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Full Length Research Paper

Gene action of some agronomic traits in corn (*Zea mays* L.) using diallel cross analysis

Mahdi Zare[1]*, Rajab Choukan[2], Eslam Majidi Heravan[3], Mohammad Reza Bihamta[4] and Kourosh Ordookhani

[1]Islamic Azad University, Firoozabad Branch, Iran.
[2]Agricultural Research Seed and Plant Improvement Institute, Karaj, Iran.
[3]Agriculture Biotechnology Research Institute, Karaj, Iran.
[4]Agriculture College, Tehran University, Karaj, Iran.
[5]Islamic Azad University, Firoozabad Branch, Iran.

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In 2007, seven inbred lines of corn were crossed in a complete diallel cross design (Griffing's method 1). The seven parents and their 42 hybrids were planted in field based on Random Complete Block Design (RCBD) with three replications in two different environments. The studied traits were days from emergence to silking, days from emergence to physiological maturity, plant height, ear height, area of ear leaf, ear length, area of flag leaf, number of rows per ear, number of kernels per row and grain yield. Results of combined ANOVA revealed that environment effect was significant for all the traits. Based on diallel cross analysis according to Griffing method 1, General Combining Ability (GCA) and Specific Combining Ability (SCA) effects were significant for the majority of traits. Reciprocal variance effects were significant for days from emergence to physiological maturity and number of rows per ear that indicate presence of cytoplasmic inheritance. ${}^{2}_{GCA}/\ {}^{2}_{SCA}$ ratio revealed that additive gene effects were predominant in controlling 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.

Key words: Corn, diallel, combining ability, heterosis.

INTRODUCTION

Corn has a remarkable place among cereals and it is used as human food, animal feeding and industry (Keskin et al., 2005) . The identification of parental inbred lines that perform superior hybrids is the most costly and time-consuming phase in maize hybrid development. Per se performance of maize inbred lines does not predict the performance of maize hybrids for grain yields (Hallauer and Miranda, 1988). Predictors of single-cross hybrid value or heterosis between parental inbred lines could therefore increase the efficiency of hybrid breeding programs (Betran et al., 2003). Plant breeders and geneticists often use diallel mating designs to obtain genetic information about a trait of interest from a fixed or randomly chosen set of parental lines (Murray et al., 2003).

The combining ability analysis is an important method to know gene actions and it is frequently used by crop breeders to choose the parents with a high general combining ability (GCA) and hybrids with high specific combining ability (SCA) effects (Yingzhong, 1999). Beside gene effects, breeders would also like to know how much of the variation in a crop is genetic and to what extent this variation is heritable, because efficiency of selection mainly depends on additive genetic variance, influence the environment and interaction between

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*Corresponding author. E-mail: zaremahdi@hotmail.com. Tel.: 0987126229701-5. Fax: 00987126224402.

genotype and environment (Novoselovic et al., 2004). Large genotype × environment effects tend to be viewed as problematic in breeding because the lack of a predictable response hinders progress from selection (Dudley and Moll, 1969). Most of the literature about maize, the most extensively studied plant species, suggests that additive effects of genes with partial to complete dominance are more important than dominance effects in determining grain yield (Lamkey and Lee 1993). Breeders still contend, however, that dominance effects caused by genes with over dominant gene action are also important (Horner et al., 1989).

According to Jones and Frey (1960), heritability of a trait approaches its maximum in successive generations following hybridization. Furthermore, the presence of additive gene effects for traits indicates the presence of additive variation, which means that selection can be successful for traits (Fehr, 1991; Gamble, 1962). An experiment was established with three FAO groups of maturity and with eight inbred lines of maize (*Zea mays* L.) within each FAO group. The significant differences between the combinations of crosses and also significant effect on the general (GCA) and specific (SCA) combining ability in the three examined FAO groups of crosses were found. These results have indicated that we have to make selection and test the inbreds and their hybrids under the conditions or in areas where we intent to establish maize production. The inbred lines of maize were significantly higher average yields of their crosses (Stipe et al., 1993) . The combining ability as well as reciprocal effect in diallel of sweet and regular corn genotypes was investigated for some traits. General Combining Ability (G.C.A.) and Specific Combining Ability (S.C.A.) mean square values were statistically significant for plant height, average ear length and weight indicating that additive and non-additive genetic effects control these characters. There was no statistical difference regarding mean square effects of average ear length and weight characters suggesting the utilization of intra and inter population breeding methods (Bordallo et al. 2005). Vasal et al. (1993) were analyzed ten parents in a diallel study in eight environments.

The results revealed that GCA effects were highly significant for all traits and SCA effects were significant for time to silk and plant height. Genotype × environment interactions and their partitions were significant for grain yield. In other diallel study, entry, environment, and entry × environment effects were significant for grain yield in the analysis combining yield data from all environments (Mickelson et al., 2001). Glover et al. (2005) using diallel cross analysis revealed that highly significant general and specific combining ability effects with 12 crosses exhibiting high-parent heterosis greater than 20% for grain yield. Bhatnagar et al. (2004) were evaluated seven white and nine yellow QPM (quality protein maize) inbreds in two separate diallel experiments in five environments. The QPM hybrids yielded less than commercial checks. Across environments, GCA effects were non significant for grain yield but highly significant for agronomic and kernel-quality traits. The F_1 progenies of a five- parent diallel cross (excluding reciprocals) were analyzed for combining ability for some quantitative traits in baby corn. The results showed that an excellent general combining abilities was found with harvesting age on direct crosses and number of cobs/plant of reciprocal off-springs. The results indicated that both characteristics had derived from additive gene action. The effect of maternal inheritance was significant in some environments (Kasikranan, 1999).

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). Some agronomy traits were examined on 45 F_1 hybrids (10 × 10 diallel cross) in order to study their genetic relationships with yield. Combining ability analysis revealed that all trait variability derived mainly from G.C.A. effects. Ear size (row number and kernels per row) components were also positively related to yield and considering S.C.A. effects, kernel number per row made the most important contribution (Ottaviano and Camussi, 1981).

