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ESTIMATION OF HETEROSIS AND COMBINING ABILITY IN SOYBEAN (*GLYCINE MAX* (L.) MERRIL) BY DIALLEL CROSS ANALYSIS

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ABSTRACT: *Nine attributes were measured in F_1 soybean crosses and their parents of a 5x5 diallel cross, excluding reciprocals. Five parents were used namely; Lamar, D79-8070, Giza35, PI416937 and L86K-73. F_1 hybrids gave average heterosis values over their midparent of 19.01% for plant height, 9.48% for number of branches per plant, 50.59% for number of pods per plant, 48.75% for number of seeds per plant and 56.34% for seed yield per plant. Hybrids were earlier in flowering and maturity than their later parents.*
Genotype mean squares were found to be highly significant for all the studied traits, except number of branches per plant. Both general and specific combining ability values were significant for all traits, except number of branches per plant, indicating the importance of additive, as well as non-additive gene action in the inheritance of these traits. High values of GCA/SCA ratio which largely exceeded the unity were detected for flowering date, maturity date, filling period, plant height and 100-seed weight. Variety Lamar was considered the best combiner for all studied traits. While Giza35 was superior combiner for number of seeds and seed yield per plant, and their F_1 crosses showed high SCA estimates for those traits.
Key Words: Saybean, Heterosis, Genotype.

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is an important food legume crop that was introduced into Egypt in the 1970's and gained local interest since then. For a highly self-fertilizing species such as soybean, two requirements should be satisfied for successful commercial production. First, there must be heterosis for seed yield and, second, an economical large-scale method of making hybrids must be found.

The development of more efficient breeding procedures is dependent upon a better understanding of the types of gene action controlling the inheritance of quantitative traits. One of the most important procedures used to supply genetic information about the parents and their crosses is the diallel analysis method. Therefore, the main objectives of this investigation were to study heterosis expression for all studied traits and combining ability analysis to help the breeder to identify and select superior genotypes for seed yield and major yield attributes. In addition, it facilitates the determination of type of gene action governing the inheritance of these traits.

MATERIALS AND METHODS

Five soybean varieties, of different maturity groups, were obtained from Food Legumes Research Section, Field Crops Res. Inst, ARC, Giza, Egypt. The common names, maturity group, growth habit, flower color and origin of these varieties are presented in Table (1). In 2000 growing season, a half diallel set of crossing involving parental varieties was carried out. Parents and their 10 F_1 hybrids were grown in 2001 season at the farm of Ital El-Baroud Agricultural Research Station. The experiment was arranged in a randomized complete block design with three replicates. Each plot consisted of one ridge 4 m long and 60 cm wide. Hills were spaces 20 cm with one seed per hill in one side of the ridge. All cultural practices were carried out as recommended for soybean production in the region.

Flowering time (in days) was recorded at 50% flowering of plants per plot. Maturity time (in days) was recorded at 95% pod maturity and filling period in days from flowering time to maturity time. At harvest, plant height (cm), number of branches per plant, number of pods per plant, number of seeds per plant, 100-seed weight (g) and seed yield per plant (g) were recorded as an average of 10 guarded plants taken randomly from each plot. The heterotic effects of F_1 crosses were estimated as percentage over mid and better parents (Mather and Jinks, 1971). The analysis of variance for combining ability and the estimation of various effects were done following the procedure of Griffing (1956) for method 2 model 1.

Table (1): Maturity group, growth habit, flower color and country of origin of the studied soybean varieties.

Variety	Maturity group	Growth habit	Flower color	Country of origin
Lamar	V	Indetermediate	White	United States
D76-8070	V	Indetermediate	White	United States
Giza35	III	Indetermediate	Purple	Egypt
PI416937	V	Determinate	Purple	United States
L86K-73	I	Indetermediate	White	United States

RESULTS AND DISCUSSION

Results in Table (2) presented means of parents and their F_1 for the studied characters; i.e., flowering date, maturity date, filling period, plant height, number of pods per plant, 100-seed weight, number of seeds per plant and seed yield per plant. All traits showed wide variation between

Table (2): Means of parents and their F_1 for the studied characters.

