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ESTIMATION OF HERITABILITY AND GENETIC EFFECTS ON SOME MORPHOLOGICAL TRAITS AND FLINT MAIZE COMBINING ABILITY UNDER MOISTURE STRESS CONDITIONS

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Abstract

To evaluate drought tolerance, eight pure lines in S6 generation were crossed with two commercial testers, i.e., K36152 and A679 along with two hybrids, i.e., KSC704 and KSC400 (18 genotypes in total), in a randomized complete block design (RCBD) with three replications under normal conditions and severe moisture stress were evaluated. Under both conditions, general combining ability (GCA) analysis showed significant differences for some traits, indicating heritability of these traits. The line L6 was recognized as the best line. A679 According to the results of specific combining ability (SCA), crosses L6 K36152 were considered as the best crosses under normal conditions and L10 K36152 crosses as the best crosses under severe moisture stress conditions. L8 line variance, in some traits, there was a According to the analysis of tester significant difference for lines and testers and the mutual effects of tester, indicating that there are additive genetic effects on these line traits. Under both conditions, ear weight, cob weight, and cob length had non-additive effects; thus, heterosis can be used to correct such traits.
Key words: Inbred line, tester, moisture stress, ability to adapt, genetic effects.

Introduction

In their environment, plants are constantly exposed to biological and non-biological stresses. Among these stresses, drought is the most important growth-limiting factor in plants. Drought affects a wide range of cellular metabolism, changes in growth and function. To understand the plant resistance, it is necessary to understand the conditions of water restriction, molecular and biochemical responses to drought.

Plants are exposed to drought, both when water is not sufficiently exposed to the root and when transpiration is very high. (Sharafi *et al.*, 2019; Aslmarz *et al.*, 2019; Abdulkhaleq *et al.*, 2019). Abiotic environmental stresses such as drought, overheating, cold, heavy metals, and high salinity slow down plant growth and productivity worldwide (Shakeel *et al.*, 2011). Different levels of drought stress affect the agronomic and morphological traits of maize. As a result of increased stress levels, traits are more affected and show a significant decrease. In addition, as stress levels increase, the yield is more affected and significantly reduced (Rahman *et al.*, 2011). In plants, drought tolerance can be managed through plant adaptation strategies such as bulk and breeding methods, marker-based selection, and exogenous applications including hormones, seed osmolyte protection or plant growth, and drought resistance engineering (Farooq *et al.*, 2009). Numerous studies on grains have shown an increase in abscisic acid (ABA) levels during drought, which plays an important role in the adaptation response of plants to reduced moisture availability of the plant.

Low molecular weight osmolytes, such as glycine, betaine, proline, and other amino acids, organic acids, and polyols are essential for maintaining cellular function under drought stress (Farooq *et al.*, 2009). Drought causes a wide variety of responses in plants, including alterations in gene expression, accumulation of metabolites such as phytohormones, abscisic acid or osmolytic active compounds, and synthesis of specific proteins such as hydrophilic proteins, chaperones, and so on. In addition to showing the direct genetic effect involved in stress tolerance, ABA levels play an important role in water conservation in plants by reducing the amount of water loss during transpiration. Importantly, the level of abscisic acid has been identified as a hormone that is unilaterally affected by moisture deficiency regimes (Tiashi *et al.*, 2006). One of the strategies is to introduce the essential genes that are directly involved in these events. With the advent of DNA microarray technology, it is possible to express the mRNA of several hundred different stress-related genes that have been divided into several classes: regulatory genes such as protein kinases and transcription factors as well as functional and essential genes (Tiashi *et al.*, 2006). At the vegetative and reproductive stage, maize is susceptible to drought and the aim is to improve water stress tolerance (Rahman *et al.*, 2011). The combinatorial analysis is a technique of classifying parental lines to investigate the potential and ability to create high-performance hybrids. It also helps in choosing the right parents for crossbreeding (Subramanian and subbaraman, 2006). Heterosis and combinability are a prerequisite for developing a hybrid maize variety that is environmentally friendly. Compounding analysis is a suitable method to determine the best combining ability for use in other crosses to obtain heterosis or to increase useful genes in the plant. It also helps to understand the genetic effects of different traits and enables the breeder to design an effective breeding method (Amiruzzaman *et al.*, 2010). Two maize inbred lines and their advanced lines were evaluated for drought-related traits. Genetic linkage maps were evaluated using RFLP markers to identify QTLs related to drought traits (Rahman *et al.*, 2010). Bill was the first to attempt in 1980 to diversify maize hybrids to increase their yield. Heterosis and combining ability are a prerequisite for developing a hybrid maize variety with suitable environmental capability (Amiruzzaman *et al.*, 2010). General combinability (in short, GCA) is the average value of a parent. Based on its status, it is estimated when combined with other parents (lines). Specific combining (SCA) is the behavior of one parent when combined with another parent. Once we have selected the veins by top-cross testing, it is important to know that after combining these veins together, a simple hybrid, a triple hybrid or a double hybrid produces more. This type of combining property of varieties is called specific combining property (Hartl and Jones, 2005).)Combining the study of CIMMYT and AREX maize inbred lines under normal and stress conditions showed that GCA was not significant for plant height and stem lodging (Xavier *et al*., 2011). Negative GCA effects were reported for days up to 50% Tassel, 50% silk and days up to 50% physiological maturity. Significant positive GCA effects were observed under normal conditions for grain yield, cob length, ear height, kernel row No./ear, kernel No./row, 100-kernel weight, grain yield per plant, biological yield per plant, relative water content and proline content (Zebrajadi *et al*., 2012). In Xavier *et al*. (2011) experiment, non-additive genes were not significant for day to pollination, the distance between pollination to crotch and ear height. In another experiment, grain yield per plant, biological yield, plant height, ear height, 100-kernel weight, relative water content and proline content under moisture stress conditions were significantly different and had a positive sca tester is a modified form of the Top Cross effect (Singhan and Gupta, 2008). Line tester technique was created in design introduced by Davies in 1962. The line 1975 by Kemptoren. The number of mixes that occur in this method is equal to the number of lines multiplied by the number of testers. As the best-inbred alleles have the best inbreeding effect because of the dominant alleles, it is best not to use them as a tester. Therefore, for a l9*ine to appear well, it is advisable to use low-status testers (Mostafavi, 2010.(tester technique has been widely The line used to estimate GCA and SCA and to understand the nature of genes involved in the emergence of quantitative traits. Using this technique, we can estimate the effects of GCA and SCA variances and genetic variance components, σ2A (incremental variance) and σ2D (dominance variance). However, this method cannot estimate the epistatic variance (Farshadfar, 2007). studies showed that the general combining ability of lines and testers was significant, and the specific hybridity of the hybrids was not significant for boll weight, crop yield and early maturity in cotton. Estimates of general combining ability (GCA) and specific (SCA) help breeders make decisions about breeding programs and genotype selection strategies (Akbar *et al*., 2008).

