GENE ACTION AND HETEROSIS OF MUSKMELON

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ABSTRACT: Six parental genotypes namely "673 (P_1), 3M-637-D (P_2), 3M-673-EB (P_3), 86E2143 (P_4), 86E2147 (P_5) and WA20 (P_6)" representing wide range of variability in most of the studied traits, were employed and crossed in half diallel fashion. This investigation was carried out at the Experimental Farm of Ismailia Agriculture Research station, Ismailia Governorate, Egypt, during the three summer seasons of 2015, 2016 and 2017, to study the important economical traits of muskmelon as fruit width, fruit length, flesh thickness, cavity diameter, total soluble solids, ascorbic acid content, carotenoids content, fruit weight, total yield/vine and fruit number/vine. A greater ratio of GCA/SCA than unity was detected for most studied traits, revealing that the inheritance of these traits was mainly controlled by additive gene effects. On the contrary, both TSS and ascorbic acid content traits, non-additive type of gene action seemed to be more prevalent. The maximum significant MP heterosis in desirable direction (112.4%) was recorded for ascorbic acid followed by total yield/vine (101.0%), number of fruits per vine (100%), TSS (65.3%), flesh thickness (62.1%), fruit weight (59.8%) and fruit length (53.6%). Heterobeltiasis (over the best parent better, BP) was observed and the maximum significant manifestation was orderd as: Ascorbic acid (108%), number of fruits per vine (69.4%), both TSS (%) and cavity diameter (58.8%) and total yield per vine (49.8%). The cross 3M-637-D (P_2) x 86E2143 (P_4) was derived from low x high general combiner parents for total yield/ vine and exhibited the highest mean yield, highest heterosis, highest SCA effects for yield. It showed also, significant or highly significant desirable SCA effects for eight important traits.

Key words: *Cucumis melo* var. reticulalus, combining ability, general combining ability, specific combining ability, heterosis and heterobeltiosis

INTRODUCTION

Although the muskmelon (2n=24) is an important crop in Egypt, however, it suffers several problems, the most important being the rise of imported seeds. A research is an attempt to provide appropriate local hybrids with good price and high quality. Many studies were done in this connection by several researchers, such as **(Feyzian *et al.*, 2009; Choudhary and Pandey, 2010; Lohani, 2013)** on muskmelon through studying combining ability effects and heterosis for many economic traits. In addition, several authors detected additive and non-additive gene effect in the genetic control of the average fruit weight and TSS traits **(Singh and**

Randhawa, 1990; Monforte *et al.*, 2004; Lohani, 2013; Tak, 2017) on muskmelon. The quality, high yield, fruit shape and size were the important objectives of melon breeding programs **(Zalapa *et al.*, 2006)**. The general combining ability (GCA) allows the identification of parents with higher frequency of favorable alleles, while the SCA indicates the most promising hybrid combinations **(Ferreira *et al.*, 2002; Valerio *et al.*, 2009)**.

Therefore, the objectives of the present study were to estimate the magnitude of heterosis as well as general and specific combining abilities for yield and its quality traits in a half diallel set to recognize desirable parents and their cross combinations as genetic resources for improving

these important traits and to identify suitable material to use it in muskmelon breeding. It is hoped that the present study may help the breeder to produce new hybrid varieties of melon to have higher yielding potentiality.

MATERIALS AND METHODS

According to data obtained from the evaluated numerous muskmelon inbred lines, developed and introduced from different sources (Table 1) having sufficient variability, in the end of the 2014 summer season, the six best inbred lines based on fruit shape, flesh color, fruit length and width and average fruit weight as main target were used as parents to produce a 6 × 6 half diallel crosses at the Experimental Farm, Ismailia Agriculture Research Station during the three summer seasons of 2015, 2016 and 2017 to study heterosis, general and specific combining ability with diallel cross system without reciprocals for some important economic traits.

Seeds of the inbred lines were sown during the summer season of 2015 to produce self progeny and were sown on summer season of 2016 to produce the fifteen F_1 hybrids by a half diallel mating design, (**Briggs and Knowles, 1967**). Parents and their fifteen hybrids were evaluated on March, 2017 in randomized complete block (RCBD) design with three replications. Each replicate contained 21 experimental units or plots (6 parents and 15 F_1). Each plot was presented by a single 1 terrace, 1.5 m width and 10 m length (experimental plot area = 15 m^2). The terraces were spaced at 1.5 m and the plants at 0.5 m. All data recorded on five plants from each plot for the all genotypes. To raise a good and healthy crop, all agricultural practices carried out as recommended by the Egyptian Agriculture Ministry for muskmelon cultivation in sandy soil with drip irrigation system.

