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COBINING ABILITY AND HETEROSIS IN EGGPLANT (*Solanum melongena* L.)

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ABSTRACT

A full diallel was established in 2006 at Duhok Univ., Iraq, to study heterosis and combining ability for growth, and yield components in four varieties, Early long purple(1),Long purple(2),Black Beauty(3), and Alton kubry (4) of eggplant. The results revealed that F1's exhibited significant heterosis for all traits. The hybrid (3×1) gave the highest heterosis value for plant height and fruit weight. The hybrid (4×2) produced the greatest value for number of branches and early yield plant^{-1} . Whereas, the hybrid (4×1) was earliest in date of flowering and possessed the highest heterosis in fruit diameter. The parent 2 (long purple) revealed as the best general combiner for most desirable traits . Analysis of combining ability indicated that GCA mean square was significant for all traits, whereas, SCA mean square was non-significant in number of branches ,number of leaves till 1st inflorescence, total and early yield. Specific combining ability results for each hybrid exhibited that 2x4 was characterized with a good specific combining ability for most traits .On the other hand ,there was a significant reciprocal effect's for date of flowering, no. of flowers inflorescence^{-1} , average fruit weight, no. of fruits plant^{-1} ,fruit length and diameter which was obviously recognized between the hybrid 3x1 and its reciprocal.

Key words : combining ability , heterosis , eggplant.

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INTRODUCTION

Eggplant (*Solanum melogena* L.) is a native to the tropical regions of the far east, which is considered as one of the most important vegetable crop in Iraq. The yield and yield quality improvement in the world production is in progress, but the production of this crop in Iraq 13889 kg ha^{-1} exhibits very low rates as compared to the world production 16176 kg.ha^{-1} (Anonymous, 1998). In order to improve yield traits, studies should be concentrated on how to use the useful production means such as suitable breeding programmes to produce hybrids of high heterosis and combining ability which in turn will be reflected in yield improvement (Al-Hubaity, 1996). Sousa and Maluf (1998) found through diallel crossing between 7 eggplant cultivars, significant heterosis relative to the parent mean was detected for total fruit yield, average fruit weight and early yield. Al-Hamadani (1999) in his study on the hybrid vigour, have obtained good F1- hybrids having many desired traits in eggplant. Al-Hayani (2000). Baishya *et al*. (2001) found out that majority of crosses showed desirable negative heterosis over better parent for days to flowering and days to ripening, the highest heterosis over mean parents was

*Part of M.Sc. thesis of the second researcher.

recorded for number of fruits plant^{-1}, fruit weight and yield plant^{-1}. AL-Shaf *et al*. (2003) found that the hybrid (Muqdadya X Abu-Eljethe) exceeded significantly the best parents in 6 from 10 traits in desired direction. Whereas, the highest heterosis percentage in plant yield was found in the hybrids (Rashidya X Abu-Ghraib) , (Muqdadya X Abu-Eljethe) and (Muqdadya X Abu-Ghraib), so they are regarded as promising hybrids. Hussain *et al*. (2004) found in a diallel cross among 5 local varieties of eggplant, the hybrid (Alton kopry X Akhdar yashel) and its reciprocal produced higher number of fruits plant^{-1}, the hybrid (Mahaly X Akhdar yashel) and reciprocal (Akhdar yashel X Sulaymaniya) produced higher average fruit weight and yield plant^{-1}. Khalil *et al*. (2004) said that the hybrid vigour was detected for both early and total fruit yield, in addition to average fruit weight. Diallel cross applied among some varieties of eggplant by many researches (Singn *et al*, 1981; Mohammed *et al* , 1995 ; Al-Hamdani, 1999; Sharma *et al* ,2002; Nandadevi *et al* ,2003 ; Bisawajiti *et al* ,2004) who illustrated that mean squar of general and specific combining abilities (GCA , SCA) were significant in many studied traits with predominant of one combining ability over the other according to the studied trait. Some of those researches state distinguishing some varieties in their good combining ability which producing hybrids characterized with good specific combining ability.

The objectives of this investigation are to determine the best single formulated hybrids which give a significant heterosis in many traits, in addition to determine the best parents using in formulating these distinguishing hybrids, through estimating general and specific combining ability and to identify the nature of gene action in order to enable plant breeders for selection of the suitable breeding method toward improving the eggplant productivity.

