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Genetical Analysis of Some Agronomic Characters in Sunflower (*Helianthus annuus* L.)

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ABSTRACT

This investigation was carried out on three strains of sunflower Giza 1, Mayak and Ro-21 during the three successive seasons 1988, 1989 and 1990 at the experimental farm, Faculty of Agriculture, Kafr El-Sheikh, Tanta Univ., Egypt. Flowering date, stem diameter, plant height, head diameter, 100-seed weight, grain yield and oil percentage were evaluated. Most of these traits showed significant heterosis and inbreeding depression values. Potence ratio for all these traits mostly exceeded the unity. Additive gene effects played a major role in the inheritance of flowering date and oil percentage. This was associated with high and moderate heritability values for such traits. On the other hand, dominance and epistatic gene effects were found also to be contributing significantly in the inheritance of other traits.

INTRODUCTION

The aim of sunflower breeding programs is to increase seed yield as well as high oil percentage. Therefore, this requires the understanding of the nature of gene action with respect to the relative magnitude of additive and non-additive types of gene action.

The most effective designs of breeding programs are dependent upon the relative amount and types of genetic variability in the used materials. If the estimates of the genetic variance and its components indicate that the additive genetic variance is of major importance, then intra-population selection will be considered as the most effective procedure for gathering the favourable genetic constitutions. On the other hand, if the non-additive genetic variability is the major components of genetic variance, inbred-hybrid program may be the appropriate choice (Cochrham, 1961). Therefore, the study of the type of gene action in the genetic materials under consideration must be in concern.

The aim of the present investigation is to study the genetic behaviour of some agronomic characters in three crosses of sunflower.

MATERIALS AND METHODS

This investigation was applied on three different sunflower cultivars; Giza 1 (Egyptian), Mayak (Russian), and Ro-21 (Romanian). The cultivars were previously selfed for five generations until the progenies were reasonably uniform agronomically.

The study had been carried out at the experimental farm, Faculty of Agriculture, Kafr El-Sheikh, Tanta Univ., Egypt, during the seasons of 1988, 1989 and 1990. The first season was in Summer 1988. Giza 1 cultivar was sown 10 days earlier to get the same flowering date for all parents in order that the artificial pollination becomes feasible. All possible hybridizations among the three cultivars were conducted to obtain the F_1 hybrids (Giza 1 X Mayak), (Giza 1 X Ro-21) and (Mayak X Ro-21). In 1989 Summer season, the F_1's plants were self-pollinated and backcrossed to their parents to obatin the F_2 and backcross seeds . In Summer 1990, all generations, parents, F_1's, backcrosses to both parents and F_2 populations for the three crosses were planted in a complete randomized block design with four replications. The plants were grown in rows of five m. long and 65 cm. apart with 30 cm. between hills. Field plot varied in size, i.e., 10 rows for F_2's, four rows for Bc.'s and two rows for each parent and F_1's. All other Agricultural Practices were done as recommended for ordinary sunflower in the area.

Data were taken on individual plants of the six populations in each cross for seven agronomic characters; flowering date, stem diameter, plant height, head diameter, 100-seed weight, grain yield and oil percentage.

Statistical and Genetical Analysis :

In each cross within the experiment the mean and the variance values were calculated for P_1, P_2, F_1, Bc_1, Bc_3 and F_2 generations. The population means and variances were used to estimate the type of gene action . Individual scaling test was applied to the six population data of each cross as outlined by Mather 1949. The parameters A, B and C and their variances were calculated as follows :

$A = 2\overline{Bc}_1 - \overline{P}_1 - \overline{F}_1$ $\qquad V_A = 4\,V_{\overline{Bc}_1} + V_{\overline{P}_1} + V_{\overline{F}_1}$

$B = 2\,\overline{Bc}_2 - \overline{P}_2 - \overline{F}_2$ $\qquad V_B = 4\,V_{\overline{Bc}_2} + V_{\overline{P}_2} + V_{\overline{F}_2}$

$C = 4\,\overline{F}_2 - 2\overline{F}_1 - \overline{P}_1 - \overline{P}_2$ $\qquad V_C = 16\,V_{\overline{F}_2} + 4\,V_{\overline{F}_1} + V_{\overline{P}_1} + V_{\overline{P}_2}$

