GENE ACTION STUDIES FOR AGRONOMIC TRAITS IN MAIZE UNDER NORMAL AND WATER STRESS CONDITIONS

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A set of six drought tolerant and susceptible maize inbred lines were evaluated under normal and water stress conditions. Significant differences among the genotypes were found for all the characters. Plant height, leaf area, grain yield per plant and harvest index, under both conditions indicated additive gene action with partial dominance which suggested that these traits might be useful during selection for developing synthetics. However over-dominance type of gene action was recorded for kernels per row and 100-grain weight. Heritability estimates ranged from moderate to high (54- 85%) for various traits. Gene action (additive and overdominance) and heritability suggested selection of desirable parents for breeding drought tolerant hybrids.

Keywords: Maize, drought, heritability, gene action, diallel cross

INTRODUCTION

Globally maize (*Zea mays* L.) is the third important cereal after wheat and rice with an area of 147.6 million hectares producing 701.3 million metric tones and overall yield of 4752 kg per hectare. In Pakistan it is grown on 1016.9 thousand hectares with annual production of 3088.4 thousand tones and average yield of 3037 kg per hectare, which was 1.59 times less as compared to the world grain yield per unit area (Anonymous, 2007).

The crop is extensively grown as grain for humans and fodder for livestock consumption. Maize is a C_4 crop and is high yielding cereal for total dry matter production. Water requirement of any crop is very much dependent on prevailing environment (temperature and humidity) in which it is grown. Maize requires 500-800 mm of water during life cycle of 80 to 110 days (Critchley and Klaus, 1991). According to Jamieson *et al.* (1995) water requirement of maize at the time of tesseling is 135 mm/month (4.5 mm/day) and this requirement may increase up to 195 mm/month (6.5 mm/day) during hot windy conditions. Thus, evolution of high yielding maize varieties under drought conditions is reliable option to cope with the menace of water shortage.

Genetic effects of heritable parameters lead a plant breeder to a clear understanding of inheritance patterns of various plant traits as their relative contribution to the final grain yield. Hayman's approach is a powerful statistical technique, which provides six genetic components of variance and ratios of dominant and recessive genes in the parents to quantify their dominance order. Such information will be of tremendous help to accurately ascertain the merits of individual characters as yield promoting traits. Drought tolerance exists in various crop species like wheat and in maize. Because of this genetic diversity for drought, new methodologies can help to evolve drought tolerant varieties. Hybrids from parents having more diversity yield more than of similar parents (Troyer *et al.,* 1998). 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 drought conditions. The information derived may be helpful to develop selection criterion and selection of most promising inbred lines for further future breeding programs.

MATERIALS AND METHODS

The selected inbred lines (Table 3a) were planted during Feb/Mar. 2006 in the field of the department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. The soil of the selected site was loamy with pH 7.70. The selected inbred lines were crossed in all possible combinations during April 2007. During September, 2007, six parents and F_1 including reciprocals were planted in the field using a randomized complete block design with three replications. Seeds were sown by dibble, keeping plant-to-plant and row-to-row distances of 20 and 75 cm. respectively. Two seeds were planted per site to have good stand. Thinning was done after germination to a single healthy seedling per site. Non-experimental lines were planted to minimize the edge border effects. Under water stress conditions, the same experiment was repeated. Except irrigation (as no irrigation was applied to drought block) all other cultural practices were kept uniform to both normal and drought conditions. At maturity, data were recorded for the following agronomic traits.

Plant height (cm)

Ten guarded plants from each entry were selected at maturity and plant height was measured with meter rod in centimeters from the ground level to the base of the tassel and average height was calculated.

Leaf area (cm^2)

Leaf area was measured as the product of the length and maximum width. Leaves obtained from ten randomly selected plants from each treatment were collected and area of each was measured using the formula suggested by Mckee, (1964).
Leaf area = Leaf length (cm) × leaf width (cm) ×0.74

Number of kernels per row

Number of kernels per row was obtained by counting the number of kernels per row with the average number of kernel rows per ear of the ten guarded plants.

100-grain weight (g)

Hundred grain weight was measured in grams with an electronic balance from the bulk produce of each plot in each replication and then averaged.