MATERIALS AND METHODS

Four varieties of eggplant, viz. Early Long Purple (1), Long purple (2), Black Beauty (3) and Alton Kubry (4), which differed considerably in many important traits were selected. They were crossed in all possible combination during growing season of 2006. All the 12 F1 hybrids and their parents were grown in a Randomized Block Design with 3 replication during 2007 season. Each variety was grown in a single- row plot 3 m. long spaced 1m. apart having 7 plants. Agricultural practices were performed as recommended (Matlob *et a*l, 1989). Plants were selected randomly from each plot and observations were recorded on; plant height (cm), number of branches/plant, flowering date (day) by counting the number of days from planting to opening the first flower, number of flowers inflorescence^{-1}, number of fruits plant^{-1}, average weight of fruit (g), fruit length and diameter (cm), early yield (kg/plant) which included the first three harvestings start from 10/8 to 29/8/2007 and the total yield plant^{-1} (kg). Heterosis was determined for various traits in each hybrid as follows:

$$\text{Heterosis } (H) = \overline{F}1 - \frac{\overline{p}i + \overline{p}j}{2} \quad \text{(Falconer, 1989)}$$

Significance of heterosis was tested by calculating t value in each hybrid according to the following equation:

$t = \frac{H}{\sqrt{V(H)}}$ where: (Aneice , 2010)

H = Heterosis

V(H) = Heterosis variance = (3/2) (mse/r)

The combining ability analysis was conducted to determine different parents and genetic parameter, by analysing the results of genotypes (4 parents +12 hybrids) according to RCB Design which was carried out by using, the first method model 1 of Griffing analysis (1956), to estimate the general, specific and reciprocal ability with their effects.

RESULTS AND DISCUSSION

Table (1) shows significant and positive heterosis over the midparent existed for three hybrids only, where the hybrid 3x1 was the longest one (13.42cm) for the plant height, whereas the hybrid 4x2 only gave a significant and desirable positive increase for the number of branches. This agreed with the finding of Borikar *et al*. (1981) and Saha *et al*., (1991) who found that heterosis tests were significant for plant height and number of branches plant^{-1}. For number of leaves till first inflorescence, the only hybrid 4x1 gave a significant undesirable increase (-2.08), while other hybrids gave non-significant increase in both desirable and undesirable directions. The hybrid 4x1 was the earliest one in flowering surpassed the mid parents, whereas, the hybrids 3x2, 3x4 and 4x2 gave significant increase but in the undesirable direction. It is observed that more hybrids producing late flowers involved parents (4) and (3), this indicates that both parents participated in increasing the value of these hybrids in this trait toward undesirable trend. This result is in accordance with those of Singh *et. al*. (1978) and Hassan *et. al.* (1982), who found significant heterosis for the date of flowering, number of flowers inflorescence^{-1}, five hybrids were superior in the desirable direction over midparents value. Hybrids 3x1, 3x2 and 3x4 revealed positive significant increase for the average weight of fruit and the hybrid 4x3 gave significant decrease in this trait. This increase in individual fruit weight of hybrids over their parents may or may not be desirable in that small fruits have been reported to be preferred for commercial production purposes Lipert and legg (1977) in muskmelon and AL-hamdany (1999) in eggplant, knowing that the Iraqi consumer prefer the small fruits of eggplant. Similar results had been obtained by Salehuzzman (1981) ; and Dixit *et.al*. (1982) , Who found significant heterosis in fruit weight . Five hybrids were superior in the desirable direction but non- significant for number of fruits plant^{-1} trait, whereas, the hybrids 2x1, 3x1 and 3x2 exhibited significant decrease. These results are in agreement with those of Joarder *et.al*. (1981) and Hassan *et.al.* (1982).Non significant heterosis were noticed in negative or positive direction for total yield plant^{-1} for all hybrids. In the early yield trait, five hybrids revealed favorable heterosis over midparent but non-significant excluding the hybrid 4x2 which gave significant and positive increase. Hybrids 3x1, 3x2 and 3x4 showed a significant decrease in fruit length and it is observed that the parent (3) contributed in decreasing values of its hybrids for this trait, while six hybrids gave non- significant positive excess.