The significance of previous values were done by t test as follows:

$$\pm t = \frac{\text{effect}}{\sqrt{\text{variance of effect}}}$$

Estimations of the types of gene effects were obtained using the relationships given by Gamble (1962) and are presented as follows :

$m = \overline{F}_2$

$a = \overline{Bc}_1 - \overline{Bc}_2$

$d = + \frac{1}{2}\,\overline{P}_1 + \frac{1}{2}\,\overline{P}_2 + \overline{F}_1 - 4\,\overline{F}_2 + 2\,\overline{Bc}_1 + 2\overline{Bc}_2$

$aa = - 4\overline{F}_2 + 2\overline{Bc}_1 + 2\overline{Bc}_2$

$ad = - \frac{1}{2}\,\overline{P}_1 + \frac{1}{2}\,\overline{P}_2 + \overline{Bc}_1 - \overline{Bc}_2$

$dd = \overline{P}_1 + \overline{P}_2 + 2\overline{F}_1 + 4\overline{F}_2 - 4\overline{Bc}_1 - 4\overline{Bc}_2$

Where,

a = additive effect
d = dominance effect
aa = additive X additive type of epistasis
ad = additive X dominance type of apistasis
dd = dominance X dominance type of epistasis

The significance of these effects were tested by the "t" test,

$$\pm t = \frac{\text{effect}}{\sqrt{\text{variance of effect}}}$$

The amount of heterosis was expressed as the percentage deviation of F_1 mean performance from mid-parent and better parent.

$$\text{Inbreeding depression (I.D.\%)} = \frac{F_1 - F_2}{F_1} \times 100$$

The variance of inbreeding depression was calculated as the following formula :

$$\text{Variance of I.D. deviation} = V_{F_1} + V_{F_2}$$

Nature of degree dominance were determined by means of potence ratio "p" method can be defined as follow :

$$\text{Potence ratio} = \frac{F_1 - M.P.}{\frac{1}{2}(P_1 - P_2)} \qquad \text{(Smith, 1952)}$$

Heritability was computed in both broad (h^2_b) and narrow senses (h^2_n) for F_2 generation as follows :

$$(h^2_b) = \frac{V_{F_2} - V_E}{V_{F_2}} = \frac{\text{Genetic variance}}{\text{Total variance}} \qquad \text{(Allard, 1960)}$$

Where $V_E = \dfrac{V_{P_1} + V_{P_2} + V_{F_1}}{3}$

$$(h^2_n) = \frac{2V_{F_2} - (V_{Bc_1} + V_{Bc_2})}{V_{F_2}} \times 100 = \frac{\frac{1}{2} D}{V_{F_2}} \qquad \text{(Mather, 1949)}$$

The predicted genetic advance under selection (Δg) was computed according to Johanson et al. (1955).

$$(\Delta g) = K \sqrt{V_{F_2}} \times h^2_n$$

Also, this expected gain represented as a percentage of F_2 mean ($\Delta g\%$) was estimated according to Miller et al. (1958).

RESULTS AND DISCUSSION

I- Scaling test and generation means :

The purpose of scaling test is to determine which additive-dominance model or non-allelic gene action is adequate for studying the gene action in the inheritance of the different traits. As mentioned above in the material and methods, there are three scaling tests; "A, B and C" which indicate the significance of types of epistasis. If one or more of the three tests showed significant value(s), it means that one or more of the additive X additive, additive X dominance and dominance X dominance are existed and significantly different from zero. In the other words, significant scaling test refers to the inadequacy of the additive dominance model and presence of the non-allelic gene interaction.

Table 1, show the scaling test and generation means of six populations of the three crosses under study for flowering date, stem diameter, plant height, head diameter, 100-seed weight, grain yield and oil percentage.

One or more of the scaling tests for flowering date, plant height, grain yield and oil percentage were significant for all crosses, this would mean that gene effects and interactions (non.alleleic) were influenced by genetic constitution. However, second order interaction was existed in this case. With regard to stem diameter, head diameter and 100-seed weight, the three tests were insignificant such as cross I (Giza 1 X Mayak) and cross II (Giza 1 X Ro-21). This would mean that gene effects and interaction (non-allelic) were slightly influenced by genetic constitution. With regard to the mean performance of the populations for each cross for the seven studied characters are also given in Table 1. The range in parent performances was not extreme for any of the characters except that of plant height and grain yield. The mean performance of the F_1 population was greater than the top parent one for all of the studied traits except that of the oil percentage. The advantage of the F_1 population means over the top parent varied among characters.

