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Mohammad Hossein Haddadi[1], Maqsadollah Esmaeilov[2],
Rajab Choukan[3], Valiollah Rameeh[4]

[1,4] Agricultural and Natural Resources Research Center
of Mazandran, Sari, Iran; [2] Tajik Agricultural University;
[3] Seed and Plant Improvement Institute, Karaj, Iran;
vrameeh@yahoo.com

GENE ACTION AND COMBING ABILITY OF SOME AGRONOMIC TRAITS IN CORN USING DIALLEL ANALYSIS

ABSTRACT

Combining ability estimates are important genetic attributes to maize breeders in anticipating improvement via hybridization and selection. To determine the combining ability for yield and yield associated traits, 8 diverse corn inbred lines were used in a half diallel mating design. Twenty eight F1 progenies along with their parents were planted in randomized complete block design with four replications in two locations during two years. Combined analysis of variance showed significant mean squares of general combining ability (GCA) and specific combing ability (SCA) for Days to silking emergence (DS), plant height (PH), 1000-kernel weight (KW), number of kernels in ear row (KR), number of rows in ear(NR) , ear diameter (ED), cob diameter (CD), kernel yield (KY) indicating that the importance of both additive and non additive genetic effects for these traits. However, high narrow-sense heritability estimates, low degree of dominance and the ratio of estimates of GCA to SCA effects for DS , NR and CD indicated that additive genetic effect was more important for these traits. Most of the crosses with significant SCA effects for KY had at least one parent with significant GCA effects for the same traits. Significant positive correlations were detected between KY and other yield components including KW, KR, NR and ED, therefore these traits can be used as indirect selection criteria for KY improvement. The crosses MO17 × Line8, MO17 × Line 10 and MO17 × Line 12, Line 8 × Line 10 and Line 8 × Line 21 with high values of KY were considered as good cross combinations for improving the trait.

Key words: combined analysis, correlation, dominance, heritability, maize.

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INTRODUCTION

Corn (*Zea mays* L.) has a notable place among cereals and it is used as human food, animal feeding and industry (Keskin *et al.*, 2005). Advances in corn genomics, breeding and production have important role on the lives of a large proportion of the world's population (Xu and Crouch, 2008). The main principle of corn breeding is to develop new inbred lines and hybrids that will outperform the existing hybrids with respect to a number of characteristics. For attending this purpose, particular attention is paid to grain yield as the most economically important trait in corn (Vasic *et al.*, 2001). Grain yield is a complex quantitative trait which is affected by a number of components, including kernel row number and kernel number per row (Zivanovic *et al.*, 2007; Bovanski *et al.*, 2009).

The identification of parental inbred lines that can be used for improving superior hybrids is the most costly and time consuming phase in corn hybrid development. Per se performance of corn inbred lines does not predict the performance of corn hybrids for grain yields (Hallauer and Miranda, 1988). Single cross hybrid performance or heterosis between parental inbred lines could therefore increase the efficiency of hybrid breeding programs (Betran *et al.*, 2003). The main objective of corn breeding is improving new hybrids with high genetic potential for yield and positive features that exceed the existing commercial hybrids (Secanski *et al.*, 2005). Therefore, combining ability analysis is an important method to realize gene actions and it is frequently used by crop breeders to select parents with a high general combining ability (GCA) and hybrids with high specific combining ability (SCA) effects (Yingzhong, 1999). Variance for GCA is related to additive genetic effects, whereas SCA indicating non-additive genetic effects, arising largely from dominance and epistatic deviations with respect to certain traits. In a classic breeding program, it is necessary to identify superior parents for hybridization and crosses to expand the genetic variability for selection of superior genotypes (Hallauer and Miranda, 1988). Genetic designs including diallel analysis have been extensively used in plant breeding to determine combining abilities of the parental lines in order to recognize superior parents for use in hybrid production (Fry, 2004; Griffing, 1956; Hayman, 1954). Combining ability has been applied by several researchers for corn breeding programs (Beck *et al.*, 1990; Crossa *et al.*, 1990; Vasal *et al.*, 1992; Kang *et al.*, 1995; Kim and Ayala, 1996; Xingming *et al.*, 2001; Betran *et al.*, 2002; Revila *et al.*, 2002; Glover *et al.*, 2005). Fry (2004) reported that heritability of a trait approaches its maximum in successive generations following hybridization. In addition, the existence of additive gene effects for a trait indicates the presence of additive variation, which means that selection could be successful for the trait (Fehr, 1991). Ojo *et al.* (2007) reported significant positive heterosis for grain yield and yield components including ear length and ear diameter in diallel crosses of seven white corn inbred lines. Additive gene action was also more important than non-additive gene action for grain yield. Ottaviano and Camussi (1981) examined several agronomic traits in diallel crosses of 10 inbred lines and their 45 F1 hybrids to study their genetic relationships with grain yield.