Grain yield per plant (g)

The grains produced by the selected plants used for biological yield were weighed in grams and average grain yield per plant was recoded.

Harvest index

Harvest index for each treatment was calculated in percentage by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield per plant}}{\text{Biological yield}} \times 100$$

RESULTS AND DISCUSSION

Analysis of variance for all the characters under both normal and water stress conditions are presented in Table 1, which revealed highly significant differences for all the traits under both regimes. Maximum plant height (225.05cm) under normal irrigation was recorded (Table 3a) for parental line Y-74 while 8-S showed minimum plant height (132.17cm). Parental line Y-74 was the tallest (161.81cm) while least plant height was displayed by the parental line 8-S, that was 98.41cm under stress condition. Among the crosses, F-141×Y-74 showed maximum plant height (233.86cm) followed by Y-74×F.128 (201.85cm) whereas 8-S×Y-158 had minimum plant height (139.96cm). The same crosses displayed maximum and minimum plant height under stress. Cross 8-S×Y-158 showed minimum plant height (101.63 cm) while cross F-141×Y-74 was the tallest (161.81cm) under water stress condition followed by Y-74×Y-158. Gu *et al*. (1989), Gu *et al.* (1990), Yang and Hsiang (1992), Vicente *et al.* (1999), Dass *et al.* (2001) and Tabassum (2004) reported reduction in plant height under water stress condition.

Table 1. Analysis of variance of six maize inbred lines and their all possible crosses for various characters

Traits	Normal	Water stress
Plant height	1861.06**	823.82**
Leaf area	4080.59**	11747.24**
Kernels per row	141.15**	82.33**
100-Grain weight	25.81**	41.75**
Leaf number	12.83**	12.79**
Grain yield per plant	3346.38**	1565.28**
Harvest index	110.95**	48.23**

** = P≤ 0.01 (df = 35)

The highest value (485.8 cm^2) for leaf area (Table 3a) was observed by the parents Y-74 followed by F-128 under normal condition and the parental line 8-S had low value (354.8cm^2) under normal condition whereas under water stress condition, the parent Y-74 showed maximum leaf area (432.8cm^2) while 8-S showed minimum leaf area (220.33cm^2). In the crosses, maximum leaf area (435.33cm^2) was displayed by F-128×Y-74 and cross Y-158×B-34 showed minimum leaf area (251.13cm^2) under stress. While under normal condition Y-74×F-141 had maximum leaf area (488.43cm^2) and minimum leaf area (373.53cm^2) was displayed by cross 8-S×Y-158.
Kernels per row (Table 3a) ranged from 22.53 for Y-74 to 34.37 for Y-158 in the parents under normal irrigation. Whereas under water stress condition kernels per row ranged from 14.4 (F-141) to 27.43 (8-S). In crosses, kernels per row ranged from 10.70 for F-128 × Y-74 to 39.03 for 8-S×Y-158 under normal planting. Parental line 8-S showed minimum 100-grain weight (27.67g) and parent F-141 displayed maximum 100-grain weight (32.67g) under normal conditions. While under stress 100-grain weight ranged from 20.67 (8-S) to 29.3 (Y-74). In case of 100-grain weight cross Y-158×Y-74 and 8-S×Y-158 had minimum value (25.67). While maximum value 37.33g was displayed by cross F-128×Y-74 under normal irrigation. While under stress 100-grain weight ranged from 20g (8-S×Y-158) to 33.33g (F-128×Y-74).
As regard grain yield per plant (Table 3b) maximum value (160.33) for grain yield per plant was displayed by parental line Y-74 and minimum value (49.18 g) was showed by parent Y-158 under normal condition and under water stress condition maximum grain yield

(110.00g) was displayed by Y-74 and minimum value (27.00 g) was recorded by the parent 8-S. Among crosses the cross F-141×Y-74 showed maximum value (184g) and minimum value (46.33g) for cross 8-S×Y-158 under normal condition and maximum value (117g) and minimum value (33.67g) under stress environment was revealed by F-141×Y-74 and 8-S×Y-158 respectively.

