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Estimation of Some Breeding Parameters for Improvement Grain Yield in Yellow Maize under Water Stress

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ABSTRACT

The present study was carried out during the three growing seasons 2011, 2012 and 2013 at Experimental Farm, Fac. of Agric., Zagazig University. A half diallel crosses among eight yellow maize inbred lines *i.e.* Z12 (P1), Z15 (P2), Z167 (P3), Z147 (P4), Z40 (P5), Z56 (P6), Z58 (P7) and Z103 (P8) were evaluated under well-watered and water stress environments. The data were recorded for the days to 50% silking, anthesis silking interval, plant height, ear leaf area, leaf water content, ear diameter, ear length, number of rows per ear, number of kernels per row, 100-kernel weight, grain yield (ard./fad.). The combined analyses of variance for combining ability revealed that mean squares for general combining ability (GCA) and specific combining ability (SCA) were highly significant across two environments for all studied characters, indicating the prevalence of additive and non-additive gene action in the gene expression of these characters, but the ratio of GCA/SCA variances were more than unity for days to 50% silking, plant height and number of rows per ear, indicating the major role of additive gene effects in controlling the genetic mechanism of these characters over water environments. In contrast, the ratio of variance GCA to variance SCA was blow one for anthesis silking interval, ear leaf area, leaf relative water content, ear diameter, ear length, number of rows per ear, number of kernels per row, 100-kernel weight and grain yield. This emphasized that, non-additive gene action was the prevailed type in controlling these characters. Narrow sense heritability estimates were high (> 50%) for days to 50% silking, plant height, ear diameter and number of rows per ear, moderate for ear leaf area (41.68%) and ear length (45.55%), and low (< 30%) for anthesis silking interval, leaf relative water content, number of kernels / row, 100-kernel weight and grain yield over two environments. Reduction % due to water stress valued, (32.83%) for grain yield (ard./fad.), (15.60%) for plant height, (14.99%) for ear length, (13.99%) for ear leaf area, (12.17%) for 100-kernel weight, (10.63%) for number of kernels/row, (6.98%) for ear diameter, (6.64%) for leaf relative water content and (4.22%) for number of rows/ear. The best parental combiners were Z167(P3) and Z147(P4) for grain yield and most its components under optimum irrigation and water deficit. The crosses, (P3 x P6), (P2 x P3), (P4 x P7), (P4 x P8) and (P6 x P8) had the most desirable and highest values for mean performance, SCA effects, heterosis effects, droght toleranc index (DI) and stress tolerance index (STI) for grain yield, anthesis silking interval and other performance traits. The yellow maize crosses (P2 x P3) and (P4 x P8) were significantly outyieled the check varieties. Grain yield had positive and significant genotypic and phenotypic correlations with ear leaf area (0.443** and 0.355**), leaf relative water content (0.488** and 0.307**), ear diameter (0.691** and 0.546**), ear length (0.783** and 0.647**), number of rows per ear (0.291* and 0.237), number of kernels per row (0.486** and 0.451**), 100-kernels weight (0.659** and 0.543**) and drought susceptibility index (0.484** and 0.388**, respectively), but had negative correlations with days to 50% silking (-0.034 and 0.004) and anthesis silking interval (-0.572** and -0.491**, respectively). The results showed that ear length exhibited the largest direct effect on grain yield (0.340) followed by drought susceptibility index (0.251), leaf relative water content (0.231), ear leaf area (0.182), number of kernels per row (0.171), ear diameter (0.135) and number of rows per ear (0.104).

Keywords: Maize, heterosis, combining ability, correlation, path analysis, water stress

INTRODUCTION

Maize is one of the most important grown cereal crops in Egypt and the world after rice and wheat for its nutritional quality and uses that provides a staple food in many parts of the world, feed, forage, bio-fuel (ethanol), vegetable oil and starch and moreover is the backbone of the poultry feed industry. Thus, attention was directed recently to increase its productivity in order to face the requirements of the over-population. The total area to worldwide reached about 185 million hectares gave total production 1040 million tons. Meanwhile, in Egypt, the total area was about 1.039 million hectares gave total production 8.059 million tons (FAOSTAT, 2014).

Agriculture currently uses over 70% (86% in developing countries) of the fresh water in the world (Edmeades, 2013). Water tables are dropping fast in countries like China, and water supplies will continue to shrink worldwide as global population will grow from the current 7 billion to more than 9 billion people in 2050 (Edmeades, 2013). Water stress is one of the important environmental challenges in crop productions to worldwide today, and recent global climate change has made this situation more serious (Geravandi *et al.*, 2011). Developing maize genotypes with tolerance to water deficit stress is complex quantitative trait and it is an important goal throughout the world, which are many genes contribute to yield and a hybrid's ability to withstand drought stress. Drought genes may respond differently depending on when the drought occurs in flowering stress (it is the most critical time for drought stress to impact maize yield) or grain filling stress, and on how severe the stress is. Drought is due to various factors, including the largely polygenic nature of the tolerance, the typically low frequency of tolerance alleles in most maize germplasm, and the difficulties commonly encountered in field evaluations (Bänziger *et al.* 2000). Westgate and Boyer (1986) reported that the losses in grain yield can be higher than 50%, it may be a consequence of the reduction in the number of seeds set per plant due to flowering inhibition, failure in the fertilization and abortion of embryos.

Edmeades (2013) reported that the yield gap between well-watered crop potential yield and water-limited yield is often large, but as a rough rule of thumb 20-25% of this gap could be eliminated by genetic improvement in drought tolerance and a further 20-25% by application of water-conserving agronomic practices. Significant yield losses in maize from drought are expected to increase with global climate change as temperatures rise and rainfall distribution changes in key traditional production areas (Campos *et al.* 2004). Heisey and Edmeades, (1999) estimated that 20-25% of the global maize area is affected by drought. Campos *et al.* (2004) showed that selection based on performance in multienvironment trials (MET) has increased grain yield under drought through increased yield potential and kernel set, rapid silk exertion, and reduced barrenness, though at a lower rate than under optimal conditions.

Anthesis-silking interval (ASI) is used as an efficient phenotypic index for selection criterion for improving grain yield under water stress and to increase yield stability (Bolanos and Edmeades, 1996, Durães *et al.*, 2002 and Magorokosho *et al.*, 2003). Chapman and Edmeades (1999) reported that selection gains in tropical maize were associated with increased flowering synchronization (*i.e.* a reduced anthesis-silking interval), fewer barren plants, a smaller tassel size, a greater harvest index and delayed leaf senescence.

Combining ability analyses give a real picture about the anticipated performance of inbred lines in hybrid combination. General combining ability (GCA) is the average performance of a line as reflected in its hybrid combinations and useful tools to select better inbred lines for the ability, while specific combining ability (SCA) indicates average performance of specific cross. Higher GCA indicates additive gene effects and additive x additive type of epistasis while higher SCA indicates the dominance gene effects. If both GCA and SCA variances are non-significant indicate that epistatic gene effects play role for studying characters. Various studies have been made on combining ability under drought stress in maize viz EL-Hosary *et al.* (2013) Alamerew and Warsi (2014), Aminu *et al.* (2014), Okasha *et al.* (2014), Umar *et al.* (2014), Wattoo *et al.* (2014), Erdal *et al.* (2015), Al-Naggar *el al.* (2016), Matin *et al.* (2016), and Saif-ul-Malook *et al.* (2016).

Path-coefficient analysis measures the direct influence (a standardized partial regression coefficient) of one predictor variable on another and it has been widely used in maize breeding program to determine the nature of relationships between grain yield (response variable) and its contributing components (predictor variables) (Pavlov *et al.* (2015). The current investigation was conducted to estimate heterosis, general and specific combining ability effects, genotypic and phenotypic correlation coefficients among the studied traits, as well as direct and indirect effects on grain yield and to identify new promising crosses for higher yield potential and better agronomic performance under optimum irrigation and water stress.

MATERIALS AND METHODS

This study was carried out during the three growing seasons 2011, 2012 and 2013 at Experimental Farm, Fac. of Agric., Zagazig University (Ghazala village, Zagazig district in Sharkia governorate, Egypt).

In 2011 season, 79 yellow maize inbred lines in different generations of inbreeding were grown and self-pollinated to increase quantities of their seeds and make one more generation of inbreeding to each line, and it was sown in two ridge; each ridge was 3 meters length and 70 cm width and distance between hills were 30 cm, in one replication. Eight inbred lines were selected from them according to their desirable mean performance of most studied traits, homozygous and homogeneous lines. These lines were originated from subtropical yellow genetic stock populations and Composite21, and produced by the Maize Dep., Field Crops Research Institute, ARC, Giza, Egypt and improved by Agronomy Dep., Fac. of Agric., Zagazig University.

In 2012 season, eight yellow inbred lines *i.e.* Z12 (P1), Z15 (P2), Z167 (P3), Z147 (P4), Z40 (P5), Z56 (P6), Z58 (P7) and Z103 (P8) were grown in two sowing date, i.e 3 and 10 June, each entry was represented by three ridges in one replication; each ridge was 6 meters length and 70 cm width and distance between hills were 30 cm. A half diallel cross was carried out among the eight yellow inbred lines giving a total of 28 single crosses.

In 2013 season, two separated experiments were undertaken in two different water irrigation treatments i.e. optimum irrigation (well-watered) and water stress (delaying irrigation, every 20 days interval after the second irrigation until the end of the growing season), each experiment included the 28 crosses along with two commercial checks (SC.168 and TWC.352). Randomized complete block design with three replications was used for both experiments. Each experimental plot consisted of single ridge of 6 meters length and 70 cm width and distance between hills were 25 cm. Trials at both water treatments were hand-planted with two seeds per hill and the thinning to one plant per hill was carried out three weeks after planting. The other recommended cultural practices for maize were applied properly throughout the growing season.

The data were recorded on random sample of ten guarded and competitive plants in the middle ridge from each plot to estimate the days to 50% silking, anthesis silking interval (calculated as the difference between days to silking and anthesis), plant height, ear leaf area, leaf relative water content, ear diameter, ear length, number of rows per ear, number of kernels per row, 100-kernel weight and grain yield (ard./fad.)

Leaf relative water content (RWC): 5 ear leaves (0.5 g) were taken per plot and fresh weight (FW), then segments were then placed in distilled water for 24 h at 4°C in the dark and reweighed to obtain turgid weight (TW). Thereafter the leaf segments were oven dried at 65°C for 48 h and re-weighed to obtain dried weight (DW). RWC was calculated using the following formula (Castillo, 1996):

The following drought tolerance indices including, Drought susceptibility index (DSI) (Fisher and Maurer, 1978), Stress tolerance index (STI) (Fernandez, 1992), Drought tolerance Index (DI) (Lan, 1998) and Yield Reduction Ratio (RR) (Golestani and Assad 1998) were calculated using the below formula,

$SSI = [1 – (Ys / Yp)] / SI$,

while SI (stress intensity) $= 1 – (\bar{Y}s / \bar{Y}p)$

$STI = (Ys \times Yp)/(\bar{Y}p2)$

$DI = (Ys\times(Ys/Yp))/\bar{Y}s$

$YRR = 1 – (\bar{Y}s / \bar{Y}p)$

Where, Ys and Yp represent yield in stress and non-stress conditions respectively. Also $\bar{Y}s$ and $\bar{Y}p$ are mean yield in stress and non-stress conditions respectively (for all genotypes).

The analysis of variance according to Steel and Torrie (1980) for each water irrigation treatment was processed and combined analysis for both experiments was applied after testing the homogeneity of error variance, Barttlet test was used in this respect. Differences among genotype means tested using a revised L.S.D. test at the 0.05 level according to Steel and Torrie (1980).