In other research, the results allowed to conclude that both GCA and SCA capacity as well as the reciprocal effects were significant ($p < 0.01$) (Keskin et al., 2005). Shopova and Jordanov (1990) investigated the inheritance of ear leaf area in maize and showed that both genotypes and environments had considerable effects on the growth period. High heterosis effect and over-dominance were evident in the inheritance of ear leaf area. Dominant gene effect [d] played an important role in the genetic control of maize ear leaf formation. It increased the expression of the character. Vidal-Martinz et al. (2001) reported that a genetic effect was found rather than an environmental effect on the expression of grain yield components. Also, dominance gene effects were the most important contributors to the inheritance of grain yield and their components.

The objective of the diallel study presented here were to estimate genetic parameters like heterosis and general and specific combining abilities of seven inbred lines of maize and phenotypic and genotypic 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

The following 7 inbred lines were studied: K18, K3218, K1264.1, MO17, K19, K74.1 and K3653.5. The lines were differed considerably in expression of various agronomy traits. Seven inbred lines were crossed in the summer of 2006 at Agricultural Research Seed and Plant Improvement Institute of Karaj in a full diallel to give 42 crosses excluding reciprocal crosses[n(n-1) where: n is the number of inbred lines]. The parents and their 42 F_1 hybrids were planted in field based on RCBD with three replications in two different environments. The first environment was research seed and plant improvement institute of Karaj (35.49°N, 51.06°E, and 1321 m above sea level) and the second environment was research station of Islamic Azad University of Firouzabad (28.35°N, 52.40°E and 1327 m above sea level). Kernels were hand-sown on May 13 and 21 in 2007 and 2008 respectively and 3 to 4 seeds were placed per hill.

Each replication contained 49 plots and each plot consisted of 1 row with 6 m long and spacing of 20 cm between plants within row and 75 cm between rows. In order to keep uniformity within replication, each replication divided to 2 blocks. After emergence, at the 3 to 4- leaf stage, the plant seedlings were thinned leaving only one plant per hill. Fertilizer treatments were 300 kg/ha of ammonium phosphate and 200 kg/ha N applied prior to planting plus an additional 200 kg/ha N topdressed at 7 to 9-leaf stage. Hand-weeding was carried out four times during the growth period. Eight plant samples were chosen from middle part of each row and were signed by lables and the border parts were left out. Then, the labled plant samples were measured for the following traits: days from emergence to silking (number of days from 50% plant emergence to 50% of plants had extruded silks), days from emergence to physiological maturity (number of days from 50% plant emergence to when 50% of plants reached physiological maturity), plant height (centimeters from the soil surface to the node below the tassel), ear height (centimeters from the soil surface to the top-ear node), area of ear leaf (was calculated as follows:

(A=WxLx0.75 where A= area of ear leaf in square centimeters, W= length of ear leaf in centimeters and L= width of ear leaf in centimeters), ear length (centimeters from the length of an unhusked ear from the butt to the tip), area of flag leaf (was calculated as follows: (A=WxLx0.75 where A= area of flag leaf in square centimeters, W= length of flag leaf in centimeters and L= width of flag leaf in centimeters), number of rows per ear, number of kernels per row and grain yield. Grain yield trait was adjusted to 14% of grain moisture.

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, direct and reciprocal crosses was conducted using the Diallel-SAS procedure developed by Zhang et al. (2005), according to Griffing's (1956) method 1, Model 1, which included the parents, direct and reciprocal crosses.

The Diallel -SAS program evaluating main genotype effects contain GCA, SCA, reciprocal, maternal and nonmaternal effects and their interaction with environment. Thus this program estimated data for environmental effects, as well as effects due to genotype, block, and the intractions between various effects. For a diallel mating from a set of inbred lines, the generation means (Y_{ijk}) observation in environment k of maternal line i and parental line j can be partitioned as the following model:

$$Y_{ijk} = \mu + g_i + g_l + s_{ij} + l_k + (gl)_{ik} + (gl)_{jk} + (sl)_{ijk} + {}_{ijk}$$

Where, Y_{ijk} = observation in environment k of parents i and j; μ = general mean; g_i or g_j = GCA effect of parents i or j; s_{ij} =SCA effect of the cross between parents i and j; l_k = effect of location k; $(gl)_{ik}$ or $(gl)_{jk}$ interaction effect between GCA of parent i or j with location k; (sl_{ijk}) interaction effect between SCA of cross ij and location k; and ${}_{ijk}$ = error of observation ijk. F values for testing combining abilities were calculated as follows:

${}^{2}_{scaEnv} = MS_{scaEnv}/MS_e$
${}^{2}_{gcaEnv} = MS_{gcaEnv}/MS_{scaEnv}$
${}^{2}_{sca} = MS_{sca}/MS_{scaEnv}$
${}^{2}_{gca} = (MS_{gca} + MS_{scaEnv})/(MS_{sca} + MS_{gcaEnv})$

Where, ${}^{2}_{gca}$, ${}^{2}_{sca}$, ${}^{2}_{gcaEnv}$ and ${}^{2}_{scaEnv}$ are variance due to GCA, SCA, GCA × environment and SCA × environment, respectively, and MS_{gca}, MS_{sca}, MS_{scaEnv}, MS_{gcaEnv} and MS_e are mean squares due to GCA, SCA, GCA × environment, SCA × environment and error, respectively.

Broad sense heritability (h_b^2) and narrow sense heritability (h_n^2) for mean values over environments were calculated following the components of variance (Teklewold and Becker 2005):

$$h_b^2 = \frac{2\sigma^2_{gca} + \sigma^2_{sca}}{2\sigma^2_{gca} + \sigma^2_{sca} + \left(\frac{2\sigma^2_{gca}}{Env}\right) + \left(\frac{\sigma^2_{sca}}{Env}\right) + \left(\frac{\sigma^2_e}{REnv}\right)}$$

$$h_n^2 = \frac{2\sigma^2_{gca}}{2\sigma^2_{gca} + \sigma^2_{sca} + \left(\frac{2\sigma^2_{gca}}{Env}\right) + \left(\frac{\sigma^2_{sca}}{Env}\right) + \left(\frac{\sigma^2_e}{REnv}\right)}$$

Baker (1978) suggested genetic ratio that the progeny performances could be predicted by the use of the ratio of combining ability variance components:

$$\text{Genetic ratio} = \frac{2MS_{gca}}{2MS_{gca} + MS_{sca}}$$

Heterosis for all traits was estimated based on the behavior of the most outstanding parent, given that such estimation is useful to justify the use of hybrid seed (Fehr 1991):

High-parent heterosis (Heterobeltosis)(%) = [(F_1-HP)/HP] × 100

Where F_1= performance of F_1 hybrid; HP= performance of the best parent. The difference of F_1 mean from the respective better parent value was evaluated as follows:

$$\text{LSD} = \sqrt{\frac{MS_e}{r}} \times t$$

Where, MS_e= the error mean squares; r= the number of replication and t= the table value of t at 5 or 1% level of significance. 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 I (Model A) diallel analysis was used to estimate GCA for the lines and SCA for the hybrids and reciprocal effects across environments. 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:

$$\frac{\sigma_{gca}^{2}}{\sigma_{sca}^{2}}$$

Where, σ_{gca}^{2} and σ_{sca}^{2} are the variance components for GCA and SCA.

