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NATURE OF GENE ACTION FOR SOME ECONOMIC TRAITS AND COMBINING ABILITY IN SEVERAL GENEOTYPES OF OKRA

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ABSTRACT

This investigation was done to study combining ability and nature of gene action for some economic traits of okra (*Abelmoschus esculentus* L. MOENCH), using four different parental genotypes that were crossed in a complete diallel design. Mean squares of genotypes were significant for all studied traits, providing evidence for presence of considerable amount of genetic variation among studied genotypes . The general combining ability (GCA) and specific combining ability (SCA) mean squares were highly significant for all studied traits expect days to first flowering which was significant only for GCA. This indicated that both GCA and SCA were important in the inheritance of these traits. Significant reciprocal effect mean squares were found for Fruit Length, Fruit Diameter, Fruit weight and Total yield per plant, indicating that these traits were controlled by extra-nuclear factors as well as nuclear factors. Significant SCA effects in desirable direction were observed for most crosses in some studied traits. Good performance of the obtained crosses may be attributed to additive × dominance or dominance × dominance epistatic interactions. This suggested that the important role of non additive gene action in the inheritance of the studied traits. The estimations of general combining ability variance (σ^2_{gi}) and specific combining ability variance (σ^2_{si}) of the parental varieties for all studied traits indicated that the developed varieties used in this study are of great importance to improving most studied traits. Estimates of genetic parameters and heritability for all studied traits verified the predominance of non additive gene action in the inheritance of these traits. As well as, indicated that the studied traits except days to first flowering were not only controlled by nuclear genetic factors, but also the cytoplasmic genetic factors play an important role in the inheritance of these traits. Therefore, the genetic material of this study could be used for hybridization to produce promising crosses with improved economic traits in okra.

Keywords: okra, *Abelmoschus esculentus*, combining ability, gene action, heritability, cytoplasmic factors, genetic material.

INTRODUCTION

To face the indigence for nutritionally balanced food for the world's increasing population and attenuate the severe pressure on land use and natural resources, plant species used as food must be diversified, (Kumar and Sreeparvathy 2010). Thus, It is necessary to improve the genetic potential of indigenous vegetables like okra (*Abelmoschus* spp.). Okra (*Abelmoschus esculentus* (L.) Moench) is a powerhouse of protein, carbohydrate, vitamins and minerals (Varmudy 2011). Okra was originated somewhere around Ethiopia, and was cultivated by the ancient Egyptians by the 12th century BC. Its cultivation spread throughout Middle East and North

Africa (Tindall 1983 and Lamont 1999). In terms of its production in Egypt: it is 97.108 tons at 2012 (FAOSTAT). To improve yield production and quality properties in okra great efforts have been directed to this. Diallel mating design has been used extensively by several researchers to purpose measure gene action and combining ability for yield and yield components in okra (Nichal *et al.*, 2000 and El-Gendy, Soher *et al* 2012). Also, a lot of researchers have studied combining ability and gene action in okra and reported the occurrence of combining ability and its usefulness in connection with the testing and comparing the performance of the lines in hybrid combinations considerable quantities for earliness, fruit, yield and its various components. So, this investigation was done with a set of complete diallel crosses to get information about combining ability, gene action effects for yield and its components in several genotypes of okra in order to choose a suitable breeding strategy and to determine potential parents and promising crosses for further exploitation.

MATERIALS AND METHODS

The present investigation was carried out at a private farm in Kafr Saad, Damietta under the supervision of the Dept. of Genetics, Fac. of Agric., Damietta University.

Four different okra varieties (*Abelmoschus esculentus* L. Moench) represented a wide range of variability in their economic traits, were used in this study. These cultivars were: local cultivar i.e., Cairo Red HK (P_1) as well as genetically divergent parents of okra $Line_1$ (P_2), $Line_2$ (P_3) and $Line_3$ (P_4) that previously in 2009 created and developed by Soher El-Gendy (Elgendy, Soher 2012).

In the summer season of 2012, at the flowering time all single crosses including reciprocals were made among these varieties according to complete diallel crosses mating design to produce 12 F_1 hybrids from 6 direct crosses and their reciprocals. In addition, the four parental varieties were also self pollinated to obtain enough seeds from each variety. In the second summer season of 2013, the parental varieties and F_1 hybrids were evaluated in a randomized complete block design (RCBD) with 4 replications. Each block consisted of 16 plots (four parents and 12 F_1 hybrids).