Genotypes	Flowering date (days)	Maturity date (days)	Filling period (days)	Plant height (cm)	No. of branches per plant	No. of pods per plant	100-seed weight (g)	No. of seeds per plant	seed yield per plant (g)
Lamar (P_1)	60	130	70	65.57	5.33	332.00	16.11	605.70	97.58
D79-8070 (P_2)	50	130	80	52.66	5.60	216.00	16.72	336.20	56.21
Giza35 (P_3)	**33**	**110**	**72**	**71.42**	**5.67**	180.30	**15.66**	**458.20**	71.57
PI416937 (P_4)	50	135	65	45.91	4.20	209.00	18.46	363.80	67.17
L86K-73 (P_5)	30	100	70	45.26	5.17	133.67	10.45	312.80	32.69
$P_1 \times P_2$	54	125	71	50.32	4.00	315.00	15.38	532.60	81.92
$P_1 \times P_3$	48	135	87	103.11	6.00	370.66	11.25	738.30	127.35
$P_1 \times P_4$	55	135	80	50.67	4.67	88.33	16.34	227.10	37.11
$P_1 \times P_5$	52	122	70	82.43	5.30	326.00	16.28	827.40	134.71
$P_2 \times P_3$	45	135	90	60.55	5.60	220.00	18.33	502.00	74.60
$P_2 \times P_4$	49	125	76	50.26	6.33	262.66	20.61	445.60	91.83
$P_2 \times P_5$	50	133	83	79.83	5.75	440.00	11.79	743.08	87.61
$P_3 \times P_4$	42	120	78	65.77	7.00	449.00	10.60	1275.80	135.24
$P_3 \times P_5$	32	105	73	60.32	5.33	196.00	14.06	518.43	72.89
$P_4 \times P_5$	40	118	78	60.56	6.50	397.00	13.62	94.20	128.30
$L.S.D_{0.05}$	3.36	3.79	3.28	8.01	1.66	33.97	3.88	12.59	7.23
$L.S.D_{0.01}$	4.53	5.10	4.41	10.79	2.24	45.74	5.22	16.95	9.73

parents and between their F_1 hybrids, these variations attributed to genetic diversity of the parents and their F_1 hybrids. The parental variety L86K-73 behaved as the earliest one (flowering date, maturity date and filling period). Also, it produced significantly the lowest seed yield per plant, number of pods per plant, number of seeds per plant and 100-seed weight. While, the parental variety 416937 was the latest one and variety lamer gave the highest value for seed yield per plant (97.58 g), number of seeds per plant and number of pods per plant. The mean performances of crosses are presented in Table (2). The hybrids tended to be late parents as compared to the early one. The cross (Giza35 x PI416937) gave the highest values for seed yield (135.24 g), number of seeds (1275.8) and number of pods (449) per plant.

Heterosis values measured from mid and better parent values are presented in Table (3). The results indicated that F_1 hybrids had more number of branches per plant (9.48%), more number of pods per plant (50.59%), more number of seeds per plant (48.75%) and higher seed yield per plant (56.34%) compared with mid parent values. Moreover, F_1 hybrids surpassed the better parent in plant height (11.39%), number of pods per plant (27.2%), number of seeds per plant (32.86%) and seed yield per plant (26.92%). These findings are in accordance with those reported by Mehta *et al.*(1984), Mansour (1991) and Ibrahim *et al.*(1996). Data presented in Table (4) indicated that mean squares with general and specific combining abilities (GCA and SCA) were highly significant in all traits, except for number of branches per plant which showed insignificant GCA and significant SCA. It is evident that additive and non-additive gene effects were involved in determining the performance of single cross progeny. Also, the results showed that all traits exhibited high GCA/SCA ratios which exceeded the unity, except number of branches per plant, number of pods per plant, number of seeds per plant and seed yield per plant. These results indicate the predominance of additive gene action in the inheritance of the traits with hight GCA/SCA ratio and predominance of non-additive gene action of the inheritance of the traits with low GCA/SCA ratio. Similar conclusion was reached by Paschal and Wilcox (1975), Gupta and Arora (1979), Bastawisy (1988), El-Refaey and Radi (1991) and Darwish (1993).

