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GENOTYPE X ENVIRONMENT INTERACTION FOR GRAIN YIELD AND ITS COMPONENTS OF SOME YELLOW MAIZE CROSSES

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ABSTRACT: *Eight yellow maize (zea mays L.) inbred lines were crossed in half diallel mating scheme in 2013 season at Gemmeiza Agric. Res. Station giving a total of 28 crosses as hybrid seeds. In 2014 summer season, these 28 crosses were evaluated in a randomized complete blocks designs experiment with four replications at two locations and two densities i.e. 20 cm (D_1) and 25cm (D_2). Gemmeiza (L_1) and Mallawy (L_2). The whole study was designated as four different environmental conditions (L_1D_1, L_1D_2, L_2D_1 and L_2D_2) in each experiment. location mean squares had significant and high significant for days to 50% tasseling, plant height, ear height, ear length, number of rows / ear, number of kernels / row and grain yield (ard / fad.) at D_1 and D_2. While, ear diamater and 100-kernel weight at D_1 and days to 50% silking at D_2 had significant location mean squares. Mean squares of densities exhibited significant and high significant for days to 50% tasseling and silking at L_2 and ear diameter at L_1. While, plant and ear heights, ear length, 100-kernel weight and grain yield / fad. had significant mean squares of densities, indicated that these traits changed their performance from location to another. Crosses mean squares were high significant for all traits under locations and densities meaning that, differences among the crosses under locations and densities were exited. Crosses x locations interaction mean squares had highly significant for days to 50% tassling, days to 50% silking and ear height at D_1. Crosses x densities interactions mean squares had significant differences at four environments for most traits*

The interactions between crosses with the partitions; locations (L), densities (D) and (L x D) were significant for all traits, meaning that the crosses were affected by change of locations, densities and interaction of locations x densities.

Key words: *(Zea mays L.), Diallel cross, Densities, Location, Genotype x environment, Yield, Yellow Maize*

INTRODUCTION

Maize (*Zea mays L*) is one of the most important cereal crops in Egypt. It is used in bread making in rural areas of the country. Also, yellow grains is used, was to feed livestock and poultry either as green fodder and silage or as grains. In addition, it is used in starch, fructose and maize oil industries. Total cultivated area of maize in Egypt is 857329 hectar which amount to about 25.00 % of total cultivated land, with average yield of 8.40 ton ha^{-1}. (FAO, 2015). Rapid increase in demand for maize is driven by the increased consumption (Ghimire *et al*., 2007). The Egyptian government aims to decrease the gap between consumption and production *via* increasing grain yield per unit area of the cultivated land. There are several approaches to increase crop productivity, improving farming practices, employing merging technology, using modern and high yielding maize hybrids which have more efficiently for using nitrogen and more response to high rate of nitrogenous fertilizer to produce more grain.

Plant density is one of the major factors determining the ability of the plant to capture resources. Modifying crop density and plant arrangement may be seen as a way of changing crop spatial and temporal structure. Grain yield loss in maize under high densities has been attributed to several factors which result in a noticeable decrease in grain number and weight and hence grain yield per unit area. Such effect were indicated by several investigators included Afsharmanesh (2007), Khalil (2007), Sikandar *et al.* (2007) and Raouf *et al.* (2009). Improved grain yield per unit area of modern maize hybrids is due to increasing optimum plant population rather than the improved grain yield per plant. Traits associated with tolerance to various stresses including high plant populations and the efficiency of capture and use of resources rendered modern hybrids more productive. The aim of this investigation is to study the effect of genotype x environment (G x E) interaction with respect to locations, plant population densities of some yellow maize crosses, for yield and its components and to illustrate the performance of these traits with changing environments.

