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Analysis of General and Specific Combining Ability of Postharvest Attributes in Melon

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ABSTRACT

Improving postharvest and cold storage related indices is one of the main purposes of melon breeding programs. With regards to the growing global market, it is important to introduce new melon types with prolonged storability. In this experiment, six melon inbred lines were used to establish a full diallel F_1 population. Harvested fruit was stored and the main postharvest indices were monitored during the storage period. The results showed that some indices were controlled by additive gene effects such as mesocarp firmness and Soluble Solids (SS). Mesocarp firmness analysis proposed that this index was controlled by additive and non-additive gene effects. General Combining Ability (GCA) analysis showed that "Khatouni" inbred line could be considered as a promising parent in breeding programs to produce melon hybrids with more appealing firmness, fewer cold storage losses, and a longer postharvest life.

Keywords: *Cucumis melo*, Diallel, Hybrid, Inbred line.

INTRODUCTION

Melon (*Cucumis melo* L.) is an important crop that is grown widely around the world. It is a member of the genus Cucumis, of the family Cucurbitaceae. It includes various groups of annual, trailing-vine plants (Wang *et al*., 1997). Due to the diversity within this species, a sophisticated classification for the groups of melons is required (Burger *et al*., 2010; Pitrat, 2016). However, muskmelon group (*Cucumis melo* var. *cantalupensis*), winter melon (*Cucumis melo* var. *inodorus*), and Pomegranate melon (*Cucumis melo* var. *dudaim*) are considered the most important groups (Robinson and Decker-Walters, 1999; Wien, 1997).

Saccharinus and inodorus groups include most of the melon accessions with a good shelf life and postharvest characteristics (Liu *et al*., 2004). These characteristics are correlated with mesocarp firmness, SS, weight loss, and the external color and appearance of the fruit, which together form the unique postharvest performance for each melon accession (Miccolis and Saltveit, 1995). Persian melons are known for their firmness and long shelf life, so, they are considered as promising material to be used in breeding programs and crossed with other cantaloupensis type melons to develop hybrids that produce fruit with more firmness, good shipping characteristics, and longer shelf life (Welbaum, 2015). Kharbozeh Khatouni is one of the most popular inodorus melon cultivars in Iran. It is characterized by its elongated oval shaped fruit with yellow rind and a greenish white odorless mesocarp that has a sweet mild taste and is known for its long shelf life.

The analysis of GCA and SCA in diallel mating experiments was first developed by Griffing (1956). In melon, diallel analysis was used to study plant related traits such

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as leaf length, leaf diameter, crown diameter, distance of internodes, number of primary branches, fusarium wilt resistance and downy mildew resistance as well as fruit related traits such as weight, number, length, diameter, shape index, net appearance, suture appearance, days needed for maturity, total yield, acceptable yield, mesocarp thickness, rind thickness, cavity length, cavity diameter, mesocarp percentage, rind firmness, mesocarp firmness and TSS content (Barros *et al*., 2011; Dehghani *et al*., 2009; Epinat and Pitrat, 1994; Feyzian *et al*., 2009; Kitroongruang *et al*., 1992; Nakazumi and Hirai, 2004; Pouyesh *et al*., 2017; Zalapa *et al*., 2006). But to our knowledge, postharvest traits such as weight loss, rind color, mesocarp color, firmness loss, and TSS during cold storage were not considered. Therefore, this study was carried out to estimate the GCA and SCA of these traits throughout the cold storage period.

MATERIALS AND METHODS

PLANT MATERIAL

The experiment was conducted at the Research Station of the Department of Horticultural Sciences (University of Tehran) in Karaj, Iran, in 2016-2017. The genotypes used for the crosses were 'Khatouni' for the inodorus group, 'Abadan', '1025', '1026' and 'Izabel' for the cantalupensis group and 'Kermanshah' for the dudaim group according to their morphological and average agronomic characteristics as mentioned in Table 1 and Figure 1.

All the possible combination crosses between each pair of these genotypes (including reciprocals) were conducted in the first year. The seeds required for the F_1 progeny were gathered and stored. Hybrid seeds were sown in seed trays in greenhouse in the second year and the seedlings were transplanted to the field in a randomized complete block design to establish the 36 F_1 hybrids progeny. All the proper agricultural practices were carried out based on standard method of melon cultivation. Fruit from each replicate was harvested and properly transported to the cold storage and stored for one month at temperature of 4°C.

Evaluation of Fruit Traits

All harvested fruit was weighed using an electronic scale and the color of the fruit was recorded using a Minolta Chroma Meter (Konica Minolta) set at day zero, 10, 20, and 30. The mesocarp firmness was measured for each fruit using a hand penetrometer equipped with an 8-mm plunger tip in three points at the stem end, equator, and blossom end. Total soluble solid of fruit mesocarp was measured using a hand refractometer with the juice extracted from the homogenate parts of the mesocarp that represented all the fruit parts. All the previous measurements were recorded at four different times including day zero, 10, 20, and 30 days in cold storage.

The weight loss was calculated as a percentage by subtracting the weight of the fruit at the day of processing after 10, 20 or 30 days in cold storage from the original weight of the same fruit at day zero. The loss of firmness was calculated using the same method but by taking the original firmness as the mean of fruit firmness processed at day zero.

Statistical Analysis

The analysis of variance for GCA, SCA and reciprocal effects was carried out using the Griffing (1956) method 1, model 1 in which F_1 hybrids and their reciprocal crosses including the parents were used. Estimates of $\sigma^2 g$ (general combining ability), $\sigma^2 s$ (specific combining ability) and $\sigma^2 r$ (reciprocal effects) were calculated using Diallel–SAS 05 on SAS platform (Zhang and Kang, 2005).

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Table 1. The morphological and average agronomic characterizations of melon inbred lines used in the study.

