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Combining ability analysis in rice (*Oryza sativa* L.)

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Abstract

Combining ability in rice was carried out by using ten parents, their forty five hybrids. The magnitudes of mean sum of square due to *sca* were greater than the *gca* for most of the traits indicating the predominance of non-additive type of gene action. The estimates of gca effects of parents indicated that there were four parents NAUR-1, GNR-3, NVSR-303-6 and GAR-13 to be good general combiners for grain yield and some of yield contributing characters. The best specific crosses for grain yield per plant involved the combinations of either poor x poor, good x poor and poor x good effects.

Key words: Combining ability, gene action, Diallel, Zn and Fe Content.

Introduction

Knowledge about combining ability would help in choosing parents for effective improvement in segregating population and at the same time elucidates the nature and magnitude of various types of gene action involved in quantitative traits. Hence, a study on combining ability of ten parents was undertaken.

Materials and Methods

The experimental material consisted of 56 genotypes including 10 parents, 1 Check and their 45 crosses. The crossing was done by using diallel fashion. The flowers were hand emasculated and pollinated at the Main Rice Research Centre, Navsari Agricultural University, Navsari during *summer* 2015. Three complete sets of 56 genotypes were evaluated during *kharif* 2015 by using randomized block design replicated three times at Main Rice Research Center, Navsari Agricultural University, Navsari. The parents and F_1's were represented by single row plot of 10 plants placed at 20 cm x 10 cm. All the agronomical practices and plant protection measures were followed as and when required to raise a healthy crop of rice. The mean values of 56 entries were subjected to combining ability analysis by employing method-II, model-1 (fixed effect) of Griffing (1956[b]).

Result and Discussion

The analysis of variance for combining ability showed that gca and sca variances were highly significant for all the characters indicating that both additive as well as non additive types of gene action were involved in the inheritance of these traits under the study (Table 1). The magnitudes of mean sum of square due to sca were greater than the gca for most of the traits indicating the predominance of non-additive type of gene action. This was supported by low magnitude of σ^2gca/ σ^2sca ratios. The findings are in confirmation with reports of Salim *et al.* (2010), Patil *et al.* (2011), Padmavathi *et al.* (2012), Sanghera and Hussain (2013), Adilakshmi and Upendra (2014) and Tiwari and Jatav (2014) in rice.

Nature and magnitude of combining ability effects provide guidelines in identifying the better parents and their utilization. The summary of general combining ability effects of the parents (Table 2) revealed that among parents, NAUR-1, GNR-3, NVSR-303-6 and GAR-13 were recognized as good general combiners for grain yield per plant and quality traits. NAUR-1 was good general combiner for productive tiller per plant, panicle length, grains per panicle and straw yield per plant. GNR-3 was good general combiner for productive tiller per plant, grains per panicle, test weight and iron content. NVSR-303-6 was found good general combiner for straw yield per plant, protein content and iron content. GAR-13 was found good general combiner for traits like grains per panicle and protein.

In case of specific combining ability effects, none of the one way hybrids excluding reciprocal crosses exhibited favorable sca effects for all the characters. In the present

Table 1: Analysis of variances for combining ability for the yield and yield contributing traits in rice

Source of Variations	df	Days to 50% flowering	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Grains per panicle	Grain yield per plant (g)
GCA	9	24.98*	102.35**	3.37**	10.12**	4145.20**	156.90**
SCA	45	27.53**	74.09**	1.63**	4.88**	3023.34**	59.62**
Error	108	10.74	23.12	0.26	0.68	75.53	2.08
σ^2 GCA		1.19	6.60	0.26	0.79	339.14	12.90
σ^2 SCA		16.79	50.96	1.37	4.20	2947.81	57.54
σ^2gca/σ^2sca		0.07	0.13	0.19	0.19	0.11	0.22

Source of Variations	df	Straw yield per plant (g)	Test weight (g)	Protein content (%)	Iron content (ppm)	Zinc content (ppm)	Amylose content (%)
GCA	9	153.40**	21.58**	1.08**	208.44**	15.44**	0.77**
SCA	45	115.89**	16.22**	1.09**	84.75**	17.41**	1.50**
Error	108	3.68	0.90	0.02	0.33	0.16	0.26
σ^2 GCA		12.48	1.72	0.09	17.34	1.27	0.04
σ^2 SCA		112.21	15.32	1.07	84.42	17.25	1.24
σ^2gca/σ^2sca		0.111	0.11	0.08	0.20	0.07	0.03

* Significant at 5 % and **Significant at 1 %

Table 2: Estimates of general combining ability effects of parents for different characters in rice.

