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Estimation of genetic components for various physiological traits in *Zea mays* L under water deficit conditions

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Abstract: Drought is a solemn environmental factor that causes great loss of yield in maize crop. Maize is highly sensitive to drought. There is need to develop drought tolerance maize genotypes to fulfill demand of feed for livestock and food for human. For this propose prescribed study was conducted to estimate genetic components for various physiological traits under normal and water tress conditions in the research area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan. It was concluded that P_1 (WFTMS) parent performed better under drought conditions for stomata frequency, stomata conductance, stomata size, cell membrane thermo stability, leaf water potential and excised leaf water loss while BC_2 for stomata conductance, F_1 for stomata size, F_2 leaf water potential and BC_1 for leaf temperature. Positive [h] dominance effects were recorded for cell membrane thermo stability, stomata afrequency and leaf water potential while [d] additive effects for leaf water potential under normal conditions. It was reported that [i] additive × additive interaction were found for cell membrane thermo stability, stomata frequency and excised leaf water loss while negative for leaf water potential under normal conditions while under drought for cell membrane thermo stability, stomata frequency, stomata conductance and excised leaf water loss. It was suggested that the traits showed [d] additive and [i] additive × additive interaction may be used to fix the increase in the expression of traits in next generations and selection for the development of synthetic varieties for drought resistance may be helpful. The [h] dominance effects showed that the traits may be used for the development of hybrid. On the basis of genetic effects it was concluded that stomata frequency, stomata size, cell membrane thermo stability, leaf water potential and excised leaf water loss may be helpful for the development of higher grain yield maize genotypes under drought conditions.

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Key words: generation mean analysis, *Zea mays*, drought, additive, dominance

1. Introduction

Zea mays is one of the most significant cereal crops consumed as feed, food and raw material in numerous industrial products useful to mankind. Maize enjoys a significant position in the existing cropping systems of Pakistan. It ranks third after wheat and rice for its grain production in Pakistan. Maize is grown in almost all the provinces of the country, but KPK and Punjab are the main production areas in Pakistan. It was estimated that its 70% production is used directly or indirectly as food and rest of it find its ways to starch manufacturing and poultry industries. Maize grain is rich source of starch 72%, protein 10%, oil 4.8%, fiber 5.8%, sugar 3.0% and ash 1.7% (Chaudhary, 1983). In Pakistan, It was grown on an area of 1083 thousand hectares with the annual production of 4271 thousand tons (Anonymous, 2012). Globally, maize is grown on an area of 144,000 thousand hectares with production of 695,000 thousand tones (FAO, 2008). Global demand for maize will increase from 526000 thousand tons to 784000 thousand tons from 1993 to 2020, with most of the increased requirement coming from developing countries (Rosegrant *et al*., 1999). Maize is cultivated two times in a year in Pakistan (autumn and spring). With the active involvement of multinationals in Pakistan, the cultivation of spring maize has been increased. Although the climatic and soil conditions of Pakistan are most friendly for maize production but still there is a very low grain yield as compared to other countries of the world that produces maize. It was an established fact that management inputs like improved varieties, seed, irrigation, sowing time, planting pattern, plant population and balanced use of fertilizers have an effective role in the enhancement of crop yield. Maize is generally grown under irrigated condition in Pakistan and due to shortage of rains, water has become scarce. Limitation on water use is being imposed in every crop (Araus *et al*., 2002 and Ali *et al*., 2011a). Significant yield losses in maize (*Zea mays* L.) are projected with drought to increase with global climatic change in major production areas. Majority of maize is grown under irrigated condition in Pakistan. Maize is suffers from drought stress between anthesis and grain filling (40-80% yield loss). Therefore, drought is considered to be a major factor affecting plant growth and yield. There is a need to recognize suitable executive techniques in maize that can resist stress situations. It was a high water demanding crop and can give high production when water and nutrients are in sufficient amount. However, maize is sensitive to water stress (Pandey *et al*., 2000; Cakir, 2004, Ali *et al*., 2011b; Ali *et al*., 2012a,b; Ali *et al*., 2013a,b,c; Ahsan *et al*., 2013) and other environmental stresses around anthesis period (Pandey *et al*., 2000).

