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MOLECULAR CHARACTERIZATION AND HETEROSIS OF SOME INBRED LINES OF MELON (*Cucumis melo*)

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ABSTRACT

Seven inbred lines of Cucumis melo L. from Egypt were molecularly characterized using ten primers for RAPD-PCR. Genetic relationship was studied by obtaining dendrogram from the combined molecular data. Dendrogram results revealed two main clusters, one cluster containing Koz El-Assal (P_1) and the other cluster contains the rest of the parents, with similarity coefficient of 0.09. Only the first 5 parents were used according to their phylogeny tree and genetic distance. Those parents were cultivated at El-Sabahia Horticulture Research Station, Alexandria Governorate. Fourteen horticulture traits were measured. Analysis of variance data revealed highly significant differences among the studied genotypes for all characters, except for number of branches/plant, which indicated difference in the genetic potential of the populations with respect to these characters. Mean squares indicated fluctuations in the environmental conditions from a year to another concerning plant length and fruit maturity date. P_1xP_2 had high mean performance values for plant length, number of branches/plant, maturity date and placenta hardness, while P_2xP_4 had high values for fruit number/plant, total fruit yield/plant, placenta hardness and fruit netting degree. Heterosis showed significant values for good characters in three crosses: (P_1xP_2), (P_2xP_4) and (P_1xP_5). Positive and significant correlation coefficients were exhibited among the following characters: plant length with each of number of branches/plant and fruit shape index, number of branches/plant with fruit shape index (0.44*), flowering date with each of average fruit number/plant (0.51*) and placenta hardness (0.59**), maturity date with placenta hardness and netting degree, average fruit weight and total yield/plant, netting degree, T.S.S and moisture content, and finally total yield with netting degree (0.69**).

Keywords: ***Cucumis melo, Melon, RAPD-PCR, Morphological characters, Heterosis.***

INTRODUCTION

Melon is a beautiful, juicy, tasty fruit. It is cultivated in all tropical and subtropical areas of the world for its nutritional and medicinal values, pharmacological effects, analgesic and anti-inflammatory activity, anti-oxidant, anti-ulcer activity, anti-cancer activity, and protection against hypothyroidism, (Milind and Kulwant 2011). A large diversity was observed among melon genotypes. Therefore, there are several classifications for melon (Pitrat *et al* 2000). In Egypt, melon is planted in four seasons, in winter under low tunnels from October to December, in spring from the first of February to the first of April, early in fall, and in summer from July to October in Aswan. This is the main time for melon exportation to the European markets. According to FAO (2014), Egyptian production of melon was 1157430 tons produced from 37518 hectare.

Plant breeding aims to improve the characteristics of plant so that they become more desirable agronomically and economically, with higher

yield and improved quality. High yield, early maturity and uniformed fruit shape and size, as well as excellent quality, are important objectives of melon breeding programs (Zalapa *et al* 2006). In melon, yield is associated with several traits including primary branch number, days to flowering, fruit number and average fruit weight/plant. Although presently planted cultivars are capable of high yield, early maturity and good quality interest still exists in pursuing further improvement of melon through breeding activities, because genetic gains can be performed without a concomitant increase in crop management costs. The complexity of these traits is a result of different processes that happen during plant development. Exploitation of genetic variability is critical for making further genetic improvement of economically important traits. Knowledge of type and amount of genetic effects will improve an efficient use of genetic variability. Traditional breeding methods in melon have led to a considerable varietal improvement. It is possible to produce viable intraspecific melon hybrids between wild-type genotypes and commercial melon varieties, with the aim of transferring some particular melon genetic traits, such as resistance to fungi, bacteria, virus, and insects, or tolerance to environmental factors, such as salinity, flooding, drought, and high or low temperature (Dane 1991).

Thangamani and Pugalendhi (2013) showed that heterosis breeding is a potential tool to achieve improvement in quantity, quality, and productivity of melons. They reported that heterosis vigor over the check was exhibited by the majority of hybrids for node on which the first female flower appeared, fruit weight, sex ratio, fruit diameter, fruit yield/vine, and number of fruits/vine. Selection based on these previous studied characteristics would help in identification of high-yielding lines. Escribano and Lazaro (2009) stated that morphological analysis was an important requirement for the initial evaluation of genetic resources and the accurate identification of local landraces. Initially, morphological assessment led to the taxonomic and horticultural classification of melon germplasm (Sari and Solmaz 2007 and Sensoy *et al* 2007). Random amplified polymorphic DNA markers (RAPD) were used to distinguish melon germplasm. Yildiz *et al* (2011) used ISSR and SRAP to assess the genetic diversity.

The aim of this research is to assess the molecular characterization of seven inbred lines of melon to evaluate the genetic distance between them, and accordingly decide the best crosses for the selection of promising recombination with better economic traits suitable for local and international market *via* their heterosis and correlation, through evaluating fourteen horticultural traits.

MATERIALS AND METHODS

Seven inbred lines were kindly provided by Abou Kamer (2014); Koz El. Assal (P_1), Line Primal (P_2), Line Orange (P_3), Line Green (P_4), Line Iedial (P_5), Line Sandafa (P_6) and Line Mostader Matroh (P_7).

