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Combining ability for grain yield and some important agronomic traits in Maize (*Zea mays* L.)

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Abstract

The 15 hybrids along with the parents evaluated in field under normal condition to determine the combining ability for grain yield and other agronomic traits in maize (*Zea mays* L.) at two years 2011 and 2012, using RCBD with three replications. Results of combined ANOVA revealed that year effect was significant for all the parameters. Based on diallel cross analysis according to Griffing method 2, the general combining ability (GCA) and Significant specific combining ability (SCA) were significant for all the traits and so in the inheritance of all the parameters, additive and non additive gene action are important. The GCA×year interaction effects were significant for plant height, ASI and grain yield. The SCA×year interaction effects were significant for days taken to tasseling, ASI and grain yield. This indicates high variability among the parents and crosses in their responses to different conditions changes in both years. The GCA/SCA variance ratio exhibited that all traits were predominantly under non-additive control and non-additive effects played a more important role than additive effects in all the parameters. Based on GCA effects (g_i), $\sigma^2_{g_i}$, $\sigma^2_{s_i}$ and per se performance for each parent, SD\17 line for 100 grain weight, ASI and grain yield, SD\15 line for number of rows per ear, SD\10 line for number of kernels per row was suitable resources to increase grain yield. Therefore these inbred line probably have potential as parents of hybrid varieties, as well as for inclusion in breeding programmes, since they may contribute superior alleles in new populations for high grain yield. Furthermore, SD\3×SD\704 and SD\17×SD\704 proved to be the best crosses to increase grain yield.

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Introduction

Maize (*Zea mays* L.), the sole cultivated member of genus Zea and tribe Maydeae, ranks as one of the three important cereal crops in the world after wheat and rice. Maize being nutritionally an important crop has multiple functions in the traditional farming system, being used as food and fuel for human being and feed for livestock and poultry. Recent projections by the International Food Policy Research Institute indicate that by 2020, the demand for maize in developing countries will overtake that for wheat and rice (Gerpacio and Pingali, 2007). In Iran, the average grain yield ha^{-1} in 2007 was 7.6 t ha^{-1}, whereas the soil and climatic conditions of Iran are suitable for maize production, but the yield is low when compared to the United States of America with 9.5 t ha^{-1} in 2007(Shiri *et al.,* 2010). Thus, it is prerequisite to select promising hybrids for different conditions in order to speed up economical crop production.

Diallel analysis provides information on average performance of individual lines in crosses known as general combining ability (GCA). It also gives information about the performance of crosses relative to the average performance of parents involved in the cross known as specific combining ability (SCA). Significant GCA and SCA effects provide information to determine the efficacy of breeding for improvements in given traits and they can be used to identify the lines to be served as parents in a breeding program for improvement (Kearsey and Pooni, 1996). In addition, this technique enables the breeder to combine desirable genes that are found in two or more genotypes (Dabholkar, 1992). General combining ability (GCA) is a breeding value of a genotype in terms of its performance ability. Its predominance can be useful to a breeder in increasing selection efficacy in segregating populations (Bocanski *et al.*, 2009). Special combining ability (SCA) is a cumulative effect of two genotypes in their hybrid. The predominance of SCA can facilitate detection of highly heterotic hybrids of economic importance. There are several methods that can be used for diallel analysis. The mostly used one is the Griffing's method (1956), which partitions the total variance to GCA variance of parents and SCA variance of crosses. Beside the conventional methods for diallel analysis for evaluation of combining abilities, recently a new approach has been used.