Large genotype × environment interaction effects tend to be viewed as problematic in breeding because the lack of a predictable response delays progress from selection. Most of the literature about corn, suggests that additive effects of genes with partial to complete dominance are more important than dominance effects in determining grain yield (Novoselovic *et al.*, 2004; Lamkey and Lee, 1993). Given the diversity of environments in which corn is cropped in Iran, the hybrid by environment interaction is normally expressive (Aguiar *et al.*, 2003). Therefore it is necessary to identify hybrids that present not only wide adaptation, assessed by the mean yield, but also have high stability, i.e., with homeostasis to adjust to environmental changes. Some studies have already compared stability in different types of hybrids (Cvarkovic *et al.*, 2009). However, there is little information regarding stability of the GCA and SCA effects. Probably single-crosses with higher stability in the GCA and SCA, the hybrid combinations obtained from these parents also present higher homeostasis for environmental variations.

The objectives of the diallel study presented here were to estimate genetic parameters like general and specific combining abilities of eight inbred lines of corn and correlations between grain yield and its components as well as other traits in different environments to recognize and choose the best parents and crosses in breeding programs.

MATERIALS AND METHODS

Eight inbred lines of maize namely Line 8, Line10, Line 12, Line 21, Line 24, Line 33, Line 36 and MO17 were crossed 8×8 diallel fashion (excluding reciprocals) to obtain 28 F_1 crosses in 2010. The resulting 28 F1 progenies along with their parents were evaluated using a randomized complete block design with four replications at two locations; Dashtenaz Agronomy Research Station located in Sari, Iran (53°11′ E longitude and 36°37′ N latitude, 10.5 m above sea level) and Qarakheil Agronomy Research Station located in Qaemshahr, Iran (52°46′ E longitude and 36°27′ N latitude, 14.7 m above sea level) during spring 2011-12. In each location the plots consisted of 3 rows, 5 m long and 75 cm apart and intra-row spacing of 20 cm. Crop management practices which included land preparation, crop rotation, fertilizer, and weed control were followed as recommended for each site. All the plant protection measures were adopted to make the crop free from insects. Ten competitive plants from the middle of each row were sampled and the following traits were recorded for each cross at each location during two years: days to silking (DS), plant height (PH) in cm, 1000-kernel weight (KW) in gram, number of kernels in ear row (KR), number of rows in ear (NR), ear diameter (ED) cm, cob diameter (CD) in cm, kernel yield (KY) in ton per hectare.

Data were analysed using the following statistical model:

$$Yijkl = \mu + \alpha l + bkl + vij + (\alpha v)ijl + eijkl$$

$$vij = gi + gj + sij$$

where *Yijkl* is observed value from each experimental unit; μ is a population mean; αl - location effect; *bkl* block or replication effect within each location; *vij* – F_1 hybrid effect, *gi* means general combining ability (GCA) for the i^{th} parent; *gj* is GCA effect of j^{th} parent; *sij* - specific combining ability (SCA) for the ij^{th} F1 hybrid), *(αv)ijl* - interaction effect between ij^{th} F_1 hybrid and location; *eijkl* = random residual effect.