Accession name	Group	Fruit shape	Rind	Mesocarp	Volatiles	Average fruit weight (g)	Average soluble solids (%)	Average flesh firmness (kg cm^{-2})
Khatouni	Inodorus	Oval elongated	Yellow – Shallow netted	Greenish white	Odorless	1827	8.33	3.94
Abadan	Cantaloupensis	Oval – Round	Dark yellow – Without net	White	Odorous (Medium)	1156	7.80	5.48
1025	Cantaloupensis	Oval – Round	Green	Green	Odorless	628	12.20	8.88
1026	Cantaloupensis	Crooked elongated	Orange with green areas – Without net	Orange	Odorous (Medium)	1206	7.23	2.43
Izabel	Cantaloupensis	Round flatted	Creamy – Shallow netted	Pale orange	Odorless	1429	5.43	8.45
Kermanshah	Dudaim	Round flatted	Dark yellow with orange areas – Without net	White	Odorous (High)	640	5.63	1.92

RESULTS AND DISCUSSION

Weight Loss

Diallel analysis of the weight loss during the storage period showed a significant GCA after 10 days of cold storage, while the SCA and reciprocal effect were not significant. After 20 days in cold storage the effects of GCA, SCA and reciprocal were significant, while after 30 days in cold storage only the SCA and reciprocal effect maintained their significant levels while GCA became non-significant.

The GCA/SCA ratio after 10, 20, and 30 days of cold storage indicated the importance of additive and non-additive control during the first 20 days of storage, while the importance of non-additive/epistasis control became more important during the last 10 days of storage. On the other hand, the extra nuclear inheritance was significant after 20 and 30 days in storage, which confirmed the importance of the female parent in this trait (Table 2).

A positive GCA and SCA for this trait correlated with the more weight loss, therefore, a more negative GCA and SCA correlates with a less weight loss, which can be seen in the 1025 and 1026 after 10 days in storage, and in Khatouni after 20 days. The hybrids with the most negative SCA were 1025×Khatouni, 1026×Kermanshah and Khatouni×Izabel after 10, 20, and 30 days in cold storage, respectively (Table 3). The significant negative GCA and SCA values related to the Khatouni parent along with many of its hybrids refer to the possibility of using this line to produce new

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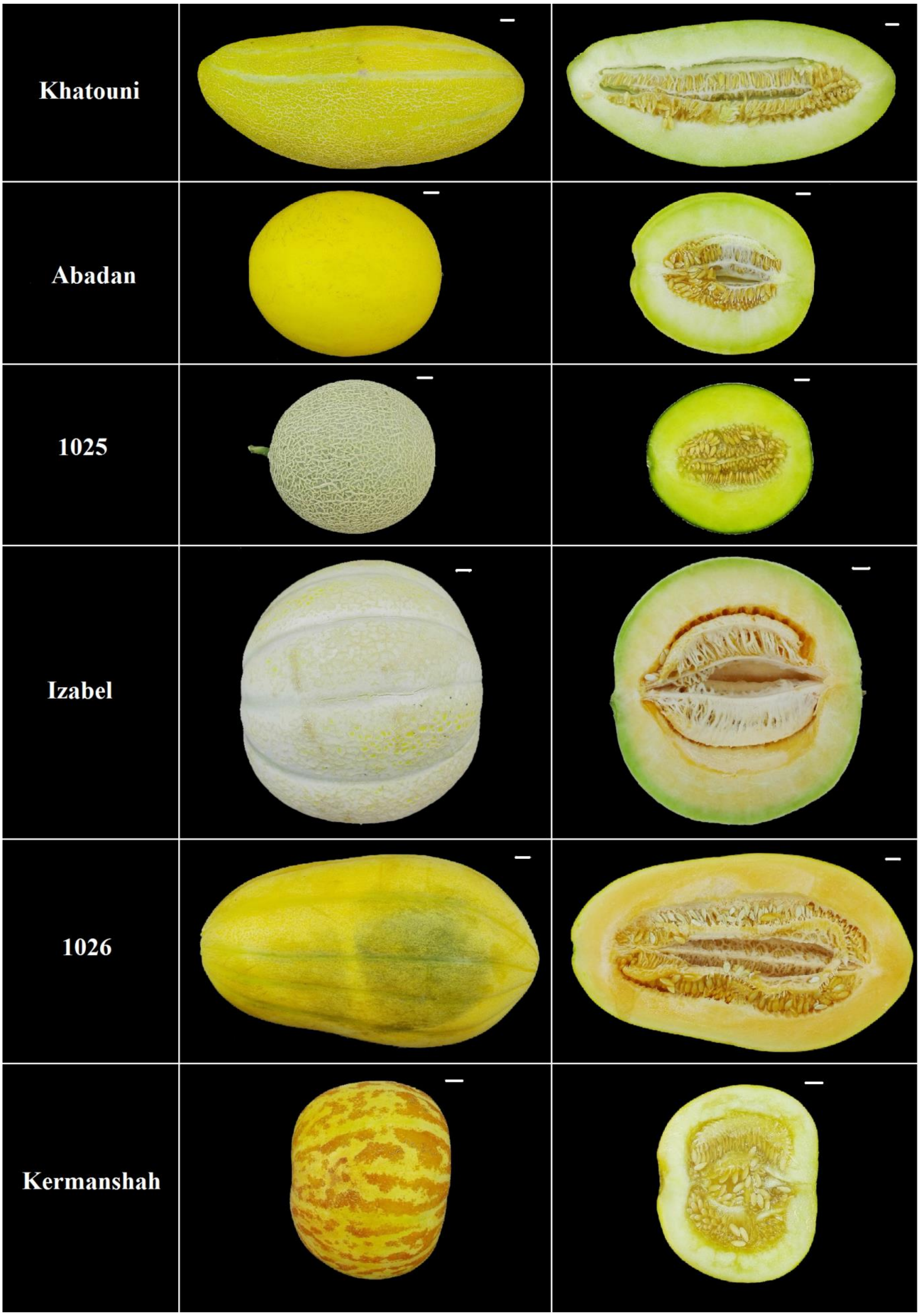

Figure 1. Melon inbred lines used in the study. The line above each type represents one centimeter.

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Table 2. General and specific combining ability significance, reciprocal effect significance and the ratio of GCA/SCA for Weight Loss (WL), Firmness (F) and Firmness Loss (FL) at each measurement (days zero, 10, 20, and 30).