Ojo *et al.*, (2007) based on seven-parent inbred diallel of white maize for grain yield and yield components (ear length, ear diameter and shelling percentage) reported that hybrid means were significantly higher than the parental means for all traits except shelling percentage. GCA and SCA mean squares were not significantly different for the yield components. GCA mean squares were however, highly significant for grain yield. Additive gene action was more important than non-additive gene action for grain yield. In other research, F_1 generation of 6×6 diallel cross of maize (*Zea mays* L.) was evaluated for combining ability effects under normal and high temperature conditions. The mean squares due to genotypes, GCA, SCA and reciprocal effects were found as highly significant under high temperature condition. The GCA/SCA variance ratio exhibited that all traits were predominantly under non-additive control (Akbar *et al.*, 2008).Zare *et al.*, (2011)based on seven-parent inbred diallel of maize reported that GCA and SCA effects were significant for the majority of traits. Based on high-parent heterosis, general and specific combining abilities of parents and hybrids, K1264.1 inbred line for production of early maturity, increasing number of rows per ear and grain yield, K18 inbred line for increasing number of kernels per row and K3653.5 inbred line for increasing area of flag leaf and number of rows per ear were suitable resources. K3218×K3653.5 and MO17×K3653.5 also proved to be the best crosses to increase grain yield. Shiri *et al.*, (2010) reported that the type of gene action for grain yield was additive and non additive. Also, over dominance type of gene action was recorded for grains per row and 100 grain weight. Bello and Olaoye (2009) based on 10 open pollinated maize varieties reported thatGCA and year effects were significant for all the parameters except plant height, while SCA and GCA×year effects were significant only for grain yield. also showed positive significant GCA×year effects for flowering traits.

Significant SCA×year interaction effects were recorded for maize grain yield and days to flowering. The objective of the present study was undertaken to study the combining ability estimates, combining ability×year intraction and also to identify the best combiners and their crosses on the basis of their general and specific combining ability for yield and other agronomic traits.

Materials and methods

Experimental site and soil characteristics

The study was conducted at dezful research station in safi abad, in Khuzestan province, Iran (32°22′ N and 48°23′ E, 82 m above sea level) in the years 2011 and 2012. The type of soil found at this location is clay loam, and its pH = 7.4 with EC = 1.2 mmhos/cm.

Plant materials,Seed sowing, cultivation and crossing

The experimental material comprised six inbred lines of maize (Table 2). The F1 seed along with their parental inbred lines were planted in field based on RCBD with three replications in two different years in 31 July (which was the planting date). Each plot contained 3 rows that are 75 cm apart and 6 m in length and they consisted of 30 hills, two seeds of which were sown and one seedling of which was removed at the 4 leaves stage. The experiment was irrigated after 90±5 mm evaporation from class A pan. while fertilizers were applied prior to sowing at a rate of 120 kg N ha^{-1} and 140 kg P ha^{-1}, and an additional side dressing of 120 kg N ha^{-1} was applied at the six leaves stage of maize plants. Non-experimental lines were planted to minimize the edge border effects.

Data collection

At maturity, data were recorded for the data pertaining to days taken to tasseling, anthesis silking interval (ASI), plant height, 100 grain weight, number of rows per ear, number of kernels per row and grain yield per plant.

Statistical analysis

The data were tested for skewness, kurtosis and normality by MINITAB (1998) statistical software. Then, Data were analyzed using SAS (1999). Analysis of traits from the parents and direct crosses was conducted using the Diallel-SAS procedure developed by Zhang *et al.*, (2005), according to Griffing's (1956) method 2, Model 1, which included the parents and direct crosses. The diallel-SAS program evaluating main genotype effects contain GCA and SCA effects and their interaction with year. Thus this program estimated data for year effects, as well as effects due to genotype, block, and the intractions between various effects. Genetic components of GCA and SCA were estimated as (Hasanuzzaman *et al.*, 2012). Combined analyses of variance based on RCBD, genetic parameters and comparison of quantitative traits means based on Duncan's new multiple range test (DNMRT), were performed in SAS (2001). Griffing's (1956) method II (Model A) diallel analysis was used to estimate GCA for the lines and SCA for the hybrids. GCA and SCA equivalent variance components of mean squares were calculated by a fixed model for the diallel design (Baker, 1978). The relative importance of general and specific combining ability on progeny performance was estimated as the ratio $\sigma^2_{gca}/\sigma^2_{sca}$: Where, σ^2_{gca} and σ^2_{sca} are the variance components for GCA and SCA.

