Egypt. J. Plant Breed. 14(1): 187 – 197 (2010)

COMBINING ABILITY AND GENE ACTION FOR YIELD AND ITS COMPONENTS IN CROSSES AMONG SEVEN FABA BEAN VARIETIES

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ABSTRACT

Seven faba bean parents were crossed in all combinations except reciprocals (Giza 3, Giza 2, Assiut 215, Giza 40, Triple White, Giza 429 and Misr 1). Parents and hybrids were evaluated. Results showed mean square due to both general and specific combining ability were highly significant for all characters studied except number of branches/plant indicating the importance of both additive and non-additive genes effects in the inheritance of these characters. The ratio of $\Sigma g_i^2/\Sigma S_{ij}^2$ mean squares were less than 1 for all studied traits, suggesting that non-additive type of gene action was more important in the inheritance of these traits. Estimates of GCA for seven parents revealed that some varieties have significant and positive GCA effects for all studied traits and these parents were considered as the best combiners for these traits except maturity dates. Significant SCA effects were observed for most crosses. Dominance gene effects played the major role in all studied traits. The parents showed unequal frequencies of dominant and recessive alleles in all traits. Narrow-sense heritability values were 0.55 for maturity dates, 0.36 for plant height, 0.51 for number of branches/plant, 0.45 for number of pods/plant, 0.23 for seed yield/plant and 0.49 for 100 seed weight.

Key words: ***Vicia faba, Faba bean, Combining ability, GCA, Heterosis, Gene action.***

INTRODUCTION

Faba bean (*Vicia faba* L.) is considered one of the most important sources of protein in Egypt and other developing countries. Also, it is an essential source for livestock feed in the world. In Egypt, there is little possibility of increasing the cultivated area. Therefore, it's important to develop high yielding varieties through breeding programs. Selection for upgrading seed yield from the "old" Egyptian faba bean varieties alone would not be effective (Ibrahim 1963), due to narrow genetic base. But, Abdalla (1964) challenged this approach and proved (Abdalla 1982) the possibility of improving faba bean through land races. Crossing genotypes could widening the genetic variability (Abdalla and Fischbeck 1983). The exploring with different exotic combining abilities of parentenal genotypes and type of gene action condition quantitative traits are of great value for the directing the breeding procedures. Generally, combining ability analysis is associated with additive effects of genes which specific combining ability is attributed primarily to non-additive (dominance and epistasis) genes. Also, identification of gene action such as additive, dominance and epistatic effect are very important for any breeding program.

Also, information on heterosis and combining ability helps the breeders to choice of suitable parents, in addition heritability estimates and the magnitude of the genetic variability for the different traits are very useful to identify the best progenies. Therefore, the breeder should evaluate the potentialities of the available germplasm for new recombinations and eventually combining ability which have proved to be of considerable use in breeding methods.

Different results were obtained by many authors with respect to heterosis, combining ability and gene action for faba bean genotypes and its hybrids for yield and its components. With respect to heterosis some workers reported that, some hybrids expressed positive and significant heterosis from mid and better parent for seed yield/plant and some other traits (Abdalla 1997, 1996, Abdalla and Fiscbeck 1983, Bakheit 1992, El-Hosary and Aziz 1997, Abdalla *et al* 1999, Abdalla *et al* 2001, Abdel-Mohsen 2004, Darwish *et al* 2005 and Farag 2007). In other studies, negative useful heterosis over mid-parent was detected special for flowering and maturity dates (El-Hady *et al* 1998b, Abdalla *et al* 1999 and 2001 and others).

General and specific combining ability and gene action wee studied by many workers using diallel crosses. In this respct, Bakheit (1992) and Youssef (1999), reported that both additive and non-additive gene effects controlling the genetic system of the studied traits. Additive gene effect was the main type in the inheritance of number of branches/plant, but dominance gene effects played the major role for the inheritance of seed yield/plant. While, Attia (2002) found dominance effects played an important role in the inheritance for plant height, 100-seed weight and number of pods and seed/plant but number of branches/plant and seed yield/plant was additive gene effects.

This work was carried out to study (1) Performance of parents and F_1 faba bean hybrids and (2) Estimate the general and specific combining ability and genetic behavior of yield and its components and other important characteristics in some faba bean crosses.