	GCA	SCA	Reciprocal	Error	σ2g	σ^2s	σ^2r	GCA/ SCA
Df	5	15	15	35				
WL 10	7.49**	2.58ns	2.54ns	1.33	0.41	0.73	0.61	0.36
WL 20	39.03***	9.03***	13.57***	2.03	2.52	4.06	5.77	0.38
WL 30	38.2ns	20.07***	13.81***	2.7	1.56	10.08	5.56	0.13
F 0	915.36***	175.98***	222.32***	46.55	61.96	75.15	87.88	0.45
F 10	1089.17***	166.75**	211.06**	59.56	77.16	62.24	75.75	0.55
F 20	1192.32***	138.18**	191.03***	43.09	88.1	55.22	73.97	0.61
F 30	780.62***	87.42***	78.86***	17.87	57.95	40.38	30.49	0.59
FL 10	841.00***	154.43ns	318.46***	107.85	57.97	32.69	107.63	0.63
FL 20	920.65***	127.97ns	288.24***	78.03	66.19	29	105.1	0.7
FL 30	740.2***	105.32ns	319.82***	76.95	52.98	16.47	121.44	0.76

*: Significant at the 0.05 level, **: Significant at 0.01 level and ***: Significant at 0.001 level. ns: Non-significant,

hybrids with lower weight loss during cold storage period.

Fruit Firmness

It was reported that consumers prefer tender melon (Pardo *et al*., 2000), so, the mesocarp firmness of melon fruit is considered an important economic trait. However, the expanding industry of fresh-cut produce created a consumer-preference for firmer fruit, because in addition to its long shelf life and storability, it tends to have a crisp bite and is more appealing (Lester *et al*., 2007).

Diallel analysis for fruit firmness showed a significant GCA, SCA, and reciprocal values directly after harvest and throughout the storage period. The GCA/SCA ratio confirmed the importance of additive and none-additive control of this trait (Table 2).

It was reported that some Quantitative Trait Loci (QTLs) control mesocarp firmness traits in melon (Barros *et al*., 2011; Moreno *et al*., 2008), which supported the results of the diallel analysis. Previous diallel analysis studies also showed the importance of additive and non-additive gene effects controlling mesocarp firmness in melon (Barros *et al*., 2011; Paris *et al*., 2008), while Pouyesh *et al*. (2017) study showed that the additive gene action is more important in controlling this trait.

The best GCA during the storage period was associated with the 1025 parent, while the best SCA was associated with the hybrid 1026×Abadan and this was the case at days zero and 30. The 1026×Kermanshah and Kermanshah×Khatouni had the best SCA after 10 and 20 days, respectively (Table 3).

The study of mesocarp firmness loss during storage showed that GCA and reciprocal values were significant, while SCA values were not significant. The GCA/SCA ratio was 0.63, 0.7, and 0.76 after 10, 20, and 30 days in cold storage, respectively, which suggested that the additive gene effects were more important in controlling firmness loss during cold storage (Table 2).

The best GCA values were associated with Khatouni and 1025 parents, while the best SCA values were associated with the 1025×Izabel hybrid (Table 3)**.** Therefore, crossing Khatouni and 1025 with other cantalupensis lines can introduce new types with medium mesocarp firmness, which is an important characteristic; especially in the types used in fruit fresh cut industry. Furthermore, the slow firmness loss of these

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Table 3. General combining ability for parents used in the study and specific combining ability or reciprocal effect for F1 hybrids.[a]

Name	WL 10	WL 20	WL 30	F 0	F 10	F 20	F 30	FL 10	FL 20	FL 30
1026	**-0.71***	**-1.5**	**-1.71**	**-9.07**	**-8.74**	**-8.49**	-6.63	4.86	4.72	1.62
Abadan	-0.19	-0.34	-0.8	1.97	-0.21	0.67	-0.98	-0.52	1.66	4.01
Izabel	**1.21**	**2.35**	1.55	0.8	-0.32	1.29	1.37	0.45	-1.8	-2.79
1025	**-0.75**	-1.11	-1.38	**13.73**	**15.18**	**14.74**	**12.47**	-7.66	-7.44	-7.47
Kermanshah	0.7	**2.16**	**2.8**	**-9.98**	**-11**	**-13.37**	**-10.31**	**11.18**	**13.59**	**12.69**
Khatouni	-0.25	**-1.56**	-0.46	2.54	5.08	5.16	4.08	**-10.57**	**-10.74**	**-8.06**
1026×Abadan	0.76	**2.2**	**3.18**	**8.62**	1.21	1.14	6.93	3.51	3.31	-3.06
1026×Izabel	-0.24	-0.36	-1.57	**-8.74**	**-11.91**	**-11.45**	**-8.04**	1.11	1.07	0.89
1026×1025	0.03	-0.09	-0.27	-1.39	0.13	5.36	-6.84	0	-0.15	6.52
1026×Kermanshah	-0.04	**-3.47**	**-3.99**	6.33	**11.75**	5.41	6.15	8.8	4.05	2.36
1026×Khatouni	-0.25	-0.69	1.09	3.53	2.25	1.96	3.36	1.22	1.06	-2.64
Abadan×Izabel	0.22	**-2.64**	0.95	-5.4	1.84	4.62	-3.89	-0.94	-2.36	0.98
Abadan×1025	0.41	-1.3	**-2.7**	-3.23	**-13.45**	**-10.28**	**-9.03**	**11.91**	9.1	**10.25**
Abadan×Kermanshah	**-1.07**	-0.1	0.72	-5.57	0.91	-0.78	3.96	4.85	-4.16	**-13.09**
Abadan×Khatouni	**-1.08**	0.2	-1.72	6.09	**11.2**	4.28	0.21	-5.65	-2.16	6.87
1025×Izabel	**-1.09**	-0.6	-1.97	**-11.72**	-4.58	-0.86	3.48	**-74.08**	**-13.91**	**-13.5**
1025×Kermanshah	-0.54	0.36	-1.14	4.45	0.31	-3.21	-2.84	-0.35	3.63	4.15
1025×Khatouni	**-1.35**	-0.93	-1.1	2.51	3.83	5.71	6.56	-2.02	-3.01	-9.44
Kermanshah×Izabel	0.56	1.26	-0.95	-1.69	-6.85	**-9.79**	-5.98	**11.64**	**16.63**	8.99
Kermanshah×Khatouni	0.09	-0.05	1	8	2.05	**8.52**	1.46	-1.67	-6.96	1.98
Khatouni×Izabel	-0.96	**-2.73**	**-4.41**	-3.45	-2.11	**-8.31**	-2.38	2.23	8.78	1
Abadan×1026 (R)[b]	**2.32**	1.92	1.87	6.44	4.8	**9.11**	**10.66**	-6.47	**-12.28**	**-15.24**
Izabel×1026 (R)	0.48	**3.1**	**3.31**	6.78	-2.34	-5.15	-4.58	**12.62**	**27.78**	**25.14**
Izabel×Abadan (R)	**1.45**	1.04	-1.01	-2.7	0.65	0.92	3.19	**-11.65**	**-16.49**	**-11.89**
Izabel×1025 (R)	**1.83**	**5.92**	**5.31**	**9.93**	**9.99**	**9.99**	**9.99**	9.91	9.91	7.55
Izabel×Kermanshah (R)	0.72	-0.25	-0.04	-3.44	-0.22	-3.47	-2.92	0.38	5.98	4.6
Izabel×Khatouni (R)	-0.28	**-3.11**	**-2.85**	**-21.9**	**-17.86**	**-8.38**	-7.22	**-41.24**	**-19.35**	**-20.13**
1025×1026 (R)	0.93	**3.04**	**3.69**	**19.71**	**26.19**	**26.42**	**9.52**	-2.98	-3.01	2.31
1025×Abadan (R)	-0.03	**-2.23**	-1.63	**10.4**	**10.74**	**11.69**	3.52	-6.35	-6.91	3.12
Kermanshah×1026 (R)	**-1.31**	**-2.93**	**-5.55**	**8.13**	3.87	5.14	5.97	4.45	5.91	3.17
Kermanshah×Abadan (R)	-1.02	-0.09	0.69	-5.29	0.86	-0.74	3.76	4.6	-3.96	**-12.44**
Kermanshah×1025 (R)	0.01	-1.17	0.28	3.47	1.72	7.39	3.15	-1.86	-8	-1.91
Khatouni×1026 (R)	**1.23**	**3.3**	0.39	**8.41**	6.81	5.43	0.88	**10.12**	8.07	**12.95**
Khatouni×Abadan (R)	**1.19**	0.62	-0.44	1.64	2.99	-3.68	**8.6**	-8.16	**10.04**	**-10.8**
Khatouni×1025 (R)	0.79	0.14	0.28	**17.57**	**15.6**	**12.46**	3.57	**14.5**	**11.58**	**16.09**
Khatouni×Kermanshah (R)	**-1.17**	**-2.7**	-2.07	5.07	4.19	5.15	-7.07	-1.67	-2.05	**18.39**

