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Full Length Research Paper

Genetic analysis of tolerance to heat stress in maize (*Zea mays* L.)

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Twenty eight hybrid combinations of eight selected inbred lines ((including 3 lines sensitive (A679, K3651/1 and K3640/5), 2 lines medium (K47/2-2-1-21-2-1-1-1 and K19) and 3 lines tolerance to heat stress (K18, K166A and K166B)) with different response to heat stress were evaluated in 2008 for grain yield and some related traits in a randomized complete block design arranged into three replications in Shoushtar City (a sub-tropical region in Khuzestan Province of Iran). Hybrids were planted at two planting dates, 6th of July (coinciding heat stress with pollination time and grain filling period) and 27th of July (normal planting). Diallel analysis was done using Griffing's method 4 and model II. As a result, grain yield in heat stress condition and 1000 grain weight in both conditions showed high general combining ability to specific combining ability ratio, indicating the effects of additive contribution. But grain yield in normal condition, grain number per ear, grain row number per ear, grain number per ear row and hektolitr weight in both conditions showed low GCA/SCA, indicating contribution of non-additive effects. General combining ability of all traits was non-significant in parents except for grain row number per ear. K18×K166B of the highest yield, positive and combining significantly in both conditions for grain yield was enjoyed.

Key words: Maize, heat stress, additive and non-additive effects, combining ability, hybrid.

INTRODUCTION

Maize is the third important leading cereal crop after wheat and rice in relation to area and production in Iran. Stress can reduce maize grain yield and quality. Further rise in temperature reduces pollen viability and silk receptivity, resulting in poor seed set and low grain yield (Johnson, 2000; Aldrich et al., 1986). Heat stress reduced the yield of inbred lines maize grain up to 70% (Khodarahmpour et al., 2010). Drought stress reduced the yield of maize grain up to 80% (Makus et al., 2000). In southern part of Iran, especially in Khuzestan Province, high temperature stress is one of the most important abiotic stresses in maize growing area.

The diallel cross mating schemes have been extensively used in breeding programs for the evaluation of the genetic potential of genotypes (Miranda and Vencovsky, 1984). Combining ability describes the breeding values of parental lines to produce hybrids. Sprague and Tatum (1942) used the term general combining ability (GCA) to designate the average performance of a line in hybrid combinations, and used the term specific combining ability (SCA) to define those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved.

Rezaei et al. (2005) and Sridic et al. (2006) reported significant variance due to GCA and SCA for grain yield, plant height and row number per ear traits. There are different reports on the genetic control of different traits in maize. Some studies revealed that grain yield and yield components were controlled by additive and non-additive genes (Wolf and Poternelli, 2000; Singh et al., 2002; Wu et al., 2003; Butruille et al., 2004; Choukan and Mosavat, 2005), Some others (Melani and Carena, 2005; He et al., 2003) reported the importance of additive effects as well as non-additive effect (Pal and Prodham, 1994; Kalla et al., 2001; Renugopal et al., 2002; Unay et al., 2004). Akbar et al. (2008) reported that GCA and SCA effects were highly significant but GCA effect on 100 grain weight under high temperature condition was non-significant. The GCA/SCA variance ratio exhibited that yields were predominantly under non-additive control. The inbred line 935006 was found as the best general combiner with better mean performance for all traits followed by R2304-2 and F165-2-4. The best cross

Table 1. Average minimum and maximum temperatures of research farm in heat stress and normal conditions in 2008.

Months	Temperature (°C)	
	Minimum	Maximum
July	31	46
August	32	46
September	31	45
October	23	38
November	17	27
December	11	21

was 935006×R2304-2. Betran et al. (2003) showed that the type of gene action appeared to be different under drought than when under low nitrogen, with additive effects more important under drought and dominance effects more important under low nitrogen. Afarinesh et al. (2008) showed additive and dominance variances role in normal condition and dominance variance in drought stress condition.

Unay et al. (2004) showed that the general and specific combining ability effects were significantly different among parental lines. Choukan and Mosavat (2005) reported that MO17×B73 and MO17×K74/1 are significant and negative when combined for grain yield in normal condition.

Genetic variation is the basis of genetic improvement in any crop. Crossing of diverse inbred lines provides sufficient variability for an effective selection of desirable traits. Suitable inbred lines and their specific combinations may be selected on the basis of combining ability effects with higher mean yield (Akbar et al., 2008). The success of identifying parental inbred lines that combine well together and produce productive crosses mainly depends on gene action that controls the traits to be improved. The variance of GCA/SCA ratio is useful in estimating the variability exited whether due to additive or non-additive or both types of gene action. Therefore, understanding of genetic mechanism for high temperature tolerance is necessary for the development of tolerant hybrids and synthetics to high temperature stress for sustainable agriculture.

