Gene Action Studies of Different 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, genetic parameters of yield and other quantitative 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 randomized complete block design with three replications. Genotypes planted at two dates, 6 July (to coincide heat stress with pollination time and grain filling period) and 27 July (as normal planting). Estimation gene effects and some of genetic parameters and graphic plot drawing to Hayman – Jinks method revealed statistics a and b significant for all traits in two conditions. Considering the average dominance degree and Hayman graphical plot, dominant effects for hektolitr weight trait under heat stress condition and for grain yield under normal condition, over dominance as well as partial dominance for other traits, were revealed.

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Key words: Maize; heat stress; genetic parameters; grafic plot

1.Introduction

Under heat stress, maize plant shows stunted growth, wilting top firing, tassel blast, silking delay and desiccation, pollen abortion and poor seed set which eventually can result in yield losses. Heat stress is 2nd major abiotic problem after drought that reduces grain yield more than 15 percent (Akbar et al, 2008). In southern part of Iran, especially in Khuzestan, heat stress is one of the most important abiotic stress in maize growing area. Therefore breeders need to develop such maize genotypes which may sustain period of heat stress stress without lowering their yield potential.

Betran et al. (2003) reported gene action for yield, ear diameter, number of grain in row, grain depth and 1000 grain weight is over dominance but for number of grain rows is partial dominance.

Barati et al. (2003) showed that gene action for yield, number of grain in row and 1000 grain weight is over dominance but for number of grain rows is partial dominance.

Srdic et al. (2007) found that dominant gene effects were more significant in maize grain yield and number of grains per row while additive gene effects were more important for grain row number and 1000 grain weight. The mode of inheritance of grain row number was partial dominance, while over dominance was of greater importance for grain yield, number of grains per row and 1000 grain weight.

Wattoo et al. (2002) revealed that the yield potential like number of days taken to tasselling, number of days taken to silking, plant height, number of ears per plant, number of grain rows per ear, number of grains per row, 100 grain weight and grain yield per plant were controlled by over dominance type of gene action.

Irshad-Ul-Haq et al. (2010) revealed that non-additive genetic effects were more pronounced in the inheritance of plant height, days to 50% tasseling, days to 50% silking, ear height and grain yield per plant. The graphic analysis showed that all the characters were under the genetic control of over dominance type of gene action. Also for grain yield the parents NYP-8 and NCQPM-2 were close to the point of origin and had an excess of dominant genes whereas FR-37 being farthest from the origin was carrying maximum number of recessive alleles.

Hussain et al. (2009) reported that plant height, leaf area, grain yield, per plant and harvest index, under normal and water stress conditions indicated additive gene action with partial dominance. Also over dominance type of gene action was recorded for grains per row and 100 grain weight. Heritability estimates ranged from moderate to high (54-85%) for various traits.

Rezaei *et al.* (2005) reported that high broadsence heritability estimates (0.85 to 0.95) were observed 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.

Heritability degrees varied from low to moderate for grain yield (Kalla et al, 2001; Singh et al, 2002).

The study of diallel analysis of the genetic traits would certainly be a valuable aid in selection and breeding for better maize hybrids and synthetics under heat stress condition. The information derived may be helpful to develop selection criterion and selection of most promising inbred lines for further future breeding programs.

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) year 2010. The soil type at this location is clay loam, pH= 7.6 with EC= 0.5 mmhos/cm.

The experimental material comprised of eight inbred lines of maize with different reaction to heat stress encompass 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). The lines were crossed during spring, 2010 in a partial diallel fashion to obtain grains of direct crosses. The F_1 seed along with their parental inbred lines were sown in a triplicated randomized complete block design under two planting dates, 6 July, to coincide heat stress with pollination time and grain filling period and 27 July, (the normal planting date) to avoid heat stress during pollination and grain filling period, in year 2010. 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 4 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 (planting date 27 July) (Table 1).

Data pertaining grain row number in ear, grain number in row, grain number in ear, 1000 grain weight, hektolitr weight and grain yield traits were statistically analyzed. Analysis of variance was performed for each individual experiment, using SPSS software. Genetic analysis was done according to the diallel technique as described by Hayman (1954) and Jinks (1954). Genetic components of variation, D (additive effects of genes), H_1 and H_2 (dominance effects of genes) and F were computed from estimates of variances and covariances. These parameters provide estimates of the relative frequency of dominant to recessive allels in the parental lines. The information on gene action and presence of dominant and recessive genes in the parents was also inferred by plotting the covariance (Wr) of each array against its variance (Vr).

