Bulgarian Journal of Agricultural Science, 28 (No 5) 2022, 810–821

Heterosis and combining ability of melon genotypes (*Cucumis melo* L.) for yield characters in full diallel crosses

Diah Rusita Handayani[1], Sumeru Ashari[2], Afifuddin Latif Adiredjo[2*], Noer Rahmi Ardiarini[3] and Mochammad Roviq[4]

[1]*Brawijaya University, Postgraduate Program of Faculty of Agriculture, 65145, Malang, East Java, Indonesia*
[2]*Brawijaya University, Plant Breeding Laboratory, Department of Agronomy, Faculty of Agriculture, 65145, Malang, East Java, Indonesia*
[3]*Plant Breeding Laboratory, Department of Agronomy, Faculty of Agriculture, Brawijaya University, Veteran Street, 65145, Malang, East Java, Indonesia*
[4]*Plant Physiology Laboratory, Department of Agronomy, Faculty of Agriculture, Brawijaya University, Veteran Street, 65145, Malang, East Java, Indonesia*
[*]*Corresponding author:* al.adiredjo@ ub.ac.id

Abstract

Handayani, D. R., Ashari, S., Adiredjo, A. L., Ardiarini, N. R. & Mochammad, R. (2022). Heterosis and combining ability of melon genotypes (*Cucumis melo* L.) for yield characters in full diallel crosses. *Bulg. J. Agric. Sci., 28 (5)*, 810–821

Combining ability and heterosis were used to assess the performance of the genotypes of the parent and their hybrids. This research aimed to evaluate the effects of heterosis and combining ability on the diallel crosses of melon (*Cucumis melo* L.) for yield and quality-related traits. Ten genotypes of melons were grown and crossed in full diallel to produce F1 hybrids. This research was conducted in 2021 by planting 100 melon genotypes in a randomized block design with three replications. Analysis of variance showed significant (P 0.01) differences among the melon genotypes for fruit diameter, fruit weight, fruit flesh thickness, and fruit total soluble solids. Combining ability analysis showed that mean squares due to general combining ability (GCA) were significant for fruit diameter, fruit weight, flesh thickness, and total soluble solids. In addition, the specific combining ability (SCA) was significant for the characters of fruit diameter, fruit weight, flesh thickness, and fruit total soluble solids. The parental genotypes 2, 3, and 10 showed the highest GCA effect for the yield characters. Therefore, this genotype can be used to produce high-yield hybrid cultivars. The research results show that all characters' GCA: SCA ratio was less than 0.50, meaning most of the traits were controlled by non additive gene action and verifying that the breeding material could be efficiently used to produce hybrid cultivars based on heterotic effects.

Keywords: heterobeltiosis; hybrid general combining ability; specific combining ability

Introduction

Melon (*Cucumis melo* L.) is one of the horticultural plants from the Cucurbitaceae family. Melon is favored for its fruit because it has a sweet fresh taste and high nutrients. In addition, melon is a healthy fruit that contains lots of vitamins, protein, and carbohydrates. The origin of the melon plant is not known for sure. However, the wild species of Cucumis found in Africa make it possible that melon plants came from the African continent. Still, recent research suggests that melons came from Asia (Shashikumar & Pitchaimuthu, 2016).

Melon is a plant that has high economic value, so it has the potential to be developed. However, melon production has decreased from year to year. The demand for melons that have good quality will increase because of the changes in the lifestyle of people who are starting to realize and pay attention to nutrition. The increased production value of melons affects the availability of seeds as planting material. The demand for the continuous availability of seeds causes an increase in seed production activities. This is followed with an increase in superior melon seeds. However, the availability of domestic melon seed production and quality seed varieties are not sufficient to meet the needs.

Efforts to increase crop yields require activities such as crop yields, assembling new superior varieties, including those with high yields, improving agronomic characters, and resistance to pests and diseases. Plant breeding activities to get new superior varieties can be done by producing hybrid varieties. Hybrids are the F1 generation from a cross of a pair of pure lines that have superior characters (Iriany et al., 2011). The assembly of hybrid varieties with superior agronomic characters in a plant breeding program is to cross two plants with superior characters. Uniformity of characters can be obtained from the melon genotype uniform, which may be homozygous or heterozygous. Homozygotes are found in pure strains, while heterozygotes are found in hybrid cultivars. Hybrid melon cultivars are more in demand than pure melon strains because of their better character and appearance and higher production (Choudhary et al., 2018).

Hybrid melon cultivars with the desired traits can be produced through diallel crosses between several genotypes of parents to obtain the best new combination (Barros et al., 2011). Diallel analysis can provide information on general combining ability (GCA) and specific combining ability (SCA) for the genotypes of the parents and their hybrids (Chukwu et al., 2019). Such information is needed to identify potential parents with combining ability and crosses with desired characters among melon genotypes (Selim, 2019). The F1 hybrid obtained through diallel crosses can have the desired heterosis effect and exceed the parental genotype. Previous studies on combining ability and heterosis incomplete diallel crosses reported desired fruit weight and melon maturity (Feyzian et al., 2009). However, studies on combining ability and heterosis using complete diallel crosses of melons for yield and quality-related traits are still limited. Therefore, this study was designed to evaluate the coupling power and effect of heterosis on a 10 melon diallel cross for yield characts.

Materials and Methods

The research was conducted at the Greenhouse of Brawijaya University, Donowarih village, Karangploso District, Malang city, East Java Province. This research site is at an altitude of ± 720 masl with an average temperature of 27°C - 30°C and a rainfall of 250 mm/month. The study was carried out for two growing seasons. The first planting season was carried out using Griffing's diallel cross method 1 from March until June 2021. Meanwhile, the second season carried out the main experiment to evaluate the results of diallel crosses with F1 plantings and their parents from July until October 2021.

The genetic material used was 10 melon parents, namely ACD211303 (1), ACD211254 (2), ACD221362 (3), ACD231380 (4), ACD231265 (5), ACL211390 (6), ACL211402 (7), ACL221402 (8), ACL221451 (9), ACL231312 (10), and 90 hybrids and reciprocals. The experiment used a randomized block design with a single factor, i.e., genotype. Each genotype was repeated three times, so there were 300 experimental units. Each experimental unit consisted of 2 plants planted in polybags measuring 20 x 40 cm. The planting medium used was a mixture of soil, manure, and sand in a ratio of 60%: 30%: 10%. Seedlings are sown for 14 days before transplanting. Fertilization is carried out once a week in the form of a solution with different doses of fertilizer given. The fertilizer given to the plants aged 10 DAP was KNO_3 Merah with a dose of 7.95 g per 8 liters of water. Furthermore, plants aged 20-35 DAP was given NPK compound fertilizer at a dose of 11.3 g in every 8 liters of water. Plants aged 40-50 DAP were given Multi KP fertilizer at a dose of 9.09 g per 8 liters of water. Melon plant-insect pest control used insecticide Curacorn 500 EC and Decis 25 EC. Meanwhile, melon plant disease control used fungicides Antracol 70 WP, Dithane M-45 80 WP, and Agri-mycin 17.