In present study, eight inbred lines varying in degree of their temperature tolerance were crossed in half diallel model to get information on genetic control of high temperature tolerance by estimating combining ability effects for morphological traits.

MATERIALS AND METHODS

The study was conducted at Shushtar City located in Khuzestan Province, IRAN (32°2 N and 48°50′ E, 150 m asl) in 2008. The soil type at this location is clay loam, pH = 7.6 with EC = 0.5 mmhos/cm.

Twenty eight hybrid combinations of eight selected inbred lines ((including 3 lines sensitive (A679, K3651/1 and K3640/5), 2 lines medium (K47/2-2-1-21-2-1-1-1 and K19) and 3 lines tolerance to heat stress (K18, K166A and K166B)) with different response to heat stress were evaluated in 2008 for grain yield and some related traits in a randomized complete block design arranged into three replications in Shushtar City (a sub-tropical region in Khuzestan Province of Iran). This was done under two planting dates, 6th July (coinciding heat stress with pollination time and grain filling period) and 27th July (the normal planting date) to avoid high temperature during pollination and grain filling period. Each plot had 3 rows of 75 cm apart and 9 m in length, with 45 hills. Two seeds each were sown, one of which seedlings were removed at 4 leaves stage. Minimum and maximum air temperatures at pollination time were 31 and 45°C under heat stress condition (planting date, 6th July) and 23 and 38°C under normal condition (planting date, 27th July) (Table 1).

Data pertaining to grain row number per ear, grain number per ear row, grain number per ear, 1000 grain weight, hektolitr weight and grain yield traits were recorded in both conditions. Analysis of variance was performed for each individual experiment randomized complete block using SPSS computer program and mean separation performed according to Duncan's Multiple Range Test at 5% probability level. Diallel analysis based on Griffing's method 4 and model II was done using Diall 98 software.

RESULT AND DISCUSSION

Significant differences were observed among hybrids in both conditions for all studied traits (Table 2). Therefore Griffing's method 4 and model II in both conditions was used to partition the genetic effect into general combining ability (GCA) and specific combining ability (SCA).

The highest grain yield in heat stress condition belonged to hybrids K18×K166B and K18×K42/2-2-1-21-2-1-1-1 and in normal condition belonged to hybrids such as K18×K166B, K18×K42/2-2-1-21-2-1-1-1 and K166A×K3640/5. There was 70% yield reduction in stressed condition compared to normal condition (Table 3). Khodarahmpour et al. (2010) showed that heat stress reduced the yield of maize grain up to 73.5%. Makus et al. (2000) reported drought stress reduced the yield of maize grain up to 80%. Hybrids such as K18×K47/2-2-1-21-2-1-1-1, K166A×K19, K166B×K19 and K47/2-2-1-21-2-1-1-1×K19 in stress condition and many number of hybrids in normal condition showed the highest grain row number per ear (Table 3). Hybrid K18×K166B in stress condition and hybrids K3651/1×K3640/5 and A679×K166A in

Table 2. Analysis of variance and combining ability for different traits maize hybrids in diallel crosses in heat stress and normal conditions.

Source of variance	df	Grain yield (kg/ha)		Grain number per ear		Grain row number per ear		Grain number per ear row		1000 grain weight (g)		Hektolitr weight (g/L)	
		Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal
Block	2	535426*	2317944*	34218*	244832**	181**	14*	97.90*	1236**	5718ns	4946ns	2052ns	5998ns
Hybrid	27	1092651**	1316319**	66388**	135981**	87**	9.57**	377.30**	651**	10357**	10738**	3395**	5170*
Error	54	145969	584733	1785	120742	20	6	27.33	584	2784	3669	582	2608
GCA	7	1190980**	1535789*	15597**	40532ns	16*	4*	96**	213ns	21539**	21021**	4935**	7485*
SCA	20	287450ns	1239505*	18264**	29039ns	22**	2ns	99.85**	152ns	6437**	7139*	2856**	4362ns
Error (combining ability)	54	193825	584733	3755	31110	5	1	16.3	121	2785	3669	852	2605
GCA/SCA		4.14	0.12	0.85	1.4	0.73	2	0.96	1.4	3.35	2.94	1.73	1.72
Baker ratio[1]		0.89	0.71	0.63	0.74	0.59	0.8	0.66	0.74	0.87	0.85	0.78	0.77

[1]-$2\delta^2$GCA/(δ^2SCA+2 δ^2GCA). [2]- ns, * and **:nonsignificant, significant at 5% and 1% probability levels, respectively.

