Genetic Analysis of Yield and Qualitative Traits in Maize (*Zea mays* L.) Under Heat stress and Normal Conditions

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Abstract: The present study was carried out to determine the type of gene action and genetic parameters of yield and qualitative traits by crossing eight diverse maize inbred lines in partial diallel fashion. Seeds of F_1 population along with their parents were evaluated in year 2010 in Shoushtar City (Khuzestan province in Iran) using a RCBD with 3 replications. Inbred lines and hybrids planted in two separate experiment at two dates, 6 July (to coincide heat stress with pollination time and grain filling period) and 27 July (as normal planting). Diallel analysis to Griffing's method 4 and model II were performed. Also estimation gene effects and some of genetic parameters to Hayman – Jinks method revealed. Grain yield in stress condition of the highest ratio GCA/SCA was enjoyed that show additive effect role important. But; other traits of ratio GCA/SCA low were enjoyed. Hybrid K18×K166B of positive and significantly combining in two conditions for grain yield were enjoyed. Analysis of variance of F_1 data showed significant differences for statistics a and b, suggesting the presence of both additive and dominance genetic effects in the expression of all traits. The average dominance degree for grain yield trait under normal condition and grain protein percent in heat stress, over dominance as well as partial dominance for other traits, were revealed.
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Key words: Maize; heat stress; general and specific combining ability; over dominance and partial dominance

1.Introduction

Maize (*Zea mays* L.), the sole cultivated member of genus Zea and tribe Maydeae, ranks as one of the three important cereal crops in the world after wheat and rice. Maize being nutritionally an important crop has multiple functions in the traditional farming system, being used as food and fuel for human being and feed for livestock and poultry. It is a source of industrial raw material for the production of oil, starch, syrup, gluten, alcohol, glucose, custard powder, dextrose, flour, flakes, ethanol and many more products (Wattoo et al. 2009).

In southern part of Iran, specially in Khuzestan, high temperature stress is one of the most important abiotic stress in maize growing area. Increasing heat tolerance of hybrids is consequently a challenge for maize breeders. For this, it is necessary for promising inbred lines as well as their combination to be tested under both normal and heat stress conditions.

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. Diallel cross technique developed by Hayman (1954) and Jinks (1954) provides information on the heritance mechanism in the early generations and helps the breeder to make effective selection.

The optimum temperature for grain development in maize (*Zea mays* L.) has been reported to be between 27 and 32^{o}C (Keeling and Greaves, 1990). Temperature during reproductive development in maize is often higher than optimum for maximum grain yielding (Keeling and Greaves, 1990). Maize ears were heat stressed for 2 and 4 days at continuous 35^{o}C, starting 5 days after pollination and caused a 20% and 48% reduction in grain final dry weight (Monjardino et al. 2005). Heat stress reduced the yield of maize grain up to 80% (Makus et al. 2000).

Akbar et al. (2008) reported that the GCA/SCA variance ratio exhibited that all traits were predominantly under non-additive control. Betran et al. (2003) reported the type of gene action appeared to be different under drought than under low nitrogen, with additive effects more important under drought and dominance effects more important under low nitrogen. Afarinesh et al. (2008) reported additive and dominance variances role in normal condition and dominance variance in drought stress condition.

Shabbir and Saleem (2002) conducted 6×6 complete diallel cross involving six maize inbred lines and reported that the nature of gene action for protein content of maize grain was additive. Rosulj et al. (2002) indicated that additive type of gene action controlling oil contents in grain. Wattoo et al. (2009) reported that grain yield were controlled by over dominance type of gene action, while quality traits like protein and oil contents were under the control of partial dominance with additive type of gene action. Mebrahtu and Mohamed (2003) conducted a study to find out the mode of inheritance of protein in a 7×7 diallel analysis in beans and indicated that both additive and non additive genetic variance were important for inheritance of protein contents.

The goal of this research was determination of gene action of qualitative (grain protein and starch) traits and grain yield in maize genotypes in heat stress and normal conditions.

2.Materials and Methods

The study was conducted at Shoushtar City located in Khuzestan province, Iran (32°2 N and 48°50′ E, 150m asl) during year 2010. Fifteen maize inbred lines and twenty eight hybrids from combination of eight selected inbred lines in year 2010 were evaluated. Inbred lines and hybrids planted in two separate experiment in two planting dates, 6 July to coincide heat stress with pollination time and 27 July as normal planting using a randomized complete block design with three replications, in Shoushtar City in south part of Iran. Each plot contained 3 rows of 75 cm apart and 9 m in length, consisted 45 hills, each of two seeds were sown, one of which seedlings was removed at 6 leaves stage. The experiment was irrigated every 5 days, fertilizers were applied prior to sowing at a rate of 120 kg N $ha^{-1}$and 140 kg P ha^{-1}, and additional side dressing of 120 kg N ha^{-1} was applied at the six leaves stage of maize plants. Minimum and maximum air temperatures at pollination time were 30°C and 46°C under heat stress condition (planting date 6 July) and 25°C and 38°C under normal condition, respectively (planting date 27 July).