Observations Recorded

1. Fruit width (FW), cm.

2. Fruit length (FL), cm.

3. Flesh thickness (FT), cm.

4. Cavity diameter (CD), cm.

5. Total soluble solids content (TSS) (%).

6. Ascorbic acid contain (A), as mg/100g was evaluated as described by **Sadasivam and Manickam (1996)**.

7. Carotenoids contain (CC), as mg/100 g in the fruit was extracted by methods reported by **Robinson and Britz (2000)** after adding a trace from sodium carbonate, then total carotenoids were determined spectrophotometrically **(Lichtenthaler and Wellburn, 1985)**.

8. Fruit weight (FWE), Kg.

9. Total yield/vine (TY), Kg.

10. Fruit number per vine (F No./vine).

Statistical Analysis

Analysis of variance

Variance for randomized complete block design (RCBD) was used to test the significance of differences among the genotypes, including crosses and parents (**Snedecor and Cochran, 1967**).

Types of heterosis

Two types of heterosis [Relative heterosis (MP) and heterobeltiosis (BP)] were estimated and expressed as percentages: Relative heterosis and heterobeltiosis were estimated as the deviation of F_1 mean over the mid-parents (MP) and high parent (HP) in each cross, respectively (**Bhatt, 1971**).

$$BP = \frac{F_1 - BP}{HP} \times 100$$

$$MP = \frac{F_1 - MP}{MP} \times 100$$

Analysis of variance for combining ability

General combining ability (GCA) and specific combining ability (SCA) were estimated by following Model-I, Method II of **Griffing (1956)** using Diallel software program.

RESULTS AND DISCUSSION

The Analysis of Variance

The analysis of variance showed highly significant differences between the parents and their hybrids for all the traits in this study (Table 2). These results indicated that, there was substantial genotypic variation among the genotypes. In Table 3, the mean squares due to general and specific combining abilities were

Table 1. Pedigree and origin of the six inbred lines of muskmelon studied

Genotype	Fruit shape	Fruit length & width (cm)	Avg. fruit weight (g)	Flesh color	Source	Picture
673 (P1)	Spherical	14.10 & 13.75	1016.67	White to Green	IPGR	
3M-637-D (P2)	Oblong	10.70 & 10.90	546.67	White to Green	HRI	
3M-673-EB (P3)	Cylindrical	23.67 &1 5.42	1850.00	Orange	HRI	
86E2143 (P4)	Spherical	17.22 & 16.07	1660.00	White	IPGR	
86E2147 (P5)	Spherical	12.50 & 13.75	1250.00	White to Green	IPGR	
WA20 (P6)	Spherical	14.57 & 14.18	750.00	Green	HRI	

IPGR = Institute for Plant Genetic Resources (Sadovo Bulgaria), **HRI** = Department of Vegetables Breeding Horticulture Research Institute, Giza, Egypt

Table 2. Mean squares from analysis of variance for some economic traits in a 6 × 6 half-diallel cross in muskmelon

SOV	DF	FW	FL	FT	CD	TSS	AAC	CC	FWE	TY/Vine	F. No./Vine
Rep.	2	0.52	0.10	0.04	0.05	0.83	2.54	3.00	13.32	659.01	0.02
Treat.	20	10.54**	39.32**	2.88**	2.54**	11.51**	86.09**	28.27**	463.54**	10039.45**	1.15*
Error	40	0.12	0.18	0.03	0.02	0.160	1.85	0.61	9.95	881.53	0.001

FW = Fruit width, FL= Fruit length, FT= Flesh thickness, C.D= Cavity diameter, TSS= Total soluble solids, AAC = Ascorbic acid contain, C.C= Carotenoids contain, F.WE= Fruit weight, TY = Total yield/ vine and F. No. = Fruit number/ vine.