Table 3. Mean comparison of different traits in maize hybrids in heat stress and normal conditions.

Name of hybrids	Grain yield (kg/ha)		Grain number per ear		Grain row number per ear		Grain number per ear row		1000 grain weight (g)		Hektolitr weight (g/L)	
	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal
K18×K3651/1	196h	2900bcde	47defg	413cdefg	7fgh	14abcdefg	4defg	29bcdef	273fgh	329cde	738abcde	762a
K18×A679	411gh	3066bcde	55cdefg	474cdef	10bcdef	14abcdefg	5cdefg	34bc	292efgh	317cdef	727cde	685ab
K18×K166A	815defgh	3220abcde	64bcdef	471cdef	10bcdef	15ab	6cdefg	31cdef	362abcdef	470a	694ef	691ab
K18×K166B	3266a	5046a	263a	456cdef	12abcd	14abcdefg	21a	33bcd	389abcde	399abcd	753abcd	706ab
K18×K3640/5	828defgh	3134bcde	65bcdef	453cdef	9efg	15ab	6cdefg	31bcdef	407abc	345cd	712def	705ab
K18×K47/2-2-1-21-2-1-1-1	2799ab	3566abc	233a	459cdef	13a	15ab	16b	30bcdef	362abcdef	329cde	742abcde	680ab
K18×K19	1074defgh	1500ef	131bc	368defgh	12abcde	12g	10c	28bcdefg	413a	352bcd	711def	667ab
K3651/1×A679	250h	3434abcd	46defg	337fgh	9efg	14abcdefg	4defg	23fg	325abcdef	331cde	732bcde	723a
K3651/1×K166A	596efgh	2320cdef	83bcdef	348efgh	11abcde	14abcdefg	6cdefg	24efg	325abcdef	321cdef	732bcde	716ab
K3651/1×K166B	1229cdefg	2800bcdef	109bcde	478cde	12abcde	14abcdefg	8cde	34bc	309bcdefg	293def	780abc	731a
K3651/1×K3640/5	833defgh	3720abc	115bcde	739a	9efg	15ab	8cde	49a	259fgh	281def	786ab	738a
K3651/1× K47/2-2-1-21-2-1-1-1	321gh	3366abcde	37efg	496bcd	7gh	15ab	4efg	35b	276fgh	280def	744abcde	767a
K3651/1×K19	335gh	3334abcde	14g	416cdefg	5h	15ab	2g	26bcdefg	304cdefgh	292def	717def	699ab
A679×K166A	468fgh	2780bcdef	83bcdef	612b	10bcdef	14abcdefg	7cdefg	45a	341abcdef	341cde	664f	702ab
A679×K166B	120 h	1054f	18g	401cdefg	6gh	15ab	2g	25defg	212h	207f	688ef	719ab
A679×K3640/5	491fgh	3300abcde	29fg	304gh	5h	14abcdefg	3fg	20g	226gh	343cd	794a	709ab
A679×K47/2-2-1-21-2-1-1-1	791defgh	3161abcde	39efg	337fgh	10bcdef	14abcdefg	3fg	23fg	266gh	221ef	731bcde	691ab
A679×K19	161h	1534def	29fg	531bc	7fgh	15ab	3fg	34bc	267fgh	347cd	689ef	683ab
K166A×K166B	1231cdefg	3479abc	124bcd	465cdef	11abcde	14abcdefg	15b	34bc	402abcd	418abc	777abc	755a

Table 3. Contd.

