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DETECTION OF EPISTASIS FOR GRAIN YIELD AND SOME OTHER TRAITS IN GIZA-10 MAIZE SINGLE CROSS HYBRID

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ABSTRACT

The importance of epistasis in breeding populations of maize (Zea mays L.) is not well understood. The objective of this study was to use the triple testcross design (TTC) to determine if epistatic effects significantly contribute to the performance of the high yield single-cross hybrid, Giza-10. Sixty random plants from the F_2 population of Giza-10 hybrid were crossed to both parents of this hybrid (Sd.7 and Sd.63) and to their F_1 hybrid. The resultant 180 testcrosses were evaluated in a randomized incomplete-block design with two replications at the two locations; Sakha and Nubaria Agric. Res. Stations in 2004. Testcrosses were evaluated for grain yield per plant (g plant^{-1}), ear weight (g ear^{-1}), ear rot disease resistance (%), number of days to mid-silking and plant and ear heights.

Based on combined data, the results showed significant differences among testcross means of Sd.7, Sd.63 and F_1 for grain yield and ear weight only. The average grain yield of Sd.7, Sd.63 and F_1 testcrosses were 141.7, 134.5 and 124.9 g plant^{-1}, respectively. In addition, ear weight of Sd.7, Sd.63 and F_1 testcrosses were 143.5, 136.4 and 127.2 g ear^{-1}, respectively. Epistasis was significant for grain yield / plant and ear weight only. Epistasis x male interaction was significant for grain yield / plant and highly significant for number of days to mid-silking and plant and ear heights. Epistatic deviations were significantly different from zero for grain yield / plant and ear weight. Positive deviations for these two traits can explain the high values that were obtained for Sd.7 and of Sd.63 testcrosses. Analysis of TTC mating design indicated that epistatic effects were important for grain yield / plant and ear weight. The F-test for epistasis indicated that additive by additive effects were present for grain yield / plant and ear weight. Epistasis by male effects showed that additive by dominance and dominance by dominance effects were more important for number of days to mid-silking and both plant and ear heights.

The results of this study provide evidence for the presence of epistasis in SC.10 (Sd.7 x Sd.63). The presence of significant positive epistatic effects may have contributed to the expression of heterosis and could explain the superiority of Giza-10 maize single cross hybrid under a wide range of Egyptian soils.

***Key words**: Maize, Epistasis, Epistatic effects, Triple testcross, Additive, Dominance.*

INTRODUCTION

Epistatic effects were assumed absent in estimation of additive and dominance genetic variances in most of the mating designs. It seems logical, however, that, whatever, the magnitude of epistatic effects, they must be present in the functioning of a genotype. Epistatic effects have been demonstrated in the expression of qualitative traits involving two loci and, thus, it does not seem reasonable that epistatic effects are not operative in the expression of a complex quantitative trait, such as yield (Hallauer and Miranda, 1988). Presence of epistasis indicates that estimates of additive and dominance variances would have been biased for these traits if they were estimated by the procedures that assume no epistasis.

The models used to estimate the genetic parameters often assume that epistasis to be absent or of little importance. Few studies have indicated that epistasis was not a significant component of genetic variability in maize populations (Eberhart *et al.*, 1966; Chi *et al.*, 1969; Silva and Hallauer, 1975). Some other studies, however, have showed that epistatic effects are important for specific combinations of inbred lines (Darrah and Hallauer, 1972; Lamkey *et al.*, 1995; Wolf and Hallauer, 1997). Also, Hallauer and Miranda (1988) reported that epistasis may contribute to the heterosis expressed in some crosses. They, also, reported that epistasis for quantitative traits surely exists, but it may account for very little of the genetic variability in maize populations beyond that accounted for by additive and dominance variances.

The effects of epistasis can not be detected by two-factor designs. Rawlings and Cocherham (1962 a, 1962 b) developed the triallel and quadrallel analyses that provide up to nine covariances of relatives. These analyses permitted F-tests for the presence of epistasis in the analyses of variance and estimation of epistatic components of variance. Measures of epistasis in maize hybrids have been estimated by (*i*) triple testcrosses, (*ii*) making comparisons among single, three-way and double cross hybrids or (*iii*) measuring variance components, using more than two covariances among relatives (Chi *et al*, 1969, Eberhart *et al*, 1966 and Hallauer and Miranda, 1988).

