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Heritability and combining ability in half diallel cross of melon (*Cucumis melo* L.)

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ABSTRACT

Purpose: The main aim of the present research was to evaluate the growth performance and genetic variation in diallel crosses of melon. **Research method:** To investigate general and specific combining abilities and how genes act in eight melon populations, one-way diallel crosses were performed at Zahak Agricultural Research Station in 2019. Then, parental seeds and hybrids were planted in the spring of 2020 in a randomized complete block design with three replications. Fruit length, fruit width, number of fruits per plant, cavity diameter, fruit weight, total soluble solids, plant length, durability (number of days to crushing), flesh thickness, and yield were examined. **Findings:** The results of the analysis of variance showed significant differences among the population for all traits. The results of diallel based on method 2 model 1 of a Griffing showed that general and specific combining abilities for the traits are statistically significant at the 5% level of statistical probability. The additive effects of genes on cavity diameter, total soluble solids, and shelf life were observed, expressing the possibility of selection in early generations for these traits. **Research limitations:** No limitations were founded. **Originality/value:** The additive effects of genes on cavity diameter, total soluble solids, and shelf life were observed, expressing the possibility of selection in early generations for these traits also durability or shelf life is the most important trait in vegetables especially in melon so, based on these results cross Sefidak × Yellow ivaneki was the best cross for improvement of this trait.

INTRODUCTION

In breeding programs implemented based on hybridization, it is important to select and identify which parent generally improves a trait (general combinability). Knowing the inheritance of traits is also essential. Such information is obtained through quantitative genetic analysis such as diallel crosses, which is a cross method for estimating genetic parameters and parental combining ability (Phumichai, 2008). Diallel crosses provide the necessary information about the heterotic relationship of the parents, and the various methods of diallel and analyses in plant breeding are described by Griffing (Griffing, 1956). Due to its advantages and disadvantages, diallel genetic schemes have been used extensively in estimating the combining abilities of horticultural traits in vegetables and, of course, melons and cantaloupes (Raghami et al., 2015). Diallel crosses were used to evaluate different traits in ten melon cultivars and well heterosis was observed for the number of days until the first fruit harvest, average fruit weight, and yield (Lippert, 1972). Genetic studies and knowing the type of gene action involved in expressing a trait and the power of combining ability in plant breeding methods are important. In particular, information and careful study of combining ability can be useful in relation to the selection of breeding methods and the selection of lines for making hybrids, general combining ability (GCA) and specific combining ability (SCA) are estimated by using diallel crosses (Talei, 1997). The diallel cross design has been used as a suitable and efficient method by plant breeding experts to identify the type of gene action, and genetic components and estimate specific and general combining ability (Ana, 2002). The first step is to find the right parents to make the necessary crosses to produce suitable hybrids, for this purpose, one of the two assumptions is that the studied genotypes are fixed or random, based on one of the Griffing analysis methods, the use of hybrid seeds of the plants is very important in crop production. In hybridization programs, it is important to select and identify which parent has the ability to transmit the desired genes. It is also important to know something about of inheritance of the special traits, information is obtained through quantitative genetic analysis such as diallel crosses, which is a known method for estimating genetic parameters and parental combining abilities (Hallauer, 1988). A crucial step in a melon breeding program is the identification of promising lines to combine and generate hybrids with performances superior to the most grown varieties. In this regard, the adoption of diallel cross designs is useful in estimating the general combining ability (GCA) of parents and the specific combining ability (SCA) of hybrids, as detailed in (Griffing, 1956).