DNA Extraction was performed using 10-15 mg of fresh leaves by "Isolate plant DNA mini Kit" (Bioline, Germany) according to the manufacturer's instructions. Ten oligonucleotide primers (Bioneer, CA) were used for DNA amplification for PCR reaction; A_1-5'CAGGCCCTTC3', A_2 – 5'TGCCGAGCTG3', A_3 – 5'AGTCAGCCAC3', A_4 – 5'AATCGGGCTG3', A_5 – 5'TGCTCTGCCC3', A_6 – 5'GGTGACGCAG3', A_7 – 5'GTCCACACGG3', A_8 – 5'CTGGGGACTT3', A_9 – 5'CTGGGGACT3', A_{10} – 5'TTTCCCACGG3'. The reactions were carried out in a DNA Thermocycler (Corbett, CG 1-96, Australia). PCR reactions were performed in 25µl reaction volume, employing 18µl water, 2.5µl DNA polymerase buffer, 1µl dNTPs, 2µl of each primer, 0.5µl Taq Polymerase at 10 u/µl and 1µl (20 ng) DNA. The amplification protocol was 2 min at 92 ºC, followed by 44 cycles of [30 Sec at 92 ºC, 1 min (Tm-5), 1 min at 72 °C], 10 min at 72 °C and a hold temperature of 4°C at the end. PCR products and DNA ladder, (MASTROGEN, 1kb DNA Ladder, USA) were size fractionate by 0.7% high resolution agarose gel (BioShop Canada Inc.), using 0.5X TBE buffer (Tris Base; Boric acid; 0.5M EDTA, pH 8) and 3µ Ethidium bromide (CarlRoth Gmbh Co., Karisruha) at 90 V for 60min. Gels with amplified fragments were visualized and photographed on Gene Sys gel documentation (version in Genius 3, UK). The photograph was imported into the Total Lab Program, which were analyzed in the form of (0, 1) according to the presence of absence of bands.

Five selected lines from the resulted dendrogram, were cultivated in fall season of 2014 to do the crossing (half diallel) at the green house of El-Sabahia Horticulture Research Station, Alexandria Governorate. In the summer seasons of 2015-2016, seeds from each genotype (5 parents + 10F_1's) and a check cultivar (Gallia F_1) were evaluated in the open field of El-Sabahia Horticulture Research Station, Alexandria Governorate, Egypt. A randomized complete blocks design with three replicates was used in this experiment. Each entry was planted in two rows per plot, 10 m long and 1.5 m width. The seeds were planted in hills 40 cm apart, three weeks later. Seedlings were thinned to one plant per hill. The other normal agricultural practices of melon production, i.e. irrigation, fertilization, weeding and pests control were practiced as recommended in the area.

Measurements were recorded on 15 plants from each population for the following horticultural traits: plant length (cm), number of branches/plant, flowering date (days), fruit maturity date (days), fruit number/plant, average fruit weight/plant (kg), total fruit yield/plant (kg), placenta hardness, fruit flesh thickness (%), fruit shape index according to Winiger and Ludwing (1974), fruit netting degree, fruit skin color, total soluble solids (TSS(%)), fruit moisture content (%). Analyses of variance

for the individual characters were done on the basis of the main values as suggested by Allard (1960).

The average degree of heterosis (ADH %) was calculated as percentage of increases or decreases of the F_1 performance above / under the mid parent (MP) value and the high parent (HP) value (Sinha and Khanna 1975).

$$\text{ADH \% (in relation to MP)} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{ADH \% (in relation to HP)} = \frac{F_1 - HP}{HP} \times 100$$

Potence ratio (PR) was calculated using the formula: **PR** $= \frac{F_1 - MP}{\sqrt{P2 - P1}} \times 100$

Where, P_2 and P_1 the highest and the lowest parents, respectively. Significance of the ADH % values was tested using " t " test at error degrees of freedom as shown by Chaudhary *et al* (1978).

$$\text{t test; for heterosis over mid parent value} = \frac{F1 - MP}{\sqrt{\frac{Me}{r} X \, 3/2}}$$

$$\text{t test; for heterosis over high parent value} = \frac{F1 - HP}{\sqrt{\frac{Me}{r} X \, 2}}$$

Where Me = error variance, and r = number of replicates. Simple correlation coefficients (r) were calculated for different pairs of the studied characters as shown by Dospekhove (1984).

RESULTS AND DISCUSSION

Seven *Cucumis melo* L. inbred lines were tested for their genetic relationship using 10 primers for RAPD-PCR technique. Molecular data was scored for computer analysis on the basis of the presence (1) or absence (0) of the amplified products for each sample. Pair-wise comparisons of lines, based on the presence or absence of unique and shared polymorphic products, were used to determine similarity coefficients, according to Raup-crick (1908). The similarity coefficients were then used to construct dendrograms, using the Unweighted Pair Group Method with Arithmetic Averages (UPGMA) employing the SAHN (Sequential, Agglomerative, Hierarchical, and Nested clustering) from the NTSYS–PC (Numerical Taxonomy and Multivariate Analysis System), version 1.80 (Applied

Biostatistics) program (Rohlf 1993). PAST: PAleontological STatistics, is specific for paleontology and ecology statistical packages. PAST also includes fourteen case studies (data files and exercises) illustrating use of the program for paleontological problems, making it a complete educational package for courses in quantitative methods (http://palaeo-electronica.org).

Dendrogram results in Fig. (1) revealed two main clusters, one cluster containing Koz El-Assal (P_1) and the other cluster contains the rest of the parents, with similarity coefficient of 0.09. This cluster was then subdivided into three sub-clusters, one containing Line Orange (P_3) with similarity coefficient of 0.81 compared to the other sub-cluster which hold two branches containing Line Primal (P_2) and Line Iedial (P_5) and the other containing Line Green (P_4), Line Sandafa (P_6) and Line Mostader Matroh (P_7). Only the first 5 parents were used according to their phylogeny tree and genetic distance.