General and specific combining ability estimates were calculated according to Griffing (1956), method 4, model 1. Heterosis effects were computed based on the two check varieties (SC. 168 and TWC. 352) for all yellow maize crosses (standard heterosis), according to Bhatt (1971).

The genotypic and phenotypic correlation coefficients were calculated according to Miller *et al.* (1958). The path coefficient analysis was estimated as outlined by Dewey and Lu (1959). A PC Microsoft Excel program, SPSS and SAS 9.1 ® Computer program for Windows were used for the statistical analysis.

RESULTS AND DISCUSSION

Analysis of variance

The combined analyses of variance for combining ability revealed that mean squares for environments, genotypes and hybrids showed highly significance differences for all studied traits Table 1, indicating the presence of adequate amount of genetic variability for applying various genetic approaches and wide differences between the environments and differential genotypic behavior across the environments. These results are in similar with those obtained by Abdel-Moneam *et al.* (2009); EL-Hosary *et al.* (2013); Alamerew and Warsi (2014); Aminu *et al.* (2014) and Matin *et al.* (2016).

Also, Mean squares due to general combining ability (GCA) and specific combining ability (SCA) were highly significant across two environments for all studied characters, indicating the prevalence of additive and non-additive gene action in the gene expression of these characters. Moreover, highly significant variances were observed among commercial checks and checks *vs.* hybrids for plant height, ear diameter, ear length, number of rows / ear, number of kernels / row and grain yield. Combined analyses of variance for genotypes x E and hybrids x E were significant for anthesis silking interval, ear leaf area, ear length and grain yield. GCA x E was significant for ear leaf area, ear length, 100-kernel weight and grain yield, while SCA x E was significant only for ear length. Non-significant variances were observed for all characters except 100-kernel weight relative to commercial checks x E, leaf relative water content and number of kernels / row for checks *vs.* H x E.

El-Shamarka *et al.* (2015) showed that that mean squares due to crosses, G.C.A. and S.C.A. were highly significant for days to 50% silking, plant height, ear diameter, ear length, number of rows / ear, number of kernels / row and grain yield (ard fad-1), indicating the importance of both additive and non-additive gene effects in the inheritance of these traits. General combining ability (GCA) effects of the inbreds and specific combining ability (SCA) of the hybrids were found to be highly significant for number of days to anthesis, anthesis-silking interval, plant height, thousand kernel weight, number of ears per plant, number of kernels per ear and grain yield (Erdal *et al.,* 2015). Umar *et al.* (2014) reported that both additive and non-additive gene actions were responsible for the control of grain yield and other traits studied under water stress and optimum conditions.

The ratio of GCA/SCA variances were more than unity for days to 50% silking, plant height and number of rows per ear, indicating the major role of additive gene effects in controlling the genetic mechanism of these characters and giving additional evidence that selection should be effective in the early segregating generations. In contrast, the ratio of variance GCA to variance SCA was blow one for anthesis silking interval, ear leaf area, leaf water content, ear diameter, ear length, number of kernels per row, 100-kernel weight and grain yield, this emphasized that, non-additive gene action was the prevailed type in controlling these characters; consequently, hybrid breeding system would be the most efficient method for improving these characters.

EL-Hosary *et al.* (2013) showed under drought stress that the dominance variances were important for grain yield, number of rows/ear, number of kernels per ear and 100 kernel weight. Erdal *et al.* (2015) also showed the importance of dominance for grain yield, plant height and 1000 kernel weight, while demonstrated the presence of additive for number of days to anthesis and anthesis-silking interval. Aminu *et al.* (2014), Okasha, *et al.* (2014), Umar *et al.* (2014) and Al-Naggar *et al.* (2016) revealed that both additive and non-additive gene actions were responsible for the control of grain yield under water stress and non-stress conditions, but the magnitude of dominance was much higher than additive variance for this trait. On the other hand, additive and additive × additive types of gene action were greater importance in the inheritance of number of rows/ear (Al-Naggar *et al.,* 2016); plant height, days to 50% silking, anthesis-silking interval (ASI), grain yield and 100-Kernel weight (Wattoo *et al.* 2014).

The ratios GCA x E / SCA x E were more than unity for days to 50% silking, anthesis silking interval, plant height, ear leaf area, ear diameter, number of kernels/row, 100-kernel weight and grain yield, indicating that variance GCA effects were more interacted with water treatments for these traits. On the other side, variance SCA effects were more affected with water treatments for leaf water content, ear length and number of rows/ear. Nawar *et al.* (1988) and El-Shamarka (1995) reported that GCA variances were more susceptible to the environmental fluctuations than SCA variances.

Narrow sense heritability estimates were high for days to 50% silking (55.14%), plant height (77.35%), ear diameter (50.81%) and number of row per ear (64.02%), suggesting that these characters are an important attributes contributing towards yield and direct selection can be practiced in early segregation generation. Moderate narrow sense heritability estimates were recorded for ear leaf area (41.68%) and ear length (45.55%). On the other side, low narrow sense heritability estimates were reported for anthesis silking interval (14.01%), leaf relative water content (29.23%), number of kernels / row (17.26%), 100-kernel weight (15.63%) and grain yield (25.48%), indicating that non-additive genetic effects controlling the inheritance of these traits. In this connection high heritability values were reported by Saif-ul-Malook *et al.* (2016) for plant height, 100-grain weight, grain rows per cob and grain yield per plant.

Table 1. Analysis of variance for grain yield and other agronomic traits combined over two environments

S.O.V	df	Days to 50% silking	Anthesis-silking interval (ASI)	Plant height (cm)	Ear Leaf area (cm^2)	Leaf water content %	Ear diameter (cm)	Ear length (cm)	No. rows /ear	No. kernels/ row	100 kernel weight (g)	Grain yield (ard./ fad.)
Environments (E)	1	609.14**	8.36**	76879.99**	247308.83**	1304.76**	4.52**	303.67**	22.72**	649.23**	444.72**	608.17**
Reps/E.	4	5.38	0.11	76.89	583.09	11.57	0.09**	1.63	5.04	4.60	2.01	2.40
Genotype (G)	29	12.19**	5.80**	1594.89**	14154.63**	7.28**	0.55**	18.31**	22.84**	81.87**	40.60**	29.55**
Hybrid	27	13.05**	6.09**	1661.16**	14922.18**	7.49**	0.54**	14.52**	22.27**	73.58**	38.00**	29.28**
GCA	7	30.48**	3.54**	5052.21**	25416.91**	10.95**	1.12**	26.73**	56.45**	53.47**	25.82**	31.31**
SCA	20	6.95*	6.99**	474.29**	11249.02**	6.28**	0.34**	10.25**	10.30**	80.62**	42.26**	28.57**
Check	1	1.24	3.31**	428.05*	4371.61	8.73	0.33*	30.47**	22.96**	167.48**	0.08	20.67**
Check Vs H	1	0.10	0.42	972.66**	3213.96	0.13	0.98**	108.44**	38.24**	219.92**	151.51**	45.63**
G x E	29	3.94	0.36**	108.61	2825.23**	4.43	0.06	2.02**	0.31	4.43	3.58	3.43*
Hybrid x E	27	3.78	0.38**	116.63	2986.23**	4.08	0.06	2.15**	0.31	3.81	3.47	3.53*
GCA x E	7	5.05	0.49	122.01	7029.43**	2.99	0.10	2.05*	0.15	6.39	5.05*	6.32**
SCA x E	20	3.34	0.34	114.75	1571.12	4.46	0.05	2.18**	0.36	2.91	2.92	2.56
Check x E	1	0.68	0.24	0.47	634.23	0.52	0.03	0.46	0.56	3.82	10.08*	2.16
Check Vs H x E	1	11.37	0.01	0.12	668.98	17.70*	0.01	0.01	0.14	21.62**	0.08	2.05
Pooled Error	108	4.10	0.13	85.74	1242.43	3.08	0.07	0.89	1.34	3.12	2.38	2.01
GCA/SCA		1.42	0.08	2.07	0.40	0.38	0.64	0.46	1.02	0.11	0.10	0.18
GCA x E / SCA x E		1.51	1.44	1.06	4.47	0.67	2.29	0.94	0.42	2.20	1.73	2.47
GCA x I / GCA		0.17	0.14	0.02	0.28	0.27	0.09	0.08	0.00	0.12	0.20	0.20
SCA x I / SCA		0.48	0.05	0.24	0.14	0.71	0.13	0.21	0.04	0.04	0.07	0.09
Tn		55.14	14.01	77.35	41.68	29.23	50.81	45.55	64.02	17.26	15.63	25.48

***,** Significant at P=0.05 and P=0.01, respectively**

Mean Performance

Mean performance for 11 studied traits of 28 yellow maize crosses as an average of two environments are presented in Table 2. Behaviors of the crosses were differed from normal irrigation to water deficit for all studied traits. Consequently, in most cases mean performances of crosses obtained from normal irrigation were mostly higher than those obtained from water stress. Based on the combined data, the earliest mean values were obtained from the crosses (P1 x P7), (P3 x P7), (P1 x P3), (P7x P8) and (P4 x P7), whereas, the maize cross (P1 x P6) was the latest. These results showed that when drought stress coincides prior to flowering, ear growth will be slow more than tassel growth and there is a delay in silk emergence relative to pollen shed, giving rise to an interval between anther extrusion and silk exposure. Richards (2006) reported that, attributed the delay in silking in drought-susceptible genotypes to the less assimilates allocation to ear growth when the ears are quite small. Even if these silks are pollinated separately, many of the grains will abort, resulting in a low grain number per ear.

Regarding anthesis-silking interval it ranged from 2.18 days (P4 x P8) to 6.05 days (P3 x P5) with a mean of 4.08 days, in addition crosses combinations (P1 x P7), (P2 x P3), (P2 x P6) and (P4 x P8) were identified as having a very short and desirable mean performances for ASI, an indication for tolerance to drought, were found to contribute to the increase in the production of grain yield. In contrast, crosses (P3 x P5), (P4 x P5), (P4 x P6), (P5 x P6) and (P7 x P8) with a high ASI an indication for poor tolerance to drought contributed to the reduction in grain yield. Similar results were obtained by Chapman and Edmeades (1999), Edmeades *et al*. (2000) and Durães *et al.* (2002).

For plant height the shortest one was 216.52 cm in the cross (P6 x P8), while the tallest one was 282.53 cm in the cross (P4 x P7). The highest value for ear leaf area was shown by the cross (P1 x P4) (551.05 cm2), while the lowest one was shown by cross (P2 x P8) (387.65 cm2). The mean values of leaf relative water content ranged from 73.47% (P2 x P7) to 77.54% (P1 x P6) with a mean of 75.95% . The yellow maize crosses (P1 x P2), (P1 x P3), (P2 x P5), (P3 x P6) and (P4 x P7) had the highest ear diameter (4.73, 4.95, 4.72, 4.59 and 4.75, respectively), whereas cross (P5 x P6) (3.88 cm) was the lowest one. The cross (P2 x P3) gave the highest ear length followed by (P4 x P7) and then cross (P3 x P6), none of the crosses had superiority over check variety (S.C. 168). Regarding number of rows/ear, it ranged from 13.43 (P6 x P7) to 20.83 (P1 x P3) with a mean of 16.83. For number kernels/row, the cross (P1 x P5) gave the highest number of kernels per row (40.34) followed by (P4 x P7) (36.80) and then cross (P5 x P8) (35.33), whereas cross (P6 x P7) gave the lowest value (24.3). The crosses (P1 x P4), (P2 x P3), (P3 x P6) and (P5 x P8) had the highest values and exhibited significant superiority over the check varieties for 100-kernel weight (29.06, 28.17, 28.18 and 28.02g, respectively) compared to the check varieties (27.77 and 27.939g).