Parents	Days to 50% flowering	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Grains per panicle	Grain yield per plant (g)
NAUR-1	0.35	-1.01	0.88**	2.04**	10.91**	4.26**
GNR-3	-1.18	-0.19	0.92**	-0.56*	22.49**	6.58**
IET-24762	3.38**	5.09**	-0.38**	1.07**	10.33**	-2.66**
GAR-13	-0.22	1.86	-0.33*	0.05	23.28**	2.49**
IET-24765	-1.09	-1.47	0.01	-0.78**	-25.99**	-2.06**
IET-24767	0.27	-2.55	0.01	-0.13	-19.10**	-1.57**
IET-24772	1.26	-5.54**	-0.03	-0.31	1.97	-3.56**
Gurjari	-1.12	1.34	-0.18	-0.54*	-27.66**	-1.29**
NVSR-303-6	-0.45	0.19	-0.77**	0.13	-1.17	2.03**
IET-23825	-1.19	2.28	-0.13	-0.97**	4.93*	-4.22**
SE (gj)	0.89	1.317	0.14	0.22	2.38	0.39
SE ((gi-gj)	1.38	1.96	0.21	0.34	3.55	0.58

Parents	Straw yield per plant (g)	Test weight (g)	Protein content (%)	Iron content (ppm)	Zinc content (ppm)	Amylose content (%)
NAUR-1	6.24**	0.36	-0.63**	-1.09**	-1.16**	0.20
GNR-3	-0.14	2.47**	0.01	1.64**	-1.04**	-0.04
IET-24762	-1.56**	-1.57**	-0.36**	2.34**	2.01**	0.48**
GAR-13	-2.20 **	-1.06**	0.26**	-7.26**	-1.74**	0.26
IET-24765	3.75**	-0.90**	0.18**	1.58**	-0.43**	-0.15
IET-24767	-3.57**	-0.88**	0.14**	-1.14**	1.11**	-0.38**
IET-24772	0.84	-0.80**	-0.16**	1.33**	0.07	-0.24
Gurjari	0.46	1.71**	0.12**	-4.01**	0.71**	0.01
NVSR-303-6	2.21**	-0.36	0.13**	8.34**	0.13	-0.04
IET-23825	-6.02**	1.04**	0.32**	-1.73**	0.34**	-0.10
SE (gj)	0.52	0.26	0.04	0.15	0.11	0.14
SE ((gi-gj)	0.78	0.38	0.06	0.23	0.16	0.20

* Significant at 5 % and **Significant at 1 %

study positive specific combining ability is desirable for all the characters except days to 50% flowering and plant height. Significant specific combining ability in favorable direction was observed in variable crosses, for days to 50% flowering (13), plant height (9), productive tillers per plant (16), panicle length (11), grains per panicle (30), grain yield per plant (18), straw yield per plant (18), test weight (22), protein content (24), iron content (19), zinc content (16) and amylose content (12) . The results are in agreement with findings of Patil *et al.* (2011), Varpe *et al.* (2011), Chandirakala *et al.* (2012). High sca effects denote undoubtedly a high heterotic response, but this may be due to poor performance of the parents in comparison with their hybrids. With the same amount of heterotic effect, the sca effect may be less, where the mean performance of the parents was higher but this estimate may also be biased (Ziauddin *et al*. 1979). This suggested that the selection of cross combination based on heterotic response would be more realistic rather than on the basis of sca effects. Adilakshmi and Upendra (2014), Tiwari and Jatav (2014), Nagaraju *et al.* (2015) and Patel *et al.* (2015) also reported similar results.