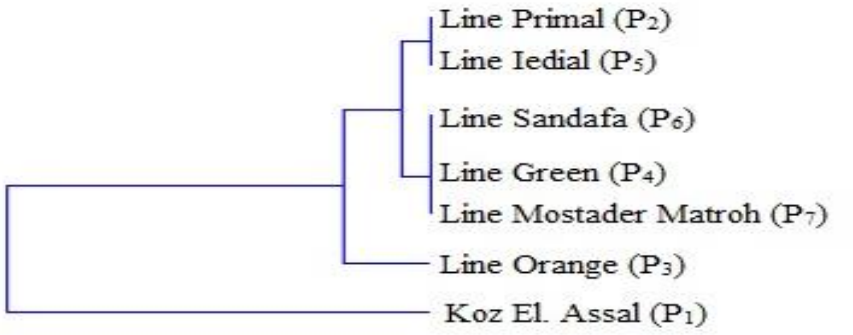

Fig. 1. Dendrogram of genetic distances constructed using RAPD data and the UPGMA method of clustering, showing DNA similarity between seven melon parents.

According to Abou Kamer (2014), Line Primal (P_2) and Line Iedial (P_5) have a green flesh color. Koz El-Assal (P_1) has orange flesh color, the latest flowering and maturity date; lowest fruit number, high fruit weight, high moisture content and finally its genes are dominant over the other parents. Line Orange (P_3) has an oval, dark orange flesh. Line Green (P_4), has a round shaped fruit, greenish yellow with light green sutures skin and dark green flesh.

Analysis of variance data for the five parents and their 10 F_1 crosses, shown in Table (1), revealed that there were highly significant differences among the studied genotypes for all the studied characters, except for number of branches/plant. These results indicated that, the evaluated populations differed in their genetic potential with respect to these characters. Year's mean squares were found to have insignificant effects for most of the studied traits except for the plant length and fruit maturity date characters.

Table 1. Combined analysis of variance for 5 parents and their 10 F_1's melon crosses across two summer seasons of 2015 and 2016.

SOV	df	Mean Squares			
		Vegetative characters		Flowering date (day)	Fruit maturity date (day)
		Plant length (cm)	No. of branches/plant		
Blocks	2	87.77	0.67	3.81	2.8
Genotypes (G)	14	2280.06**	0.54	30.03**	143.45**
Years (Y)	1	5228.84**	0.17	0.54	199.51**
(G) x (Y)	14	814.77	0.39	9.13**	25.17**
Error	58	916.74	0.39	2.52	1.28

SOV	df	Yield and its components		
		Fruits No./plant	Average fruit weight/plant (kg)	Total fruit yield/plant (kg)
Blocks	2	0.144	0.01	0.25
Genotypes (G)	14	1.47**	0.13**	0.49**
Years (Y)	1	0.04	0.01	0.07
(G) x (Y)	14	0.61	0.02	0.30
Error	58	0.48	0.02	0.16

SOV	df	Fruit characteristics						
		Placenta hardness	Fruit flesh thickness (%)	Fruit shape Index	Fruit netting degree	Fruit skin color	T.S.S (%)	Fruit moisture content (%)
Blocks	2	0.27	4.66	0.003	0.34	0.87	0.47	0.76
Genotypes (G)	14	0.63	45.71**	0.153**	1.87**	1.61**	5.04**	6.78**
Years (Y)	1	0.01	25.55	0.003	0.1	0.17	0.9	8.45
(G) x (Y)	14	0.86*	11.38	0.004	0.33	0.58	1.93	1.73
Error	58	0.38	15.79	0.004	0.78	0.40	1.18	2.62

*** and ** Significance at the 0.05 and 0.01 levels of probability, respectively.**

These results indicated that, there were fluctuations in the environmental conditions from year to another throughout the two experiments of this investigation concerning those two characters. No significant variances were found in genotypes (G) x years (Y) interaction for most of the studied characters, except in flowering date, fruit maturity date and placenta hardness. The insignificant G x Y interaction mean squares indicated that, the improvement for these characters would be effective by selection. Results are in agreement with those of Rahman *et al* (2002) on Snake gourd, who stated that the genotypic coefficient of variation was significant for fruit yield, number of fruit/plant, stem length and flesh thickness.

Concerning important characters of genotypes in Table (2), P_1 recorded the highest value of 222.5 cm at plant length while P_5 recorded the lowest mean value of 208.0 cm.

Table 2. Mean performance of melon for vegetative characters, flowering date, maturity date and yield and its components across two summer seasons of 2015 and 2016.

Genotypes		Vegetative characters		Flowering date (day)	Fruit maturity date (day)	Yield and its components		
		Plant length (cm)	No. of branches /plant			Fruits No./ plant	Average fruit weight/ plant (kg)	Total fruit yield/ plant (kg)
Parents	P1	222.50b-e	4.50ab	43.5a	79.50d	1.83d	1.18a	2.15cd
	P2	220.33c-e	3.83b	38.33de	77.50e	2.83bc	0.75d-g	2.35b-d
	P3	219.67c-e	4.17ab	41.17b	76.67e	2.33cd	0.92b-f	2.36b-d
	P4	213.83c-e	4.33ab	38.33de	81.50c	3.17a-c	0.74e-g	2.39b-d
	P5	208.00de	4.83a	39.00c-e	88.83b	2.83bc	0.73fg	2.16cd
F_1's	P1 x P2	271.33a	4.83a	40.00b-d	72.17g	3.33ab	0.83c-g	2.47a-d
	P1 x P3	251.17a-c	4.67ab	39.33b-e	72.33g	3.00bc	1.04ab	2.38b-d
	P1 x P4	231.33a-d	4.00ab	36.16fg	79.50d	3.00bc	1.07ab	2.95a
	P1 x P5	260.67ab	4.33ab	37.50ef	79.33d	2.83bc	0.93b-e	2.86ab
	P2 x P3	231.67a-d	4.33ab	36.33fg	77.00e	3.00bc	0.70g	2.07cd
	P2 x P4	262.83a	4.33ab	41.00bc	82.50c	4.00a	0.98bc	2.99a
	P2 x P5	239.00a-d	4.00ab	40.50bc	80.83cd	3.50ab	0.72fg	2.19cd
	P3 x P4	253.50a-c	4.50ab	39.83b-d	88.33b	3.17a-c	0.97bc	2.55a-d
	P3 x P5	251.00a-c	4.67ab	34.67g	74.67f	3.33ab	0.78c-g	2.59a-c
	P4 x P5	231.83a-d	4.33ab	39.17b-e	82.33c	3.17a-c	0.94b-d	2.55a-d
Check Variety	Gallia F_1	187.00e	4.33ab	45.17a	90.50a	2.67b-d	0.73fg	2.02d

Means with different superscripts in a column are significantly different at (P<0.05), using Duncan's Multiple Range Test.