Opsahl (1956) proposed the triple testcross design for unambiguous detection of epistasis in an F_2 population, resulting from a cross of two inbred lines. He showed that, in the absence of epistasis, the some of the backcross means of an F_2 population to each of the parents equals twice the mean of the backcross to the F_1 generation. Kearsey and Jinks (1968) developed the theory for the triple testcross design as an extension of design III, which was developed by Comstock and Robinson (1952). Kearsey and Jinks (1968) showed that, in addition to the clear detection of epistasis, TTC could provide tests for additive and dominance effects in the absence of epistasis.

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Modification of Kearsey-Jinks triple testcross design has been proposed (Jinks *et al.*, 1969; Perkins and Jinks, 1970; Jinks and Perkins, 1970; Pooni *et al.*, 1994; Ramsay *et al.*, 1994). Eta-Ndu (1994) modified the triple testcross design of Kearsey and Jinks (1968) to test for epistasis in two single crosses of maize.

The single-cross hybrid, Giza-10 (Sd.7 x Sd.63), is the highest yielding and widely accepted hybrid at present in Egypt. It is possible that favorable epistatic effects contributed to the exceptional performance of this hybrid. The objective of this study was to use the triple testcross design to determine if epistatic effects significantly contribute to the performance of Giza-10 maize single-cross hybrid.

MATERIALS AND METHODS

Experimental Procedures

Sd.7 and Sd.63 inbred lines were developed in the national maize breeding program and they constituted the two parents of the single cross hybrid, Giza-10. The single cross hybrid, Giza-10 (Sd.7 x Sd.63), was planted in an isolated plot in Nubaria breeding nursery in 2002 to produce the F_2 generation (F_2 population). In 2003, the F_2 population of Giza-10 along with the two inbreds, Sd.7 and Sd.63, in addition, the F_1 of Giza-10 were planted in the breeding nursery. The triple testcross (TTC) mating design, as described by Kersey and Jinks (1968), was used to cross sixty unselected F_2 plants, designated as males, to Sd.7 and Sd.63 inbreds and to F_1 of Giza-10. Each male plant was crossed to one female plant from each of Sd.7, Sd.73 and F_1 of Giza-10.

The resultant 180 testcrosses were divided into six sets and evaluated, using a randomized incomplete - block design with two replications. Each set contained thirty entries, which represented the three testcrosses resulting from each of the ten F_2 population plants. Testcrosses were evaluated in 2004 at two different locations; i.e., Sakha and Nubaria Agriculture Research Stations. Plot size consisted of a single row, 5 m long and 70 cm wide and 25 cm among hills. Plots were over planted and thinned later to one plant / hill. Testcrosses were evaluated for grain yield / plant (g $plant^{-1}$), ear grain weight (g ear^{-1}), ear rot disease resistance (number of healthy ears / total number of ears, caused by *Fusarium milinoforme*), number of days from planting to mid-silking and plant and ear heights (cm), as averages of five competitive plants/plot.

Statistical Analysis

Bartlett's test (Snedecor and Cochran, 1989) indicated homogeneity of error variances of testcrosses. Hence, individual environments and combined data were analyzed, using SAS Software, 1997 (SAS Institute, Release 6.12). Analysis of epistasis was performed, according to Kearsey and Jinks (1968). Males were considered random effect and testers represented the fixed effect. Source of variation for testers and tester by male interaction were partitioned to test for epistasis.

Epistasis test

The triple testcross procedure was developed by Kearsey and Jinks (1968) and was implemented in maize by Wolf and Hallauer (1997). In this procedure, the three testcrosses for each male (i) with Sd.7 (P_1), Sd.63 (P_2) and their F_1 were designated as L_{1i}, L_{2i} and L_{3i} respectively. Their means overall the F_2 plants were designated as L_1, L_2 and L_3 respectively.

According to Perkins and Jinks (1970), the variation among the three testers could orthogonally be partitioned to C_1 (parents vs F_1) and this component is indicative of additive x additive epistasis. The other contrast, C_2, is the difference between the two parental testers. Both contrasts would be tested, using F-test. The second F-test for epistasis is the interaction between C_1 x males and this source is a function of additive x dominance and dominance type of epistasis.

Another test of epistasis $(\overline{D})$ was calculated, using t-test from the following equation, $\overline{D} = L_1 + L_2 - 2L_3$, and its variance $(V.\overline{D}) = VL_1 + VL_2 + 4VL_3$.

