International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 5, No. 8, p. 173-179, 2014

INNSPUB

RESEARCH PAPER OPEN ACCESS

Genetic analysis for grain yield and yield contributing characters in maize (*Zea mays* L.)

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Key words: General combining ability, specific combining ability, Gene action, *Zea mays*.

http://dx.doi.org/10.12692/ijb/5.8.173-179 Article published on October 29, 2014

Abstract

The F_1 hybrids along with the parents were evaluated in field to Genetic analysis for yield and yield contributing characters in maize (*Zea mays* L.) at Dezful Research Station in Safi Abad, in 2011 using RCBD with three replications. Results analysis of variance showed that variations among genotypes were highly significant for all the traits studied. Based on diallel cross analysis according to Griffing method 2, the results indicated significant differences among the parents for general combining ability (GCA) and crosses for specific combining ability (SCA) for all the characters studied and so in the inheritance of all the parameters, additive and non additive gene action are important. Based on GCA effects and per se performance for each parent, SD\3 and SD\17 line 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\17 proved to be the best cross to increase grain yield. These best parents and cross combinations could be effectively utilized in maize breeding for the improvement of yield components and thus their incorporation in further breeding program is suggested.

Abbreviations

ANOVA- Analysis of variance,
GCA- General combining ability
SCA- Specific combining ability.

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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).

The diallel analysis helps to obtain information on the genetic systems governing the inheritance of attributes to be improved, and hence may help in predicting the performance in subsequent generations by assessing the potential of different crosses. Plant breeders use diallel analysis as an aid in selection and to investigate genetic properties of parents and their crosses. 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 beused 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). Also, Srdic *et al.* (2007) found that dominant gene effects were more significant in maize grain yield and number of grains per row, while additive gene effects were more important for grain row number and 1000 grain weight. The mode of inheritance of grain row number was partial dominance, while over dominance was of greater importance for grain yield, number of grains per row and 1000 grain weight. Wattoo *et al.* (2009) revealed that the yield potential like number of days taken for tasselling, plant height, number of grain rows per ear, number of grains per row, 100 grain weight and grain yield per plant were controlled by the over dominance type of gene action. Irshad-Ul-Haq *et al.* (2010) revealed that non-additive genetic effects were more pronounced in the inheritance of plant height, days to 50% tasseling, and grain yield per plant. 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. Ojo *et al.* (2007) based on seven-parent inbred diallel of white maize for grain yield and yield components reported that 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, F1 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). the present study was undertaken to estimate the general combining ability (GCA), specific combining ability (SCA) and heritability for yield and yield contributing characters in maize (*Zea mays* L.).

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. The type of soil found at this location is clay loam, and its pH = 7.4 with EC = 1.2 mmhos/cm. The experimental material comprised six inbred lines of maize (CML, SD\3, SD\17, SD\10, SD\15, SD\704 SD\704). The F_1 seed along with their parental inbred lines were planted in field based on RCBD with three replications 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. The grains produced by the selected plants used for biological yield were weighed in grams and average grain yield per plant was recoded. Grain yield trait was adjusted to 14% of grain moisture. Harvest index for each treatment was calculated in percentage by using the following formula: Harvest index (%) =(Grain yield per plant)/(Biological yield)× 100.

Data analysis

Combining ability of the diallel cross was analyzed following method 2 (parents and one set of F_1s but no reciprocals) and model 1 (fixed effects model) of Griffing (1956a). The analysis was performed on individual environments using the DIALLEL-SAS 05 program (Zhang *et al.*, 2005). Genetic Components of GCA and SCA were estimated as (Singh and Chaudhury, 2005):

Results and discussion

Analysis of variance

The analysis of variance (ANOVA) for yield and yield contributing characters indicated significant differences among genotypes for all the traits studied (Table 1). ANOVA for combining ability showed that GCA and SCA variance was significant for all the traits (Table 2). For almost all characters both additive and non-additive gene action influenced the performance of the hybrids. The non-additive effects played a more important role than additive effects. The magnitudes of GCA and SCA effects are indicative of the relative importance of additive and non-additive gene actions in the inheritance of a trait, respectively. The large GCA: SCA variance ratio suggests the importance of additive gene effects, while a low ratio signifies presence of dominant and/or epistatic gene effects (Kornegay and Temple, 1986). The lower σ2g/σ2s ratio indicates that the predominance of non-additive (dominance or epistasis) gene action is important for all the traits (Table 2). The results suggested the possibility of the hybrid vigor exploitation because of the significant non-additive effects for all the traits. These effects could be important in maximizing these traits. A very few researchers reported the gene action in Maize (Zea mays L.), 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, Zare *et al.*, 2011).