For crosses there were no significant differences between them excluding the check cultivar. Cross (P_1xP_2) recorded the highest mean value while cross (P_1xP_4) recorded the lowest in the plant length character. Regarding number of branches/plant there were insignificant differences between all the studied genotypes, except for parent (P_2) which gave the lowest value. On the other hand, P_5 and P_1xP_2 cross recorded the highest values (4.83). The crosses P_1xP_4, P_2xP_3 and P_3xP_5 gave the lowest value for flowering date character with insignificant differences among them, that's why these genotypes might be elected for producing early fruits. On the other hand, P_1 and the check variety gave the latest values for flowering from planting of 43.50 and 45.17 days. Concerning yield and its

components, the highest fruit number/plant was recorded by P_2xP_4 (4.00) while P_1 recorded the lowest (1.83). On the contrary P_1 and P_1xP_4 recorded the highest average fruit weight, while the lowest value was recorded by P_2xP_3 cross. The highest fruit yield/plant was produced by P_1xP_4 followed by P_2xP_4 with insignificant differences among these two genotypes as shown in Table (2). On the other hand, the lowest fruit yield /plant was obtained by the commercial cultivar Gallia F_1 followed by P_2xP_3 cross.

With reference to fruit characters (Table 3), there were insignificant differences among all the studied genotypes in placenta hardness, except for P_1 with the lowest value; loose placenta fruits, had a short shelf life, which is not a desired character by the consumer and exportation, also it is related to central part of the vacuole which reflects fruit flesh thickness. As for fruit flesh thickness (%), P_3xP_5 cross showed the thickest flesh, while P_1 was the narrowest among all genotypes. For fruit shape index character, P_1 parent seemed to have an oblong fruit shape (1.54), while P_4 and P_4xP_5 produced semi-spherical fruits (0.93). For fruit netting degree, results showed that there were insignificant differences among the studied genotypes, except for the parent P_1 which recorded the lowest netting value; netting is a very good desired character for stress distribution in the fruit skin and makes fruit bear loading and afford transportation, smooth fruits show more damage during transportation. Most genotypes showed yellow color with insignificant differences among them, except for P_1, P_3 and P_4. The average percentage of (T.S.S.), ranged from 12.17% in P_1 to 14.58 % in P_3. As for P_3xP_5 cross, it had the lowest TSS (12.88%) and P_1xP_5 had the highest TSS (%). The cultivar Gallia 1 recorded the lowest percentage in this respect. As to moisture content, P_1 showed the highest content (93.78%) keeping in mind that it has the lowest TSS and P_2xP_3 cross had the lowest content (89.37%). Low moisture content can give more shelf life to the fruits, more preferred for exportation and more desired by consumer, high moisture content makes is difficult in the manipulation.

Rashidi and Keyvan (2007) stated that, fruit shape is one of the most important physical properties and quality parameters of all agricultural produce. It is vital in evaluating agricultural produce, meeting quality standards and increasing market value, also, helpful in planning packaging, transportation and marketing operation. Consumers prefer fruits of equal weight and uniform shape. Malformed fruits are generally rejected according to sorting standards of fruit (Waseem *et al* 2002). Classification of fruit can increase uniformity in size and shape and also may provide an optimum packaging configuration (Tabatabaeefar *et al* 2000). It is also helpful in planning packaging, transportation and marketing operation (Koc., 2007).

Table 3. Mean performance of melon for fruit characteristics over two summer seasons of 2015 and 2016.

Genotypes		Placenta hardness	Fruit flesh thickness (%)	Fruit shape Index	Fruit netting degree	Fruit skin color	T.S.S (%)	Fruit moisture content (%)
Parents	P1	8.33b	57.80d	1.54a	7.67b	9.00bc	12.17e	93.78a
	P2	9.50a	62.40b-d	1.04c-e	9.33a	8.50cd	14.33a-c	91.71a-c
	P3	9.67a	63.15bc	0.97d-f	9.50a	9.83ab	14.58a-c	92.73ab
	P4	9.33a	62.28b-d	0.93f	9.50a	8.17d	13.68	90.51b-d
	P5	9.50a	65.29ab	0.99c-f	9.83a	9.67ab	14.50a-c	90.05cd
F_1's	P1 x P2	9.67a	63.49b	1.27b	9.33a	9.83ab	14.30a-c	90.89b-d
	P1 x P3	9.67a	65.57ab	1.06cd	9.33a	9.83ab	15.03a-c	91.22b-d
	P1 x P4	9.67a	66.65ab	1.09c	9.83a	9.67ab	14.27a-d	91.07b-d
	P1 x P5	9.50a	65.66ab	0.94f	9.83a	9.67ab	15.70a	90.53b-d
	P2 x P3	9.67a	64.31b	1.08c	9.33a	10.00a	14.92a-c	89.37d
	P2 x P4	9.67a	64.29b	1.10c	10.00a	9.33ab	14.68a-c	90.83b-d
	P2 x P5	9.50a	66.51ab	0.94ef	9.67a	9.67ab	13.53cd	90.71b-d
	P3 x P4	9.67a	63.01bc	1.06cd	10.00a	9.50ab	14.88a-c	91.19b-d
	P3 x P5	9.33a	69.84a	1.01c-f	9.67a	9.67ab	12.88de	91.72a-c
	P4 x P5	9.50a	61.47b-d	0.93f	9.83a	9.33ab	15.17ab	91.27b-d
Check Variety	Gallia F_1	9.67a	58.34cd	0.93f	8.83a	9.67ab	11.82e	92.18a-c

Means with different superscripts in a column are significantly different at (P<0.05), using Duncan's Multiple Range Test.