The above equation was used to test for the additive x additive type of epistasis for each environment and combined analysis for the two environments. The t-test was conducted to determine if deviation means were different from zero, as follows:

$$t = \overline{D} / (V.\overline{D})^{½}$$

RESULTS AND DISCUSSION

Highly significant differences were observed among testers for grain yield / plant and ear weight, based on combined data (Table 1), while the differences among testers for number of days to mid-silking, plant height, ear height and ear rot disease resistance were insignificant.

On combined analysis basis, epistasis was significant for grain yield and ear weight (Table 3), which was in accordance with ANOVA results. Epistasis x male interaction was significant for grain yield / plant, number of days to mid silking and plant and ear heights (Table 4). Male effect, only, was significant for number of days to mid-silking.

Mean performance

Significant differences were observed among Sd.7, Sd.63 and F_1 of Giza.10 testcross means, only, for grain yield and ear grain weight, based on combined analysis results. On the average, grain yield at Sakha was 14% higher than that at Nubaria, reflecting favorable growing conditions at Sakha. (Tables 1 & 2).

Table 1. Combined triple testcross analysis of variance for grain yield/plant, grain weight/ear, ear rot disease resistance, number of days to mid-silking and plant and ear heights for SC.10 (Sd.7 x Sd.63) F_2 population in 2004.

S.O.V.	df	Grain yield / plant	Ear grain weight	Ear rot resistance
Environment (Env)	1	256630.9**	1313506.2**	64.39**
Set (S)	5	12330.9**	7789.5**	0.34
Env x S	5	4119.9*	2360.0	3.79
Rep/Env x S	12	1326.4	975.9	3.94
Tester (T) / S	12	11139.5**	7225.7**	3.72
P_1 vs P_2 / S	6	3573.6	2109.3**	6.10
Epistasis (Eps) / S	6	18705.4**	12342.2**	1.33
Env x T / S	12	1347.9**	891.9*	1.85**
Env x P_1 vs P_2 / S	6	2267.7**	988.8	1.66
Env x Eps / S	6	428.2	795.2	2.05
Male (M) / S	54	2984.9	1452.1	0.96
Env x M / S	54	2280.7**	1187.5**	1.04
T x M / S	108	762.6	507.7	1.03
(P_1 vs P_2) M / S	54	810.1	635.2	1.23
Eps x M / S	54	715.1*	380.3	0.82
Env x T x M / S	108	559.4	437.9	1.09
Env x P_1 vs P_2 x M / S	54	634.4	453.6	1.08
Env x Eps x M / S	54	484.3	733.9	1.11
Error	348	557.0	460.0	0.82
Mean		133.7	135.7	78.9
CV		15.5	16.3	10.2

S.O.V.	df	Number of days to mid-silking	Plant height	Ear height
Environment (Env)	1	7.61	2537806.3**	933840.1**
Set (S)	5	24.02	9862.2**	5013.3**
Env x S	5	28.81	1327.8	343.1
Rep/Env x S	12	10.63	1054.1	828.2
Tester (T) / S	12	3.50	1309.9	350.3
P_1 vs P_2 / S	6	3.48	2402.0	512.1
Epistasis (Eps) / S	6	3.53	217.8	188.5
Env x T / S	12	5.02**	727.4**	180.1**
Env x P_1 vs P_2 / S	6	7.42**	1205.3**	340.9**
Env x Eps / S	6	2.63	249.6	190.3
Male (M) / S	54	6.07*	444.7	197.2
Env x M / S	54	3.42**	372.5**	148.3**
T x M / S	108	3.72	324.5	153.8
P_1 vs P_2 x M / S	54	3.36	324.3	150.1
Eps x M / S	54	4.07**	324.8**	157.5**
Env x T x M / S	108	3.47**	308.1**	167.0**
Env x P_1 vs P_2 x M / S	54	3.82**	361.0**	203.4**
Env x Eps x M / S	54	3.12**	255.3**	130.7**
Error	348	0.95	85.9	64.4
Mean		67.7	245.7	129.0
CV		1.4	4.4	7.3

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 2. Testcrosses means and least significant differences ($LSD_{0.05}$) for Sd.7, Sd.63 and SC.10-F_1 at Sakha, Nubaria and combined data in 2004.