Melon is a common crop consumed by many Iranians, especially during the hot summer, melon is the most polymorphic species of the cucurbit family, which is particularly true for fruit related traits (Esmaeili et al., 2022). Melon play a significant role in human nutrition, especially in tropical and subtropical countries where their consumption is high, therefore, the development of locally adapted, competitive, high-yielding genotypes with export quality may be a unique and valuable practical solution for this problem. High yield, uniform fruit shape, fruit size, and excellent quality are prerequisites for the release of superior melon cultivars (Zalapa, 2006). Combining ability analysis is an important tool for the selection of desirable parents together with the information regarding the nature and magnitude of gene effects controlling quantitative traits (Basbag et al., 2007). Response of additive effects (GCA) and non-additive effects (SCA) is involved in genetic control of trait and results of general and specific combining ability provide relevant information on parents and progeny to continue advancing in breeding program (Cavalcante et al., 2020). The GCA (additive) and SCA (non-additive) depend on the allele frequency of the parents involved in the diallel and on the level of dominance of the trait. The general combining ability effect is an indicator of the superiority of the population, in terms of frequency of the favorable genes, and the differences between the gene frequencies of the population and the mean frequencies in the group (Badami et al., 2020). However, combining ability analyses are commonly used in corn breeding programs to determine GCA and SCA information from populations for genetic diversity evaluation, inbred line selection, heterotic pattern classification, heterosis estimation, and hybrid development (Fan et al., 2008). Therefore, the main objectives of the present investigation are to obtain clear and determining information about the relative importance of additive and non-additive gene actions involved in the inheritance of some growth and yield characteristics of melon through the estimation of both the general and specific combining abilities of eight parental cultivars and their all possible F1 combinations, respectively, using a diallel cross system in one direction. Heritability percentages, in narrow senses, were, also, estimated.

MATERIALS AND METHODS

In this project, eight populations of melons based on their variation in traits were selected, including 1- Sefidak 2- Jajrood 3- Shadegan 4- Qasri 5- Ghaenat 6- Dargazi 7- Green-striped 8- Yellow Ivaneki in 2019 and were crossed in half diallel crosses to produce the 28 possible F_1 hybrids in the greenhouse (Table 1). 28 hybrids and 8 parents were planted in March 2020 in Zahak Agricultural Research Station (30/54// N, 61/46// W; 483 m above sea level) in Sistan and Baluchestan Province, as randomized complete block design with three replications. Mean annual precipitation and mean annual temperature during the experimental period were 59 mm and 28 °C, respectively. Spacing was 2 m between rows and 0.5 m between plants. Fertilizer treatments were 100 kg ha^{-1} NPK (2:2:1) and 10 tons ha^{-1} cow manure before planting, with an additional 100 kg ha^{-1} of N, 45 days after sowing. Plots were irrigated every week for the first month after sowing, and at 4-day intervals for the rest of the cropping season. Plants were thinned five weeks after sowing. All plots were weeded manually to maintain proper weed control. The harvest in both years was begun in June and continued until July. Mature fruits were harvested every day during this time. Samples of three random ripe fruits per plot were, randomly taken to measure the fruits' characteristics. The traits measured were Plant length, fruit weight, shelf life (number of days in storage), fruit length, fruit width, flesh thickness, total soluble solids, and cavity diameter, hand refractometer was used for measuring total soluble solids (TSS) in extracted juice. The refractometer measures the refractive index, which indicates how much a light beam will be slowed down when it passes through the fruit juice, the values being expressed in Brix. Finally, general and specific combining abilities analyzes were performed based on Method 2, the model1 of Griffing (1956). All analyzes were performed with AGD-R software (Rodriguez et al., 2015) and Excel.

Table 1. Cultivars and origins of eight selected melons.

Cultivar	Origin (Iran)
Sefidak	South-eastern
Jajrood	Central
Shadegan	South-western
Qasri	North-eastern
Ghaenat	North-eastern
Dargazi	North-eastern
Green striped	North-eastern
Yellow ivaneki	Central