Materials and Methods

The study was conducted in June 2018 00007at the Khorramabad Agricultural and Natural Resources Research Farm, south of Khorramabad, with a longitude of 48º 18', the latitude of 33º 29', a height of 1371 meters above sea level, and an average rainfall of 356 mm. Silty clay, semi-tropical climate with an average temperature of a maximum of 38.7 and a minimum of 10.8. In this study, eight lines were compared with two fused testers (sixteen genes in total) and two control cultivars (KSC400 and KSC704) under severe and normal stress conditions. Seeds of all crosses were obtained from Khorasan Agricultural and Natural Resources Research Center. It is worth noting that these seeds are the result of crossing the line S6 as the maternal parent of two commercial testers, namely A679, and K3615/2 as the paternal parent in two isolated farms that were produced in 2009. The plan was conducted in two experiments, each experiment individually in a RCBD with three replications. The ground was plowed in the fall, perpendicular to the disk in the spring, and finally leveled by a trowel. Each plot was planted with two lines 5 m in length with 18 cm plant spacing and 75 cm spacing (density of 70000 plants per hectare). Accordingly, evaporation rates of 130-140 mm (severe moisture stress) and 70-80 mm (normal) were considered. Fertilization and feeding were performed according to soil tests. Growth morphological traits including plant height, ear height from ground level, the total number of leaves, number of the leaf above ear and stem diameter were measured and recorded on 5 randomly competing plants in each plot. Chlorophyll content was measured by spandex. For this purpose, five samples were taken from each plot. To measure stomatal resistance by porometer in m^2s/mol, 300-kernel weight, cob length, ear diameter, ear diameter, kernel depth, ear weight, cob weight, and cob percentage in five random maize plots were determined in each plot and averaged. Grain moisture meter model GMK-303R was used to measure grain moisture. For analysis of variance, mstat-c software was used. The combinations tester software (written in the and genetic effects were estimated by line Qbasic environment by Venkatesh *et al*., 2001).

Results and Discussion

According to Table 1, linear analysis of variance under normal conditions, genotypes in traits of chlorophyll content, ear weight, cob weight, stomatal conductance, number of leaves above ear, ear diameter, plant height, number of leaves, cob percentage, cob length, kernel depth, and ear diameter at 1% probability level and grain row at maize at 5% probability level were significant. In terms of traits: stem diameter, ear weight, cob weight, and cob length, lines were significantly different at the 5% probability level. In addition, in terms of 300-kernel weight, maize number, ear diameter, ear height, plant height, number of leaves, row No./ear, cob percentage, kernel depth, and ear diameter showed significant differences at 1% probability level. Tests showed no significant differences tester on traits: Chlorophyllfor any of the traits. Interaction effect of line content, ear diameter, and kernel depth were significant at the 5% probability level. Traits: ear weight, stomatal conductance, and cob length showed significant differences at the 1% probability level. Significance of the mean of squares linearity indicates the role of dominance and non-additive effects in controlling these traits (Manuela *et al*., 2003). Significant differences among genotypes for different traits indicate genetic diversity in the studied maize veins for use in the breeding program. If the σsca2/σgca2 ratio is greater than 1, the trait has an additive effect and if it is less than 1, the trait has a non-additive effect. The number of leaves above the maize had an additive effect. Relative water content traits, chlorophyll content, ear weight, cob weight, ear diameter, ear height, number of grains per maize, cob percentage, cob length, and kernel depth had non-additive effects. For other traits including yield, stem diameter, 300-kernel weight, stomatal conductance, plant height, the number of leaves, row No./ear, physiological maturity, and ear diameter, values of zero or negative were estimated. In Musa Abadi (2011) study, ear height, plant height, stem diameter, the spacing between pollen and crocus, and the number of leaves above the ear, increased genetic variance more than a dominant genetic variance. For day to day, more dominant physiological maturity variance was observed.

Table 1: Line x tester ANOVA of genetic variance components under normal conditions.

Change source	DOF	Yield	Stem diameter	Relative water content	Chlorophyll content	Ear weight	Cob weight	300-kernel weight	Stomatal conductance	No. leaves above ear	Ear diameter
Replication	2	11016/396	0/007	96/136	44/173*	33917/771*	209/813	16/075	0/181	0/311**	0/048**
Cross	15	20676/988	0/035	35/914	43/585**	29182/706**	1799/265**	62/879	10/471**	0/473**	0/084**
Line	7	14358/235	0/052*	45/480	63/815	45472/940*	2721/973*	110/204**	11/860	0/913**	0/163**
Tester	1	6556/688	0/007	72/668	1/577	736/333	1/688	4/877	0/385	0/141	0/023
Line×tester	7	29012/926	0/022	21/097	29/357*	16956/238	1133/354**	23/840	10/523**	0/080	0/014*
Error	30	17144/729	0/018	30/971	11/362	7430/526	106/057	61/987	2/092	0/057	0/006
Total	47										
2A**σ**		0/000	0/001	0/842	0/808	694/686	37/836	2/218	0/000	0/022	0/004
2D**σ**		3956/065	0/001	0/000	5/998	3175/237	342/432	0/000	2/811	0/007	0/003
2gca**σ**		0/000	000	0/421	0/404	347/343	18/918	1/109	0/000	0/011	0/002
2sca**σ**		3956/065	0/001	0/000	5/998	3175/237	342/432	0/000	2/811	0/007	0/003
2gca/σ2sca**σ**		0/000	0/000	0/128	0/067	0/011	0/055	0/000	0/000	1/571	0/667
COVHSline		-2442/448	0/005	4/064	5/743	4752/784	264/770	14/394	0/223	0/139	0/025
COVHStester		-935/677	-0/001	2/149	-1/157	-675/829	-47/153	-0/790	-0/422	0/003	0/000
COVHSaverage		-236/816	0/000	0/421	0/404	347/343	18/918	1/109	-0/001	0/011	0/002
COVFS		148/384	0/003	4/587	6/201	4078/424	367/981	-6/705	1/835	0/092	0/018

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels

Table 1 (continued): Line×tester ANOVA of genetic variance components under normal conditions.