Trait	Testcross	Environments		
		Sakha	Nubaria	Combined
Grain yield (g plant^{-1})	Sd.7	150.2	133.2	141.7
	Sd.63	143.6	125.4	134.5
	F_1	134.4	115.4	124.9
	$LSD_{(0.05)}$	6.5	5.5	4.2
Ear weight (g ear^{-1})	Sd.7	156.9	130.0	143.5
	Sd.63	146.1	126.7	136.4
	F_1	140.4	114.0	127.2
	$LSD_{(0.05)}$	6.7	5.9	3.9
Ear rot resistance (%)	Sd.7	84.8	73.3	79.0
	Sd.63	85.7	72.1	78.8
	F_1	82.1	75.7	78.8
	$LSD_{(0.05)}$	0.41	0.53	ns
Days to mid-silking (d)	Sd.7	67.9	67.9	67.9
	Sd.63	67.4	67.8	67.6
	F_1	67.5	67.7	67.6
	$LSD_{(0.05)}$	ns	ns	ns
Plant height (cm)	Sd.7	269.1	225.7	247.4
	Sd.63	265.0	221.1	243.1
	F_1	269.3	223.9	246.6
	$LSD_{(0.05)}$	2.4	ns	ns
Ear height (cm)	Sd.7	148.2	112.4	130.3
	Sd.63	145.3	110.7	128.0
	F_1	145.6	111.5	128.6
	$LSD_{(0.05)}$	2.1	ns	ns

ns, Testcross means not significantly different from each other.

The average grain yield for Sd.7, Sd.63 and F_1 of SC.10 testcrosses across environments were 141.7, 134.5 and 124.9 g plant^{-1}, respectively, while, for ear grain weight, it was 143.5, 136.4 and 127.2 g ear^{-1}, respectively (Table 2). The average grain yield and ear grain weight of Sd.7 testcrosses was slightly higher than that of Sd.63 and F_1 SC.10 testcrosses at separate and combined locations.

Differences among testcrosses for ear rot disease resistance were significant, only, at separate locations. It was observed that ear rot disease resistance levels for the tested testcrosses was less at Nubaria than at Sakha , indicating that the environmental conditions at Nubaria were more favorable for ear rot infection, as compared to Sakha. From a practical point of view, no big differences were detected among testcrosses of Sd.7, Sd.63 and F_1 of Giza 10 regarding their response to ear rot disease infection at both locations.

No significant differences, based on combined data, were detected for plant and ear heights and number of days to mid-silking among Sd.7, Sd.63 and F_1 of SC.10 testcross means. However, significant differences were existed at Sakha for plant and ear heights. Plant and ear heights at Sakha were taller than at Nubaria.

Analysis of TTC design allows to test for epistasis and epistasis x male, the first (epistasis) is indicative of additive x additive type of epistasis, while the second (epistasis x male) is a function of both additive x dominance and dominance x dominance type of epistasis. The F-tests for epistasis from TTC analysis are given in Table 1 and their significance levels are summarized in Table 3.

Several reports showed that epistasis played a minor role in the inheritance of maize traits. However, several researches indicated the significance and importance of epistasis for some traits. Gamble (1962 a, b) reported that additive by additive and additive by dominance effects were important for grain yield, while additive by dominance effects were important for plant and ear heights. Darrah and Hallauer (1972) and Sprague and Suwantaradon (1975) reported that additive by additive and dominance by dominance effects were detected, frequently, for components of yield than for yield and plant and ear heights and those additive by additive effects were more frequent for ear length than for yield and other components of yield. Russell (1976) showed that epistatic effects were present for three sets of loci and epistasis should be considered when designing long-term breeding programs.

As reported in other crops, Singh *et al.* (1979) showed that the additive x additive was, in general, a minor component, but the additive x dominance and dominance x dominance were important elements for all studied characters in barley. Teferal and Peat (1997) reported that epistasis was detected for grain yield and yield components in teef. Also, the additive, dominance and epistatic components were important, since the crop is self-fertilized; only the additive and additive x additive terms are important to develop pure breeding varieties. Upadhyaya and Nigam (1999) showed that epistasis affected the expression of eleven studied traits in peanut. Khattak *et al* (2002) reported that epistasis was observed for studied traits in mungbean and the partitioning of total epistasis revealed that both additive x additive, additive x dominance and dominance x dominance interactions were significant.