The F_2 population mean was greater than the mid-parent with few exception other than 100-seed weight and grain yield. However, even for 100-seed weight and grain yield, the performance of F_2 population was greater than the top parent value.

In the most of studied characters, the performance of back-crosses population was related with its recurrent parent. That is, the backcross to the better performing parent was generally the better performing of the two backcross populations for any one cross. The degree of association of the backcross with its recurrent parent varied somewhat among the characters.

II- Heterosis, inbreeding depression and potence ratio :

Heterosis was clearly observed in all crosses for the studied quantitative characteristics. Heterosis relative to mid-parent (H.M.P.) and better parent (H.B.P.) were calculated and presented in table 3. However, both the magnitude and the direction (positive or negative) of heterosis, varied with respect to different characters. The crosses showed highly significant values in both H.M.P. and H.B.P. for all characters under study with the exception for plant height. Heterosis might be due to dominance or epistatic types of gene action. Similar results were obtained by Putt (1965), Seetharam (1977) and El-Hity (1987). These results may be encouraging for utilizing heterosis in sunflower.

Concerning the inbreeding depression values from F_1 to F_2 (table 3), it was apparent that, the crosses showed highly significant values for most studied characters. Both heterosis and inbreeding depression are coincide to a same particular phenomenon, therefore, it is logical to anticipate that heterosis in the F_1 will be followed by an appreciable reduction in the F_2 performance. So, significant effects for both heterosis relative to M.P. and inbreeding depression were associated. In these cases the expression of heterosis in F_1 was followed by considerable reduction in F_2 performance. This is logic and expected.

regarding to the potence ratio (table 3), it was apparent that potence ratio (P) for all these characters mostly exceeded the unity, indicating the importance of types of epistatic gene action.

III- Types of gene action :

a) Additive gene effects :

Additive gene effects were significant in 6, 2 and 5 of the 7 studied characters for cross I, Cross II and cross III respectively. This suggests that additive gene effects make a significant contribution to the inheritance of the characters in these crosses. Thus, the contribution of any effects depend on the cross itself. The magnitude of the "a" estimates relative to the mean effects and dominance effects suggets that this contribution is not as important as the contribution of dominance gene effects. The estimates indicate, however, that additive gene effects contributed relatively more to the characters flowering date and oil percentage than to others. All significant estimates of additive gene effects were positive for the characters except for oil percentage which exhibited significant negative additive gene effects.

The three crosses (especially for cross I and cross II) exhibited significant estimates of additive gene effects which indicate the presence of additive variation in the majority of the studied characters, the magnitudes of these estimates suggest that additive gene effects are less important than other types of gene effects. Nevertheless a sufficient amount of additive variation appears to be present which could be useful and successful for any selection program relative to those characters especially for flowering date and oil percentage. Additive gene effects played a major role in the inheritance of such characters. These findings generally agree with those reported by Alexander (1963), Putt (1965), Singh et al (1971) and Asthana (1977). (Table 2).

b) Dominance gene effects :

The importance of dominance gene effects for a character will be indicated by the relationship of the F_1 to the top parent mean. If the F_1 performs better than the top parent, dominance effects will generally be the most important inheritance and the relative importance becomes greater as the advantage of the F_1 mean over the top parent mean becomes greater.

In this study, the dominance gene effects appeared to be the most important gene effects in the inheritance of the most characters with the exception of flowering date and oil percentage. The majority of dominance gene effects were estimates positively significant. On the other hand, two significant negative estimates were obtained for plant height and oil percentage in cross II (Giza 1 X Ro-21).