For days to 50% flowering, the gca and sca effects of the parents and hybrid in negative direction were considered to be desirable as the earliness is preferred over the late varieties. The gca effects of the parents varied from -1.19 (IET-23825) to 3.38 (IET-24762). Six parents *viz.*, IET-23825, GNR-3, Gurjari, IET-24765, NVSR-303-6 and GAR-13 showed negative gca effect for this trait indicating good general combiner for earliness. Estimates of specific combining ability effect ranged from -12.16 for cross combination (GNR-3 x Gurjari) to 10.20 for cross combination (IET-24762 x NVSR-303-6). Total 13 crosses showed significant sca effects for this trait but only five crosses showed significant negative sca effects in desirable direction. The cross combination GNR-3 x Gurjari showed minimum desirable sca effect (-12.16) followed by GNR-3 x NVSR-303-6 and GAR-13 x IET-24772 for days to 50% flowering.

For plant height the gca effects of the parents varied from IET-24772 (-5.54) to IET-24762 (5.09). Five parents *viz.*, IET-24772, IET-24767, IET-24765, NAUR-1 and GNR-3 showed negative gca effect for plant height indicating good general combiner for short plant stature, while the estimates of sca effect ranged from -22.44 for the cross (GNR-3 x IET-23825) to 13.35 for the cross (IET-24762 x GAR-13). Nine crosses showed significant negative desirable sca effects. The cross combination GNR-3 x IET-23825 followed by IET-24765 x IET-23825 and NAUR-1 x IET-24762 depicted significant negative desirable sca effect for plant height.

The estimates of gca effect for productive tillers per plant was found to be significant for the five parents, of which two exhibited significant positive effects in desirable direction (Table 2). The parents, GNR-3 (0.92) showed the highest significant positive gca effect followed by NAUR-1 (0.88) and were found to be good general combiners for more tiller per plant. With regards to sca effects of the crosses, 16 crosses had positive sca effects, and were classified as better specific cross combinations for more number of productive tillers per plant. The sca effect ranged from -1.04 for the cross combination (IET-24767 x IET-23825) to 2.10 (IET-24762 x Gurjari) (Table 3). Cross combination IET-24762 x Gurjari (2.10) exhibited the maximum positive sca effect followed by the cross combination IET-24767 x NVSR-303-6 (1.85) and GNR-3 x IET-24772 (1.72).

For the trait panicle length the gca effect was found to be significant for the six parents, of which two parents namely NAUR-1 (2.04) and IET-24762 (1.07) showed gca effect in positive direction and were classified as better general combiner for longer panicle length. While, the sca effects of hybrids were concerned, 11 hybrids had positive and significant estimates and were categorized as better specific cross combinations for longer panicles. The sca effect ranged from -2.99 (NAUR-1 x GNR-3) to 4.25 (Gurjari x IET-23825). The top hybrids, which exhibited high positive sca effect were Gurjari x IET-23825 (4.25), IET-24765 x IET-23825 (3.29), IET-24762 x IET-23825 (3.11) and IET-24767 x IET-23825 (3.11).

Higher number of grains per panicle is a desirable feature in rice since it is related to higher grain yield. Therefore, the parents and hybrids with positive gca and sca effects, respectively are preferable for this trait. The estimates of gca effect of parents showed that eight parents showed significant gca effects out of these significant parents only five parents have significant positive gca effects, parents GAR-13 (23.28) and GNR-3 (22.49) showed the highest significant positive gca effect followed by, NAUR-1 (10.91), IET-24762 (10.33) and IET-23825 (4.94) and were found to be good general combiners for higher number of grains per panicle (Table 2). In case of sca effects of crosses, 30 crosses exhibited significant and positive desirable sca effects and were grouped as better specific cross combinations for more number of grains per panicle. The sca effect ranged from-81.19 (IET-24762 x Gurjari) to 66.32 (IET-24762 x IET-24765) (Table 3). The cross

Table 3: Estimation of specific combining ability effect for days to 50% flowering, plant height and productive tillers per plant, panicle length, grains per panicle and grain yield per plant in rice.