Change source	DOF	Ear height	Plant height	No. leaves	Kernel No./row	Kernel row/ear	Cob percentage	Physiological maturity	cob length	Kernel depth	Ear diameter
Replication	2	231/262**	516/273**	2/122**	1/776	1/884	1/598	11/896**	0/870	0/013*	0/086
Cross	15	0/000	410/890**	1/108**	14/794	4/169*	7/329**	7/476	7/462**	0/054**	0/241**
Line	7	360/248**	790/700**	2/006**	15/290	7/818**	12/931**	1/568	12/287*	0/100**	0/504**
Tester	1	2/684	107/102	0/480	12/000	2/341	0/608	2/521	0/101	0/035	0/010
Line×tester	7	64/434	74/478	0/299	14/698	0/781	2/687	1/235	3/689**	0/012*	0/012
Error	30	49/501	91/027	0/310	7/770	1/785	0/842	1/935	1/060	0/004	0/034
Total	47										
2A**σ**		7/610	19/114	0/046	0/005	0/192	0/264	0/014	0/214	0/002	0/013
2D**σ**		4/978	0/000	0/000	2/309	0/000	0/615	0/000	0/876	0/003	0/000
2gca**σ**		3/805	9/557	0/023	0/003	0/096	0/132	0/007	0/107	0/001	0/007
2sca**σ**		4/978	0/000	0/000	2/309	0/000	0/615	0/000	0/876	0/003	0/000
2gca/σ2sca**σ**		0/764	0/000	0/000	0/0013	0/000	0/215	0/000	0/122	0/333	0/000
COVHSline		49/302	119/370	0/284	0/099	1/173	1/707	0/056	1/433	0/015	0/082
COVHStester		-2/573	1/359	0/008	-0/112	0/065	-0/087	0/054	-0/150	0/001	0/000
COVHSaverage		3/805	9/557	0/023	0/003	0/096	0/132	0/007	0/107	0/001	0/007
COVFS		25/912	64/946	0/175	2/072	0/492	1/346	-0/079	1/290	0/013	0/038

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

According to Table 2, genotypes for traits such as ear height, number of leaves, maize row per maize, cob length, ear weight, and ear diameter were significant for linear analysis of variance under severe moisture stress conditions. The percentages of maize and ear weight were significantly different at the 5% probability level. In terms of traits: ear height, plant height, number of leaves and ear diameter, lines showed significant differences at the 1% probability level. In addition, in terms of traits: leaf above ear, percentage of maize, row of maize per maize and weight of 300-kernel, they showed significant differences at the 5% probability level. In terms of trait: ear diameter, testers showed significant differences at the 5% probability level. In addition, in terms of trait: ear diameter, they showed a significant difference at the 1% probability level. Traits: Seed row per maize, linear effect interaction showed significant difference at 5% level. In addition, in terms of ear weight, it showed a significant difference at the 1% probability level. The sca2σ / gca2σ ratio showed that plant height had additive effects and traits: ear weight, cob weight, ear height, cob percentage, maize row per maize, physiological maturity, and cob length had non-additive effects. Under all three conditions, ear weight, cob weight and cob length had non-additive effects; therefore, heterosis should be used to correct such traits. The results were consistent with some of the researchers' results and in some cases did not. In Mostafavi *et al*., (2010) experiment, the number of grain rows, 100-kernel weight, and cob percentage and grain moisture content had additive effects. In addition, grain yield, plant height, ear height, ear diameter, and kernel row No./ear and the number of maize per maize had additive effects. For cob length and seed weight per maize, the role of additive and non-additive effects was the same. In Amiruzzaman *et al*. (2010) experiment, ear diameter and 1000-grain weight had non-additive effects. In Ouk *et al*. (2006) experiment, the number of days to physiological maturity, cob length, number of kernels per maize and number of kernels per maize were affected by genetic enhancement.

Table 2: Line×tester ANOVA of genetic variance components under severe moisture stress conditions.

Change source	DOF	Chlorophyll content	Ear height	Plant height	No. leaves above ear	No. leaves	Kernel No./row	Cob percentage	Kernel row/ear	Physiological maturity	cob length
Replication	19/271	2	33/131	62/266	41/566	0/103	1/331*	14	4/384	1/548	19/271
Cross	6/821	15	13/829	541/491**	611/920**	0/174	1/421**	12/984	6/107*	6/169**	6/821
Line	4/402	7	17/637	897/068**	1159/642**	0/295*	2/648**	12/579	9/556*	9/625*	4/402
Tester	13/021	1	8/927	134/670	210/422	0/067	0/403	35/278	0/995	4/625	13/021
Line×tester	8/354	7	10/722	244/032	121/556	0/068	0/340	10/203	3/389	2/932*	8/354
Error	10/604	30	13/204	138/807	105/871	0/091	0/344	12/570	2/655	0/993	10/604
Total	47										
2A**σ**		0/000	0/177	16/901	27/862	0/006	0/061	0/158	0/077	0/184	0/000
2D**σ**		0/000	0/000	35/075	8/228	0/000	0/000	0/000	0/245	0/647	0/000
2gca**σ**		0/000	0/088	8/451	13/931	0/003	0/031	0/079	0/077	0/092	0/000
2sca**σ**		0/000	0/000	35/075	5/228	0/000	0/000	0/000	0/245	0/647	0/000
2gca/σ2sca **σ**		0/059	0/000	0/241	2/665	0/000	0/000	0/000	0/314	0/142	0/059
COVHSline		-0/659	1/153	108/839	173/014	0/038	0/385	0/396	1/028	1/116	-0/659
COVH Stester		0/194	-0/075	-4/557	3/703	0/000	0/003	1/045	-0/100	0/071	0/194
COVHSaver age		-0/044	0/088	8/451	13/931	0/003	0/031	0/079	0/077	0/092	-0/044
COVFS		-0/613	-0/376	84/216	111/871	0/013	0/221	2/156	0/561	1/456	-0/613