Data were recorded on three plants chosen at random from each plot for the following traits: Days to first flowering (DFF), Plant height (PH cm), Fruit length (FL cm), Fruit diameter (FD cm), Number of fruits per plant (NF), Fruit weight (FW gm) and Total yield per plant (TY/p kg).

Data were subjected in order to test the significance of differences among the four parental varieties and 12 F_1 hybrids from 6 direct crosses and their reciprocals. Differences among genotypic means for all studied traits were tested for significance using F test according to Steel and Torri (1960).

Sum of squares for genotypes was partitioned according to Griffing's Approach, method-1, model-1 Griffing (1956) into sources of variations due to GCA and SCA. The variances of GCA (σ^2_g) and SCA (σ^2_s) were obtained on the basis of the expected mean squares for all studied traits.

Additive (VA) and Non-additive (dominance and epistasis) (VD) genetic variances were estimated according to Griffing (1956)as follows:

$$V_A = 2\sigma^2_g$$

$$V_D = \sigma^2_s$$

Reciprocal variance was estimated as follow:

$$\sigma^2_r = 1/2\ (M_r - M_e)$$

where

σ^2_r : is the variance of reciprocal effects.

M_r and M_e : are the mean squares of reciprocal effect and error, respectively.

Average degree of dominance: (Dd) was estimated according to Matzinger and Kempthorne (1956) as follow:

$$Dd = \sqrt{\frac{2\ V_D}{V_E}}$$

Estimates of heritability in both broad and narrow sense were calculated according to Singh and Chaudhary (1985):

$$h^2_{bs}\% = \frac{V_A + V_D}{V_A + V_D + \sigma^2_e}$$

$$h^2_{ns}\% = \frac{V_A}{V_A + V_D + \sigma^2_e}$$

Where:

σ^2_e = Me, The variance of experimental error i.e. environmental variance

RESULTS AND DISCUSSIONS

This study was carried out to identify and reinforcement the superiority among the different okra genotypes with respect to some economic traits. For this purpose, the set of diallel crosses with reciprocals hybrids among four different okra varieties. The results obtained from the evaluation of complete diallel crosses in order to determine the behavior of varieties in crosses as well as to partition the genotypic variance to its components. The genetic information of studied traits targeted to help to devise a meaningful breeding strategy for developing improved okra genotypes. Therefore, the obtained results and their discussion will be presented in the following,

Test of significance of the mean squares of genotypes, which appear in Table 1 indicated the presence of highly significant differences among these genotypes. This finding was obtained for all the studied traits. The significance of mean squares of genotypes suggested that the presence of large variations among these traits and the planned comparisons for understanding the nature of variation and the determination of the amounts of heterosis for traits are valid, and therefore could be made. Thus, the partitioning of the genetic variation into its components could be made through the analysis of complete crosses. These results are in agreement with the earlier finding of Obiadalla-Ali *et al.* (2013) and El-Gendy, Soher *et al.* (2012).

Table 1: Analysis of variance and mean squares of all genotypes for studied traits in okra.

Source	DF	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
Reps	3	76.9**	572.7	1.27**	0.23*	0.92	7543**	0.30**
Geno (G)	15	3.5*	1469.7**	3.60**	2.78**	12.85**	4716**	0.83**
Error	45	1.7	207.0	0.24	0.08	0.71	1155	0.05
Total	63							

***,**Significant at 0.05 and 0.01 levels probability, respectively, DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant.**

Mean performance of the parental varieties and F_1 hybrids for all studied traits are shown in Table 2.

The results indicated that all hybrids were higher than all parental varieties for total yield per plant trait. Also, most hybrids were higher than all parental varieties for Fruit Length and Fruit weight traits.

Table 2: Mean performance of Parents and it's F_1 hybrids for all the studied traits in okra.