The differences between the F1 genotypes in each character were tested using the F test at a 5% significance level. The characters that had a significant effect were further analyzed using the Honest Significant Difference Test (BNJ) to determine the best hybrid. The value of heterosis was estimated based on the average value of the parents (mid-parent heterosis), namely $((\mu F1-\mu MP)/\mu MP) \times 100\%$. The value of heterobeltiosis is based on the average value of the highest parent, namely $((\mu F - HP)/\mu HP) \times 100\%$; where F1 is the hybrid means, MP is the Mid Parent $((P1 + P2)/2)$, and HP is the highest parent. The general coupling power value and the specific combining power value were estimated based on Method I (Griffing, 1956) using TNAUSTAT software.

Results

Analysis of Variance

Analysis of variance and mean performance of genotypes (Table 1). Analysis of variance shows a highly significant difference between parents and hybrids for all characters of fruit diameter, fruit weight, fruit flesh thickness, and total soluble solids of fruit. These results indicate a fairly large variety of genotypes. The average character of melon yield is presented in the table. The highest average fruit diameter values were shown by parents 1, followed by 3x1, 3x2, 3x4, 3x7, 3x9, 4x1, 4x2, 5x1, 5x3, and 7x3 crosses with a value of 12.03 cm until 13.45 cm. The highest average fruit weight values were shown by parents 1 and 6, with values of 631.88 g and 684.18 g. The cross combinations with the highest fruit weight were shown by 3x1, 3x2, 3x4, 3x7, 3x9, 4x1, 4x2, 5x7, 5x8, and 7x3 with values from 944.97 g until 1215.07 g. All average values for the thickness of the flesh were more than 1 with the highest value of 1.68 cm which was owned by parent 1. The average values for the combination of crosses were 3x1, 3x2, 3x9, 4x1, 4x6, 5x7, 5x8, 6x4, and 6x7 more than 2 cm with a range of 2.45 cm until 2.66 cm. Other fruit characters observed were total soluble solids, in which elders 9 and 10 had the highest average value with each value of 10.20 °Brix to 10.10 °Brix. The highest average cross combination values were 1x6, 2x3, 3x5, 4x8, 6x1, 7x3, 10x2, 10x3, 10x4, 10x6 and 10x7 with an average value range of 11.13 °Brix until 12.23 Brix (Table 2).

GCA Effect

General combining ability (GCA) has a significant and highly significant effect on the characters of fruit diameter, fruit weight, fruit flesh thickness, and total soluble solids (Table 3). Four parents showed an insignificant effect of GCA for this trait. Parents 3 and 7 were positive and highly significant (P 0.01) for fruit diameter (Table 4). Similarly, parent 4 showed a positive and significant value (P 0.05). On the other hand, the other three elders had a highly significant negative GCA effect (P 0.01).

The effect of parents 3's GCA was positive and highly significant (P 0.01) in the desired direction for fruit weight. Parents 2 and 10 had a positive and significant effect on GCA (P 0.05). The effects of the other parental GCA were not significant for this trait. Three parents showed a non-significant effect of GCA on pulp thickness. Parents 8, 9, and 10 were positive and highly significant (P 0.01) for fruit flesh thickness. On the other hand, parents 1 and 7 had a significant negative GCA effect (P 0.05). Similarly, parents 2 and 5 had a significant negative GCA effect (P 0.05).

The GCA effect from parents 2, 6, and 10 was positive and highly significant (P 0.01) for the total soluble solids of the fruit. Parent 9 had a significant and positive effect of GCA (P 0.05). On the other hand, parents 2 and 7 had a significant negative GCA effect (P 0.05). Similarly, the parent 5 had a highly significant negative GCA effect (P 0.01). Whereas parent 3 showed an insignificant effect of GCA for this trait.

SCA Effect

The specific combining ability (SCA) had a significant and highly significant effect on the character of fruit di-

Table 1. Analysis of variance for various yield-related traits in melon

SOV	df	Mean square							
		FD, cm		FW, g		FFT, cm		TTS, °Brix	
Replications	2	3.57	**	16362.78	**	0.41	**	6.89	**
Genotypes	99	0.70	**	45667.38	**	0.18	**	1.87	**
Error	198	0.378		16262.74		0.05		0.75	
Total	299								

Note: (*) significant at 5%, (**) significant at 1%, (SOV) sources of variation (df) degrees of freedom, (FD) fruit diameter, (FW) fruit weight, (FFT) fruit flesh thickness, (TSS) fruit total soluble solids

Table 2. Analysis of variance for combining ability and GCA: SCA ratio

SOV	df	Mean square							
		FD, cm		FW, g		FFT, cm		TTS, °Brix	
GCA	9	1.44	**	30478.6	**	0.18	**	0.85	**
SCA	45	1.50	**	16489.9	**	0.12	**	0.88	**
Reciprocals	45	0.87	**	11029.47	**	0.22	**	0.47	*
Error	198	0.27		5501.52		0.07		0.29	
GCA: SCA		0.04		0.11		0.11		0.04	
% GCA		7.40		10.54		5.27		6.05	
% SCA		38.77		28.51		17.11		31.19	
% Reciproc		22.54		19.07		32.45		16.65	

Note: (*) significant at 5%, (**) significant at 1%, (SOV) sources of variation (df) degrees of freedom, (FD) fruit diameter, (FW) fruit weight, (FFT) fruit flesh thickness, (TSS) fruit total soluble solids