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

Table 3. Mean squares from analysis of variance for combining ability and GCA/SCA ratio for some economic traits in a 6 x 6 half-diallel cross in muskmelon

SOV	DF	FW	FL	FT	CD	TSS	AAC	CC	F.WE	TY/ Vine	F. No./Vine
GCA	5	4.24*	24.69**	1.14**	1.10**	0.58**	22.51**	13.56**	221.40**	7458.30**	2.76**
SCA	15	3.98*	10.94**	0.90**	0.76**	4.92**	30.76*	8.043**	132.21**	1975.88**	0.76*
Error	40	0.06	0.07	0.01	0.01	0.05	0.62	0.203	3.32	293.84	0.17
GCA/SCA		1.06	2.27	1.27	1.44	0.12	0.73	1.69	1.67	3.77	3.36

FW= Fruit width, FL= Fruit length, FT= Flesh thickness, C.D= Cavity diameter, TSS= Total soluble solids, AAC= Ascorbic acid contain, CC= Carotenoids contain, F.WE= Fruit weight, TY= Total yield/ vine and F. No = Fruit number/ vine.

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

significant for all studied traits, this result suggesting the presence of both additive and non-additive gene effects in the expression of all traits under studying. The magnitude of general combining ability variance was higher than that of the specific one for all studied traits except both total soluble solids (TSS) and ascorbic acid contents, indicating that additive gene effects playing an important role in the expression of these traits, the ratio GCA/SCA, which exceeded one substantiated this finding. However, although additive gene effects made the greatest contribution to variability of the majority of traits, the role of dominance and overdominance in the genetic system of control of yield components was also considerable. **Lohani (2013) and Tak (2017)** reported similar results.

General and Specific Combining Ability Effects

Estimates of GCA effects of individual parental genotypes in the F_1 generation (Table 4) were found to be significant or highly significant for the most studied traits. In this regard, P_4 was a good combiner for all trait except TSS and cavity diameter, whereas P_1, P_2 and P_5 were the best general combiner for cavity diameter trait, P_6, P_1 and P_3 showed the highest value for fruits number trait (Table 4), while P_5 appeared to be good general combiner for each of TSS, cavity diameter and ascorbic acid and fruit weight. Similar results were observed by **Choudhary and Pandey (2010)**.

The potentiality of crossing between specific parents were detected by estimating specific combining ability (SCA) effects of each F_1 cross

combination for all studied traits (Table 5). 5 out of 15 crosses exhibited significant positive SCA effects for total yield/vine. Four out of these five crosses namely: (P_1 x P_2), (P_1 x P_5), (P_2 x P_4) and (P_3 x P_6) exhibited significant desirable positive SCA for fruit width, fruit length and fruit thickness. Three out of these four crosses (P_1 x P_2, P_2 x P_4 andP_3 x P_6) along with the best cross (P_5 x P_6) exhibited significant desirable positive SCA for ascorbic acid content. Three out of the four later crosses namely: (P_2 x P_4), (P_3 x P_6) and (P_5 x P_6) exhibited significant desirable positive or negative SCA effects for both of cavity diameter and carotenoids, as well as the superiority of (P_2 x P_4) and (P_5 x P_6) for SCA effect of TSS indicating the possibility of combine both high yield and good quality characters. The five cross combinations, which exhibited significant positive SCA for yield/ vine, were also combined significant/highly significant desirable negative or positive (due to the breeder's point of view) SCA effects for two or more important yield components particularly fruit width, fruit length, fruit thickness, number of fruits, fruit weight, cavity diameter, TSS.. *etc.* These results are in harmony with **Monforte *et al.* (2004)**.

Furthermore, comparing the performance of the cross combinations on the basis of total yield per vine and highest desirable heterotic response for yield as well as SCA effects of crosses along with GCA effects of the parents were done to the most important crosses. The best crosses, which classified on the basis of these parameters are shown in Table 6. Three out of these 7 best crosses were derived from P_4 (86E2143) as male

Table 4. Estimates of general combining ability (GCA) of six muskmelon-inbred lines for some economical traits