Significant differences in grain yield (ard./fad.) were detected among the tested F1 crosses. The highest grain yield was obtained from crosses (P4 x P8) and (P2 x P3) (24.24 and 23.58 ard./fad., respectively), they were significantly outyielded the check S.C. 168. On the other side, the cross (P2 x P7) gave the lowest yield (15.87 ard./fad.).

Drought stress reduced expression of studied traits by the following percentages relative to performance under well-watered condition, i.e. plant height (15.60%), ear leaf area (13.99%), leaf relative water content (6.64), ear diameter (6.98%), ear length (14.99%), number of rows/ear (4.22%), number of kernels/row (10.63%), 100-kernel weight (12.17%) and grain yield (ard./fad.) (32.83%). In contrast, drought stress increased expression of days to 50% silking and anthesis silking interval (ASI) by the following percentages relative to performance under well-watered condition (6.25% and 11.05%, respectively). Reduction in many traits have been reported by various researchers viz EL-Hosary *et al.* (2013), Erdal *et al.* (2015) Al-Naggar *et al.* (2016) and Saif-ul-Malook *et al.* (2016). Okasha, *et al.* (2014) reported the reduction due to drought (50% F.C) had the maximum value for grain yield (27.53% and 39.96%), followed by number of kernels row (20.82 and 26.91%) and 100-kernels weight (12.50 13.64%) in Ismailia and Rommana locations, respectively.

Table 2. Means of grain yield and other agronomic traits for 28 F_1 crosses and 2 check varieties as an average of two environments

Crosses	Days to 50% silking	Anthesis-silking interval (ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water content%	Ear diameter (cm)	Ear length (cm)	No. rows /ear	No. kernels/ row	100 kernel weight (g)	Grain yield (ard./fad.)
P1 X P2	62.92	3.60	246.65	430.32	75.84	4.73	16.01	17.27	30.61	21.90	18.24
P1 X P3	61.05	4.60	245.89	409.13	76.70	4.95	15.55	20.83	27.73	19.83	18.91
P1 X P4	63.06	3.80	266.56	551.05	76.07	4.56	17.71	16.85	32.82	29.06	20.98
P1 X P5	63.40	3.02	232.50	539.82	76.16	4.28	15.72	18.08	40.34	23.85	20.45
P1 X P6	65.09	4.52	225.00	452.51	77.54	4.17	14.30	15.91	27.67	21.23	19.79
P1 X P7	59.70	2.90	245.00	431.36	74.19	4.23	15.37	18.18	30.50	24.32	20.05
P1 X P8	63.58	4.73	228.33	435.63	76.19	4.38	14.77	18.87	35.00	25.33	18.25
P2 X P3	62.50	2.97	252.89	536.91	76.76	4.83	19.51	17.56	33.37	28.17	23.58
P2 X P4	64.33	3.45	271.50	545.32	77.45	4.47	17.86	14.77	35.13	25.69	21.73
P2 X P5	64.76	4.38	239.16	495.74	75.95	4.72	15.69	17.90	26.97	25.19	18.90
P2 X P6	61.91	2.90	239.38	432.90	75.67	3.90	13.78	14.40	28.00	24.05	16.13
P2 X P7	64.46	3.72	235.60	470.04	73.47	4.13	13.87	17.16	33.83	23.38	15.87
P2 X P8	65.08	4.88	223.00	387.65	76.78	4.05	14.90	15.90	34.83	19.92	18.62
P3 X P4	62.92	4.20	260.06	488.17	76.45	4.51	17.39	18.48	30.93	24.48	19.41
P3 X P5	63.90	6.05	242.50	447.91	76.86	4.29	15.56	17.50	30.03	22.48	19.37
P3 X P6	61.64	3.70	254.11	520.48	76.74	4.59	17.87	18.33	33.12	28.18	21.79
P3 X P7	60.18	3.05	241.00	493.78	75.28	4.35	15.21	19.23	35.17	23.77	20.09
P3 X P8	62.25	4.72	233.17	492.23	76.87	4.10	14.80	18.83	28.50	21.58	18.00
P4 X P5	63.65	5.35	266.08	546.14	75.17	4.46	16.29	16.65	29.86	26.16	19.11
P4 X P6	64.08	5.88	276.46	550.60	73.61	4.05	17.77	14.40	31.87	23.59	17.53
P4 X P7	61.15	3.05	282.53	534.37	75.14	4.75	18.94	16.63	36.80	26.44	21.36
P4 X P8	62.90	2.18	229.49	473.60	76.59	4.55	17.58	18.70	34.67	25.63	24.24
P5 X P6	63.89	5.18	244.17	516.28	75.64	3.88	14.14	13.57	34.17	20.95	16.95
P5 X P7	63.34	3.98	240.69	519.71	75.93	3.93	14.40	13.86	30.83	21.50	17.64
P5 X P8	64.27	3.13	230.36	543.43	77.09	4.37	15.73	14.98	35.33	28.02	21.73
P6 X P7	61.22	4.87	243.35	402.42	76.69	4.00	15.33	13.43	24.43	22.20	16.32
P6 X P8	63.91	3.93	216.52	481.51	76.15	4.18	17.47	17.80	34.00	25.17	21.75
P7 X P8	61.07	5.50	231.67	480.22	73.63	4.01	15.73	15.20	34.33	24.73	16.35
Mean	62.94	4.08	244.41	486.04	75.95	4.34	16.04	16.83	32.17	24.17	19.40
Checks											
SC. 168	62.52	3.75	259.71	522.07	75.20	4.80	20.75	13.60	40.34	27.77	22.73
TWC. 352	63.16	4.80	247.76	483.90	76.91	4.47	17.56	16.37	32.87	27.93	20.10
LSD 0.05	2.37	0.35	9.14	35.21	2.23	0.27	0.94	1.21	1.73	1.52	1.42
CV %	4.33	11.59	5.47	9.70	2.85	8.06	7.23	11.12	6.62	9.66	9.97
Reduction %	-6.25	-11.05	15.60	13.99	6.64	6.98	14.99	4.22	10.63	12.17	32.83

General combining ability (GCA)

The analysis of variance for combining ability was performed using method 4 model 1 of Griffing (1956). Estimates of general combining ability effects (GCA) for all studied traits are shown in Table 3, data are the combined over two environments. Positive GCA effects were desirable for all studied traits, except for silking date, ASI and plant height which exhibited negative values indicate tendency towards earliness and shortness. Therefore, it might be more resistant to stalk breakage, lodging and increasing plant density.

Table 3. General combining ability (GCA) effects for grain yield and other agronomic traits combined over two environments

Inbred lines	Days to 50% silking	Anthesis-silking interval (ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water content%	Ear diameter (cm)	Ear length (cm)	No. rows /ear	No. kernels /row	100 kernel weight(g)	Grain yield (ard./fad.)
P1 (Z12)	-0.29	-0.23*	-3.50	-25.41**	0.17	0.16*	-0.48*	1.36**	-0.09	-0.61	0.15
P2 (Z15)	0.90*	-0.44**	-0.45	-17.24**	0.05	0.08	-0.12	-0.48	-0.41	-0.15	-0.45
P3 (Z167)	-1.02	0.12	3.12	-2.28	0.67	0.21*	0.60*	2.16**	-1.06*	-0.12	0.89*
P4 (Z147)	0.26	-0.11	23.63*	47.82**	-0.20	0.17*	1.87**	-0.22	1.15*	1.98**	1.43*
P5 (Z40)	1.11*	0.42**	-2.58	34.45*	0.19	-0.07	-0.80*	-0.88*	0.39	-0.17	-0.27
P6 (Z56)	0.20	0.40**	-1.98	-7.60	0.06	-0.26*	-0.28	-1.66**	-1.99**	-0.64	-0.92*
P7 (Z58)	-1.57*	-0.25*	1.49	-11.73	-1.22*	-0.16*	-0.58*	-0.69*	0.11	-0.48	-1.35*
P8 (Z103)	0.42	0.09	-19.73**	-18.01*	0.28	-0.12*	-0.22	0.41	1.91*	0.20	0.53
LSD $_{0.05}$ (gi)	0.85	0.15	3.76	15.05	0.72	0.11	0.39	0.50	0.74	0.66	0.61
LSD $_{0.01}$ (gi)	2.23	0.39	9.85	39.44	1.88	0.30	1.02	1.31	1.94	1.72	1.59
LSD $_{0.05}$ (gi-gi)	1.29	0.23	5.69	22.76	1.09	0.17	0.59	0.75	1.12	0.99	0.92
LSD $_{0.01}$ (gi-gi)	3.38	0.59	14.90	59.63	2.85	0.45	1.55	1.98	2.94	2.60	2.40

***,** Significant at P=0.05 and P=0.01, respectively**

The results indicate that for days to 50% silking, the parental lines P2 (Z15) and P5 (Z40) exhibited positive and significant GCA effects (undesirable) which represented late maturing variety, whereas P7 (Z58) possessed negative and significant GCA effects, indicating earliness (desirable). For ASI, P1 (Z12), P2 (Z15) and P7 (Z103) showed negative and significant GCA effects indicating earliness, while P5 (Z56) exhibited positive and significant GCA effects which represented late maturing variety. Respecting plant height P8 (Z103) possessed negative and significant GCA effects. With respect to ear leaf area, P4 (Z147) and P5 (Z40) had positive and significant GCA effects. None of the parents recorded positive and significant GCA effects for leaf water content. Positive and significant GCA effects for ear diameter were observed in P1 (0.16), P3 (0.21) and P4 (0.17). Positive and significant valueS of GCA were recorded in two genotypes out of eight such as P3 (0.6) and P4 (1.87) for ear length, P1(1.36) and P3 (2.16) for number of rows per ear and P4 (1.15) and P8 (1.91) for number kernels/row. Positive and significant value of GCA for 100-kernels was found only in P4 (1.98). Further, for grain yield (ard./fad.) positive and significant GCA effects were recorded in two out of eight parents such as P3 (0.89) and P4 (1.43) toward higher yielding ability. On the other hand, inbred lines P6 (-0.92) and P7 (-1.35) possessed negative and significant GCA effects, indicating poor yielding ability.

It could be concluded that, the best combiners were P3 (Z167) and P4 (Z147) inbred lines for grain yield and its components under normal irrigation and water deficit. This result indicated that the two previous lines could be considered as good combiners for improving hybrids with yielding ability. The parental inbred lines P7 (Z167) and P8 (Z103) possessed favorable genes for improving hybrids with earliness and short plants, respectively. A similar finding was reported by Abdel-Moneam *et al.* (2009), Alamerew and Warsi (2014) and Aminu *et al.* (2014), Okasha *et al.* (2014) and Matin *et al.* (2016).

In this respect, Duvick 2005 and Troyer (2006) reported that inbred yield testing will be better select for stress tolerance because inbreds are more susceptible to stress than their hybrids and it will speed up genetic progress for higher yields. So plant breeders should more directly measure and improve the adaptedness of inbred parents based on inbred yield, because the genotype of the maize hybrid is determined completely by the genotypes of its parental inbreds (Troyer and Wellin 2009).

Specific combining ability (SCA)

Estimated of specific combining ability (SCA) effects for all studied traits combined over two environments for 28 crosses are present in Table 4.