RESULTS AND DISCUSSION

The analysis of variance of combing ability effects on the various studied characters of the eight parental cultivars and their all F_1 hybrid combinations (in one direction) are presented in Table 2. The results, generally, illustrated that the estimated variances for the effects of both general and specific combining abilities showed relatively high values for all the studied characters. These results are partially in agreement with those previously published reported (Bahari et al., 2012). Moreover, it was noticed for most studied characters that non-additive gene effects were found to be more pronounced for their contributions to the genetic variability than that due to the additive gene effects. The ratio of GCA/SCA was more than unity for all studied traits. These results indicating that the additive genetic effects were more important and played the major role in all studied traits except for yield and durability also a trait whose Bakers' ratio is close to 1 indicates that the GCA effects were more important in conditioning the heritability of that trait, whereas a ratio that is close to zero would indicates that SCA effects would be more important in controlling trait heritability. Based on the results, the mean squares of general and specific combining ability for all traits were significant at the level of 1% probability, which shows the differences between parents in terms of general combining ability and also the possibility of choosing a suitable parent to participate in the hybridization and shows the effect of the additive effect of the gene in controlling these traits. The mean squares of specific combining ability in all the evaluated traits were significant at the level of one percent, which indicates the effect of the non-additive action of genes in controlling the studied traits. Among eight parents, Jajrood was the best general combiner for fruit length, fruit width, fruit weight, plant length, and yield (Table 4).

Table 2. Mean squares from diallel analysis and ANOVA for various characters in melon (Griffing's method 2 model1).

Source of variation	Degree of freedom	Fruit length	Fruit width	Number fruit per plant	Cavity length	Cavity width	Fruit weight
Replication	2	19.5	1.57	0.005	2.98	14.5	648175
Genotype	35	98.7**	31.52**	0.65**	96.6**	12.9**	4207263**
GCA	7	151.8**	46.6**	1.007**	138.1**	19.42**	5343509**
SCA	28	85.4**	27.7**	0.56**	86.2**	11.31**	3923176**
Error	70	1.96	0.8	0.008	4.77	1.5	27879
Baker ratio		0.78	0.77	0.78	0.76	0.77	0.73
GCA/SCA		1.77	1.68	1.7	1.6	1.71	1.36

**Significant at 0.01 statistical level.

Table 2. (Continued).

Source of variation	Degree of freedom	Total soluble solids	Plant length	Durability	Flesh thickness	Yield
Replication	2	0.16	2360	0.44	0.06	12503634
Genotype	35	22.89**	6764**	1.07**	1.51**	204087377**
GCA	7	28.42**	6271**	0.74	3.67**	34484950**
SCA	28	21.51**	6887**	1.15**	0.98**	168896921**
Error	70	0.31	203	0.51	0.23	716099
Baker ratio		0.72	0.64	0.78	0.88	0.28
GCA/SCA		1.32	0.91	0.64	3.74	0.2

Table 3. Comparison of means in the evaluated traits in parents.

Cultivar	Fruit length (cm)	Fruit width (cm)	Number fruit per plant	Cavity length (cm)	Cavity width (cm)	Fruit weight (gr)
Sefidak	17.8 ^{D}	11 ^{B}	2^{AB}	15.3^{C}	6.7 ^{B}	745 ^{EF}
Jajrood	25.9 ^{A}	13^{AB}	2^{AB}	22^{A}	8.9 ^{A}	1537 ^{B}
Shadegan	26.9 ^{A}	13.1 ^{AB}	1^{B}	22.5^{A}	7.0 ^{B}	2210 ^{A}
Qasri	18.5 ^{CD}	13.7 ^{AB}	2^{AB}	13.0^{D}	8.4 ^{A}	1418^{C}
Ghaenat	22.1 ^{AB}	9.8 ^{C}	1^{B}	21.2^{AB}	5.9 ^{C}	885 ^{E}
Dargazi	31.6 ^{A}	12.1 ^{B}	2.2^{A}	10.3^{E}	7.1 ^{B}	2421 ^{A}
Green striped	20.1 ^{BC}	14.4^{A}	1^{B}	18.8^{BC}	8.9 ^{A}	1523 ^{B}
Yellow ivaneki	27.4 ^{A}	14.4 ^{A}	2^{AB}	20.3^{B}	8.7 ^{A}	2187 ^{A}

Means with the same letter(s) in each column are not significantly different based on Duncan's test at 5% probability level.

Table 3. (Continued).