The combining ability analysis was performed using mean values of the F_1 generation along with parents by using Griffing's method 2. The statistical t-Student test was applied to examine the effects GCA and SCA.

Pearson coefficient of correlation was detected based on means values the traits as:

$$r = \frac{Covariance(XY)}{\sqrt{Variance(X) \times Variance(Y)}}$$

where X and Y were considered as different traits under study.

A special SAS software (version 9) tool for diallel analysis developed by Zhang *et al.* (2005) was used to determine GCA effects, SCA effects, and their interaction effects with locations and also coefficient of correlation.

RESULTS AND DISCUSSION

Combined diallel analysis of variance

Results of combined analysis of variance across environments revealed that environment effects were highly significant (P<0.01) for days from emergence to silking (DS), plant height(PH), 1000-kernel weight (KW), number of kernels in ear row (KR), ear diameter (ED), cob diameter (CD), kernel yield (KY) indicating that these traits are influenced by environmental conditions. While, environment effects was not significant (P>0.05) for number of rows in ear (NR), indicating this trait is not influenced by environmental conditions (Table 1). Other researchers have found that environment effects were significant for days from emergence to silking, plant height (Mickelson *et al.*, 2001), number of rows per ear, number of kernels per row (Vidal-Martinez *et al.*, 2001) and grain yield (Doerksen *et al.*, 2003; Soengas *et al.*, 2003; Mickelson *et al.*, 2001; Vidal-Martinez *et al.*, 2001).Significant mean squares of general combining ability (GCA) and specific combining ability (SCA) estimates were detected for all the traits indicating the importance of both additive and non additive genetic effects for these traits (Table 1). Similarly, in earlier studies (Beck *et al.*, 1990; Crossa *et al.*, 1990; Vasal *et al.*, 1992; Kang *et al.*, 1995; Kim and Ayala, 1996; Xingming *et al.*, 2001; Bertan *et al.*, 2002; Revilla *et al.*, 2002; Glover *et al.*, 2005) were recorded significant mean square of GCA and SCA effects of yield components in corn.

Table1

Combined analysis of variance for different traits in 8 corn inbred lines and their F_1 diallel crosses across 4 environments (two years and two locations).

S.O.V	DF	DS	PH	KW	KR	NR	ED	CD	KY
Env.(E)	3	4820.2**	36258.79**	50533.38**	237.64**	4.22^{NS}	2.82**	0.376**	150.59**
E (REP)	12	134.98**	2565.7**	4648.83**	39.17**	12.32**	0.3**	0.073**	17.28**
Genotypes(G)	35	116.4**	7812.0**	5735.17**	273.89**	65.39**	1.58**	0.67**	54.1**
E×G	105	8.38^{NS}	532.8^{NS}	1479.59^{NS}	24.04**	7.18**	0.87**	0.044*	3.63**
GCA	7	363.97**	5440.53**	15087.0**	227.7**	208.9**	3.2**	2.17**	50.47**
SCA	28	46.14**	8435.6**	3983.77**	290.26**	28.66**	1.09**	0.27**	56.93**
GCA×E	21	10.99^{NS}	904.04*	1406.39^{NS}	1.45^{NS}	6.63**	0.11*	0.067**	3.78**
SCA×E	84	7.22^{NS}	469.05^{NS}	1452.81^{NS}	1.32*	7.03**	0.75^{NS}	0.038^{NS}	3.47**
Error	420	7.67	506.97	1207.79	16.8	2.1	0.06	0.033	1.87
GCA/SCA		7.89**	0.645^{NS}	3.787**	0.78^{NS}	7.288**	2.928**	8.07**	0.886^{NS}
h^2_N		0.607	0.1047	0.4318	0.1266	0.5907	0.365	0.618	0.146
d/a		1.08	4.01	1.35	3.6	1.13	1.81	1.05	3.36