Table 3. Means of five traits of ten melon parents and 90 crosses

Parents and crosses	Traits			
	Fruit diameter, cm	Fruit weight, g	Fruit flesh thickness, cm	Fruit total soluble solids, °Brix
1	8.78	631.88	1.68	8.17
2	8.74	602.18	1.66	7.93
3	8.29	611.25	1.49	9.40
4	8.43	617.07	1.50	9.83
5	8.65	622.05	1.64	7.83
6	8.22	684.18	1.62	9.35
7	8.43	600.92	1.66	8.03
8	8.44	623.52	1.59	9.63
9	8.62	625.78	1.64	10.20
10	8.43	590.20	1.62	10.10
Cross 1x2	9.55	709.77	1.84	9.83
Cross 1x3	10.13	886.60	2.03	10.63
Cross 1x4	9.57	732.30	1.99	9.93
Cross 1x5	9.69	717.48	1.95	10.47
Cross 1x6	10.30	755.62	2.06	11.13
Cross 1x7	9.52	716.10	1.89	10.11
Cross 1x8	9.81	765.33	1.93	10.93
Cross 1x9	9.67	733.27	1.96	10.83
Cross 1x10	9.31	732.07	1.81	10.10
Cross 2x1	9.46	675.85	1.95	9.70
Cross 2x3	9.41	706.18	2.01	11.20
Cross 2x4	9.53	726.28	1.97	10.10
Cross 2x5	9.54	704.82	1.93	9.93
Cross 2x6	9.64	695.33	1.97	11.07
Cross 2x7	9.73	647.13	2.01	10.57
Cross 2x8	9.56	733.18	1.81	9.80
Cross 2x9	9.61	844.75	2.00	9.97
Cross 2x10	9.45	727.17	1.97	10.37
Cross 3x1	12.03	1215.07	2.57	10.90
Cross 3x2	12.06	1013.05	2.46	10.20
Cross 3x4	12.14	944.97	2.34	11.00
Cross 3x5	10.87	763.73	1.97	11.20
Cross 3x6	11.95	983.35	1.98	10.97
Cross 3x7	12.49	1077.38	2.22	10.37
Cross 3x8	10.12	860.33	1.95	9.90
Cross 3x9	13.45	1210.07	2.66	10.63
Cross 3x10	10.85	763.98	2.05	10.37
Cross 4x1	12.25	996.62	2.55	9.47
Cross 4x2	12.76	1058.38	2.37	9.43
Cross 4x3	11.50	767.42	2.16	9.90
Cross 4x5	11.19	749.55	2.06	10.30
Cross 4x6	10.63	775.30	2.54	10.60
Cross 4x7	10.92	754.78	2.10	10.10
Cross 4x8	11.97	788.58	2.09	11.80
Cross 4x9	11.34	814.45	2.01	9.80
Cross 4x10	10.84	745.90	2.33	9.77

Table 3. (continued)

Cross 5x1	12.34	856.47	2.03	10.75
Cross 5x2	10.60	768.78	2.01	10.70
Cross 5x3	12.60	938.95	2.12	9.70
Cross 5x4	11.25	804.73	2.00	10.37
Cross 5x6	10.86	704.12	2.16	9.63
Cross 5x7	11.36	1009.40	2.62	9.43
Cross 5x8	11.32	1014.28	2.63	9.60
Cross 5x9	10.43	767.92	2.04	9.83
Cross 5x10	10.30	765.25	1.96	10.07
Cross 6x1	11.79	835.43	2.35	11.70
Cross 6x2	10.61	876.65	2.21	10.20
Cross 6x3	10.41	740.07	2.22	10.35
Cross 6x4	11.16	761.15	2.59	9.50
Cross 6x5	10.93	841.95	2.33	10.43
Cross 6x7	11.06	701.18	2.45	10.27
Cross 6x8	11.79	798.33	2.17	10.35
Cross 6x9	11.96	822.97	2.44	10.20
Cross 6x10	10.22	668.28	2.31	10.73
Cross 7x1	11.46	833.02	2.19	10.23
Cross 7x2	10.93	694.78	2.00	10.43
Cross 7x3	12.25	1024.70	2.20	12.10
Cross 7x4	10.76	674.52	2.05	10.80
Cross 7x5	11.35	845.58	2.20	9.27
Cross 7x6	10.55	725.55	2.21	10.33
Cross 7x8	11.62	850.70	2.20	9.73
Cross 7x9	10.70	768.83	2.04	9.10
Cross 7x10	11.28	690.03	2.06	8.83
Cross 8x1	11.00	732.60	1.99	10.27
Cross 8x2	10.78	811.97	2.04	9.63
Cross 8x3	10.15	671.77	2.10	10.33
Cross 8x4	11.44	875.72	2.25	9.77
Cross 8x5	10.77	667.07	2.03	9.57
Cross 8x6	11.21	920.28	2.07	9.97
Cross 8x7	11.82	838.03	2.17	10.27
Cross 8x9	11.58	827.63	2.06	10.10
Cross 8x10	10.36	688.60	2.16	10.20
Cross 9x1	10.69	815.72	2.28	10.87
Cross 9x2	11.59	798.02	2.02	10.90
Cross 9x3	11.21	873.52	2.02	9.97
Cross 9x4	10.53	733.28	2.00	10.93
Cross 9x5	11.04	865.55	2.15	10.30
Cross 9x6	10.45	766.37	2.14	10.17
Cross 9x7	10.51	700.50	1.96	10.47
Cross 9x8	10.68	793.82	2.24	11.00
Cross 9x10	10.44	731.20	2.01	9.97
Cross 10x1	10.20	713.43	2.02	10.43
Cross 10x3	10.41	668.95	2.31	11.13
Cross 10x4	10.10	806.82	2.37	11.83

Table 3. (continued)

Cross 10x5	10.17	688.15	2.27	10.90
Cross 10x6	10.49	671.57	2.22	12.23
Cross 10x7	11.08	712.62	2.25	11.37
Cross 10x8	10.76	710.35	2.49	10.03
Cross 10x9	11.39	760.00	2.27	10.53
Mean	10.61	780.53	2.10	10.23
CV, %	8.05	16.33	11.33	8.48

Table 4. Estimates for general combining ability effects in parental genotypes

Parents	Fruit diameter, cm		Fruit Weight, g		Fruit flesh thickness, cm		Fruit total soluble solids, °Brix	
1	-0.27	**	5.66	ns	-0.09	**	-0.02	ns
2	-0.42	**	-23.36	*	-0.06	*	-0.17	*
3	0.37	**	86.76	**	0.01	ns	0.21	**
4	0.17	*	6.99	ns	-0.04	ns	-0.05	ns
5	0.07	ns	6.48	ns	-0.07	*	-0.34	**
6	0.01	ns	-15.48	ns	0.04	ns	0.21	**
7	0.24	**	-6.52	ns	-0.12	**	-0.15	*
8	0.09	ns	-2.18	ns	0.09	**	-0.10	ns
9	0.09	ns	12.84	ns	0.17	**	0.12	*
10	-0.37	**	-71.19	**	0.09	**	0.31	**