MATERIALS AND METHODS

The field trials of the investigation were conducted at Agricultural Experimental Farm Al-Azhar University, Assiut during 2005/2006, 2006/2007 and 2007/2008 seasons. Seven genotypes of faba bean of diverse origin were used as parental lines. The common names and origin are presented in Table (1).

Table 1. Name and origin of the parental varieties.

No.	Variety	Origin
1	Giza 3	Egypt, through hybridization
2	Giza 2	Egypt, through hybridization
3	Assiut 215	From hybridization program, Waly Assiut
4	Giza 40	Egypt, selection from Rebaya 40
5	Triple White	Introduction from Sudan
6	Giza 429	Egyptian selection from Giza 402
7	Misr 1	Egypt, through hybridization

In the (2005/2006) season, the seven parental genotypes were sown in a field in two planting dates with two weeks a part to ensure flowering sychronization. Parents were crossed in all possible combinations except reciprocals to produce 21 F_1 hybrids. These parents were crossed again during (2006/2007) season to obtained more hybrids seeds of all combinations. In the (2007/2008) season the seven parents and the 21F_1 hybrids were evaluated in a randomized complete block design with three replications. Planting was carried out on 29 October 2007. Plants were grown on rows, 3 m long and 45 cm apart, with single-seeded hills spaced at 20 cm. Each parent was represented by two rows/plot, while F_1 hybrid was represented by one row/plot. The recommended agricultural practices of faba bean production were used. The data were measured using ten guarded plants/plot at harvest for both of parents and F_1 hybrids. The following characters were recorded: days to maturity, plant height (cm), number of branches/plant, number of pods/plant, seed yield/plant (g) and100-seed weight (seed index).

Statistical analysis was made on an entry mean basis according to Gomez and Gomez (1984). The variation due to genotypes was partitioned into general and specific combining abilities as illustrated by Griffing (1956) Method (2), Model 1. The covariance matrix of Hayman (1954) was used to provide estimates of the standard error for the genetic parameters D, H_1, H_2 and F, their ratios and heritabilities.

RESULTS AND DISCUSSION

Analysis of variance for studied traits of the 7x7 half diallel cross is listed in Table (2). All components including genotypes, parents, 21 F_1's and parents *vs.* crosses were highly significantly except parents *vs.* crosses for number of branches and pods/plant. These results indicated the existing of differences among both parents and F_1 crosses. Also, distinctness of crosses from parents is tabulated. Mean squares due to general (GCA) and specific (SCA) combining ability were also highly significant for all characters for pods/plant. This suggesting that both additive and non-additive gene actions were important in the inheritance of all studied traits except number of

Table 2. Mean squares for eight agronomic traits of the 7x7 diallel mating cross.

Source of variation	d.f	Mean squares					
		Maturity date	Plant height	No. of branches/ plant	No. of pods/ plant	Seed yield/ plant	100-seed weight
Genotypes	27	22.37**	61.64**	1.45**	0.053**	58.07**	327.36**
Parents	6	83.56**	102.35**	1.52**	0.066**	66.17**	305.80**
Crosses	20	4.18**	50.83**	1.50**	0.051**	58.03**	327.55**
Parents vs crosses	1	29.00**	33.65**	0.02	0.002	10.35**	406.36**
GCA	6	40.10**	28.36**	1.27**	0.123**	23.97**	222.13**
SCA	21	17.30**	71.15**	1.50**	0.033	18.04**	76.83**
$\Sigma g_i^2/\Sigma S_{ij}^2$		0.26	0.04	0.09	0.43	0.15	0.32

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

pods/plant. The expected mean square ratio of $\Sigma g_i^2/\Sigma S_{ij}^2$ were less than 1 (Table 2) for all studied traits. These results indicating that the largest part of the total genetic variance is due to the non-additive gene effect than the additive one.