Keeping above facts in view, this study was carried out with the following objectives,

- Estimation of variability for various physio-genetic traits of crosses and parents under normal and water stress conditions.
- The information so derivative may be helpful in developing selection criterion and for further upcoming breeding programs to develop maize drought tolerant genotypes.

Materials and methods

The current experiment was conducted in the research area of department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Two lines (one drought tolerant and one susceptible) were selected as parent P_1 (WFTMS) and P_2 (Q66) respectively. Each entry was planted by keeping row-to-row and plant-to-plant distances of 75 and 25 cm respectively in each replication. Normal agronomic and crop husbandry practices were followed to raise the crop.

Development of F1 generation:

The P_1 and P_2 were sown in the field under optimum conditions during spring 2009. Normal agronomic practices were followed to raise the crop. Tolerant and susceptible parents were crossed to develop F_1. Parent P_1 was used as male because it was found good pollen producer; while parent P_2 was used as female.

Development of F_1, F_2, BC_1, BC_2 generation:

The P_1, P_2 and F_1 were grown in the next cropping season autumn 2009. At maturity F_1 plants were selfed. This selfed seed was the source of F_2 population. The F_1 plants were also crossed with the parents P_1 and P_2 to develop BC_1 and BC_2 respectively. F1 was also be developed by crossing P1 and P2 as mentioned in section 3.3.

Raising of basic six generations, P_1, P_2, F_1, F_2, BC_1 and BC_2:

The experiment was sown at the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2010. The experimental material was planted in field. The seeds of all the generations such as P_1, P_2, F_1, F_2, BC_1 and BC_2 were planted in nested block design with three replications. Two contrasting water levels i.e., normal and water stressed were applied to all generations in nested block design. Each entry was planted by keeping row-to-row and plant-to-plant distances of 75 and 25 cm respectively in each replication. Normal agronomic and crop husbandry practices were followed to raise the crop.

Generation Mean Components

Data of basic six generations were analyzed using nested design. Analysis of variance depicted significant variation between generations. Therefore, data were subjected to the generation mean analysis to determine the type of genetic effects associated with the traits under study within each water regime. Generation mean analysis was carried out following Mather and Jinks (1982). Generation mean analyses were computed using a computer programme provided by Dr. Muhammad Ahsan, Associate professor, Department of Plant Breeding and Genetics. Mean and variances of each population (parents, backcrosses, F_1 and F_2) used in the analysis were calculated from individual plants pooled over replications. A weighted least square analysis was performed on the generation mean commencing with the simplest model using parameter m only and tested for goodness of fit. If the chi-squared value of one parameter model [m] was significant then further models of increasing complexity [md, mdh, etc.] were tried and tested for goodness of fit. The best model was chosen as the one which had significant estimates of all parameters along with non-significant chi-squared value. The parent with higher magnitude was always taken as P_1 in the model fitting for each trait. Theoretical genetic components of generation mean used in the analysis are shown in the Table 1.

Table 1. Coefficients of parameters for the weighted least squares analysis of generation mean (Mather and Jinks, 1982)

Generations	Components of genetic effects					
	M	[d]	[h]	[i]	[j]	[l]
P_1	1	1.0	0.0	1.00	0.00	0.00
P_2	1	-1.0	0.0	1.00	0.00	0.00
F_1	1	0.0	1.0	0.00	0.00	1.00
F_2	1	0.0	0.5	0.00	0.00	0.25
BC_1	1	0.5	0.5	0.25	0.25	0.25
BC_2	1	-0.5	0.5	0.25	-0.25	0.25

M = mean, d = additive, h = dominance, i = additive-additive, j = additive-dominance and l = dominance-dominance

Results and discussions

Cell membrane thermo stability:

It was indicated from figures 1 and 2 showed significant differences among the generations and greater cell membrane thermo stability was found for P_1 generation as compared to P_2, F_1, F_2, BC_1 and BC_2 both under normal and drought conditions. Higher cell membrane thermo stability was reported for P_1 (78.57%) and P_2 (77.14%) generations under normal while P_1 (50.74%) and P_2 (47.27%) under drought (Table 3). It was persuaded from Table 2 that higher heritability was found for cell membrane thermo stability under normal (80.89%) as compared to drought (75.79%). For cell membrane thermo stability, the model with three parameters [mhi] fit to under normal condition, two parameters [mi] under drought conditions (Table 2). Significant residual effects [m] (60.56±4.67) and higher [h] dominance effects (14.97±5.48) indicted that increase may be achieved by selecting genotypes on the basis of cell membrane thermo stability under normal condition. Additive × additive interaction [i] (17.76±4.77 under normal condition) and (5.19±2.43 under drought condition) were found positive for cell membrane thermo stability which indicted that it is possible to fix increase at infinity generations for cell membrane thermo stability under normal and drought conditions while residual effects [m] (44.04±1.91) was found under drought condition. Similar results were reported by Bernardo *et al*. (1991) in maize; Gomaa *et al*. (1999); Amand and Wehner (2001) in cucumber; Azizi *et al*. (2006) in mazie; Ashour *et al*. (2006) ; Golparvar *et al*. (2006); Munir *et al*. (2007) in wheat and Naveed *et al*. (2009) in okra. The higher dominance effects showed that selection may be effective for the development of drought resistant maize hybrid while additive × additive interaction indicated that selection may be helpful for the development of synthetic varieties. Similar results were reported by Ashraf *et al*. (1999); Winter *et al*. (1988); Blum *et al*. (2001) in wheat; Tripathy *et al*. (2000) in rice; Rehman *et al*. (2006); Ullah *et al*. (2006); Jabeen *et al*. (2008); Kamran *et al*. (2009) and Taheri *et al*. (2011) in wheat.

Stomata conductance: It was found from figures 3 and 4 that significant differences were reported for stomata conductance and higher stomata conductance was found for P_1 as compared to P_2, F_1, P_2, F_2, BC_1 and BC_2 generations under normal conditions and also under drought condition higher stomata conductance was found for P_1. Higher stomata conductance was found for P_1 (43.33 mmol m^{-2} s^{-1}) and P_2 (42.30 mmol m^{-2} s^{-1}) generations under normal while P_1 (42.47 mmol m^{-2} s^{-1}) and BC_2 (42.76 mmol m^{-2} s^{-1}) under drought (Table 3). For stomata conductance, one parameter model [m] provided best fit to under normal condition while simple model with two parameters [mi] under drought conditions in the field fit to the data under drought conditions (Table 2). Significant residual effects [m] (42.43±0.25) while residual effects [m] (40.98±0.18) and [i] additive × additive interaction (1.08±0.39) were found under drought condition which indicated that it is possible to fix increase stomata conductance by selecting genotypes on the basis of that trait. Similar results were reported by Bernardo *et al.* (1991) in maize; Gomaa *et al.* (1999); Amand and Wehner (2001) in cucumber; Azizi *et al.* (2006); Ashour *et al.* (2006); Golparvar *et al.* (2006); Munir *et al*. (2007) in wheat and Naveed *et al.* (2009) in okra. The additive × additive interaction indicated that selection may be helpful for the development of drought resistance synthetic varieties. Similar results were reported by Ashraf *et al.* (1999); Winter *et al.* (1988); Blum *et al.* (2001) in wheat; Tripathy *et al.* (2000) in rice; Aslam *et al.* (1999) in maize; Rehman *et al*. (2006); Ullah *et al.* (2006); Jabeen *et al.* (2008); Kamran *et al*. (2009); Taheri *et al.* (2011) in rice, Ali *et al*., (2011a,b,e) and Ali *et al*., (2013a,c,d) in maize.