RESULTS AND DISCUSSION

Results of combined ANOVA across environments revealed that environment effects were highly significant ($P<0.01$) for days from emergence to silking, days from emergence to physiological maturity, ear height, area of ear leaf, ear length, area of flag leaf, number of rows per ear and number of kernels per row, indicating that these traits are influenced by environmental conditions. While, environment effects were not significant ($P>0.05$) for plant height and grain yield indicating that both traits are not influenced by environmental conditions (Table 1). Other authors have found that environment effects were significant for days from emergence to silking, plant height (Mickelson et al., 2001), number of rows per ear, ear length (Soengas et al., 2003), 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).

Genotype × environment interaction effects were not significant ($P>0.05$) for days from emergence to silking, area of flag leaf and grain yield, suggesting that genotypes maintain their rank for these traits across environments. Non significant genotype × environment interaction effects indicated that selection for days from emergence to silking, area of flag leaf and grain yield at one environment might be effective for a broad range of environments. Genotype × environment interaction effects were significant for other traits, indicating that genotypes did not respond to the environments similarly (Table 1). Other researchers have reported that genotype × environment 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; Welcker et al. 2005). Genetic variability of genotypes was significant for all traits. As a result, the genotype sum of squares was partitioned into GCA, SCA and Reciprocal effects (Table 1). Mickelson et al. (2001) similarly revealed that genotype effects were highly significant for plant height, days from emergence to silking and grain yield.

Our results showed that general combining ability (GCA) was highly significant ($P<0.01$) for days from emergence to silking, days from emergence to physiological maturity, plant height, area of ear leaf, ear length, area of flag leaf, number of rows per ear and number of kernels per row, and significant ($P<0.05$) for ear height and grain yield, indicating that additive gene action is important in the inheritance of these traits (Table 1). Specific combining ability (SCA) was also highly significant ($P<0.01$) for all traits except area of flag leaf indicating that non additive gene action is important in the inheritance of these traits. Variance of reciprocal effects was statistically significant for days from emergence to physiological maturity and number of rows per ear. Maternal main effects also were significant for plant height, area of ear leaf and number of rows per ear. Significant non-maternal effect was shown only for days from emergence to physiological maturity and number of rows per ear. GCA × environment interaction effects were significant for all trairs except days from emergence to silking and plant height. SCA×environment interaction effects were significant for all trairs except area of ear leaf, area of flag leaf and grain yield. REC×environment and NONMAT×environment effects were not significant for all trairs except number of rows per ear and number of kernels per row. Estimation of genetic parameters is given in Table 2. The closer genetic ratio (Baker 1978) to unity shows the predictability based on GCA alone. Also the GCA/SCA ratio reveals that different traits show an 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, days from emergence to silking, days from emergence to physiological maturity, plant height, ear height, number of rows per ear, number of kernels per row and grain yield, 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; hence, heterosis and use of hybrid vigor could be applied for improving them. 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), area of plant leaf (Suneetha et al., 2000), ear length (Rezaei and Roohi, 2004; Vidal-Martinez et al., 2001), ear height (Rezaei and Roohi, 2004; Alam et al., 2008), number of rows per ear (Saeed et al., 2000; Vidal-Martinez et al., 2001), number of kernels per row (Vidal-Martinez et al., 2001; Srdic et al., 2007) and grain yield (Rezaei and Roohi, 2004; Srdic et al., 2007; Bhatnagar et al., 2004).

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). Area of ear leaf, ear length and area of flag leaf

Table 1. Combined analysis of different traits of maize based on Griffing's method 1(Model A) in a 7*7 diallel crosses.

Traits Source of variation [1)]	d.f.	Days from emergence to silking	Days from emergence to physiological maturity	Plant height (cm)	Ear height (cm)	Area of ear leaf (cm^2)	Ear length (cm)	Area of flag leaf (cm^2)	Number of rows per ear	Number of kernels per row	Grain yield (gr/plant)
		Mean squares									
ENV	1	419.05 **	16001.91 **	6823.77 ns	104838.38 **	2160803.7 **	8624.53 **	204783.54 **	174.65 **	3806.64 **	2.42 ns
REP/ENV	4	16.36	65.99	7606.02	1396.65	8475.06	29.8	6635.49	6.71	81.6	3.24
Genotype	48	38.86 **	37.62 **	1677.23 **	774.31 **	15783.43 **	6.8 *	3017.03 **	34.97 **	114.61 **	4.52 **
GCA	6	93.78 **	138.97 **	1693.41 **	1007.15 *	40718.28 **	19.39 **	15535.77 **	213.44 **	286.72 **	5.28 *
SCA	21	51.53 **	21.76 **	2926.92 **	1241.29 **	17259.11 **	7.45 **	1838.22 ns	14.65 **	155.12 **	5.72 **
REC	21	10.51 ns	24.52 **	422.95 ns	240.80 ns	7183.49 ns	2.55 ns	619.06 ns	4.31 **	24.91 ns	3.10 ns
MAT	6	2.69 ns	12.04 ns	822.34 *	280.46 ns	19546.09 *	3.08 ns	900.85 ns	5.46 **	40.08 ns	2.97 ns
NONMAT	15	13.64 ns	29.51 **	263.2 ns	224.93 ns	2238.45 ns	2.34 ns	506.34 ns	3.85 *	18.84 ns	3.15 ns
Genotype×ENV	48	19.36 ns	32.32 **	933.73 **	415.24 **	15873.47 **	9.99 **	6113.41 ns	9.1 **	56.15 **	2.98 ns
GCA×ENV	6	26.6 ns	145.82 **	770.45 ns	1151.95 **	76285.77 **	52.03 **	37251.97 **	28.60 **	85.54 **	4.91 *
SCA×ENV	21	27.97 **	24.26 **	1376.98 **	479.07 **	9180.09 ns	5.8 **	1115.01 ns	6.23 **	62.57 **	2.88 ns
REC×ENV	21	8.67 ns	7.96 ns	537.14 ns	140.93 ns	5306.18 ns	2.18 ns	2215.09 ns	6.39 **	41.33 *	2.52 ns
MAT×ENV	6	5.98 ns	4.34 ns	402.42 ns	243.5 ns	7813.91 ns	1.64 ns	3042.96 ns	7.88 **	32.10 ns	3.25 ns
NONMAT×ENV	15	9.75 ns	9.41 ns	591.02 ns	99.9 ns	4303.09 ns	2.39 ns	1883.94 ns	5.80 **	45.02 *	2.22 ns
Error	192	12.92	6.36	378.8	144.18	6789.43	2.18	1672.49	1.88	23.61	2.24
Total	293										

ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively. 1) ENV: Environment; REP: Replication; REC: Reciprocal effects; GCA: General Combining Ability; SCA: Specific Combining Ability; MAT: maternal effects; NONMAT: non-maternal effects.

traits showed additive genetic effects, indicating additive genetic effects were more important than non-additive genetic effects in controlling the inheritance of these traits. According to important role of GCA, the improvement of these traits is easy through selection. The values of mean degree of dominance $(\sigma^2_D/\sigma^2_{A})^{0.5}$ was less than unity for days from emergence to silking, plant height, ear height, number of kernels per row and grain yield, indicating the existence of partial dominance for them.

In Table 3, the GCA effects of traits are listed. 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. The significant GCA effects for all of the parents were only found in the number of rows per ear, and in the other traits it was significant for some of the parents' except for ear height and ear length. K18 inbred line showed to be the best general combiner for number of kernels per row (2.28). K3218 inbred line was the best combiner for days from emergence to silking (1.67) and days from emergence to physiological maturity (1.87). K1264.1 inbred line was the best combiner for grain yield (0.46) and the worst parent for days from emergence to silking (-1.71), days from emergence to physiological maturity(-2.44) and area of flag leaf (-15.06) and the second worst parent for area of ear leaf (-30.20). MO17 inbred

Table 2. Estimation of genetic parameters of maize in a 7*7 diallel crosses.

Genetic parameters[1)]	Days from emergence to silking	Days from emergence to physiological maturity	Plant height (cm)	Ear height (cm)	Area of ear leaf (cm^2)	Ear length (cm)	Area of flag leaf (cm^2)	Number of rows per ear	Number of kernels per row	Grain yield (gr/plant)
σ_D^2	15.724	23.51	1556.86	1.062	760.244	0.584	1.746	0.100	2.976	15.724
σ_A^2	86.647	30.146	577.66	0.3647	70.162	0.392	3.937	0.181	1.527	86.647
$\sigma_{gca}^2 / \sigma_{sca}^2$	0.15	0.97	0.09	0.39	1.357	1.46	5.42	0.74	0.22	0.28
Genetic ratio	0.24	0.66	0.15	0.44	0.73	0.74	0.92	0.60	0.31	0.36
DH	0.555	1.396	0.426	0.883	1.642	1.706	3.292	1.220	0.666	0.743
h_b^2	0.41	0.58	0.47	0.51	0.49	0.57	0.54	0.55	0.46	0.35
h_n^2	0.10	0.38	0.07	0.22	0.36	0.42	0.50	0.33	0.14	0.13
σ_{gca}^2	7.862	11.755	778.43	0.531	380.122	0.292	0.873	0.050	1.488	7.862
σ_{sca}^2	86.647	30.146	577.66	0.3647	70.162	0.392	3.937	0.181	1.527	86.647

1) σ_D^2: dominance variance, σ_A^2: additive variance, DH: degree of dominance, h_b^2: broad sense heritability, h_n^2: narrow sense heritability, σ_{gca}^2: GCA variance, σ_{sca}^2: SCA variance. ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively.

Table 3. General combining ability and maternal effects in a 7*7 complete diallel.

Parent	Days from emergence to silking		Days from emergence to physiological maturity		Plant height		Ear height		Area of ear leaf	
	GCA	MAT	GCA	MAT	GCA	MAT	GCA	MAT	GCA	MAT
K18	-0.06 ^{ns}	0.29 ^{ns}	0.08 ^{ns}	0.29 ^{ns}	3.47 ^{ns}	3.11 ^{ns}	4.41 ^{ns}	1.58 ^{ns}	17.14 ^{ns}	0.33 ^{ns}
K3218	1.67 **	0.64 ^{ns}	1.87 *	0.64 ^{ns}	-0.02 ^{ns}	-0.72 ^{ns}	4.16 ^{ns}	-0.82 ^{ns}	4.18 ^{ns}	-0.22 ^{ns}
K1264.1	-1.71 **	-0.07 ^{ns}	-2.44 **	-0.07 ^{ns}	2.49 ^{ns}	0.97 ^{ns}	-2.37 ^{ns}	0.01 ^{ns}	-30.20 *	6.81 ^{ns}
MO17	0.28 ^{ns}	-0.44 ^{ns}	0.17 ^{ns}	-0.44 ^{ns}	2.53 ^{ns}	0.77 ^{ns}	-3.48 ^{ns}	0.83 ^{ns}	-31.1 *	-14.97 ^{ns}
K19	0.71 ^{ns}	-0.14 ^{ns}	-0.16 ^{ns}	-0.14 ^{ns}	0.45 ^{ns}	3.20 ^{ns}	2.21 ^{ns}	1.38 ^{ns}	19.14 ^{ns}	11.30 ^{ns}
K74.1	-0.37 ^{ns}	-0.37 ^{ns}	-0.15 ^{ns}	-0.37 ^{ns}	0.84 ^{ns}	-1.45 ^{ns}	-2.93 ^{ns}	0.74 ^{ns}	18.62 ^{ns}	20.66 ^{ns}
K3653.5	-0.52 ^{ns}	0.10 ^{ns}	0.63 ^{ns}	0.10 ^{ns}	-9.77 **	-5.89 *	-2.01 ^{ns}	-3.71 ^{ns}	2.22 ^{ns}	-23.90 ^{ns}