DS: Days to ear silking, PH: plant height, KW: 1000-kernel weight, KR: number of kernels in ear row, NR: number of rows in ear, ED: ear diameter, CD: cob diameter, KY: kernel yield.; Ns,* and **: Non significant , significant at 5% and 1% levels , respectively

The narrow-sense heritability estimates were varied from 0.11 to 0.62 for PH and CD, respectively and the degree of dominance for these traits ranged form 4.01 to 1.05, respectively. The ratio of the GCA to SCA mean squares of the traits were varied from 0.78 to 7.89 for KR and DS, respectively (Table 1). Due to the moderately high narrow-sense heritability estimates, low degree dominance and significant GCA to SCA mean squares for DS, NR and CD, concluded that the additive genetic effect was more important for these traits. Non significant interaction effects of GCA and environments for DS, KW and KR revealed that the trend of variation of

GCA effects of parents were similar across the environments including years and locations. Non significant interaction effects of SCA × environments for most of the traits except KR and KY, indicated similar trend variations of SCA effects for most of the traits except KR and KY.

General combining ability of the parents

Table2

General combining effects of 8 corn lines for grain yield and related traits in two years and two locations using Griffing's method 2

Traits→ Lines↓	DS	PH	KW	KR	NR	ED	CD	KY
MO17	3.07**	-6.53**	21.26**	1.7**	-1.45**	-0.15* *	-0.168**	0.64 * *
Line8	1.146*	9.54**	4.85 N S	0.42 NS	0.96**	0.17**	0.092**	0.875* *
Line10	0.19 NS	5.94**	-3.37 N S	2.03**	-0.12 NS	-0.09**	-0.069**	0.207 N S
Line12	-1.22**	-4.55*	3.61 N S	-0.62 NS	0.68**	0.2**	0.154**	0.21 NS
Line21	-0.22 NS	-5.52**	-3.89 N S	-1.07*	0.39**	0.061**	0.07**	-0.45**
Line24	0.17 NS	2.2 NS	-3.06 N S	-0.7 NS	0.05 NS	0.06**	0.1**	-0.189 N S
Line33	-1.28**	3.63 NS	-7.58 *	-0.62 NS	0.52**	-0.04 NS	-0.027 NS	-0.443**
Line36	-1.85**	-4.71*	-11.83**	-1.14**	-1.03**	-0.22**	-0.15**	-0.845**

DS: Days to ear silking, PH: plant height, KW: 1000-kernel weight, KR: number of kernels in ear row, NR: number of rows in ear, ED: ear diameter, CD: cob diameter, KY: kernel yield; Ns,* and **: Non significant , significant at 5% and 1% levels , respectively

The mean of combining ability effects of parents for all the traits across the environments are presented in Table 2. For improving the early maturity maize genotypes lower values of DS is favorable, therefore Line 12, Line 33 and Line 36 with significant negative GCA effects were considered as good combiners for improving this trait. The parents; Line 33 and Line 36 with mean of 60.06 and 60.94 for DS are more profitable for improving this trait (Table 3). Lower plant height makes more tolerant to lodging, therefore the parents MO17, Line12 and Line 21 with means of 153.91, 147.33 and 160.06 cm of PH, respectively were suitable parents for this trait. All of these parents had significant negative GCA effects of PH. The mean of KW ranged from 227.86 to 280.14 g and the parents MO17, Line 12 and Line21 with 261.76, 268.03 and 280.14g mean of KW had high mean values for this trait. The Parent MO17 with significant positive GCA effect for KW was considered to be good combiners for improving this trait. Parents Line10 and MO17 had significant positive GCA effects for KR, hence were good combiners for increasing this trait. The mean value of the parents for KR varied from 26 to 32.5 in Line 24 and Line 10, respectively. Parents Line 8, Line 12, Line 21 and Line 33 had significant positive GCA effects for NR. The high values of this trait were detected for Line 8 and Line 22. Parents Line 8 and Line 12, Line 21 and Line 33 had significant positive GCA effects for ED making them good combiners for improving the trait. In addition, these parents had high mean values for ED (Table 3). The parents L10 and MO17 which had significant negative GCA effects for CD were good combiners for improving the trait. The low means value of this trait were also detected for MO17 and Line 36. Inbred lines Line 8, Line10, Line 12 and Line 21 had high means for KY (Table 3). Inbred lines MO17 and Line 8 with significant positive GCA effects of KY were good combiners for improving seed yield. Ojo *et al.* (2007) reported significant GCA effects for grain yield and yield components including ear length and ear diameter in diallel crosses of seven white corn inbred lines.