Table (3) presents data of the performance of parents and hybrids. The average number of days from planting to maturity for the parents ranged from 137.9 for Triple White to 153.1 days for Giza 40 with an average of 149.6 days. While, the F_1 crosses ranged from 148.7 for cross Triple White x Misr 1 to 153.0 days for Cross Giza 40 x Misr 1 with an average of 150.7 days. The average of the F_1 was more than average of the parents indicating positive heterotic effect. Moreover, the cross Triple White x Misr 1 was the best cross in maturity. With respect to plant height, the parents ranged from 75.3 for Giza 429 to 91.5 cm for Giza 3 with an average of 85.2 cm, while the F_1 crosses ranged from 78.7 to 93.4 cm with an average of 83.8 cm (Table 3). The average of the F_1 crosses was less than the average of the parents indicating negative heterosis.

Great variation among genotypes in number of branches/plant was obtained. The average of the F_1 crosses was approximately equal to the average of the parents (Table 3).

The average number of pods/plant, seed yield/plant and 100-seed weight for F_1 hybrids exceeded the average of parents indicating a positive heterotic effects for these traits (Table 3). The cross Giza 429 x Misr 1 approximately showed the highest number of pods and seed yield/plant.

Table 3.Mean days to maturity, plant height, number of branches and pods/plant, seed yield and 100-seed weight of the parents and F_1 crosses.

Genotypes	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	Seed yield (g)	100-seed weight (g)
P_1 (Giza 3)	151.4	91.5	6.37	28.5	90.0	72.6
P_1 x P_2	148.8	78.7	4.59	26.9	87.0	62.6
P_1 x P_3	151.4	88.5	5.53	29.3	88.0	61.3
P_1 x P_4	148.7	93.0	5.55	25.9	92.5	56.1
P_1 x P_5	150.4	81.2	4.61	24.2	89.4	61.7
P_1 x P_6	150.7	80.0	4.65	22.8	92.0	75.4
P_1 x P_7	151.3	82.8	4.27	24.4	83.2	52.8
P_2 (Giza 2)	149.9	86.1	5.24	26.6	85.1	60.4
P_2 x P_3	151.0	86.6	5.82	24.0	80.3	97.7
P_2 x P_4	129.3	93.4	5.16	23.2	85.6	75.5
P_2 x P_5	151.7	86.2	5.67	26.1	84.0	63.6
P_2 x P_6	152.0	84.5	5.17	27.4	83.6	64.4
P_2 x P_7	150.5	82.0	4.85	28.6	89.2	67.9
P_3 (Assiut 215)	150.5	87.7	5.82	28.7	83.5	56.7
P_3 x P_4	150.7	88.8	5.07	28.3	85.0	67.8
P_3 x P_5	151.0	79.9	6.12	28.7	91.1	70.3
P_3 x P_6	151.9	84.1	6.75	29.1	81.2	57.6
P_3 x P_7	149.7	86.2	4.79	30.0	91.1	64.5
P_4 (Giza 40)	153.1	87.0	5.36	24.3	90.2	68.0
P_4 x P_5	150.9	89.3	4.37	28.6	76.6	74.7
P_4 x P_6	149.9	83.9	6.36	25.2	88.5	65.7
P_4 x P_7	153.0	77.7	5.65	29.3	89.2	58.4
P_5 (Triple White)	137.9	79.3	5.65	24.0	77.3	46.2
P_5 x P_6	150.8	91.1	6.12	27.9	75.7	51.6
P_5 x P_7	148.7	84.8	6.28	29.1	83.2	50.3
P_6 (Giza 429)	151.9	75.3	4.53	23.1	81.1	51.0
P_6 x P_7	152.1	87.0	5.20	29.0	88.9	50.9
P_7 (Misr 1)	152.5	89.8	4.34	21.0	82.5	47.9
Parents mean ± S.E.	149.9 ±0.29	85.2 ±1.84	5.33 ±0.02	25.2 ±0.15	84.2 ±0.27	57.5 ±0.18
F_1 means + S.E.	150.7 ±0.23	83.8 ±1.29	5.36 ±0.19	27.0 ±0.18	85.1 ±0.47	62.9 ±1.56
L.S.D. 5%						
Parents	0.55	2.60	0.03	0.29	0.52	0.35
F_1	0.44	2.53	0.38	0.35	0.92	3.10

Estimates of general combining ability (GCA) effects of parental genotypes and specific combining ability (SCA) of their crosses are shown in Tables (4, 5, and 6) for different characters. Results revealed that all GCA effects of parents were statistically different from zero except for Giza 2 for maturity date, Giza 40 and Giza 3 for plant height, Giza 40 and Giza 429 for number of branches/plant, Triple White for number of pods/plant and Giza 2 for seed yield/plant. On the other hand, the parent Triple White gave the highest negative and significant GCA for maturity date, thus this parent was a good combiner for this trait. While the parents Giza 3 and Misr 1 have the highest positive GCA values for seed yield/plant thus these parents could be considered the best combiner for this trait. With respect to 100 seed weight, the parents Giza 2 and Assiut 215 gave the highest positive and significant GCA thus these parents were good combiners for this trait.