Parent	Ear length		Area of flag leaf		Number of rows per ear		Number of kernels per row		Grain yield	
	GCA	MAT	GCA	MAT	GCA	MAT	GCA	MAT	GCA	MAT
K18	0.74 ^{ns}	0.12 ^{ns}	-4.06 ^{ns}	0.16 ^{ns}	-0.81 **	0.03 ^{ns}	2.28 **	0.97 ^{ns}	-0.09 ^{ns}	-0.09 ^{ns}
K3218	0.17 ^{ns}	-0.19 ^{ns}	-7.31 ^{ns}	-0.14 ^{ns}	-1.24 **	0.19 ^{ns}	-0.33 ^{ns}	-0.62 ^{ns}	0.18 ^{ns}	0.12 ^{ns}
K1264.1	-0.50 ^{ns}	0.18 ^{ns}	-15.06 *	1.32 ^{ns}	1.11 **	0.23 ^{ns}	1.28 ^{ns}	0.75 ^{ns}	0.46 **	0.36 ^{ns}
MO17	0.35 ^{ns}	0.28 ^{ns}	4.84 ^{ns}	2.31 ^{ns}	-2.05 **	0.31 ^{ns}	1.94 **	0.29 ^{ns}	-0.29 ^{ns}	-0.23 ^{ns}
K19	0.12 ^{ns}	-0.03 ^{ns}	-3.51 ^{ns}	-3.78 ^{ns}	-0.77 **	-0.32 ^{ns}	-2.08 **	-0.07 ^{ns}	-0.02 ^{ns}	-0.03 ^{ns}

Table 3. Contd.

K74.1	-0.57^{ns}	-0.19^{ns}	-2.66^{ns}	4.7^{ns}	1.97 **	-0.24^{ns}	-0.93^{ns}	-0.57^{ns}	-0.20^{ns}	-0.06^{ns}
K3653.5	-0.31^{ns}	-0.16^{ns}	27.75 **	-4.56^{ns}	1.78 **	-0.21^{ns}	-2.15 **	-0.75^{ns}	-0.03^{ns}	-0.06^{ns}

ns, * and **: Not significant and significant at 5% and 1% levels, respectively.

line was the second best combiner for number of kernels per row (1.94) and the worst parent for area of ear leaf (-31.1) and number of rows per ear (-2.05). K19 inbred line was the second worst combiner for number of kernels per row (-2.08). K74.1 inbred line was the best combiner for number of rows per ear (1.97) . K3653.5 inbred line was the best combiner for area of flag leaf (27.75) and second best for number of rows per ear (1.78) and the worst parent for plant height (-5.89) and number of kernels per row (-2.15).

Results of maternal effects revealed that k3653.5 had negative significant maternal effects for plant height (-5.89). In the majority of cases, good general combiners showed better per se performance revealing the fact that the parental material may be selected either on the basis of GCA or per se performance. Negative and positive values of SCA effects indicate a tendency towards low and high value of these traits, respectively. The SCA effect is an indication of the heterosis (interaction) for a specific trait. Results of SCA effects of traits for all crosses showed that the worst specific combination to produce progeny with desirable days from emergence to silking (-6.357) was cross of K19×K3653.5 (Table 4). K18×K1264.1, K18×K74.1, K18×K3653.5 and K1264.1×K74.1 crosses also had significant negative SCA and high-parent heterosis effects (Tables 4 and 5).

In plant breeding, decreasing days from emergence to silking trait is suitable for grain yield improvement. Therefore, these crosses seem to be suitable. Alam et al. (2008) also reported significantly negative heterosis over better parent for this trait. K18×K3653.5 proved to be the best specific combination to improve plant height (47.388) in superior progeny. K3218×MO17, K3218×K3653.5, K1264.1×K19, K1264.1×K74.1, K1264.1×K3653.5 and MO17×K3653.5 crosses also had significant positive SCA and high- parent heterosis effects. Therefore, these crosses seem to be suitable for plant height improvement. Alam et al. (2008) and Muraya et al. (2006) also observed significantly positive heterosis for this trait. The significant reciprocal (17.267) effects for plant height were indicated in combinations of K19×K3653.5. K3218×K3653.5 and K18×K3653.5 proved to be the best crosses (43.155 and 28.955, respectively) to improve ear height. High-parent heterosis values of these crosses were also significant. Alam et al. (2008) and Ojo et al. (2007) indicated significantly positive heterosis for this trait.

The highest value of reciprocal effects (16.3) was belonged to K19×K3653.5. MO17×K3653.5 and K3218×K3653.5 had the highest significant values of SCA effects (154.541 and 124.653, respectively) for area of ear leaf. The best specific combination to produce progeny with desirable number of rows per ear (2.221) was cross of K19×K3653.5. K18×K3653.5, K1264.1×K19 and MO17×K3653.5 also had significant positive SCA and MO17×K74.1 cross had significant negative SCA effects. Therefore, these crosses seem to be suitable for number of rows per ear and grain yield improvement except MO17×K74.1 cross. MO17×K3653.5 and K3218×K3653.5 proved to be the best specific combination (13.702 and 10.717, respectively) to imrove number of kernels per row. K18×K19 cross showed to be the worst specific combiner for this trait (-3.798). The highest significant values of SCA and high-parent heterosis effects for grain yield were indicated in combinations of K3218×K3653.5. K1264.1×MO17, K1264.1×K3653.5 and MO17×K3653.5 also had significant positive SCA and high- parent heterosis and K19×K3653.5 cross had significant negative SCA and high-parent heterosis effects. Therefore, these crosses seem to be suitable to increase grain yield except K19×K3653.5 cross. Other authors also reported significantly positive heterosis for grain yield (Fan et al., 2009; Liu 2008; Akbar, 2008; Amaregouda and Kajidoni, 2007; Rodrigues et al., 2006; Muraya et al., 2006; Welcker et al., 2005).

Selection of desirable varieties to increase grain yield isbased on yield component. Therefore, K18 line for number of kernels per row, K1264.1 line for grain yield and number of rows per ear and K3653.5 inbred line for area of flag leaf and number of rows per ear was suitable resources to increase grain yield. Furthermore, K3218 ×K3653.5 and MO17×K3653.5 proved to be the best crosses to increase grain yield.

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Table 4. Specific combining ability and reciprocal effects of the crosses.