K166A×K3640/5	945defgh	4366ab	103bcde	421cdefg	10bcdef	15ab	6cdefg	28bcdefg	278fgh	327cde	744abcde	559c
K166A×K47/2-2-1-21-2-1-1-1	771defgh	4020abc	63bcdef	361defgh	9efg	15ab	5cdefg	25defg	412ab	294def	689ef	691ab
K166A×K19	1375cdef	3896abc	134bc	401cdefg	13a	13efg	10c	30cdef	358abcdef	462ab	740abcde	731a
K166B×K3640/5	1508cde	3366abcde	109bcde	342efgh	12abcde	14abcdefg	8cde	23fg	401abcd	357abcd	731bcde	721a
K166B×K47/2-2-1-21-2-1-1-1	1544cd	3500abc	89bcdef	393cdefgh	12abcde	14abcdefg	7cdefg	27cdefg	338abcdef	388abcd	718def	696ab
K166B×K19	2096bc	3100bcde	137b	465cdef	13a	14abcdefg	10c	33bcd	393abcde	391abcd	727cde	712ab
K3640/5×K47/2-2-1-21-2-1-1-1	803defgh	3178abcde	47defg	263h	10bcdef	13efg	4defg	20g	300defgh	323cdef	790a	618bc
K3640/5×K19	793defgh	3141bcde	21g	478cde	7fgh	15ab	3efg	32bcd	270fgh	292def	700def	711ab
K47/2-2-1-21-2-1-1-1×K19	625defgh	2509bcdef	242a	398cdefg	13a	13efg	19ab	30bcdef	323abcdef	306cdef	700def	671ab
Average[2]	953	3135	90	421	10	14	7	20	323	334	730	701

[2] Means with similar letter(s) in each trait is not significantly different at 5% probability level according to Duncan's multiple range test.

normal condition showed the highest grain number per row (Table 3). Hybrids K18×K166B, K18×K47/2-2-1-21-2-1-1-1 and K47/2-2-1-21-2-1-1-1×K19 in stress condition and hybrid K3651/1× K3640/5 in normal condition showed the highest grain number per ear. In heat stress condition, hybrid K18×K19 and in normal condition hybrid K18×K166A had the highest 1000 grain weight. Hybrids A679×K3640/5 and K3640/5×K47/2-2-1-21-2-1-1-1 in stress condition and many hybrids for example K18×K3651/1 in normal condition had the highest hektolitr weight (Table 3).

General combining ability variance for all traits except grain number per ear row and grain number per ear in normal condition was significant (Table 2). Grain yield trait in heat stress condition and grain row number per ear, grain number per ear row, grain number per ear and hektolitr weight traits in normal condition showed non-significant specific combining ability variance. Other traits showed significant specific combining ability (Table 2).

Akbar et al. (2008) reported that GCA and SCA effects were found as highly significant but non-significant to GCA effect for 100 grain weight under high temperature condition. Rezaei et al. (2005) and Sridic et al. (2006) reported significant variance due to GCA and SCA for grain yield, plant height and row number per ear traits. Unay et al., (2004) reported general and specific combining ability effects were significantly different among parental lines.

Grain yield in heat stress condition and 1000 grain weight in both conditions showed high GCA/SCA ratio, indicating importance of additive than non-additive effects (Table 2). But grain yield in normal condition, grain number per ear, grain row number per ear, grain number per ear row and hektolitr weight in both conditions showed low GCA/SCA, showing the importance of non-additive effects, compared to additive gene effects (Table 2). Also Baker's ratio for these traits indicates genetic control of these traits by additive effect and non-additive genes, but with more portion of non-additive genes effect (Table 2). Unay et al. (2004) and Kalla et al. (2001) reported grain yield was under the non-additive gene effect. Akbar et al. (2008) reported that the GCA/SCA variance ratio exhibited that all traits were predominantly under non-additive control in high temperature and normal conditions.

General combining ability except grain row number per ear trait, in other traits in two conditions in neither of parents was nonsignificant (Table 4). Therefore in two conditions for breeding these traits can of breeding methods base hybridization used. Line K3651/1 in stress condition and lines K166B and K47/2-2-1-21-2-1-1-1 in normal condition showed negative effect and significant and line K3640/5 positive effect and significant for grain row number per ear trait (Table 4).

Hybrid K18×K166B was significant and positive, combining in two conditions for grain yield; and hybrid K18×K47/2-2-1-21-2-1-1-1 was significant and positive, combining in stress condition for grain row number per ear; hybrids K166A×K47/2-2-1-21-2-1-1-1 and K18×K19 in stress condition and hybrid K3651/1×K166B in normal condition were significant and positive, combining for grain number per ear row; hybrid K18×K19 in two condition for grain number per ear trait was significant and positive; hybrid A679×K166B and K166A×K3640/5 for 1000 grain weight and hektolitr weight traits respectively were significant and negative, combining in normal condition (Table 5). Rezaei et al. (2005) reported general combining ability effects were significant for most

Table 4. Parent's general combining using Griffing's method 4 in heat stress and normal conditions.