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

Table 2 (continued): Line×tester ANOVA of genetic variance components under severe moisture stress conditions

Change source	DOF	Ear diameter	Relative water content	Ear weight	Cob weight	Kernel depth	Yield	Ear diameter	Stem diameter	300-kernel weight	Stomatal conductance
Replication	2	0/039	27/428	3716/646	198/146	0/030	46271/583	0/009	0/021	15/568	8/062
Cross	15	0/116	26/352	26634/794	1543/999**	0/040	14142/394	0/108**	0/024	92/032	46/859
Line	7	0/183	19/986	35542/179	2112/783	0/053	20541/893	0/211**	0/033	151/335*	22/547
Tester	1	0/175*	1/132	28421/333	623/521	0/005	2160/083	0/106**	0/008	0/255	108/601
Line×tester	7	0/041	36/321	17472/190	1106/711**	0/032	9454/655	0/007	0/017	45/839	62/350
Error	30	0/071	21/130	11812357	218/590	0/065	44716/228	0/011	0/023	46/989	31/866
Total	47										
2A**σ**		0/004	0/000	520/602	24/846	0/000	266/349	0/006	0/000	2/625	0/000
2D**σ**		0/000	5/064	1886/611	2960/040	0/000	0/000	0/000	0/000	0/000	10/161
2gca**σ**		0/002	0/000	260/301	12/423	0/000	133/174	0/003	0/000	1/312	0/000
2sca**σ**		0/000	5/064	1886/611	2960/040	0/000	0/000	0/000	0/000	0/000	10/161
2gca/σ2sca**σ**		0/000	0/000	0/138	0/042	0/000	0/000	0/000	0/000	0/000	0/000
COVHSline		0/024	-2/723	3011/665	167/679	0/003	1847/873	0/034	0/003	17/583	-6/634
COVHStester		0/006	-1/466	456/214	-20/133	-0/001	-303/940	0/004	0/000	-1/899	1/927
COVHSaverage		0/002	-0/283	260/301	12/423	0/000	133/174	0/003	0/000	1/312	-0/440
COVFS		0/018	-0/284	4763/891	337/574	-0/012	-11510/016	0/029	-0/001	4/524	11/464

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

According to Table 3, for general combining effects of lines and testers under normal conditions, traits having a general combining effect were as follows: Stem diameter with L7 was negatively correlated with stem diameter. Using this line in the breeding program reduces stem diameter and reduces its stiffness. Chlorophyll content in line L6 and L14 showed a positive and significant correlation, which can be used to increase chlorophyll content and photosynthetic ability of the plant. The ear weight was positively correlated with the L6 and L14 lines, which can be used to increase ear weight in breeding programs. L7 and L13 lines showed a negative correlation. Ear weight was positively correlated with L5, L10 and L14 lines. L7, L8 and L13 lines showed a negative correlation. Three hundred seed weight was positively correlated with the L6 line and should be considered for increasing three hundred seed weight in breeding programs. The L7 line has a negative correlation. The stomatal conductance of lines L5, L6 and L7 were positively correlated. Ear diameter had a positive correlation with L5 and L14 lines and negative correlation with L6, L7, L8, L10, and L13 lines. Plant height was positively correlated with L5 and L8 lines, which can be used to increase plant height. In addition, it had a negative correlation with L14 and L15 lines. The number of leaves had a positive correlation with L5 and L6 lines and a negative correlation with L13 and L15 lines. The kernel No./row was positively correlated with the L10 line, which is used to increase the kernel No./row. Seed row per maize had a negative correlation with L6 and L13 lines and a positive correlation with lines L14 and L15, which increased the number of seed row per maize. In total, using L6 line increased chlorophyll content, ear weight, 300-kernel weight, stomatal conductance, leaf above ear, number of leaves and cob length. In addition, it reduces the diameter of the maize, the number of rows of grain per maize in breeding programs. L14, L5, L10, and L15 lines had high general combining ability in most of the studied traits. Overall, L6, L14, and L15 lines were identified as the best lines under normal conditions.

Table 3: General combining values of lines and testers of studied traits under normal conditions.

Line	Yield	Stem diameter	Relative water content	Chlorophyll content	Ear weight	Cob weight	300-kernel weight	Stomatal conductance	No. leaves above ear	Ear diameter
L5	18/604	0/096	0/322	-2/585	19/208	16/521**	2/298	1/823**	-0/029	0/119**
L6	13/938	0/021	4/248	5/015**	114/208**	4/521	7/531*	1/323*	0/471**	-0/108**
L7	-10/396	-0/196**	1/109	1/498	-108/125**	-29/146**	-6/669*	1/273*	-0/196*	-0/058*
L8	-25/063	-0/029	-2/611	-5/335**	-62/958	-19/813**	-2/285	-1/077	-0/796**	-0/067*
L10	23/104	0/071	-5/001	-1/235	0/292	29/188**	0/631	-0/460	-0/063	-0/088**
L13	-100/229	-0/026	0/059	0/165	-111/125**	-18/146**	-0/669	-2/344**	0/138	-0/148**
L14	10/938	-0/014	0/711	3/148*	90/708**	21/021**	2/381	-0/010	0/371**	0/356**
L15	69/104	0/076	1/163	-0/669	58/375	-4/146	-3/219	-0/527	0/104	-0/008
S.E gi□	53/455	0/055	2/272	1/376	35/191	4/204	3/214	0/590	0/098	0/030
S.E.(gi□-gj□)	75/597	0/078	3/213	1/946	49/768	5/946	4/546	0/835	0/138	0/043
K3615.2	-11/688	0/012	1/230	0/181	3/917	-0/188	-0/319	0/090	0/054	0/022
A679	11/688	-0/012	-1/230	-0/181	-3/917	0/188	0/319	-0/090	-0/054	-0/022
S.E gj□	26/728	0/027	1/136	0/688	17/596	2/102	1/607	0/295	0/049	0/015
S.E.(gi□-gj□)	37/799	0/039	1/607	0/973	24/884	2/973	2/273	0/417	0/069	0/021

ns,* and ** are insignificant and significant, respectively, at the 5% and 1% probability level.