Results and discussion

Analysis of variance

Results of combined ANOVA across years revealed that year effects were highly significant (P<0.01) for all the characters showed significant differences between two years. This suggests differential response of inbred lines to factors of year in the two years. Other authors have found that year effects were significant for days from emergence to silking, plant height (Mickelson *et al.*, 2001), number of rows per ear (Soengas *et al.*, 2003, Zare *et al.*, 2011), number of kernels per row (Vidal-Martinez *et al.*, 2001, Zare *et al.*, 2011) and grain yield (Doerksen *et al.*, 2003, Soengas *et al.*, 2003, Mickelson *et al.*, 2001, Vidal-Martinez *et al.*, 2001). Genotype×year interaction effects were not significant for 100 grain weight, ASI,number of rows and number of kernels per row. Genotype×year interaction effects were significant for other traits, indicating that genotypes did not respond to the years similarly and that additive gene action played a major role in the inheritance of this characters (Table 2). Other researchers have reported that genotype×year interaction effects were significant for days from emergence to silking, plant height (Mickelson *et al.*, 2001), number of rows per ear, ear length and grain yield (Doerksen *et al.*, 2003, Soengas *et al.*, 2003, Mickelson *et al.*, 2001, Vidal-Martinez *et al.*, 2001, Zare *et al.*, 2011). Genetic variability of genotypes was significant for all traits. As a result, the genotype sum of squares was partitioned into GCA and SCA effects (Table 2). results showed that general combining ability (GCA) and specific combining ability (SCA) were highly significant (P<0.01) for all the characters. indicating that additive and non additive gene action is important in the inheritance of these traits (Table 2). GCA×year interaction effects were significant for plant height, ASI and grain yield. SCA×year interaction effects were significant for days taken to tasseling, ASI and grain yield. This indicates high variability among the parents and crosses in their responses to different conditions changes in both years. This underscores earlier view of Kang (1988) who noted that environment played prominent role in phenotypic expression of agronomic characters. The author suggested that ignoring environmental component in the fields would likely reduce progress and advances in selection. Also the GCA/SCA ratio reveals that different traits show additive or non-additive genetic effect. A GCA/SCA ratio with a value greater than one indicates additive genetic effect, whereas a GCA/SCA ratio with a value lower than one indicates dominant genetic effect. In this study, all traits, showed non-additive genetic effects, indicating preponderance of non-additive gene effects for inheritance of these traits (Table 2). The predominance of SCA variance denotes that non-additive genetic effects were largely influencing the expression of these traits. These results were in agreement with reports of other researchers about predominance of non-additive genetic effects for days to silking (Alam *et al.*, 2008) plant height (Alam *et al.*, 2008, Akbar *et al.*, 2008, Zare *et al.*, 2011), number of rows per ear (Vidal-Martinez *et al.*, 2001, Zare *et al.*, 2011), number of kernels per row (Vidal-Martinez *et al.*, 2001, Srdic *et al.*, 2007, Zare *et al.*, 2011) and grain yield (Srdic *et al.*, 2007, Bhatnagar *et al.*, 2004, Zare *et al.*, 2011). However, in contrast to our results, other researchers indicated predominance of additive genetic effects for plant height (Vacaro *et al.*, 2002), number of rows per ear (Srdic *et al.*, 2007), number of kernels per row (Saeed *et al.*, 2000) and grain yield (Vacaro *et al.*, 2002, Ojo *et al.*, 2007).

Table 1. list, Code and Origin Inbred lines used in test.

Row	Inbreds	Code	Origin
1	CML384	CML	CIMMYT
2	SD\(3-6)\2-2-1-2-m-1	SD\3	research station in safi abad
3	SD\172-1-2-2-2-1-1	SD\17	research station in safi abad
4	SD\10\1-1-1-1-3-1-1	SD\10	research station in safi abad
5	SD\15\1-1-1-2-1-1-1	SD\15	research station in safi abad
6	SD\704\4-1-1-3-1-1	SD\704	research station in safi abad