Favorable heterosis was found for fruit diameter trait in 2 hybrids 2X4 and 4X1 recorded (0.73) cm and (0.96) cm respectively and 3 hybrids gave significant increase in undesirable direction. Elongation of fruit shape, and increases of fruit weight were reported by Joarder *et al*. (1981) and Dixit *et.al.* (1982).

Combining Ability: Table (2) shows the results of variance analysis for general ,specific and reciprocal effects .It is clear that the significant differences were present among genotypes for all traits except early yield plant^{-1} which had not reached the significant level.General combining ability mean squares were significant of probability of 1% for all traits expect the early yield trait which was significant at level 5% . Similer results are reported by Lal and Pathak (1974) and Muhammed *et al* (1995). Mean square of SCA were significant at the level 1% for plant height, date of flowering and fruit diameter and at the level 5% for number of flowers inflorescence $^{-1}$, average fruit weight, fruits number plant^{-1} and fruit length traits, but it was not significant in number of branches, number of leaves till first inflorescence ,total yield and early yield .These results showed concordance with those of Saha *et al* (1991) and Muhammed *et al* (1995) for plant height and agreed with those of Singh and Singh (1981) for number of fruits plant^{-1} , date of flowering, fruit length and fruit weight. On the other hand, the ratio between variance of general and specific combining ability was found to be larger than one in all traits with the maximum value of (9.79) for the average fruit weight ,this is due to the increase of variation components belonging to the general combining ability and shortage of variation components belonging to specific combining ability .This is in conformity with the finding of Singh *et al* (1974) , Lal and Pathak (1979) , Dharmegowda *et al* (1979) and Singh and Singh (1981). To evaluate the parents according to their combining ability, the effect of general combining was estimated for each parent as shown in table (3). It is obvious that parent (1) was a good combiner for number of branches, number of flowers inflorescence $^{-1}$, number of fruits plant^{-1} , total yield and fruit length. And its effect was negatively significant for plant height number of leaves till first inflorescence, average fruit weight , date of flowering , early yield and fruit diameter.On the other hand, parent (2) was significantly a good combiner in the desirable direction with number of branches, number of flowers inflorescence^{-1} , fruits number plant^{-1}, fruit length, yet it had no a significant combination with plant height, number of leaves till first inflorescence, date of flowering, total and early yield, but it was significant in an undesirable direction with fruit weight and fruit diameter.

It was found that parent (3) had a significant desirable GCA effect for the average fruit weight, early yield and fruit diameter, and in the undesirable for plant height, number of leaves till first inflorescence, number of branches, date of flowering, number of flowers inflorescence^{-1} fruits number plant^{-1}, total yield of fruit length. As for parent (4), its general combining ability was toward the desirable direction for plant height and average fruit weight and revealed undesirable direction for number of leaves till first inflorescence , date of flowering , number of flowers inflorescence^{-1}, fruits number plant^{-1} and total yield. It is evident from the abovementioned results that parent (2) gave a desirable general combining ability in most traits. Table (4) showed estimation on specific combining ability effect for each hybrid in the studied traits.

It was observed that hybrid the 1x2 had a specific combining ability effect in the desirable direction for fruit length and diameter, while it exhibited undesirable direction effect for both number of fruit^{-1} and total yield. The hybrid 1x3 revealed a specific combining effect in the desirable direction for plant height and fruit weight and undesirable direction for number of leaves till 1st inflorescences, number of flowers inflorescence^{-1} , no. of fruits plant^{-1} , fruit length and diameter. The effect of specific combining ability in the hybrid 1x4 showed negatively an undesirable direction for average fruit weight, but it had a desirable direction for plant height date of flowering, number of flowers inflorescence^{-1} , number of leaves till 1st inflorescence , total yield and fruit length . As for the hybrid 2x3 , it had a desirable specific combining ability effect for plant height and revealed undesirable from for number of flowers inflorescence^{-1} , fruit and diameter. The hybrid 2x4 recorded a specific combining ability effect in the desirable direction for number of branches, total yield, early yield, fruit length and diameter traits. Whereas, the hybrid 3x4 had undesirable specific combining ability effect for plant height, date of flowering and fruit diameter. From the above-mentioned results, it could be concluded that the hybrid 1x4 was characterized by significant specific combining ability in desirable directions for most important traits .