Table 3 (continued): General combining values of lines and testers of studied traits under normal conditions.

Line	Ear height	Plant height	No. leaves	Kernel No./row	Kernel row/ear	Cob percentage	Physiological maturity	Cob length	Kernel depth	Ear diameter
L5	11/259**	13/331**	1/033**	-0/083	-0/421	1/263**	0/229	0/462	-0/84**	0/016
L6	4/409	12/131**	0/567	1/733	-1/371**	-0/854*	1/063	1/779**	0/009	-0/117
L7	4/759	8/265*	0/100	-0/600	0/562	-1/554**	-0/271	-0/838*	-0/031	-0/107
L8	5/859*	0/665	-0/433	-1/250	0/146	-1/088**	-0/271	-0/571	-0/086**	-0/164*
L10	-2/474	-8/535*	-0/233	2/267*	-0/838	2/729**	0/229	2/146**	-0/141**	-0/264**
L13	-4/174	2/915	-0/600**	-1/667	-1/138*	-0/338	-0/104	-1/604**	-0/054*	-0/228**
L14	-10/407**	-18/485**	0/133	-1/767	1/363**	0/813*	-0/604	-1/638**	0/236**	0/573**
L15	-9/232**	-10/285**	-0/567*	1/367	1/696**	-0/971**	-0/271	2/262**	0/149**	0/293**
S.E gi□	2/872	3/895	0/227	1/138	0/545	0/375	0/575	0/420	0/024	0/075
S.E.(gi□-gj□)	4/062	5/508	0/321	1/609	0/771	0/530	0/813	0/594	0/034	0/106
K3615.2	0/236	1/494	0/100	-0/500	0/221	-0/113	-0/229	-0/046	-0/027	0/014
A679	-0/236	-1/494	-0/100	0/500	-0/221	0/113	0/229	0/046	0/027	-0/014
S.E gj□	1/436	1/948	0/114	0/569	0/273	0/187	0/288	0/210	0/012	0/037
S.E.(gi□-gj□)	2/031	2/754	0/161	0/805	0/386	0/265	0/407	0/297	0/017	0/053

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

According to Table 4, for general combining effects of lines and testers under severe moisture stress, line L5 is effective in increasing the number of leaves, plant height, ear height, cob percentage, ear weight and ear diameter and decreasing chlorophyll content, number Row of Seeds at Bilal. L6 line has high general combining ability with: plant height, ear height, number of leaves and 300-kernel weight. L8 line has high general combining ability with: plant height, ear height, number of grains per maize, cob percentage, cob length, and ear weight. L14 line showed high combining ability with: Kernel row No./ear, ear diameter, ear weight, cob weight, and ear diameter. Overall, L6 and L14 were identified as the best lines under severe stress conditions. Under both conditions, the L6 line was identified as the best line. The results of the)Zebrajadi *et al*.,2012 (experiment showed that among parents, some inbred lines had a negative general combining effect for days up to 50% tassels, days up to 50% silage, and days to physiological maturity. The downside is that these lines can be used prematurely.

Table 4: General combining values of lines and testers of studied traits under severe moisture stress conditions

Line	Chlorophyll content	Ear height	Plant height	No. leaves above ear	No. leaves	Kernel No./row	Cob percentage	Kernel row/ear	Physiological maturity	Cob length
L5	-2/906*	11/75*	12/152**	0/088	1/083**	-0/026	1/456*	-0/931*	-0/521	0/727
L6	1/927	16/275**	18/385**	0/154	0/517*	1/007	-1/376*	-2/065**	-0/688	0/294
L7	2/210	-9/525*	8/152	0/288*	0/217	0/007	-1/294	1/069**	1/479	0/173
L8	-1/373	14/475**	8/602*	-0/413**	0/217	2/974*	1/856**	-0/481	0/979	1/110*
L10	-1/023	-1/958	-7/798	-0/212	-0/117	-0/326	0/339	-0/331	-0/521	0/277
L13	0/294	-4/592	-3/481	-0/013	-1/083**	-1/018	-0/027	-0/065	-0/521	-0/590
L14	0/177	-13/958**	-19/648**	-0/013	-0/317	-1/659	0/373	1/985**	0/479	-1/690**
L15	0/694	-11/792*	-16/365**	0/121	-0/517*	-0/959	-1/327*	0/819*	-0/688	0/044
S.E gi□	1/483	4/810	4/201	0/123	0/240	1/447	0/665	0/407	1/329	0/485
S.E.(gi□-gj□)	2/098	6/802	5/941	0/174	0/339	2/047	0/941	0/575	1/880	0/686
K3615.2	-0/431	1/675	-2/094	-0/038	0/092	-0/857	-0/144	0/310	0/521	-0/410
A679	0/431	-1/675	2/094	0/038	-0/092	0/857	0/144	-0/310	-0/521	0/410
S.E gj□	0/742	2/405	2/100	0/062	0/120	0/724	0/333	0/203	0/665	0/242
S.E.(gi□-gj□)	1/049	3/401	2/970	0/087	0/169	1/023	0/470	0/288	0/940	0/343