Crosses	Days to 50% flowering	Plant height (cm)	Productive tillers per plant	Panicle length (cm)	Grains per panicle	Grain yield per plant (g)
NAUR-1xGNR-3	-2.53	1.17	0.14	-2.99**	-1.07	-12.23**
NAUR-1xIET 24762	-2.85	-13.90**	0.31	-0.09	-45.84**	3.30*
NAUR-1xGAR-13	0.71	-11.80**	-0.39	1.32*	-73.19**	4.65**
NAUR-1xIET-24765	0.03	9.71*	0.32	-2.91**	-1.24	9.82**
NAUR-1xIET-24767	-0.88	-11.66**	1.06*	0.77	43.12**	1.25
NAUR-1xIET-24772	6.48*	12.92**	0.36	2.68**	40.71**	6.86**
NAUR-1xGurjari	1.78	-2.76	-0.55	-1.02	40.61**	-0.33
NAUR-1xNVSR-303-6	-1.64	5.92	1.23**	2.11**	41.39**	-3.24*
NAUR-1xIET-23825	-0.02	7.50	0.06	-1.32*	14.22*	0.95
GNR-3xIET-24762	-4.53	4.34	1.20*	-0.69	25.40**	3.57**
GNR-3xGAR-13	3.08	1.97	-0.10	2.85**	-31.72**	12.01**
GNR-3xIET-24765	3.50	9.49*	0.82*	0.55	53.42**	6.86**
GNR-3xIET-24767	6.15*	-1.41	0.16	-0.22	27.67**	-7.51**
GNR-3xIET-24772	4.25	8.63*	1.72**	-0.37	17.20*	-0.48
GNR-3xGurjari	-12.16**	4.08	0.20	0.97	55.16**	8.96**
GNR-3xNVSR-303-6	-10.90**	5.30	1.12**	-0.75	9.47	1.88
GNR-3xIET-23825	2.84	-22.44**	-0.17	1.14	23.84**	12.75**
IET-24762xGAR-13	-4.63	13.35**	-0.40	-2.10**	14.84*	5.44**
IET-24762xIET-24765	-2.62	0.34	0.85*	-0.94	66.32**	15.61**
IET-24762xIET-24767	10.03**	0.49	0.12	-1.98**	61.16**	1.24
IET-24762xIET-24772	8.74**	-7.38**	0.29	-1.93*	16.03*	0.20
IET-24762xGurjari	-0.32	-5.13	2.10**	-0.31	-81.19**	-12.80**
IET-24762xNVSR-303-6	10.20**	-4.04	-0.43	-0.51	49.90**	-15.26**
IET-24762xIET-23825	-4.81	-0.59	0.26	3.11**	41.39**	-2.73*
GAR-13xIET-24765	-3.00	2.71	-0.85*	-0.59	59.97**	-5.37**
GAR-13xIET-24767	2.37	10.53*	0.88*	-1.57*	37.74**	-1.45
GAR-13xIET-24772	-7.89**	-11.28*	1.11*	2.67**	38.27**	10.24**
GAR-13xGurjari	-0.02	-1.29	-0.13	0.83	34.43**	-6.55**
GAR-13xNVSR-303-6	7.10*	-3.14	0.78*	-0.43	49.75**	2.54*
GAR-13xIET-23825	-1.29	-12.23**	1.35**	-0.01	29.17**	-2.03
IET-24765xIET-24767	4.58	4.52	1.14*	0.32	-6.31	-8.98**
IET-24765xIET-24772	4.27	-8.02*	-0.42	0.97	-35.97**	2.09
IET-24765xGurjari	1.18	1.62	0.45	0.92	-20.97**	1.92
IET-24765xNVSR-303-6	-1.62	-3.89	0.44	1.92*	-21.43**	-0.05
IET-24765xIET-23825	-1.28	-15.24**	1.08*	3.29**	43.85**	-3.51**
IET-24767xIET-24772	-7.76**	-3.54	0.78	-1.87*	-19.27*	2.07
IET-24767xGURJARI	1.94	-2.15	0.06	1.01	-11.74	2.54*
IET-24767xNVSR-303-6	-6.45*	-9.00*	1.85**	-0.25	-47.26**	8.62**
IET-24767xIET-23825	-2.32	6.64	-1.04*	3.11**	-11.10	-2.80*
IET-24772xGurjari	2.19	4.23	0.49	0.26	14.82*	-3.18*
IET-24772xNVSR-303-6	-4.37	-4.08	-0.78	-1.60*	39.84**	-9.95**
IET-24772xIET-23825	-1.33	-1.30	0.78	2.16**	43.96**	-4.79**
GurjarixNVSR-303-6	-0.43	2.96	0.09	-1.51*	61.38**	12.49**
GurjarixIET-23825	5.12*	-5.85	1.32**	4.25**	24.14**	5.80**
NVSR-303-6xIET-23825	7.05*	10.83*	0.05	-0.74	32.29**	5.08**
SE (Sij)	3.02	4.43	0.47	0.76	8.00	1.33
SE (Sij- Skl)	4.23	6.21	0.66	1.06	11.21	1.86

* Significant at 5 % and **Significant at 1 %

combinations (IET-24762 x IET-24765) 66.32 exhibited the maximum positive sca effect followed by (Gurjari x NVSR-303-6) 61.38 and (IET-24762 x IET-24767) 61.16 (Table 3).