[a] Traits of Weight Loss (WL), Firmness (F) and Firmness Loss (FL) (days zero, 10, 20 and 30). [b] Hybrids with the letter R next to their name are Reciprocals. * Bold numbers refer to significant GCA values in parents, significant SCA values in direct hybrids or significant RCA values in reciprocals.

emerging types is considered as an important postharvest trait, whether in fresh cut or full fruit markets.

Total Soluble Solids (TSS)

Several QTLs associated with TSS content and sugar content have been reported (Harel-Beja, 2010; Monforte *et al*., 2004; Park *et al*., 2009; Sinclair *et al*., 2006). Diallel analysis of TSS showed that all three components - GCA, SCA and reciprocal values - were significant throughout the storage period. The GCA/SCA ratio showed the importance of both additive and non-additive genic control of this trait at the beginning of storage (directly after harvest)

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with a value of 0.45. This ratio increased during storage and reached values of 0.68, 0.71 and 0.58 after 10, 20 and 30 days in cold storage respectively showing the importance of an increase in additive genetic control during storage (Table 4). These results are similar to those found by Cuarteiro *et al*. (1985), Kalb and Davis (1984) and Singh and Randhawa (1990) that showed the predominance of additive and non-additive effects. However, other research suggests SCA had a non-significant role (Lippert and Hall, 1972; Paris *et al*., 2008; Zalapa *et al*., 2006). While Monforte *et al*. (2004) reported a non-additive control for this trait in crosses with Pele de Sapo melon which supports the idea of specific inheritance for this trait depending on the cross, Barros *et al*. (2011) suggested that these differences are mainly due to the participating parents in each program as well as the different environmental conditions and methods of data analysis.

Our study shows that the best parent to be used to improve TSS is 1025 after harvest and during the storage period, while the best SCA was found in a 1025×Kermanshah combination. (Table 5). Interestingly, this hybrid gained the aroma profile of the dudaim parent Kermanshah with the sweetness of 1025. These findings refer to the importance of using types with high SS content and lack complexity in their aromatic profiles, such as Khatouni and 1025 lines, along with other melon types with attractive volatiles profile and low or medium soluble solids content.

Mesocarp Color

The genetic control of mesocarp color in commercial melon fruit is not yet clears (Dogimont *et al*., 2011). Several QTLs for mesocarp color were reported in near isogenic lines, and three QTLs were associated with white, green and orange color variations (Cuevas *et al*., 2010; Cuevas *et al*., 2009; Eduardo *et al*., 2007; Harel-Beja *et al*., 2010; Monforte *et al*., 2004; Obando *et al*., 2008). Other QTLs related to beta carotene content, which is directly related to the intensity of orange color in mesocarp (Cuevas *et al*., 2008).

The diallel analysis of mesocarp color showed that the Lightness component (L*) has a significant GCA during the storage period, except for 10 days after the start of cold storage, which was not significant, while the SCA and reciprocal effect were always significant. The GCA/SCA ratio shows that L* is mainly controlled by non-additive gene effects during the first 20 days of cold storage, while the importance of additive gene effects increases during the last 10 days of storage (after 30 days) (Table 6).

The analysis of the Chroma component (C*) showed that the GCA of this component was not significant, except for the last read that was taken after 30 days in cold storage, while the SCA and reciprocal

Table 4. General and specific combining ability significance, reciprocal effect significance and the ratio of GCA/SCA for Soluble Solids (SS%) at each measurement (days zero, 10, 20 and 30).