GCA effect), $\sigma^2_{g_i}$ and $\sigma^2_{s_i}$ of the parents

Estimates of the GCA effects(g_i), $\sigma^2_{g_i}$ and $\sigma^2_{s_i}$ and per se mean for each parent are shown in Table 3. A parent with a significant negative value would contribute a low value of these traits, where as a parent with a positive value would contribute towards high value of them. To produce the best progeny, parental lines with the highest GCA for a specific trait should be used. The potential of a parent in hybridization may be accessed by it's per se performance, F_1 performance and GCA effects. A high general combiner(parent) is characterized by its better breeding value when crossed with a number of other parents. Depending upon the character concerned, the nature(direction/sign) and magnitude(size) of g_i are both consider. Besides, per se(mean) performance of the parent is also considered in unison with g_i since the former offers reliability/authenticity to g_i as a guide to selection of parent. Further, the other associated parameters, $\sigma^2_{g_i}$(GCA variance) and $\sigma^2_{s_i}$(SCA variance) with each parent play significant role in choice of parents. For instance, a parent showing high $\sigma^2_{g_i}$and low $\sigma^2_{s_i}$ with high g_i and high mean would certainly be a right choice as a component of synthetic variety. Similarly, a parent with high $\sigma^2_{g_i}$and $\sigma^2_{s_i}$ is a better parent for creating high-yielding specific combinations, as high $\sigma^2_{s_i}$ arises mainly from its highly differential(specific) ability to transmit its characters(genes) into its hybrid progenies. The significant GCA effects for all of the parents were only found in the 100 grain weight, and in the other traits it was significant for some of the parents' except for days taken to tasseling. CML inbred line showed to be the second best general combiner for 100 grain weight(1.11) buth low per se mean, $\sigma^2_{g_i}$ and high $\sigma^2_{s_i}$ for this trait. SD\3 inbred line was the second best combiner for plant height (3.29) and 100 grain weight (1.22), this inbred line have high per se mean, $\sigma^2_{g_i}$ and $\sigma^2_{s_i}$ for plant height and 100 grain weight, Thus, this inbred line is a better parent for creating high-yielding specific combinations. SD\17 inbred line was the second best combiner for plant height (3.26), the best parent for ASI (0.61), be the best general combiner for 100 grain weight (2.94) and the best parent for grain yield per plant(8.59), this inbred line have high per se mean, $\sigma^2_{g_i}$ and $\sigma^2_{s_i}$ for plant height, Anthesis-silking interval, 100 grain weight and grain yield per plant, suggests that this inbred line could be a better parent for creating high-yielding specific combinations. Thus, SD\3 inbred line may prove to be a potential specific combiner useful to transgressive breeding. This parent probably have genes that can be introgressed into other promising lines for plant height, Anthesis-silking interval, 100 grain weight and grain yield. This report agrees with that of Paul and Debenth (1999) and Zare*et al.*, (2011) who noted significant GCA effects for days to anthesis. Anthesis-silking interval is a trait used mostly in screening genotypes for tolerance to stresses. SD\10 inbred line was the second worst combiner for plant height (-4.18) and 100 grain weight (-1.48) and the best parent for number of kernels per row (1.06), this inbred line had high per se mean for number of kernels per row and $\sigma^2_{s_i}$was more than$\sigma^2_{g_i}$ may be desirable for F_1 hybrids. SD\15inbred line was the worst combiner for plant height (-7.54) and the second worst combiner for 100 grain weight (-2.84) and the best parent for number of rows per ear (0.69), at this inbred line$\sigma^2_{s_i}$was more than$\sigma^2_{g_i}$ may be desirable for F_1 hybrids. and SD\704 be the best general combiner for plant height (5.27) and the second worst combiner for 100 grain weight (-0.95), this inbred line had high $\sigma^2_{g_i}$and $\sigma^2_{s_i}$ for plant height. Thus, this inbred line is a better parent for creating high-yielding specific combinations for

plant height.

Table 2. Combined analysis of different traits and estimation of genetic parameters of maize based on Griffing's method2 (Model 1).

Source of variation	d.f	plant height (cm)	days taken to tasseling	ASI (day)	100 grain weight(gr)	number of rows per ear	number of kernels per row	grain yield (gr/Plant)
Year	1	12124.57**	1866.87**	87.50**	271.63**	218.70**	346.67**	51324.2**
REP/Year	4	156.49**	21.37**	0.52ns	4.18ns	4.54**	4.75ns	49.08ns
Genotype	20	1292.74**	68.15**	4.84**	436.24**	17.31**	65.26**	4602.5**
GCA	5	1062.81**	16.45**	6.26**	494.27**	5.53**	20.71**	1199.9**
SCA	15	1480.50**	86.63**	4.73**	70.93**	21.97**	83.12**	5851.5**
Genotype×Year	20	39.35*	6.48*	2.55ns	6.39ns	0.60ns	4.26ns	424.0**
GCA×Year	5	78.17**	3.96ns	4.49*	5.41ns	0.82ns	5.67ns	700.0**
SCA×Year	15	15.57ns	7.62*	3.77*	7.65ns	0.57ns	3.97ns	412.9**
Error	80	21.33	3.45	1.76	5.8	1.06	4.53	63.5
σ^2_D	-	1459.17	2.16	2.97	55.13	20.91	78.59	5788.00
σ^2_A	-	173.58	8.32	0.17	79.75	0.74	2.70	189.41
$\sigma^2_{gca}/\sigma^2_{sca}$	-	0.060	0.130	0.128	0.723	0.018	0.017	0.016
h^2_b	-	66.57	64.29	63.16	71.60	66.29	59.31	67.29
h^2_n	-	7.12	13.25	12.91	30.05	2.27	1.97	2.13
σ^2_{gca}	-	86.79	1.08	0.38	39.87	0.37	1.35	94.70
σ^2_{sca}	-	1459.17	8.32	0.128	55.13	20.91	78.59	5788.00

ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively), REP: Replication, GCA: General Combining Ability, SCA: Specific Combining Ability.

Table 3. Estimates of general combining ability effects (g_i), $\sigma^2_{g_i}$ and $\sigma^2_{s_i}$ (GCA and SCA variance) and per se mean (numbers in parentheses) for each parent for maize yield and agronomic traits.

Parrents	parameters	plantheight (cm)	days taken to tasseling	ASI (day)	100-grain Weight(g)	number of rows	number of kernels per row	grain yield per Plant(g)
CML	g_i	-0.04(167.8)	0.51(57.7)	-0.24(4.50)	1.11**(32.7)	-0.08(9.3)	-0.66(24.7)	-2.02(140.6)
	$\sigma^2_{g_i}$	-4.45	0.46	0.31	0.02	0.21	0.50	-9.15
	$\sigma^2_{s_i}$	247.9	1.68	-0.59	13.73	0.53	3.22	270.71
SD\3	g_i	3.29*(198.9)	-0.63(58.8)	0.26(5.83)	1.22**(44.5)	-0.19(12.3)	-0.27(29.0)	3.98(182.3)
	$\sigma^2_{g_i}$	6.37	0.65	0.30	1.28	-0.18	0.87	2.61
	$\sigma^2_{s_i}$	242.51	0.74	1.12	34.91	2.46	11.16	1135.75
SD\17	g_i	3.26*(206.5)	-0.85(60.3)	0.61*(5.50)	2.94**(45.3)	-0.31(11.7)	0.03(26.0)	8.59*(173.7)
	$\sigma^2_{g_i}$	6.18	0.01	1.02	7.43	0.12	0.94	60.56
	$\sigma^2_{s_i}$	241.01	6.31	2.15	35.47	1.03	12.19	1118.89
SD\10	g_i	-4.18*(193.0)	0.48(62.7)	-0.43(4.50)	-1.48**(40.0)	0.03(12.0)	1.06**(30.7)	-4.30(173.0)
	$\sigma^2_{g_i}$	13.02	-0.49	0.19	0.98	0.22	0.18	5.26
	$\sigma^2_{s_i}$	121.35	34.25	2.50	2.90	2.26	20.78	813.54
SD\15	g_i	-7.54**(186.3)	-0.05(61.3)	0.04(4.17)	-2.84**(32.5)	0.69**(12.2)	-0.69(30.3)	-5.02(151.3)
	$\sigma^2_{g_i}$	52.40	-0.72	-0.37	6.86	0.26	0.46	11.97
	$\sigma^2_{s_i}$	141.62	15.71	0.18	4.39	1.74	20.42	647.99
SD\704	g_i	5.27**(203.3)	0.54(61.0)	-0.24(5.83)	-0.95*(37.7)	-0.14(11.2)	0.53(29.2)	-1.22(170.2)
	$\sigma^2_{g_i}$	23.32	-0.43	-0.31	-0.32	-0.20	-0.66	-11.74
	$\sigma^2_{s_i}$	871.96	61.98	2.70	63.32	14.85	50.72	4130.36

* and **: significant at the 5% and 1% levels of probability, respectively.