Epistatic deviations for each environment and averaged across environments are listed in Table 4. The deviations were significantly different from zero for grain yield / plant and ear weight at Sakha, Nubaria and combined data. Positive deviation for grain yield / plant and ear weight explained the higher observed values for Sd.7 and Sd.63 testcrosses, as compared to the SC.10-F_1 testcrosses for these traits. Negative deviations of plant height explained the higher performance of SC.10-F_1 testcrosses, as compared to Sd.7 and Sd.63 testcrosses (Table 4).

The presence of positive or negative epistatic deviations indicated that interaction of epistasis with environments existed (Table 4). Deviations in the two studied environments showed that Nubaria environment had more significant deviation values. Epistasis seemed to be more important in the extreme environment, rather than the optimum growing environment. James and Rountman (1995) showed that the contributions of epistasis to the additive, dominance and interaction genetic variance were specified and, also, it could make substantial contributions to each of these variance components. Wolf and Hallauer (1997) reported that the frequency and magnitude of epistasis were greater in extreme environments. Upadhyaya and Nigam (1998) reported that epistatic effects for quality traits were less stable due to strong interaction with environment, as compared with additive and dominance effects. Additive x additive gene effects proved to be more sensitive to environmental differences in previous studies.

The tester used during testcross evaluation could influence the expression of epistatic effects. Eta-Ndu (1994) observed variation in expression of epistasis with different testers. Maize breeders, generally, use elite inbred testers for early generation testing. Sprague and Tatum (1942) indicated that the use of inbred tester in early generations of inbreeding would select for specific combining ability (dominance and epistatic effects), consequently, early identification of new inbreds posing favorable expression of epistatic effects in the specific tester x line combinations. The choice of the best tester for a source population is important to gain maximum expression of specific combining ability in the testcrosses. A proper tester can increase the ability to identify new inbred lines with excellent specific combining ability when epistasis is present (Wolf and Hallauer, 1997). Mahgoub *et al* (1996) and Shehata *et al* (1997) suggested that narrow genetic base tester could effectively be used to identify lines having good general combining ability (GCA) and the most efficient was the one having a low frequency of favorable alleles. Upadhyaya and Nigam (1999) showed that choice of tester in studies of epistasis was very important because measured epistasis referred only to the loci, for which the testers differed. However, use of two or more testers or more testing locations could have further improved detection of epistasis.

The results of this study provided evidence for the presence of epistasis in Sd.7 x Sd.63. The triple testcross analysis suggested that epistatic effects were significant for grain yield / plant and ear grain weight in the F_2 population of the single cross, Giza-10 (Sd.7 x Sd.63), where, the TTC analysis showed that additive by additive effects were more important for grain yield and ear weight. Additive by dominance and dominance by dominance effects were more important for number of days to mid silking and plant and ear heights. The presence of epistatic effects might have contributed to the expression of heterosis and could explain the superiority of Giza-10 (Sd.7 x Sd.63) single cross.

Table 3. Significant levels for epistasis and epistasis by male, for separate locations and combined data for the triple testcross of SC.10 (Sd.7 x Sd.63) F_2 population.

Trait	Environment		
	Sakha	**Nubaria**	**Combined**
Grain yield (g plant^{-1})			
Epistasis	*	**	**
Epistasis x male	ns	**	*
Ear weight (g ear^{-1})			
Epistasis	**	**	**
Epistasis x male	ns	*	ns
Ear rot resistance (%)			
Epistasis	ns	ns	ns
Epistasis x male	ns	ns	ns
Silking date (d)			
Epistasis	ns	ns	ns
Epistasis x male	**	**	**
Plant height (cm)			
Epistasis	ns	ns	ns
Epistasis x male	**	**	**
Ear height (cm)			
Epistasis	ns	ns	ns
Epistasis x male	**	**	**

*, ** Significant at the 0.05 and 0.01 probability levels, respectively; otherwise not significant (ns).

Table 4. Epistatic deviations for each environment and combined data in SC.10 (Sd.7 x Sd.63) F_2 population, in 2004.

Trait	Environments		
	Sakha	**Nubaria**	**Combined**
Grain yield (g plant^{-1})	25.0 **	27.8 **	26.4 **
Ear weight (g ear^{-1})	22.2 **	28.7 **	25.5 **
Ear rot resistance (%)	0.35	- 0.35	0.0
Silking date (d)	0.3	0.3	0.3
Plant height (cm)	- 4.5 *	- 1.0	- 2.7
Ear height (cm)	2.3	0.1	1.1

*, ** Significantly different from zero at 0.05 and 0.01 levels of probability, respectively.