	Df	SS 0	SS 10	SS 20	SS 30
GCA	5	24.679***	33.4***	32.3***	34.85***
SCA	15	4.45***	3.01**	2.82**	3.66***
Reciprocal	15	5.03***	3.00**	3.12**	3.17***
Error	35	0.84	0.95	1.06	2.61
σ2g		1.69	2.54	2.46	1.69
σ^2s		2.10	1.20	1.02	1.21
σ^2r		2.10	1.03	1.03	0.74
GCA/SCA		0.45	0.68	0.71	0.58

: Significant at 0.01 level and *: Significant at 0.001 level.

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Table 5. General combining ability for parents used in the study and specific combining ability or reciprocal effect for F1 hybrids.

Name	SS 0	SS 10	SS 20	SS 30
1026	-1	-1.33	-1.24	-1.45
Abadan	0.25	-0.01	0.12	0.11
Izabel	-1	-0.67	**-1.55**	**-1.5**
1025	**2.57***	**2.98**	**2.81**	**2.79**
Kermanshah	-1.21	**-1.57**	-0.96	-1.07
Khatouni	0.39	0.6	0.81	1.11
1026×Abadan	-0.35	-0.94	-0.92	-0.54
1026×Izabel	1.06	1.02	0.78	1.12
1026×1025	-1.28	-0.71	**-1.78**	-0.85
1026×Kermanshah	0.42	0.14	-0.15	-0.26
1026×Khatouni	-1.05	-0.55	0.22	-0.46
Abadan×Izabel	0.2	1.14	0.46	0.67
Abadan×1025	**1.99**	0.93	0.7	0.33
Abadan×Kermanshah	**-2.7**	**-2.02**	**-2.5**	-0.84
Abadan×Khatouni	**1.6**	**1.27**	1.22	0.46
1025×Izabel	-0.81	-0.92	-0.31	-0.45
1025×Kermanshah	**2.61**	**1.94**	1.3	**1.71**
1025×Khatouni	0.79	0.35	0.81	**1.54**
Kermanshah×Izabel	0.33	0.72	0.91	0.62
Kermanshah×Khatouni	-0.67	-0.97	-0.44	**-1.97**
Khatouni×Izabel	-0.19	**-1.61**	-0.84	**-2.45**
Abadan×1026 (R)[a]	0.81	-0.33	1.28	1.08
Izabel×1026 (R)	-0.74	-1.13	-1.13	-0.65
Izabel×Abadan (R)	0.65	0.79	-0.68	-1.06
Izabel×1025 (R)	0.59	0.64	0.88	0.65
Izabel ×Kermanshah (R)	0.6	0.55	1.31	0.55
Izabel × Khatouni (R)	**-2.48**	0.94	-0.46	0.19
1025×1026 (R)	**3.28**	**2.56**	**2.15**	**3.4**
1025×Abadan (R)	-1.21	0.15	-1.38	-1.36
Kermanshah×1026 (R)	1.38	**1.34**	**1.69**	0.83
Kermanshah×Abadan (R)	**-2.56**	**-1.92**	**-2.38**	-0.8
Kermanshah×1025 (R)	**1.65**	-0.4	-0.49	0.61
Khatouni×1026 (R)	**2.36**	**1.27**	0.43	1.1
Khatouni×Abadan (R)	**-1.64**	**-2.29**	**-2.2**	**-2.03**
Khatouni×1025 (R)	**2.03**	**1.73**	**1.58**	0.59
Khatouni ×Kermanshah (R)	-0.29	0.74	0.5	0.41

[a] Hybrids with the letter R next to their name are Reciprocals for the Soluble Solids (SS%) at each measurement (days zero, 10, 20 and 30). * Bold numbers refer to significant GCA values (in parents), significant SCA values (in direct hybrids) or significant RCA values (in reciprocals).

effect were significant throughout the storage period. The GCA/SCA ratio also revealed that Chroma was totally controlled by non-additive gene effects with a slight increase in importance for additive gene effects after 30 days in cold storage (Table 6).

The GCA/SCA ratio for Hue angle showed the importance of additive control for this trait with a slight incensement in non-additive gene effects control during the final 10 days of storage (Table 6).

The slight increase in additive gene effects control at the last phase of storage for L* component and C* component might be related to the QTLs that control cold storage physiological disorders such as chilling injury sensitivity and the high susceptibility

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Table 6. General and specific combining ability significance, reciprocal effect significance, and the ratio of GCA/SCA for Light component of Mesocarp color (ML), Chroma of Mesocarp color (MC) and Hue angle of Mesocarp color (MH) at each measurement (days zero, 10, 20 and 30).

	GCA	SCA	Reciprocal	Error	σ2g	σ^2s	σ^2r	GCA/SCA
Df	5	15	15	35				
ML0	52.47^{**}	20.42^{***}	15.01^{**}	4.17	2.72	9.43	5.43	0.22
ML10	10.9^{ns}	5.56^{***}	13.82^{***}	1.23	0.46	2.51	6.3	0.15
ML20	13.76^{*}	5.91^{**}	15.32^{***}	2.12	0.66	2.2	6.6	0.23
ML30	24.18^{***}	5.44^{***}	6.32^{***}	1.49	1.57	2.29	2.41	0.41
MC0	258.71^{ns}	278.26^{***}	155.38^{***}	37.87	0	139.58	58.75	0
MC10	99.16^{ns}	251.79^{***}	217.39^{*}	61.81	0	110.31	77.79	0
MC20	273.44^{ns}	230.67^{***}	270.40^{***}	31.22	4.1	115.81	119.59	0.03
MC30	378.47^{*}	174.34^{***}	164.21^{***}	39	17.38	78.57	62.6	0.18
MH0	308.61^{***}	36.42^{ns}	31.3^{ns}	24.12	22.72	7.15	3.59	0.76
MH10	216.69^{***}	12.96^{ns}	28.55^{ns}	8.34	16.99	2.68	10.11	0.86
MH20	234.47^{***}	40.4^{***}	51.4^{***}	9.87	16.25	17.72	20.76	0.48
MH30	251.28^{***}	34.29^{***}	22.65^{*}	9.12	18.15	14.61	6.77	0.55

*: Significant at the 0.05 level, **: significant at 0.01 level and ***: significant at 0.001 level, ns: non-significant,

to scalding (Fernández Trujillo *et al*., 2007; Fernández Trujillo *et al*., 2008; Fernández Trujillo *et al*., 2011; Martínez *et al*., 2009).