The estimates of gca effect for the grain yield per plant of parents was ranged from -4.218 for IET-23825 to 6.58 for GNR-3. The parents, GNR-3 exhibited maximum significant gca effect in positive direction (6.58), followed by NAUR-1 (4.26), GAR-13 (2.49) and NVSR-303-6 (2.03) and were considered as good general combiners for higher grain yield per plant (Table 2). Estimates of sca effect ranged from -15.26 (IET-24762 x NVSR-303-6) to 15.61 (IET-24762 x IET-24765). Total 18 hybrids showed significant and positive sca effect (Table 3). The top hybrids showed significant and positive effect were (IET-24762 x IET-24765) 15.61 followed by (GNR-3 x IET-23825) 12.75 and (Gurjari x NVSR-303-6) 12.49 and these were appeared as good specific cross combinations in positive direction for obtaining higher grain yield per plant.

The estimates of gca effect for straw yield of parents was ranged from -6.02 for IET-23825 to 6.24 for NAUR-1. Among the all parents, three parents showed significant positive gca effects, parents NAUR-1 (6.24) had highest gca effects followed by IET-24765 (3.75) and NVSR-303-6 (2.21) and these were considered as good general combiners for obtaining higher straw yield per plant (Table 2). The estimates of sca effect ranged from -22.02 (GNR-3 x IET-23825) to 23.81 (GNR-3 x NVSR-303-6). Total 18 hybrids showed significant and positive sca effect. The hybrids which showed significant and positive effect was (GNR-3 x NVSR-303-6) 23.81 followed by (GNR-3 x IET-24765) 19.66 and (NAUR-1 x IET-24765) 16.80 and were appeared as good specific cross combinations for obtaining higher straw yield per plant (Table 3).

In case of test weight, the estimates of gca effect of parents ranged from -1.57 for the parent IET-24762 to 2.47 for GNR-3. Among the all parents, total three parents GNR-3 (2.47), Gurjari (1.71) and IET-23825 (1.04) showed significant positive gca effect and were considered as to be good general combiners for the development of rice varieties with more test weight. Range of sca effect of hybrids varied from -5.76 for cross combinations (IET-24772 x Gurjari) to 5.95 for the cross combinations (NAUR-1 x IET-24762). Total 22 hybrids showed significant and positive sca effect. The cross combination (IET-24772 x Gurjari) -5.76 was classified as better specific combination for the development of rice varieties with fine grain while cross combination (NAUR-1 x IET-24762) 5.95 was considered as better specific combination for development of variety with coarse grain.

For the protein content the estimates of gca effect of parents ranged from -0.63 for NAUR-1 to 0.32 for IET-23825 (Table 2). Among the all parents, six parents showed significant positive gca effects, parents IET-23825 (0.32) had highest gca effects followed by GAR-13 (0.26) and IET-24765 (0.18) these were considered as good general combiners for high protein content. The estimates of sca effect for protein content was ranged from -2.36 (Gurjari x NVSR-303-6) to 1.37 (NAUR-1 x GAR-13). Total 24 hybrids showed significant and positive sca effect. The top three hybrids which showed significant and positive effect was (NAUR-1 x GAR-13) 1.37 followed by (IET-24762 x IET-24765) 1.27 and (NAUR-1 xIET-24765) 1.22 and were appeared as good specific cross combination for obtaining higher protein content.

The range of gca effects for the iron content of parents were -4.01 for the parent Gurjari to 8.34 for the parent NVSR-303-6. Total five parents have significant positive gca effects were NVSR-303-6 (8.34), IET-24762 (2.34), GNR-3 (1.66), IET-24765 (1.58) and IET-24772 (1.33) and were considered as good general combiners for the development of bio fortified rice varieties. The values of sca effect varied from -14.72 for the cross (NAUR-1 x NVSR-303-6) to 15.32 for the cross (NAUR-1 x GNR-3). 19 hybrids showed positive and significant sca effect and were came out as better specific cross combinations for higher iron content. The top ranking three crosses with high sca effect were (NAUR-1 x GNR-3) 15.32 followed by cross (IET-24762 x IET-24767) 12.91 and (GNR-3 x IET-24765) 12.67.