Note: (*) significant at 5%, (**) significant at 1%

Tabel 5. Estimates for specific combining ability effects in F1 hybrids for various traits in melon

Hybrid	Fruit diameter, cm		Fruit weight, g		Fruit flesh thickness, cm		Fruit total soluble solids, °Brix	
	SCA	Resiproc	SCA	Resiproc	SCA	Resiproc	SCA	Resiproc
1x2	-0.39*	0.16	-68.89**	16.96	-0.27*	0.16	-0.37*	-16.91*
1x3	0.47*	-0.83**	179.00**	-164.23**	-0.01	-0.50**	0.40*	-5.24
1x4	0.34*	-1.50**	72.38**	-132.15**	-0.45**	0.00	-0.66**	-12.58*
1x5	0.60**	-1.33**	-4.58	-69.50*	0.07	-0.50**	0.95**	-19.63*
1x6	0.67**	-0.67**	25.93*	-39.91	0.29**	-0.16	1.07**	-7.06
1x7	0.10	-1.00**	-3.97	-58.46*	0.29**	0.33**	-0.06	9.85
1x8	-0.07	-0.67**	-33.94*	16.36	0.07	-0.33**	0.39*	-9.93
1x9	-0.24	-0.50*	-23.42*	-41.25	-0.01	-0.33**	0.65**	7.15
1x10	-0.11	-0.16	16.38	16.81	0.07	-0.33**	-0.19	-5.13
2x3	-0.04	-1.50**	16.81	-153.45**	-0.04	-0.16	0.22	-5.14
2x4	0.82**	-1.83**	129.28**	-166.05**	-0.49**	0.00	-0.34*	-9.31
2x5	-0.24	-0.67**	-25.73*	-31.98	-0.12	0.33**	0.60**	-12.86*
2x6	-0.01	-0.50*	45.41**	-90.67**	0.09	-0.33**	0.39*	9.20
2x7	-0.07	-0.33	-78.57**	-23.83	0.26*	0.00	0.75**	-3.21
2x8	-0.09	-0.50*	18.71	-39.40	0.37**	0.00	-0.29	22.33**
2x9	0.24	-0.83**	52.50**	23.35	0.46**	-0.50**	0.30	10.58
2x10	0.20	-0.67**	40.95**	1.38	0.21*	-0.50**	0.62**	-5.03
3x4	0.52*	0.33	-16.99	88.76**	-0.22*	0.33**	-0.06	-1.31
3x5	0.62**	-0.67**	-21.33	-87.61**	-0.02	-0.50**	0.39*	-9.03
3x6	0.19	0.83**	11.01	121.63**	0.19*	-0.50**	0.00	6.20

3x7	1.29**	0.16	186.89**	21.83	0.19*	-0.33**	0.87**	6.62
3x8	-1.06**	0.00	-97.94**	94.26**	0.14	0.16	-0.34*	-1.33
3x9	1.10**	1.16**	162.75**	168.26**	0.06	-0.16	-0.24	8.92
3x10	-0.09	0.16	-78.51**	47.51	-0.02	0.00	0.07	-3.69
4x5	0.32	0.16	-15.74	-27.56	0.19*	0.33**	0.49*	14.97*
4x6	-0.11	-0.33	-2.69	7.08	0.24*	-0.16	-0.39*	-9.79
4x7	-0.34*	0.00	-65.22**	40.15	-0.09	-0.33**	0.30	13.38*
4x8	0.80**	0.33	39.58**	-35.23	0.19*	0.16	0.75**	19.83**
4x9	0.14	0.33	-25.39*	40.58	0.11	0.16	0.02	8.92
4x10	0.10	0.50*	61.15**	-30.45	0.02	0.33**	0.34*	11.63
5x6	0.32	0.00	2.61	-68.91*	-0.22*	0.00	-0.27	21.32**
5x7	0.42*	0.00	148.11**	81.90*	0.11	-0.16	-0.24	8.07
5x8	0.40*	0.16	56.96**	173.60**	0.22*	0.50**	-0.29	8.78
5x9	-0.26	-0.16	18.00	-48.80	-0.02	0.00	-0.02	-18.63*
5x10	-0.12	0.16	12.01	38.53	-0.10	-0.50**	0.29	27.42**
6x7	-0.17	0.33	-44.04**	-12.18	-0.34**	0.16	0.20	-17.36*
6x8	0.97**	0.33	97.58**	-60.98*	-0.05	0.67**	-0.01	1.68
6x9	0.47*	0.83**	17.88	28.28	-0.14	0.67**	-0.24	-2.39
6x10	-0.06	-0.16	-22.80*	-1.65	0.27*	0.33**	0.90**	-9.18
7x8	0.74**	0.00	73.66**	6.35	-0.39**	0.16	0.02	-23.89**
7x9	-0.42*	0.16	-51.05**	34.16	0.02	0.33**	-0.21	9.68
7x10	0.87**	0.00	-0.35	-11.31	0.27*	-0.16	-0.06	12.73*
8x9	0.39*	0.50*	3.47	-0.26	-0.19*	-0.67**	0.57**	-13.43*
8x10	0.02	0.00	-6.56	-10.83	-0.27*	-0.16	-0.44*	-26.38**
9x10	0.69**	-0.67**	24.53*	-14.38	-0.02	-0.16	-0.67**	2.70

Note: (*) significant at 5%, (**) significant at 1%

ameter, fruit weight, fruit flesh thickness, and total soluble solids (Table 5). The following cross fruit diameters, 1x3, 1x4, 1x5, 1x6, 2x4, 3x4, 3x5, 3x7, 3x9, 4x8, 5x7, 5x8, 5x9, 6x8, 6x9, 7x8, 8x9, and 9x10, were positive significant and highly significant. Crosses of 1x2, 3x8, 4x7, and 7x9 had significant and highly significant negative SCA effects. The remainder of the crosses showed no significant effect of SCA (Table 5). The effect of SCA on fruit weight was positively significant and highly significant for 1x3, 1x4, 2x4, 2x6, 2x9, 2x10, 3x7, 4x8, 4x10, 5x7, 5x8, 6x8, 7x8, and 9x10 crosses. Crosses of 1x2, 1x6, 1x8, 1x9, 2x5, 2x7, 3x8, 3x10, 4x7, 4x9, 6x7, 6x10, 7x9, and 9x10 had significant and highly significant negative SCA effects. For the thickness of the flesh, crosses of 1x6, 1x7, 2x7, 2x8, 2x9, 2x10, 3x6, 3x7, 4x5, 4x6, 4x8, 5x8, 6x10, and 7x10 had a significant and highly significant positive SCA effect. The effect of SCA on total soluble solids was positively significant and highly significant for the crosses of 1x3, 1x5,1x6, 1x8, 1x9, 2x5, 2x6, 2x7, 2x10, 3x5, 3x7, 4x5, 4x8, 4x10, 6x10 and 8x9.