Table 4. Estimates of general and specific combining ability effects for days to maturity (above diagonal) and plant height (below diagonal) of seven parents and their 21 crosses.

Parents	SCA							GCA
	Giza 3	Giza 2	Assiut 215	Giza 40	Triple white	Giza 429	Misr 1	
Giza 3	-	-1.69**	0.51**	-2.42**	2.60**	-0.72**	-0.01	0.09**
Giza 2	-6.71**	-	0.30*	-1.79**	3.99**	0.78**	-0.71**	-0.02
Assiut 215	3.33**	0.34	-	-0.65**	2.93**	0.06	-1.84**	0.36**
Giza 40	-3.95**	8.47**	-3.89**	-	2.53**	-1.99**	1.27**	0.61**
Triple White	-1.77*	2.12*	-3.94**	-2.27**	-	2.20**	0.18	-2.66**
Giza 429	-2.95**	0.52	0.41	1.42	9.53**	-	0.05	0.85**
Misr 1	-2.23*	-4.07**	0.37	-6.89**	1.12	3.38**	-	0.77**
GCA	0.11	1.15**	0.94**	-0.35	-1.25**	-1.35**	0.77*	

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

	Days to maturity	Plant height
S.E. (g_i)	0.033	0.302
S.E. (S_{ij})	0.082	0.088
L.S.D$_{0.05}$ ($g_i - g_j$)	0.005	0.210
L.S.D$_{0.05}$ ($S_{ij} - S_{ik}$)	0.041	1.700
L.S.D$_{0.05}$ ($S_{ij} - S_{kl}$)	0.036	1.490

Regarding specific combining ability estimates eight cross combinations showed significant and negative SCA effects for maturity date. The cross (Giza 40 x Giza 3) had the highest significantly negative SCA effect and it could be considered the most desirable cross for improving maturity date. Also, four, nine, thirteen, eight and seven crosses showed significant and positive SCA values for plant height, number of branches and pods/plant, seed yield/plot and 100 seed weight, respectively.

Table 5. Estimates of general and specific combining ability effects for number of branches (above diagonal) and pods/plant (below diagonal) of seven parents and their 21 crosses.

Parents	SCA							GCA
	Giza 3	Giza 2	Assiut 215	Giza 40	Triple white	Giza 429	Misr 1	
Giza 3	-	-0.541**	-0.092	0.288**	-0.827**	-0.665**	-0.644**	-0.099**
Giza 2	0.900**	-	0.263*	-0.077	0.251*	-0.121	-0.036	-0.120**
Assiut 215	1.339**	-3.786**	-	-0.612**	0.266*	1.021**	-0.537**	0.321**
Giza 40	0.001	-2.611**	0.531**	-	-1.174**	0.951**	0.636**	0.004
Triple White	-2.135**	-0.134	0.532**	2.387**	-	0.532**	1.091**	0.183**
Giza 429	-3.020**	1.731**	1.523**	-0.408**	1.879**	-	0.139	0.055
Misr 1	-1.930**	2.395**	1.887**	3.133**	2.550**	3.001**	-	-0.340**
GCA	-0.243**	-0.374**	1.594**	-0.391*	-0.012	-0.547*	-0.027	

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

	No. of branches/plant	No. of pods/plant
S.E. (g_i)	0.36	0.192
S.E. (S_{ii})	0.104	0.185
L.S.D$_{0.05}$ ($g_i - g_j$)	0.055	0.158
L.S.D$_{0.05}$ ($S_{ii} - S_{ik}$)	0.156	0.164
L.S.D$_{0.05}$ ($S_{ii} - S_{ki}$)	0.145	0.153

Table 6. Estimates of general and specific combining ability for seed yield/plant (above diagonal) and 100-seed weight (below diagonal) for seven parents and their 21 crosses.