The gca effect for the zinc content was found to be significant for eight parents but only four had significant positive effect. The range of gca effects for parents was -1.74 for GAR-13 to 2.01 for IET-24762. The parents IET-24762 (2.01), IET-24767 (1.11) Gurjari (0.71) and IET-23825 (0.34) had significant positive gca effects, these were considered as good general combiner for higher zinc content, while the estimates of sca effect for this trait was ranged from -5.80 (Gurjari x IET-23825) to 10.03 (NVSR-303-6 x IET-23825). 16 hybrids showed positive and significant sca effect and were came out as better specific combinations for higher zinc content. The hybrids which showed significant and positive effect was NVSR-303-6 x IET-23825 (10.03) followed by GAR-13 x Gurjari

(8.89) and GNR-3 x IET-24762 (8.18) were appeared as good specific cross combinations for obtaining higher zinc content.

Out of ten parents, only one parents exhibited significant positive gca effects for amylose content. The variation for the gca effects was from -0.38 (IET-24767) to 0.48 (IET-24762). The parents IET-24762 (0.48) are considered as the good general combiner for more amylose content. The values of sca effect varied from -2.75 for the cross (NAUR-1 x GNR-3) to 2.49 for the cross (GNR-3 x NVSR-303-6). 12 hybrids showed positive and significant sca effect and were categorized as better specific combinations for higher amylose content. The top ranking three crosses with high sca effect were (GNR-3 x NVSR-303-6) 2.49 followed by cross (NAUR-1 x IET-23825) 1.97 and (GNR-3 x IET-24767) 1.82.

From the foregoing discussion, it can be concluded that the crosses having best specific combination for grain yield per plant would have obtained either through poor x poor, poor x good and good x poor parental combinations. A character with preponderance of additive genetic variance would lead to the improvement of a character through selection in segregating generations. The presence and magnitude of various components of non-additive gene effect could be justified with heterosis breeding and in the present investigation yield and yield attributing traits were under the control of non-additive type of gene action hence, for the further improvement in yield and quality traits heterosis breeding may be rewarding. Further the parents NAUR-1, GNR-3, NVSR-303-6 and GAR-13 had good general combining ability for the grain yield and some of the yield attributing traits so, these parents may given due consideration for the further breeding programme. The crosses GNR-3 x GAR-13, GNR-3 x IET-23825, GNR-3 x Gurjari, Gurjari x NVSR-303-6 and NAUR-1 x IET-24765 could be exploited fully in future rice breeding programme by adopting heterosis breeding.

Table 4: Estimation of specific combining ability effect for straw yield per plant, test weight and protein content, iron content, zinc content and amylose content in rice.