MATERIALS AND METHODS

Eight yellow (*zea mays L.*) inbred lines with a wide range of diversity for several traits were crossed in half diallel mating scheme in 2013 season at Gemmeiza Agric. Res. Station giving a total of 28 crosses as hybrid seeds. In 2014 summer season, these 28 crosses were evaluated in a randomized complete blocks design experiment with four replications Gemmeiza (L_1) and Mallawy (L_2) at two locations and two densities 26.250 and 21.000 p/fed. Four different environmental were designated as L_1D_1, L_1D_2, L_2D_1 and L_2D_2. Agriculture Research Stations at Gemmeiza and Mallawy, represented delta and upper Egypt regions, respectively. Name and origin of the parents were shown in Table (1).

The experimental plot was one ridge of 5 m long, 80 cm width and the hills were spaced at 20 cm apart in D_1 (26,250 plants per faddan) and 25cm apart in D_2 (21,000 plants per faddan). All cultural practices were applied as recommended. In the four environments, data were recorded at plot basis for the following characters; days to 50% tasseling, days to 50% silking, plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of rows / ear, number of kernels / row, 100 – kernel weight (gm) and grain yield, which was adjusted to 15.5 % moisture content (estimated in kg/plot and ard./fad.).

Analysis of variance for randomized complete blocks design according to the method outlined by Snedecor and Cochran (1967) used for each environment. Bartlett test (1937) has been done for error means squares of the four environments to estimate, homogeneity of errors combined analysis was done in case of errors homogeneity. The form of the analysis of variance of the combined data for the four environments and the interactions between environments was as shown in Tables (2 and 3).

Table (1) : Name and origin of the eight yellow inbred lines .

No. of parent	Name	Origin
P_1	GM6005	Gm.Y.Pop.
P_2	GM6017	Gm.Y.Pop.
P_3	GM6020	Gm.Y.Pop.
P_4	GM6021	Campsite 45
P_5	GM6023	Campsite 45
P_6	GM6029	Campsite 45
P_7	GM6039	Campsite 45
P_8	GZ639	Sd.62 X B.73 (B.73-NYD-410,B.37)

Table (2): Form of the analysis of variance and expected mean squares for single environment.

S.O.V.	d f	EMS
Rep. (r)	(r-1) = 3	
Crosses (Cr)	(cr-1) = 27	$\sigma^2 e + rk^2$ Cr
Error ($\sigma^2 e$)	(r-1) (Cr-1) = 81	$\sigma^2 e$

Table (3): The analysis of variance and expected mean squares for testing the combined data of 28 crosses for each experiment and their orthogonal plus possible interactions.

S.O.V.	d f	EMS
Env.	3	
D	1	$\sigma^2 e + rk^2 LD + rL\ k^2 D$
L	1	$\sigma^2 e + r\ k^2 LD + rD\ k^2 L$
L x D	1	$\sigma^2 e + r\ k^2 LD$
Cr	27	$\sigma^2 e + rk^2$ Cr.L.D + rlK^2cr.D + rdK^2 crL + rld K^2 Cr.
Cr x L	27	$\sigma^2 e + rk^2$ CrL D + rdk^2 Cr. L
Cr x D	27	$\sigma^2 e + rk^2$ crL D + rlk^2 Cr. D
Cr x D x L	27	$\sigma^2 e + rk^2$ Cr LD
Error	324	$\sigma^2 e$

The LSD test at 5% and 1% according to Steel and Torrie (1960) was used for comparison between the mean performances of the different genotypes.

$$LSD = t_{table} \times (2\sigma^2 e / r)^{½}$$

RESULTS AND DISCUSSION

The present investigation consisted of the diallel cross of eight yellow inbred lines of maize. The experiments were carried out in four different environments *i.e.,* two locations at Gemmeiza (L_1) and Mallawy (L_2) Agricultural Research Stations, each alternated with two plant densities; 26,250 (D_1) and 21,000 (D_2) plants/fad. The four environmental conditions are designated as; L_1D_1, L_1D_2, L_2D_1 and L_2D_2.

Analysis of variance:

A-Separate environment:

Mean squares of crosses were highly significant for the ten studied traits under four environments. This might indicated that, there were differences among the crosses under the four environments for all traits. (Table 4).