Estimates of general combining ability effects ($\hat{g}i$), presented in Table (5), revealed that Lamar and Giza35 cultivars were superior combiners for plant height, number of seeds per plant and seed yield per plant, because they showed highly significant positive ($\hat{g}i$) effects. The parental variety D76-8070 seemed to be the best combiner for earliness (flowering date, maturity date and filling period). The variety L86K-73 exhibited highly significant negative ($\hat{g}i$) effects for all traits under investigation. Similar results were obtained by

Table (3): Percentage of heterotic effects relative to mid (M.P) and better (B.P) parents for the studied traits.

Crosses	Flowering date (days)		Maturity Date (days)		Filling period (days)		Plant height (cm)		No. of branches /plant		No. of Pods /plant		100-seed weight (g)		No. of Seeds /plant		Seed yield /plant (g)	
	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P	M.P	B.P
$P_1 \times P_2$	-1.82	8.00**	-3.85**	-3.85*	-5.33**	1.43	-14.53*	-23.08**	-26.87	-28.57	14.96**	-5.12	-6.31	-8.01	13.09**	-12.07**	6.53	-16.05**
$P_1 \times P_3$	3.23	45.45**	12.50**	22.73**	22.54**	24.28**	51.47**	45.07**	9.09	5.82	44.70**	11.64*	-29.18**	-30.17*	38.79**	21.89**	50.58**	30.51**
$P_1 \times P_4$	0.00	10.00**	1.89	3.70	3.23	14.29**	-9.09	23.08**	-2.10	-12.38	-67.35**	-73.39**	-5.47	-11.48	-53.15**	-62.51**	-54.95**	-61.97**
$P_1 \times P_5$	15.56**	73.33**	6.09**	22.00**	0.00	0.00	49.09**	26.15**	0.95	-0.56	40.01**	-1.81	22.59	1.06	80.16**	36.60**	106.82**	38.05**
$P_2 \times P_3$	8.43*	36.36**	12.50**	22.73**	18.42**	25.00**	-1.63	-14.79*	-0.71	-1.23	11.03	1.85	13.22	9.63	26.38**	9.56**	16.76**	4.23
$P_2 \times P_4$	-2.00	-2.00	-5.66**	-3.85*	-7.88**	-5.00**	3.09	-3.85	29.18*	13.04	23.60**	21.60**	17.17	11.65	27.31**	22.48**	48.86**	36.71**
$P_2 \times P_5$	25.00**	66.67**	15.65**	33.00**	10.67**	18.57**	62.89**	51.92**	6.68	2.68	151.67**	103.70**	-13.21	-29.49*	128.99**	121.02**	97.10**	55.86**
$P_3 \times P_4$	1.20	27.27**	-2.04	9.09**	-0.64	8.33**	12.07*	-8.45	41.70**	23.46	130.67**	114.83**	-37.87**	-42.58**	210.41**	178.44**	94.95**	88.96**
$P_3 \times P_5$	1.59	6.67**	0.00	5.00*	2.82	4.86**	3.45	-15.49**	-1.66	-6.00	24.85*	8.71	7.70	-10.22	34.48**	13.14**	39.82**	1.84
$P_4 \times P_5$	0.00	33.33**	0.43	18.00**	0.65	11.43**	33.33**	33.33**	38.59*	25.73	131.71**	89.95**	-5.76	-26.22*	-72.15**	-74.11**	156.96**	91.01**
Mean	5.12	30.51	3.75	12.86	4.45	10.32	19.01	11.39	9.48	2.20	50.59	27.20	-3.71	-13.58	48.57	32.86	56.34	26.92

P_1, P_2, P_3, P_4 and P_5 are Lamar, D79-8070, Giza35, PI416937, L86K-73 varieties, respectively.