Table 3

Means of parents for different traits in eight corn lines in two years and two locations

Parents	DS	PH [cm]	KW [g]	KR	NR	ED [cm]	CD [CM]	KY [ton×ha^{-1}]
MO17	70.44	153.91	261.76	26.38	12.00	3.63	2.01	3.95
Line8	66.00	169.49	258.51	29.50	16.06	4.31	2.48	5.63
Line10	65.38	175.01	242.96	32.50	15.19	4.14	2.42	5.94
Line12	63.38	147.33	268.03	26.94	15.88	4.48	2.67	5.48
Line21	63.19	160.06	280.14	29.44	15.06	4.33	2.64	5.43
Line24	65.88	163.32	244.48	26.00	13.81	3.98	2.42	3.97
Line33	60.06	186.60	258.18	30.25	15.14	4.06	2.37	5.11
Line36	60.94	167.16	227.86	24.38	12.94	3.54	2.06	3.23
LSD5%	1.912	15.56	24.04	2.838	1.087	0.169	2.43	0.96

Specific combining ability of the crosses

The result of SCA effects of crosses across the four environments for the different traits are presented in Table 4. Non of the crosses had significant SCA effects for DS. This could be due to the relatively high narrow-sense heritability estimates that were observed for the trait, an indication that additive genetic effects were more important. The DS means varied from 57.94 to 65.31 for Line 12 × Line33 and MO17 × Line8, respectively (Table 5). The crosses with low value for DS had at least one parent with significant negative GCA effect for this trait. The parents can, therefore be used in breeding for early maturity. Out of 28 crosses, 3 crosses had significant SCA effects for PH. The cross MO17 × L21 with high negative SCA effects for PH was the best cross combination for this trait. Low values for plant height were observed for MO17 × Line 21 (172.98 cm), Line 12 × Line 36 (187.34cm) and Line 33 × Line 36 (196.35 cm), respectively.

Table 4

Specific combining effects of eight corn lines crosses for kernel yield and related traits in two years and two locations using Griffing's method 2