Table 4. Specific combining ability (GCA) effects for grain yield and other agronomic traits combined over two environments

Crosses	Days to 50% silking	Anthesis-silking interval (ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water content%	Ear diameter (cm)	Ear length (cm)	No. rows / ear	No. kernels / row	100 kernel weight (g)	Grain yield (ard./fad.)
P1 X P2	-0.63	0.20	6.18	-13.07	-0.33	0.16	0.56	-0.45	-1.06	-1.51*	-0.85
P1 X P3	-0.58	0.63*	1.85	-49.22*	-0.09	0.24	-0.61	0.48	-3.29*	-3.61*	-1.53*
P1 X P4	0.16	0.06	2.01	42.59*	0.14	-0.10	0.28	-1.12*	-0.41	3.53*	0.01
P1 X P5	-0.36	-1.25**	-5.84	44.74*	-0.15	-0.14	0.95*	0.77	7.87**	0.47	1.18
P1 X P6	2.25*	0.27	-13.93*	-0.51	1.35	-0.06	-0.99*	-0.62	-2.42*	-1.69*	1.16
P1 X P7	-1.37	-0.70*	2.59	-17.53	-0.71	-0.10	0.38	0.68	-1.70*	1.23	1.85*
P1 X P8	0.52	0.80*	7.14	-7.00	-0.21	0.01	-0.58	0.26	1.01	1.58*	-1.82*
P2 X P3	-0.32	-0.79*	5.81	70.38*	0.10	0.21	2.99**	-0.95	2.67*	4.26**	3.74**
P2 X P4	0.24	-0.08	3.91	28.69	1.65*	-0.11	0.06	-1.36*	2.23*	-0.30	1.35*
P2 X P5	-0.18	0.32	-2.22	-7.52	-0.24	0.37*	0.55	2.43*	-5.18**	1.35	0.23
P2 X P6	-2.13*	-1.14**	-2.59	-28.30	-0.39	-0.25*	-1.87*	-0.29	-1.77*	0.67	-1.89*
P2 X P7	2.19*	0.33	-9.85*	12.97	-1.31	-0.13	-1.49*	1.49*	1.96*	-0.16	-1.72*
P2 X P8	0.82	1.16**	-1.23	-63.14*	0.51	-0.25*	-0.81	-0.86	1.16	-4.30**	-0.85
P3 X P4	0.74	0.11	-11.11*	-43.41*	0.03	-0.20	-1.13*	-0.29	-1.32	-1.55*	-2.31*
P3 X P5	0.88	1.43**	-2.46	-70.30*	0.05	-0.19	-0.28	-0.61	-1.47	-1.39	-0.65
P3 X P6	-0.48	-0.90**	8.56*	44.32*	0.06	0.31*	1.50*	1.01	4.00*	4.76**	2.42*
P3 X P7	-0.16	-0.90**	-8.02	21.75	-0.12	-0.04	-0.85	0.93	3.94*	0.19	1.15
P3 X P8	-0.09	0.43*	5.36	26.48	-0.02	-0.33*	-1.62*	-0.57	-4.52**	-2.67*	-2.82*
P4 X P5	-0.65	0.95**	0.61	-22.18	-0.78	0.03	-0.83	0.92	-3.84*	0.19	-1.44*
P4 X P6	0.69	1.51**	10.41*	24.33	-2.21*	-0.19	0.13	-0.54	0.54	-1.92*	-2.38*
P4 X P7	-0.47	-0.67*	12.99*	12.24	0.61	0.41*	1.60*	0.71	3.37*	0.77	1.88*
P4 X P8	-0.71	-1.88**	-18.82*	-42.26*	0.56	0.17	-0.11	1.68*	-0.56	-0.71	2.89*
P5 X P6	-0.35	0.28	4.31	3.38	-0.57	-0.12	-0.83	-0.72	3.60*	-2.41	-1.26
P5 X P7	0.86	-0.27	-2.64	10.95	1.01	-0.17	-0.27	-1.41*	-1.84*	-2.02*	-0.14
P5 X P8	-0.20	-1.46**	8.25	40.94*	0.67	0.22	0.71	-1.39*	0.86	3.82**	2.08*
P6 X P7	-0.34	0.63*	-0.57	-64.29*	1.89*	0.09	0.14	-1.05*	-5.86**	-0.86	-0.81
P6 X P8	0.36	-0.64*	-6.19	21.07	-0.14	0.23	1.92*	2.22*	1.91*	1.44	2.75*
P7 X P8	-0.71	1.58**	5.50	23.92	-1.37	-0.05	0.49	-1.35*	0.14	0.84	-2.22*
LSD $_{0.05}$ (Sij)	1.89	0.33	8.32	33.32	1.59	0.25	0.86	1.10	1.64	1.45	1.34
LSD $_{0.01}$ (Sij)	4.95	0.87	21.80	87.30	4.17	0.65	2.26	2.89	4.30	3.81	3.52
LSD $_{0.05}$ (Sij-Sik))	2.88	0.51	12.71	50.90	2.43	0.38	1.32	1.69	2.51	2.22	2.05
LSD $_{0.01}$ (Sij-Sik))	7.55	1.33	33.31	133.35	6.36	1.00	3.46	4.42	6.57	5.82	5.38
LSD $_{0.05}$ (Sij-Ski))	2.58	0.45	11.37	45.52	2.17	0.34	1.18	1.51	2.24	1.99	1.83
LSD $_{0.01}$ (Sij-Ski))	6.76	1.19	29.79	119.27	5.69	0.89	3.09	3.95	5.87	5.21	4.81

***,** Significant at P=0.05 and P=0.01, respectively**

In the present study, crosses manifested considerable variation in specific combining ability effects for different characters. Negative and significant SCA effects were detected in one cross (P2 x P6) for days to 50% silking, 10 crosses for anthesis silking interval and 4 crosses for plant height. In contrast, positive and significant SCA effects were detected in 5 crosses for ear leaf area, 2 crosses for leaf water content, 3 crosses for ear diameter, 5 crosses for ear length, 4 crosses for number rows/ear, 9 crosses for number kernels/row, 5 crosses for 100-kernels weight and 8 crosses for grain yield. Therefore, these crosses could be selected for specific combining ability to improve these traits. All these crosses had also the highest mean performance values for all these traits as shown before in Table 2.

It is worthy to note that 10 out of 28 crosses had most significantly desirable SCA effects over environments for all studied traits. Meanwhile, the best cross (P3 x P6) showed significantly desirable SCA effects for anthesis silking interval (-0.90), ear leaf area (44.32), ear diameter (0.31), ear length (1.50), number kernels/row (4.0), 100-kernels weight (4.76) and grain yield (2.42). The cross (P2 x P3) had positive and significant SCA effects for ear leaf area (70.38), ear length (2.99), number kernels/row (2.67), 100-kernels weight (4.26) and grain yield (3.74), also it possessed negative and significant SCA effects for anthesis silking interval (-0.79). The greatest significant and desirable SCA effects were shown in two crosses (P4 x P7) and (P6 x P8) for anthesis silking interval (-0.67 and -0.64, respectively), ear length (1.60 and 1.92, respectively), number kernels/row (3.37 and 1.91, respectively) and grain yield (2.89 and 2.75, respectively).

Moreover, the cross (P4 x P8) exhibited negative and significant SCA effects for anthesis silking interval (-1.88) and plant height (-18.82) and it possessed positive and significant SCA effects for number of rows per ear (1.68) and grain yield (2.89). The cross (P5 x P8) displayed a negative significant SCA effects for anthesis silking interval (-1.46) and positive significant SCA for ear leaf area (40.94), 100-kernels weight (3.82) and grain yield (2.08).

It could be concluded from the above mentioned results that the five crosses, (P3 x P6), (P2 x P3), (P4 x P7), (P4 x P8) and (P6 x P8) are the best hybrids over two environments with regard to grain yield, anthesis silking interval and other performance traits.

Other researchers also obtained crosses which showed desirable specific combining ability effects for various traits using different genotypes under water stress (Desai and Singh, 2000; Abdel-Moneam *et al.*, 2009; Alamerew and Warsi, 2014; Umar *et al.*, 2014); Aminu *et al.* 2014; Okasha *et al.*, 2014; and Matin *et al.*, 2016)

Heterosis

Heterosis percentages for grain yield and other agronomic traits across environments for 28 F_1 crosses relative to SC.168 and TWC.352 are presented in Table 5.

Table 5. Heterosis relative to SC. 168 and TWC. 352 for grain yield and other agronomic traits across environments

Crosses	Days to 50% silking		Anthesis-silking interval (ASI)		Plant height (cm)		Ear leaf area (cm^2)		leaf water content %	
	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352
P1 X P2	0.63	-0.39	-4.17**	-33.33**	-5.29	-0.45	-21.32	-12.45	0.84	-1.41
P1 X P3	-2.42*	-3.47**	18.48**	-4.35**	-5.62	-0.76	-27.61	-18.27	1.95	-0.27
P1 X P4	0.85	-0.17	1.32**	-26.32**	2.57	7.05	5.26	12.19	1.14	-1.11
P1 X P5	1.38	0.37	-24.31**	-59.12**	-11.70*	-6.56	3.29	10.36	1.26	-0.98
P1 X P6	3.95**	2.96*	16.97**	-6.27**	-15.42**	-10.12	-15.37	-6.94	3.02**	0.82
P1 X P7	-4.73**	-5.80**	-29.31**	-65.52**	-6.00	-1.13	-21.03	-12.18	-1.37	-3.67**
P1 X P8	1.67	0.66	20.77**	-1.41**	-13.74*	-8.51	-19.84	-11.08	1.30	-0.94
P2 X P3	-0.03	-1.06	-26.40**	-61.80**	-2.70	2.03	2.76	9.87	2.03*	-0.19
P2 X P4	2.81*	1.81	-8.70**	-39.13**	4.34	8.74	4.26	11.26	2.90**	0.70
P2 X P5	3.46**	2.47*	14.45**	-9.51**	-8.59	-3.60	-5.31	2.39	0.98	-1.26
P2 X P6	-0.99	-2.02	-29.31**	-65.52**	-8.49	-3.50	-20.60	-11.78	0.62	-1.63
P2 X P7	3.00*	2.00	-0.90**	-29.15**	-10.23	-5.16	-11.07	-2.95	-2.37*	-4.69**
P2 X P8	3.93**	2.94*	23.21**	1.71**	-16.46**	-11.10*	-34.67	-24.83	2.06*	-0.16
P3 X P4	0.63	-0.39	10.71**	-14.29**	0.13	4.73	-6.94	0.88	1.63	-0.60
P3 X P5	2.16	1.16	38.02**	20.66**	-7.10	-2.17	-16.56	-8.03	2.15*	-0.06
P3 X P6	-1.43	-2.47*	-1.35**	-29.73**	-2.20	2.50	-0.31	7.03	2.01*	-0.22
P3 X P7	-3.89**	-4.95**	-22.95**	-57.38**	-7.76	-2.81	-5.73	2.00	0.10	-2.17*
P3 X P8	-0.44	-1.47	20.49**	-1.77**	-11.38*	-6.26	-6.06	1.69	2.17*	-0.05
P4 X P5	1.78	0.77	29.91**	10.28**	2.39	6.88	4.41	11.40	-0.05	-2.32*
P4 X P6	2.44*	1.44	36.26**	18.41**	6.06	10.38	5.18	12.11	-2.17	-4.48**
P4 X P7	-2.25	-3.30**	-22.95**	-57.38**	8.08	12.31*	2.30	9.45	-0.09	-2.36*
P4 X P8	0.61	-0.41	-71.76**	-119.85**	-13.16*	-7.96	-10.23	-2.17	1.81	-0.42
P5 X P6	2.14	1.14	27.65**	7.40**	-6.36	-1.47	-1.12	6.27	0.58	-1.68
P5 X P7	1.28	0.27	5.86**	-20.50**	-7.90	-2.94	-0.45	6.89	0.96	-1.29
P5 X P8	2.72*	1.72	-19.68**	-53.19**	-12.74*	-7.55	3.93	10.96	2.45*	0.23
P6 X P7	-2.13	-3.17**	22.95**	1.37**	-6.72	-1.81	-29.73	-20.25	1.93	-0.29
P6 X P8	2.18	1.17	4.66**	-22.03**	-19.95**	-14.43**	-8.42	-0.50	1.24	-1.00
P7 X P8	-2.38*	-3.43**	31.82**	12.73**	-12.10*	-6.94	-8.72	-0.77	-2.14*	-4.46**