L5	-2/906*	11/75*	12/152**	0/088	1/083**	-0/026	1/456*	-0/931*	-0/521	0/727
L6	1/927	16/275**	18/385**	0/154	0/517*	1/007	-1/376*	-2/065**	-0/688	0/294
L7	2/210	-9/525*	8/152	0/288*	0/217	0/007	-1/294	1/069**	1/479	0/173
L8	-1/373	14/475**	8/602*	-0/413**	0/217	2/974*	1/856**	-0/481	0/979	1/110*
L10	-1/023	-1/958	-7/798	-0/212	-0/117	-0/326	0/339	-0/331	-0/521	0/277
L13	0/294	-4/592	-3/481	-0/013	-1/083**	-1/018	-0/027	-0/065	-0/521	-0/590
L14	0/177	-13/958**	-19/648**	-0/013	-0/317	-1/659	0/373	1/985**	0/479	-1/690**
L15	0/694	-11/792*	-16/365**	0/121	-0/517*	-0/959	-1/327*	0/819*	-0/688	0/044
S.E gi□	1/483	4/810	4/201	0/123	0/240	1/447	0/665	0/407	1/329	0/485
S.E.(gi□-gj□)	2/098	6/802	5/941	0/174	0/339	2/047	0/941	0/575	1/880	0/686
K3615.2	-0/431	1/675	-2/094	-0/038	0/092	-0/857	-0/144	0/310	0/521	-0/410
A679	0/431	-1/675	2/094	0/038	-0/092	0/857	0/144	-0/310	-0/521	0/410
S.E gj□	0/742	2/405	2/100	0/062	0/120	0/724	0/333	0/203	0/665	0/242
S.E.(gi□-gj□)	1/049	3/401	2/970	0/087	0/169	1/023	0/470	0/288	0/940	0/343

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

Table 4 (continued): General combining values of lines and testers of studied traits under severe moisture stress conditions.

Line	Ear diameter	Relative water content	Ear weight	Cob weight	Kernel depth	Yield	Ear diameter	Stem diameter	300-kernel weight	Stomatal conductance
L5	-0/040	1/361	-4/708	18/521**	-0/110	18/625	0/085	0/070	3/202	-0/913
L6	-0/127	0/198	21/458	-11/979*	0/010	61/458	-0/122**	-0/073	8/785**	1/654
L7	-0/100	-1/197	-8/542	-13/646*	-0/117	-102/042	0/031	-0/042	-0/148	0/337
L8	0/040	-1/244	73/292	28/854**	0/116	24/292	-0/122**	0/097	3/752	-1/229
L10	-0/060	1/736	-41/875	-2/146	0/046	5/792	-0/075	-0/005	-5/515*	0/871
L13	-0/065	-3/380	-112/208*	-15/146*	0/116	-42/542	-0/169**	-0/110	-2/181	-2/263
L14	0/415**	0/623	132/625**	16/668**	0/015	-39/375	0/415**	-0/010	-1/865	-1/879
L15	-0/063	1/901	-60/042	-21/146**	-0/077	73/792	-0/042	0/073	-6/031*	3/421
S.E gi□	0/109	1/877	44/370	6/036	0/104	86/329	0/042	0/062	2/798	2/305
S.E.(gi□-gj□)	0/154	2/654	62/749	8/536	0/147	122/088	0/059	0/087	3/958	3/259
K3615.2	0/060	-0/154	-24/333	-3/604	0/011	6/708	0/047	-0/013	0/073	-1/504
A679	-0/060	0/154	24/333	3/604	-0/011	-6/708	-0/047	0/013	-0/073	1/504
S.E gj□	0/055	0/938	22/185	3/018	0/052	43/165	0/021	0/031	1/399	1/152
S.E.(gi□-gj□)	0/077	1/327	31/375	4/268	0/073	61/044	0/030	0/044	1/979	1/630

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

According to Table 5, for the effects of specific combining under normal conditions, the K3615/2cross and increased ear weight was positively correlated with the L10 A679 has a negative correlation. The ear weight. The confluence of the L10 A679, and K3615/2, L6 weight of maize has a negative correlation with the L5 A679 crosses and it reduces ear weight. In addition, there was a positive L10 K3615/2. Stomatal K3615/2, and L10 A679, L6 correlation between crosses L5 T2, and A679, L6 conductance has a positive correlation with crosses L5 K3615/2 and is used to increase stomatal conductance. In addition, it has a L14 A679. Overall, K3615/2, and L14 K3615/2, L6 negative correlation at crosses L5 A679 crosses were identified as the best crosses for K3615/2, and L6 the L10 specific combining under normal conditions.

Table 5: Specific combining values of lines and testers of studied traits under normal conditions.

Line×tester	Yield	Stem diameter	Relative water content	Chlorophyll content	Ear weight	Cob weight	300-kernel weight	Stomatal conductance	No. leaves above ear	Ear diameter
L5×K3615/2	22/021	-0/079	0/485	-0/515	-50/083	-13/646*	3/669	-1/706*	0/013	-0/002
L5×A679	-22/021	0/079	-0/485	0/515	50/083	13/646*	-3/669	1/706*	-0/013	0/002
L6×K3615/2	-107/313	0/113	-1/217	2/402	-4/417	14/021*	1/202	-1/673*	0/246	0/052
L6×A679	107/313	-0/113	1/217	-2/402	4/417	-14/021*	-1/202	1/673*	-0/246	-0/052
L7×K3615/2	-99/646	0/029	0/495	-3/765*	23/583	2/354	-1/831	1/610	-0/87	0/022
L7×A679	99/646	-0/029	-0/495	3/765*	-23/583	-2/354	1/831	-1/610	0/087	-0/022
L8×K3615/2	18/354	-0/064	-2/699	-2/631	-30/917	-7/979	-1/815	-0/740	-0/088	-0/035
L8×A679	-18/354	0/064	2/699	2/631	30/917	7/979	1/815	0/740	0/088	0/035
L10×K3615/2	2/854	0/003	-0/205	0/135	117/750**	25/688**	0/402	0/377	-0/088	0/065
L10×A679	-2/854	-0/003	0/205	-0/135	-117/750**	-25/688**	-0/402	-0/377	0/088	-0/065
L13×K3615/2	49/854	0/026	3/791	1/969	3/917	0/021	-0/798	0/427	-0/021	-0/028
L13×A679	-49/854	-0/026	-3/791	-1/969	-3/917	-0/021	0/798	-0/427	0/021	0/028
L14×K3615/2	93/021	0/004	-0/934	0/852	-23/917	-9/479	-2/015	1/760*	0/054	0/008
L14×A679	-93/021	-0/004	0/934	-0/852	23/917	9/479	2/015	-1/760*	0/054	-0/008
L15×K3615/2	20/854	-0/032	0/285	1/502	-35/917	-10/979	1/185	-0/056	0/079	-0/082*
L15×A679	-20/854	0/032	-0/285	-1/502	35/917	10/979	-1/185	0/056	-0/079	0/082*
S.E.sij	75/597	0/078	3/213	1/946	49/768	5/946	4/546	0/835	0/138	0/043
S.E.(sij-ski)	106/910	0/110	4/544	2/752	70/382	8/409	6/428	1/181	0/196	0/061

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

Table 5 (continued): Specific combining values of lines and testers of studied traits under normal conditions.