Crosses	DS	PH	KW	KR	NR	ED	CD	KY
MO17XLine8	-0.69 ^{NS}	-2.46 ^{NS}	27.57**	4.16**	-0.72**	0.062 ^{NS}	-0.03 ^{NS}	2.62**
MO17XLine10	0.01 ^{NS}	-0.68 ^{NS}	27.33**	2.74**	-0.068 ^{NS}	0.026 ^{NS}	-0.06 ^{NS}	0.9*
MO17XLine12	-0.33 ^{NS}	21.59 ^{NS}	-1.5 ^{NS}	5.88**	-0.053 ^{NS}	0.198**	0.072 ^{NS}	2.04**
MO17XLine21	-2.2 ^{NS}	-18.59 ^{NS}	-23.24**	-5.6**	0.81**	-0.028 ^{NS}	0.058 ^{NS}	-1.79**
MO17XLine24	-0.59 ^{NS}	8.83 ^{NS}	6.39 ^{NS}	2.65**	0.07 ^{NS}	0.108 ^{NS}	0.06 ^{NS}	0.55 ^{NS}
MO17XLine33	1.11 ^{NS}	7.3 ^{NS}	4.52 ^{NS}	1.57 ^{NS}	-0.21 ^{NS}	0.045 ^{NS}	0.081*	-0.14 ^{NS}
MO17XLine36	0.18 ^{NS}	20.66 ^{NS}	7.96 ^{NS}	0.35 ^{NS}	1.15**	0.146*	0.004 ^{NS}	0.997**
Line 8X Line 10	1.12 ^{NS}	24.18**	-1.72 ^{NS}	0.89 ^{NS}	0.51*	0.158*	0.062 ^{NS}	0.73 ^{NS}
Line 8X Line 12	0.28 ^{NS}	2.09 ^{NS}	10.4 ^{NS}	-0.71 ^{NS}	0.53*	0.107 ^{NS}	0.129**	-0.14 ^{NS}
Line 8X Line 21	0.41 ^{NS}	11.58 ^{NS}	-3.43 ^{NS}	1.74 ^{NS}	-0.31 ^{NS}	0.003 ^{NS}	-0.059 ^{NS}	0.8*
Line 8X Line 24	-1.36 ^{NS}	1.00 ^{NS}	-5.75 ^{NS}	-0.38 ^{NS}	0.28 ^{NS}	0.025 ^{NS}	0.013 ^{NS}	0.15 ^{NS}
Line 8X Line 33	-0.65 ^{NS}	6.74 ^{NS}	-14.9 ^{NS}	-0.08 ^{NS}	1.06**	0.09 ^{NS}	0.023 ^{NS}	-0.22 ^{NS}
Line 8X Line 36	-1.02 ^{NS}	10.08 ^{NS}	7.31 ^{NS}	0.44 ^{NS}	0.42 ^{NS}	0.07 ^{NS}	0.11**	0.011 ^{NS}
Line 10X Line 12	-1.76 ^{NS}	-0.238 ^{NS}	-6.4 ^{NS}	1.06 ^{NS}	-0.07 ^{NS}	-0.122*	0.002 ^{NS}	0.24 ^{NS}
Line 10X Line 21	-1.076 ^{NS}	2.81 ^{NS}	-0.1 ^{NS}	0.76 ^{NS}	-0.1 ^{NS}	-0.065 ^{NS}	-0.104**	0.16 ^{NS}
Line 10X Line 24	-0.53 ^{NS}	8.07 ^{NS}	4.97 ^{NS}	0.57 ^{NS}	-0.57 ^{NS}	0.024 ^{NS}	-0.055	-0.06 ^{NS}
Line 10X Line 33	-0.139 ^{NS}	4.43 ^{NS}	-0.119 ^{NS}	-0.38 ^{NS}	0.77**	0.14*	0.14**	0.35 ^{NS}
Line 10X Line 36	-0.818 ^{NS}	1.9 ^{NS}	-5.41 ^{NS}	0.64 ^{NS}	0.003 ^{NS}	0.011 ^{NS}	-0.004 ^{NS}	0.0002 ^{NS}
Line 12X Line 21	0.96 ^{NS}	12.6*	0.444 ^{NS}	1.22 ^{NS}	0.35 ^{NS}	0.112 ^{NS}	0.064 ^{NS}	0.418 ^{NS}
Line 12X Line 24	-1.12 ^{NS}	9.62 ^{NS}	2.7 ^{NS}	0.16 ^{NS}	1.07**	0.157*	0.05 ^{NS}	0.202 ^{NS}
Line 12X Line 33	-1.35 ^{NS}	8.51 ^{NS}	10.53 ^{NS}	-0.86 ^{NS}	0.35 ^{NS}	0.121*	-0.02 ^{NS}	0.58 ^{NS}
Line 12X Line 36	-0.717 ^{NS}	-7.00 ^{NS}	-8.71 ^{NS}	-0.21 ^{NS}	-0.79**	-0.178**	-0.121**	-0.55 ^{NS}
Line 21X Line 24	0.26 ^{NS}	15.12*	1.47 ^{NS}	0.86 ^{NS}	0.79**	0.126*	0.083*	0.69 ^{NS}
Line 21X Line 33	0.15 ^{NS}	6.64 ^{NS}	-7.35 ^{NS}	2.35*	-0.24 ^{NS}	-0.118 ^{NS}	-0.194**	0.39 ^{NS}
Line 21X Line 36	-0.34 ^{NS}	2.33 ^{NS}	12.55 ^{NS}	1.8*	0.32 ^{NS}	0.24**	0.189**	0.84*
Line 24X Line 33	-0.12 ^{NS}	-3.18 ^{NS}	3.56 ^{NS}	-0.47 ^{NS}	0.41 ^{NS}	0.02 ^{NS}	0.126**	0.62 ^{NS}
Line 24X Line 36	-0.29 ^{NS}	5.24 ^{NS}	4.32 ^{NS}	3.93**	0.14 ^{NS}	0.17**	0.042 ^{NS}	1.35**
Line 33X Line36	0.158 ^{NS}	-6.18 ^{NS}	-1.28 ^{NS}	1.1 ^{NS}	-0.33 ^{NS}	0.05 ^{NS}	-0.045 ^{NS}	0.28 ^{NS}