Trait	P1	P2	P3	P4	P5	P6	gca(j)
Parent							
Fruit width	-0.44**	-0.69**	0.32**	1.20**	-0.61**	0.22**	0.10
Fruit length	-0.53**	-0.67**	-1.20**	3.54**	-0.82**	-0.33**	0.08
Flash thickness	-0.05^{ns}	-0.18**	-0.17**	0.55**	-0.25**	0.09**	0.03
Cavity diameter	-0.34**	-0.33**	0.66**	0.10**	-0.12**	-0.03	0.04
TSS	0.06	-0.24**	-0.38**	-0.13**	0.56**	0.14^{ns}	0.09
Ascorbic acid contain	-2.39**	-1.87**	0.68**	1.37**	1.30**	0.92**	0.253
Carotienoids contain	0.50**	-0.77**	-1.01**	2.27**	0.19	-1.19**	0.1456
Fruit weight	-61.53**	-109.65**	-6.74ns	288.68**	15.35ns	-126.11**	15.32
Total yield/vine	33.89	-578.40**	-428.40**	1933.26**	-685.90**	-274.44*	114.95
Fruit No./vine	0.28*	-0.06^{ns}	-0.26*	0.15^{ns}	-0.39**	0.28*	0.13

Table 5. Estimates of specific combining ability (SCA) effects of fifteen muskmelon F_1 hybrids for some economical traits

Crosses	FW	FL	FT	CD	TSS	AAC	CC	FWE	TY	FN
P1×P2	1.86**	1.49**	0.60**	0.65**	-0.04	0.91*	-0.22^{ns}	103.01*	1324.91**	0.90^{ns}
P1×P3	0.61**	2.22**	0.02	0.56**	3.44**	3.49**	0.97**	316.76**	-25.09^{ns}	-1.22*
P1×P4	-0.67**	-1.62**	-0.90**	1.13**	-0.98**	-2.02**	4.41**	221.34**	529.91^{ns}	-0.30^{ns}
P1×P5	1.37**	1.24**	0.70**	-0.03^{ns}	0.17^{ns}	-0.78*	-0.09^{ns}	-438.66**	1232.41**	1.90**
P1×P6	-2.39**	-2.09**	-0.84**	-0.71**	-0.25^{ns}	1.58**	1.37**	-212.20**	-1787.38**	-0.43^{ns}
P2×P3	-0.47*	-1.45**	-0.08	-0.31*	2.23**	-3.68**	0.03	-261.79**	-1919.46**	-0.89^{ns}
P2×P4	2.84**	7.86**	1.96**	-1.08**	1.48**	5.88**	2.62**	369.46**	4475.54**	1.36*
P2×P5	-1.54**	-0.95**	-0.77**	-0.01^{ns}	-0.38^{ns}	3.28**	1.75**	442.80**	261.37^{ns}	-1.43*
P2×P6	1.63**	0.23^{ns}	0.69**	0.25^{ns}	-0.79**	0.86*	0.74**	84.26*	-350.09^{ns}	-0.43^{ns}
P3×P4	0.23	-0.68**	-0.18	0.59**	-0.71**	4.51**	0.83**	-100.12*	-1757.80**	-0.76^{ns}
P3×P5	-4.27**	-7.61**	-1.98**	-0.13^{ns}	-0.54*	3.9**	0.13	-866.79**	-3441.13**	2.24**
P3×P6	1.01**	4.25**	0.88**	-0.74**	0.19	4.71**	1.35**	48.01	2449.91**	0.78^{ns}
P4×P5	-3.60**	-4.56**	-0.87**	-1.87**	3.52**	2.99**	0.61**	-255.54**	-1733.63**	-0.30^{ns}
P4×P6	0.37	-2.65**	-0.21^{ns}	0.79**	-1.73**	1.96**	2.94**	69.26^{ns}	471.58^{ns}	0.36^{ns}
P5×P6	0.35^{ns}	1.37**	0.39*	-0.43**	3.58**	7.89**	-0.01^{ns}	275.92**	1524.08**	-0.10^{ns}
LSD$_{0.05}$	0.40	0.28	0.30	0.30	0.47	0.70	0.41	80.02	714.01	1.17
LSD$_{0.01}$	0.56	0.38	0.41	0.41	0.65	0.97	0.56	110.66	987.42	1.62

Table 6. **The best crosses chosen for yield on the basis of heterosis responses and SCA along with GCA effects of the involved parents**