Cultivar	Total soluble solids (%)	Plant length (cm)	Durability (day)	Flesh thickness (cm)	Yield (kg/$^{ha-1}$)
Sefidak	6.17 ^{DE}	216 ^{BC}	5.3 ^{D}	2.33 ^{D}	10570^{G}
Jajrood	10.3 ^{A}	230 ^{ABC}	6.0 ^{C}	2.8 ^{CD}	20490C
Shadegan	6.6 ^{CD}	214 ^{C}	7.0^{C}	4.1 ^{A}	14140^{F}
Qasri	6.4 ^{CD}	239 ^{ABC}	6.0 ^{C}	3.05 ^{BC}	18910^{D}
Ghaenat	4.5 ^{F}	243 ^{ABC}	6.7 ^{C}	2.63 ^{CD}	5900^{H}
Dargazi	5.6 ^{E}	170 ^{D}	7.8 ^{B}	2.76 ^{CD}	15230 ^{E}
Green striped	7.8 ^{B}	257 ^{AB}	6.0 ^{C}	3.2 ^{BC}	10160^{G}
Yellow ivaneki	6 ^{DE}	215 ^{C}	9.3 ^{A}	3.56 ^{AB}	29160 ^{A}

Means with the same letter(s) in each column are not significantly different based on Duncan's test at 5% probability level.

Table 4. Estimates of general combining ability (GCA) effects on the various studied characters of the eight parental cultivars of melon.

Parent	Fruit length (cm)	Fruit width (cm)	Number fruit per plant	Cavity length (cm)	Cavity width (cm)	Fruit weight (gr)	Total soluble solids (%)	Plant length (cm)	Durability (day)	Flesh thickness (cm)	Yield (kg/ha^{-1})
Sefidak	-4.9**	1.83**	0.3**	-5.0**	1.02**	246.8**	0.63**	19.81**	-0.15	0.77**	4583**
Jajrood	2.09**	1.1**	0.22**	1.17*	0.97**	574.2**	0.65**	21.91**	-0.008	0.05	5073**
Shadegan	-0.77*	-2.1**	-0.07**	-0.35	-1.4**	-672**	-1.2**	-14.5**	0.12	-0.41**	-3894*
Qasri	1.66**	0.43*	-0.07**	1.07*	-0.29	54.29	0.92**	2.31	0.09	-0.23*	-628**
Ghaenat	-0.12	-1**	0.02**	0.16	-0.02	-108**	0.67**	-0.25	0.12	-0.09	-4**
Dargazi	0.29	-0.35	-0.17**	0.72	-0.22	80.54*	-1.2**	-3.65	-0.17	0.07	-1830*
Green striped	1.62**	0.4*	-0.07**	1.72**	0.32	356**	0.62**	-8.78**	0.27*	-0.06	512**
Yellow Ivaneki	0.19	-0.31	-0.17**	0.54	-0.27	-507**	-1**	-16.8**	0.22*	-0.09	-3812*
S.E(gi)	0.23	0.15	0.006	0.37	0.21	28.51	0.09	2.43	0.12	0.08	144.5

*and**significant at 0.05 and 0.01 statistical level respectively.

Results showed that there were significant differences between all the traits among the genotypes by comparing the means of the tests (Duncan multiple range method), Yellow ivaneki separated from other genotypes by comparing the means for fruit weight, durability and fruit width (Table 3)

Green striped and Yellow Ivaneki was the best general combiner for shelf life. On the other hand, Qaenat, Sefidak, and Jajrood were the best combiner for total soluble solids, also Sefidak was the best general combiner for flesh thickness. It has been documented that the parental line Hara Madhu was the best general combiner for total fruit yield per plant in melon (Vashisht et al., 2010). A study (Akrami & Arzani, 2019) reported positive and significant general combining ability for fruit length and expressed the broad and narrow sense heritability for this trait as 0.88 and 0.12, respectively. Specific combining ability should be used in combination with hybrid means and GCA of the respective parents for better hybrid selection. However, according to Ferreira et al. (2002), two high GCA parents when crossed will not always originate the best diallel hybrid. Many research results stated that the hybrid combinations with mean performance, desirable SCA estimates, and involving at least one of the parents with high GCA would be considered favorable allele combinations

(Gnanamalar et al., 2013). It was observed that the cross combination Khatooni × Zarde Ivanaki had the highest SCA values in a significant direction for fruit length (Table 5).