* and **: Significant at 5% and 1% level of probability, respectively.

Table (4): Mean squares for genotypes and their general and specific combining abilities and GCA/SCA ratio for the studied traits.

Trait	Genotypes	GCA	SCA	GCA/SCA	Error
Flowering date	234.37**	735.65**	33.86**	21.73	4.04
Maturity date	379.31**	838.23**	195.74**	4.28	5.13
Filling period	130.66**	138.51**	127.54**	1.09	3.84
Plant height	761.84**	949.00**	686.97**	1.38	22.92
Number of branches/plant	1.89	1.12	2.20*	0.51	0.99
Number of pods/plant	36433.15**	1924.53**	50236.59**	0.04	411.90
100-seed weight	27.92**	38.95**	23.50**	1.66	5.37
Number of seeds/plant	537900.47**	220065.80**	665034.34**	0.33	56.61
Seed yield/plant	5708.04**	2356.36**	7048.71**	0.33	18.65

* and ** : Significant at 5% and 1% level of probability, respectively.

Table (5): Estimates of general combining ability effects ($\hat{g}i$) of parents for the studied characters.

Parents	Flowering date	Maturity date	Filling period	Plant height	Number of branches /plant	Number of pods /plant	100-seed weight	Number of seeds /plant	Seed yield /plant
Lamar	7.42**	4.73**	-2.46**	5.84**	Not significant	15.68**	0.20	11.98**	4.27**
D76-8070	3.18**	4.83**	2.11**	-4.39**		2.20	1.36**	-79.61**	-13.98**
Giza35	-6.11**	-3.55**	0.97**	7.47**		-8.28*	-0.69	164.17**	10.86**
PI416937	1.47**	3.45**	2.41**	-8.46**		-5.61	1.10*	-4.52**	7.08**
L86K-73	-5.96**	-9.46**	-3.03**	-0.46		-3.99	-1.97**	-92.02**	-8.23**
S.E ($\hat{g}i$)	0.39	0.44	0.38	0.93		3.96	0.45	1.47	0.84
S.E ($\hat{g}i - \hat{g}j$)	0.62	0.70	0.61	1.48		6.26	0.71	2.32	1.33

* and ** : Significant at 5% and 1% level of probability, respectively.

Leffel and Weiss (1958), El-Hosary (1985), El-Hosary and Sedhom (1988), El-Hady *et al.*(1991), Habeeb (1998) and Mansour *et al.*(2001).

Comparison between specific combining ability effects ($\hat{S}_{ij}$) for crosses, Table (6) indicated that crosses (Lamar x Giza35), (Lamar x L86K-73) and (D76-8070 x L86K-73) had the highest and significant positive SCA effects for maturity date, filling period, plant height, number of pods per plant and seed yield per plant. Also, the cross (Giza35 x PI416937) exhibited the highest value and significant positive SCA effects for number of seeds per plant. Moreover, the cross (Giza35 x L86K-73) had significant and negative SCA effects for all the studied traits. For number of branches per plant, all crosses expressed insignificant SCA effects, except crosses (Lamar x D79-8070) gave negative and significant and (Giza35 x PI416937) and (PI416937 x L86K-73) had significant positive effects.

If crosses showing high SCA effects involve only one good combiner, such combinations would throw out desirable transgressive segregates providing that additive genetic system present the good combiner and complementary and epistatic effects present in the crosses act in the same direction to reduce undesirable plant characteristics and maximize the character in view. Therefore, the most previous crosses might be of prime importance in breeding program for traditional breeding procedures.