Inbred line	Grain yield (kg/ha)		Grain number per ear		Grain row number per ear		Grain number per ear row		1000 grain weight (g)		Hektolitr weight (g/L)	
	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal
K18	259.97ns	64.7ns	4ns	71ns	-1ns	0ns	-0.21ns	4ns	37.91ns	33.73ns	-5.85ns	-2.29ns
K3651/1	-303.29ns	-9.97ns	-49ns	-43ns	-2*	0ns	-3.6ns	-4ns	-33.36ns	-35.26ns	19.56ns	37.67ns
A679	-341.98ns	483ns	-13ns	-21ns	1ns	0ns	-1.58ns	-3ns	-56.95ns	-38.91ns	-14.65ns	0.53ns
K166A	-19.87ns	284ns	-4ns	32ns	0ns	0ns	0.59ns	1ns	34.5ns	48.91ns	-12.09ns	-10.77ns
K166B	419.89ns	53.14ns	31ns	50ns	1ns	-1*	1.81ns	4ns	28.7ns	19.02ns	10.15ns	21.50ns
K3640/5	-82.43ns	310.08ns	-28ns	-33ns	1*	1*	-2.13ns	-2ns	-21.68ns	-11.81ns	24.13ns	-24.8ns
K47/2-2-1-21-2-1-1-1	54.46ns	180.47ns	32ns	-62ns	0ns	-1*	3.03ns	-4ns	1.07ns	-32.98ns	0.12ns	-16.09ns
K19	13.24ns	-39.36ns	28ns	5ns	1ns	0ns	2.09ns	2ns	37.91ns	33.73ns	-21.37ns	-5.74ns
SE (GCA)[3]	257.23	53.14	29.44	47.45	0.95	0.5	2.31	3.44	33.36	35.26	16.56	20.39

[3] ns, * and **:nonsignificant, significant at 5% and 1% probability levels, respectively.

Table 5. Parent's specific combining using Griffing's method 4 in heat stress and normal conditions.

Name of hybrids	Grain yield (kg/ha)		Grain number per ear		Grain row number per ear		Grain number per ear row		1000 grain weight (gr)		Hektolitr weight (g/L)	
	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal
K18×K3651/1	-330ns	-243.08ns	-5ns	-124ns	1ns	-1ns	1.33ns	-8ns	-56.07ns	-3.99ns	-5.72ns	25.29ns
K18×A679	-218ns	362.8ns	-4ns	-135ns	1ns	0ns	-0.23ns	-9ns	-13.75ns	-12.27ns	16.89ns	-14.27ns
K18×K166A	-213ns	-281.52ns	14ns	-57ns	2ns	-1ns	-0.73ns	-3ns	-34.41ns	53.44ns	-18.27ns	2.84ns
K18×K166B	827**	1411.14*	-16ns	119ns	-2ns	0ns	-1.29ns	10ns	-1.64ns	12.5ns	18.23ns	-14.84ns
K18×K3640/5	-356ns	-367.48ns	-35ns	25ns	-1ns	0ns	-1.67ns	2ns	66.21ns	-10.87ns	-36.99ns	30.88ns
K18×K47/2-2-1-21-2-1-1-1	429ns	99.81ns	-188ns	-26ns	5**	2ns	8.84ns	-5ns	-1.70ns	-5.7ns	17.65ns	-13.18ns
K18×K19	-139ns	-981.7ns	164*	200*	4ns	0ns	11.44*	12ns	41.38ns	-33.11ns	8.21ns	-26.72ns
K3651/1×A679	364ns	730.8ns	68ns	52ns	1ns	0ns	4.16ns	4ns	90.71ns	71.12ns	-2.99ns	-16.70ns
K3651/1×K166A	124ns	-927.9ns	20ns	-62ns	1ns	0ns	0.66ns	-3ns	-0.45ns	-26.93ns	-5.54ns	-12.63ns
K3651/1×K166B	-171.25ns	-311.52ns	5ns	172ns	0ns	0ns	0.77ns	15*	-11/07ns	-24.41ns	20.25ns	-29.77ns
K3651/1×K3640/5	81.98ns	176.53ns	-2ns	44ns	-2ns	0ns	0.05ns	1ns	-10.46ns	-6.25ns	12.07ns	23.81ns
K3651/1× K47/2-2-1-21-2-1-1-1	-49.38ns	14.48ns	-50ns	-24ns	-3ns	1ns	-4.45ns	-2ns	-15.86ns	14.36ns	-6.42ns	43.99ns
K3651/1×K19	-19.96ns	559.64ns	-36ns	-59ns	1ns	0ns	-2.51ns	-6ns	3.20ns	-23.89ns	-11.64ns	-33.99ns
A679×K166A	110.65ns	-86.3ns	-50ns	87ns	-3ns	1ns	-4.03ns	4ns	38.64ns	-3.35ns	-40ns	10.97ns
A679×K166B	-469.9ns	-1235.63ns	-6ns	-120ns	0ns	0ns	0.08ns	-10ns	-84.25ns	-107.56*	-38.27ns	-4.43ns
A679×K3640/5	164.56ns	313.09ns	33ns	14ns	2ns	-1ns	2.69ns	1ns	-19.47ns	59.57ns	54.65ns	31.82ns

Table 5. Contd.