Parents	SCA							GCA
	Giza 3	Giza 2	Assiut 215	Giza 40	Triple white	Giza 429	Misr 1	
Giza 3	-	0.492	1.08**	-4.91	5.74**	-2.57**	-4.03**	1.54**
Giza 2	-7.05**	-	-5.22**	-0.34	1.68**	0.51	2.94**	0.12
Assiut 215	-6.11**	25.00**	-	-1.37	8.39**	-2.35**	4.44**	0.55**
Giza 40	-9.28**	4.88**	-0.63	-	-6.57**	4.46**	2.04**	1.03**
Triple White	4.03**	0.66	9.62**	-3.95**	-	-4.61**	-0.23	-2.68**
Giza 429	6.28**	0.05	-4.51**	5.62**	-0.75	-	4.67**	-1.85**
Misr 1	-4.47**	5.39**	4.21**	0.16	0.02	-1.03	-	1.28**
GCA	1.39**	6.66**	4.46**	2.42**	-5.31**	-3.88**	-5.74**	

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

	Seed yield/plant	100-seed weight
S.E. (g_i)	0.09	0.29
S.E. (S_{ii})	0.27	0.71
L.S.D$_{0.05}$ ($g_i - g_j$)	0.14	0.44
L.S.D$_{0.05}$ ($S_{ii} - S_{ik}$)	0.40	1.23
L.S.D$_{0.05}$ ($S_{ii} - S_{ki}$)	0.38	1.15

The cross (Misr 1 x Giza 40) had the highest positive and significant SCA effect and it could be considered the most desirable cross for improving number of pods/plant. With respect to seed yield/plant, the cross combinations: (Giza 2 x Misr 1), (Assiut 215 x Misr 1), (Giza 40 x Misr 1), and (Giza 429 x Misr 1) have the highest positive and significant effects and could be considered for improving this trait. Since they having the highest seed yield/plant and SCA. The parent Misr 1 which had the high positive GCA effect for yield was as a common parent in those four crosses for seed yield/plant. These results were in agreement with those obtained by Bakheit (1992), Abd El-Mohsen (2004) and Attia (2002).

Estimates of the genetic components and their corresponding standard errors are presented in Table (7). The results showed that the magnitude of additive effect "D" was significant for maturity date, plant height, number of pods/plant, seed yield/plant and 100 seed weight, but insignificant for number of branches/plant. The H_1 and H_2 estimates were significant and greater than D, indicating that the dominance gene effects play a major role in the inheritance of all traits. The $H_2/4H_1$ values were less than 0.25, indicating unequal distribution of dominant and recessive alleles among the parents for all traits. The quantities of $(H_1/D)^{½}$, a weighted measure of the average degree of dominance at each locus, were found to be more than unity for all traits, indicating the presence of over-dominance. Hayman (1954) stated that epistasis can decrease or increase the average degree of dominance. Moreover, Mather and Jinks (1971) noted that the most important shortening of estimating D and H is that unless U=V=½ at each locus, D does not contain only additive genetic effects and H contains less than the whole of the dominance effects, with the consequence that the ratio of H to D is not a measure of the degree of dominance. Consequently, the over-dominance obtained for all traits from the ratio $(H_1/D)^{½}$ is not reliable. The "F" values were positive and highly significant for all traits, indicating an excess of dominant over recessive alleles. This result was confirmed by the ratio KD/KR which was more than one. These results are in line with those reported by El-Hady *et al* (1998a), Attia *et al* (2002), Salama and Mohamed (2004) and Farag (2007) for some traits.

Broad and narrow-sense heritability estimates (Table 7) were 0.93 and 0.55 for maturity date, 0.88 and 0.36 for plant height, 0.94 and 0.51 for number of branches/plant, 0.98 and 0.45 for number of pods/plant, 0.96 and 0.23 for seed yield/plant and 0.97 and 0.49 for 100-seed weight. Accordingly, selection could be effective in the segregating generations for improving these traits. These finding are in agreement with many reviewed authors.

Table 7. Estimates of components of genetic varieties and their ratios in a 7x7 diallel cross for the studied traits.