Crosses	Mean yield/vine (kg)	Heterosis		SCA	GCA		Desirable significant (for other traits)	
		MP	HP		1st p	2nd p	MP Heterosis	SCA
$P_2 \times P_4$	11.783	100.97**	33.50**	4475.5**	-578.4**	1933.26**	All	All
$P_1 \times P_4$	8.450	18.93**	-4.27	529.9	33.89	1933.26**	f,g,h	g, h
$P_4 \times P_6$	8.083	23.63**	-8.42**	471.6	1933.26**	-274.44**	f,g,h,i	a,f,g,h
$P_3 \times P_6$	7.700	48.31**	25.54**	2449.9**	-428.4*	-274.44**	All except h	All except e,h
$P_1 \times P_2$	6.733	62.58**	25.08**	1324.9**	33.89	-578.4**	All	All except d,e,g
$P_1 \times P_5$	6.533	34.25**	21.36**	1232.4**	33.89	-685.9**	All except a,b,c,h	a,b,c,i
$P_5 \times P_6$	6.516	51.55**	49.81**	1524.1**	-685.9**	-274.44**	All except a,b,c	All except g,i

FW= Fruit width, FL= Fruit length, FT= Flesh thickness, C.D= Cavity diameter, TSS= Total soluble solids, AAC= Ascorbic acid contain, CC= Carotienoids contain, F.WE= Fruit weight, TY= Total yield/ vine and F. No = Fruit number/ vine..

or female parent that was above classified as a good general combiner in desirable trend for all studied traits. Therefore, this parent (86E2143) could be used as promising progenitors for abovementioned traits either for heterosis breeding or in genetic improvements by means of selection in segregating generations. The first cross (3M-637-D x 86E2143) was derived from poor x good general combiner parents for yield/vine and exhibited the highest mean yield, highest desirable heterosis (for yield and all other traits), similar results were reported by **Feyzian *et al.* (2009)** and highest desirable SCA effects (for yield and all other traits).

Again, these results reveal that this cross can be considered the best combination among the 15 crosses evaluated in the present work. The second (673 x 86E2143) and third (86E2143 x WA20) yielded crosses showed high SCA values involve one only good combiner, while all other 4-best crosses namely (3M-673-EB x WA20), (673 x 3M-637-D), (673 x 86E2147) and (86E2147 x WA20) were derived from poor x poor general combiner parents, and each showed high mean yield/vine, highly significant desirable heterosis and highly significant SCA effects for at least two important yield and quality contributing traits. However, parents with high GCA effects did not necessarily produce hybrid with high SCA effects and *vice versa*. In most of the best crosses showing high SCA involve one only good combiner, such combinations would throw out desirable transgressive segregates provided that the additive genetic system present in 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 (**Habeeb, 1998**). Results revealed that the abovementioned cross combinations might be of prime importance in breeding program for traditional breeding procedures for yield or some of its important components through selection in the segregating generations to exploit a fixable additive gene action which is due to the significance of GCA effects. Also, it could be used for the exploitation of non-additive gene effects, that related to the significance of SCA effects, in heterosis breeding. So, the characters like TSS and ascorbic acid, which are mainly controlled by non-additive gene effects, could be exploit by heterosis breeding. These results are similary with those of **Chalha and Nandpuri (1980) and Singh and Randhawa (1990)**.

Types of Heterosis

Heterosis values for 15 F_1 hybrids of fruit width were given in Table 7. A wide range of heterosis values was existed namely: from -32.05% to 26.79% over to mid-parent and from

-34.25% to 15.46% over to high respective parents. Desirable positive MP heterosis was observed in 4 F_1 crosses, while three F_1 crosses showed HP desirable heterosis. The heterotic expression for fruit length varied with values ranging from -41.13% to 53.62% for both types of heterosis with 5 and 4 crosses exhibited significant positive MP and HP heterosis, respectively. The magnitude of significant positive heterosis for flesh thickness (Table 7) was up to 62.06% over MP and 20.8% over HP.

Heterosis for cavity diameter (in the same Table) varied from -41.59% to 58.81% when all the two types of heterosis are considered. Desirable negative MP heterosis was observed in nine F_1 crosses and four one exhibited desirable HP heterosis. On the other hand, the largest number of crosses having desirable positive MP and BP heterosis was observed in carotenoids, ascorbic acid and TSS as 15, 14 and 11 crosses exhibited up to 39.09%, 112.36%

and 65.31% desirable MP heterosis, respectively and 14, 13 and 9 crosses showed up to 35.93%, 107.98% and 58.82% heterobeltiosis for the three traits, respectively. Out of 15 studied crosses, 8 over MP and 5 over BP showed significant positive heterosis for fruit weight.