B- Over locations and densities:

Data in Tables from 5 to 9 showed that, location mean squares had significant and high significant for days to 50% tasseling, plant height, ear height, ear length, number of rows / ear, number of kernels / row and grain yield (ard / fad.) at D_1 and D_2. While, ear diamater and 100-kernel weight at D_1 and days to 50% silking at D_2 had significant location mean squares. This means that these traits either at D_1 and D_2 or at D_1 only changing their behavior from location to another. Mean squares of densities exhibited significant and high significant for days to 50% tasseling and silking at L_2 and ear diameter at L_1. While, plant and ear height, ear length, 100-kernel weight and grain yield / fad. had significant mean squares of densities, indicated that these traits could be changed their performance from location to another. However, number of rows / ear and number of kernels / row did'nt change their behavior from location to another due to insignificant of their densities mean squares under both locations. Crosses mean squares were highly significant for all traits under locations and densities meaning that, differences among the crosses under locations and densities were exited.

Table (4) : Mean squares from analysis of variance for the ten traits at four different environments.

Traits	S.O.V.	d.f.	Mean squares			
			L_1D_1	L_1D_2	L_2D_1	L_2D_2
Days to 50 % Tasseling	Reps	3	16.366**	5.012*	3.795*	8.798**
	Crosses	27	21.223 **	5.896 **	16.729 **	5.525 **
	Error	81	2.354	1.648	1.356	1.631
Days to 50 % Silking	Reps	3	11.738**	3.818*	4.976**	13.438**
	Crosses	27	21.907 **	5.176 **	18.865 **	5.898 **
	Error	81	2.213	1.337	1.328	2.008
Plant height (cm)	Reps	3	2164.509**	232.440**	1394.583**	491.310
	Crosses	27	757.102 **	636.276 **	1900.766 **	585.235 **
	Error	81	178.552	57.595	195.225	233.390
Ear height (cm))	Reps	3	936.310**	116.071*	342.214**	290.631*
	Crosses	27	535.119 **	201.720 **	1361.661**	292.017 **
	Error	81	62.698	33.664	36.980	92.020
Ear length (cm)	Reps	3	2.425**	4.887	8.970**	16.734**
	Crosses	27	4.53 **	13.23 **	3.47 **	10.54 **
	Error	81	0.525	2.428	1.007	2.451
Ear diameter (cm)	Reps	3	0.031	0.280*	0.098	0.225
	Crosses	27	0.39**	0.29 **	0.25 **	0.42 **
	Error	81	0.058	0.100	0.068	0.149
No. of rows/ear	Reps	3	3.620	0.915	0.256	2.538**
	Crosses	27	4.61**	7.56 **	3.48*	2.11 **
	Error	81	1.687	0.425	2.123	0.393
No. of kernels/row	Reps	3	14.742	1.786	37.484**	35.403**
	Crosses	27	45.41 **	20.39 **	41.07 **	8.96 **
	Error	81	8.849	4.349	8.838	3.848
100-kernel weight (gm)	Reps	3	5.285	17.198	5.247	13.754
	Crosses	27	39.04 **	40.63 **	48.13 **	32.27 **
	Error	81	2.782	11.457	7.654	9.851
Grain yield ard/fed.	Reps	3	16.742	4.284	7.792	11.620
	Crosses	27	28.32**	22.50**	29.37**	34.03**
	Error	81	10.543	5.680	6.972	9.195

*,** significant at 0.05 and 0.01 level of probability , respectively

Table (5) : Mean squares from analysis of variances for testing the combing data, over locations and densities for days to 50 % tassling and silking date.