Reciprocal Effect: Table (2) shows the significant reciprocal effects of date of flowering, number of flowers in inflorescence, average fruit weight, number of fruits plant^{-1}, length and diameter of fruit, whereas, they were non significant in other traits . These results are in harmony with those of Trinklein and Lambeth(1975) in tomato. It is evident from table (5) that the greatest differences was between the hybrid 3 x 1 and its reciprocal 1x3 , whereas, the lowest differences was found between the hybrid 2x1 and its reciprocal 1x2 and well in the hybrid 4x1 and its reciprocal 1x4 . This indicates that both parent (1) and (3) were genetically distanced . On the other hand, both parents (1) and (2) as well as parents (1) and (4) were very close. Relatively, this coincides with their hybrids towards the parents (1) and (3) . However, the differences of intensity between reciprocal hybrids 4x2 , 2x4 , and 2x1 , 1x2 were almost matching . Similar results were recorded with the differences between the reciprocal hybrids 3x2 , 2x3 , and 4x3 , 3x4. These differences can be attributed to the existence of the cytoplasmic genetical differences, as obtained by other workers (AL_Hamdani, 1999; AL-Hayani, 2000; Hussain *et al* , 2004). This effect in the parents can be divided into three categories : parent (3) represents the first part; parents (2) and (4) comprise the second part; and the third; involves parent (1) . This divisions vary with each other , but the differences between first and third divisions are more pronounced.

From the previously mentioned results, the following conclusion can be drawn that the parent (Long Purple) possessed the best combination and superiority in many traits , which supports their abilities to be included in eggplant breeding programe. On the other hands , the hybrid 1x4 characterized by significant specific combining ability in desirable directions for most important traits.

Table (1): Heterosis relative to the parental mean for the studied traits.

Hybrids	Plant height (cm)	No. of branches / plant	No. of leaves till 1st inflorescence	Date of flowering (day)	No.of flowers/ inflorescence	Average wt. of fruit (g)	No. of fruits/ plant	Early yield / plant (kg)	Fruit length (cm)	Fruit diameter (cm)	Total yield / plant (kg)
1x2	4.25	-0.25	-0.23	-3.17	-0.78	3.09	-8.44	-0.18	1.16	0.16	-0.31
1x3	-1.58	-3.17	-0.78	-1.67	0.10	1.98	-9.72	-0.12	-1.00	-2.71**	0.19
1x4	4.00	1.00	-1.38	-3.00	0.32	-6.27	2.88	0.10	-0.75	-0.04	0.46
2x1	6.25	0.58	0.23	-0.17	-0.55	13.81	-21.00**	0.05	0.16	0.63	-0.61
2x3	10.67 *	1.00	-0.40	-1.5	-0.45	-11.61	1.05	-0.10	-0.12	-2.32**	0.21
2x4	-0.58	0.92	-1.28	0.16	-0.90	-1.19	3.22	0.07	0.81	0.73*	0.54
3x1	13.42**	-1.42	1.30	1.66	-1.67**	41.74**	-27.38**	0.03	-2.43**	-0.24	-0.53
3x2	10.00 *	0.17	0.93	4.83**	-2.75**	37.58**	-18.39**	-0.07	-2.55**	-0.43	-0.30
3x4	-18.58**	1.25	0.08	7.33**	-0.68	21.58**	-1.94	-0.04	-1.71*	0.01	0.22
4x1	-1.33	-1.33	-2.08*	-4.33*	0.98	-4.43	0.22	-0.12	0.06	0.96*	0.53
4x2	-0.58	1.75*	0.48	3.83*	0.43	-0.39	-0.44	0.47**	0.76	0.17	0.33
4x3	-12.08*	-0.25	-0.92	0.67	0.42	-14.47*	1.39	-0.01	0.22	-2.40**	-0.19

* , ** significant at P (0.05 , 0,01) respectively.

Table (2): Analysis of variance of general, specific and reciprocal effect for studied traits.