For reciprocals, it had a significant and highly significant effect on characters fruit diameter, fruit weight, fruit flesh thickness, and total soluble solids (Table 5). The fruit diameter's positive and highly significant reciprocal effect was only on crosses of 3x6, 3x9, 4x10, 6x9, and 8x9. For the reciprocal effect

of fruit weight which had a significant positive reciprocal effect and highly significant crosses of 3x4, 3x6, 3x8, 3x9, 5x7, and 5x8. For the thickness of the flesh, crosses of 1x7, 2x5, 3x4, 4x5, 4x10, 5x8, 6x8, 6x9, 6x10, and 7x9 had a significant and highly significant positive reciprocal effect. The positive reciprocal effect for total soluble solids was significant and highly significant for crosses of 2x3, 3x4, 3x5, 4x6, 4x8, and 7x9.

Heterosis

The values of heterosis and heterobeltiosis for fruit diameter, fruit weight, flesh thickness, and total soluble solids were desired in melon. The highest positive heterosis value for fruit diameter was observed in crosses of 3x7, 3x9 and 4x2 with values of 49.02%, 56.86% and 47.17% similarly heterobeltiosis values of 46.15%, 53.85%, and 39.29%. For fruit weight, crosses 3x1 and 3x9 had higher positive heterosis values than other crosses with values of 95.48% and 95.63%, followed by high heterobeltiosis values of 92.29% and 93.35%, respectively. For the thickness of the flesh,

Table 6. Estimate percent of heterosis and heterobeltiosis

Hybrid	Fruitdiameter,cm		Fruitweight,g		Fruitfleshthickness,cm		Fruittotalsolublesolids,°Brix	
	Heterosis	Heterobelti-osis	Heterosis	Heterobelti-osis	Heterosis	Heterobelti-osis	Heterosis	Heterobelti-osis
Cross 1x2	7.41	3.57	15.03	12.33	14.29	0.00	20.83*	20.83*
Cross 1x3	21.57**	19.23**	42.64**	40.31**	-25.00	-25.00	23.08**	14.29
Cross 1x4	9.80**	7.69**	17.27**	15.89*	-40.00*	-50.00**	9.43	0.00
Cross 1x5	11.54**	11.54**	14.44	13.55	-25.00	-25.00	36.17**	33.33**
Cross 1x6	21.57**	19.23**	20.95	19.58	25.00	25.00	33.33**	25.93**
Cross 1x7	11.54**	11.54**	16.18	13.33	71.43	50.00	22.45**	20.00*
Cross 1x8	11.54**	11.54*	21.92	21.12	-11.11	-20.00	20.75*	10.34
Cross 1x9	11.54*	11.54*	16.60	16.04	-11.11	-20.00	20.00**	6.45
Cross 1x10	13.73*	11.54	22.26	18.23	0.00	0.00	14.81*	3.33
Cross 2x1	3.70	0.00	9.53	6.96	-14.29	-25.00	20.83*	20.83*
Cross 2x3	1.89**	-3.57	16.39**	15.53*	14.29	0.00	26.92**	17.86
Cross 2x4	5.66**	0.00*	19.14**	17.70**	-33.33	-50.00**	13.21	3.45
Cross 2x5	3.70	0.00	15.14	13.31	42.86	25.00	27.66**	25.00**
Cross 2x6	9.43*	3.57	14.01	12.59	14.29	0.00	29.41**	22.22*
Cross 2x7	11.11*	7.14	7.57	7.46	66.67*	66.67	30.61**	28.00**
Cross 2x8	7.41	3.57	19.63	17.59	50.00*	20.00	9.43	0.00
Cross 2x9	7.41*	3.57	37.58*	34.98	25.00*	0.00	9.09*	-3.23
Cross 2x10	5.66	0.00	21.97	20.76	14.29*	0.00	14.81**	3.33
Cross 3x1	41.18**	38.46**	95.48**	92.29**	50.00	50.00	26.92**	17.86
Cross 3x2	35.85**	28.57	66.98**	65.74*	42.86	25.00	15.38**	7.14
Cross 3x4	44.00**	44.00**	53.86**	53.14*	-0.00	-16.67	15.79	13.79
Cross 3x5	29.41**	26.92**	23.85**	22.77*	-25.00	-25.00	33.33**	21.43
Cross 3x6	44.00**	44.00**	60.05**	59.23*	0.00	0.00	20.00*	17.86
Cross 3x7	49.02**	46.15**	76.27**	74.78**	14.29	0.00	16.98**	10.71*
Cross 3x8	17.65*	15.38	39.35	37.98	33.33	20.00	1.75	0.00
Cross 3x9	56.86**	53.85**	95.63**	93.35**	11.11	0.00	8.47	3.23
Cross 3x10	28.00**	28.00**	27.17	24.99	25.00	25.00	6.90	3.33
Cross 4x1	45.10**	42.31**	59.59**	57.72*	-40.00*	-50.00**	5.66	-3.45
Cross 4x2	47.17**	39.29*	73.61**	71.52**	-33.33	-50.00**	5.66	-3.45
Cross 4x3	36.00**	36.00	24.96**	24.37*	-40.00	-50.00	1.75	0.00
Cross 4x5	33.33**	30.77**	20.99	20.50	20.00	0.00	19.23*	6.90
Cross 4x6	24.00**	24.00**	25.60	25.55	-0.00	-16.67	14.29	10.34
Cross 4x7	25.49**	23.08**	23.95	22.33	-33.33	-50.00	11.11*	3.45
Cross 4x8	41.18**	38.46**	27.13*	26.47	9.09	0.00	24.14	24.14
Cross 4x9	33.33**	30.77**	31.06	30.14	9.09	0.00	0.00	-3.23
Cross 4x10	32.00**	32.00**	23.57	20.88	20.00	0.00	1.69	0.00
Cross 5x1	42.31**	42.31**	36.61	35.54	50.00	50.00	40.43**	37.50**
Cross 5x2	18.52	14.29	25.59	23.59	-14.29	-25.00	36.17**	33.33**
Cross 5x3	45.10**	42.31**	52.26**	50.94*	50.00	50.00	13.73**	3.57
Cross 5x4	29.41**	26.92**	29.89	29.36	-20.00	-33.33	19.23*	6.90
Cross 5x6	29.41**	26.92**	13.60	13.19	0.00	0.00	12.00*	3.70
Cross 5x7	30.77**	30.77**	65.07**	62.27**	14.29	0.00	20.83*	16.00
Cross 5x8	30.77**	30.77**	62.86*	62.67*	55.56	40.00	7.69	-3.45
Cross 5x9	19.23**	19.23*	23.08*	22.71	11.11	0.00	7.41	-6.45
Cross 5x10	21.57**	19.23*	26.25	23.02	-25.00	-25.00	13.21*	0.00