The growing understanding of the nutritional and health value of carotenoids, which are found in fruit with orange mesocarp, underlines the importance of the types with orange flesh, such as 1026 and Izabel. Furthermore, the significant GCA for Hue angle presented in this study is a clear indicator of the importance of classic breeding method to introduce new types that fulfill the growing market demand for orange melons.

Rind Color

It appears that melon rind color is based on the different combinations of three major pigments, namely, chlorophyll, carotenoids, and naringerin-chalcone (Tadmor *et al*., 2010). The accumulation of these three pigments was said to be controlled by a single dominant gene for naringerin-chalcone and two linked genes for chlorophyll and carotenoids, while the quantitative variance in accumulation of these pigments is supposed to be controlled by minor genes (Dogimont *et al*., 2011). The QTLs responsible for the control of external fruit color was reported in Eduardo *et al*. (2007), Monforte *et al*. (2004), and Obando *et al*. (2008).

Diallel analysis of skin color components L*, Chroma, and Hue was performed. The results showed that the GCA of all color components were significant throughout the storage period, except for light component, which had a significant GCA at the beginning of the storage period and then decreased and became non-significant. The SCA effect was significant for all color components and during the whole storage period, except for the Hue angle after 20 days of cold storage, which had a non-significant value. The reciprocal effect had a significant value for all components before storage, while it became non-significant during the storage period, except for the Chroma component after 10 and 30 days of cold storage (Table 7).

The GCA/SCA ratio for L* component was 0.34, which supported the idea of the equal importance of additive and non-additive genetic controls of this trait before storage. It reached zero after 10 and 20 days in cold storage and increased again to 0.17 at the final read after 30 days, suggesting a non-additive genetic control of this trait

Table 7. General and specific combining ability significance, reciprocal effect significance, and the ratio of GCA/SCA for light component of Rind Color (RL), Chroma of Rind color (RC) and Hue angle of Rind color (RH) at each measurement (days zero, 10, 20 and 30).

	GCA	SCA	Reciprocal	Error	σ2g	σ^2s	σ^2r	GCA/SCA
Df	5	15	15	35				
RL0	41.59**	11.11***	5.11*	2.47	2.56	5.02	1.32	0.34
RL10	26.85ns	31.8***	5.22ns	3.71	0	16.31	0.76	0
RL20	15.29ns	20.04**	11.15ns	6.32	0	7.96	2.41	0
RL30	29.47ns	14.8**	5.48ns	4.6	1.25	5.91	0.43	0.17
RC0	2068.24***	171.55***	103.93***	24.25	158.45	85.53	39.84	0.65
RC10	1759.48***	142.77***	93.4**	30.3	135.03	65.3	31.3	0.67
RC20	1706.25***	105.66***	129.91ns	12.77	133.63	53.94	58.57	0.71
RC30	1310.60***	139.10***	85.71***	18.1	97.95	70.26	33.81	0.58
Rh0	119.96***	15.21***	9.53**	3.34	8.76	6.89	3.1	0.56
Rh10	126.43***	8.48**	7.02ns	4.04	9.84	2.58	1.49	0.79
Rh20	140.53**	9.89ns	13.55ns	9.29	10.89	0.39	2.13	0.97
Rh30	173.38***	15.4***	6.71ns	3.82	13.2	6.73	1.45	0.66

*: Significant at the 0.05 level, **: Significant at 0.01 level and ***: Significant at 0.001 level, ns: Non-significant.

during cold storage and the decay of any differences caused by additive gene effects that were present at the beginning of the storage period (Table 7).

The GCA/SCA ratios for Chroma and Hue components were 0.65 and 0.56, respectively, and increased during the next 20 days and then decreased slightly after 30 days (Table 7). All these values indicted that additive gene effects play an important role in controlling these traits throughout the cold storage period.

CONCLUSIONS

The usage of Persian melon in breeding programs was previously suggested to improve storability and other fruit characteristics. This experiment showed that including Khatouni melon in breeding programs can significantly enhance fruit traits such as TSS and firmness. Furthermore, Khatouni hybrids were characterized by low firmness loss and weight loss, suggesting an enhanced storability and postharvest quality. Furthermore, the crosses between types having high sweetness and no sensible volatile profile with other melon types with highlighted aromatic content and low SS content can introduce new types with an interesting intermediate state.

REFERENCES

1. Barros, A. K. D. A., Nunes, G. H. D. S., Queiróz, M. A. D., Pereira, E. W. L. and Costa Filho, J. H. D. 2011. Diallel Analysis of Yield and Quality Traits of Melon Fruits. *Crop Breed. Appl. Biot.,* **11:** 313-319.
2. Burger, Y., Paris, H. S., Cohen, R., Katzir, N., Tadmor, Y., Lewinsohn, E. and Schaffer, A.A. 2010. Genetic Diversity of *Cucumis melo*. In “Horticultural Reviews”, (Ed.): Janick, J. PP. 36, 165.
3. Burger, Y., Saar, U., Katzir, N., Paris, H. S., Yeselson, Y., Levin, I. and Schaffer, A.A. 2002. A Single Recessive Gene for Sucrose Accumulation in *Cucumis melo* Fruit. *J. Am. Soc. Hortic. Sci.,* **127:** 938-943.
4. Cuarteiro, M. L. G. J., Abadia, J. and Nuez, F. 1985. Herencia de Caracteres Cualitativos en Melón. *Instituto Nacional de Investigacióny Tecnología Agraria y Alimentaria,* **28:** 72-82.
5. Cuevas, H. E., Staub, J. E. and Simon, P. W. 2010. Inheritance of Beta-Carotene-Associated Mesocarp Color and Fruit

[DOR: 20.1001.1.16807073.2020.22.6.2.8]