Description of fruit shape is often necessary in horticultural research for a range of different purposes such as cultivar description in applications for plant variety rights or cultivar registers), evaluation of consumer preference (Gerhard *et al* 2001), investigating heritability of fruit shape traits (White *et al* 2000 and Cunie *et al* 2000), stress distribution analysis in the fruit skin (Considne and Brown 1981), determining misshapen fruit in a cultivar (Sadmia *et al* 2007), effect of orientation on the fruit size (Moreda *et al* 2007) and estimation of fruit volume and weight (Koc 2007). Fruit skin color and flesh color have importance not only for consumer acceptability but also in association with aroma, flavor, and health benefits (Burger *et al* 2006). Melon cultivars tested lost the green color of the fruit skin at maturity, suggesting that this loss is connected with ethylene synthesis.

Heterosis

Results of vegetative characters (plant length, number of branches/plant), flowering date and maturity date are presented in Table (4).

Table 4. Average degree of heterosis (ADH %) based on the mid parents (MP) and the highest parents (HP) and potence (PR) ratio of 10 F_1's crosses of melon for vegetative characters, flowering date and maturity date.

Crosses	Vegetative characters						Flowering date (day)			Fruit maturity date (day)		
	Plant length (cm)			No. of branches/plant								
	ADH%		PR	ADH%		PR	ADH%		PR	ADH%		PR
	MP	HP		MP	HP		MP	HP		MP	HP	
P_1 x P_2	22.54**	21.95**	46.00	15.97**	7.33	1.99	-2.24	-8.05**	-0.35	-8.08**	-6.89**	-6.34
P_1 x P_3	13.61*	12.88	21.18	7.62	3.56	1.94	-3.87*	-9.59**	-0.61	-7.36**	-5.65**	-4.05
P_1 x P_4	6.03	3.97	3.04	-9.40	-11.11	-4.88	-11.62**	-16.87**	-1.84	-1.24	-2.45**	-1.0
P_1 x P_5	21.00**	17.15*	6.26	3.96	-3.78	0.49	-9.09**	-13.79**	-1.67	-5.74**	10.29**	-1.04
P_2 x P_3	5.03	5.14	34.82	8.39	13.05	-2.08	-8.59**	-5.22*	-2.41	-0.10	0.44	-0.19
P_2 x P_4	21.08**	19.27**	14.08	6.13	13.05	-1.0	6.97**	6.97**	0.00	3.77**	1.23	-1.50
P_2 x P_5	11.60	8.47	4.03	4.44	4.44	0.00	4.75*	5.66**	-5.48	-2.81**	-9.01**	-0.41
P_3 x P_4	16.96**	15.41*	12.61	6.01	8.17	-3.0	0.21	-3.23	-0.06	11.70	8.38**	-3.82
P_3 x P_5	17.38**	14.27	6.38	16.65*	12.02	4.03	-13.52**	-15.79**	-5.02	-9.77**	-15.95**	-1.33
P_4 x P_5	9.92	8.42	7.17	6.13	0.00	1.0	1.28	2.17	-1.48	-3.33**	-7.32**	-0.77

*** and ** significance at the 0.05 and 0.01 level of probability, respectively**

There were positive and significant or highly significant heterosis over mid-parent (MP) and high parent (HP) for plant length character in the crosses $P_1 \times P_2$, $P_1 \times P_5$, $P_2 \times P_4$ and $P_3 \times P_4$, positive and significant or highly significant heterosis over mid-parent (MP) in only two crosses $P_1 \times P_3$ and $P_3 \times P_5$. The high obtained potence ratio (PR) values for all the crosses were in accordance with the hybrid vigor. These results may be referring to the over dominance detected toward the high plant length in all hybrids. Obtained results for number of branches/plant declared that there was positive significant or highly significant heterosis over mid-parent (MP) only in the two crosses $P_1 \times P_2$ and $P_3 \times P_5$. The potence ratio was positive and high in the four crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_3 \times P_5$ and $P_4 \times P_5$, which indicated complete or over dominance for the high number of branches in these

crosses. Heterosis values for flowering date are a well-recognized and prime objective of any breeding program. It was negative and highly significant over high parent (HP) in most crosses, while it was positive and significant in $P_2 \times P_4$ and $P_2 \times P_5$. Potence ratio (PR) was negative in all of tested crosses, except in the cross $P_2 \times P_4$. These results indicated that there was partial dominance or over dominance toward early date to flowering. Fruit maturity date heterosis values were found to be negative and highly significant over mid-parent (MP) and high parent (HP) in the crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_2 \times P_5$, $P_3 \times P_5$ and $P_4 \times P_5$ which indicated over dominance toward low parent in theses crosses. Potence ratio was in accordance with the hybrid vigor for early date to flowering.

Results of yield and its component were illustrated in Table (5). Fruits number/plant heterosis values were positive and highly significant over mid-parent (MP) and high parent (HP) in the crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_2 \times P_4$ and $P_3 \times P_5$, while the crosses $P_1 \times P_4$, $P_1 \times P_5$ and $P_3 \times P_4$ showed positive and significant heterosis over high parent (HP) and the crosses $P_2 \times P_3$ and $P_2 \times P_5$ showed positive and significant heterosis over mid-parent (MP).

Table 5. Average degree of heterosis (ADH %) based on the mid parents (MP) and the highest parents (HP) and potence ratio (PR) of 10 F1's crosses of melon for yield and its components.