Source	d.f	Means Squars										
		Plant height (cm)	No. of branches /plant	No. of leaves till 1st infloresc ence	Date of flowering (day)	No of flowers / inflorescence	Average wt. of fruit (g)	No. of fruit / plant	Early yield / plant (kg)	Fruit length (cm)	Fruit diameter (cm)	Total yield / plant (kg)
Replications	2	14.67	0.30	0.10	6.27	1.99 *	179.79	141.18	0.12	0.957	0.79	o.11
Genotypes	15	476.45 **	3.09*	4.83 **	93.42 **	4.12 **	2547.81 **	884.46 **	0.08	13.44 **	13.09 **	0.83*
GCA	3	568.14 **	2.3 **	4.77 **	120.92 **	3.72 **	3120.09 **	1147.51 **	0.05*	19.01 **	17.17 **	0.90**
SCA	6	87.95 **	0.46	1.09	7.39 **	0.58*	111.44 *	90.01*	0.02	1.08 *	0.91 **	0.15
Reciprocal	6	25.01	0.96	0.55	9.99 **	0.99 **	451.69**	73.29 *	0.02	1.11 *	1.42 **	0.09
Error	30	40.77	1.21	1.26	4.60	0.45	97.71	69.99	0.05	1.03	0.22	0.25
$\frac{Ø^2 \text{ g.c.a.}}{Ø^2 \text{ s.c.a}}$		1.86	8.05	1.61	5.09	2.07	9.79	4.21	2.22	5.9	5.12	3.01

* , ** significant at P (0.05 , 0.01) respectively.

Table(3): Estimate of general combining ability effects (ĝi) for each parents of studied traits.

Parents	Mean squares										
	Plant height(cm)	No. of branches/ plant	No. of leaves till 1st inflorescence	Date of flowering (day)	No. of flowers /inflorescence	Average of wt. of fruit (g)	No.of fruits/ plant	Early yield / plant (kg)	Fruit length (cm)	Fruit diameter (cm)	Total yield /plant (kg)
1	- 7.323	0.438	- 1.069	- 5.167	0.313	-15.328	13.604	-0.095	1.385	-1.079	0.465
2	- 1.281	0.396	- 0.002	- 0.500	0.771	-14.544	5.701	0.001	0.892	-0.912	0.022
3	- 3.469	- 0.708	0.727	3.917	- 0.783	26.713	-13.285	0.102	-1.990	2.104	- 0.215
4	12.073	- 0.125	0.344	1.75	- 0.300	3.159	-6.021	-0.008	-0.286	-0.112	- 0.272
SE (gi- gi)	1.843	0.317	0.324	0.619	0.193	2.854	2.415	0.062	0.292	0.134	0.143

Table(4): Estimate of specific combining ability effects (ŝij) of hybrid in studied traits.

Hybrids	Plant height (cm)	No. of branches/ plant	No. of leaves till 1st inflorescence	Date of flowering (day)	No. of flowers /inflorescence	Average of wt. of fruit (g)	No.of fruits/ plant	Early yield/ plant (kg)	Fruit length (cm)	Fruit diameter (cm)	Total yield /plant (kg)
1x2	-0.760	0.042	0.015	-0.542	-0.188	0.141	-6.201	-0.062	0.647	0.340	- 0.376
1x3	3.427	-0.438	1.019	0.208	-0.300	11.108	-8.660	0.027	-0.754	-0.650	- 0.054
1x4	2.719	-0.188	-1.115	-2.625	0.433	-5.858	3.190	-0.029	-0.259	0.344	0.327
2x3	7.219	0.188	-0.115	0.042	-0.692	3.317	-1.201	-0.068	-0.750	-0.572	0.057
2x4	0.177	0.604	0.152	1.208	-0.025	-0.217	1.312	0.184	0.496	0.311	0.251
3x4	-11.052	0.208	-0.194	2.292	0.079	-0.306	1.021	-0.040	-0.056	-0.456	- 0.138
SE(sij-sik)	3.193	0.549	0.561	1.073	0.334	4.942	4.183	0.108	0.507	0.233	0.248
SE(sij-ski)	2.607	0.449	0.458	0.876	0.273	4.035	3.415	0.088	0.414	0.190	0.202

Table (5): The reciprocal effect of each hybrid for studied traits.