Stomata frequency: It was suggested from figures 5 and 6 that higher stomata conductance was found for P_1 as compared to P_2, F_1, F_2, BC_1 and BC_2 generations under normal conditions and under drought conditions. The results showed that P_1 was drought resistant. Higher stomata conductance was found for P_1 (227.34) and P_2 (215.88) generations under normal while P_1

(192.26) and P_2 (190.06) under drought as compared to other generations (Table 3). In the stomata frequency, the model with three parameters [mhi] under well-watered and model with two parameters [mi] provided a good fit data suggesting presence of additive × additive variance under drought condition. This indicated the presence of additive and dominance along with additive × additive interaction under normal in both crosses and additive type of gene action along with dominance × dominance interaction under drought conditions in both crosses for the trait. The fact showed complex inheritance (Table 2).

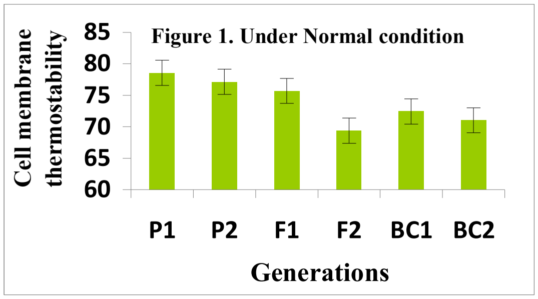
Figure 1. Under Normal condition

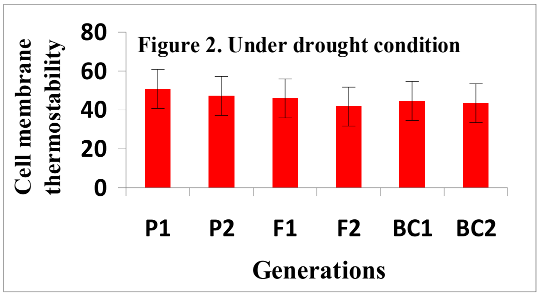
Figure 2. Under drought condition

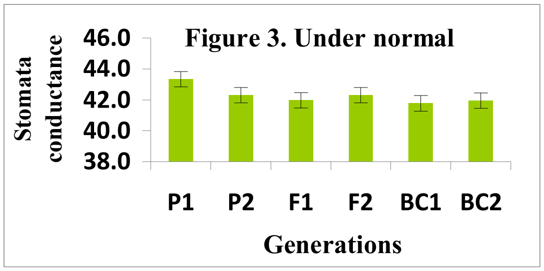
Figure 3. Under normal

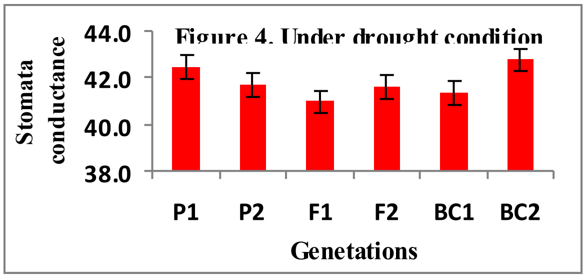
Figure 4. Under drought condition

Figure 1.

Significant residual effects [m] (150.64±19.69), higher [h] dominance effects (50.68±24.93) and highest [i] additive × additive interaction (71.55±21.04) were found for stomata frequency under normal condition while residual effects [m] (177.67±4.06) and [i] additive × additive interaction (13.95±5.59) were found under drought condition. Positive dominance indicated that increase in the stomata conductance under normal conditions. Positive i indicated that it is possible to fix the increase by selecting genotypes on the basis of stomata conductance. The higher dominance effects showed that selection may be effective for the development of drought resistant maize hybrid while additive × additive interaction indicated that selection may be helpful for the development of synthetic varieties. Similar results were reported by Gomaa *et al.* (1999) in wheat; Amand and Wehner (2001) in cucumber; Azizi *et al.* (2006); Ashour *et al.* (2006); Golparvar *et al.* (2006); Munir *et al.* (2007) in wheat and Naveed *et al.* (2009) in okra.