Crosses	Fruits No./plant			Average fruit weight/plant (kg)			Total fruit yield/plant (kg)		
	ADH%		PR	ADH%		PR	ADH%		PR
	MP	HP		MP	HP		MP	HP	
$P_1 \times P_2$	42.92**	81.97**	2.00	-13.99*	-29.66**	-0.63	10.02	15.42	2.14
$P_1 \times P_3$	44.23**	63.93**	3.68	-1.90	-12.71*	-0.15	5.57	10.75	1.19
$P_1 \times P_4$	20.24	63.93**	0.76	11.46	-9.32	0.50	30.24**	37.85**	5.48
$P_1 \times P_5$	21.46	54.64**	1.00	-2.62	-21.19**	-0.11	32.56**	33.18**	70.0
$P_2 \times P_3$	16.28**	6.01	1.68	-16.17*	-6.67	-1.59	-11.91	-11.91	0.00
$P_2 \times P_4$	33.56**	41.34**	6.09	30.20**	29.33**	45.00	25.74**	26.81**	30.50
$P_2 \times P_5$	23.67*	23.67	0.00	-2.70	-4.0	-2.0	-3.33	-7.23	0.79
$P_3 \times P_4$	15.12	35.62*	1.00	16.87*	5.43	1.56	7.17	8.09	8.50
$P_3 \times P_5$	29.32**	42.92**	3.08	-5.45	-15.22	0.45	14.86*	10.21	3.53
$P_4 \times P_5$	5.99	0.00	1.00	27.89**	27.03**	41.0	12.09	6.69	2.39

*** and ** significance at the 0.05 and 0.01 level of probability, respectively**

Potence ratio was positive for this character among all crosses. These results indicated the presence of over dominance of inheritance in these crosses. Average fruit weight/plant showed positive and highly significant over mid-parent (MP) and high parent (HP) in $P_2 \times P_4$ and $P_4 \times P_5$ crosses. These results indicated over dominance toward the high parent, Potence ratio also, in theses crosses was in accordance with the hybrid vigor

for heavy weight fruits. On the other hand the crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_5$ and $P_2 \times P_3$ showed negative and significant heterosis values over mid-parent (MP) or high parent (HP), indicating partial dominance or over dominance toward the low parent. Total fruit yield/plant showed that showed high positive and significant heterosis over mid-parent (MP) and high parent (HP) in the three crosses $P_1 \times P_4$, $P_1 \times P_5$ and $P_2 \times P_4$; in that way the potence ratio (PR) showed positive over dominance for these crosses.

Data presented in Table (6) showed heterosis values for fruit characteristics. Heterosis values for placenta hardness were positive but insignificant in most crosses over mid-parent (MP) and high parent (HP) with the exception of $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$ and $P_1 \times P_5$. These results may reveal that the hybrid vigor goes towards the direction of high placenta hardness. Potence ratio (PR) values were in the promising direction and in accordance with the hybrid vigor, except for $P_3 x P_5$ cross. Fruit flesh thickness (%) showed insignificant heterosis for all crosses, except $P_3 x P_5$ in mid-parent (MP) and high parent (HP), $P_1 x P_5$ in mid-parent (MP) and $P_1 x P_4$ in high parent (HP). Potence ratio (PR) was positive for all crosses.

Table 6. Average degree of heterosis (ADH %) based on the mid parents (MP) and the highest parents (HP) and potence (PR) ratio of 10 F1's crosses of melon for fruit characteristics.

Crosses	Placenta hardness			Fruit flesh thickness (%)			Fruit shape index			Fruit netting degree		
	ADH%		PR	ADH%		PR	ADH%		PR	ADH%		PR
	MP	HP		MP	HP		MP	HP		MP	HP	
$P_1 \times P_2$	8.36**	15.97**	1.27	5.66	1.76	1.48	-1.55	-17.53**	-0.08	9.83*	21.80**	1.00
$P_1 \times P_3$	7.39*	15.97**	1.00	8.74	4.13	1.98	-15.54**	-31.17**	-0.68	8.74	21.80**	0.82
$P_1 \times P_4$	9.40**	15.97*	1.66	11.02	7.03*	2.95	-11.38**	-29.22**	-0.45	14.57**	28.33**	1.36
$P_1 \times P_5$	6.56**	14.05**	1.00	8.30**	2.08	1.36	-26.48**	-39.61**	-1.22	15.72**	28.33**	1.60
$P_2 \times P_3$	9.58	1.68	1.00	2.45	1.84	4.09	-7.46**	3.85	2.14	-0.90	0.00	-1.00
$P_2 \times P_4$	2.60	1.68	2.88	3.14	3.23	35.55	11.22**	4.81	1.83	6.21	7.18	6.88
$P_2 \times P_5$	5.26	5.26	0.00	4.17	1.85	1.83	-7.39**	-9.62**	-3.00	3.54	3.54	0.00
$P_3 \times P_4$	1.74	0.00	1.00	0.48	1.17	0.70	12.17**	9.28**	4.60	5.26	5.26	0.00
$P_3 \times P_5$	9.58	-3.42	-3.13	8.76**	6.97*	5.23	2.04	3.09	2.00	2.60	1.68	2.88
$P_4 \times P_5$	0.90	1.82	1.00	-3.63	-5.85	1.54	-2.62	1.09	0.71	4.41	3.47	4.88

Table 6. Cont.