Data pertaining grain yield, grain starch percent and grain protein percent traits were statistically analyzed. Analysis of variance was performed for each individual experiment, using SPSS software. Diallel analysis to way Griffing's method 4 and model II using Diall 98 software was performed. Genetic analysis was done according to the diallel technique as described by Hayman (1954) and Jinks (1954).

3.Results

Significant differences were observed among the parents and F_1 hybrids in both conditions for studied traits (data not shown) and thus allowed the use of Griffing's method 4 and model II and also Hayman – Jinks model for genetic analysis of these characters in both conditions.

General combining ability variance for all traits except grain protein percent and grain starch percent in normal condition was significant (Table 1). Grain yield in stress condition and grain protein percent and grain starch percent traits in normal condition showed nonsignificant specific combining ability variance. This traits were observed significant specific combining ability under other condition (Table 1). Akbar et al. (2008) reported that GCA and SCA effects were found as highly significant except nonsignificant to GCA effect for 100 grain weight under high temperature condition.

Except grain yield in stress condition, other traits were low ratio GCA/SCA that observed role important non-additive effect ration to additive genes effect. Addition to Baker's ratio for this traits indicating of genetic control this traits by additive effect and non-additive genes, but with more portion non-additive genes effect (Table 1). Akbar et al. (2008) reported that the GCA/SCA variance ratio exhibited that all traits were predominantly under non-additive control. Betran et al. (2003) reported the type of gene action appeared to be different under drought than under low nitrogen, with additive effects more important under drought and dominance effects more important under low nitrogen. The importance of additive effects increased with intensity of drought stress. Afarinesh et al. (2008) reported additive and dominance variances role in normal condition and dominance variance in drought stress condition.

General combining ability in all traits in two conditions in neither of parents was nonsignificant (Table 2). Therefore in two conditions for breeding this traits can of breeding methods base hybridization used.

Hybrid K18×K166B significant and positive combining in two conditions for grain yield, 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 significant and positive combining for grain starch percent showed (Table 3). 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.

Analysis of variance of F_1 data showed significant differences for statistics a and b, suggesting the presence of both additive and dominance genetic effects in the expression of all traits (Table 4). Significance of b1 revealed the presence of directional dominant effects of genes. The b1 statistic for grain yield under both conditions, for grain protein percent traits under stress condition and grain starch percent under normal condition was significant. Among inbred lines, asymmetrical gene distribution for grain yield under both conditions, for grain protein percent and grain starch percent under heat stress condition were evident due to significant of b2 statistic. Also, among parents, specific gene effects for all traits under both conditions were evident due to significant of b3 statistic (Table 4). Irshad-Ul-Haq et al. (2010) reported that a, b, b1, b2 and b3 items for all traits were significant.

Genetic component of variation showed (Table 5) significant value of D for grain yield, grain protein percent and grain starch percent traits under heat stress condition, indicating the importance of additive genetic effects. Under both planting conditions significant H components (H_1 and H_2) revealed important dominant variation. Different distribution of dominant genes was displayed by unequal value of H_1 and H_2 under both experimental conditions.

Under both conditions, environmental variation (E) was significant (Table 5), that indicating important effects of environments on traits.

Degree of dominance $\sqrt{\frac{H1}{D}}$ indicated over dominance gene action for grain yield trait under normal condition and grain protein percent in heat stress and partial dominance gene action for other traits (Table 5). Betran et al. (2003) reported over dominance gene action for yield, but; partial dominance for number of grain rows. Over dominance type gene action in maize reported by Prakash and Ganguli (2004) and Ali et al. (2007) for grain yield. Shabbir and Saleem (2002) reported that the nature of gene action for protein content of maize grain was additive. Rosulj et al. (2002) indicated that additive type of gene action controlling oil contents in grain. Wattoo et al. (2009) reported that grain yield were controlled by over dominance type of gene action, while quality traits like protein and oil contents were under the control of partial dominance with additive type of gene action. Mebrahtu and Mohamed (2003) conducted a study to find out the mode of inheritance of protein in a 7×7 diallel analysis in beans and indicated that both additive and non additive genetic variance were important for inheritance of protein contents.