Maturity of Melon (*Cucumis melo* L.). *Euphytica*, **173:** 129-140.
6. Cuevas, H. E., Staub, J. E., Simon, P. W. and Zalapa, J. E. 2009. A Consensus Linkage Map Identifies Genomic Regions Controlling Fruit Maturity and Beta-Carotene-Associated Flesh Color in Melon (*Cucumis melo* L.). *Theor. Appl. Genet.*, **119:** 741-756.
7. Cuevas, H. E., Staub, J. E., Simon, P. W., Zalapa, J. E. and McCreight, J. D. 2008. Mapping of Genetic Loci that Regulate Quantity of Beta-Carotene in Fruit of US Western Shipping Melon (*Cucumis melo* L.). *Theor. Appl. Genet.,* **117:** 1345-1359.
8. Dehghani, H., Feyzian, E., Rezai, A. M. and Jalali, M. 2009. Correlation and Sequential Path Model for Some Yield-Related Traits in Melon (*Cucumis melo* L.). *J. Agr. Sci. Tech.*, **11:** 341-353.
9. Dogimont, C. 2011. 2011 Gene List for Melon. *Cucurbit Genetics Cooperative* Report. **33**:104-133.
10. Eduardo, I., Arús, P., Monforte, A. J., Obando, J., Fernández-Trujillo, J. P., Martínez, J. A., Alarcón, A. L., Álvarez, J. M. and van der Knaap, E. 2007. Estimating the Genetic Architecture of Fruit Quality Traits in Melon Using a Genomic Library of Near Isogenic Lines. *J. Am. Soc. Hortic. Sci.,* **132:** 80-89.
11. Epinat, C. and Pitrat, M. 1994. Inheritance of Resistance to Downy Mildew (*Pseudoperonospora cubensis*) in Muskmelon (*Cucumis melo*). I. Analysis of a 8×8 Diallel Table. *Agronomie*, **14(4):** 239-248.
12. Fernández Trujillo, J. P., Martínez López, J. A., Alarcón Vera, A. L., Varó Vicedo, P., Dos-Santos-Carrillo, N., Obando Ulloa, J. M. and Bueso Sánchez, M. C. 2011. *Identification of Quantitative Trait Loci Using Near-Isogenic Lines of Melon. A Lines of Melon. A Research Review Covering Potential Applications in Fruit Quality.* ISSN 2172-0436, Technology and Knowledge Transfer e-Bulletin, Vol. 2,
13. Fernández-Trujillo, J. P., Obando, J., Martínez, J. A., Alarcón, A. L., Eduardo, I., Arús, P. and Monforte, A. J. 2007. Mapping Fruit Susceptibility to Postharvest Physiological Disorders and Decay Using a Collection of Near-Isogenic Lines of Melon. *J. Am. Soc. Hortic. Sci.*, **132:** 739-748.
14. Fernández-Trujillo, J. P., Obando-Ulloa, J. M., Martínez, J. A., Moreno, E., García-Mas, J. and Monforte, A. J. 2008. Climacteric and Non-Climacteric Behavior in Melon Fruit: 2. Linking Climacteric Pattern and Main Postharvest Disorders and Decay in a Set of Near-Isogenic Lines. *Postharvest Biol. Tec.*, **50:** 125-134.
15. Feyzian, E., Dehghani, H., Rezai, A. M. and Javaran, M. J., 2009. Diallel Cross Analysis for Maturity and Yield-Related Traits in Melon (*Cucumis melo* L.). *Euphytica*, **168:** 215-223.
16. Griffing, B. 1956. Concept of General and Specific Combining Ability in Relation to Diallel Crossing Systems. *Aust. J. Biol. Sci.*, **9:** 463-493.
17. Harel-Beja, R., Tzuri, G., Portnoy, V., Lotan-Pompan, M., Lev, S., Cohen, S., Dai, N., Yeselson, L., Meir, A., Libhaber, S. E. and Avisar, E. 2010. A Genetic Map of Melon Highly Enriched with Fruit Quality QTLs and EST Markers, Including Sugar and Carotenoid Metabolism Genes. *Theor. Appl. Genet.*, **121:** 511-533.
18. Kalb, T. J. and Davis, D. W. 1984. Evaluation of Combining Ability, Heterosis, and Genetic Variance for Fruit Quality Characteristics in Bush Muskmelon. *J. Am. Soc. Hortic. Sci.*, **109:** 411-415.
19. Kitroongruang, N., Poo-Swang, W. and Tokumasu, S. 1992. Evaluation of Combining Ability, Heterosis and Genetic Variance for Plant Growth and Fruit Quality Characteristics in Thai-Melon (*Cucumis melo* L., var. Acidulus Naud.). *Sci. Hortic.*, **50:** 79-87.
20. Lester, G. E., Saftner, R. A. and Hodges, D. M. 2007. Market Quality Attributes of Orange-Fleshed, Non-Netted Honey Dew Melon Genotypes Following Different Growing Seasons and Storage Temperature Durations. *HortTechnology*, **17:** 346-352.
21. Liu, L., Kakihara, F. and Kato, M. 2004. Characterization of Six Varieties of *Cucumis melo* L. Based on Morphological and Physiological Characters, Including Shelf-Life of Fruit. *Euphytica*, **135(3):** 305.
22. Martínez, J. A., Jowkar, M. M., Obando-Ulloa, J. M., Varó, P., Moreno, E., Monforte, A. J. and Fernández-Trujillo, J. P. 2009. Uncommon Disorders and Decay in Near-Isogenic Lines of Melon and