For TSS content, the best cross combination was sefidak×jajrood. Regarding one research (Katherine et al., 2011) for the SCA, no significant differences were found for soluble solids content, indicating that the GCA for this character, although negative in some parents, when combined, allelic complementation occurred, which favored the increase of the soluble solids content in the hybrid combinations thus pointing to the action of additive effects controlling this trait. These results differ from those presented another report (Barros et al., 2011). It also was observed that the cross combination Qasri Mashahd × Khatooni had the highest SCA values in a significant direction for fruit weight. It has been shown that dominance and epistatic genetic effects mainly are controlled fruit weight per plant (Zalapa, 2006; Zalapa, 2007; Zalapa, 2008). The amount of dominance variance for this trait was higher than the additive variance (Table 7). Broad sense heritability for this trait was 0.98 and narrow heritability was 0.26, which was consistent with the results of previous publish report (Akrami & Arzani, 2011).

Table 5. Estimates of specific combining ability (SCA) effects on the various studied characters of the 28 F1 hybrids of melon.

Cross	Fruit length	Fruit width	Number of fruit per plant	Cavity length	Cavity width	Fruit weight
1×2	-4.4**	-2.1**	0.1**	-4.8**	-0.8	-1152**
1×3	-7.1**	1.1**	0.2**	-7.4**	1.8**	139
1×4	-3.7**	1.2*	-0.5**	-2.8*	2.2**	10
1×5	2.6**	1.3**	-0.4**	2.9*	0.4	510**
1×6	4.5**	1.9**	0.8**	1.8	1.9**	843**
1×7	-4.8**	-1.1*	-0.5**	-1.9	1.1	-924**
1×8	0.25	-1.2*	-0.4**	-0.4	-1.5*	-542**
2×3	-0.9	1.4**	-0.1**	-1.5	-1.5*	275**
2×4	0.4	0.8	0.3**	-4.9**	0.6	6
2×5	5**	-0.1	0.4**	11.4**	-0.6	1245**
2×6	-4**	-4.5**	-0.2**	1.6	-1.7*	-1044**
2×7	4.1**	0.8	0.7**	1.1	1	290**
2×8	1.5*	1.1**	-0.3**	2.6*	0.3	411**
3×4	-4.2**	3**	0.6**	-3.8**	1.6*	-43
3×5	-0.1	-6.1**	-0.05**	0.06	-2.1**	-1169**
3×6	0.05	-0.7	-0.05**	0.6	0.2	-98
3×7	-2.8**	8.1**	-0.1**	-4.1**	4.3**	1772**
3×8	-3.5**	-3.9**	0.04**	-1.01	-3.4**	-1839**
4×5	4.6**	-0.9	-0.4**	6.8**	-0.3	1283**
4×6	-2*	3**	-0.1**	-3.7**	-0.06	500**
4×7	3.7**	1.4**	0.8**	1.9	2.3**	1175**
4×8	-7.8**	-4.5**	-0.2**	-5.7**	-0.6	-1873**
5×6	-3.2**	0.6	-0.1**	-3**	-1.2*	-418**
5×7	-0.19	1.6**	0.5**	0.9	1.3*	805**
5×8	3.3**	-2.1**	-0.3**	2.7*	-2.2**	-1581**
6×7	-1.8*	0.3	-0.05**	0.6	1.1	592**
6×8	-5**	-2.8**	-0.1**	-4.6**	-3.5**	-1219**
7×8	7.5**	-3.1**	-0.05**	10.8**	0.8	-1414**
$Standard.error._{gij}$	0.63	0.41	0.0004	0.99	0.25	76.04

* and ** significant at 0.05 and 0.01 statistical level respectively, 1- Sefidak 2- Jajrood 3- Shadegan 4- Qasri 5- Ghaenat 6- Dargazi 7- Green-striped 8- Yellow Ivaneki.

Table 5. (Continued).