Stomata size:

It was indicated from figures 7 and 8 that higher stomata size was found for P_1 as compared to P_2, F_1, F_2, BC_1 and BC_2 generations under normal conditions and under drought conditions. Higher stomata size was recorded for P_1 (1406.9 μm^2) and P_2 (1386.7 μm^2) generations under normal while P_1 (1354.8 μm^2) and F_1 (1312.7 μm^2) under drought (Table 3). It was persuaded from table 2 that higher heritability was bound for stomata size under normal (86.45%) and drought (60.00%) condition (Table 3). One parameter model [m] provided a good fit to normal condition, under drought conditions also provided a good fit to the parameter [m] (Table 2). Significant residual effects [m] (1373.05±20.14) was found for stomata size under normal condition while residual effects [m] (1302.83±33.58) was found under drought condition. No genetic effects were found for this trait which indicated that further progeny testing is required. The selection of drought resistant genotypes on the basis of stomata size may be less effective for the improvement of grain yield under limited water conditions. Similar results were reported by Bernardo *et al.* (1991) in maize; Gomaa *et al.* (1999); Amand and Wehner (2001) in cucumber; Azizi *et al.* (2006); Ashour *et al.* (2006); Golparvar *et al.* (2006); Munir *et al.* (2007) in wheat and Naveed *et al.* (2009) in okra and Ali *et al.*, (2021c,d) in maize.

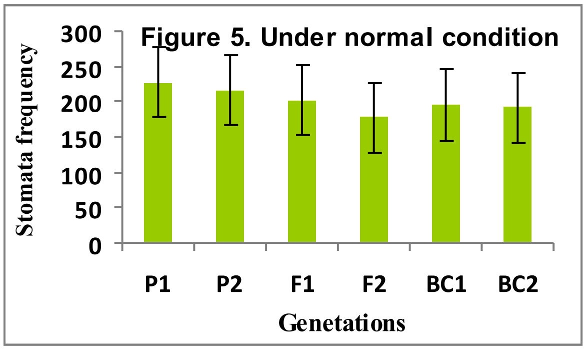

Figure 5. Under normal condition

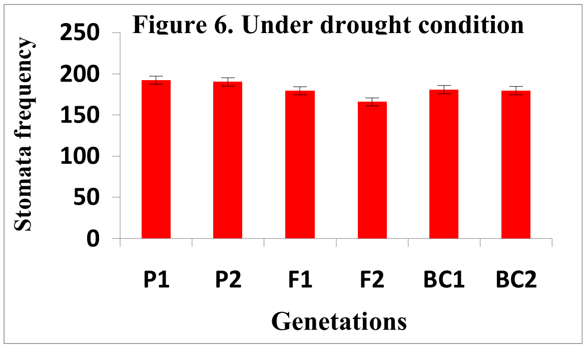

Figure 6. Under drought condition

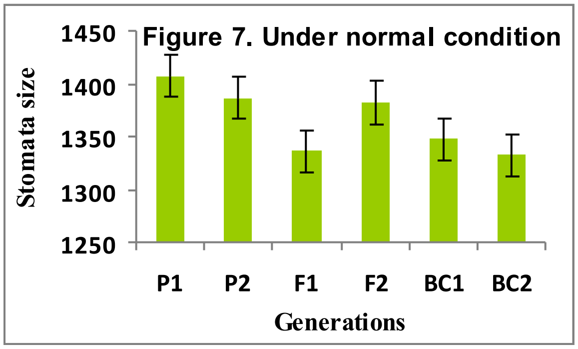

Figure 7. Under normal condition

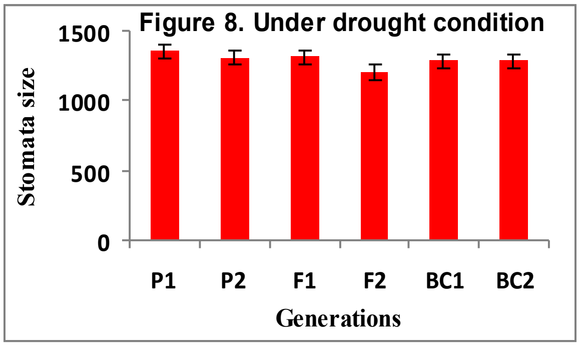

Figure 8. Under drought condition

Leaf water potential:

It was shown from figure 9 that higher leaf water potential was recorded for F_2 and BC_1 generations while under drought condition higher leaf water potential was found for P_1 generation while lower was for P_2 (Figure 10). Higher leaf water potential was found for F_2 (0.67 Pa) and BC_1 (0.62 Pa) generations under normal while P_1 (1.86 Pa) and F_2 (1.41 Pa) under drought (Table 3). Four parameters model [mdhi] under normal and one parameter model [m] under drought condition (Table 2). Significant residual effects [m] (0.26±0.01), [d] additive effects (0.06±0.01), [h] dominance effects (0.67±0.15) and negative [i] additive × additive interaction (-0.51±0.15) were found for leaf water potential under normal condition while residual effects [m] (1.3±0.04) was found under drought condition. Positive dominance indicated significant increase in that trait while negative i indicated that is possible to fix decrease by selection genotypes on the basis of leaf water potential. Similar results were reported by Bernardo *et al.* (1991) in wheat; Amand and Wehner (2001) in cucumber; Azizi *et al.* (2006); Munir *et al.* (2007) in wheat and Naveed *et al.* (2009) in okra.

Excised leaf water loss:

It was suggested from figure 11 that higher excised leaf water loss was reported for P_1 generation as compared to other generations under normal conditions but under drought condition higher excised leaf water loss was found for P_1 generation while lower were for other generations (Figure 12). Higher excised leaf water loss was reported for P_1 (363.15%) and P_2 (347.75%) generations under normal while P_2 (225.55%) and P_1 (242.60%) under drought (Table 3). In the excised leaf water loss, model with two parameters [mi] provided a good fit to the data suggesting presence of additive × additive variance both normal and drought conditions (Table 2). Significant residual effects [m] (339.41±6.38) and [i] additive × additive interaction (17.35±8.52) were found for excised leaf water loss under normal condition while residual effects [m] (210.12±6.97) and [i] additive × additive interaction (21.25±9.31) were found under drought condition. Positive additive × additive interaction may be exploited for this trait for the development of synthetics in future breeding programe (Bernardo *et al.* (1991); Gomaa *et al.* (1999); Amand and Wehner (2001); Azizi *et al.* (2006); Ashour *et al.* (2006); Golparvar *et al.* (2006); Munir *et al.* (2009) and Naveed *et al.* (2009).