3.Results

Significant differences were observed among the parents and F_1 hybrids in both conditions for all studied traits (Table 2) and thus allowed the use of Hayman – Jinks model for genetic analysis of these characters.

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 2). Significance of b1 revealed the presence of directional dominant effects of genes. The b1 statistic for grain yield under both conditions, for grain number in ear, grain row number in ear, grain number in row and hektolitr weight traits under normal condition and 1000 grain weight under heat stress condition was significant. Among inbred lines, asymmetrical gene distribution for grain yield, grain row number and hektolitr weight under both conditions, for grain number in ear, grain number in row under heat stress condition and 1000 grain weight under normal 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. 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 3) significant value of D under both heat stress and normal conditions for grain row number in ear, 1000 grain weight and hektolitr weight traits, for grain yield, grain number in row and grain number in ear 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.

Significant and positive additive and dominance effects covariance (F) as criterion of dominance and additive alleles frequency for 1000 grain weight trait under both conditions, grain number in ear and hektolitr weight under heat stress condition and grain row number in ear under normal condition, indicated that the positive genes were more frequent.

Importance of the heterozygous loci for plants was indicated by significant value of h^2 that for grain number in ear and hektolitr weight traits under normal condition and 1000 grain weight under heat stress condition.

Under both conditions, environmental variation (E) was significant, 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, hektolitr weight under stress condition and partial dominance gene action for other traits. Betran et al. (2003) reported over dominance gene action for yield, ear diameter, number of grain in row, grain depth and 1000 grain weight, but partial dominance for number of grain rows. Hussain et al. (2009) reported that plant height, leaf area, grain yield, per plant and harvest index, under normal and water stress conditions indicated additive gene action with partial dominance. Also over dominance type of gene action was recorded for grains per row and 100 grain weight. Over dominance type gene action in maize reported by Prakash and Ganguli (2004) and Ali et al. (2007) for grain yield and for all traits by Wattoo et al. (2002) and Irshad-Ul-Haq et al. (2010).

The proportion of genes with positive and negative effects $\frac{H2}{4H1}$ in the parents for all traits except grain number in row and grain number in ear under normal condition was found to be less than 0.25 denoting asymmetry at the loci showing dominance. 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 0.44 for grain number in ear 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. Heritability degrees varied from low to moderate for grain yield (Kalla et al, 2001; Singh et al, 2002).

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.

Graphical representation revealed that the regression line intercepted the Wr axis just below the point of origin which indicated the presence of over dominance type of gene action for grain yield under normal condition (Fig 1b) and hektolitr weight under heat stress condition (Fig 6a) traits. But for other traits the regression line intercepted the Wr axis just above the point of origin which indicated the presence of partial dominance type of gene action, that this results in agreement is with results received of degree of dominance $\sqrt{\frac{H1}{D}}$.

Inbred line K166B for grain yield trait under both conditions being closer to the origin possessed maximum dominant genes, while inbred line K18 had most recessive alleles. For grain number in ear, inbred lines K47/2-2-1-21-2-1-1-1 and K19 under stress condition and inbred lines K3640/5 and K3651/1 under normal condition, inbred lines K18 and K166B under stress condition and inbred lines A679 and K166A under normal condition for grain number in row, lines K18 and K47/2-2-1-21-2-1-1-1 under stress condition and lines K3651/1 and K47/2-2-1-21-2-1-1-1 under normal condition for grain row number in ear trait, lines K18 and K19 under stress condition and K18 and K166A under normal condition for 1000 grain weight and for hektolitr weight, lines K3640/5 and K19 under heat stress condition and lines K166A and K166B under normal condition showed maximum dominant and recessive genes, respectively. Saleem et al. (2007) indicated that inbred lines B-46 possessed maximum dominant genes for 100 grain weight and line EX-285 for grain yield per plant. For number of days taken to tasseling, number of days taken to silking and number of grain row per ear, inbred line SYP-24 had maximum dominant genes. Irshad-Ul-Haq et al. (2010) indicated that for grain yield the parents NYP-8 and NCQPM-2 were close to the point of origin and had an excess of dominant genes whereas FR-37 being farthest from the origin was carrying maximum number of recessive alleles.