Table 3. (continued)

Cross 6x1	37.25**	34.62**	33.73	32.22	50.00	50.00	37.25**	29.63**
Cross 6x2	20.75*	14.29*	43.74	41.95	71.43	50.00	21.57**	14.81*
Cross 6x3	24.00**	24.00**	20.46**	19.84*	75.00	75.00	12.73*	10.71
Cross 6x4	32.00**	32.00**	23.30	23.25	20.00	0.00	-0.00	-3.45
Cross 6x5	29.41**	26.92**	35.84	35.35	0.00	0.00	24.00*	14.81
Cross 6x7	29.41**	26.92**	15.09	13.54	14.29	0.00	23.08**	18.52
Cross 6x8	41.18**	38.46**	28.65**	28.04*	55.56	40.00	10.71	6.90
Cross 6x9	41.18**	38.46**	32.37	31.50	55.56	40.00	10.34	3.23
Cross 6x10	20.00**	20.00*	10.66	8.22	75.00*	75.00	15.79**	10.00*
Cross 7x1	34.62**	34.62**	35.15	31.84	14.29	0.00	22.45**	20.00*
Cross 7x2	18.52*	14.29	15.50	15.38	66.67*	66.67	30.61**	28.00*
Cross 7x3	45.10**	42.31**	69.07**	67.64**	71.43	50.00	35.85**	28.57**
Cross 7x4	25.49**	23.08**	10.76	9.31	11.11	-16.67	18.52*	10.34*
Cross 7x5	30.77**	30.77**	38.28**	35.93**	42.86	25.00	16.67*	12.00
Cross 7x6	21.57**	19.23**	19.09	17.49	-14.29	-25.00	19.23**	14.81
Cross 7x8	34.62**	34.62**	38.96*	36.44*	0.00	-20.00	7.41	0.00
Cross 7x9	23.08**	23.08*	25.35	22.85	50.00	20.00	0.00	-9.68
Cross 7x10	33.33**	30.77**	15.86	14.83	42.86*	25.00	-1.82	-10.00
Cross 8x1	26.92**	26.92*	16.71	15.94	33.33	20.00	16.98*	6.90
Cross 8x2	18.52	14.29	32.49	30.23	50.00*	20.00	9.43	0.00
Cross 8x3	17.65*	15.38	8.81	7.74	11.11	0.00	8.77	6.90
Cross 8x4	33.33**	30.77**	38.49*	37.77	-9.09	-16.67	0.00	0.00
Cross 8x5	26.92**	26.92**	7.11*	6.99*	-11.11	-20.00	11.54	0.00
Cross 8x6	33.33**	30.77**	48.31**	47.60*	-33.33	-40.00	10.71	6.90
Cross 8x7	34.62**	34.62**	36.88*	34.40*	-25.00	-40.00	14.81	6.90
Cross 8x9	34.62**	34.62**	26.99	26.76	-40.00	-40.00	3.33	0.00
Cross 8x10	21.57**	19.23*	13.46	10.44	-11.11	-20.00	5.08	3.33
Cross 9x1	23.08*	23.08*	29.72	29.10	33.33	20.00	20.00**	6.45
Cross 9x2	25.93*	21.43	29.97*	27.52	100.00*	60.00	20.00*	6.45
Cross 9x3	29.41**	26.92**	41.22**	39.58**	33.33	20.00	1.69	-3.23
Cross 9x4	25.49**	23.08**	18.00	17.17	-9.09	-16.67	6.67	3.23
Cross 9x5	23.08**	23.08*	38.72*	38.31	11.11	0.00	14.81	0.00
Cross 9x6	21.57**	19.23**	23.27	22.46	-33.33	-40.00	3.45	-3.23
Cross 9x7	19.23**	19.23*	14.21	11.94	0.00	-20.00	14.29	3.23
Cross 9x8	23.08**	23.08**	27.08	26.84	40.00	40.00	13.33	9.68
Cross 9x10	21.57**	19.23**	20.26	16.84	11.11	0.00	-4.92	-6.45
Cross 10x1	17.65*	15.38	16.76	12.91	50.00	50.00	14.81*	3.33
Cross 10x1	17.65*	15.38	16.76	12.91	50.00	50.00	14.81*	3.33
Cross 10x2	20.75	14.29	21.51	20.30	100.00*	75.00	29.63**	16.67
Cross 10x3	24.00**	24.00**	11.36	9.44	25.00	25.00	17.24	13.33
Cross 10x4	20.00**	20.00**	33.66	30.75	-20.00	-33.33	18.64	16.67
Cross 10x5	17.65**	15.38*	13.54	10.63	50.00	50.00	24.53*	10.00
Cross 10x6	24.00**	24.00*	11.21	8.75	25.00*	25.00	29.82**	23.33*
Cross 10x7	33.33**	30.77**	19.66	18.59	71.43*	50.00	27.27	16.67
Cross 10x8	21.57**	19.23*	17.05	13.93	11.11	0.00	-1.69	-3.33
Cross 10x9	37.25**	34.62**	24.99	21.44	33.33	20.00	1.64	0.00

Note: (*) significant at 5%, (**) significant at 1%

crosses of 9x2 and 10x2 with a value of 100% and 100% had the highest and positive values. On the other hand, the highest positive values were also shown for the heterobeltiosis values of 60.00% and 75.00%. For total dissolved solids, high positive heterosis was 37.25% and 40.43% in 6x1 and 5x1 crosses. Similarly, the positive heterobeltiosis values were high at 29.63% and 37.50% (Table 6).