Table (6): Estimates of specific combining ability effects ($\hat{S}_{ij}$) of F_1 for the studied characters.

Crosses	Flowering date	Maturity date	Filling period	Plant height	Number of branches /plant	Number of pods /plant	100-seed weight	Number of seeds /plant	Seed yield /plant
Lamar x D76-8070	-2.56*	-8.54**	-6.19**	-13.81**	-1.14*	21.41*	-0.91	24.74**	0.58
Lamar x Giza35	0.73	9.84**	10.95**	27.33**	0.52	87.56**	-3.33**	-13.33**	21.17**
Lamar x PI416937	0.16	2.84*	2.52*	-9.74**	-0.46	-	-0.03	-355.85**	-65.29**
Lamar x L86K-73	4.59**	2.75*	-2.05*	14.26**	0.09	197.45**	2.98*	331.95**	47.59**
D76-8070 x Giza35	1.97	9.75**	9.38**	-4.95*	-0.12	38.60**	2.60*	-158.04**	-13.25**
D76-8070 x PI416937	-1.60	-7.25**	-6.05**	0.48	0.69	-49.63**	3.09*	-45.76**	7.69**
D76-8070 x L86K-73	6.83**	13.32**	6.38**	21.48**	0.24	-9.64	-2.67*	339.20**	18.75**
Giza35 x PI416937	0.68	-3.87**	-2.91**	3.62	1.23*	166.08**	-4.87**	1191.67**	95.26**
Giza35 x L86K-73	-1.89	-5.97**	-2.48*	-9.38**	-0.52	187.18**	1.65	-129.07**	-20.81**
PI416937 x L86K-73	-1.46	0.03	1.10	6.55**	1.00*	-67.44**	-0.58	-384.76**	38.38**
S.E ($\hat{S}_{ij}$)	1.01	1.14	0.99	2.41	0.50	130.89**	1.17	3.79	2.18
	1.39	1.56	1.35	3.30	0.69	10.23	1.60	5.19	2.98
S.E ($\hat{S}_{ij}$ - $\hat{S}_{kj}$)						14.01			

* and ** : Significant at 5% and 1% level of probability, respectively.

REFERENCES

Bastawisy, M.H. 1988. Genetical studies on soybean (*Glycine max* (L.) Merril). Ph.D. Thesis, Genetics Department, Faculty of Agric., Minufiya Univ., Egypt.

Darwish, G.A. 1993. Breeding studies on soybean. Ph.D. Thesis, Agronomy Department, Faculty of Agric., Saba Basha, Alex. Univ., Egypt.

El-Hady, M.M., M.A. Omar and S.A. Khalil, 1991. Heterosis combining ability and genetic components for yield and its variables in diallel crosses of faba bean. Egypt. J. Appl. Sci., 6 (10): 1-13.

El-Hosary, A.A. 1985. Heterosis and combining ability in F_1 and F_2 diallel crosses of faba bean (*Vicia faba* L.). Egypt. J. Agron., 10: 13-24.

El-Hosary, A.A. and S.A. Sedhom, 1988. Heterosis and combining ability for yield and its components in field bean (*Vicia faba* L.). Egypt. J. Agron., 131: 1-12.

El-Refaey, R.A. and M.M. Radi, 1991. Genetic analysis of seed yield and its related characters in soybean. II. Inbreeding depression and interrelation among traits in the F_1 and F_2 generations. J. Agric. Res. Tanta Univ., 17: 334-345.

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

Gupta, S.N. and N.D. Arora, 1979. Combining ability and gene action studies in mungbean. (C.F. Plant Breeding Abst., 8543, 49: 799).

Habeeb, M.B. 1998. Heterosis and combining ability in F_2 diallel crosses of soybean (*Glycine max* (L.) Merril). Minufiya J. Agric. Res., 23: 261-271.

