amylose content suggested population improvement approach for improvement of these characters along with high grain yield and earliness. These findings are similar to those of Adilakshmi and Reddy (2011) [1], Nagesh *et al*. (2012) [6] and Venkanna *et al.* (2014) [10].

Table A: Mean values of parents, F1 and F2 generation for days to flowering, Plant height, Productive tillers per plant, Panicle length, grains per panicle 100 seed weight, kernel length, kernel breadth and kernel L/B ratio

Cross	Generations			
	P_1	P_2	F_1	F_2
Days to flowering				
I	92.46	89.93	92.13	86.15
II	90.40	88.20	89.53	85.47
III	93.26	92.60	92.73	91.73
IV	91.86	90.98	91.59	94.60
Plant height (cm)				
I	101.22	90.98	95.32	110.90
II	102.41	90.23	94.77	112.19
III	122.93	104.51	101.57	113.99
IV	98.25	92.11	100.46	115.36
Productive tillers per plant				
I	9.87	9.47	11.40	12.57
II	12.87	11.67	15.13	12.02
III	11.20	12.47	14.27	11.37
IV	10.73	12.20	15.07	11.50
Panicle length (cm)				
I	20.48	20.86	21.44	21.32
II	21.18	23.19	22.21	20.43
III	21.72	19.99	22.40	19.95
IV	22.11	21.36	21.44	20.94
Grains per panicle				
I	113.76	117.92	115.90	143.58
II	121.94	118.69	111.56	128.21
III	110.12	116.30	118.13	130.91
IV	112.38	123.94	114.23	140.62
100 seed weight (g)				
I	2.80	2.65	3.00	2.78
II	2.85	2.63	3.18	2.82
III	2.16	2.50	2.47	2.76
IV	2.05	2.08	2.17	2.32
Kernel length (cm)				
I	6.15	6.04	6.69	6.46
II	6.08	6.69	6.11	6.34
III	6.02	6.56	6.14	6.27
IV	6.39	6.46	6.18	6.51
Kernel breadth (cm)				
I	1.75	1.97	1.72	2.19
II	1.66	1.85	1.76	2.20
III	1.67	2.00	1.83	2.22
IV	1.69	1.90	1.73	2.23
Kernel L/B ratio				
I	3.58	3.14	3.90	3.22
II	3.69	3.65	3.49	3.19
III	3.62	3.36	3.43	3.16
IV	3.79	3.43	3.58	3.20

Where

Cross-I (GR-104 x IET-26215), cross-II (IET-24617 x NWGR-9081) and cross-III (IET-26214 x GAR-1)

Table B: Mean values of parents, F1 and F2 generation for grain yield per plant, straw yield per plant, harvest index, protein content, amylose content, milling (%), hulling (%) and head rice recovery (%)

Cross	Generations			
	P_1	P_2	F_1	F_2
Grain yield per plant				
I	20.95	26.77	29.74	25.05
II	28.15	22.97	32.05	26.50
III	20.28	24.17	27.44	28.76
IV	23.42	16.29	28.42	25.98
Straw yield per plant (g)				
I	43.27	36.49	44.36	33.21
II	26.57	28.87	28.42	28.98
III	26.81	34.38	33.87	31.61
IV	28.21	34.61	34.14	29.72
Harvest index (%)				
I	32.64	42.07	40.23	43.25
II	52.76	44.94	52.62	47.54
III	43.70	40.89	44.44	47.11
IV	45.39	32.02	45.35	46.54
Protein content (%)				
I	6.00	5.42	5.23	5.12
II	6.91	7.66	7.98	7.95
III	8.01	8.21	6.90	8.06
IV	7.15	8.08	8.21	8.14
Amylose content (%)				
I	24.21	24.71	21.12	23.80
II	24.19	24.27	22.53	23.08
III	23.92	23.88	22.58	24.04
IV	23.12	24.56	21.73	23.71
Milling (%)				
I	51.37	58.68	68.29	55.94
II	59.31	55.95	73.40	59.31
III	63.26	55.71	64.54	58.66
IV	37.15	52.67	61.84	58.12
Hulling (%)				
I	61.52	74.17	71.68	73.97
II	64.72	71.17	73.47	78.37
III	72.66	66.99	68.46	65.51
IV	65.94	72.59	73.73	79.05
Head rice recovery (%)				
I	35.66	52.37	61.84	57.17
II	35.68	55.10	64.17	59.00
III	41.64	45.68	57.80	52.38
IV	36.84	50.46	54.97	56.54