Crosses	Fruit skin color			Total soluble solids (T.S.S.) (%)			Fruit moisture content (%)		
	ADH%		PR	ADH%		PR	ADH%		PR
	MP	HP		MP	HP		MP	HP	
P_1 x P_2	12.34**	15.65**	4.32	3.19*	0.00	1.00	-2.32**	-3.40**	-2.08
P_1 x P_3	4.41	0.00	1.00	12.12**	3.09	1.37	-2.18**	-2.73**	-3.88
P_1 x P_4	12.59**	18.38**	2.57	10.37**	4.24	1.76	-1.17	-2.89**	-0.66
P_1 x P_5	3.54	0.00	1.00	17.78**	8.28*	2.03	-1.51	-3.47**	-0.75
P_2 x P_3	9.11**	1.73	1.26	3.15	2.26	3.64	-3.08**	-2.54**	-5.57
P_2 x P_4	12.00**	14.34**	5.88	4.82	7.31	2.08	-0.31	-0.96	-0.48
P_2 x P_5	9.08*	0.00	1.00	-6.14	-6.69	-10.41	-0.19	-1.09	-0.21
P_3 x P_4	5.61	16.24**	0.60	5.31	8.77*	1.67	-0.47	-1.68	-0.39
P_3 x P_5	-0.87	0.00	-1.00	-11.42**	-11.17**	-41.50	0.37	-1.08	0.25
P_4 x P_5	4.71	-3.42	0.56	7.59*	4.55	2.61	1.10	0.84	4.30

*** and ** significance at the 0.05 and 0.01 level of probability, respectively.**

Potence ratio (PR) indicated negative partial dominance or over dominance for roundness shape in the crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$, $P_1 \times P_5$ and $P_2 \times P_5$ and positive partial dominance or over dominance for the other tested crosses. In the same direction heterosis values in fruit shape index were negative and highly significant over mid-parent (MP) or high parent (HP) in the same five crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$ $P_1 \times P_5$ and $P_2 \times P_5$. Fruit netting degree demonstrated positive and significant heterosis values in just the four crosses $P_1 \times P_2$, $P_1 \times P_3$, $P_1 \times P_4$ and $P_1 \times P_5$. Potence ratio was positive in all crosses, except in $P_2 \times P_3$; this result cleared also that there was over dominance for high parent in the crosses $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_4$, $P_3 \times P_5$ and $P_4 \times P_5$ and partial dominance in the cross $P_1 \times P_3$. Meanwhile, complete dominance for high parent was observed in the cross $P_1 \times P_2$. Fruit skin color heterosis values were positive and highly significant heterosis over mid-parent (MP) and high parent (HP) in the three crosses $P_1 \times P_2$, $P_1 \times P_4$ and $P_2 \times P_4$, positive significant heterosis over mid-parent (MP) in the two crosses $P_2 \times P_3$ and $P_2 \times P_5$ and positive and highly significant over high parent (HP) in the cross $P_3 \times P_4$. These results demonstrated complete dominance or over dominance towards the high parent in this character. Over dominance for total soluble solids (T.S.S) appeared in most crosses towards high parent. These results may reveal that the hybrid vigor may go towards the direction of high (T.S.S) content. Heterosis values in this case were positive in all crosses, except in one cross ($P_3 \times P_5$) which appeared negative and highly significant values over mid-parent (MP) and high parent (HP). Obtained heterosis results for moisture content (%) showed, generally, negative and highly significant values over mid-parent (MP) and high parent (HP) in the three crosses $P_1 \times P_2$, $P_1 \times P_3$ and $P_2 \times P_3$ with potence ratio

of over dominance or hybrid vigor go towards the direction of low moisture content. These results were in accordance with the results found by Hatem *et al* (2009) and Shamel (2013). Ibrahim (2012) in sweet gourd reported that the aim of heterosis study was to identify the best heterotic combination and its exploitation for commercial purpose. They found both positive and negative heterosis for different qualitative and quantitative characters in F_1 hybrids of sweet gourd and none of the hybrids exhibited maximum heterosis for all the traits but significant and desirable level of heterosis over mid parent and better parent was obtained in several hybrids for the different traits.

According to Taha *et al* (2003), information on the correlation and linkage among different horticultural characteristics is of primary importance in the field of crop improvement. Linkage relationships can be used to increase breeding efficiency by allowing earlier selection and reducing plant population size during selection. Data in Table (7) showed the correlation coefficient values among pairs of characters.

Table 7. Correlation coefficient values (r) for each pair of characters of melon studied traits across two summer seasons of 2015 and 2016.

Traits	PL	NB	FD	MD	FN/P	AFW/P	TY/P	PH	FTH	F SH I	ND	SC	TSS
NB	0.64**												
FD	0.37	0.02											
MD	-0.20	-0.5*	0.31										
FN/P	0.32	-0.02	0.51*	0.19									
AFW/P	0.09	-0.03	0.16	0.23	-0.14								
TY/P	0.31	-0.13	-0.04	0.26	0.18	0.70**							
PH	-0.15	-0.47*	0.59**	0.60**	0.26	-0.17	-0.39						
FTH	-0.02	-0.06	-0.6**	-0.40	0.00	-0.21	0.09	-0.17					
F SH I	0.44*	0.49*	0.15	-0.39	0.18	0.06	0.01	0.10	-0.18				
ND	0.01	-0.43*	0.15	0.84**	0.29	0.44*	0.69**	-0.12	-0.11	-0.41			
SC	-0.05	0.23	-0.38	-0.69**	-0.49*	-0.43*	-0.59**	0.15	0.30	0.37	-0.86**		
TSS	0.07	-0.002	0.27	0.23	-0.41	0.45*	0.15	-0.06	-0.69**	-0.07	0.10	-0.08	
MC	0.12	0.19	-0.003	0.10	0.15	0.47*	0.41	-0.36	0.28	-0.22	0.40	-0.55**	-0.36

*** and ** significance at the 0.05 and 0.01 level of probability, respectively,**

PL: Plant length (cm). **NB: No. of branches/plant.** **FD: Flowering date (days).** **MD: Fruit Maturity date (days).**
FN/P: Fruits number/plant. **AFW/P: Average fruit weight/plant (kg).** **TY/P: Total fruit yield/plant (kg)** **PH: Placenta hardness.**
F TH: Fruit flesh thickness (%) **F SH I: Fruit shape index.** **ND: Fruit netting degree.** **SC: Fruit skin color**
TSS: Total soluble solids (%) **MC: Fruit moisture content (%).**