***,** Significant at P=0.05 and P=0.01, respectively**

The degree of heterosis varied from hybrid to hybrid and from trait to another, considering commercial hybrids SC.168 and TWC.352 as a checks, negative and significant heterosis was found for crosses combinations (P1 x P3), (P1 x P7), (P3 x P7) and (P7 x P8) relative to SC.168 and crosses combinations (P1 x P3), (P1 x P7), (P3 x P6) (P3 x P7), (P6 x P7) and (P7 x P8) relative to TWC.352 for days to 50% silking, and it ranged from -4.73 to 3.95% and from -5.80 to 2.96 % relative to SC.168 and TWC.352, respectively. The negative heterosis for days to 50% silking is desirable in breeding for earliness. The result are in agreement with the findings of Aminu *et al.* (2014)

For anthesis-silking interval, 12 and 21 out of 28 crosses showed significantly negative heterosis relative to SC.168 and TWC.352, respectively, and that ranged from -71.76 to 38.02% for SC.168 and from -119.85 to 20.66% for TWC.352. For plant height, heterosis varied from – 19.95 to 8.08% relative to SC.168 and from – 14.43 to 12.31% relative TWC.352. In this respect, 9 and 2 out of 28 crosses showed significantly negative heterosis relative to SC.168 and TWC.352, respectively. The negative heterosis were recorded for plant height and ear height are desirable in breeding for short stature hybrids that could resist lodging particularly in windy environment. The results are in agreement with the findings of Aminu *et al.* (2014).

Heterosis for ear leaf area, none of the crosses showed significantly positive heterosis and that ranged from -34.67 to 5.26% and from -24.83 to 12.19% relative to SC.168 and TWC.352, respectively. Regarding leaf relative water content 8 out of 28 crosses exhibited positive and significant heterosis relative to SC.168. But relative to TWC.352, none of the crosses showed significantly positive heterosis. It ranged from -2.37 to 3.02% and from -4.69 to 0.82% relative to SC.168 and TWC.352, respectively.

Respecting ear diameter, the crosses (P1 x P3) and (P2 x P3) had positive and significant heterosis relative to SC.168, while 9 hybrid showed positive heterosis relative to TWC.352. The increase in ear diameter ranged from -23.61 to 3.03 and from -15.02 to 9.76 relative to SC.168 and TWC.352, respectively. For ear length, all hybrids attained negative and significant heterotic effect relative to SC.168. While four crosses out of 28 crosses manifested highly positive and significant heterosis relative to TWC.352. This trait varied from -50.54 to -6.34 and from -27.42 to 9.99 relative to SC.168 and TWC.352, respectively.

Out of 28 hybrids 26 and 18 manifested highly positive and significant heterosis for number of rows/ear relative to SC.168 and TWC.352, respectively. The range of heterosis was recorded from -1.28 to 34.72% and from -21.88 to 21.44 relative to SC.168 and TWC.352, respectively. For number kernels/row, all the crosses showed that none positive and significant heterosis relative to SC.168, while 13 crosses expressed positive and significant heterosis relative to TWC.352, heterosis varied from -65.10 to 0.0% relative to SC.168 and from – 34.52 to 18.52% relative TWC.352.

Regarding 100-kernel weight, heterosis varied from – 40.84 to 4.45% relative to SC.168 and from – 40.84 to 3.88% relative TWC.352, where only one cross (P1 x P4) (4.45 and 3.88%) showed merely positive and significant heterosis relative to SC.168 and TWC.352, respectively, and all others were negative.

Table 5. Continued …

Crosses	Ear diameter (cm)		Ear length (cm)		No. rows / ear		No. kernels / row		100-kernel weight (g)		Grain yield (ard./fad.)	
	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352	SC. 168	TWC.352
P1 X P2	-1.41**	5.63**	-29.60**	-9.69**	21.24**	5.21**	-31.80**	-7.39**	-26.80**	-27.56**	-22.16**	-9.19**
P1 X P3	3.03**	9.76**	-33.44**	-12.95**	34.72**	21.44**	-45.47**	-18.53**	-40.00**	-40.84**	-18.28**	-5.73**
P1 X P4	-5.24**	2.07**	-17.14**	0.85	19.29**	2.87**	-22.91**	-0.15	4.45**	3.88**	-7.60**	3.82**
P1 X P5	-12.06**	-4.28**	-32.03**	-11.75**	24.79**	9.49**	0.00	18.52**	-16.42**	-17.12**	-10.16**	1.54
P1 X P6	-15.20**	-7.20**	-45.10**	-22.82**	14.52**	-2.87**	-45.81**	-18.80**	-30.77**	-31.55**	-13.50**	-1.45
P1 X P7	-13.39**	-5.51**	-35.03**	-14.29**	25.21**	9.99**	-32.26**	-7.77**	-14.19**	-14.87**	-12.17**	-0.26
P1 X P8	-9.51**	-1.90**	-40.52**	-18.94**	27.92**	13.25**	-15.26**	6.09**	-9.61**	-10.26**	-22.10**	-9.14**
P2 X P3	0.69**	7.59**	-6.34**	9.99**	22.56**	6.80**	-20.90**	1.49**	1.41	0.82	3.33**	13.59**
P2 X P4	-7.33**	0.12	-16.17**	1.67**	7.90**	-10.84**	-14.82**	6.45**	-8.08**	-8.73**	-4.22**	6.84**
P2 X P5	-1.77**	5.30**	-32.28**	-11.97**	24.02**	8.57**	-49.59**	-21.89**	-10.21**	-10.88**	-18.33**	-5.77**
P2 X P6	-23.08**	-14.53**	-50.54**	-27.42**	5.56**	-13.66**	-44.07**	-17.39**	-15.45**	-16.15**	-36.39**	-21.92**
P2 X P7	-16.13**	-8.06**	-49.64**	-26.66**	20.74**	4.61**	-19.23**	2.85**	-18.75**	-19.46**	-38.36**	-23.67**
P2 X P8	-18.52**	-10.29**	-39.25**	-17.86v	14.47**	-2.94**	-15.81**	5.64**	-39.41**	-40.25**	-19.95**	-7.22**
P3 X P4	-6.39**	1.00**	-19.35**	-1.02	26.39**	11.41**	-30.41**	-6.26**	-13.44**	-14.12**	-15.51**	-3.25**
P3 X P5	-11.98**	-4.20**	-33.35**	-12.86**	22.29**	6.48**	-34.32**	-9.44**	-23.50**	-24.24**	-15.72**	-3.43**
P3 X P6	-4.51**	2.75**	-16.14**	1.70**	25.82**	10.73**	-21.81**	0.75	1.45	0.86	-3.93**	7.10**
P3 X P7	-10.34**	-2.68**	-36.44**	-15.48**	29.29**	14.90**	-14.71**	6.54**	-16.83**	-17.53**	-11.93**	-0.05
P3 X P8	-17.07**	-8.94**	-40.20**	-18.67**	27.79**	13.10**	-41.54**	-15.33**	-28.65**	-29.42**	-23.66**	-10.54**
P4 X P5	-7.72**	-0.24**	-27.35**	-7.79**	18.32**	1.70*	-35.08**	-10.06**	-6.14**	-6.78**	-17.11**	-4.68**
P4 X P6	-18.52**	-10.29**	-16.79**	1.15**	5.56**	-13.66**	-26.59**	-3.14**	-17.69**	-18.40**	-26.62**	-13.18**
P4 X P7	-1.05**	5.96**	-9.54**	7.29**	18.24**	1.60*	-9.62**	10.68**	-5.01**	-5.64**	-5.86**	5.38**
P4 X P8	-5.49**	1.83**	-18.01**	0.12	27.27**	12.48**	-16.37**	5.19**	-8.32**	-8.97**	5.76**	15.76**
P5 X P6	-23.61**	-15.02**	-46.71**	-24.18**	-0.25	-20.64**	-18.07**	3.80**	-32.54**	-33.33**	-30.52**	-16.66**
P5 X P7	-22.03**	-13.56**	-44.10**	-21.97**	1.85**	-18.11**	-30.83**	-6.60**	-29.15**	-29.92**	-25.91**	-12.55**
P5 X P8	-9.92**	-2.29**	-31.89**	-11.63**	9.18**	-9.29**	-14.17**	6.98**	0.90	0.31	-4.21**	6.85**
P6 X P7	-20.00**	-11.67**	-35.33**	-14.54**	-1.28	-21.88**	-65.10**	-34.52**	-25.08**	-25.83**	-34.97**	-20.64**
P6 X P8	-14.74**	-6.77**	-18.80**	-0.55	23.60**	8.05**	-18.65**	3.33**	-10.30**	-10.96**	-4.12**	6.93**
P7 X P8	-19.65**	-11.34**	-31.89**	-11.63**	10.55**	-7.65**	-17.50**	4.27**	-12.26**	-12.94**	-34.73**	-20.43**

***,** Significant at P=0.05 and P=0.01, respectively**

For grain yield, highly positive and significant heterosis was identified in two crosses (P2 x P3) and (P4 x P8) and it ranged from -38.36 to 5.76% relative to SC.168, while 8 crosses exhibited positive and significant heterosis and it ranged from -23.67 to 15.76% relative to TWC.352.

From the previous results it could be concluded that, the yellow maize cross (P2 x P3) was significantly surpassing the check varieties SC.168 and TWC.352 for anthesis-silking interval, leaf relative water content, ear diameter, number of rows per ear and grain yield. Moreover, the cross (P4 x P8) exhibited significantly surpassing two check varieties for anthesis-silking interval, plant height, number of rows per ear and grain yield. Also, it could be recommended the following crosses for using in maize improvement under water deficit, (P2 x P4), (P3 x P6), (P4 x P7), (P5 x P8) and (P6 x P8). Similar results were reported by several investigators (Duvick, 2005; Sultan *et al.,* 2013; EL-Hosary *et al.,* 2013; Aminu *et al.,* 2014 and El-Shamarka *et al.,* 2015).

Drought susceptibility index (DSI)

The drought susceptibility index (DSI) values were calculated for determining the stress tolerance of yellow maize crosses based on minimization of yield, losses at water deficit compared to normal irrigation. The maize crosses showing DSI values less than 1.0 (DSI < 1) are more tolerant to drought stress while those with values above 1.0 are sensitive to drought stress. Analysis of variance for drought susceptibility index recorded significant differences for maize genotypes and F_1 crosses for all studied traits except number of rows/ear, Table 6. Also highly significant differences for maize genotypes and F_1 crosses were recorded for resistance index (DI) and stress tolerance index (STI) for grain yield (ard./fad.).