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الملخص العربى

تقدير مكونات التفوق الوراثى لصفة محصول الحبوب وبعض الصفات الأخرى فى هجين الذره الشاميه الفردى "جيزه-١٠"

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تهدف هذه الدراسة الى استخدام تحليل الهجن الاختبارية الثلاثية (TTC) لتحديد ما إذا كانت تأثيرات التفوق تتحكم معنويا فى كفاءة الهجين الفردى (جيزه-١٠) ، ولهذا فقد تم إختيار ستين نباتا عشوائيا من عشيرة الجيل الثانى (F_2) للهجين "جيزه-١٠" ، ثم تم تهجين كل نبات من هذه النباتات كآباء فى ثلاثة اتجاهات وهى: نباتات فردية عشوائية من السلالات "سدس-٧ وسدس-٦٣" (آباء الهجين الفردى "جيزه-١٠") بالاضافة الى تهجينها مع نباتات فردية من الجيل الأول (F_1) للهجين تحت الدراسة. ثم تم تقويم الهجن الاختبارية الناتجة (١٨٠ هجينا) باستخدام تصميم القطاعات العشوائية الناقصة فى مكررتين بكل من محطتى البحوث الزراعية بسخا والنوبارية موسم ٢٠٠٤. وقد تم قياس كل من صفات: محصول الحبوب للنبات الفردى ووزن الحبوب للكوز الواحد ونسبة المقاومة لمرض عفن الكوز وموعد التزهير وإرتفاعى النبات والكوز.

أوضحت النتائج على أساس التحليل التجميعى للمنطقتين وجود فروق معنوية بين متوسط الهجن الاختبارية لكل من الجيل الأول للهجين الفردى "جيزه-١٠" (F_1) والسلالات الأبوية "سدس-٧ وسدس-٦٣" لكل من صفتى محصول الحبوب للنبات الفردى ووزن الحبوب للكوز. بينما كانت الفروق غير معنوية لباقى الصفات تحت الدراسة. وقد كان متوسط محصول الحبوب للنبات الفردى للهجن الاختبارية للهجين الفردى "جيزه-١٠" (F_1) "وسدس-٧ وسدس-٦٣" (١٢٤,٩ و١٤١,٧ و١٣٤,٥ جم / نبات على التوالى) ، بينما كان وزن حبوب الكوز الواحد للهجن الاختبارية (١٢٧,٢ و١٤٣,٥ و١٣٦,٤ جم / كوز على التوالى).

أظهرت النتائج فروقا معنوية للتفوق لكل من صفتى محصول حبوب النبات الفردى ووزن حبوب الكوز الواحد. وقد أظهر تفاعل التفوق مع الآباء فروقا معنوية لصفتى وزن الحبوب للكوز وموعد التزهير وإرتفاعى النبات والكوز. وأظهر متوسط إنحرافات التفوق فروقا معنوية لصفات محصول الحبوب للنبات ووزن الحبوب للكوز. وتوضح القيم الموجبة لإنحرافات التفوق لهذه الصفات أن القيم المقدرة للسلالات "سدس-٧ وسدس-٦٣" كانت عالية. وقد أوضحت نتائج تحليل الهجن الإختبارية الثلاثية أن تأثيرات التفوق كانت مهمة لكل من صفات محصول حبوب النبات ووزن حبوب الكوز. كما أوضح إختبار معنوية التفوق أن تفاعل التأثيرات المضيفة كان واضحا لصفات محصول حبوب النبات ووزن حبوب الكوز ، بينما أوضح تفاعل التفوق مع الآباء أن تفاعل التأثيرات المضيفة مع تأثيرات السيادة وأيضا تأثيرات السيادة مع بعضها كانت مهمة لصفات محصول حبوب النبات وموعد التزهير وإرتفاعى النبات والكوز.

يتضح من محصلة نتائج هذه الدراسة وجود تأثيرات التفوق فى السلالات الأبوية للهجين الفردى "جيزه-١٠" (سدس-٧ وسدس-٦٣) وأن وجود هذه التأثيرات الموجبة والمعنوية للتفوق هى من أسباب تفوق الهجين الفردى "جيزه-١٠" وإنتشار زراعته فى مدى واسع من الأراضى المصرية.