Genotypes / Traits	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
P_1	44.8 ±2.8	211.0 ±13.6	3.4 ±0.3	4.8 ± 0.3	4.5 ±0.4	180.5 ±29.0	0.82 ±0.12
P_2	46.3 ±1.7	255.3 ±15.3	3.8 ±0.4	4.8 ± 0.3	4.7 ±0.5	168.3 ±21.8	0.79 ±0.10
P_3	45.0 ±3.2	195.8 ±8.3	4.4 ±0.3	4.5 ± 0.1	4.5 ±0.2	168.5 ±14.8	0.76 ±0.06
P_4	45.5 ±2.4	188.0 ±12.7	3.1 ±0.5	4.5 ± 0.3	4.0 ±0.6	228.0 ±41.4	0.90 ±0.16
P_1 x P_2	45.8 ±2.9	238.0 ±10.2	3.4 ±0.4	4.5 ± 0.3	4.6 ±0.8	202.8 ±52.8	0.93 ±0.24
P_2 x P_1	45.3 ±2.2	244.8 ±23.9	4.5 ±0.2	5.6 ± 0.2	6.1 ±0.3	225.0 ±19.3	1.37 ±0.12
P_1 x P_3	45.3 ±2.8	254.0 ±17.8	4.8 ±0.9	4.1 ± 0.3	4.8 ±1.3	264.0 ±69.2	1.26 ±0.33
P_3 x P_1	45.0 ±3.2	232.0 ±17.5	4.7 ±0.6	5.3 ± 0.1	6.1 ±0.3	219.0 ±14.1	1.34 ±0.09
P_1x P_4	42.3 ±3.3	237.8 ±11.2	3.3 ±0.2	4.3 ± 0.4	4.3 ±0.6	260.8 ±65.3	1.11 ±0.28
P_4 x P_1	44.0 ±2.6	220.3 ±22.6	5.6 ±0.5	7.0 ± 0.2	10.6 ±0.7	213.5 ±57.3	2.25 ±0.61
P_2 x P_3	45.8 ±2.2	242.3 ±21.5	5.9 ±0.2	5.6 ± 0.1	6.8 ±0.5	196.8 ±44.2	1.34 ±0.30
P_3 x P_2	45.8 ±2.2	242.3 ±10.3	5.2 ±0.6	5.7 ± 0.5	6.5 ±0.5	216.8 ±18.4	1.40 ±0.12
P_2x P_4	45.3 ±2.2	216.3 ±9.3	5.0 ±0.5	5.6 ± 0.2	7.1 ±1.0	171.5 ±30.9	1.24 ±0.22
P_4 x P_2	44.3 ±2.2	230.5 ±10.6	4.3 ±0.8	6.4 ± 0.4	7.6 ±1.7	211.8 ±9.6	1.59 ±0.07
P_3 x P_4	45.0 ±1.4	226.0 ±6.7	5.6 ±0.9	6.2 ± 0.6	8.2 ±1.3	254.3 ±12.0	2.08 ±0.10
P_4 x P_3	45.3 ±2.2	219.8 ±16.2	5.9 ±0.9	5.7 ± 0.3	7.2 ±1.1	273.5 ±48.4	1.93 ±0.34
$LSD_{5\%}$	1.8	20.5	0.7	0.4	1.2	48.4	0.30
$LSD_{1\%}$	2.5	27.3	0.9	0.5	1.6	64.6	0.41

DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant, P_1 (HK), P_2 ($Line_1$), P_3 ($Line_2$), P_4 ($Line_3$).

The best combination for days to first flowering was (P_1 x P_4) with mean of 42.3, with significantly and insignificantly increase compared to all parental varieties. But, the cross (P_1 x P_3) was the best for plant height trait with mean 254.0, however, it was insignificantly lowest than P_2 in this trait. Meanwhile, the crosses (P_2 xP_3) and (P_4 x P_3) were the best for fruit length trait with mean 5.9, with a highly significant increase compared to all parental varieties. Also, for number of fruits per plant trait, (P_4 x P_3) was the best combination with mean 273.5, with significantly and insignificantly increased compared to all parental varieties. For fruit diameter, fruit weight and total yield per plant traits, (P_4 x P_1) was the best hybrid with mean of 7.0, 10.6 and 2.25, respectively. Also, this hybrid highly significant exceeded all parental varieties in these traits .Thus, these promising crosses could be used for further breeding studies to improve the economic traits of okra.