Positive, significant and highly significant correlation were observed among the following characters**;** plant length with number of branches/plant and fruit shape index, number of branches/plant with fruit shape index (0.44*), flowering date with each of average fruit number/plant (0.51*) and placenta hardness (0.59**), maturity date with placenta hardness and netting degree, average fruit weight with total yield/plant, netting degree, T.S.S, and moisture content, and total yield with netting degree (0.69**). It should be mentioned, that the absence of a significant correlation between any pair of characters indicates that selection any of these characters is largely independent from the other character. Results of Nasrabadi *et al* (2012) are in agreement with the positive correlation between melon yield and average fruit weight/plant. Also, Zalapa *et al* (2006) detected negative correlation between fruit number/plant and average fruit weight/plant. These results suggested that breeding strategies to increase fruit number/plant and fruit weight/plant while maintaining commercially acceptable average weight/fruit in melon will likely to be complicated by contrasting trait correlations and genetic effect × environment effect interaction.

CONCLUSION

Hybrid seeds of melon were recently used by farmers. High yield with good economic characters are a major goal for melon breeders. It is necessary for breeders to study the hybrid vigor and correlation co-efficient to step up the future breeding program. Three crosses were chosen from this study with good economic traits and high yield: (1) P1xP2 gave the highest values for plant length, number of branches/plant, maturity date and placenta hardness. Also, it had a highly significant heterosis (ADH%) for plant length, fruit maturity date, number of fruits/plant, placenta hardness, fruit netting degree, skin color and moisture content. (2) P2xP4 recorded high values for number of fruits/plant, total yield/plant, placenta hardness and fruit netting degree, in addition to a highly significant value for ADH% in plant length, number of fruits/plant, average fruit weight/plant, total fruit yield/plant and skin color. (3) P1xP5 had a highly significant ADH% values in plant length, flowering date, maturity date, total fruit yield/plant, placenta hardness, fruit netting degree, TSS and moisture content. From these results it is possible to produce new melon hybrids with good economic characteristics suitable for local and international market under the Egyptian conditions, on the commercial scale and to make further investigation on their resistance to fungal diseases or insect infestation and their tolerance to environmental stress (drought, salinity, climatic changes… etc.).

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التوصيف الجزيئي وقوة الهجين لبعض السلالات المرباة داخلياً من القاوون

سارة عماد الدين جمال جمعه

قسم تربيه الخضر والنباتات الطبيه والعطرية، معهد بحوث البساتين، مركز البحوث الزراعية – مصر

أجريت هذه الدراسه على مستوى التوصيف الجزيئي لسبع سلالات مرباه داخلياً من القاوون باستخدام عشرة بادئات لإجراء RAPD-PCR، وجاءت نتائج درجة القرابه الوراثيه فى مجموعتين رئيسيتين، مجموعة واحدة تحتوي على (P_1) والأخرى تحتوي على ما تبقى من الآباء، مع معامل التشابه ٠,٠٩. ثم تم التهجين بين أبعد خمس أباء وراثيا وفقا لشجرة القرابه الوراثيه وذلك بصوب محطة بحوث البساتين بالصبحية بمحافظة الإسكندرية. وتلى ذلك، زراعه الأباء بالإضافة للهجن المتحصل عليها للتقييم بمزرعة المحطة في الموسم الصيفي لعامي ٢٠١٥-٢٠١٦ وتم أخذ بيانات لأربعة عشر صفة. كشف تحليل التباين لها عن فروقات معنوية عالية بين التراكيب الوراثية المدروسة لجميع الصفات باستثناء عدد الفروع/نبات. كما وجدت اختلافات معنوية بين موسمي الزراعة مما يوضح وجود تقلبات في الظروف البيئية من عام لآخر في صفه طول النبات والتبكير في نضج الثمار. أعطي الهجين P_1xP_2 قيم عالية لصفة طول النبات، وعدد الأفرع/نبات، ميعاد النضج وتماسك المشيمة، في حين كان للهجين P_2xP_4 قيم عالية لعدد الثمار/نبات، وزن الثمار/نبات، وتماسك المشيمة ودرجة الشبكية. وأظهرت قوة الهجين تفوق الهجن (P_2xP_4), (P_1xP_2) (P_1xP_5) علي متوسط الابوين وكذلك علي قيم الاب الاعلي لصفات طول النبات، تاريخ النضج، عدد الثمار/نبات، تماسك المشيمة، درجة الشبكية، لون الثمرة الخارجي، متوسط وزن الثمرة، المحصول الكلي من الثمار، نسبة المواد الصلبة الذائبة والمحتوي الرطوبي للثمار. كما ظهر تلازم معنوى كبير بين: طول النبات مع عدد الفروع/نبات وشكل الثمرة، عدد الأفرع/نبات وشكل الثمرة (٠,٤٤)، وميعاد النضج مع متوسط عدد الثمار/نبات (٠,٥١*) وصلابة المشيمة (٠,٥٩ **)، وميعاد النضج مع تماسك المشيمة ودرجة الشبكيه، ومتوسط وزن الثمرة والمحصول الكلي/نبات، ودرجة الشبكيه، ونسبه المواد الصلبه الكليه والمحتوى الرطوبي، ووزن المحصول الكلي مع درجة الشبكيه (٠,٦٩**). ومن مجمل هذه النتائج نوصي بإنتاج هذه الهجن محلياً على نطاق تجاري تحت الظروف المصرية لخصائصها الاقتصادية الجيدة والمناسبة للسوق المحلي والدولي.*

المجلة المصرية لتربية النبات ٢١ (٢) : ٢٢٧ - ٢٤٤ (٢٠١٧)