S. O. V	d.f.	Days to 50 % tassling				Days to 50 % silking`			
		L1	L2	D1	D2	L1	L2	D1	D2
L	1			23.14**	56.00**			0.07	7.88*
D	1	0.04	6.11*			0.75	11.61**		
Cr	27	14.11**	11.09**	28.12**	9.16**	14.63**	12.55**	30.96**	8.88**
Cr x L	27			9.83**	2.26			9.81**	2.19
Cr x D	27	13.01**	11.16**			12.45**	12.21**		
Error	162	2.001	1.493	1.855	1.639	1.775	1.667	1.771	1.671

*,** significant at 0.05 and 0.01 level of probability , respectively

Table (6): Mean squares from analysis of variances for testing the combing data, over locations and densities for plant and ear height (cm).

S . O. V	d.f.	Plant height (cm)				Ear height (cm)			
		L1	L2	D1	D2	L1	L2	D1	D2
L	1			27258.22**	35754.02**			3366.18**	13299.45**
D	1	5352.79**	9438.02**			1828.57**	7455.17**		
Cr	27	734.34**	1742.84**	2033.64**	1003.31**	404.10**	938.97**	1541.87**	409.77**
Cr x L	27			624.23**	218.20**			354.91**	83.97
Cr x D	27	659.04**	743.17**			332.74**	714.71**		
Error	162	118.073	214.308	186.889	145.492	48.181	78.000	63.339	62.842

*,** significant at 0.05 and 0.01 level of probability , respectively

Table (7): Mean squares from analysis of variances for testing the four combing data, over locations and densities for ear length and ear diameter (cm).

S . O. V	d.f.	ear length (cm)				ear diameter (cm)			
		L1	L2	D1	D2	L1	L2	D1	D2
L	1			28.32**	34.34**			0.39*	0.21
D	1	11.78*	8.37*			0.32*	0.16		
Cr	27	10.26**	8.18**	5.33**	17.22**	0.21*	0.40**	0.44**	0.39**
Cr x L	27			2.67**	6.54**			0.19**	0.31**
Cr x D	27	7.51**	5.83**			0.46**	0.27**		
Error	162	1.477	1.729	0.766	2.439	0.079	0.108	0.063	0.125

*,** significant at 0.05 and 0.01 level of probability , respectively

Table (8): Mean squares from analysis of variances for testing the combing data, over locations and densities for no. of rows/ear and no. of kernels/row.

S . O. V	d.f.	No. of rows/ear				No. of kernels/row			
		L1	L2	D1	D2	L1	L2	D1	D2
L	1			359.82**	472.70**			226.81*	323.79**
D	1	1.38	2.55			2.53	2.55		
Cr	27	6.78**	3.10**	5.14**	6.79**	45.67**	23.36**	45.08**	13.49**
Cr x L	27			2.96*	2.88**			41.40**	15.85**
Cr x D	27	5.39**	2.49**			20.14**	26.66**		
Error	162	1.056	1.258	1.905	0.409	6.599	1.258	8.843	5.218

*,** significant at 0.05 and 0.01 level of probability , respectively

Table (9): Mean squares from analysis of variances combing data, over locations and densities for 100- kernel weight (gm.) Grain yield (ard./fed.)

S . O. V	d.f.	100- kernel weight (gm.)				Grain yield (ard./fad.)			
		L1	L2	D1	D2	L1	L2	D1	D2
L	1			323.79**	3.33			1129.19**	409.21**
D	1	39.94*	505.80**			2152.14**	1090.11**		
Cr	27	33.58**	30.86**	55.37**	47.33**	25.18**	31.88**	26.62**	30.23**
Cr x L	27			31.81**	25.57**			31.07**	26.30**
Cr x D	27	46.09**	49.54**			25.64**	31.52**		
Error	162	7.119	8.753	5.218	10.654	8.111	8.084	8.757	7.437