Hence, The results exhibited that means of most hybrids from direct crosses differed significantly from that of their reciprocal crosses for fruit Length, fruit diameter, fruit weight and total yield per plant traits, indicating the existence of maternal effects in inheritance of these traits.

Mean squares of general and specific combining ability and reciprocal effects for all studied traits are given in Table 3. The results exhibited that mean squares of general combining ability (GCA) and specific combining ability (SCA) were highly significant for all studied traits expect days to first flowering which was significant only for GCA. These results indicated that both GCA and SCA were important in the inheritance of these traits.

Table 3: The analysis of variance and mean squares for combining ability analysis.

S.O.V.	DF	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
GCA	3	1.62*	852.6**	1.31**	0.33**	1.2**	1763.1**	0.16**
SCA	6	0.97	403.8**	0.99**	0.67**	3.7**	1472.6**	0.30**
Reciprocals	6	0.41	88.5	0.61**	0.90**	3.8**	593.4	0.14**
Pooled Error	45	0.432	51.8	0.06	0.02	0.2	288.8	0.01

***,**Significant at 0.05 and 0.01 levels probability, respectively, DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant.**

In addition, significant reciprocal effect mean squares were observed for all studied traits expect days to first flowering , plant height and number of fruits per plant , indicating that these traits were controlled by extra-nuclear factors as well as nuclear factors . These results are in harmony with those previously obtained by Singh *et al.* (2006) and El-sherbeny *at al.* (2005).

Estimates of general combining ability effects (g_i) of each parent for all studied traits are presented in Table 4. It could be seen from this Table that $Line_1$ (P_2) was a good general combiner for plant height trait. Meanwhile, the results showed that the GCA effects were negative and significant toward shorter for $Line_3$ (P_4) in plant height trait. $Line_2$ (P_3) was good general combiner for fruit length trait. $Line_3$ (P_4) was good general combiner for fruit weight trait. It could be suggested that the developed varieties $Line_1$, $Line_2$ and $Line_3$ possess favorable genes to improve hybrids for plant height, fruit length and fruit weight traits.

Because, the consumers usually prefer less determinative of fruit diameter (Düzyaman and Vural, 2003), the local cultivar HK (P_1) was a good general combiner for fruit diameter trait.

Table 4: Estimates of general combining ability effects (g_i) of each parental lines for all studied traits in okra.

Traits / Parents	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
P_1	-0.37^{P}	2.7^{P}	-0.41^{*P}	-0.23^{*G}	-0.41^{P}	2.30^{P}	-0.08^{P}
P_2	0.50^{P}	12.2^{*G}	-0.08^{P}	0.08^{P}	-0.08^{P}	-20.81^{*P}	-0.14^{P}
P_3	0.26^{P}	-2.4^{P}	0.56^{**G}	-0.09^{P}	-0.03^{P}	4.18^{P}	0.04^{P}
P_4	-0.39^{P}	-12.5^{*P}	-0.06^{P}	0.24^{*P}	0.52^{*G}	14.33^{P}	0.18^{P}
SE(g_i)	0.20	2.20	0.08	0.043	0.13	5.20	0.033
LSD (g_i-g_j)	0.64	7.05	0.24	0.14	0.413	16.65	0.104

*,**Significant at 0.05 and 0.01 levels probability, respectively, DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant, P_1 (HK), P_2 ($Line_1$), P_3 ($Line_2$), P_4 ($Line_3$).
$^{G\ (good)}$ Denotes significant general combining ability effect in favorable direction.
$^{P\ (poor)}$ Denotes non-significant general combining ability effects in favorable direction, significant and non-significant general combining ability effects in unfavorable.

Table 5: Estimates of specific combining ability effects (S_{ij}) of each cross for all studied traits in okra.