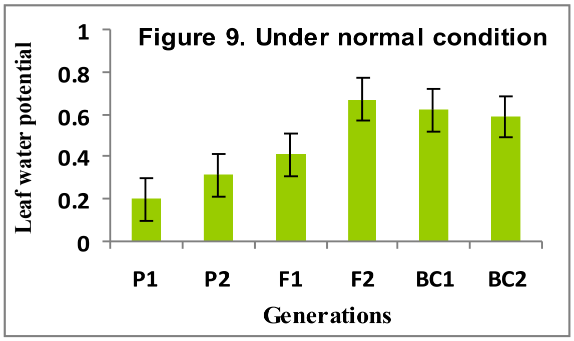
Figure 9. Under normal condition

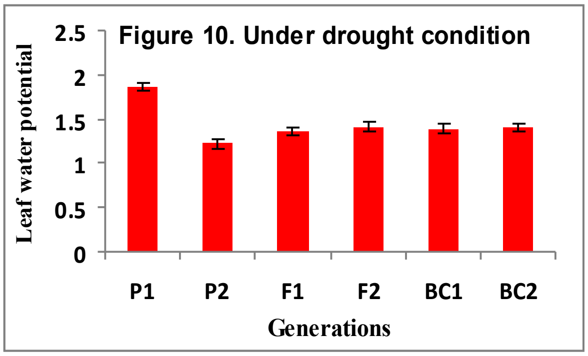
Figure 10. Under drought condition

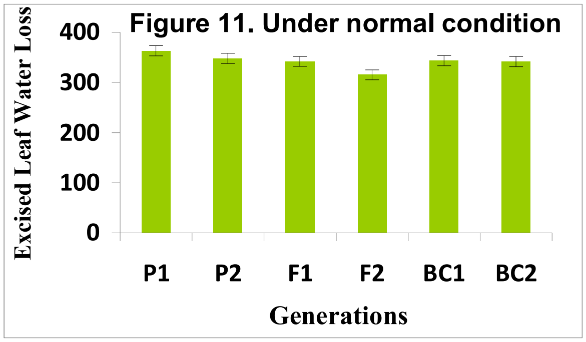
Figure 11. Under normal condition

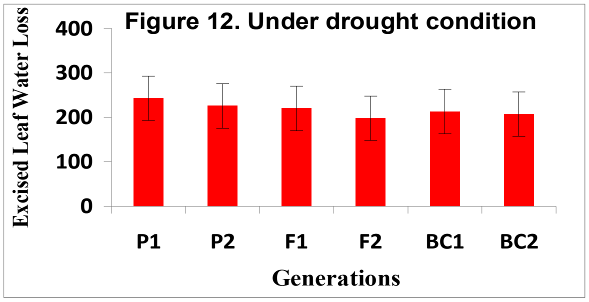
Figure 12. Under drought condition

Leaf temperature: It was indicated from figure 13 that higher leaf temperature was found for BC_2 and P_1 generations while lower were for BC_1 under normal conditions but under drought condition higher leaf temperature was found for P_2 generation while lower were for other generations (Figure 14). Higher leaf temperature was recorded for BC_2 (34.44°C) and P_1 (34.48°C) generations under normal while BC_1 (33.53°C) and P_2 (33.66°C) under drought (Table 3).

Lower leaf temperature under drought conditions indicated that P_1 and BC_1 generations were highly drought resistant as compared to other generations. The plants with lower leaf temperature indicated that transpiration rate is higher to maintain optimum leaf temperature to facilitate leaf for photosynthesis under drought conditions. In the case of leaf temperature, one parameter model [m] provided a very good fit to the data under normal and drought condition (Table 2). Significant residual effects [m] (34.13±0.09) were found for leaf temperature under normal condition while residual effects [m] (33.35±0.023) were found under drought condition. Significant residual effects recommended further progeny testing for the improvement of leaf temperature (Bernardo *et al*. (1991) in maize and Azizi *et al*. (2006); Ashour *et al*. (2006); Golparvar *et al*. (2006); Munir *et al*. (2009) in wheat.