Table 1. Analysis of variance for different yield parameters of Parents and F_1 in maize.

	df	Days taken to tasseling	ASI	Plant height	100 grain weight	No. of rows/ear	No. of kernels/row	HI	Grain yield /plant
Rep.	2	40.44**	8.26**	8.27**	9.23*	4.16*	9.13*	29.38*	153.62**
Genotype	20	18.84**	6.08*	1252.74**	149.74**	6.63**	122.26**	125.55**	1201.27**
Error	40	4.63	0.39	25.39	0.01	0.46	2.23	14.09	63.51
C.V		3.14	13.40	6.89	5.73	7.79	6.82	9.86	10.14

* P<0.05, ** P<0.01 respectively.

GCA effect of the parents

Estimates of the GCA effect and mean of the parents in F_1 generation are shown in Table 3. We found that some of the parents are good general combiners for yield and yield contributing characters. The parent SD\3 was found as a good general combiner for yield per plant along with plant height, number of kernels per row and ASI. The GCA effects of 100 grain weight and HI in the parent CLM, Plant height and 100 grain weight in the parent SD\17 were also positively high and significant. Good general combiners for number of kernels per row, plant height, 100 grain weight and yield of maize were reported by a number of researchers Paul and Debenth (1999) and Zare *et al.*, (2011) who noted significant GCA effects for days to anthesis.

Table 2. Analysis of variance for combining ability of different yield parameters of maize in F_1 Generation.

	df	Days taken to tasseling	ASI	Plant height	100 grain weight	No.of rows/ear	No. of kernels/row	HI	Grain yield /plant
Genotype	20	18.84**	6.08*	1252.74**	149.74**	6.63**	122.26**	125.55**	1201.27**
GCA	5	36.37**	6.45*	992.79**	158.04**	5.93*	98.14**	130.15**	1520.91**
SCA	15	22.93**	6.52*	1132.43**	145.68**	6.82**	18.84**	6.08*	1252.74**
Error	40	10.12	2.11	52.62	8.45	2.39	16.35	22.52	11.02
σ_A^2		9.38	0.72	156.70	299.18	0.59	163.58	145.28	251.65
σ_D^2		12.81	4.41	1079.81	137.23	4.43	113.89	107.64	231.32
σ_g^2		3.19	0.36	78.35	149.59	0.30	81.79	72.64	125.82
σ_s^2		12.81	4.41	1079.81	137.23	4.43	113.89	107.64	231.32
σ_g^2/σ_s^2		0.14	0.08	0.07	1.09	0.07	0.72	0.09	0.54
h_b^2		62.94	70.86	83.76	98.10	67.75	94.45	91.82	97.78
h_n^2		25.93	9.94	12.15	67.25	7.96	55.67	52.74	50.94

* P<0.05, ** P<0.01 respectively, h_b^2: Broad Sense heritability(%) and h_s^2: Narrow Sense heritability (%).

Table 3. GCA effects and mean performance for different yield parameters of the six different maize parents.

Parent		Days taken to tasseling	ASI	Plant height	100 grain weight	No. of rows/ear	No. of kernels/row	HI(%)	Grain yield /plant
CML	GCA	0.18ns	-0.36ns	-0.44ns	1.10**	-0.17ns	0.63ns	3.07**	2.82ns
	Mean	66.83	5.33	190.66	32.85	10.45	26.96	44.32	160.6
SD\3	GCA	-2.16*	0.89*	2.11**	0.52ns	-0.11ns	3.26*	-1.41*	23.07**
	Mean	61.20	4.27	191.33	32.22	9.50	26.53	38.25	182.3
SD\17	GCA	-0.61ns	0.13ns	2.98**	2.81**	-0.08ns	-0.32ns	-0.81ns	18.90**
	Mean	59.00	4.67	167.23	34.39	10.46	26.07	37.56	173.7
SD\10	GCA	0.32ns	-0.25ns	-3.50**	-1.55**	-0.05ns	0.91ns	-0.75ns	-3.17ns
	Mean	53.29	5.00	169.32	31.62	9.88	20.46	39.42	143.0
SD\15	GCA	0.16ns	0.33ns	-7.22**	-2.53**	0.51*	-0.80ns	1.05ns	-0.31ns
	Mean	57.35	3.71	177.23	31.38	10.59	23.35	38.26	151.3
SD\704	GCA	0.42ns	-0.35ns	6.08**	-0.35ns	-0.20ns	-0.02ns	-1.09ns	-0.66ns
	Mean	53.00	4.26	174.00	31.46	13.67	21.73	36.69	170.2
S.E. (g_i)		0.59	0.38	1.03	0.54	0.29	0.76	0.88	2.56

* P<0.05, ** P<0.01 respectively.