Crosses	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
P_1x P_2	0.45	-2.0	-0.14	-0.07	-0.24	16.6	0.05
P_1x P_3	0.23	14.2*	0.08	-0.26*	-0.20	18.9	0.02
P_1x P_4	-1.08*	10.5*	0.37*	0.35**	1.22**	4.5	0.26**
P_2x P_3	-0.05	4.1	0.50*	0.34**	0.65*	7.4	0.15*
P_2x P_4	-0.55	-4.7	0.23	0.40**	0.80*	-17.8	0.05
P_3x P_4	0.26	9.4	0.73**	0.54**	1.10**	29.6*	0.46**
SE (S_{ij})	0.37	4.0	0.14	0.08	0.24	9.5	0.06
LSD (S_{ij} -S_{ik})	1.12	12.2	0.42	0.24	0.72	28.85	0.18
LSD (S_{ij} -S_{kl})	0.91	10.0	0.34	0.19	0.58	23.55	0.15

*,**Significant at 0.05 and 0.01 levels probability, respectively, DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant, P_1 (HK), P_2 ($Line_1$), P_3 ($Line_2$), P_4 ($Line_3$).

Table 6: Estimates of reciprocal effects (r_{ij}) of each reciprocal cross (F_{1r}) for all studied traits in okra.

Traits / crosses	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
F_2x P_1	0.33	-3.38	-0.54*	-0.55**	-0.74*	-11.02	-0.22*
P_3x P_1	0.13	10.88	0.02	-0.62**	-0.63	22.46	-0.04
P_4x P_1	-0.92	8.73	-1.13**	-1.35**	-3.18**	23.48	-0.57**
P_3x P_2	0.04	-0.15	0.39	-0.06	0.13	-10.04	-0.03
P_4x P_2	0.52	-7.15	0.31	-0.37**	-0.23	-20.21	-0.18
P_4x P_3	0.04	2.98	-0.15	0.23	0.47	-9.69	0.07
SE (r_{ij})	0.47	5.09	0.17	0.10	0.58	12.02	0.08
LSD (r_{ij}- r_{kl})	1.29	14.10	0.48	0.27	0.83	33.31	0.21

*,**Significant at 0.05 and 0.01 levels probability, respectively DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant, P_1 (HK), P_2 ($Line_1$), P_3 ($Line_2$), P_4 ($Line_3$).

Specific combining ability and their reciprocal effects are explained in Tables 5 and 6, respectively. The results showed that significant SCA effects in desirable direction were observed for most crosses in some studied traits as follows:

The cross combination (P_1 x P_4) was good specific combiner showing negative significant SCA effects for days to first flowering which is desirable for earliness. This cross involved poor × poor general combiners as parents.

While, The combiners (P_1 x P_3) and (P_1 x P_4) were good specific combiners which exhibited positive significant SCA effects for plant height. These crosses also involved poor × poor general combiners as parents.

For fruit length the crosses (P_3 x P_4) , (P_2 x P_3) and (P_1 x P_4) respectively, have good specific combiners. These crosses involved good x poor general combiners as parents.

Meanwhile, for fruit diameter the combiners (P_4 x P_1), (P_3 x P_1), (P_2 x P_1), (P_4 x P_2) and (P_1 x P_3) respectively, exhibited a negative significant SCA effects which is desirable for consumers. These crosses involved good x poor general combiners as parents except (P_4 x P_2) involved poor × poor general combiners as parents.

Also, the crosses (P_1 x P_4), (P_3 x P_4), (P_2 x P_4) and (P_2 x P_3) respectively, have good specific combiners for fruit weight. These crosses involved good x poor general combiners as parents except (P_2 x P_3) which involved poor × poor general combiners as parents.

For number of fruits per plant, the cross (P_3 x P_4) showed a good specific combiner involved poor × poor general combiners as parents. Eventually, the crosses (P_3 x P_4), (P_1 x P_4) and (P_2 x P_3) respectively, have good specific combiners for total yield per plant. These crosses involved poor × poor general combiners as parents.

From these results, it could be noticed that the GCA status of the parents of good specific combiners for various traits, gives evident that the good specific combiners involved good x poor and poor × poor general combiners as parents, indicating that high specific combiners are not only obtained from the combination of good x good general combiners but also obtained from the combination of good x poor and poor × poor general combiners. Thus, good GCA effects of the parents, therefore, do not seem to be a reliable criterion for the prediction of high SCA effects. Good performance of these crosses may be attributed to additive × dominance (good × poor), or dominance × dominance (poor × poor) epistatic interactions. These results suggested the important role of non additive gene action in the inheritance of the studied traits and are in agreement with those reported by Rewale *et al.*, (2003) and Reedy *et al* (2013b).