The proportion of genes with positive and negative effects $\frac{H2}{4H1}$ in the parents for all traits except grain starch percent under normal condition was found to be less than 0.25 denoting asymmetry at the loci showing dominance (Table 5). Irshad-Ul-Haq et al. (2010) reported that the proportion of genes with positive and negative effects for traits plant height, days to 50% tasseling, days to 50% silking and ear height to be less than 0.25 and for grain yield to be 0.25.

Broad sense heritability varied from 0.56 for grain starch percent under normal condition to 0.86 for grain yield under heat stress condition. Narrow sense heritability was of non-additive nature and displayed lower than 50 percent of the genetic variation transferred from the parents (Table 5). Heritability degrees varied from low to moderate for grain yield (Betran et al. 2003; Hussain et al. 2009). Rezaei et al. (2005) reported high broadsence heritability estimates (0.85 to 0.95) for most traits, the estimates for narrowsence heritability were relatively low, the lowest values belonging to number of grain row and grain yield (0.23 and 0.38) respectively. Hussain et al. (2009) reported heritability estimates ranged from moderate to high (54-85%) for various traits.

Table 1. Mean squares obtained from combining abilities different traits hybrids in diallel crosses in heat stress and normal conditions

Source of Variance	Df	Grain yield (kg/hac)		Grain protein percent		Grain starch percent	
		Stress	Normal	Stress	Normal	Stress	Normal
GCA	7	1190980**	1535789*	8.84**	3.05ns	96**	213ns
SCA	20	287450ns	1239505*	4.72**	2.03ns	99.85**	152ns
Error (combining ability)	54	193825	584733	1.51	1.29	16.3	121
GCA/SCA		4.14	0.12	1.87	1.50	0.96	1.4
Baker ratio[1]		0.89	0.71	0.79	0.75	0.66	0.74

1- $2\delta^2GCA/(\delta^2SCA+2\delta^2GCA)$

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

Table 2. Parents general combining to Griffing's method 4 in heat stress and normal conditions

Inbred lines	Grain yield (kg/hac)		Grain protein percent		Grain starch percent	
	Stress	Normal	Stress	Normal	Stress	Normal
K18	259.97ns	64.7ns	-1.08ns	-0.77ns	-0.21ns	4ns
K3651/1	-303.29ns	-9.97ns	0.72ns	0.67ns	-3.6ns	-4ns
A679	-341.98ns	483ns	0.54ns	-0.11ns	-1.58ns	-3ns
K166A	-19.87ns	284ns	0.13ns	-0.17ns	0.59ns	1ns
K166B	419.89ns	53.14ns	-0.57ns	-0.11ns	1.81ns	4ns
K3640/5	-82.43ns	310.08ns	0.65ns	0.24ns	-2.13ns	-2ns
K47/2-2-1-21-2-1-1-1	54.46ns	180.47ns	-0.75ns	0.17ns	3.03ns	-4ns
K19	13.24ns	-39.36ns	0.36ns	0.08ns	2.09ns	2ns
SE (GCA)	257.23	53.14	0.7	0.41	2.31	3.44

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

Table 3. Parents specific combining to Griffing's method 4 in heat stress and normal conditions