Line×tester	Ear height	Plant height	No. leaves	Kernel No./row	Kernel row/ear	Cob percentage	Physiological maturity	Cob length	Kernel depth	Ear diameter
L5×K3615/2	2/330	4/273	0/433	-1/250	-0/204	-0/521	-0/271	-0/154	0/027	0/006
L5×A679	-2/330	-4/273	-0/433	1/250	0/204	0/521	0/271	0/154	-0/027	-0/006
L6×K3615/2	-4/953	-4/594	-0/100	1/100	0/046	1/263*	-0/104	1/063	-0/086**	-0/054
L6×A679	4/953	4/594	0/100	-1/100	-0/046	-1/263*	0/104	-1/063	0/086**	0/054
L7×K3615/2	-1/836	-4/094	-0/233	-1/500	0/113	-0/004	0/229	-0/654	0/040	0/043
L7×A679	1/836	4/094	0/233	1/500	-0/113	0/004	-0/229	0/654	-0/040	-0/043
L8×K3615/2	0/997	0/006	0/100	-0/350	-0/171	-0/337	0/229	-0/488	-0/008	-0/054
L8×A679	-0/997	-0/006	-0/100	0/350	0/171	0/337	-0/229	0/488	0/008	0/054
L10×K3615/2	-1/136	-1/594	0/033	3/167*	0/046	0/746	-0/937	1/396*	0/037	0/066
L10×A679	1/136	1/594	-0/033	-3/167	-0/046	-0/746	0/937	-1/396*	-0/037	-0/066
L13×K3615/2	-2/036	-1/177	-0/067	-0/500	0/146	-0/054	0/063	-0/554	0/024	-0/031
L13×A679	2/036	1/177	0/067	0/500	-0/146	0/054	-0/063	0/554	-0/024	0/031
L14×K3615/2	0/730	4/323	-0/267	-1/200	0/646	-0/537	0/562	-0/454	0/007	-0/004
L14×A679	-0/730	-4/323	0/267	1/200	-0/646	0/537	-0/562	0/454	-0/007	0/004
L15×K3615/2	5/905	2/856	0/100	0/533	-0/621	-0/554	0/229	-0/154	-0/040	0/029
L15×A679	-5/905	-2/856	-0/100	-0/533	0/621	0/554	-0/229	0/154	0/040	-0/029
S.E.sij	4/062	5/508	0/321	1/609	0/771	0/530	0/813	0/594	0/034	0/106
S.E.(sij-ski)	5/745	7/790	0/455	2/276	1/091	0/749	1/150	0/841	0/048	0/150

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

According to Table 6, for the effects of specific combining ability under severe moisture K3615/2 stress conditions, ear weight has a negative correlation at cross L8 and decreases maize. In addition, it has a positive correlation at cross A679. For the ear height attribute, it has a positive correlation at the L8 K3615/2 and increases the ear height. In addition, it has a cross of L7 A679. For the number of grain rows per maize, negative correlation at cross L7 K3615/2 and increases the number of grain it has a positive correlation at L8 A679. rows per maize. In addition, it has a negative correlation at cross L8 K3615/2. In For the cob length, it has a negative correlation at cross L8 A679 and increases the addition, it has a positive correlation at cross L8 K3615/2 cross was considered to be the length of the maize. Overall, the L8 best cross for specific combining under severe moisture stress conditions, reducing maize, increasing grain number per maize and decreasing cob length.

Table 6: Specific combining values of lines and testers of studied traits under severe moisture stress conditions.

Line×tester	Ear diameter	Relative water content	Ear weight	Cob weight	Kernel depth	Yield	Ear diameter	Stem diameter	300-kernel weight	Stomatal conductance
L5×K3615/2	-0/034	-0/096	-27/833	-0/063	0/019	37/458	-0/050	0/035	0/044	-1/413
L5×A679	0/034	0/096	27/833	0/063	-0/019	-37/458	0/050	-0/035	-0/044	1/413
L6×K3615/2	-0/127	1/114	31/000	10/771	-0/147	-3/042	0/023	0/088	2/494	0/021
L6×A679	0/127	-1/114	-31/000	-10/771	0/147	3/042	-0/023	-0/088	-2/494	-0/021
L7×K3615/2	-0/074	-1/535	-17/000	-2/896	-0/034	28/458	-0/037	-0/044	2/594	2/071
L7×A679	0/074	1/535	17/000	2/896	0/034	-28/458	0/037	0/044	-2/594	-2/071
L8×K3615/2	-0/014	0/265	-107/833	-30/396**	0/053	-21/208	-0/004	-0/065	-0/606	0/838
L8×A679	0/014	-0/265	107/833	30/396**	-0/053	21/208	0/004	0/065	0/606	-0/838
L10×K3615/2	0/133	2/995	-1/333	1/604	0/103	61/958	0/016	0/033	0/594	2/804
L10×A679	-0/133	-2/995	1/333	-1/604	-0/103	-61/958	-0/016	-0/033	-0/594	-2/804
L13×K3615/2	0/008	-4/468	7/667	8/271	-0/001	-49/708	0/010	-0/005	-2/006	2/604
L13×A679	-0/008	4/468	-7/667	-8/271	0/001	49/708	-0/010	0/005	2/006	-2/604
L14×K3615/2	0/031	-1/171	60/833	13/104	-0/019	-44/208	0/053	0/015	2/377	0/221
L14×A679	-0/031	1/171	-60/833	-13/104	0/019	44/208	-0/053	-0/015	-2/377	-0/221
L15×K3615/2	0/076	2/898	54/500	-0/396	0/026	-9/708	-0/010	-0/055	-5/490	-7/146
L15×A679	-0/076	-2/898	-54/500	0/396	-0/026	9/708	0/010	0/055	5/490	7/146
S.E.sij	0/154	2/654	62/749	8/536	0/147	122/088	0/059	0/087	3/958	3/259
S.E.(sij-ski)	0/218	3/753	88/741	12/072	0/208	172/658	0/084	0/123	5/597	4/609

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

Table 6 (continued): Specific combining values of lines and testers of studied traits under severe moisture stress conditions.