The estimation of general combining ability variances (σ^2_{gi}) and specific combining ability variances (σ^2_{si}) of each parental varieties for all studied traits are presented in Table 7. The results showed that the largest values of σ^2_{gi} and σ^2_{si} were detected in P_4 (Line$_3$) for fruit diameter, fruit weight and total yield per plant which indicated that this parent has contributed to the inheritance of these traits in some hybrids. While, P_4 showed high estimation of σ^2_{gi} only for plant height trait which indicated that this parent has contributed to the inheritance of this trait to most hybrids. These results indicated that P_4 was the best suited parent to improve these traits. Also, The results showed that the largest values of σ^2_{gi} and σ^2_{si} were detected in P_3 (line$_2$) for fruit Length trait, which indicated that this parent has contributed to the inheritance of this trait in some hybrids and the best suited parent to improve this trait. As well, P_2 showed high estimation of σ^2_{gi} only for days to first flowering and number of fruits per plant traits which indicated that this parent has contributed to the inheritance of these traits in most hybrids. These results were in agreement with those obtained by AL-Hamdany (2014).

Table 7: Variance estimates of general combining ability (σ^2_{gi}) and specific combining ability (σ^2_{si}) of each parental varieties for all studied traits in okra.

Traits / Parents	DFF		PH cm		FL cm		FD cm		FW gm		NF		TY/p kg	
	σ^2_{gi}	σ^2_{si}	σ^2_{gi}	σ^2_{si}	σ^2_{gi}	σ^2_{si}	σ^2_{gi}	σ^2_{si}	σ^2_{gi}	σ^2_{si}	σ^2_{gi}	σ^2_{si}	σ^2_{gi}	σ^2_{si}
P_1	0.09	0.57	2.6	143.0	0.1658	0.0617	0.053	0.091	0.15	0.74	-21.8	235.7	0.0055	0.0319
P_2	0.21	0.12	144.6	5.4	0.0005	0.1573	0.005	0.219	-0.01	0.50	406.0	233.4	0.0177	0.0297
P_3	0.03	-0.07	1.0	138.2	0.3026	0.8392	0.006	0.188	-0.02	0.78	-9.6	553.9	0.0004	0.2006
P_4	0.11	0.63	152.1	95.0	-0.0016	0.8570	0.054	0.825	0.26	1.61	178.3	516.8	0.0313	0.2990

DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant, P_1 (HK), P_2 ($Line_1$), P_3 ($Line_2$), P_4 ($Line_3$).

(-) Negative values as a result of an error in kind so is zero.

The previously results from Table 7, indicated that the developed varieties $Line_1$, $Line_2$ and $Line_3$ are of great importance to improve most studied traits.

The different genetic parameters were estimated based on the analysis of combining ability, and the results are presented in Table 8. The ratio σ^2_g/σ^2_S was lower than one for all studied traits, referring the importance of non additive gene effect in these traits. This result was in agreement with those results obtained by Mohamad *et al.* (2007).

Table 8: Estimates of genetic parameters and heritability in broad (H^2_{bs}%) and narrow (H^2_{ns}%) sense for all studied traits.

Traits / Parameters	DFF	PH cm	FL cm	FD cm	FW gm	NF	TY/p kg
σ^2_g/σ^2_S	0.3	0.3	0.2	0.06	0.04	0.2	0.06
V_A	0.3	200.2	0.3	0.08	0.25	368.6	0.04
V_D	0.5	352.0	0.9	0.65	3.47	1183.8	0.29
σ^2_r	-0.0	18.4	0.3	0.44	1.80	152.3	0.06
Dd	1.9	1.9	2.4	4.06	5.24	2.5	4.99
H^2_{bs}%	65.9	91.4	95.4	97.40	95.46	84.3	96.7
H^2_{ns}%	23.5	33.1	24.0	10.52	6.49	20.0	10.8

DFF: Days to first flowering, PH: Plant height, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, NF: Number of fruits per plant, TY/P: Total yield per plant