SCA effect of the crosses

SCA effects of the crosses in F_1 generation are given in Table 4. The table shows that there were a good number of crosses with significant SCA effects in desirable direction for yield and yield contributing characters. The SCA effect showed that the best specific combination for Days taken to tasseling with significant negative values was SD\3×SD\17, where as hybrid SD\3×SD\17 showed significant positive values of SCA effects for plant height. The hybrids

SD\3×SD\17, CLM×SD\17 and CLM×SD\3 showed significant high positive SCA effects for 100 grain weight. The hybrid SD\3×SD\15, showed significant high positive SCA effects for number of rows per ear. The hybrids SD\3×SD\704, CLM×SD\17 and CLM×SD\15 showed significant high positive SCA effects for number of kernels per row. The hybrid CLM×SD\3, showed significant high positive SCA effects for HI. Maximum positive SCA effect and per se performance (Table 4) for grain yield per plant was observed in hybrids SD\3×SD\17 and SD\3×SD\15. According to Griffing (1956b), 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. Hybrids were descended from one or two parents with maximum values for yield and yield related traits and at least one of the parents with significant positive GCA and SCA effects identified, indicating the efficiency of diallel method in Maize breeding. Both considering the SCA effects and per se performance, cross SD\3×SD\17 was the best and the two parents, SD\3 and SD\17, involved in the crosses were identified as good general combiners.

Table 4. Estimate of SCA effects for different yield parameters of maize crosses.

Cross	Days taken to tasseling	ASI	Plant height	100 grain weight	No. of rows/ear	No. of kernels/row	HI	Grain yield /plant
CML×SD\3	1.24	0.29	3.94	4.50**	1.48	0.97	5.32**	7.34
CML×SD\17	10.92**	0.89	2.92	3.62**	0.43	2.34*	0.89	8.39
CML× SD\10	9.39	-0.32	3.39	1.09	0.49	1.30	-0.25	8.92
CML×SD\15	-0.68	-0.93	1.38	-3.44**	1.52	2.72**	-0.89	-6.84
CML×SD\704	1.58	1.33	2.24	1.06	0.08	0.35	0.29	4.69
SD\3×SD\17	-5.86**	0.35	31.47**	2.84**	0.27	0.44	1.35	69.15**
SD\3×SD\10	-1.09	-0.53	3.86	-0.25	1.47	0.41	-0.65	2.98
SD\3×SD\15	0.98	0.17	3.58	-0.88	2.84**	-0.50	3.19	17.29**
SD\3×SD\704	4.23	-0.57	1.03	11.33**	1.02	7.53**	-0.03	9.51
SD\17×SD\10	-0.54	1.78	0.41	-1.47	-0.42	0.94	0.95	2.29
SD\17×SD\15	0.78	-0.10	3.78	4.73	0.71	1.19	3.12	9.38
SD\17×SD\704	2.12	-0.17	4.12	2.56	0.85	-0.71	-0.68	7.31
SD\10×SD\15	1.08	-0.08	0.27	0.14	1.15	1.32	3.54	2.97
SD\10×SD\704	0.39	-3.03**	0.39	1.51	0.81	1.36	1.89	3.26
SD\15×SD\704	3.08	1.26	2.08	1.44	1.07	0.98	2.48	5.98
S.E. (g_i)	2.83	0.38	2.83	1.49	0.74	2.08	2.43	8.29

* P<0.05, ** P<0.01 respectively.

Heritabilit

Estimation of heritability for yield and yield contributing traits are presented in Table 4. Broad sense heritability of all the characters was above, indicating that traits are highly heritable. Wide variation in narrow sense heritability was observed in all traits. Narrow sense heritability of 100 grain weight(67.25), HI(52.74), number of kernels per row(55.67) and grain yield per plant(50.94) were high, Days taken to tasseling(25.93) was medium and ASI(9.94), number of row per ear(7.96) and plant height(12.15) was low according to classification of Robinson, (1965). The observed high broad sense heritability estimates indicated genetic variances with lesser influence of the environment and the potential effectiveness of selection of the hybrids for traits of interest (Allard, 1960). Selection of a trait should fairly be easy if heritability of that trait is very high. This is because there would be a close correspondence between genotype and phenotype due to a relatively smaller contribution of environment to the phenotype. Nevertheless, for a trait with low heritability, selection may be considerably difficult or virtually impractical due to the masking effect of the environment on the genotypic effects (Singh, 1990). Based on previous reports and results of the present study, in respect of all the traits, high heritability estimates appear to be important for effective improvement of maize.

Conclusion

It may be said that overall information obtained in the present study if practised with care can, in general,, tow parents, SD/3 and SD/17, exhibited high GCA in grain yield per plant and yield related traits and may be utilized for improvement in grain yield. Significant SCA and per se performance of hybrids SD/3×SD/17 indicates there is an opportunity for developing F_1 hybrids. Thus, heterosis could be exploited for developing inbreds and hybrids. Since development of intermating population is a long term approach, population improvement through methods like reciprocal recurrent selection, biparental mating and diallel selective mating as supplement to conventional breeding system is advocated for improvement of grain yield in maize.

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