Components	Days to maturity	Plant height	No. of branches/ plant	No. of pods/plant	Seed yield (g)	100-seed weight (g)
D	27.8** ±0.16	31.5* ±3.56	0.46 ±6.83	8.23** ±0.26	21.8** ±1.06	99.1** ±7.8
H_1	30.2** ±0.38	105.2** ±8.57	2.26** ±0.16	31.59** ±0.62	78.5** ±2.56	347.5** ±18.8
H_2	16.18** ±0.33	74.3** ±7.55	1.16** ±0.14	21.00 ±0.54	65.4** ±2.25	241.3** ±16.6
F	30.04** ±0.38	60.3** ±8.54	0.88** ±0.16	10.10** ±0.61	24.6** ±2.55	84.4** ±18.8
$(H_1/D)^{½}$	1.04	1.83	2.22	1.96	1.90	1.87
$H_2/4H_1$(UV)	0.13	0.18	0.18	0.17	0.21	0.17
KD/KR	3.14	3.20	2.52	3.00	1.35	1.59
Broad sense heritability	0.93	0.88	0.94	0.98	0.96	0.97
Narrow sense heritability	0.55	0.36	0.51	0.45	0.23	0.49

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

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القدرة على الائتلاف وفعل الجين للمحصول ومكوناته فى الهجن الناتجة بين سبعة أصناف من الفول البلدى

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الهدف من هذا البحث هو تقدير الأهمية النسبية للقدرة العامة والخاصة على التآلف لصفات المحصول ومكوناته بالإضافة إلى فعل الجين فى الفول البلدى باستخدام تحليل الدياليل . وقد أستخدم عدد سبعة آباء من الفول البلدى (جيزه ٣، جيزه ٢، سلالة أسيوط ٢٠٥، جيزه ٤٠، تربل ويت، جيزه ٤٢٩، مصر ١) تم التهجين بينهم فى كل الاتجاهات عدا الهجن العكسية. وتم دراسة الآباء والهجن فى الموسم ٢٠٠٧ ، ٢٠٠٨ بالنسبة للصفات التالية (عدد الأيام حتى النضج، طول النبات، عدد الفروع/ للنبات، عدد القرون/للنبات ، محصول البذرة / للنبات، وزن ١٠٠ بذرة) .ويمكن تلخيص أهم النتائج فيما يلى :

١- كان مربع الانحرافات الراجعة إلى قوة التآلف العامة والخاصة معنوية جداً لجميع الصفات تحت الدراسة فيما عدا القدرة الخاصة لعدد الأفرع للنبات مما يؤكد أهمية كل من الفعل المضيف وغير المضيف للجين فى وراثة هذه الصفات .

٢- كانت النسبة بين مجموع مربع الانحرافات لقوة التآلف العامة والخاصة لكل الصفات تحت الدراسة أقل من ١ وهذا يبين أهمية الفعل الغير مضيف فى وراثة هذه الصفات .

٣- أوضحت قوة التآلف العامة لسبعة آباء أن بعض الأصناف كانت معنوية وموجبة فى جميع الصفات التى تمت دراستها وعليه فإن هذه الآباء تعتبر الأحسن فى القدرة العامة على التآلف لهذه الصفات فيما عدا تاريخ النضج .

٤- أوضحت تقديرات القدرة الخاصة على التآلف وجود تأثير معنوى فى معظم الصفات تحت الدراسة.

٥- كان للتأثيرات الوراثية السائدة الدور الرئيسى فى توريث جميع الصفات التى تم دراستها.

٦- أظهرت الآباء تكرارات غير متساوية للأليلات السائدة والمتنحية فى جميع الصفات المدروسة .

٧- كانت قيم التوريث الخاصة ٠.٥٥ لتاريخ النضج ، ٠.٣٦ لطول النبات ، ٠.٥١ لعدد الأفرع /للنبات ، ٠.٤٥ لعدد القرون / للنبات ، ٠.٢٣ للمحصول البذرى للنبات بالإضافة إلى ٠.٤٩ لوزن ١٠٠ بذرة.

المجله المصريه لتربية النبات ١٤ (١) : ١٨٧ - ١٩٧ (٢٠١٠)