Line×tester	Chlorophyll content	Ear height	Plant height	No. leaves above ear	No. leaves	Kernel No./row	Cob percentage	Kernel row/ear	Physiological maturity	Cob length
L5×K3615/2	-0/635	-0/775	-1/806	0/104	0/142	-1/009	0/194	-0/244	-1/354	-0/006
L5×A679	0/635	0/775	1/806	-0/104	-0/142	1/009	-0/194	0/244	1/354	0/006
L6×K3615/2	-1/969	-1/442	-3/073	0/038	-0/225	0/224	0/692	-0/444	-0/521	0/960
L6×A679	1/969	1/442	3/073	-0/038	0/225	-0/224	-0/692	0/444	0/521	-0/960
L7×K3615/2	1/115	15/625*	8/760	-0/096	0/208	0/891	0/011	-0/244	2/313	0/060
L7×A679	-1/115	-15/625*	-8/760	0/096	-0/208	-0/891	-0/011	0/244	-2/313	-0/060
L8×K3615/2	-1/269	-3/508	-6/623	-0/129	0/075	-2/409	-1/506	1/540**	-1/188	-1/490*
L8×A679	1/269	3/508	6/623	0/129	-0/075	2/409	1/506	-1/540**	1/188	1/490*
L10×K3615/2	0/048	-2/142	0/544	0/004	-0/392	0/957	0/344	-0/577	0/312	0/144
L10×A679	-0/048	2/142	-0/544	-0/004	0/392	-0/957	-0/344	0/577	-0/312	-0/144
L13×K3615/2	0/668	-1/842	-1/206	0/071	0/108	-0/668	0/811	0/223	0/312	-0/090
L13×A679	-0/665	1/842	1/206	-0/071	-0/108	0/668	-0/811	-0/223	-0/312	0/090
L14×K3615/2	2/215	-2/742	2/394	-0/129	-0/192	0/357	0/077	-0/527	0/646	-0/023
L14×A679	-2/215	2/742	-2/394	0/129	0/192	-0/357	-0/077	0/527	-0/646	0/023
L15×K3615/2	-0/169	-3/175	1/010	0/138	0/275	1/657	-0/623	0/273	-0/521	0/444
L15×A679	0/169	3/175	-1/010	-0/138	-0/275	-1/657	0/623	-0/273	0/521	-0/444
S.E.sij	2/098	6/802	5/941	0/174	0/339	2/047	0/941	0/575	1/880	0/686
S.E.(sij-ski)	2/967	9/620	8/401	0/246	0/479	2/895	1/330	0/813	2/659	0/970

ns, * and ** are insignificant and significant, respectively, at the 5% and 1% probability levels.

Conclusion

The traits with the highest share of lines indicate that the confluence with the tester did not work. Inbound lines should be considered to correct such traits. Attributes in which the effect of line crossing with the tester has been substantially indicative of its successful crossing with the tester. Based on tester, significant differences were observed the analysis of variance of line tester on some traits, indicating for lines and testers and the effects of line that there is an additive genetic effect on these weight, cob weight and cob length had non-additive effects. Therefore, heterosis can be used to correct such traits. Examination of general combining ability under all three conditions showed significant differences for some traits, indicating the specific heritability of these traits. The L6 line was recognized as the best A679 crosses K3615/2 and L6 line. Specific combining results showed that L10 A679 crosses as were recognized as the best crosses under normal conditions, L8 K3615/2 crosses as best best crosses under moderate humidity conditions, and L8 crosses under moisture stress conditions, respectively.

Table 7: Contribution of lines and testers and Line×tester for studied traits under normal conditions.

	Ear height	Plant height	No. leaves	Kernel No./row	No. Kernel row/ear	Cob percentage	Physiological maturity	Cob length	Kernel depth	Ear diameter
Line	84/751	89/804	84/510	48/231	87/512	82/341	49/577	76/840	85/810	97/433
Tester	0/090	1/738	2/889	5/408	3/743	0/553	11/383	0/090	4/270	0/263
Line×tester	15/159	8/459	12/600	46/362	8/745	17/107	39/040	23/070	9/920	2/305

Table 7 (continued): Contribution of lines and testers and Line×tester for studied traits under normal conditions.

	Yield	Stem diameter	Relative water content	Chlorophyll content	Ear weight	Cob weight	300-kernel weight	Stomatal conductance	No. leaves above ear	Ear diameter
Line	32/406	69/248	59/098	68/326	72/717	70/598	81/790	52/859	90/130	90/511
Tester	2/114	1/384	13/489	0/241	0/168	0/006	0/517	0/245	1/986	1/792
Line×tester	65/480	29/368	27/413	31/432	27/115	29/395	17/693	46/899	7/884	7/697

Table 8: Contribution of lines and testers and Line×tester for studied traits under severe moisture stress conditions.

	Ear diameter	Relative water content	Ear weight	Cob weight	Kernel depth	Yield	Ear diameter	Stem diameter	300-kernel weight	Stomatal conductance
Line	73/568	35/393	62/273	63/858	61/433	67/784	90/614	65/140	76/738	22/454
Tester	10/071	0/286	7/114	2/692	0/905	1/018	6/539	2/232	0/018	15/451
Line×tester	16/361	64/321	30/613	33/450	37/662	31/198	2/847	32/628	23/244	62/095

Table 8 (continued): Contribution of lines and testers and Line×tester for studied traits under severe moisture stress conditions.

	Ear diameter	Relative water content	Ear weight	Cob weight	Kernel depth	Yield	Ear diameter	Stem diameter	300-kernel weight	Stomatal conductance
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Tester	10/071	0/286	7/114	2/692	0/905	1/018	6/539	2/232	0/018	15/451
Line×tester	16/361	64/321	30/613	33/450	37/662	31/198	2/847	32/628	23/244	62/095

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