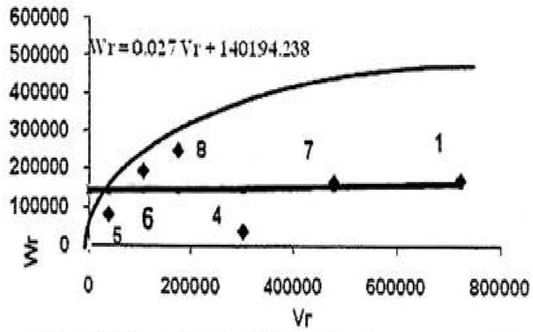

Fig 1a. Vr/Wr graph grain yield (kg/plot) in heat stress condition

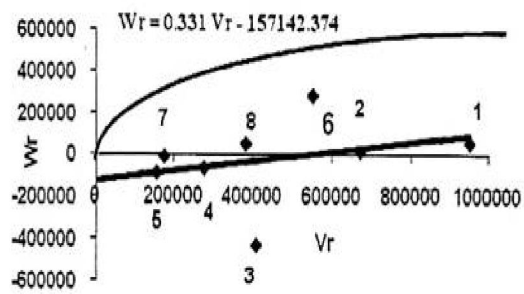

Fig 1b. Vr/Wr graph grain yield (kg/plot) in normal condition

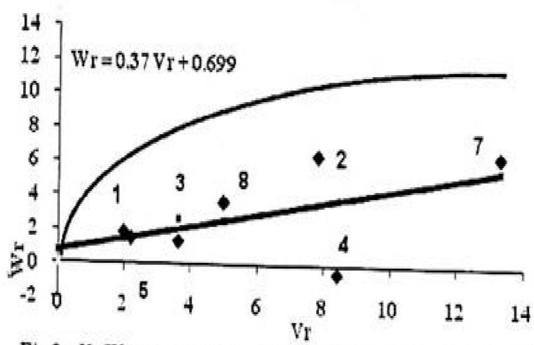

Fig 2a. Vr/Wr graph grain row number in ear in heat stress condition

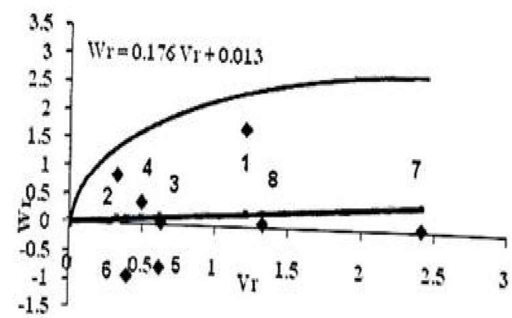

Fig 2b. Vr/Wr graph grain row number in ear in normal condition

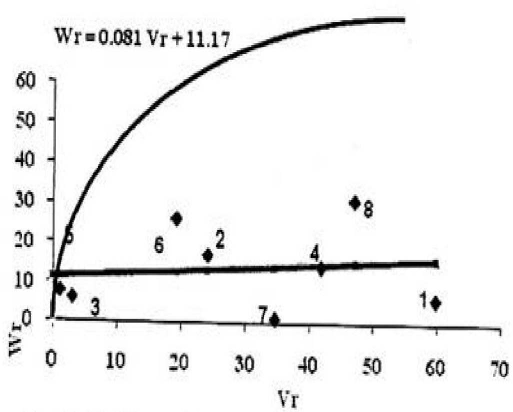

Fig 3a. Vr/Wr graph grain number in row in heat stress condition

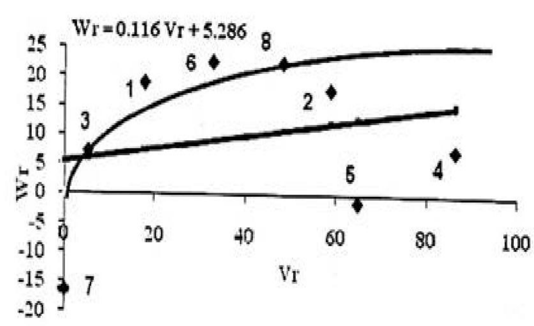

Fig 3b. Vr/Wr graph grain number in row in normal condition

1: K18; 2: K3651/1; 3: A679; 4: K166A; 5: K166B; 6; K3640/5; 7: K47/2-2-1-21-2-1-1-1; 8: K19

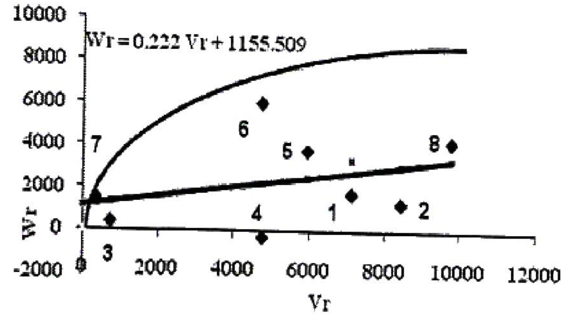