Cross	Days from emergence to silking		Days from emergence to physiological maturity		Plant height		Ear height		Area of ear leaf	
	SCA	Rec	SCA	Rec	SCA	Rec	SCA	Rec	SCA	Rec
2 1	-1.611 ns	-1.167	-0.927 ns	0.083	2.152 ns	1.317	0.499 ns	1.183	-13.668 ns	5.791
1 3	-2.063 *	1.333	0.216 ns	-1.083	6.087 ns	2.5	4.659 ns	2.383	18.067 ns	2.156
1 4	-0.468 ns	1.417	-0.808 ns	0.167	-1.382 ns	4.3	-0.329 ns	1.95	35.223 ns	19.009
1 5	1.104 ns	-0.25	-0.070 ns	-0.917	-0.367 ns	-2.3	-1.750 ns	0.683	15.478 ns	-5.802
1 6	-2.158 *	-1.25	0.002 ns	0.5	10.437 ns	8.233	6.501 ns	1.367	12.581 ns	-40.221
1 7	-5.702 **	-0.5	-1.298 ns	3.25	47.388 **	7.717	28.955 *	3.467	117.731 ns	21.379
2 3	1.378 ns	0.833	0.347 ns	3.167	-0.770 ns	3.55	0.726 ns	3.867	-18.901 ns	-5.387
2 4	-0.444 ns	-1.5	0.073 ns	0.5	13.628 *	-4.117	10.20 ns	-5.933	37.162 ns	16.265
2 5	-1.706 ns	0.833	0.311 ns	0.75	12.009 ns	1.617	11.883 ns	2.567	-2.765 ns	-14.939
2 6	0.449 ns	0.917	-0.951 ns	0.5	5.080 ns	-5.45	-2.332 ns	-4.317	22.143 ns	-7.899
2 7	-1.726 ns	-1.083	-0.595 ns	-0.333	46.912 **	0.7	43.155 **	-0.75	124.653 *	16.2
3 4	-0.313 ns	0.75	0.883 ns	2.667	3.363 ns	4.833	3.480 ns	3.15	-5.586 ns	34.425
3 5	0.092 ns	0.583	-1.129 ns	1	14.928 *	0.583	5.126 ns	1.75	9.565 ns	7.585
3 6	-2.67 **	-0.917	-1.391 ns	0.083	12.766 *	-1.45	6.061 ns	-0.817	6.11 ns	-17.859
3 7	-3.274 ns	0.083	-3.238 ns	-2.167	37.160 **	8.867	19.645 ns	2.233	32.252 ns	20.287
4 5	0.604 ns	0.083	-0.070 ns	-1.167	-0.441 ns	-3.65	3.154 ns	-1.6	-1.509 ns	-38.907
4 6	0.259 ns	-0.5	-0.082 ns	0.5	1.047 ns	7.933	2.906 ns	2.65	19.595 ns	-2.818
4 7	-3.202 ns	-0.5	-4.214 ns	0.917	45.395 **	6.133	23.567 ns	3.9	154.541 *	6.608
5 6	-0.92 ns	1.75	-1.844 ns	0.417	-4.255 ns	1.417	1.202 ns	-3.233	2.409 ns	-15.579
5 7	-6.357 **	0.583	-3.702 ns	-1.75	14.08 ns	17.267 *	-4.612 ns	16.3 *	-27.014 ns	42.591
6 7	-1.845 ns	0.25	1.393 ns	-0.583	0.360 ns	0.517	-13.314 ns	0.8	-27.505 ns	60.218

	Ear length		Area of flag leaf		Number of rows per ear		Number of kernels per row		Grain yield	
	SCA	Rec	SCA	Rec	SCA	Rec	SCA	Rec	SCA	Rec
1 2	0.434 ns	0.71	-12.469 ns	-4.235	0.030 ns	-0.233	1.401 ns	1.6	-0.483 ns	-0.269
1 3	0.561 ns	-0.057	9.608 ns	2.48	0.649 ns	0.067	2.074 ns	-0.75	-0.118 ns	-0.436
1 4	0.441 ns	-0.737	20.834 ns	1.306	0.144 ns	-1.067	-0.935 ns	0.767	0.199 ns	-0.057
1 5	-0.256 ns	-0.148	-10.611 ns	1.938	-0.801 ns	0.5	-3.798 *	2.725	0.104 ns	0.21
1 6	-0.572 ns	0.235	-9.189 ns	4.729	-0.111 ns	1.1	2.952 ns	2.383	-0.237 ns	0.4
1 7	-0.082 ns	0.817	10.390 ns	-5.112	2.152 *	-0.133	5.394 ns	0.067	1.028 ns	-0.469
2 3	-1.061 ns	-0.222	10.398 ns	8.916	-0.789 ns	-0.067	-1.982 ns	0.05	-0.315 ns	-0.739
2 4	1.197 ns	-0.257	2.723 ns	-1.829	0.873 ns	0.167	2.392 ns	-0.85	-0.175 ns	1.101 *
2 5	0.683 ns	0.02	3.092 ns	3.66	0.694 ns	-0.667	3.121 ns	-2.333	-0.135 ns	-0.089
2 6	0.197 ns	-0.265	19.220 ns	-18.165	0.851 ns	0.567	2.962 ns	0.883	0.670 ns	0.445

Table 4. Contd.

2 7	1.133 ^{ns}	0.107	-5.10 ^{ns}	2.221	-0.243 ^{ns}	1.1	10.717 **	-0.483	1.988 **	-0.178
3 4	-0.364 ^{ns}	0.895	-1.028 ^{ns}	3.126	0.425 ^{ns}	0.067	2.533 ^{ns}	2.2	0.920 *	0.897 *
3 5	0.222 ^{ns}	0.212	-0.559 ^{ns}	6.159	1.147 *	1	2.328 ^{ns}	0.75	0.182 ^{ns}	0.601
3 6	1.056 ^{ns}	0.143	-5.412 ^{ns}	-1.294	0.904 ^{ns}	0.7	1.186 ^{ns}	0.683	-0.119 ^{ns}	0.327
3 7	1.571 ^{ns}	-0.287	-13.113 ^{ns}	12.625	0.071 ^{ns}	-0.133	2.610 ^{ns}	0.917	1.872 *	-0.49
4 5	0.073 ^{ns}	0.18	-18.370 ^{ns}	6.848	-0.491 ^{ns}	0.6	1.352 ^{ns}	1.8	-0.250 ^{ns}	-0.37
4 6	-0.720 ^{ns}	1.05	7.509 ^{ns}	-0.221	-1.234 *	0.467	-1.723 ^{ns}	0.5	0.602 ^{ns}	0.307
4 7	1.164 ^{ns}	0.607	42.551 ^{ns}	12.139	1.510 *	0.267	13.702 **	1.85	1.640 *	0.383
5 6	1.574 ^{ns}	0.128	5.795 ^{ns}	-6.858	0.770 ^{ns}	-0.617	2.747 ^{ns}	0.042	-0.096 ^{ns}	-0.347
5 7	1.720 ^{ns}	-0.082	1.105 ^{ns}	-1.014	2.221 *	-0.167	1.524 ^{ns}	2.383	-2.273 **	0.471
6 7	-0.441 ^{ns}	-0.02	5.084 ^{ns}	11.094	-0.319 ^{ns}	0.533	-4.860 ^{ns}	0.533	-0.942 ^{ns}	0.706