*,** significant at 0.05 and 0.01 level of probability , respectively

Crosses x Locations interactions were highly significant for days to 50% tasseling, days to 50% silking and ear height at D_1. The other traits exhibited highly significant mean squares of the crosses x locations interaction under both densities. These results indicated that, crosses affected by changing locations at both densities. The mean squares of crosses x densities were highly significant for all studied traits at both locations. This might indicated that, the behavior of crosses for these traits could be changed from densities to another at L_1 as well as L_2. Sadek *et al*. (2011) found highly significant mean squares of location x genotype interaction for days to 50 %silking, plant height, ear height and grain yield. Zare *et al.* (2011) found that, the genotype × environment interaction effects were not significant (P>0.05) for days from emergence to silking, area of flag leaf and grain yield, suggesting that genotypes maintain their rank for these traits across environments. Non significant genotype × environment interaction effects indicated that selection for days from emergence to silking, area of flag leaf and grain yield at one environment might be effective for a broad range of environments. Genotype × environment interaction effects were significant for other traits, indicating that genotypes did not respond to the environments similarly. El-Badawy (2012). Showed that, significant genotype x nitrogen rate mean squares were obtained for days to 50% maturity, no. of rows / ear and shelling % , revealing that the performance of genotypes differed from nitrogen rate to another. However, insignificant interaction mean squares between parents x nitrogen and hybrids x nitrogen rates were detected for all traits, except for hybrid x nitrogen level for days to 50 % maturity, no. of rows/ ear and grain yield /plant, revealing that the performances of parents and crosses were responded similar to environmental changes For the exceptional traits, significant interaction mean squares between hybrid and nitrogen rates were detected indicating that, these hybrids behaved somewhat differently from nitrogen rate to another.

C- The combined data:

Mean squares of the ten studied traits combined over environments are presented in Table 10. Environments mean squares for all studied traits were significant revealing that, the differences among the four environments were noticeable. The differences among locations (L) were significant for all studied traits, except for, days to 50% silking and ear diameter, indecently that the performance of these traits were differed from location to another. While, for other traits the performance is somewhat stable from location to another.

Data in Table 10 showed that, the mean squares of densities (D) were significant for plant height, ear height, 100-kernel weight and grain yield / fad., indicating that, these traits performed differently way from density to another. While, other traits had not affected in with density chase. Moreover, the mean squares of locations x densities interactions (L x D) were significant for ear height and grain yield/fad., indicating that, the effect of density on these traits had differed from location to another. Mean squares among crosses were highly significant for the ten studied traits from combined data, indicating that there were differences among the crosses under the four environments and the combined data.

The interaction between crosses with locations (G X L), densities (G X D) and (G X L x D) interactions were significant for all traits, meaning that the crosses were affected by change of locations, densities and the interaction of both. Crosses x densities interactions mean squares had significant differences at all environments for all traits. Amer *et al. (*2004) found significant crosses x densities interaction for silking data, no. of ears / plant and no. of rows/ear. Marchao *et al.* (2005) found significant interaction between maize hybrid and plant density for grain yield at both locations. Marchao and Brasil (2007) showed that, maize grain yield was significantly affected by the interaction between hybrid and plant density. Kamara *et al.* (2014) found that (C × N) interaction was significant for all the studied traits, revealing that these crosses differed in their order from level of nitrogen fertilizer to another for these traits. Mousa (2014). Reported that mean squares due to crosses (C) and crosses x locations (C x L) were found to be significant or highly significant for all studied traits, except for no. of rows/ear and no. of grains/row. This result indicated wide genetic diversity between the studied materials which obviously were affected by change in environmental conditions. Kamara (2015) observed significant interaction mean squares between crosses and nitrogen levels (C x N) for all the studied traits. This indicates that, these crosses behaved somewhat differently from nitrogen level to another.

Table (10): Mean squares from analysis of variance for ten traits under combined data .