Harvest index (Table 3b) ranged from 36.70 (8S) to 67.17 (Y-74) for the parental lines under normal condition whereas under water stress environment it ranged from 32.21g to 51.8. In crosses, harvest index ranged from 43.7g to 64.61g for crosses 8-S×Y-158 and F-141×Y-74 respectively under normal irrigation while under water stress conditions harvest index ranged from 37.81g to 51.13g by the same crosses.

Genetic component of variation were estimated according to Hayman (1954b) and are presented in Table 2. Significant value of D under both normal and water stress conditions indicated the importance of additive genetic effects. Under both planting condition 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 environmental conditions.

(1986), Tabassum (1989), Mahajan and Khera (1991) and Perez *et al*. (1996) who reported additive gene action for plant height. While Sharma and Bhalla (1990), and Tabassum (2004) reported dominance type of gene action for this trait. Saddiqui (1999), Shakil (1992), Yousaf (1992) and Shabbir and Saleem (2002) reported over dominance type of gene action for plant height.

Genetic components (D and H) were significant under normal and water stress conditions for leaf area which indicated additive and dominant genetic effects. Different distribution of dominant and recessive genes was revealed by the un-equal value of H_1 and H_2. The value of F was found non significant under both planting environment, suggesting positive and dominant genes were less important for leaf area per plant. Significant dominant effect due to heterozygous loci indicated by significant value of h^2 under both conditions. Environmental variation (E) was found non significant under normal and water stress conditions. Degree of dominance H/D indicated the additive gene action for inheritance of leaf area per plant.

Genetic components (D and H) were significant under both planting conditions revealed that kernels per row were under the control of both additive and dominant genetic effects. Differently distribution of dominant and

Table 2. Estimates of components of variation for various traits under normal and water stress conditions

Character	Condition	D	H_1	H_2	F	h^2	E	$(H_1/D)^{0.5}$	$h^2_{(n.s)}$
Plant height	Normal	1410.36	438.318	421.046	195.359	56.078	1.427	0.557	0.85
	W. stress	537.71	226.584	213.646	21.298	42.805	1.146	0.649	0.83
Leaf area	Normal	2361.08	1193.87	1079.89	-116.48	590.95	16.39	0.71	0.61
	W. stress	6581.09	3985.95	3527.07	-226.64	881.61	28.09	0.778	0.60
Kernels per ear row	Normal	19.27	89.27	74.07	-24.79	58.54	6.01	2.152	0.54
	W. stress	22.58	40.36	31.90	-10.12	16.54	2.98	1.336	0.65
!00-grain weight	Normal	3.34	16.67	13.82	-4.53	11.90	1.08	2.231	0.54
	W. stress	12.94	25.20	18.86	-0.99	10.06	1.21	1.39	0.63
Harvest index	Normal	103.73	29.80	25.61	42.33	39.77	4.66	0.536	0.64
	W. stress	42.63	9.19	7.17	19.21	15.03	5.32	0.464	0.54
Grain yield/plant	Normal	2718.41	845.11	802.00	580.98	73.86	8.80	0.557	0.73
	W. stress	1051.27	429.81	406.78	73.46	70.82	8.35	0.639	0.71

A significant and positive value of F indicated that the positive genes were more frequent under normal and water stress condition. Important effect of heterozygous loci for plants was indicated by significant value of h^2 under water stress condition. Under both planting condition environmental variation (E) was non significant. Heritability was of additive nature and displayed more than 70 percent of the genetic variation transferred from the parents. Under both conditions, degree of dominance indicated additive gene action for the inheritance of plant height. The results are in accordance with those of Bukhari

recessive genes revealed by unequal values of H_1 and H_2. Significant value of h^2 under both environments indicated dominance effects due to heterozygous loci. The value of F was found non significant under both planting conditions suggesting dominant genes were less frequent, while environmental variance E was non significant in stress planting conditions indicating negligible effects of environments in determining the kernels per row. While E was significant under normal irrigation revealed important effect of environment for this trait. The results are in accordance with those of Shakil (1992), and Shabbir and Saleem (2002).