Crosses	Straw yield per plant (g)	Test weight (g)	Protein content (%)	Iron content (ppm)	Zinc content (ppm)	Amylose content (%)
NAUR-1xGNR-3	6.83**	2.37**	-0.74**	15.32**	5.06**	-2.75**
NAUR-1xIET 24762	-0.74	5.95**	0.65**	1.37**	6.70**	1.38**
NAUR-1xGAR-13	-0.50	0.69	1.37**	-9.21**	1.36**	0.93*
NAUR-1xIET-24765	16.80**	-0.98	1.22**	-10.43**	1.94**	0.69
NAUR-1xIET-24767	-0.52	-0.28	-1.52**	2.53**	2.03**	0.57
NAUR-1xIET-24772	4.95**	3.44**	-0.45**	-0.23	2.27**	0.10
NAUR-1xGurjari	-5.38**	2.26**	0.12	-3.89**	-4.87**	1.19*
NAUR-1xNVSR-303-6	0.44	-0.70	-0.49**	-14.72**	-5.29**	1.24**
NAUR-1xIET-23825	4.48*	-2.93**	-1.79**	-1.33*	5.06**	1.97**
GNR-3xIET-24762	0.53	4.97**	-0.14	8.55**	8.18**	-0.36
GNR-3xGAR-13	10.93**	-0.07	0.96**	-7.07**	-3.26**	0.18
GNR-3xIET-24765	19.66**	-2.02*	0.95**	12.67**	-4.07**	1.60**
GNR-3xIET-24767	-6.45**	0.10	-0.17	-8.55**	0.85*	1.82**
GNR-3xIET-24772	-6.27**	5.41**	0.38**	-0.23	3.44**	-0.64
GNR-3xGurjari	-7.96**	-3.48**	-1.78**	-0.64	-1.06**	1.10*
GNR-3xNVSR-303-6	23.81**	-1.76*	0.60**	-9.46**	-2.58**	2.49**
GNR-3xIET-23825	-22.02**	-3.56**	-0.04	-9.83**	-3.06**	1.55**
IET-24762xGAR-13	-1.52	2.17*	-0.40**	4.43**	-5.33**	-0.09
IET-24762xIET-24765	12.86**	1.26	1.27**	1.92**	0.64*	-0.25
IET-24762xIET-24767	6.39**	-0.35	-0.76**	12.91**	-0.64*	-2.03**
IET-24762xIET-24772	-5.52**	-0.76	0.42**	-4.04**	-2.06**	0.49
IET-24762xGurjari	-14.78**	-3.33**	-0.96**	4.43**	-1.67**	-1.08*

Crosses	Straw yield per plant (g)	Test weight (g)	Protein content (%)	Iron content (ppm)	Zinc content (ppm)	Amylose content (%)
IET-24762xNVSR-303-6	-1.28	3.60**	-0.29*	-10.80**	0.06	0.29
IET-24762xIET-23825	1.83	-0.76	0.82**	-10.96**	-2.20**	0.02
GAR-13xIET-24765	-4.53**	-1.09	-2.29**	6.01**	-0.69*	-0.03
GAR-13xIET-24767	12.53**	-0.39	-0.70**	10.04**	0.33	0.52
GAR-13xIET-24772	-7.43**	3.87**	-1.12**	5.55**	-0.45	1.05*
GAR-13xGurjari	-11.90**	3.75**	0.70**	1.35*	8.89**	-0.19
GAR-13xNVSR-303-6	-8.58**	0.62	1.08**	0.57	-1.79**	-0.14
GAR-13xIET-23825	12.73**	4.18**	0.53**	-2.93**	6.64**	-0.75
IET-24765xIET-24767	-8.33**	5.31**	0.01	-14.37**	-2.63**	-0.06
IET-24765xIET-24772	-8.61**	5.56**	-0.30*	11.19**	0.44	0.13
IET-24765xGurjari	7.11**	3.99**	0.34**	-4.80**	4.83**	-0.12
IET-24765xNVSR-303-6	-17.84**	-0.19	0.50**	-8.28**	-3.69**	-1.05*
IET-24765xIET-23825	-10.33**	3.07**	0.77**	0.47	-3.43**	-0.33
IET-24767xIET-24772	6.28**	5.24**	1.10**	-9.85**	-2.40**	0.02
IET-24767xGURJARI	-3.83*	1.56*	0.34**	5.46**	-4.02**	-0.55
IET-24767xNVSR-303-6	9.28**	-0.09	0.74**	-10.23**	-1.45**	0.49
IET-24767xIET-23825	1.11	3.37**	0.75**	-8.03**	5.59**	-1.11*
IET-24772xGurjari	13.12**	-5.76**	0.96**	2.21**	-1.08**	-0.36
IET-24772xNVSR-303-6	-10.14**	-1.89*	1.00**	4.19**	-2.07**	0.35
IET-24772xIET-23825	10.25**	1.79*	0.08	-9.85**	-3.76**	-1.58**
GurjarixNVSR-303-6	-12.52**	1.53*	-2.36**	-1.60**	-2.02**	-1.56**
GurjarixIET-23825	10.51**	1.58*	1.02**	1.60**	-5.80**	0.82*
NVSR-303-6xIET-23825	5.54**	2.46**	0.84**	5.06**	10.03**	-1.12*
SE (Sij)	1.77	0.88	0.13	0.53	0.37	0.47
SE (Sij- Skl)	2.47	1.23	0.18	0.74	0.52	0.66

* Significant at 5 % and **Significant at 1 %

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