The magnitude of the dominance gene effects relative to the magnitude of the mean effects were larger for the grain yield showing that dominance effects were relatively more important in the inheritance in sunflower grain yield, thus, increasing yield performance in sunflower could be achieved through a breeding procedure which emphasizes the dominance gene effects for such crosses. Similar results with regard to dominance gene effects have been reported by Velkov (1970 and 1971), Towar and Singh (1973) and Katiyar et al (1974). (Table 2).

c) Epistatic gene effects :

For the material used in this study, epistatic gene effects are presented in sufficient magnitude considering importance inheritance of these characters under study. The epistatic gene effects in this study are relatively more important than additive gene effects but generally less important than the dominance gene effects.

With regard to the individual types of digenic epistatic gene effects, the additive X additive gene effects are exhibited more frequently than the other two types of digenic epistasis, but the estimates of the dominance X dominance gene effects have relatively greater magnitude for all the studied characters. Two of these epistatic gene effects apparently counteract each other. The "aa" gene effects which were mostly significant and positive indicated an enhancing effect in the inheritance . In contrast, all the "dd" gene effects were negatively significant suggesting a diminishing effect due to this type of gene effect and undesirable epistasis. Additional evidence for the undesirability of "dd" gene effects might be inferred from grain yield performance. Dominance X dominance gene effects were the least important of the epistatic effects in the inheritance of grain yield, however, the F_1, F_2 and backcross performance was superior to the top parent performance. This suggests that no important diminishing gene effects were present in grain yield performance. (Table 2)

IV- Heritability and genetic advance from selection :

Heritability estimates in both broad and narrow senses and expected genetic advance for the seven characters are presented in table 3. Generally heritability values in broad sense, as expected, were notably higher than the corresponding narrow sense in the three crosses for all studied characters. The crosses differed from each other in their estimated values of heritability in both broad and narrow senses.

Moderate heritability values in narrow sense for some characters such as flowering date and oil percentage may be due to the predominance of the non-additive gene effects in the inheritance of this two traits, which were clear in the previously discussed type of gene action, where "a" gene effects and "ad" type of epistatic effects realized the major role in the inheritance

Table (1): The results of scaling test and mean value for some agronomic characters in three crosses of sunflower.