Table 3a. Means and LSD values of plant height, leaf area and kernels per row in an 6×6 diallel cross

Parental Lines / Crosses	Plant height		Leaf area		Kernels per ear row	
	Normal	Water stress	Normal	Water stress	Normal	Water stress
B-34	150.16	116.55	392.83	273.57	29	20.53
B-34 x 8-S	155.46	119.50	404.80	292.13	28.40	19.30
B-34 x Y-74	189.61	134.01	455.70	354.50	16.73	10.50
B-34 x F-128	158.03	119.90	405.03	296.47	19.67	18.83
B-34 x Y-158	146.48	113	386.97	259.13	31.17	21.17
B-34 x F-141	168.80	124.53	427.30	319.40	27.13	20.90
8-S x B-34	151.15	116.12	392.47	281	27.33	22.03
8-S	132.17	98.41	354.80	220.33	33.10	27.43
8-S x Y-74	163.27	126.04	408.63	322.63	28.33	19.07
8-S x F-128	164.35	130.52	413.37	341.83	20.70	13.70
8-S x Y-158	139.96	101.63	373.53	230	39.03	28.43
8-S x F-141	152.72	116.13	396.87	278.40	26.17	21.93
Y-74 x B-34	187.33	132.10	458.37	349.50	20.33	14.97
Y-74 x 8-S	161.87	128.69	409.53	330.40	20.37	15.87
Y-74	225.05	161.81	485.80	432.80	22.53	14.40
Y-74 x F-128	201.85	154.77	488.43	424	15.90	11.30
Y-74 x Y-158	193.56	144.81	464.13	410.80	15.80	11.30
Y-74 x F-141	222.92	159.04	486.77	424.13	12.13	9.87
F-128 x B-34	158.24	124.31	410.87	317	19	17.60
F-128 x 8-S	165.38	127.23	417.40	323.33	24.10	17.93
F-128 x Y-74	203.18	155.62	491.60	435.33	10.70	10.37
F-128	158.64	158.7	412.63	321.40	27.37	19.20
F-128 x Y-158	164.76	121.97	418.73	308.57	22.90	18.53
F-128 x F-141	155.67	117.43	400.27	276.33	28.37	23.90
Y-158 x B-34	148.38	112.10	389.87	251.13	30.27	23.43
Y-158 x 8-S	143.64	101.70	383.40	236.33	36.83	26.83
Y-158 x Y-74	192.48	144.27	464.97	412.77	12.70	9.17
Y-158 x F-128	167.39	122.06	423.97	297.63	25.30	19.50
Y-158	136.09	101.88	367.23	226.33	34.37	25.60
Y-158 x F-141	158	122.19	410.93	302.87	24.37	19.30
F-141 x B-34	166.15	122.78	422.47	310.13	24.97	18.83
F-141 x 8-S	155.56	119.54	404.13	291.37	27.80	23.90
F-141 x Y-74	233.86	161.81	492.13	432.33	15.03	10.87
F-141 x F-128	158.06	115.55	408.67	273.60	30.13	21.73
F-141 x Y-158	155.85	117.80	401.8	282.60	21.73	21.13
F-141	176.97	132.24	441.13	350.87	22.63	16.63
LSD	3.34	3.03	11.49	15.01	6.96	4.87

Degree of dominance (H1/D½) revealed an over dominance type of gene action. Heritability estimates under both planting conditions displayed that more than 50% of the genetic variation transferred from the parents was of additive nature. Genetic component (D) for100-grain weight was significant and indicated that this trait was under the control of additive genetic effect in both conditions. It was also found significant which meaning dominant genetic effects under both environments. Un-equal value of H_1 and H_2 revealed different distribution of dominant and recessive genes. The F value was found negative and non-significant under both conditions suggesting that positive and dominant genes were less frequent under normal and stress conditions. The effects of heterozygous loci among the parents under both conditions were important as revealed by significant item h^2. Environmental effect was non-significant under both normal and stress condition indicated the average degree of dominance type of gene action.