Table 6. Analysis of variance for drought susceptibility index (DSI) for all studied traits and drought tplerance index (DI) and stress tolerance index (STI) for grain yield only

S.O.V	df	Days to 50% silking	Anthesis-silking interval (ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water content%	Ear diameter (cm)	Ear length (cm)	No. rows / ear	No. kernels / row	100 kernel weight(g)	Grain yield (ard./fad.) DSI	STI	DI
Reps	2	0.0001	0.3216	0.0002	0.0035	0.0005	0.0011	0.0025	0.0173	0.0078	0.0083	0.002	0.005	0.006
Genotype	29	0.76**	6.12**	0.10**	0.85**	0.31*	1.07*	0.48*	1.20	0.49**	0.63**	0.058*	0.072**	0.031**
Hybrid	27	0.73**	6.41**	0.11**	0.90*	0.28*	1.13*	0.50*	1.15	0.46**	0.62**	0.063*	0.071**	0.033**
Check	1	0.11	4.52*	0.01	0.10	0.05	0.59	0.21	3.89*	0.07	1.48*	0.006	0.056**	0.004
Check Vs H	1	2.39**	0.11	0.01	0.27	1.20**	0.08	0.07	0.01	1.65**	0.04	0.001	0.108**	0.022
Error	58	0.29	2.40	0.05	0.45	0.16	0.64	0.28	0.76	0.21	0.31	0.036	0.004	0.008

***,** Significant at P=0.05 and P=0.01, respectively**

Results presented in Table 7 showed that the following crosses had the most desirable susceptibility index to drought resistance, i.e., SC. 168, (P2 x P5), (P5 x P7) and (P5 x P8) for days to 50% silking; (P3 x P7), (P2x P6), (P4 x P6) and TWC.352 for anthesis silking interval; (P7 x P8) for plant height; (P1 x P5), (P1 x P6) and (P1 x P8) for ear leaf area; (P2 x P3) and (P2 x P8) for leaf water content; (P2 x P5), (P1 x P7), (P1 x P6) and (P1 x P5) for ear diameter; (P5 x P6), (P2 x P7) and (P3 x P7) for ear length; (P3 x P6), (P3 x P7), TWC.352 and (P7 x P8) for number rows/ear; (P4 x P5), (P2 x P7) and (P7 x P8) for number of kernels/row; (P5 x P8), (P4 x P5) and TWC.352 for 100-kernels weight and (P2 x P7), (P3 x P7), (P5 x P6), (P1 x P6) and (P7 x P8) for grain yield.

Table 7. The mean performance of 28 F_1 maize crosses and two check varieties for drought susceptibility index (DSI) for all studied traits and drought tolerance index (DI) and stress tolerance index (STI) for grain yield only

Crosses	Days to 50% silking	Anthesis-silking interval(ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water conten%	Ear diameter (cm)	Ear length (cm)	No. rows / ear	No. kernels /row	100 kernel weight(g)	Grain yield (ard./fad.) DSI	STI	DI
P1 X P2	2.11	2.47	0.75	0.42	0.86	0.59	0.72	2.05	1.74	1.46	1.06	0.58	0.60
P1 X P3	1.89	1.74	1.22	0.53	1.39	0.87	0.93	1.31	1.08	1.16	1.24	0.61	0.53
P1 X P4	1.54	0.81	0.98	0.87	1.09	0.91	1.23	0.89	1.56	0.86	1.08	0.77	0.67
P1 X P5	0.67	1.78	0.72	0.08	0.70	0.51	0.50	1.33	1.58	1.66	0.76	0.75	0.84
P1 X P6	1.28	-1.68	0.88	0.23	0.70	0.50	1.64	0.36	1.05	0.85	0.96	0.69	0.70
P1 X P7	0.68	4.74	0.85	1.37	0.86	0.47	1.89	0.49	1.05	1.96	1.03	0.70	0.67
P1 X P8	1.43	1.18	1.11	0.31	0.87	0.77	1.04	1.32	1.28	1.41	1.16	0.57	0.55
P2 X P3	0.86	4.31	1.01	0.71	0.52	-0.24	1.42	0.83	0.65	1.20	1.04	0.97	0.79
P2 X P4	1.02	1.35	1.09	1.33	1.74	-0.31	1.27	0.48	0.76	1.83	1.02	0.83	0.73
P2 X P5	0.38	-1.59	1.40	0.37	1.18	0.40	1.03	1.76	0.98	0.68	0.99	0.63	0.66
P2 X P6	1.72	0.14	1.16	0.94	0.95	0.85	0.57	0.55	0.77	1.10	1.04	0.46	0.54
P2 X P7	1.02	1.00	1.26	2.02	0.94	0.77	0.28	0.55	0.39	0.88	0.74	0.45	0.66
P2 X P8	1.24	0.82	0.82	1.76	0.52	0.68	1.17	0.93	0.83	0.96	0.93	0.61	0.68
P3 X P4	1.67	2.34	1.00	1.38	1.21	1.66	1.12	1.91	0.68	1.14	1.07	0.66	0.63
P3 X P5	0.64	0.95	1.20	0.92	1.05	1.11	1.56	-0.17	1.22	0.47	1.20	0.65	0.57
P3 X P6	0.57	3.47	0.93	0.67	1.35	2.43	1.36	0.11	1.46	0.72	1.01	0.84	0.75
P3 X P7	1.62	0.11	1.11	0.69	0.92	1.33	0.51	0.20	0.69	0.91	0.67	0.73	0.87
P3 X P8	1.24	1.63	0.96	0.89	0.64	1.14	1.02	1.25	0.68	0.41	0.95	0.57	0.64
P4 X P5	0.88	0.96	0.93	1.09	0.91	1.81	0.94	-0.17	0.17	0.31	0.91	0.65	0.71
P4 X P6	1.56	0.26	1.12	1.67	1.45	1.41	0.88	1.03	1.02	0.87	1.31	0.52	0.46
P4 X P7	0.57	3.32	0.77	2.20	0.77	0.63	1.21	1.49	0.79	1.23	1.00	0.81	0.74
P4 X P8	0.62	1.32	0.79	1.20	0.96	1.22	0.99	1.24	1.35	1.26	0.92	1.04	0.89
P5 X P6	0.86	-0.33	0.78	0.84	0.75	0.90	0.07	0.33	0.67	0.89	0.81	0.51	0.67
P5 X P7	0.32	1.12	1.09	0.69	0.65	1.89	0.73	1.35	0.51	0.71	0.84	0.56	0.69
P5 X P8	0.31	0.99	1.27	0.36	0.87	1.85	0.93	1.62	1.20	0.25	1.03	0.83	0.73
P6 X P7	0.94	0.78	1.17	0.32	0.62	1.14	0.99	1.04	0.98	0.11	1.03	0.47	0.55
P6 X P8	0.92	0.99	0.90	1.31	1.02	0.54	0.74	1.56	0.54	1.25	0.97	0.83	0.76
P7 X P8	1.14	1.11	0.65	1.08	1.45	0.79	0.53	0.31	0.39	0.91	0.92	0.47	0.60
Checks													
SC. 168	0.27	2.02	0.93	1.28	1.52	0.76	0.68	1.77	1.58	1.39	1.03	0.91	0.76
TWC. 352	0.55	0.28	0.98	1.03	1.33	1.38	1.05	0.16	1.37	0.40	0.97	0.71	0.71
LSD 0.05	0.88	2.53	0.37	1.09	0.66	1.31	0.86	ns	0.76	0.90	0.31	0.10	0.15
LSD 0.01	1.17	3.37	0.49	1.46	0.88	1.75	1.15	ns	1.01	1.20	0.41	0.13	0.20

Concerning, drought toleranc index (DI) and stress tolerance index (STI) for grain yield, the most desirable and superior values were obtained from the crosses (P4 x P8), (P2 x P3), (P1 x P5), (P2 x P4), (P3 x P6), (P3 x P7), (P5 x P8) and (P6 x P8). It was noticed that, all these previous crosses had also the highest mean performance values, SCA effects and heterosis effects for this trait. Similar findings were reported by EL-Hosary *et al.* (2013) and Erdal *et al.* (2015), they recorded a wide range of response to water deficit tolerance in maize genotypes.

Genotypic and phenotypic correlations

Genotypic and phenotypic correlations based on the combined data over environments were calculated among all possible combinations of the all studied traits are listed in Table 8.

In general for all studied traits, genotypic correlations were higher than phenotypic ones reflecting the relatively large error variances and covariances. Days to 50% silking had positive and significant genotypic correlations with anthesis silking interval (0.342**) and leaf relative water content (0.325*), but had negative and highly significant genotypic correlations with number of rows per ear (-0.337**). Anthesis silking interval had negative and significant genotypic and phenotypic correlations with ear diameter, number kernels/ear, 100-kernels weight and grain yield. Positive and highly significant genotypic and phenotypic correlations between plant height with ear leaf area, ear diameter, ear length and 100-kernel weight, also between ear leaf area with ear length, number kernels/row, 100-kernel weight and grain yield.

Leaf relative water content was positive and significantly genotypic correlated to ear diameter (0.343**), drought susceptibility index (0.558**) and grain yield (0.488**).

The genotypic and phenotypic correlations between ear diameter and ear length, number rows/ear, 100-kernels weight, drought susceptibility index and grain yield were positive and significant. Also ear length was positive and high correlated with number kernels/row, 100-kernels weight, drought susceptibility index and grain yield. Number of rows per ear exhibited low genotypic and phenotypic correlations with grain yield (0.291* and 0.237, respectively) and negative correlated with other traits except ear diameter (0.519** and 0.431**, respectively).

Number of kernels per row had positive and significant (P<0.01) genotypic and phenotypic correlations with 100-kernels weight and grain yield, while it exhibited negative correlations with drought susceptibility index, ASI, leaf relative water content and number of rows per ear. 100-kernels weight exhibited positive and significant (P<0.01) genotypic and phenotypic correlations with grain yield, plant height, ear leaf area, ear diameter, ear length and number of kernels per row, while it exhibited negative correlations with, days to 50% silking, ASI, leaf relative water content and number of rows per ear.

Table 8. Genotypic (rg) and phenotypic (rph) correlation coefficients as calculated from the combined analysis of variance of various metric traits in yellow maize genotypes across two environments

		Anthesis-silking interval (ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water content %	Ear diameter (cm)	Ear length (cm)	No. rows / ear	No. kernels / row	100 kernel weight (g)	DSI for grain yield	Grain yield (ard./fad.)
Days to 50% silking	rg	0.342**	-0.257	0.228	0.325*	-0.177	-0.158	-0.337**	0.083	-0.102	-0.009	-0.034
	rph	0.236	-0.120	0.089	0.222	-0.126	-0.071	-0.147	0.052	-0.062	-0.011	0.004
ASI	rg	1.000	0.023	-0.159	-0.122	-0.330*	-0.226	-0.213	-0.350**	-0.383**	0.165	-0.572**
	rph	1.000	0.025	-0.139	-0.053	-0.304*	-0.212	-0.193	-0.333*	-0.333*	0.079	-0.491**
Plant height	rg		1.000	0.555**	-0.276*	0.425**	0.628**	-0.209	0.078	0.398**	0.621**	0.166
	rph		1.000	0.482**	-0.137	0.356**	0.510**	-0.144	0.069	0.335**	0.207	0.157
Ear leaf area	rg			1.000	-0.125	0.212	0.546**	-0.216	0.482**	0.634**	0.031	0.443**
	rph			1.000	-0.099	0.149	0.433**	-0.160	0.416**	0.542**	-0.011	0.355**
Leaf water content %	rg				1.000	0.343**	0.050	0.176	-0.208	-0.026	0.558**	0.488**
	rph				1.000	0.097	0.045	0.107	-0.125	0.008	0.119	0.307*
Ear diameter	rg					1.000	0.719**	0.519**	0.197	0.517**	0.809**	0.691**
	rph					1.000	0.536**	0.431**	0.127	0.374**	0.324*	0.546**
Ear length	rg						1.000	-0.011	0.453**	0.729**	0.829**	0.783**
	rph						1.000	-0.008	0.412**	0.617**	0.345**	0.647**
No. Rows / ear	rg							1.000	-0.035	-0.023	0.246	0.291*
	rph							1.000	-0.069	0.032	0.079	0.237
No. kernels / row	rg								1.000	0.428**	-0.252	0.486**
	rph								1.000	0.376**	-0.042	0.451**
100 kernel	rg									1.000	0.439**	0.659**
	rph									1.000	0.201	0.543**
DSI for grain yield	rg										1.000	0.484**
	rph										1.000	0.388**

***,** Significant at P=0.05 and P=0.01, respectively**

Grain yield had positive and significant genotypic and phenotypic correlations with ear leaf area (0.443** and 0.355**), leaf relative water content (0.488** and 0.307**), ear diameter (0.691** and 0.546**), ear length (0.783** and 0.647**), number of rows per ear (0.291* and 0.237), number of kernels per row (0.486** and 0.451**), 100-kernels weight (0.659** and 0.543**) and drought susceptibility index (0.484** and 0.388**, respectively), but had negative correlations with days to 50% silking (-0.034 and 0.004) and anthesis silking interval (-0.572** and -0.491**, respectively). Moreover grain yield and plant height had a non-significant genotypic (0.166) and phenotypic (0.157) correlations.