Heterosis of total yield per vine expressed as the percentage deviation of F_1 mean performance from MP and HP are presented in Table 7. Estimates of the both types of heterosis varied between -50.65% and 100.97%. Nine out of the 15 crosses showed significant positive MP heterosis, while 7 crosses exhibited HP heterosis. Significant positive heterosis for fruit number per vine up to 100 % over MP and 69.44% over HP was recorded. Out of all studied crosses, 8 over MP and 6 over HP showed significant positive heterosis for this trait. Similar results were reported by **Choudhary and Pandey (2010)**.

Table 7. Range of heterosis (%) for studied traits and number of superior crosses showing significant desirable heterosis

Trait	Heterosis (%) over		No. of superior crosses on the base of	
	MP	**BP**	**MP**	**BP**
Fruit width (cm)	-32.05 - 26.79	-34.25 - 15.46	4	3
Fruit length (cm)	-31.85 - 53.62	-41.13 - 27.00	5	4
Flesh thickness (cm)	-39.92 - 62.06	-34.06 - 20.80	5	4
Cavity diameter (cm)	-41.59 - 28.51	-38.79 - 58.81	9	4
TSS	-12.15 - 65.31	-16.07 - 58.82	11	9
Ascorbic acid	9.26 - 112.36	1.53 - 107.98	14	13
Carotenoids	11.83 - 39.09	7.80 - 35.93	15	14
Fruit weight (g)	-61.62 - 59.81	-62.27 - 31.00	8	5
Total yield/vine	-32.99 - 100.97	-50.65 - 49.81	9	7
Fruit No./vine	-20.00 - 100.00	-37.5 - 69.44	8	6

MP : Mid-parent.   BP : Better parent

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الفعــل الجينــي وقــوة الهجيــن فــي القــاوون الشــبكي

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تم استخدام ستة سلالات أبوية من القاوون الشبكي وتسمى: 673 (P₁), 3M-637-D (P₂), 3M-673-EB (P₃ , 86E2143 "(P₄), 86E2147 (P₅) and WA20 (P₆)" التي تمثل مجموعة واسعة من التباين في معظم الصفات المدروسة، في نظـام التهجين الدوري في اتجاه وحد، وقد أجريت هذه الدراسة في المزرعة التجريبية، محطـة البحوث الزراعيـة بمحافظـة الإسماعيلية، مصر، خلال مواسم الصيف الثلاثة في سنوات ٢٠١٥ و ٢٠١٦ و ٢٠١٧، لدراسة أهمية الصفات الاقتصادية كعرض الثمار وطول الثمار وسمك اللحم وقطـر التجويف والمواد الصلبة الذائبة الكلية ومحتوى حمض الاسكوربيك ومحتوى الكاروتينات ووزن الثمار والمحصول الكلي/نبات وعدد الثمار/نبات وقد كانت نسبة SCA / GCA أكبر من الوحدة في معظم الصفات المدروسة، وكشف ذلك عن أن توريث هذه الصفات أساسـا كـان يسيطر عليها تأثيرات مضيفة للجينـات، بل علـى العكس، يبدو كـلا TSS وحمـض الاسكوربيك الصفات المحتوى، غير مضافة الجينات لتكون أكثر انتشـارا، وسـجلت الاتجـاه %١١٢,٤ rable للحمـض الأسـكوربيك تليهـا المحصـول الكلـي/نبات (%١٠١,٠)، وعـدد الثمار/نبات (%١٠٠)، TSS %٦٥,٣، لحم سمك (%٦٢,١)، وزن الثمرة (%٥٩,٨) وطـول الفاكهـة (%٥٣,٦)، لـوحظ أن قوة الهجين المتزنة (أكثر من الأب الأفضل) وكان الحد الأقصى لقوة الهجين على النحو التالي: حمض الأسكوربيك (%١٠٨)، وعـدد الثمـار/نبـات (%٦٩,٤)، وكـل مـن %TSS وتجويـف قطـر (%٥٨,٨) والمحصـول الكلـي/نبات (%٤٩,٨)، وقد استمدت الهجن (P4٣) 86E2143 × (P2) M-637-D) من أقل عالية × الأب الأفضل المحصـول/نبات وأظهرت أعلى متوسط المحصول، أعلى قوة الهجين، أعلى آثار SCA لمحصول. كمـا أظهـر أيضًـا ، تـأثيرات SCA المرغوبة أو الهامة للغاية لثمانية صفات مهمة.