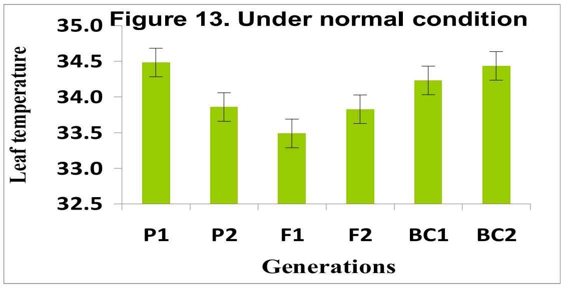
Figure 13. Under normal condition

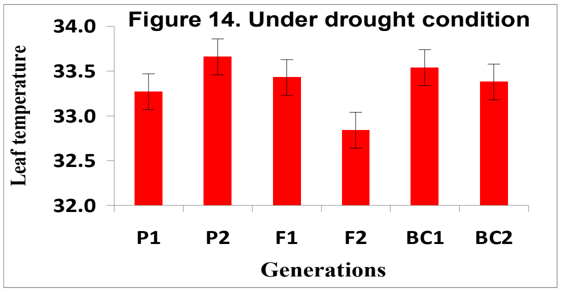
Figure 14. Under drought condition

Conclusions

It was suggested that the traits showed [d] additive and [i] additive × additive interaction may be used to fix the increase in the expression of traits in next generations and selection for the development of synthetic varieties for drought resistance may be helpful. The [h] dominance effects showed that the traits may be used for the development of hybrid. On the basis of genetic effects it was concluded that stomata frequency, stomata size, cell membrane thermo stability , leaf water potential and excised leaf water loss may be helpful for the development of higher grain yield maize genotypes under drought conditions.

Table 2. Generation mean analysis for various physiological traits under normal and drought conditions
CMT: Cell Membrane Thermo stability , **LWP:** Leaf Water Potential**, SC:** Stomata Conductance**, LT:** Leaf Temperature, **SF:** Stomata Frequency, **SS:** Stomata Size**, EWL:** Excised Leaf water Loss

Trait	**Condition**	**Genetic effects**						χ^2 **(df)**
		m	**d**	**h**	**i**	**j**	**l**	
CMT	Normal	60.56±4.67		14.97±5.48	17.76±4.77			0.77(3)
	Drought	44.04±1.91			5.19±2.43			2.60(4)
SC	Normal	42.43±0.25						5.26(5)
	Drought	40.98±0.18			1.08±0.39			1.60(4)
SF	Normal	150.64±19.69		50.68±24.93	71.55±21.04			1.14(3)
	Drought	177.67±4.06			13.95±5.59			0.89(4)
SS	Normal	1373.05±20.14						2.12(5
	Drought	1302.83±33.58						1.33(5)
LWP	Normal	0.26±0.01	0.06±0.01	0.67±0.15	-0.51±0.15			4.15(2)
	Drought	1.3±0.04						3.51(5)
EWL	Normal	339.41±6.38			17.35±8.52			3.15(4)
	Drought	210.12±6.97			21.25±9.31			4.13(4)
LT	Normal	34.13±0.09						9.74(5)
	Drought	33.35±0.23						0.44(5)

Table 3. Generation mean for various traits in maize under normal (N) and drought (D) conditions

Traits	**Cross#**	**Generations**						**Pop. Effects**	**LSD (0.05)**
		P1	**P_2**	**F_1**	**F_2**	**BC_1**	**BC_2**		
Cell membrane thermo stability	Normal	78.57	77.14	75.70	69.382	72.43	71.02	**	0.67
	Drought	50.74	47.27	45.86	41.75	44.61	43.42	**	1.03
Stomata conductance	Normal	43.33	42.30	41.97	42.30	41.77	41.945	**	0.34
	Drought	42.47	41.67	40.97	41.59	41.36	42.76	**	0.62
Stomata frequency	Normal	227.34	215.88	201.60	177.13	194.87	191.48	**	2.88
	Drought	192.26	190.06	179.40	165.85	180.75	179.62	**	2.08
Stomata size	Normal	1406.9	1386.7	1336.6	1382.1	1347.7	1332.5	**	18.31
	Drought	1354.8	1306.1	1312.7	1202.4	1282.3	1282.7	**	31.512
Leaf water potential	Normal	0.20	0.31	0.41	0.67	0.62	0.59	**	0.02
	Drought	1.86	1.22	1.36	1.41	1.39	1.40	**	0.51
Excised leaf water loss	Normal	363.15	347.75	341.87	315.27	343.45	341.52	**	4.13
	Drought	242.60	225.57	220.07	197.75	213.00	207.11	**	5.33
Leaf temperature	Normal	34.48	33.86	33.49	33.83	34.23	34.44	**	0.15
	Drought	33.27	33.66	33.43	32.84	33.54	33.38	**	0.35

in the field. *; P < (0.05); **, P < (0.01), ns = non-significant

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