Name of hybrids	Grain yeild (kg/hac)		Grain protein percent		Grain starch percent	
	Stress	Normal	Stress	Normal	Stress	Normal
K18×K3651/1	-330ns	-243.08ns	-0.71ns	-0.41ns	1.33ns	-8ns
K18×A679	-218ns	362.8ns	-0.82ns	-0.28ns	-0.23ns	-9ns
K18×K166A	-213ns	-281.52ns	1.85ns	-1.16ns	-0.73ns	-3ns
K18×K166B	827**	1411.14*	0.33-ns	-0.88ns	-1.29ns	10ns
K18×K3640/5	-356ns	-367.48ns	2.36ns	1.02ns	-1.67ns	2ns
K18×K47/2-2-1-21-2-1-1-1	429ns	99.81ns	-0.74ns	1.24ns	8.84ns	-5ns
K18×K19	-139ns	-981.7ns	-1.60ns	0.47ns	11.44*	12ns
K3651/1×A679	364ns	730.8ns	-0.37ns	0.26ns	4.16ns	4ns
K3651/1×K166A	124ns	-927.9ns	-0.83ns	0.34ns	0.66ns	-3ns
K3651/1×K166B	-171.25ns	-311.52ns	-0.52ns	0.07ns	0.77ns	15*
K3651/1×K3640/5	81.98ns	176.53ns	-0.17ns	0.41ns	0.05ns	1ns
K3651/1× K47/2-2-1-21-2-1-1-1	-49.38ns	14.48ns	1.79ns	-0.41ns	-4.45ns	-2ns
K3651/1×K19	-19.96ns	559.64ns	0.81ns	-0.26ns	-2.51ns	-6ns
A679×K166A	110.65ns	-86.3ns	0.22ns	0.95ns	-4.03ns	4ns
A679×K166B	-469.9ns	-1235.63ns	1.63ns	0.81ns	0.08ns	-10ns
A679×K3640/5	164.56ns	313.09ns	-0.46ns	-0.81ns	2.69ns	1ns
A679×K47/2-2-1-21-2-1-1-1	113.98ns	323.03ns	-1.41ns	-1.51ns	1.19ns	9ns
A679×K19	-65.35ns	-407.8ns	1.22ns	0.58ns	-3.86ns	0ns
K166A×K166B	-213.3ns	62.63ns	-0.41ns	-0.42ns	-4.09ns	-2ns
K166A×K3640/5	-5.64ns	399.42ns	-0.46ns	0.02ns	-0.47ns	1ns
K166A×K47/2-2-1-21-2-1-1-1	-57.62ns	242.7ns	0.8ns	0.97ns	13.03*	5ns
K166A×K19	254.67ns	715.2ns	-1.16ns	-0.71ns	-4.36ns	-3ns
K166B×K3640/5	101.44ns	-169.25ns	-0.63ns	-0.53ns	8.64ns	-3ns
K166B×K47/2-2-1-21-2-1-1-1	-222.29ns	58.03ns	0.75ns	0.66ns	-2.2ns	-3ns
K166B×K19	148.57ns	309.87ns	-0.48ns	0.29ns	-1.92ns	-7ns
K3640/5×K47/2-2-1-21-2-1-1-1	-10.36ns	-447.58ns	-1.52ns	-0.35ns	-4.59ns	-5ns
K3640/5×K19	23.86ns	92.25ns	0.88ns	0.23ns	-4.64ns	2ns
K47/2-2-1-21-2-1-1-1×K19	-202.93ns	-290.47ns	0.34ns	-0.59ns	5.86ns	1ns
SE (SCA)	309.54	642.78	1.25	0.82	5.68	7.11

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

Table 4. Analysis of mean of squares of diallel crosses of eight maize inbred lines in heat stress and normal conditions

Source of Variance	Df	Grain yield (kg/hac)		Grain protein percent		Grain starch percent	
		Stress	Normal	Stress	Normal	Stress	Normal
a	7	3990058**	1944439**	19.25**	8.23**	277.54**	461.82**
b	28	1377319**	2775917**	9.17**	3.82**	158.36**	297.16**
b1	1	1574644**	10723930**	1646**	3.4ns	5.2ns	1685.29**
b2	7	854254**	2488819**	7.33**	2.07ns	62.14**	81.87ns
b3	20	1645986**	2479001**	9.44**	4.6**	200**	303.11**
Error	126	192710	535380	1.44	1.25	15	107.44

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

Table 5. Estimation of statistical indices and genetics parameters for different traits in eight maize inbred lines diallel crosses in heat stress and normal conditions

Traits	Grain yield (kg/hac)		Grain protein percent		Grain starch percent	
Parameter	Stress	Normal	Stress	Normal	Stress	Normal
D	318442*	275424ns	2.5**	2ns	143.5**	133.4ns
H1	308959**	1982055**	6.66**	1.91*	104.8**	120.1*
H2	283308**	1499272**	5.19**	1.73*	93.9**	127.6*
E	64237**	178460**	0.47**	0.42**	5.93**	35.8**
$\sqrt{\frac{H1}{D}}$	0.98	2.68	1.63	0.98	0.85	0.95
$\frac{H2}{4H1}$	0.23	0.19	0.19	0.23	0.22	0.27
h^2b	0.86	0.71	0.81	0.64	0.85	0.56
h^2n	0.44	0.09	0.30	0.28	0.27	0.17

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

4. Discussions

Prediction in the case of additive gene action would be expected to be more reliable as compared to the traits which are controlled by non-additive type of gene action. In this research, grain yield under normal condition and grain protein percent trait under heat stress condition were under the control of over dominance type of gene action. But; grain yield in stress condition, grain protein percent in normal condition and grain starch percent in both conditions were under the control of partial domainance with additive type of gene action. Over dominance for traits reveals that selection in later generations may be more effective and the selection in early generations will be more effective for the traits which is additively controlled.

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