Cross	Total soluble solids	Plant length	Durability	Flesh thickness	Yield
1×2	4.1**	-34**	-1.7**	-0.1	-5671**
1×3	-3**	69**	-0.06	-0.4	4638**
1×4	-0.1	24**	-0.7	-0.1	-5725**
1×5	1.1**	-3	0.1	0.7**	-3460**
1×6	3.5**	75**	-1**	0.3	10641**
1×7	-2.2**	-35**	-0.3	-0.5*	-9769**
1×8	-3.9**	-30**	1	-0.46	7892**
2×3	2.7**	-31**	0.06	0.48*	-1279**
2×4	1.6**	-72**	-0.7	-0.4	2583**
2×5	0.7*	-24**	-0.5	0.8**	12538**
2×6	-2.9**	-52**	-1*	-0.6*	-5837**
2×7	-2.6**	78**	0.03	-0.1	8240**
2×8	2.9**	35**	1**	1**	-2995**
3×4	0.1	-30**	-0.5	0.3	7031**
3×5	-0.09	-41**	-0.03	-0.1	-3800**
3×6	-1.4**	-9	-0.3	-0.3	-1155*
3×7	1.8**	84**	0.3	0.2	3998**
3×8	-1.2**	-19**	0.2	-0.1	-5586**
4×5	3**	-11	-0.4	0.3	-1856**
4×6	-1.1**	-3	0.06	-0.1	345
4×7	3.4**	74**	0.7	0.4	16723**
4×8	-3.5**	-46**	-0.2	-1.1**	-9578**
5×6	-2.6**	11	-0.2	-0.01	-3695**
5×7	0.19	85**	-0.2	-0.1	9058**
5×8	0.6*	-3	0.3	-0.9**	-9964**
6×7	3.4**	16*	0.2	0.3	1170*
6×8	-1**	-36**	0.1	-0.7**	-5953**
7×8	-2.2**	-20*	-0.4	0.3	-5570**
Standard.error.$_{gij}$	0.25	6.49	0.32	0.22	385.3

* and ** significant at 0.05 and 0.01 statistical level respectively, 1- Sefidak 2- Jajrood 3- Shadegan 4- Qasri 5- Ghaenat 6- Dargazi 7- Green-striped 8- Yellow Ivaneki.

One of the important traits with more focus on Sefidak was that it was considered. Significant general and specific combining abilities were identified for this trait. The highest positive general combining ability in relation to this trait was obtained for Khatooni and Zard Ivanaki populations, which indicates that these populations can be effective in increasing shelf life (Table 4). The degree of private combinability for Sefidak intersections in Ivanaki yellow and Qaenat in Khatooni was positive and significant (Table 5). The degree of variance of dominance for this trait was less than the additive variance (Table 7). Broad sense heritability for this trait was 0.56 and narrow sense heritability was 0.12. Given the slightly greater contribution of the non-additive effect in the control of the soluble solids trait, the selection potential for this trait may be more effective. It has been reported that diallel analysis for fruit firmness showed significant GCA, SCA, and reciprocal values directly after harvest and throughout the storage period (Alabboud et al., 2020), and confirmed the importance of additive and non-additive control of this trait. It has been also revealed the GCA variances were several times higher than SCA’s indicating that additive gene actions are more important than non-additive ones, also in general, while in Latina PI414723 was the best contributing parent in terms of heterosis, in Perugia, the most interesting lines were PI161375 and Hale’s Best Jumbo (Napolitano et al., 2020). Therefore, based on LsM, it can be stated that, in Latina, PI414723 performed the best in crossing with Vedrantais, Ita1, Ogen, and Magyar Kincs, while in Perugia it was PI161375 performed the best with Ogen, Top Mark, and Hale’s Best Jumbo. Cavity length was another trait that was measured, general and specific combining abilities were significant for this trait. The highest positive general combining ability in relation to this trait was obtained for Jajrood and Khatooni populations, which indicates that these populations can be effective in increasing fruit width (Table 4). The degree of private combinability was positive and significant for the intersections of Jajrood in striped green and Khatooni in Zarde Ivanaki (Table 5). The use of heterosis breeding offers the possibility of improving the quantity, quality and productivity of any crop. Identifying the best combiner employed in crosses to generate desirable segregates and accumulate fixable genes or exploit heterosis requires the employment of a strong tool that considers the combiner's abilities and its heterosis, heterosis was estimated for each characteristic as a percentage of increase in F_1 hybrid over mid-parent (Table 6). For the all traits, heterosis ranged from the -65 to 41, The cross $P_1 \times P_6$ was the top hybrid with effects in the desirable direction except for durability. Among all the F_1, twenty-eight crosses for trait of durability just cross $P_1 \times P_8$ was positively highly. The degree of variance of dominance for this trait was less than the additive variance (Table 7), which was consistent with the results of Katherine et al. (2011). Broad sense heritability was 0.88 for this trait and narrow sense heritability was 0.62. Given the contribution of the additive effect in the control of the cavity length trait, the selection potential for this trait will be effective.