Discussion

Analysis of variance shows that genotype had a highly significant effect on all observed characters. The analysis of combining ability variance revealed that in melons, the mean square of GCA was significant for fruit diameter, fruit weight, fruit flesh thickness, and total soluble solids of fruit. Akrami & Arzani (2019) revealed that in the melon genotype, the mean square due to GCA and SCA was significant for fruit diameter and other yield and quality-related traits. The results further revealed that fruit diameter, fruit weight, fruit flesh thickness, and total soluble solids of fruit were controlled by non-additive genes. Characters with high and significant GCA effects were controlled by additive genes, while characters with higher SCA effects than GCA effects were controlled by non-additive genes (Ferreira et al., 2004).

The results showed a GCA: SCA ratio < 0.50 for all characters. Therefore, the action of non-additive genes controlled all the characters, and the melon cultivar assembly program should be directed toward the heterosis effect. Other studies on combining ability show that the majority of the characters in melon (Badami et al., 2020), cucumber (Bhutia et al., 2015), and sweet potato (Rukundo et al., 2017) were controlled by non-additive genes. For reciprocal, the mean square was significant (P 0.01) of fruit diameter, fruit weight, flesh fruit thickness, and total soluble solids (Table 6). Badami et al. (2020) and Feyzian et al. (2009) revealed that the mean square due to the reciprocal effect was significant for yield characters in melon's full diallel crosses. In melon, the importance of the reciprocal effect may be due to the extrachromosomal influence on these characters. The effect of GCA parental 3 and 7 for fruit diameter was positive and significant at (P0.01), indicating the presence of an additive gene action controlling the expression of this trait. According to Badami et al. (2020), characters that have DGU with highly significant or significant effects are controlled by the action of additive genes. The following crosses of 1x3, 1x4, 1x5, 1x6, 2x4, 3x4, 3x5, 3x7, 3x9, 4x8, 5x7, 5x8, 5x9, 6x8, 6x9, 7x8, 8x9, and 9x10 had significant and highly significant positive SCA effects. This indicates the presence of non-additive gene action in addition to additive gene action. It is difficult to select one or two parents and predict the crosses that will result from these parents with good SCA effects. The parents included in the cross that produced a significant positive SCA effect were also found in the cross that produced a significant negative SCA. Therefore, it is important to make as many crosses as possible to obtain the desired combination with a high and positive SCA effect. All significant SCA and reciprocal values showed a positive and negative appearance effect. Similar results were also obtained by EL- Sayed et al. (2019) in melon, indicating that the reciprocal value was significant for fruit diameter in melon's full diallel crosses.

Parent 3 had a positive and highly significant GCA effect, indicating the presence of additive gene action. The effect of SCA for fruit weight was positively significant and highly significant for 1x3, 1x4, 2x4, 2x6, 2x9, 2x10, 3x7, 4x8, 4x10, 5x7, 5x8, 6x8, 7x8, and 9x10 crosses. A significant and positive SCA effect indicates the contribution of non-additive gene action to fruit weight expression. This was also reported by Baros et al. (2011) and Varinder & Vashisht (2018) in their research examining several melon genotypes, and the findings show the action of non-additive genes controlled fruit weight yield.

Parents 8, 9, and 10 had positive and highly significant (P 0.01) GCA effects for fruit flesh thickness, implying that additive gene action controlled the inheritance of this trait. This is in line with Paris et al. (2008)the characterization of quantitative trait loci (QTL, stating that the action of additive genes can be seen from the significance of the GCA value. Only crosses of 1x6, 1x7, 2x7, 2x8, 2x9, 2x10, 3x6, 3x7, 4x5, 4x6, 4x8, 5x8, 6x10, and 7x10 had significant and highly significant positive SCA effects, suggesting non-additive gene action for the expression of this trait. Therefore, the action of additive and non-additive genes is important for the expression of fruit flesh thickness.

Parents 2, 6, and 10 showed a positive and highly significant effect of GCA (P 0.01) for total fruit soluble solids. The effect of GCA on fruit sweetness levels was also reported by Shashikumar and Pitchaimuthu (2016) who stated that there was a high significance value in some parents that could increase the nutrition value. The higher the total soluble solids value, the higher the sweetness level of the melon. Crosses of 1x6, 1x7, 2x7, 2x8, 2x9, 2x10, 3x6, 3x7, 4x5, 4x6, 4x8, 5x8, 6x10, and 7x10 had a significant and highly significant positive SCA effect. Significant different values indicate that the cross combination is ideal for cross combinations that produce a high sweetness value compared to other combinations. This is in line with Fasahat et al. (2016), which stated that diallelic crosses with components (GCA, SCA, and reciprocals) can be used to determine the heterotic group of a genotype in the development of hybrid plant breeding programs.

Heterosis describes the superior performance of heterozygous hybrid plants or inbred lines of their homozygous parents. This phenomenon occurs as a result of the accumulation of dominant genes, excessive dominance, and non-allelic interactions (Arif et al., 2013). Heterosis was observed in most of the crosses for fruit diameter. All heterobeltiosis estimates and most heterobeltiosis estimates were positive, indicating the possibility of selecting the better-performing offspring. This is in line with Singh and Tiwari (2018), stating that heterosis and heterobeltiosis were present in the diameter of the fruit for several cross combinations carried out.

Heterosis for fruit weight of 3x1 and 3x9 crosses had higher positive heterosis and heterobeltiosis values than other crosses. This indicates the possibility of selecting progeny that exceeds both parents. For the thickness of the fruit flesh, crosses of 9x2 and 10x2 had the highest and positive values of heterosis and heterobeltiosis. Negative and positive values were also found in melon fruit yields (Omprasad et al., 2021; Shashikumar & Pitchaimuthu, 2016; EL- Sayed et al., 2019). For total dissolved solids, heterosis and positive heterobeltiosis were high in crosses of 6x1 and 5x1. This result is in line with the study by Kamer et al. (2015) and Iria et al. (2009), resulting in positive and significant values of heterosis and heterobeltiosis.

Conclusion

GCA:SCA ratios for all the traits were less than 0.50, indicating that all characters were controlled by dominant gene action. Therefore, the melon cultivar assembly program should be directed toward utilizing heterotic effects. The parental genotypes 3 exhibited high GCA values for fruit diameter and fruit weight, while parental genotypes 10 exhibited high GCA values for fruit flesh thickness and fruit total soluble solids. F1 Hybrids of 1x3, 1x6, 1x7, 2x3, 2x4, 2x8, 2x10, 3x7, 3x9, 4x2, 4x3, 5x7, 7x3, 6x8, 8x1, 9x3, and 9x6 were identified and selected as prosper cross combinations based on the value of GCA, SCA, and heterosis effect for fruit diameter, fruit weight, fruit flesh thickness, and fruit total soluble solids. These genotype candidates can be used as a source population to develop hybrid melon cultivars.