Where
Cross-I (GR-104 x IET-26215), cross-II (IET-24617 x NWGR-9081) and cross-III (IET-26214 x GAR-1)

Table 1: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for days to flowering, plant height, productive tillers per plant, panicle length, grains per panicle and 100 seed weight in four crosses of rice

Estimates (%)	Days to flowering	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Grains per panicle	100 seed weight (g)
Cross-I (GR-104 x IET-26215)						
RH %	1.02	-0.81	17.93*	3.70	0.05	9.72**
HB %	-0.36	4.77	20.42	4.67	1.88	13.08**
ID %	6.49**	-16.35**	-10.23	0.53	-23.88**	7.10**
Cross-II (IET-24617 x NWGR-9081)						
RH %	0.26	-1.61	23.37**	0.09	-7.28	16.02**
HB %	-0.95	5.04	29.71**	-4.86	-8.52	21.09**
ID %	4.54**	-18.38**	20.59*	7.98	-14.92**	11.33**
Cross-III (IET-26214 x GAR-1)						
RH %	-0.21	-10.68	20.56*	7.39	4.35**	5.82**
HB %	0.56	-17.36*	27.38**	12.05	7.27	14.19**

ID %	1.08	-12.22*	20.33**	10.92	-10.82*	-12.03**
Cross-IV (IET-26215 x GNR-2)						
RH %	0.19	5.55	31.40**	-1.37	-3.33	5.19
HB %	-0.29	9.08	40.37**	0.34	1.64	5.86
ID %	-3.28*	-14.83*	23.67**	2.30	-23.10	-7.15

* and **, significant at 5% and 1%, respectively

Table 2: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for kernel length, kernel breadth, kernel L/B ratio, grain yield per plant, straw yield per plant and harvest index in four crosses of rice

Estimates (%)	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Grain yield per plant (g)	Straw yield per plant (g)	Harvest Index (%)
Cross-I (GR-104 x IET-26215)						
RH %	9.78**	-7.51*	16.06**	24.65**	11.23*	7.70
HB %	10.82**	-1.71	23.94**	41.95**	21.59*	23.26*
ID %	3.44*	-27.23**	17.43**	15.78**	25.13**	-7.49
Cross-II (IET-24617 x NWGR-9081)						
RH %	-4.30*	0.23	-5.01	25.39**	2.51	7.72
HB %	0.49	-4.68	-5.50	39.53**	6.93	17.08
ID %	-3.77*	-24.72**	8.63	17.32**	-1.97	9.66*
Cross-III (IET-26214 x GAR-1)						
RH %	-2.45	-0.47	-1.72	23.49**	10.69**	5.07
HB %	1.93	-8.66*	2.28	35.34**	26.30*	8.68
ID %	-2.15	-21.45**	7.78	-4.78	6.69	-6.00
Cross-IV (IET-26215 x GNR-2)						
RH %	-3.95*	-3.67**	-0.72**	43.10**	8.68	17.14**
HB %	-4.47	-9.10**	4.47	74.40**	20.98*	41.59**
ID %	-5.39**	-28.52**	10.73**	8.59	12.93**	-2.63

* and **, significant at 5% and 1%, respectively

Table 3: Estimates of relative heterosis (RH %), heterobeltiosis (HB %) and inbreeding depression (ID %) for protein content, amylose content, milling, hulling and head rice recovery in four crosses of rice