Hybrids	Plant height (cm)	No. of branches/ plant	No. of leaves till 1st inflorescence	Date of flowering (day)	No. of flowers /inflorescence	Average of wt. of fruit (g)	No.of fruits/ plant	Early yield/ plant (kg)	Fruit length (cm)	Fruit diameter (cm)	Total yield /plant (kg)
2x1	1.000	0.417	0.233	1.500	0.117	5.362	-6.278	0.116	-0.500	0.239	- 0.152
3x1	7.500	-0.666	-0.033	1.667	-0.883	19.881	-8.833	0.077	-0.717	1.233	- 0.361
4x1	-2.667	-1.167	-0.350	-0.667	0.333	0.920	-1.333	-0.106	0.406	0.500	0.036
3x2	-0.333	-0.416	0.666	3.167	-1.150	24.600	-9.722	0.017	-1.217	0.945	- 0.254
4x2	0.000	0.417	0.883	1.833	0.667	0.397	-1.834	0.197	-0.022	-0.278	- 0.103
4x3	3.250	-0.750	-0.500	-3.333	0.550	-18.026	1.667	0.013	0.967	-1.206	- 0.208
SE(*rij*-*rki*)	3.686	0.634	0.648	1.239	0.386	5.707	4.830	0.125	0.585	0.269	0.286

Figures: Showing difference among the parents and some hybrids.

تحليل قدرة الائتلاف وقوة الهجين في الباذنجان
(*Solanum melongena* L.)

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الخلاصة

استخدم في البحث أربعة أصناف من الباذنجان(1) Early Long purple ، Long purple (2) ، Black Beauty (3) ، و Alton Kobry (4) ، مع اثنتا عشر هجينا ناتجة من التهجين التبادلي الكامل خلال موسم النمو 2006 لدراسة قوة الهجين وطبيعة الفعل الجيني. أظهرت النتائج أن الهجين (3x 1) أعطى قوة هجين متفوقة على متوسط الأبوين لصفتي ارتفاع النبات ومعدل وزن الثمرة واظهر الهجين (4×2) أعلى قوة هجين لصفة عدد الأفرع والحاصل المبكر، في حين كان الهجين (4×1) أظهر أبكر الهجن تزهيراً و أعطى أعلى قوة هجين في صفة قطر الثمرة. أظهر الأب 2(Long purple) بأنه الأكثر تالفا في اغلب الصفات المدروسة وفي أن واحد وبالاتجاه المرغوب مما يعني أمكانية الاستفادة منه في تحسين الصفات. بينت النتائج أن الهجن الجيل الأول أظهرت قوة هجين معنوية في جميع الصفات المدروسة ، حيث أن الهجين 3x 1 أعطى أعلى قوة هجين لارتفاع النبات ووزن الثمرة ، والهجين 4x 2 نتج عنه أعلى القيم في عدد الأفرع والحاصل المبكر للنبات ، في حين أن الهجين 4x 1 كان أبكر الهجن تزهيرا وأعطى أعلى قوة هجين في قطر الثمرة ، أظهر الأب الثاني (Long purple) بأنه الأكثر تالفا وبالاتجاه المرغوب في أغلب الصفات ،مما يعني أمكانية الاستفادة منه في تحسين تلك الصفات . أشار تحليل قدرة الائتلاف آن متوسط مربعات قدرة الائتلاف العامة كان معنوياً لجميع الصفات ، بينما متوسط مربعات قدرة الائتلاف الخاصة كان غير معنوي في صفات عدد الأفرع ، عدد الأوراق لظهور أول نورة زهرية ، الحاصل الكلي والحاصل المبكر .أما التأثير العكسي فظهر معنوياً لصفات موعد التزهير ، عدد الأزهار في النورة ، معدل وزن الثمرة ، عدد الثمار للنبات ، طول وقطر الثمرة ، وقد تجلى هذا التأثير بوضوح في الهجين التبادلي (3 x1) الناتج عن تهجين الأبوين Early Long Purple مع Black Beauty .

كلمات دالة : قدرة الائتلاف ، قوة الهجين ، باذنجان

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