In this connection, correlation studies indicated that maize grain yield was significantly and positively associated with number of kernels per row at both genotypic (0.837) and phenotypic (0.798) levels under drought stress condition (Mostafavi *et al.*, 2013); ear length, ear diameter and plant height (Kinfe and Tsehaye, 2015); 100-kernel weight, ear girth, number of kernels per row and ear length (Reddy and Jabeen, 2016). Chapman and Edmeades (1999) reported that lengthening of anthesis-silking interval (ASI) is an indicator of poor tolerance to drought, is negatively correlated with grain yield.

Path coefficient

Direct and indirect effects of grain yield and other agronomic traits of yellow maize genotypes across two environments relative to phenotypic correlation (rph) are presented in Table 9. The direct effect on grain yield of all studied traits were positive and moderately high or small except anthesis silking interval and plant height which were negative (-0.277and -0.169, respectively).

The results showed that ear length had exhibited the largest direct effect on grain yield (0.340) followed by drought susceptibility index (0.251), leaf relative water content (0.231), ear leaf area (0.182), number of kernels per row (0.171), ear diameter (0.135) and number of rows per ear (0.104), indicating the effectiveness of direct selection. While the direct effect of days to 50% silking and 100-kernels weight on grain yield was positive but very low in magnitude (0.034 and 0.030, respectively).

For all traits which had positive direct effect on grain yield, positive indirect effects were often observed of the ear leaf area, leaf water content, ear diameter, ear length, number of kernels per row and drought susceptibility index via each other. On the other side, for anthesis silking interval and plant height, which had negative direct effect on grain yield, their indirect effects through other traits were also negative or with low value. Days to 50% silking which had negative or low value of indirect effects on miaze grain yield.

Generally, the previous results revealed that ear length, ear leaf area, leaf water content, ear diameter, number of kernels per row and drought susceptibility index were considered the major yield components and attributes that the maize breeder should take into account for developing high yielding yellow maize hybrids under water deficit.

Similar results were reported earlier in maize by Ahmad and Saleem (2003) who reported that the direct effect of plant height was negative and low on grain yield, while Filipovic *et al*., (2014) found strongest impact of plant height on grain yield. The positive direct effect was observed by Rafiq *et al.* (2010), Wannows *et al.* (2010) and Reddy and Jabeen (2016) of ear diameter. Rafiq et al. (2010), Zarei *et al.* (2012), Nataraj *et al*. (2014) and Reddy and Jabeen (2016) reported that the grain yield considerably associated with 100 kernels weight. While Zarei *et al.* (2012) observed the high positive direct effect of ear length. Sofi and Rather (2007), Nataraj *et al.* (2014) and Reddy and Jabeen (2016) recorded that the high positive direct effect of the number of kernels/row on grin yield was detected.

Table 9. Direct (Diagonal) and indirect effects of some agronomic traits on grain yield of yellow maize genotypes across two environments relative to phenotypic correlation (rph)

Characters	Days to 50% silking	Anthesis-silking interval (ASI)	Plant height (cm)	Ear leaf area (cm^2)	Leaf water content %	Ear diameter (cm)	Ear length (cm)	No. rows / ear	No. kernels / row	100 kernel weight (g)	DSI for grain yield	Correlation with grain yield
Days to 50% silking	0.034	-0.065	0.020	0.016	0.051	-0.017	-0.024	-0.015	0.009	-0.002	-0.003	0.004
Anthesis-silking interval (ASI)	0.008	-0.277	-0.004	-0.025	-0.012	-0.041	-0.072	-0.020	-0.057	-0.010	0.020	-0.491
Plant height	-0.004	-0.007	-0.169	0.088	-0.032	0.048	0.173	-0.015	0.012	0.010	0.052	0.157
Ear leaf area	0.003	0.039	-0.081	0.182	-0.023	0.020	0.147	-0.017	0.071	0.016	-0.003	0.355
Leaf water content %	0.007	0.015	0.023	-0.018	0.231	0.013	0.015	0.011	-0.021	0.000	0.030	0.307
Ear diameter	-0.004	0.084	-0.060	0.027	0.022	0.135	0.182	0.045	0.022	0.011	0.082	0.546
Ear length	-0.002	0.059	-0.086	0.079	0.010	0.072	0.340	-0.001	0.070	0.019	0.087	0.647
No. Rows / ear	-0.005	0.054	0.024	-0.029	0.025	0.058	-0.003	0.104	-0.012	0.001	0.020	0.237
No. kernels / row	0.002	0.092	-0.012	0.076	-0.029	0.017	0.140	-0.007	0.171	0.011	-0.011	0.451
100 kernel	-0.002	0.092	-0.056	0.099	0.002	0.050	0.210	0.003	0.064	0.030	0.051	0.543
DSI for grain yield	0.000	-0.022	-0.035	-0.002	0.028	0.044	0.117	0.008	-0.007	0.006	0.251	0.388
Residual =		0.495										

REFERENCES

Abdel-Moneam, M.A.; A.N. Attia; M.I. EL-Emery and E.A. Fayed (2009). Combining Ability and Heterosis for Some Agronomic Traits in Crosses of Maize. Pakistan Journal of Biological Sciences, 12: 433-438.

Ahmad, A. and M. Saleem (2003). Path coefficient analysis in *Zea mays* L. International Journal of Agriculture & Biology, 245-248.

Alamerew, S and M.Z.K. Warsi (2014). Hetrosis and combining ability of sub tropical maize inbred lines. African Crop Science Journal, 23 (2):123 – 133.

Al-Naggar, A. M. M.; M. M. M. Atta; M. A. Ahmed and A. S. M. Younis (2016). Numerical and graphical diallel analyses of maize (*Zea mays* L.) agronomic and yield traits under well watering and water deficit at silking. Archives of Current Research International, 5(3): 1-18.

Aminu, D.; Dawud, M.A. and A. Modu (2014). Combinig ability and heterosis of different agronomic traits in maize (*Zea mays* L.) under drought conditions in northern Guinea and Sudan savannas of Borno State. Journal of Plant Breeding and Crop Sciences 6(10):128- 134.

Bänziger, M.; Edmeades, G. O.; D. Beck; and M. Bellon (2000). Breeding for Drought and Nitrogen Stress Tolerance in Maize: From Theory to Practice. Mexico, D.F.CIMMYT.

Bhatt, G. M. (1971). Heterosis performance and combining ability in adiallel cross among spring wheat (Triticum astivum L.). Australian J. Agric. Res., 22:329-368.

Bolanos, J. and , G.O. Edmeades (1996). The importance of the anthesissilking interval in breeding for drought tolerance in tropical maize. Field Crops Res., 48, 65-80

Campos, H.; A. Cooper; J.E. Habben; G.O. Edmeades and J.R. Schussler. (2004). Improving drought tolerance in maize: a view from industry. Field Crops Res., 90(1):19-34.

Castillo, F.J. (1996). Antioxidative protection in the inducible CAM plant Sedum album L. following the imposition of severe water stress and recovery. Oecologia, 107: 469–477.

Chapman, S.C. and G.O. Edmeades (1999). Selection improves drought tolerance in tropical maize populations: II. Direct and correlated responses among secondary traits. Crop Sci., 39:1315-1324.

Desai, and R.D. Singh (2000). combining ability analysis of yield and yield components contributing to drought tolerance in maize . Karnataka J. Agric. Sci., 13 (3): 554-556.

Dewey, D. R. and K .H. Lu (1959). A Correlation and path coefficient analysis of components of crested wheat grass production. Agron. J., 51: 515-518.

Durães, F. O. M. ; P. C. Magalhães; A. Carlos de Oliveira; M. X. dos Santos; E. E. Gomes and Gama and C.T. Guimarães (2002). Combining ability of tropical maize inbred lines under drought stress conditions. Crop Breeding and Applied Biotechnology, 2(2): 291-298.

Duvick, D.N. (2005). The contribution of breeding to yield advances in maize (*Zea mays* L.). Adv. Agron., 86:83–145.

Edmeades G.O.; Bänziger, M. and Ribaut, J.M., (2000) Maize improvement for drought-limited environments. In "Physiological bases for maize improvement" (Otegui, M.E. and Slafer, G.A., eds.) :75-111.

Edmeades, G.O. (2013). Progress in Achieving and Delivering Drought Tolerance in Maize - An Update, ISAAA: Ithaca, NY. http://www. isaaa. org

EL-Hosary, A.A.; M. EL-Badawy; T.A.E. Abdallah; A.A.A. El Hosary and I.A. Abou Hussen (2013). Evaluation of diallel maize crosses for physiological and chemical traits under drought stress. Egypt. J. Plant Breed., 17(2) :357-374.

El-shamarka Sh. A. (1995). Estimation of heterotic and combining ability effects for some quantitative characters in maize under two nitrogen levels. Menofiya. J .Agri. Res., 20(2):441-462.

El-Shamarka, Sh. A; M. Abdel-Sattar Ahmed and Marwa M. El-Nahas (2015). Heterosis and combining ability for yield and its components through diallel cross analysis in maize (Zea mays L.). Alex. J. Agric. Res, 60 (2) : 87- 94.

Erdal, S.; M.t Pamukcu; A. Ozturk; K. Aydinsakir and S. Soylu (2015). Combining abilities of grain yield and yield related traits in relation to drought tolerance in temperate maize breeding. Turk J Field Crops, 20(2): 203-212.

FAOSTAT, (2014). Food and Agricultural Organization Statistical Database. http://www.fa.org/ faostat / en / #data/QC

Fernandez, G.C.J. (1992) Effective selection criteria for assessing plant stress tolerance. Proceeding of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress, Aug. 13–16, Shanhua, Taiwan, pp. 257–270.

Filipovic, M.; M. Babic; N. Delic; G. Bekavac and V. Babic (2014). Determination relevant breeding criteria by the path and factor analysis in maize. Genetika, 46 (1): 49-58.

Fischer, R. A. and R. Maurer (1978). Drought resistance in spring wheat cultivars 1. Grain yield responses. Aust. J. Res., 29: 897–912.

Geravandi, M.; E. Farshadfar, and D. Kahrizi (2011). Evaluation of some physiological traits as indicators of drought tolerance in bread wheat genotypes. Russ. J. Plant Physiol, 58(1): 69-75.