ns, * and **: Not significant and significant at 5% and 1% levels, respectively.

Table 5. High-parent heterosis effects for different traits in maize hybrids.

Parent	Days from emergence to silking	Days from emergence to physiological maturity	Plant height	Ear height	Area of ear leaf	Ear length	Area of flag leaf	Grain dept	Number of rows per ear	Number of kernels per row	Grain yield
1*2	-8.590 **	-2.580 ^{ns}	20.467	29.238 **	7.541 ^{ns}	12.268 *	-12.821 ^{ns}	17.483 ^{ns}	3.077 ^{ns}	12.397 ^{ns}	10.468 ^{ns}
1*3	-11.894 **	-3.675 *	25.329 *	27.589 **	-6.580 ^{ns}	-2.143 ^{ns}	-20.072 ^{ns}	13.882 ^{ns}	0 ns	12.186 ^{ns}	14.497 ^{ns}
1*4	-5.286 *	-3.230 *	21.741	18.362 **	1.478 ^{ns}	-2.851 ^{ns}	10.578 ^{ns}	14.901 ^{ns}	-8.715 ^{ns}	9.561 ^{ns}	11.879 ^{ns}
1*5	-5.728 *	-2.490 ^{ns}	11.103 ^{ns}	11.044	18.053 ^{ns}	-8.235 ^{ns}	-13.646 ^{ns}	-9.221 ^{ns}	5.9 *	-5.934 ^{ns}	41.845 ^{ns}
1*6	-12.365 **	-2.357 ^{ns}	30.701 **	27.966 **	6.044 ^{ns}	-9.502 ^{ns}	-7.181 ^{ns}	10.381 ^{ns}	6.798 ^{ns}	17.858 ^{ns}	47.094 ^{ns}
1*7	-7.049 **	-0.489 ^{ns}	26.668 *	36.723 **	20.958	-5.701 ^{ns}	-7.905 ^{ns}	35.761 *	3.123 ^{ns}	3.258 ^{ns}	1.016 ^{ns}
2*3	-4.698 *	-2.334	24.618 *	52.405 **	8.781 ^{ns}	-8.164 ^{ns}	33.681 *	-5.711 ^{ns}	-12 ^{ns}	2.882 ^{ns}	-41.631 *
2*4	-5.369 **	-2.334	24.137 *	49.913 **	44.703	6.93 ^{ns}	21.214 ^{ns}	2.950 ^{ns}	7.484 ^{ns}	30.594 *	86.100 **
2*5	-4.646 **	-1.720 ^{ns}	18.854	30.576 **	9.454 ^{ns}	12.713 ^{ns}	20.082 ^{ns}	2.126 ^{ns}	9.625 ^{ns}	26.891 ^{ns}	20.637 ^{ns}
2*6	-6.593 **	-2.826	17.165	29.629 **	22.664	-0.773 ^{ns}	32.988 ^{ns}	-6.045 ^{ns}	6.798 ^{ns}	60.482 **	67.377 ^{ns}
2*7	-3.580	-1.222 ^{ns}	26.542 *	46.154 **	43.659	-4.512 ^{ns}	-15.560 ^{ns}	37.591 ^{ns}	-4.301 *	33.996 *	154.032 **
3*4	-4.588 *	-2.485 ^{ns}	24.904 *	44.763 **	31.710	-10.608 ^{ns}	-2.149 ^{ns}	10.431 ^{ns}	-8.802 ^{ns}	33.796 *	9.806 ^{ns}
3*5	-10.840 **	-4.979 **	21.518	12.537 ^{ns}	-3.72 ^{ns}	25.133 ^{ns}	3.872 ^{ns}	15.774 *	8.796 ^{ns}	14.187 ^{ns}	1.437 ^{ns}
3*6	-11.648 **	-4.841 **	26.278 *	38.803 **	2.335 ^{ns}	12.709 **	2.106 ^{ns}	22.787 ^{ns}	21.978 ^{ns}	13.955 ^{ns}	7.671
3*7	-7.030 **	-6.237 **	29.112 **	23.026 **	16.160	16.367 *	-28.763 *	8.204 *	1.172	0.346 *	17.498 **
4*5	-4.866 *	-3.479 *	9.669 ^{ns}	4.306 ^{ns}	1.169 ^{ns}	-15.228 ^{ns}	-4.761 ^{ns}	-5.017 ^{ns}	4.865 ^{ns}	30.078 **	31.664 ^{ns}
4*6	-9.670 **	-1.491 ^{ns}	24.350 *	37.436 **	27.559	-12.845 ^{ns}	21.010 ^{ns}	10.989 ^{ns}	-11.202 ^{ns}	17.611	23.158 ^{ns}

Table 5. Contd.