(-) Negative values as a result of an error in kind so is zero

The results indicated that the magnitudes of non-additive genetic variances (V_D) were larger than their corresponding estimates of additive genetic variances (V_A) for all the studied traits. This suggests that dominance genetic variance played major role in the inheritance of all studied traits. The fact could be emphasized by average degree of dominance (Dd), which exceeded one for all studied traits. As well, the heritability estimations in broad sense (h^2_{bs}%) were larger than their ones in narrow sense (h^2_{ns}%) for all studied traits. Furthermore, the broad sense heritability estimates (h^2_{bs}%) were more than 65.9% and larger than their corresponding narrow sense heritability (h^2_{ns}%) for all studied traits. However, estimates of narrow sense heritability were 23.5%, 33.1%, 24.0%, 10.5%, 6.5%, 20.0% and 10.8% for days to first flowering, plant height, fruit length, fruit diameter and fruit weight, total yield per plant and number of fruits per plant, respectively. These results verified the predominance of non-additive gene action in the inheritance of these traits. These results are in good agreement with those reported by Saeed *et al* (2014) and Reedy *et al.* (2013).

Furthermore, the reciprocal variance σ^2_r was positive and lower than non-additive genetic variance for all studied traits except days to first flowering with a less negative value -0.009, suggesting that these traits were not only controlled by nuclear genetic factors, but also the cytoplasmic genetic factors play an important role in the inheritance of these traits. These results are in conflict with Abdelmageed *et al.* (2010).

CONCLUSION

Most studied traits in this investigation were shown to be mainly controlled by non additive effects and cytoplasmic genetic factors. Good performance of the obtained crosses in this study may be attributed to additive × dominance (good × poor), or dominance × dominance (poor × poor) epistatic interactions. Thus, the developed varieties used in this study could be utilized for hybridization with the aim of producing promising crosses to improve economic traits in okra.

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طبيعة فعل الجين لبعض الصفات الإقتصادية والقدرة على التآلف في عدد من التراكيب الوراثية فى البامية

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تمت دراسة طبيعة الفعل الجينى لبعض الصفات الاقتصادية فى البامية وذلك باستخدام أربعة أنواع من التراكيب الوراثية أدخلت كآباء بنظام التهجين الدائرى الكامل. كانت قيم متوسط مربعات التراكيب الوراثية معنوية لجميع الصفات المدروسة مما أكد على وجود تباين وراثى كبير بين التراكيب الوراثية المختبرة. كذلك كانت تقديرات متوسط مربعات القدرة العامة والخاصة على التآلف عالية المعنوية بالنسبة لجميع الصفات المدروسة عدا صفة عدد الأيام حتى خروج أول زهرة مما أوضح أن كلا النوعين من القدرة على التآلف هام بالنسبة لتوارث باقى الصفات الاقتصادية المدروسة. كذلك فقد كانت تقديرات متوسط مربعات تأثيرات الهجن العكسية معنوية بالنسبة لصفات طول وقطر ووزن الثمرة ومحصول النبات مما أوضح أن هذه الصفات يتحكم فيها عومل وراثية لا نووية بجانب العوامل الوراثية النووية .أيضا فقد أوضحت النتائج وجود قدرة خاصة على التآلف معنوية فى الاتجاه المرغوب لمعظم الهجن الناتجة فى بعض الصفات المدروسة. هذا السلوك الجيد للهجن الناتجة ربما يعزى للتفاعل التفوقى من النوع (الإضافى X السيادى) أو (السيادى X السيادى)، مما يوحى بالدور الهام للفعل الجينى غير المضيف فى توارث الصفات محل الدراسة. كذلك فقد أكدت تقديرات المقاييس الوراثية والمكافئ الوراثى على سيطرة الفعل الجينى غير المضيف على توارث الصفات المدروسة وكذالك أوضحت أن الصفات المدروسة عدا صفة عدد الأيام حتى خروج أول زهرة لا يتحكم فيها بواسطة عوامل وراثية نووية فقط بل تلعب العوامل الوراثية السيتوبلازمية دوراً هاماً فى توارثها. لذلك كله فإن المادة الوراثية الخاصة بهذه الدراسة يمكن استغلالها فى التهجينات المختلفة لإنتاج هجن متميزة فى صفات البامية الاقتصادية.