DS: Days to ear silking, PH: plant height, KW: 1000-kernel weight, KR: number of kernels in ear row, NR: number of rows in ear, ED: ear diameter, CD: cob diameter, KY: kernel yield.; Ns,* and **: Non significant, significant at 5% and 1% levels , respectively

Table 5-

Means of different traits in diallel crosses of eight corn lines in two years and two locations

Crosses	DS	PH [cm]	KW [g]	KR	NR	ED [cm]	CD [CM]	KY [ton/ha]
MO17X Line 8	65.31	204.17	321.94	41.00	14.69	4.57	2.43	11.98
MO17X Line 10	65.06	202.35	313.49	41.19	14.25	4.27	2.24	9.60
MO17X Line 12	63.31	214.12	291.64	41.69	15.06	4.73	2.60	10.74
MO17X Line 21	62.44	172.98	262.39	29.75	15.65	4.37	2.50	6.25
MO17X Line 24	64.44	208.13	292.86	38.38	14.56	4.51	2.53	8.85
MO17X Line 33	64.69	208.03	286.47	37.38	14.75	4.34	2.42	7.91
MO17X Line 36	63.19	213.03	285.66	35.63	14.56	4.27	2.22	8.64
Line 8X Line 10	64.25	243.27	268.03	38.06	17.25	4.73	2.62	9.67
Line 8X Line 12	62.00	210.69	287.13	33.81	18.06	4.96	2.91	8.80
Line 8X Line 21	63.13	219.22	265.79	35.81	16.94	4.72	2.64	9.07
Line 8X Line 24	61.75	216.36	264.30	34.06	17.19	4.75	2.74	8.69
Line 8X Line 33	61.00	223.53	250.61	34.44	18.44	4.71	2.63	8.07
Line 8X Line 36	60.06	218.52	268.59	34.44	16.25	4.51	2.58	7.89
Line 10X Line 12	59.00	204.76	262.11	37.19	16.38	4.47	2.43	8.50
Line 10X Line 21	60.69	206.84	260.91	36.44	16.06	4.39	2.51	7.76
Line 10X Line 24	61.63	219.83	266.81	36.63	15.25	4.49	2.58	7.80
Line 10X Line 33	60.56	217.61	257.19	35.75	17.06	4.50	2.31	7.96
Line 10X Line 36	59.31	206.74	247.66	36.25	14.75	4.19	2.83	7.21
Line 12X Line 21	61.31	206.14	268.43	34.25	17.31	4.85	2.84	8.02
Line 12X Line 24	59.63	210.88	271.52	33.56	17.69	4.90	2.64	8.07
Line 12X Line 33	57.94	211.20	274.83	32.63	17.44	4.76	2.42	8.19
Line 12X Line 36	58.00	187.34	251.34	32.75	14.75	4.29	2.79	6.67
Line 21X Line 24	62.00	215.42	262.78	33.81	17.13	4.74	2.39	7.90
Line 21X Line 33	60.44	208.36	249.44	35.38	16.56	4.39	2.65	7.34
Line 21X Line 36	59.38	195.71	265.10	34.31	15.58	4.57	2.74	7.39
Line 24X Line 33	60.56	206.26	261.18	32.94	16.88	4.53	2.53	7.84
Line 24X Line 36	59.81	206.34	257.70	36.81	15.06	4.51	2.31	8.17
Line 33X Line36	58.81	196.35	247.58	34.06	15.06	4.28	2.39	6.84
LSD 5%	1.912	15.56	24.04	2.838	1.087	0.169	2.43	0.96