References

Akrami, M. & Arzani, A. (2019). Inheritance of fruit yield and quality in melon *(Cucumis melo* L.) grown under field salinity stress. *Sci. Rep., 9(1),* 1–13. doi: 10.1038/s41598-019-43616-6.

Arif, A. Bin, Sujiprihati, S. & Syukur, M. (2013). Estimation of heterosis and heterobeltiosis in Six Chili genotypes using full diallel cross analysis. *J. Horti., 22(2),* 103.doi:10.21082/jhort.v22n2.2012.p103-110.

Badami, K., Daryono, B. S., Amzeri, A. & Khoiri, S. (2020). Combining ability and heterotic studies on hybrid melon *(Cucumis melo* L.) Populations for fruit yield and quality traits. *J. Breed. Genet., 4(52),* 402–417.

Barros, A. K. A., Nunes, G. H. S., Queiróz, M. A. Q., Pereira, E. W. L & Filho, J. H. (2011). Diallel analysis of yield and quality traits of melon fruits. *Crop Breed. Appl. Biotechnol., 11(4),* 313–319.

Bhutia, N. D., Seth, T., Shende, V. D., Dutta, S. & Chattopadhyay, A. *(*2015). Estimation of heterosis, dominance effect and genetic control of fresh fruit yield, quality and leaf curl disease severity traits of chilli pepper (*Capsicum annum* L.). *Sci. Hortic., 182(1),* 47–55. doi: 10.1016/j.scienta.2014.11.017.

Choudhary, B. R., Haldhar, S. M. & Maheshwari, S. (2018). Identification and possibility of monoecious inbred of muskmelon (*Cucumis melo* L.) for heterosis breeding. *J. Veg. Sci., 45(1),* 118–120.

Chukwu, S. C., Okporie, E. O., Onyishi, G. C., Ekwu, L. G. & Nwogbaga, A. C. (2019). Application of diallel analyses in crop improvement. *Agric. Biol., 7(2),* 95–106. doi:10.5251/abjna.2016.7.2.95.106

El- Sayed, A. A., Gharib, A. H. & El-Tahawey, M. A. F. A. (2019). Heterosis and combining ability in melon (*Cucumis melo* L.). *J. Plant Prod., 4(5),* 429–441. doi: 10.21608/mjppf.2019.174938.

Fasahat, P., Rajabi, A., Rad, J. M. & Derera, J. (2016). Principles and utilization of combining ability in plant breeding. *J. Int., 4(1),* 1–22. doi:10.15406/bbij.2016.04.00085.

Ferreira, F. M., Junior, J. I. R., Pacheco, C. A. P., Silva, C. H. O. & Filho, S. M. *(*2004). Genetic components of combining ability in a complete diallel. *Crop. Breed. Appl. Biotechnol., 4(3),* 338–343. doi: 10.12702/1984-7033.v04n03a12.

Feyzian, E., Dehghani, H., Rezai, A. M. & Javaran, M. J. (2009). Diallel cross analysis for maturity and yield-related traits in melon (*Cucumis melo* L.). *168(2),* 215–223. doi: 10.1007/s10681-009-99049.

Iria, F.-S., Moreno, E., Eduardo, I., Arus, P. & Alvarez, J. M. (2009). On the genetic control of heterosis for fruit shape in melon (*Cucumis melo* L.). *J. Hered., 100(2),* 229–235. doi: 10.1093/jhered/esn075.

Iriany, R. N., Sujiprihati, S., Syukur, M., Koswara, J. & Yunus, M. (2011). Evaluation of combining power and heterosis of five sweet corn (*Zea mays* var. *saccharata*) lines from diallelic crosses. *J. Agron. Indonesia, 39(2),* 103–111.

Kamer, A., Mona, Yousry, M. & El-Gamal, A. M. (2015). Heterosis and heritability studies for fruit characters and yield in melon (*Cucumis melo* L.). *J. Appl. Sci., 5(1),* 262–273.

Malik, S. I., Malik, H. N., Mahmood, N. & Munir, M. (2011). General and specific combining ability studies in maize diallel crosses. *Int. J. Agric. Biol., 6(5),* 856–859. http://www.ijab.org.

Omprasad, J., Madhumathi, C., Sadarunnisa, S., Priya, T. & Jayaprada, M. (2021). Heterosis for growth, yield and quality characters in muskmelon (*Cucumis melo* L .). *Pharma Innov. J., 10(8),* 1056–1063.

Paris, M. K., Zalapa, J. E., McCreight, J. D. & Staub, J. E. (2008). Genetic dissection of fruit quality components in melon

(*Cucumis melo* L.) using a RIL population derived from exotic x elite US Western Shipping germplasm. *Mol. Breed., 22(3),* 405–419. doi: 10.1007/s11032-008-9185-3.

Rukundo, P., Shimelis, H., Laing, M. & Gahakwa, D. (2017). Combining ability, maternal effects, and heritability of drought tolerance, yield and yield components in sweet potato. *Plant Sci., 7(1),* 1–14. doi: 10.3389/fpls.2016.01981.

Selim, M. A. M. (2019). Heterosis and combining ability for some fruit quality traits of Egyptian Melon Inbred Lines Using Line × Tester Analysis. *J. Agric. Res., 97(1),* 317–342. doi: 10.21608/ejar.2019.68694.

Shashikumar, K. & Pitchaimuthu, M. *(*2016). Heterosis and combining ability analysis of quantitative and qualitative traits in Muskmelon (*Cucumis melo* L.). *Int. J. Agric. Sci. Res., 6(2),* 341–348. http://www.tjprc.org/view-archives.php.

Singh, H. K. & Tiwari, A. (2018). Exploitation of heterosis for yield and contributing traits in cucumber (*Cucumis sativus* L.). *J. Pharmacogn. Phytochem., 7(3),* 395–397.

Varinder, S. & Vashisht, V. K. (2018). Heterosis and combining ability for yield in muskmelon (*Cucumis melo* L.). *Int. J. Curr. Microbiol. Appl. Sci., 7(8),* 2996–3006. doi:10.20546/ijcmas.2018.708.318.

Werle, A. J. K., Ferreira, F. R. A., Pinto, R. J. B. & Mangolin, C. A., Scapim (2011). Diallel analysis of maize inbred lines for carotenoids and grain yield. *Crop Breed. Appl. Biotechnol., 182(3),* 395-404. doi: 10.1007/s10681-011-0513-z

Received: **March, 30, 2022**; *Approved*: **June, 02,2022;** *Published*: **October, 2022**