S.O.V	d.f.	Days to 50% tasseling	Days to 50 % silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Number of rows/ ear	Number of kernels/ row	100 – kernel weight (g)	Grain yield (ard/fad.)
Env.	3	27.24**	5.69*	25838.46**	8916.033**	27.55**	0.35*	277.54**	295.15**	247.37**	1563.74**
L	1	75.57*	4.72	62724.56**	16831.51**	62.51 *	0.59	828.68 **	810.01 **	196.38 **	1448.97**
D	1	2.58	9.14	14503.13**	8804.01**	20.00	0.46	0.09	24.14	415.01 **	3152.82**
L x D	1	3.57	3.22	287.68	1112.58*	0.15	0.01	3.84	51.30	130.73	89.44 **
Cr	27	19.56 **	21.44 **	1943.26 **	1102.04**	13.34**	0.37 **	6.57 **	33.81 **	40.78 **	34.26 **
Cr x L	27	5.65 **	5.74 **	533.91 **	241.03**	5.09 **	0.24 **	3.31 **	35.23 **	23.67 **	22.80 **
Cr x D	27	17.73 **	18.40 **	1093.69 **	849.60**	9.22 **	0.47 **	5.36 **	24.77 **	61.92 **	22.59 **
Cr x L x D	27	6.44 **	6.26 **	308.52 **	197.85**	4.12 **	0.26 **	2.52 **	22.02 **	33.72 **	34.57 **
Error	324	1.747	1.721	166.191	63.091	1.603	0.094	1.157	6.471	7.936	8.097

*,** significant at 0.05 and 0.01 level of probability , respectively

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التفاعل بين التراكيب الوراثية والبيئة لصفه محصول الحبوب ومكوناته لبعض هجن الذرة الشامية الصفراء

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الملخص العربي

تم التهجين بين ثمانية سلالات أذرة صفراء مرباه داخليا بنظام التزاوج النصف دائري في موسم 2013 بمحطة البحوث الزراعية بالجميزه حيث تم الحصول علي 28 هجينا . قيمت هذه الهجن في تجربه بتصميم القطاعات كاملة العشوائية ذات الأربع مكررات في موقعين (الجميزة L_1 ، ملوي L_2) وكثافتين نباتيتين (26250 D_1 ، 21000 D_2 نبات/فدان).

كان تباين المواقع معنويا لصفات عدد الأيام حتى ظهور 50% من النورات المذكرة ، طول النبات، ارتفاع الكوز ، طول الكوز ،عدد الصفوف بالكوز ، عدد الحبوب بالصف ومحصول الحبوب(أردب/فدان) تحت الكثافة الأولي D_1 والكثافة الثانية D_2 . بينما كان تباين المواقع معنويا لصفات قطر الكوز ، وزن الـ 100 حبة تحت الكثافة الأولي D_1 وعدد الأيام حتى ظهور 50% من النورات المؤنثة تحت الكثافة الثانية D_2 .

كان تباين الكثافة النباتية معنويا لصفات عدد الأيام حتى ظهور 50% من النورات المذكرة والمؤنثة في الموقع الثاني L_2 وقطر الكوز في الموقع الأول L_1 . بينما كان التابين معنويا لصفات ارتفاع النبات ، ارتفاع الكوز، طول الكوز ، وزن الـ100 حبة ومحصول الحبوب للفدان مما يدل علي أن هذه الصفات يتغير سلوكها بتغير المواقع . كان تباين الهجن عالي المعنوية لجميع الصفات في الموقعين وللكثافتين بما يعني أن الاختلافات بين الهجن كانت موجودة .

كان تباين التفاعل بين الهجن والمواقع عالي المعنوية لصفات عدد الأيام حتى ظهور 50% من النورات المذكرة والمؤنثة وارتفاع الكوز تحت الكثافة النباتية الأولي D_1 . وكان تباين التفاعل بين الهجن والكثافة النباتية معنويا لجميع البيئات ولمعظم الصفات.

كان التفاعل بين الهجن وكلا من المواقع ، الكثافة النباتية ، التفاعل بين الهجن ، تفاعل المواقع والكثافة النباتية معنويا لجميع الصفات مما يشير إلي أن الهجن تأثر سلوكها بتغير المواقع والكثافة النباتية والتفاعل بينهما.