Estimates (%)	Protein content (%)	Amylose content (%)	Milling (%)	Hulling (%)	Head rice recovery (%)
Cross-I (GR-104 x IET-26215)					
RH %	-8.35*	-13.65**	24.10**	5.65	40.49**
HB %	-12.77**	-14.52**	32.93**	16.51*	73.40**
ID %	2.16	-12.64**	18.08**	-3.19	7.55**
Cross-II (IET-24617 x NWGR-9081)					
RH %	12.44**	-7.03**	27.36**	8.13	41.37**
HB %	15.54**	-7.17*	31.18**	13.52	79.84**
ID %	7.38**	-2.45	19.19**	-6.67*	8.05*
Cross-III (IET-26214 x GAR-1)					
RH %	-14.93**	-5.52*	8.49**	-1.95	32.39**
HB %	-15.96**	-5.60*	15.85*	2.20	26.54**
ID %	-16.79**	-6.46**	8.73**	4.31	9.38**
Cross-IV (IET-26215 x GNR-2)					
RH %	7.75*	-8.85**	37.7.**	6.46	25.94**
HB %	14.72**	-11.53**	66.46**	11.83	49.21**
ID %	0.85	-9.10**	6.02*	-7.21*	-2.86

* and **, significant at 5% and 1%, respectively

Conclusion

Finally the two cross combinations, GR-104 x IET-26215, IET-24617 x NWGR-9081 and IET-26214 x GAR-1 identified as better crosses for productive tillers per plant and 100 seed weight, were identified as better crosses for further advancement to develop pure lines with high yield and quality. The significant relative heterosis or heterobeltiosis in desired direction were observed for productive tillers per plant, 100 seed weight, kernel breadth, kernel L/B ratio, straw yield per plant, harvest index, protein content, milling (%) and head rice recovery (%) there by heterosis breeding would be more practical approach for higher grain yield in rice. Though the trait days to flowering had negative estimates in those crosses that showed significantly positive relative heterosis and/or heterobeltiosis for grain yield, revealed the negative association among grain yield and its component traits. For improvement of such traits along with high grain yield, population improvement methods such as reciprocal recurrent selection would be beneficial. But it was too much difficult in crop like rice. The crosses which depicted positively significant heterosis for protein content had less grain yield, the quality of rice could be improved by heterosis breeding but it might resulted into lower yields therefore population improvement is a good option to improve all these traits.

References

1. Adilakshmi D, Reddy PR. Heterosis and inbreeding depression for grain quality traits in rice (*Oryza sativa* L.). Research on Crops, 2011; 12(2):489-492.
2. Anis G, El-Sabagh A, El-badry A, Barutcular C. Improving grain yield of rice (*Oryza sativa* L.) by estimation of heterosis, genetic components and

correlation coefficient. Int. J. Current Res. 2016; 8(1):25080-25085.
3. Borah P, Sharma D, Hazarika GN. Magnitude of heterosis for yield and its components in hybrid rice (*Oryza sativa* L.). International Journal of Agricultural Science and Research. 2017; **7**(2):2250-2257.
4. Kempthorne D. An introduction to genetic statistics. John Wiley and Sons Inc, New York, U.S.A, 1957.
5. Kheradanam M, Bassiri A, Nikhejad M. Heterosis, inbreeding depression and reciprocal effects for yield and some yield components in a cowpea cross. Crop sci., 1975; 15(5):689-691.
6. Nagesh V, Ravindrababu G, Reddy T. Heterosis studies for grain iron and zinc content in rice. Annals Biol. Res. 2012; 3(1):179-184.
7. Patil PP, Vashi RD, Shinde DA, Lodam VA. Nature and magnitude of heterosis for grain yield and yield attributing traits in Rice (*Oryza sativa* L.) Plant Archives. 2011; 11(1):423-427.
8. Rumanti IA, Purwoko BS, Dewi IS, Aswidinnoor H, Widyastuti Y. Combining ability for yield and agronomic traits in hybrid rice derived from wild abortive, gambiaca and kalinga cytoplasmic male sterile lines. Sabrao J. 2017; 49(1):69-76.
9. Soni S, Sharma D. Studies on heterosis for grain yield and its component traits for developing new plant type hybrids in rice (*Oryza sativa* L.). Elec. J. of Plant Breed. 2011; 2(4):543-548.
10. Venkanna V, Raju CS, Lingaiah N, Rao VT. Studies on heterosis and inbreeding depression for grain yield and grain quality traits in rice (*Oryza sativa* L.). Int. J. Sci. Envt. and Technol. 2014; 3(3):910-916.