Significant values for estimates of genetic components of variation D and H for grain yield displayed that both additive and dominance effects of genes were due to heterozygous loci. Un-equal values of H_1 and H_2 under both environments displayed different distribution of dominant genes. Significant and positive values of F depicted that positive genes were more frequent under normal condition. Non-significant value of h^2 indicated

Table 3b. Means and LSD values of grain yield per plant, harvest index and 100-grain weight in an 6×6 diallel cross

Parental Lines / Crosses	Grain Yield Per Plant		Harvest Index		100-grain weight	
	Normal	Water stress	Normal	Water stress	Normal	Water stress
B-34	73	51.67	50.71	41.54	29.67	26
B-34 x 8-S	78.33	55	53.42	44.61	30.33	25.67
B-34 x Y-74	108.11	77.17	58.55	48.14	35.33	31.33
B-34 x F-128	81.11	56	54.92	44.76	34	24.67
B-34 x Y-158	65.44	45.33	51.27	41.30	28.67	24.67
B-34 x F-141	87.67	60.67	53.09	44.95	30.67	25.67
8-S x B-34	73.33	52.67	50.54	43.55	30	24.33
8-S	37.33	27	36.79	32.21	27.67	20.67
8-S x Y-74	86	64.33	55.60	45.03	30	27
8-S x F-128	85	67.67	54.15	44.70	33.67	29.67
8-S x Y-158	46.33	33.67	43.70	37.81	25.67	20
8-S x F-141	72.33	50	50.67	41.60	31.33	24.67
Y-74 x B-34	114	73	58.10	46.09	33.67	29
Y-74 x 8-S	85	67.33	52.58	47.10	33.33	28.33
Y-74	160.33	110	67.17	51.80	32.33	29.33
Y-74 x F-128	134.33	102.2	62.37	48.90	35.33	32.33
Y-74 x Y-158	120.33	90.67	59.39	48.01	35.67	33
Y-74 x F-141	162	111	63.53	50.43	37	32
F-128 x B-34	83	57.33	57.09	43.94	34.67	28
F-128 x8-S	87.67	69.67	54.42	47.82	31.67	27.67
F-128 x Y-74	141	103	61.83	49.99	37.33	33.33
F-128	83.2	62.33	52.39	44.44	30.33	25.33
F-128 x Y-158	90.33	62.33	57.9	44.96	32	26.33
F-128 x F-141	75	51	52.66	43.62	30	23
Y-158 x B-34	72	46.33	49.78	41.81	29.33	24.33
Y-158 x 8-S	48.67	34.33	46.90	38.51	26.67	20.67
Y-158 x Y-74	123	92.33	60.67	46.65	36.67	33.33
Y-158 x F-128	95	62.67	57.19	45.17	31.67	26.67
Y-158	49.18	33.33	43.91	37.95	28	20.67
Y-158 x F-141	77.33	56	53.45	42.05	31.67	26
F-141 x B-34	88.33	62.67	56.42	46.54	32	26.33
F-141 x 8-S	74.67	53	50.68	45.03	30.33	22.67
F-141 x Y-74	184	117	64.61	51.13	36	32
F-141 x F-128	77	52.33	53.14	44.07	29.67	24.67
F-141 x Y-158	80.67	57	54.23	43.76	32.67	25
F-141	98	73.33	56.17	47.20	32.67	28.67
LSD	8.41	8.12	6.07	6.52	2.95	3.12

absence of imported effect of heterozygous loci. Heritability was found more than 70%. Degree of dominance was more than 50% which showed additive type of gene action. The results are in accord with those of Tabassum (1989), Damborsky *et al*. (1994), Dutu (1999), and Mani *et al.* (2000) who reported additive gene action. The results differ from those of Bhukhari (1986), Naveed (1989), Arif (1990), Malik (1990) and Shabir and Saleem (2002) who reported over dominance type of gene action.

Genetic components of variation D and H for harvest index were significant under both conditions revealed additive and dominance genetic effects. Unequal value of H_1 and H_2 showed different distribution of dominant genes. A positive and significant value of F indicated that positive genes were more frequent. Value of h^2 indicated the important effect of heterozygous loci for harvest index.. Environmental variation (E) was significant under both planting environments, indicating important effects of environments, in determining harvest index. The results are in line with those of Shakil (1992) and Shabbir and Saleem (2002) and in case of water stress Tabassum (2004). Degree of dominance under both was less than one indicating additive type of gene action under both conditions.

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