SCA effect of the crosses

Results of SCA effects of traits for all crosses showed that SD\3×SD\704, CML×SD\704 and SD\17×SD\704 proved to be the best specific combination to improve plant height in superior progeny. Therefore, these crosses seem to be suitable for plant height improvement. SD\10×SD\704 had the highest significant values of SCA effects (11.94) for days taken to tasseling. The highest significant values of SCA for ASI were indicated in combination of SD\17×SD\704 (2.38) and SD\10×SD\704 cross had significant negative SCA effect (3.03). SD\3×SD\704 and SD\17×SD\704 crosses had the highest significant values of SCA effects (11.33 and 10.72, respectively) for 100 grain weight and CML×SD\704, CML×SD\3, CML×SD\17, CML×SD\10, SD\3×SD\17, SD\17×SD\15 and SD\10×SD\704 also had significant positive SCA for this trait. CML×SD\15 cross also had significant negative SCA effects(3.44) for this trait, Therefore, these crosses seem to be suitable to increase 100 grain weight except CML×SD\15 cross. SD\15×SD\704 and SD\3×SD\704 crosses had significant positive SCA(6.00 and 3.11, respectively) for number of rows per ear. SD\10×SD\704 cross had the highest significant values of SCA effects(9.19) for number of kernels per row and SD\3×SD\704, SD\17×SD\704, SD\15×SD\704, CML×SD\704, SD\17×SD\10 and CML×SD\15 cross also had significant positive SCA. CML×SD\17 cross showed to be the worst specific combiner for this trait. Therefore, these crosses seem to be suitable to increase number of kernels per row except CML×SD\17 cross. The highest significant values of SCA for grain yield per plant were indicated in combinations of SD\17×SD\704 and SD\3×SD\704 and SD\10×SD\704, SD\15×SD\704, SD\17×SD\15 and CML×SD\704 also had significant positive SCA. Therefore, these crosses seem to be suitable to increase grain yield per plant. According to Griffing (1956), choosing the hybrids with high specific combining ability effects, and including at least one parent with high or average GCA effects for a particular trait is a good strategy for plant breeding. Selection of desirable varieties to increase grain yield is based on yield component. Therefore, based on GCA effects (g_i), $\sigma^2_{g_i}$,$\sigma^2_{s_i}$ and per se (mean) performance for each parent, SD\17 line for 100 grain weight, ASI and grain yield, SD\15 line for number of rows per ear, SD\10 line for number of kernels per row was suitable resources to increase grain yield. Therefore these inbred line probably have potential as parents of hybrid varieties, as well as for inclusion in breeding programmes, since they may contribute superior alleles in new populations for high grain. Furthermore, SD\3×SD\704 and SD\17×SD\704 proved to be the best crosses to increase grain yield.

Table 4. Specific combining ability (SCA) effects of selected crosses for maize grain yield and agronomic characters.

crosses	plant height (cm)	days taken to tasseling	ASI (day)	100-grain Weight(g)	Number of Rows per ear	Number of Kernels per row	Grain yield per Plant(g)
CML×SD\3	2.93	-0.84	0.51	4.50**	1.08	0.97	13.16
CML×SD\17	10.65**	0.88	-0.15	3.62**	0.53	-2.34*	-0.12
CML× SD\10	4.54	1.87	-0.13	2.70**	0.54	1.30	12.12
CML×SD\15	1.23	1.07	-0.93	-3.44**	0.03	2.72**	-8.84
CML×SD\704	30.19**	3.31	1.33	7.06**	1.89*	3.31*	28.69*
SD\3×SD\17	5.68	-0.15	0.35	2.84**	0.14	0.44	14.55
SD\3×SD\10	5.56	1.02	-0.63	-0.25	1.47*	0.41	3.44
SD\3×SD\15	3.43	1.88	0.07	-0.88	0.14	-0.50	9.33
SD\3×SD\704	30.83**	2.83	-0.09	11.33**	3.11**	7.53**	65.19**
SD\17×SD\10	-0.21	0.41	2.38*	-1.47	-0.42	2.94**	8.99
SD\17×SD\15	7.15	1.78	-0.10	4.73**	0.75	1.19	23.72**
SD\17×SD\704	28.83**	5.61*	-0.17	10.72**	2.50*	6.83**	81.31**
SD\10×SD\15	-10.13*	0.27	-0.08	0.14	1.58**	1.32	10.77
SD\10×SD\704	19.88**	11.94**	-3.03**	4.64**	2.66**	9.19**	55.58**
SD\15×SD\704	21.53**	8.08**	-2.26*	1.44	6.00**	4.21**	44.03**

* and **: significant at the 5% and 1% levels of probability, respectively.

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Abbreviations

ANOVA- Analysis of variance, GCA- General combining ability, SCA- Specific combining ability, g_i- GCA effects, $\sigma^2_{g_i}$ and $\sigma^2_{s_i}$- variance of GCA and SCA for each parent, respectively.