No. of plants	Generation	Characters						
		Flowering date (days)	Stem diameter (Cm)	Plant height (Cm)	Head diameter (Cm)	100-seed weight (g)	Yield per plant (g)	Oil percentage
30	P_1	80.98±1.22	2.49±0.08	195.71± 5.37	21.01±0.84	7.75±0.33	65.81± 6.21	30.22±0.81
30	P_2	77.89±1.33	2.05±0.07	155.63± 2.91	16.81±0.52	5.88±0.24	48.93± 5.99	44.43±0.75
30	F_1	88.01±1.13	2.85±0.09	197.26± 3.71	21.91±0.55	9.61±0.39	91.65± 6.35	29.47±1.11
50	Bc_1	85.84±1.64	2.91±0.13	188.27± 5.69	22.01±0.71	9.48±0.38	89.43± 6.12	30.15±1.10
50	Bc_2	74.25±1.51	2.40±0.11	175.50± 5.60	18.90±0.85	7.45±0.34	71.51± 5.93	33.45±0.95
150	F_2	80.81±1.04	2.05±0.06	166.61± 3.52	20.95±0.49	8.26±0.21	72.22± 3.88	30.22±0.72
-	A	2.69±3.67	0.48±0.28	-16.43±13.11	1.10±1.73	1.60±0.92	30.40±16.37*	0.61±2.59
-	B	-18.04±3.48**	-0.10±0.24	- 1.89±12.15	-0.91±1.68	-0.59±0.82	2.44±13.75	-8.00±2.32**
-	C	-11.65±5.06*	-2.04±0.31**	-79.42±16.71**	2.16±2.45	-0.19±1.16	-0.16±20.08	-12.71±3.51**
30	P_1	80.98±1.22	2.49±0.08	195.71± 5.37	21.01±0.84	7.75±0.33	65.81± 6.71	30.22±0.81
30	P_2	66.78±1.52	2.40±0.12	145.91± 5.55	18.75±0.72	6.24±0.29	35.72± 3.93	42.18±0.76
40	F_1	78.21±1.38	2.55±0.10	185.78± 4.72	21.81±0.76	8.66±0.38	84.32± 6.01	22.65±1.07
40	Bc_1	75.65±1.42	2.39±0.12	180.25± 5.48	20.38±0.86	8.21±0.32	82.08± 6.23	33.98±0.96
40	Bc_2	72.64±1.49	2.15±0.14	144.91± 4.48	19.45±0.69	8.26±0.36	75.68± 5.36	30.08±0.92
150	F_2	74.65±1.01	2.51±0.07	178.22± 3.06	20.98±0.47	8.15±0.22	72.91± 3.75	33.85±0.69
-	A	-7.89±3.38*	-0.26±0.27	-20.99±13.08	-2.06±2.05	0.01±0.81	14.03±15.16	9.09±2.34**
-	B	0.29±3.62	0.35±0.32	-41.87±11.59**	-1.66±1.73	1.62±0.86	31.32±12.90*	-10.67±2.26**
-	C	-5.58±5.26	0.05±0.37	-0.30±17.22	0.54±2.42	1.29±1.24	21.47±20.75	5.70±3.37
30	P_1	77.89±1.33	2.05±0.07	155.63± 2.91	16.81±0.52	5.88±0.24	48.93± 5.90	44.43±0.75
30	P_2	66.78±1.52	2.40±0.12	145.91± 5.55	18.75±0.72	6.24±0.29	35.72± 2.93	42.18±0.71
40	F_1	65.15±1.27	2.32±0.10	159.75± 3.41	19.09±0.63	7.56±0.30	76.81± 6.18	42.21±0.81
40	Bc_1	76.28±1.31	2.70±0.09	166.80± 3.78	21.68±0.77	7.81±0.25	88.23± 5.91	42.48±0.89
40	Bc_2	65.95±1.46	2.22±0.08	142.39± 4.39	19.85±0.75	7.12±0.29	60.75± 6.24	46.75±0.92
150	F_2	69.14±0.89	2.07±0.05	144.66± 2.69	17.95±0.45	6.70±0.16	51.08± 2.81	43.36±0.65
-	A	9.52±3.20**	1.03±0.21**	18.22± 8.78*	7.46±1.36*	2.18±0.16**	50.72±14.58**	-1.68±1.98
-	B	-.030±3.52	-0.28±0.22	-20.88±10.93	1.86±1.42	0.44±0.63	8.97±14.22	9.11±1.67**
-	C	1.99±4.81	-0.80±0.37	-42.40±14.19**	-1.94±2.28	0.44±0.95	-33.94±17.95	2.41±2.71

* Significant at 5% probability level. ** Significant at 1% probability level.

Table (2): Types of gene action for some agronomic characters in three crosses of sunflower.

Crosses	Flowering date (days)	Stem diameter (Cm)	Plant height (Cm)	Head diameter (Cm)	100-seed weight (g)	Grain yield per plant (g)	Oil percentage
Cross I :							
m	80.98**	2.05**	166.61**	20.95**	8.26**	72.22**	30.22**
a	11.59**	0.51**	12.77	3.11**	2.03**	17.92*	-3.30
d	5.52	3.00**	82.69**	1.02	3.62**	71.78**	-1.54
aa	3.06	2.42**	61.69**	-1.98	0.82	33.00	6.32
ad	10.05**	0.73**	-7.27	1.01	1.10**	9.48	3.81*
dd	17.77	-2.80**	-42.78	1.80	-2.09	56.84	-0.07
Cross II :							
m	74.65**	2.51**	178.22**	20.98**	8.15**	72.91**	33.85**
a	3.01	0.26	35.34**	0.93	0.05	6.40	3.90**
d	2.30	0.15	-47.59*	-2.33	2.00	57.40*	-14.83**
aa	-2.02	0.04	-62.56**	-4.26	1.14	23.88	-7.28*
ad	-4.09	-0.22	10.45	-0.20	-0.81	-8.05	9.88**
dd	9.62	-0.13	125.42**	7.98	-1.97	-69.23	8.86
Cross III:							
m	69.14**	2.07**	144.66**	17.95**	6.70**	51.08**	43.36**
a	10.33**	0.48**	24.41**	1.83	0.69	27.48**	-4.27**
d	0.72	1.65**	48.72**	12.57**	4.56**	128.13**	3.92
aa	-7.90	1.56**	41.74**	11.26**	3.06**	93.64**	5.02
ad	4.78*	0.65**	29.27**	2.81*	0.87*	20.88*	-5.40**
dd	-17.39	-2.30**	-37.08	-20.58**	-5.68**	-153.33**	-12.45*

* Significant at 5% probability level.
** Significant at 1% probability level.