Fig 4a. Vr/Wr graph grain number in ear in heat stress condition

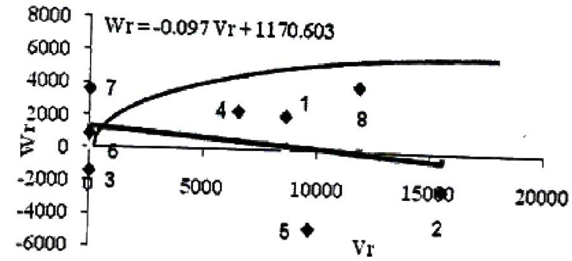

Fig 4b. Vr/Wr graph grain number in ear in normal condition

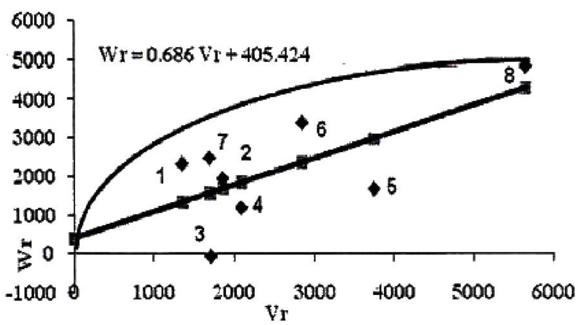

Fig 5a. Vr/Wr graph 1000 grain weight (gr) in heat stress condition

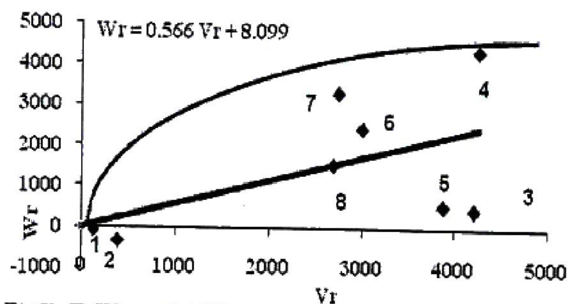

Fig 5b. Vr/Wr graph 1000 grain weight (gr) in normal condition

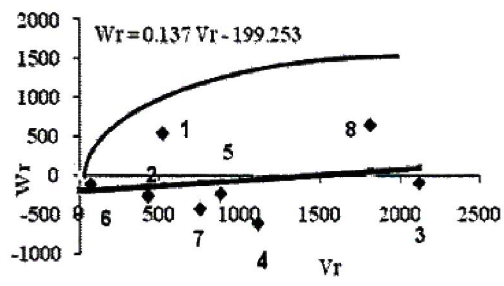

Fig 6a. Vr/Wr graph hektolitr weight (gr/lit) in heat stress condition

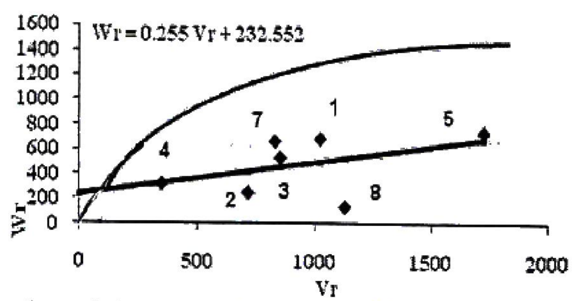

Fig 6b. Vr/Wr graph hektolitr weight (gr/lit) in normal condition

1: K18; 2: K3651/1; 3: A679; 4: K166A; 5: K166B; 6; K3640/5; 7: K47/2-2-1-21-2-1-1-1; 8: K19

Table 1. Average minimum and maximum temperature of research farm in heat stress and normal conditions in 2010 year