Ibrahim, H.M., A.I. Nawar and S.H. Mansour, 1996. Heterosis, combining ability and components of genetic variance in soybean (*Glycine max* (L.) Merril). Minufiya J. Agric. Res., 21: 851-862.

Leffel, R.C. and M.G. Weiss, 1958. Analysis of diallel crosses among ten varieties of soybean. Agron. J., 50: 529-534.

Mansour, S.H. 1991. Genetical studies on soybean (*Glycine max* (L.) Merril). Ph.D. Thesis, Genetic Department, Faculty of Agric., Alex. Univ., Egypt.

Mansour, S.H., A.E. Khaled and A.A.M. Nassar, 2001. Combining ability of diallel analysis and heterosis performance of some faba bean varieties. J. Adv. Agric. Res., 6: 531-542.

Mather, K. and J.L. Jinks, 1971. Introduction to Biometrical Genetics. Cornell Univ. Press, New York, 231 pp.

Mehta, S.K.; M.S. Lal and A.B. Beohar, 1984. Heterosis in soybean crosses. Indian J. Agric. Sci., 54: 682-684.

Paschal, E.H. and J.R. Wilcox, 1975. Heterosis and combining ability in exotic soybean germplasm. Crop Sci., 13: 344-349.

تقدير قوة الهجين والقدرة على التآلف فى فول الصويا بإستخدام تحليل الهجن التبادلية

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الملخص العربى

تم عمل جميع الهجن الممكنة بين خمسة أباء من فول الصويا ماعدا الهجن العكسية وكانت الأباء المســتخدمة فى الدراسة هى (لامار، د٧٦-٧٠-٨٠، جيزة٣٥، ب أى ٤١٦٩٣٧، ل٨٦ ك-٧٣) وذلك بهــدف تقديــر قوة الهجين والقدرة العامة والخاصة على الإئتلاف وذلك فى الجيل الأول لصفات ميعاد التزهــير - ميعاد النضج - فترة النضج - طول النبات - عدد الفروع للنبات - عدد القرون للنبات - وزن ١٠٠بذرة - عدد البذور للنبات - وزن محصول النبات.

وأجرى هذا البحث بمحطة بحوث إيتاى البارود مواسم ٢٠٠٠ و ٢٠٠١ وقد حللت النتائج وراثياً حسب ما إقترحه العالم جريفنج سنة ١٩٥٦.

ويمكن تلخيص أهم النتائج المتحصل عليها كالآتى:

أعطــت هجن الجيل الأول متوسط قوة هجين أعلى من متوسط أبويها للصفات التالية: طول النبات (١٩,٠١%)، عــدد الفــروع للنبات (٩,٤٨%)، عدد القرون للنبات (٥٠,٥٩%)، لعدد البذور للنبات (٤٨,٧٥%) وكان محصول النبات الفردى أعلى بنسبة (٥٦,٣٤%).

أظهــر التبايــن الراجع للتراكيب الوراثية معنوياً لكل الصفات المدروسة ماعدا صفة عدد الفروع للنــبات الفــردى. وكــان التباين الراجع للقدرة العامة والخاصة على الإئتلاف معنوى لكل الصفات مما يشــير إلى أهمية كل من التأثير المضيف وغير المضيف للفعل الجينى على توريث الصفات المدروسة ومن ناحية أخرى أوضحت نسبة القدرة العامة إلى القدرة الخاصة على الإئتلاف زيادة فى تأثير التباين الوراثى المضيف فى الصفات المرتبطة بالتبكير وطول النبات ووزن ١٠٠ بذرة.

أظهــرت النــتائج أيضاً تفوق الصنف لامار فى قدرته العامة والخاصة على الإئتلاف فى كل الصــفات المدروســة بيــنما تفوق الصنف جيزة٣٥ فى الصفات المرتبطة بالمحصول ومكوناته، حيث أوضحت الهجن الناتجة منهما تقديرات عالية للقدرة الخاصة على الإئتلاف لتلك الصفات.