Table 6

Correlation between the traits in half diallel crosses of eight parents of maize

Traits	DS	PH	KW	KR	NR	ED	CD	KY
DS	1							
PH	0.071ns	1						
KW	-0.016ns	0.27ns	1					
KR	-0.049ns	0.80**	0.56**	1				
NR	-0.21ns	0.59**	0.06ns	0.29ns	1			
ED	-0.051ns	0.66**	0.41*	0.54**	0.86**	1		
CD	-0.04ns	0.28ns	0.07ns	0.23ns	0.57**	0.65**	1	
KY	0.071ns	0.85**	0.61**	0.91**	0.53**	0.77**	0.35*	1

Significant, positive correlations were determined for KY with KW, NR and ED (Table 6), implying that crosses with high means value of these traits can be used for improving of KY. Among the crosses, only MO17 × Line 8 and MO17 × Line 10 had significant positive SCA effect for KW and these crosses had high means for KW. Significant positive correlation were detected between KR and KY. Therefore, the genotypes with high value for KR will have high KY. The crosses MO17 × Line 8, MO17 × Line 10, MO17 × Line 12, MO17 × Line 24, Line 21 × Line26 and Line 24 × Line 36 had significant positive SCA effect for KR were considered suitable cross combinations for KR. All of the crosses with significant positive SCA effect for KR had at least on parent (MO17) with significant positive GCA effect for KR. Out of 28 crosses, 8 crosses had significant positive SCA effect for NR. Significant positive correlation was determined between ED and KY, therefore this trait can also be used as indirect selection criterion for improving KY. Out of 28 crosses, 6crosses had significant SCA effects for ED. The crosses including MO17 × Line 12, MO17 × Line 36, Line10 × Line36, Line 12 × Line 24, Line 12 × Line 33, Line 21 × Line 24,L12 × L36 and Line 24 × Line 36 had significant positive SCA effects and were considered as good cross combinations for improving ED. Low mean value of CD is favored, therefore the crosses Line10 × Line21, Line 12 × Line 36 and Line 21 × Line 36 with significant negative SCA effects were preferred for improving this trait. Out of 28 crosses, 7 crosses had significant SCA effects for KY. Most of the crosses with SCA effects for KY had at least one parent with significant GCA effect for this trait. The crosses MO17 × Line8, MO17 × Line 10 and MO17 × Line 12, Line 8 × Line 10 and Line 8 × Line 21 had high KY were considered as good combinations for improving the trait. Significant SCA effects were reported for kernel yield and yield components in diallel crosses of corn breeding lines (Revila *et al.*, 2002; Glover *et al.*, 2005; Fan *et al.*, 2007).

CONCLUSION

High narrow-sense heritability estimates, low degree dominance and significant GCA to SCA mean squares were estimated for DS, NR and CD, implied that the additive genetic effect was more important for these traits. Non significant interaction effects of GCA and environments for DS, KW and KR indicated that the trend of variation of GCA effects of parents were similar across the environments including years and locations. Non significant interaction effects of SCA × environments for most of the traits except KR and KY, indicated similar trend variations of SCA effects for most of the traits except KR and KY. Significant, positive correlations were determined for KY with KW, NR and ED, implying that crosses with high means value of these traits can be used for improving of KY. Most of the crosses with high values of KY had at least one parent with significant positive GCA effect for this trait.

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