Reference Cultivars. *Hortic. Bras.*, **27:** 505-514.
23. Miccolis, V. and Saltveit, M. E. 1995. Influence of Storage Period and Temperature on the Postharvest Characteristics of Six Melon (*Cucumis melo* L., Inodorus Group) Cultivars. *Postharvest Biol. Tec.*, **5:** 211-219.
24. Monforte, A. J., Oliver, M., Gonzalo, M. J., Alvarez, J. M., Dolcet-Sanjuan, R. and Arus, P. 2004. Identification of Quantitative Trait Loci Involved in Fruit Quality Traits in Melon (*Cucumis melo* L.). *Theor. Appl. Genet.*, **108:** 750-758.
25. Moreno, E., Obando, J. M., Dos-Santos, N., Fernández-Trujillo, J. P., Monforte, A. J. and Garcia-Mas, J. 2008. Candidate Genes and QTLs for Fruit Ripening and Softening in Melon. *Theor. Appl. Genet.*, **116:** 589-602.
26. Nakazumi, H. and Hirai, G. 2004. Diallel Analysis for Resistance of Melon (*Cucumis melo*) to Fusarium Wilt Caused by *Fusarium oxysporum* f. sp. Melonis Race 1, 2y. *Breeding Research*, **6(2): 65-70.** (in Japanese).
27. Obando, J., Fernández-Trujillo, J. P., Martinez, J. A., Alarcón, A. L., Eduardo, I., Arús, P. and Monforte, A. J. 2008. Identification of Melon Fruit Quality Quantitative Trait Loci Using Near-Isogenic Lines. *J. Am. Soc. Hortic. Sci.*, **133:** 139-151.
28. Om, Y. H., Oh, D. G. and Hong, K. H. 1987. Evaluation of Heterosis and Combining Ability for Several Major Characters in Oriental Melon. Research Reports of the Rural Development Administration-Horticulture (Korea R.).
29. Pardo, J. E., Alvarruiz, A., Varón, R. and Gómez, R. 2000. Quality Evaluation of Melon Cultivars. Correlation among Physical-Chemical and Sensory Parameters. *J. Food Quality*, **23:** 161-170.
30. Paris, M. K., Zalapa, J. E., McCreight, J. D. and Staub, J. E. 2008. Genetic Dissection of Fruit Quality Components in Melon (*Cucumis melo* L.) Using a RIL Population Derived from Exotic×Elite US Western Shipping Germplasm. *Mol. Breed.*, **22**: 405-419.
31. Park, S. O., Hwang, H. Y. and Crosby, K. M. 2009. A genetic Linkage Map Including Loci for Male Sterility, Sugars, and Ascorbic Acid in Melon. J. Am. Soc. *Hortic. Sci.*, **134:** 67-76.
32. Pitrat, M. 2016. Melon Genetic Resources: Phenotypic Diversity and Horticultural Taxonomy. In: "*Genetics and Genomics of Cucurbitaceae*", Springer, Cham, PP. 25-60.
33. Pouyesh, A., Lotfi, M., Ramshini, H., Karami, E., Shamsitabar, A. and Armiyoun, E., 2017. Genetic Analysis of Yield and Fruit Traits in Cantaloupe Cultivars. *Plant Breed.*, **136:** 569-577.
34. Robinson, R. W. and Decker-Walters, D. S. 1999. *Cucurbits*. CAB International, Wallingford, New York, NY, 226 PP.
35. Sinclair, J. W., Park, S. O., Lester, G. E., Yoo, K. S. and Crosby, K. M. 2006. Identification and Confirmation of RAPD Markers and Andromonoecious Associated with Quantitative Trait Loci for Sugars in Melon. *J. Am. Soc. Hortic. Sci.*, **131:** 360-371.
36. Singh, M. J. and Randhawa, K. S. 1990. Assessment of Heterosis and Combining Ability for Quality Traits in Muskmelon. *Indian J. Hortic.*, **47:** 228-232.
37. Tadmor, Y., Burger, J., Yaakov, I., Feder, A., Libhaber, S. E., Portnoy, V., Meir, A., Tzuri, G., Sa'ar, U., Rogachev, I. and Aharoni, A. 2010. Genetics of Flavonoid, Carotenoid, and Chlorophyll Pigments in Melon Fruit Rinds. *J. Agr. Food Chem.*, **58:** 10722-10728.
38. Wang, Y. H., Thomas, C. E. and Dean, R. A. 1997. A Genetic Map of Melon (*Cucumis melo* L.) Based on Amplified Fragment Length Polymorphism (AFLP) Markers. *Theor. Appl. Genet.*, **95:** 791-798.
39. Welbaum, G. E. 2015. *Vegetable Production and Practices.* CABI, UK.
40. Wien, H. C. 1997. The Cucurbits: Cucumber, Melon, Squash and Pumpkin. In: "*The Physiology of Vegetable Crops*", (Ed.): Wien, H. C. CAB International, New York, NY, PP. 345-386.
41. Zalapa, J. E., Staub, J. E. and McCreight, J. D. 2006. Generation Means Analysis of Plant Architectural Traits and Fruit Yield in Melon. *Plant Breed.*, **125**: 482-487.
42. Zhang, Y., Kang, M. S. and Lamkey, K. R. 2005. Diallel-Sas05. *Agron. J.*, **97:** 1097-1106.

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تجزیه و تحلیل ترکیب پذیری عمومی و خصوصی ویژگی های بعد از برداشت در خربزه

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چکیده

بهبود شاخص های مربوط به پس برداشت و نگهداری در سردخانه یکی از اهداف اصلی برنامه‌های اصلاحی تولید خربزه می باشد. با توجه به رشد بازار جهانی، معرفی انواع خربزه و طالبی های جدید با قابلیت انبارمانی طولانی مدت اهمیت زیادی دارد. در این آزمایش، به منظور ایجاد یک جمعیت کامل دی آلل F1 ، از ۶ اینبرید لاین خربزه استفاده شد. میوه های برداشت شدهدر سردخانه نگهداری شدند و شاخص های مهم پس از برداشت در طول مدت نگهداری تحت مورد اررزیابی قرار گرفتند. نتایج نشان داد که برخی شاخص‌ها تحت تأثیر اثرات ژنی افزایشی مانند استحکام میان بر و مواد جامد محلول (SS)قرار می گیرند. تجزیه و تحلیل استحکام میان بر پیشنهاد کرد که این شاخص توسط اثرات ژنتیکی افزایشی و غیر افزایشی کنترل شود. تجزیه و تحلیل ترکیب پذیری عمومی (GCA) نشان داد که می توان اینبرد لاین خاتونی را در برنامه‌های اصلاحی برای تولید هیبرید خربزه با استحکام مناسب تر، کاهش تلفات انبارمانی و ماندگاری بیشتر، به عنوان والد مطلوب در نظر گرفت.

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