Golestani, S. A. and M. T. Assad (1998). Evaluation of four screening techniques for drought resistance and their relationship to yield reduction ratio in wheat. Euphytica 103: 293–299.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol Sci, 9:463-493.

Heisey, P.W. and G.O. Edmeades (1999). Maize production in drought-stressed environments: Technical options and research resource allocation. Part 1 of CIMMYT 1997/1998 World Facts and Trends; Maize Production in Drought-Stressed Environments: Technical Options and Research Resource Allocation. Mexico, D.F.: CIMMYT.

Kinfe, H. and Y. Tsehaye (2015). Studies of heritability, genetic parameters, correlation and path coefficient in elite maize hybrids. Academic Research Journal of Agricultural Science and Research, 3(10): 296-303.

Lan, J. (1998) Comparison of evaluating methods for agronomic drought resistance in crops. Acta Agriculturae Boreali-occidentalis Sinica 7: 85–87.

Magorokosho, C.; K.V. Pixley and P. Tongoona (2003). Selection for drought tolerance in two tropical maize populations. African Crop Science Journal, 11 (3): 151-161.

Matin, M. Q. I.; Md. G. Rasul; A. K. M. A. Islam; M. A. K. Mian; N. A. Ivy and J. U. Ahmed (2016). Combining Ability and Heterosis in Maize (*Zea mays* L.). American Journal of BioScience, 4(6): 84-90.

Miller, P. A.; J.C. Williams, H. F. Robinson and R. E. Comstock (1958). Estimates of genotypic and environmental variance and covariance in Upland cotton and their implication in selection. Agron. J., 50 : 126-31.

Mostafavi, K. ; M. Ghaemi and S. K. Khorasani (2013). Using correlation and some genetics methods to study of morphological traits in corn (*Zea mays* L.) yield and yield components under drought stress condition Intl. Res. J. Appl. Basic. Sci., 4 (2): 252-259.

Nataraj, V.; J. P. Shahi and V. Agarwal (2014). Correlation and path analysis in certain inbred genotypes of maize (*Zea Mays* L.) at varanasi. International journal of innovative research & development, 3(1): 14-17.

Nawar, A.A.; F.A. Hendawy; H.A. Dawwam and A.A. El-Hosary (1988). Study of the reciproical effects on the performance of double crosses under two nitrogen levels in maize . Proc. 3rd Egyptian Conf. Agron. Kafr El-Sheikh, 1:1-13.

Okasha, S.A.; M.A. Al-Ashry; A. Aly; T. Bayoumy and Manal Hefny (2014). Combining ability of some maize inbreds and their hybrids (*zea mays* L.) under water stress conditions. Egypt. J. Plant Breed. 18 (2):347 – 371.

Pavlov, J.; N. Delic; K. Markovic; M. Crevar; Z. Camdžija and M. Stevanovic (2015). Path analysis for morphological traits in maize (*Zea mays* L.). Genetika. , 47(1): 295-301.

Rafiq, C.M.; Rafique, M.; Hussain, A. and A. Altaf (2010). Studies on heritability, correlation and path analysis in maize (*Zea mays* L.). Journal of Agricultural Research, 48 (1): 35-38.

Reddy v. R. and F. Jabeen (2016). Narrow sense heritability, correlation and path analysis in maize (*Zea mays* L.) SABRAO J. Breed. Genet., 48 (2) 120-126.

Richards, R.A. (2006). Physiological traits used in the breeding of new cultivars for water-scarce environments. Agricultural Water Management , 80: 197–211.

Saif-ul-Malook, Q. Ali; M. Ahsan; M. K. Shabaz; M. Waseem and A. Mumtaz (2016). Combining ability analysis for evaluation of maize hybrids under drought stress . J. Natn. Sci. Foundation Sri Lanka, 44 (2): 223-230.

Sofi, P. and A.G. Rather (2007). Studies on genetic variability, correlation and path analysis in maize (*Zea mays* L.). Maize Genetic Cooperation, Newsletter. 81: 26-27.

Steel, R. G. D., and J. H. Torrie (1980). Principles and Procedures of Statistics. 2nd ed. New York: McGraw-Hill.

Sultan, M.S.; M.A. Abdel-Moneam; S.M.G. Salama and A.M. El-Oraby (2013). Combining ability and heterosis for some flowering and vegetative traits of five maize inbreds under two nitrogen levels fertilization. J. of Plant production, Mansoura Univ., 4(2): 749-766.

Troyer, A. F. and E. J. Wellin. (2009). Heterosis decreasing in hybrids: yield test inbreds. Crop Sci., 49:1969–1976.

Troyer, A.F. (2006). Adaptedness and heterosis in corn and mule hybrids. Crop Sci., 46:529–543.

Umar, U.U.; S.G. Ado; D.A. Aba; and S.M. Bugaje (2014). Estimates of combining ability and gene action in maize (*Zea mays* L.) under water stress and non-stress Conditions. Journal of Biology, Agriculture and Healthcare. 4 (25): 247-253.

Wannows, A. A.; H. K. Azzam and S. A. AL-Ahmad (2010). Genetic variances, heritability, correlation and path coefficient analysis in yellow maize crosses (*Zea mays* L.). Agric. Biol. J. N. Am, 1(4): 630-637.

Wattoo, F. M.; M. Saleem, M. Sajjad (2014). Identification of potential F1 hybrids in maize responsive to water deficient condition. American Journal of Plant Sciences, 5: 1945-1955

Westgate, M.E. and J.S. Boyer (1986). Reproduction at low silk and pollen water potentials in maize. Crop Sci., 26:951-956.

Zarei, B.; Kahrizi, D.; A.P. Aboughadaresh; and F. Sadeghi (2012). Correlation and path coefficient analysis for determining interrelationships among grain yield and related characters in corn hybrids. International Journal of Agriculture and Crop Sciences (IJACS), 4 (20): 1519-1522.

تقييم بعض المؤشرات الوراثية لتحسين محصول الحبوب للذرة الشامية الصفراء تحت الاجهاد المائي

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تم اجراء هذه الدراسة خلال ثلاث مواسم زراعية ٢٠١١ ،٢٠١٢ و ٢٠١٣ بمحطة بحوث كلية الزراعة – جامعة الزقازيق . وتم تقييم الهجن الناتجة من التهجين بين ثماني سلالات (Z12 ، Z15 ، Z167 ، Z147، Z40، Z56 ، Z58 و Z103) تحت الري الامثل و الاجهاد المائي. وتم تسجيل الصفات التالية: عدد الايام حتى ظهور ٥٠% من الحراير ، الفترة بين تزهير النورة المذكرة والمؤنثة، ارتفاع النبات ، مساحة ورقة الكوز ، المحتوى النسبي للماء بالورقة، قطر الكوز، طول الكوز، عدد صفوف الكوز، عدد حبوب الصف ، وزن ١٠٠ حبة ومحصول الحبوب (اردب/فدان). أظهر التحليل التجميعي أن تباينات القدرة العامة والخاصة على التالف كانت عالية المعنوية لجميع الصفات تحت الدراسة، مما يشير الى أهمية كل من الفعل الجيني المضيف والسيادي في وراثة هذه الصفات، ولكن كانت نسبة تباين القدرة العامة الى القدرة الخاصة على التالف اكبر من الوحدة لصفات عدد الايام حتى ظهور ٥٠% من الحراير وعدد صفوف الكوز، مما يشير الى أهمية الفعل الجيني المضيف في وراثة تلك الصفات ، بينما كانت أقل من الوحدة لصفات الفترة بين تزهير النورة المذكرة والمؤنثة، مساحة ورقة الكوز، المحتوى النسبي للماء بالورقة، قطر الكوز، طول الكوز، عدد صفوف الكوز، عدد حبوب الصف ، وزن ١٠٠ حبة ومحصول الحبوب (اردب/فدان)، مما يوضح دور الفعل الجيني السيادي في وراثة تلك الصفات تحت ظروف الاجهاد المائي. وكانت قيم معامل التوريث بالمعنى الخاص مرتفعة (>٥٠%) لصفات عدد الايام حتى ظهور ٥٠% من الحراير ، ارتفاع النبات ، وعدد صفوف الكوز و قطر الكوز، ومتوسطة لصفات مساحة ورقة الكوز (٤١.٦٨%) ، و طول الكوز (٤٥.٥٥%) ومنخفضة (< ٥٠%) لصفات الفترة بين تزهير النورة المذكرة والمؤنثة ، المحتوى النسبي للماء بالورقة ، عدد حبوب الصف ، وزن ١٠٠ حبة ومحصول الحبوب. أدى الاجهاد المائي الى انخفاض معظم الصفات تحت الدراسة بالنسب التالية : ارتفاع النبات (١٥.٦%) ، مساحة ورقة الكوز (١٣.٩٩%) ، المحتوى النسبي للماء بالورقة (٦.٦٤%)، قطر الكوز (٦.٩٨%)، طول الكوز (١٤.٩٩%)، عدد صفوف الكوز (٤.٢٢%)، عدد حبوب الصف (١٠.٦٣%)، وزن ١٠٠ حبة (١٢.١٧%) ومحصول الحبوب (٣٢.٨٣%). أظهرت النتائج ان السلالات (Z167) P3 و (Z147) P4 كانت أفضل الاباء للقدرة العامة على التآلف للمحصول ومعظم مكوناته . أعطت الهجن (P3 x P6)، (P2 x P3)، (P4 x P7)، (P4 x P8) و (P6 x P8) أعلى قيم مرغوبة لمتوسط السلوك ، القدرة الخاصة على التآلف ، قوة الهجين ، ودليل تحمل الجفاف (DI) ودليل تحمل الاجهاد (STI) لصفات محصول الحبوب والفترة بين تزهير النورة المذكرة والمؤنثة وبعض الصفات الاخرى. أظهرت الهجن (P2 x P3) و (P4 x P8) قوة هجين موجبة ومعنوية مقارنة بالأصناف التجارية. أظهر محصول الحبوب قيم موجبة ومعنوية لكل من معامل الارتباط الوراثي والمظهري مع صفات مساحة ورقة الكوز (٠.٤٤٣ و ٠.٣٥٥) ، محتوى الماء النسبى بالورقة (٠.٤٨٨ و ٠.٣٠٧) ، قطر الكوز (٠.٦٩١ و ٠.٥٤٦)، طول الكوز (٠.٧٨٣ و ٠.٦٤٧) و عدد صفوف الكوز (٠.٢٩١ و ٠.٢٣٧) و عدد حبوب الصف (٠.٤٨٦ و ٠.٤٥١) و وزن ١٠٠ حبة (٠.٦٥٩ و ٠.٥٤٣) ودليل الحساسية للجفاف (٠.٤٨٤ و٠.٣٨٨ على التوالي)، ولكن ارتبط محصول الحبوب سلبيا مع عدد الايام حتى ظهور ٥٠% من الحريرة (-٠.٠٣٤ و ٠.٠٠٤) و الفترة بين تزهير النورة المذكرة والمؤنثة (-٠.٥٧٢ و -٠.٤٩١ على التوالي). وأوضحت النتائج أن طول الكوز (٠.٣٤) أعطى أعلى تأثير مباشر على محصول الحبوب ، ثم دليل الحساسية للجفاف (٠.٢٥١) ، محتوى الماء النسبي بالورقة (٠.٢٣١) ، مساحة ورقة الكوز (٠.١٨٢) و عدد حبوب الصف (٠.١٧١) وقطر الكوز (٠.١٣٥) وعدد صفوف الكوز (٠.١٠٤)