4*7	-7.256 **	-4.156 **	25.074 *	27.443 **	41.840	-0.4113 ^{ns}	12.085 ^{ns}	13.283 ^{ns}	-3.129 ^{ns}	44.218 *	118.506 *
5*6	-4.834 *	-3.10 *	9.407 ^{ns}	0.426 ^{ns}	10.168 ^{ns}	7.25 ^{ns}	4.733 ^{ns}	1.619 ^{ns}	1.998 ^{ns}	32.996 *	-4.571 *
5*7	-7.743 **	-5.25 **	12.798 ^{ns}	9.551 ^{ns}	7.870 ^{ns}	19.371 ^{ns}	-18.534 ^{ns}	9.3 ^{ns}	-0.785 ^{ns}	16.718 ^{ns}	22.118 ^{ns}
6*7	-8.352 **	-2.811 ^{ns}	13.363	24.222 **	27.977	2.4897 ^{ns}	-6.953 ^{ns}	26.323 ^{ns}	26.953 *	30.473 ^{ns}	51.893 *
2*1	-5.507 **	-2.58 ^{ns}	18.790 ^{ns}	25.894 **	-6.892 ^{ns}	0.354 ^{ns}	-23.411 ^{ns}	-8.888 ^{ns}	6.669 ^{ns}	2.313 ^{ns}	3.244 ^{ns}
3*1	-13.877 ***	-1.394 ^{ns}	22.145 *	20.857 **	-16.950	-11.931 ^{ns}	-31.836 ^{ns}	18.891 ^{ns}	-0.804 ^{ns}	16.913 ^{ns}	34.953 **
4*1	-9.032 **	-3.851 **	16.263	12.853 ^{ns}	1.351 ^{ns}	-0.771 ^{ns}	15.902 ^{ns}	-0.037 ^{ns}	7.692 ^{ns}	4.727 ^{ns}	5.61 ^{ns}
5*1	-5.067 *	-0.871 ^{ns}	13.888 ^{ns}	9.295 ^{ns}	19.276 ^{ns}	-2.534 ^{ns}	-18.130 ^{ns}	-19.264 ^{ns}	-1.792 ^{ns}	-23.108 ^{ns}	-23.843 ^{ns}
6*1	-10.827 **	-2.978 *	20.212	24.106 **	11.567 ^{ns}	-16.750 ^{ns}	-3.182 ^{ns}	7.338 ^{ns}	-6.402 ^{ns}	2.836 ^{ns}	7.449 ^{ns}
7*1	-6.608 **	-6.479 **	16.836 ^{ns}	26.931 **	16.330	-18.424 *	-8.175 ^{ns}	2.832 ^{ns}	4.687 ^{ns}	2.836 ^{ns}	-36.456 *
3*2	-5.593 **	-7.248 **	19.899 ^{ns}	38.957 *	3.433 ^{ns}	-13.647 ^{ns}	-2.632 ^{ns}	-6.71 ^{ns}	-11.202 *	2.536 ^{ns}	-15.596 ^{ns}
4*2	-1.566 ^{ns}	-1.8423 ^{ns}	29.399 **	70.551 **	40.432	8.749 ^{ns}	25.265 ^{ns}	12.909 ^{ns}	4.813 ^{ns}	37.15 *	117.712 **
5*2	-4.424 *	-2.457 ^{ns}	16.895	24.008 **	9.491 ^{ns}	18.402 *	27.719 ^{ns}	20.647 ^{ns}	20.318 ^{ns}	47.242 **	58.319 *
6*2	-5.934 **	-3.685 *	24.161 *	44.388 **	25.615	-5.278 ^{ns}	18.175 ^{ns}	5.03 ^{ns}	0 ^{ns}	51.966 *	75.423 *
7*2	-4.027	-0.855 ^{ns}	25.560 *	48.493 **	38.242	-7.584 ^{ns}	-23.661 ^{ns}	9.98 ^{ns}	-17.191 ^{ns}	38.434 ^{ns}	158.267 **
4*3	-6.652 **	-6.46 **	18.726	33.646 **	29.346	-15.566 ^{ns}	2.572 ^{ns}	-1.481 ^{ns}	-5.982 ^{ns}	18.571 ^{ns}	-23.246 ^{ns}
5*3	-8.628 **	-6.099 **	20.812 ^{ns}	8.060 ^{ns}	-7.268 ^{ns}	15.338 ^{ns}	-9.202 ^{ns}	24.457 *	-3.204 ^{ns}	8.997 ^{ns}	-24.979 ^{ns}
6*3	-13.187 **	-5.958 **	28.138 *	41.595 **	7.178 ^{ns}	17.647 ^{ns}	-1.928 ^{ns}	15.440 ^{ns}	13.596 ^{ns}	9.228 ^{ns}	-5.642 ^{ns}
7*3	-7.256 **	-3.178 *	16.682 ^{ns}	16.060 ^{ns}	12.01 ^{ns}	20.562 *	-34.510 ^{ns}	7.425 ^{ns}	2.730 ^{ns}	-5.997 ^{ns}	-17.371 ^{ns}
5*4	-3.761	-1.491 ^{ns}	14.090 ^{ns}	8.400 ^{ns}	5.687 ^{ns}	-9.313 ^{ns}	-7.935 ^{ns}	-10.121 ^{ns}	-4.865 ^{ns}	16.196 ^{ns}	25.849 ^{ns}
6*4	-5.934 **	-1.612 ^{ns}	14.209 ^{ns}	28.376 **	17.321	-11.792 ^{ns}	6.732 ^{ns}	-23.33 *	-16.71 ^{ns}	13.755 *	-0.507 ^{ns}
7*4	-6.35 **	-5.745 **	17.234	15.281 *	34.808	-6.496 ^{ns}	0.522 ^{ns}	-0.161 ^{ns}	-6.252 ^{ns}	29.950 *	77.164 *
6*5	-8.571 **	-5.087 **	7.691 ^{ns}	8.699 ^{ns}	6.987 ^{ns}	17.764 ^{ns}	13.468 ^{ns}	10.138 ^{ns}	9.396 ^{ns}	32.634 **	54.017 ^{ns}
7*5	-10.84 **	-2.445	-8.115	-32.154 **	1.362 ^{ns}	20.652 *	-1.539 ^{ns}	-5.439 ^{ns}	1.172 ^{ns}	-4.068 ^{ns}	-14.958 ^{ns}
7*6	-9.010 **	-2.203 ^{ns}	12.700 ^{ns}	21.727 **	26.83	6.193 ^{ns}	-8.297 ^{ns}	-2.397 ^{ns}	20.701 *	25.571 ^{ns}	47.498 *
LSD 5%	4.07	2.85	22.02	13.59	93.24	1.67	46.28	1.55	5.50	1.69	4.07
LSD 1%	5.35	3.75	28.95	17.86	122.55	2.20	60.82	2.04	7.23	2.23	5.35

Genotypes' names: ns, * and **: Not significant and significant at 5% and 1% levels, respectively. 1. K18 2. K3218 3. K1264.1 4. MO17 5. K19 6. K74.1 7. K3653.5.

Elham Zare and Reza Moeini.

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