A679×K47/2-2-1-21-2-1-1-1	113.98ns	323.03ns	22ns	106ns	2ns	0ns	1.19ns	9ns	-2.18ns	-41.49ns	14.75ns	5.73ns
A679×K19	-65.35ns	-407.8ns	-64ns	-4ns	-4ns	-1ns	-3.86ns	0ns	-9.70ns	33.99ns	-5.02ns	-13.12ns
K166A×K166B	-213.3ns	62.63ns	-68ns	-41ns	-2ns	0ns	-4.09ns	-2ns	14.12ns	15.82ns	48.56ns	43.14ns
K166A×K3640/5	-5.64ns	399.42ns	-1ns	38ns	1ns	0ns	-0.47ns	1ns	-59.46ns	-44.68ns	1.86ns	-107.17**
K166A×K47/2-2-1-21-2-1-1-1	-57.62ns	242.7ns	139ns	52ns	2ns	0ns	13.03*	5ns	52.12ns	-56.08ns	-29.70ns	16.23ns
K166A×K19	254.67ns	715.2ns	-54ns	-17ns	-2ns	0ns	-4.36ns	-3ns	-10.56ns	61.78ns	43.09ns	46.62ns
K166B×K3640/5	101.44ns	-169.25ns	133ns	9ns	3ns	1ns	8.64ns	-3ns	69.24ns	15.34ns	-33.84ns	22.82ns
K166B×K47/2-2-1-21-2-1-1-1	-222.29ns	58.03ns	-27ns	-53ns	0ns	-1ns	-2.2ns	-3ns	-16.57ns	67.38ns	-22.54ns	-11.94ns
K166B×K19	148.57ns	309.87ns	-21ns	-87ns	1ns	0ns	-1.92ns	-7ns	-30.18ns	20.93ns	7.62ns	-4.99ns
K3640/5×K47/2-2-1-21-2-1-1-1	-10.36ns	-447.58ns	-53ns	-76ns	1ns	-1ns	-4.59ns	-5ns	-3.69ns	34.07ns	35.38ns	-42.59ns
K3640/5×K19	23.86ns	92.25ns	-76ns	-54ns	-3ns	1ns	-4.64ns	2ns	-42.37ns	-47.17ns	-33.13ns	40.43ns
K47/2-2-1-21-2-1-1-1×K19	-202.93ns	-290.47ns	87ns	21ns	3ns	-1ns	5.86ns	1ns	-12.12ns	-12.53ns	-9.12ns	-8.23ns
SE (SCA)[4]	309.54	642.78	78.03	98.38	2.69	0.76	5.68	7.11	46.32	48.78	30.86	38.13

[4] ns, * and **:nonsignificant, significant at 5% and 1% probability levels, respectively.

parents in all the studied traits. Unay et al. (2004) reported two parents W552 and DNB statistically significant and positive GCA effects. Akbar et al. (2008) reported that the inbred line 935006 was found as the best general combiner with better mean performance for all traits under both temperatures followed by R2304-2 and F165-2-4. The best cross was 935006×R2304-2. Choukan and Mosavat (2005) reported MO17×B73 and MO17×K74/1 as significant and negative combining for grain yield.

Based on the results of this study, only line K3640/5 for grain row number per ear in normal condition was significant and showed positive effect. Hybrid K18×K166B of the highest yield, positive and significantly combining in two conditions for grain yield was enjoyed. Grain yield in heat stress condition and 1000 grain weight in both conditions are controlled by additive type of gene action and other traits are controlled by non-additive type of gene action. Therefore, for improvement of grain yield in normal condition, grain number per ear, grain row number per ear, grain number per ear row and hektolitr weight traits in both conditions heterosis should be used and for 1000 grain weight in two conditions and grain yield in heat stress using the two methods of hybrid production and selection can be effective. But hybrid production and use of heterosis are priority.

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