Table (3): Heterosis, inbreeding depression, potence ratio, heritability in broad and narrow senses and genetic advance for seven agronomic characters in three crosses of sunflower.

Character	Cross	Heterosis %		Inbreeding depression	Potence ratio	Heritability %		Expected genetic advance	
		M.P.	B.P.	%		h^2_b %	h_n %	g	g%
Flowering date (days)	I	10.80**	8.68**	8.18**	5.50	72.10	46.75	12.30	15.20
	II	5.86**	- 3.42**	4.55**	0.61	72.80	61.40	18.30	24.50
	III	-9.94**	-16.35**	-6.14**	-12.90	52.10	38.10	9.60	13.90
Stem diameter (Cm)	I	25.55**	14.45**	28.07**	2.64	68.20	64.30	0.97	47.98
	II	4.29**	2.41**	1.57**	2.33	58.30	31.20	0.55	21.90
	III	4.27**	-3.33**	10.78**	-0.54	28.40	6.90	0.09	4.20
Plant height (Cm)	I	12.29**	0.79**	15.54**	1.07	72.50	28.50	16.20	9.70
	II	8.79	-5.07	4.07	0.60	41.70	21.70	16.80	9.40
	III	5.95	2.65	9.45*	1.84	53.10	45.40	30.80	21.30
Head diameter (Cm)	I	15.86**	4.28**	4.40**	1.42	64.40	28.30	3.50	16.70
	II	9.70**	3.80**	3.79**	1.71	45.50	16.90	2.00	9.60
	III	7.40**	1.80**	5.97**	-0.68	65.20	10.20	1.10	6.00
100-seed weight (g)	I	41.00**	24.00**	14.04**	2.79	52.00	3.80	0.20	2.40
	II	23.80**	11.74**	5.89**	2.21	48.90	40.60	2.25	27.60
	III	24.75**	21.15**	11.38**	-8.33	39.50	8.90	0.36	5.40
Grain yield per plant (g)	I	59.75**	39.26**	21.20**	4.06	49.20	38.70	37.90	52.50
	II	66.11**	28.12**	13.53**	2.23	57.30	39.90	37.80	51.80
	III	81.47**	56.98**	33.49**	5.22	55.50	28.20	27.40	54.80
Oil percentage	I	-21.03**	-23.67**	- 2.54	1.10	84.20	70.80	12.86	42.60
	II	-37.43**	-46.30**	-49.44	2.26	83.30	77.00	13.40	39.60
	III	- 2.54*	- 4.99**	- 2.72*	1.01	72.80	70.60	11.60	26.70

* Significant at 5% probability level. ** Significant at 1% probability level.

of these traits. So, the most suitable type of selection is recurrent one which may be of importance for maturity and high oil percentage. On the other hand, the magnitude of heritability values in broad sense could be attributed to the low magnitude of the total genetic variance existed in F_2 generation and/or due to the high magnitude of error variance.

The medium and low values of heritability regarding to grain yield , 100 seed weight, head diameter, plant height and stem diameter are due to the low values of additive gene effects suggesting that selection as a method for this traits may be of no values in sunflower.

Consequently the expected genetic advance from selection (Δ g) and its percentage relative to the F_2 performance (Δ g%) exhibited the same trend and situation as heritabilities behaved.

Generally, from the previous discussion and according to the results obtained herein all genetic parameters of the crosses under study with respect to all characters indicated some guide lines. For example. flowering date and oil percentage traits results indicated that the additive effects and "ad" type of epistatic effects are more important than other types of gene effects. This was associated with high heritability values for the two traits. This conclusion may be useful to the breeder of sunflower in planning a selection program for improving the oil characters in such crosses. On the other hand, dominance and epistatic gene effects were found also to be contributing significantly in their inheritance. These characters were grain yield, 100-seed weight, head diameter, plant height and stem diameter. This suggested that non-additive gene action was important for these characters, in other words, the existance of dominance or epistatic justifies the use of hybridization for their improvement.

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