Months	Temperature (°C)	
	Minimum	Maximum
July	31 °C	46 °C
August	32 °C	46 °C
September	30 °C	46 °C
October	25 °C	38 °C
November	17 °C	27 °C
December	11 °C	21 °C

Table 2. Analysis of variance mean squares obtained from in 8×8 diallel crosses and 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 number in ear		Grain row number in ear		Grain number in row		1000 grain weight (gr)		Hektolitr weight (gr/lit)	
		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	35	1092651**	1316319**	66388**	135981**	87**	9.57**	377.30**	651**	10357**	10738**	3395**	5170*
Error	70	145969	584733	1785	120742	20	6	27.33	584	2784	3669	582	2608
a	7	3990058**	1944439**	45742.9**	76050.9*	44.21**	6.53**	277.54**	461.82**	55983.9**	46883**	6006.9**	11128**
b	28	1377319**	2775917**	29670.4**	59029.1**	37.09**	6.11**	158.36**	297.16**	11895**	13836.8**	6261.2**	5208.6**
b1	1	1574644**	10723930**	98.5ns	305419**	0.14ns	5.84*	5.2ns	1685.29**	48205.6**	10108.7ns	2082.4ns	49859.8**
b2	7	854254**	2488819**	14300.13**	26550.7ns	14.56*	13.75**	62.14**	81.87ns	3914ns	13110**	8428**	2430.6*
b3	20	1645986**	2479001**	36528.6**	77580**	49.38**	3.45**	200**	303.11**	12873**	14277.6**	5711.9**	3209.8**
Error	126	192710	535380	3552.4	27638.8	6.20	1.20	15	107.44	2790.2	3320	1096	983

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

Table 3. 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 row number in ear		Grain number in row		Grain number in ear		1000 grain weight (gr)		Hektolitr weight (gr/lit)	
Parameter	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal
D	318442*	275424ns	30.12*	7.4**	143.5**	133.4ns	20431.9**	-22034ns	6676*	9876.99*	1154.6*	4274.35*
H1	308959**	1982055**	22.6**	6.42**	104.8**	120.1*	20098.9**	20654.8**	6351.04**	9458.5**	5276.8**	3162.03*
H2	283308**	1499272**	20.7**	3.29**	93.9**	127.6*	17448.9**	21214.8**	6099.2**	7045.6**	3455.3**	2830.8*
F	43524ns	646364ns	8.5ns	6.1**	32.9ns	-32.5ns	7602.9*	-6340.4ns	524.7*	3694.2*	2578.6*	653.02ns
h^2	258888ns	1490713ns	-0.92ns	0.689ns	-1.67ns	231.08ns	-481.3ns	40761.6**	6648.5*	1020.25ns	153.9ns	7991.36**
E	64237**	178460**	2.07**	0.396**	5.93**	35.8**	1184.14**	9212.9**	930.07**	1106.7**	365.23**	327.6**
$\sqrt{\frac{H1}{D}}$	0.98	2.68	0.87	0.93	0.85	0.95	0.99	0.97	0.97	0.98	2.14	0.86
$\frac{H2}{4H1}$	0.23	0.19	0.23	0.13	0.22	0.27	0.22	0.26	0.24	0.19	0.16	0.22
h^2b	0.86	0.71	0.77	0.72	0.85	0.56	0.84	0.44	0.80	0.76	0.74	0.78
h^2n	0.44	0.09	0.2	0.15	0.27	0.17	0.24	0.11	0.47	0.39	0.14	0.32

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

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4.Discussions

It may be concluded that overall information obtained in the present study if practiced with care, in general, go a long way in developing promising synthetics and hybrids of maize. All the traits, except grain yield under normal condition and hektolitr weight trait under heat stress condition were under the control of additive type of gene action. The grain yield under normal condition and hektolitr weight trait under heat stress condition were under the control of over dominance 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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