Table 6. Estimation of heterosis on the various studied characters of the melon.

Cross	Fruit length	Fruit width	Number of fruit per plant	Cavity length	Cavity width	Fruit weight
1×2	-8.7	-3.4	18.1	-58	-19	-68.3
1×3	-6.3	2.2	26.3	-64	29	67.1
1×4	-5.2	1.9	-34.2	-18	31	23.2
1×5	4.3	1.8	-26.2	17	15	61.8
1×6	5.6	2.8	23.3	21	34	76.3
1×7	-7.3	-3.3	-38.7	-9	24	-78.3
1×8	1.8	-2.5	-35	-3	-23	-43.1
2×3	2.3	1.9	-24	-12	-26	26.5
2×4	2.9	1.8	-35	-35	17	6.6
2×5	3.1	-1.3	51	56.4	-18	81.7
2×6	-5.3	-5.8	-31	26	-31	-74.2
2×7	5.7	1.3	61	18	22	28.1
2×8	2.5	2.7	-37	37	14	48.4
3×4	-6.1	4	59	-26	23	-37
3×5	-1.4	-9.1	-13	8.6	-31	-83
3×6	1.2	-1.8	-15	6.8	12	-69
3×7	-3.4	9.5	-14	-36	55	86
3×8	-5.7	-4.2	-18	-23	43	-81
4×5	7.4	-1.2	-32	78	-15	87.2
4×6	-4.1	4	-15.3	-37	-11	44.9
4×7	7.2	3.7	67	33	37	88.2
4×8	-8.6	-6.2	-15	-61	-16	-75.1
5×6	-5.3	2.8	-34	-36	-26	-36.3
5×7	-2.1	2.7	63	29	31	58.2
5×8	6.2	-3.5	-27	21	-37	-87.3
6×7	-24.3	1.3	-10	8	13.4	48.4
6×8	-7.5	-4.2	-25	-39	-42	-89.5
7×8	9.8	-4.2	-8	81	19.3	89.3

1- Sefidak 2- Jajrood 3- Shadegan 4- Qasri 5- Ghaenat 6- Dargazi 7- Green-striped 8- Yellow Ivaneki.

Table 6. (Continued).

Total soluble solids	Plant length	Durability	Flesh thickness	Yield
51.3	-43	-17.3	-10	-65
-41	70	-3.4	-14	34
-18	33	-1.9	-13	-32
15.9	-15	10.4	17	-33
46	85	-12.4	13	48
-31.7	-43	-1.6	-15	-29
-41	-40	43.7	-56	41
29	-38	6.9	58	-23
19.4	-81	-29	-14	45
9.6	-37	-13.5	18	54
-31	-62	-10.3	-16	29
-34.3	83	15.7	-15	38
32.9	44	20.5	35	-13
10.6	-42	-5.9	13	45
-3.6	-52	-12.6	-17	-29
-16	-22	-21.6	-13	-21
20.5	78	3.8	22	44
14.6	-26	21.9	-18	-42
29.3	-21	-11.7	13	-19
-18.8	-12	6.9	-10	8
47.9	80	8.6	38	7
-38.9	-55	-12.6	-48	-19
-21.7	22	-12.8	-7	-32
25.4	88	-22.7	-11	34
8.9	-15	13.5	-19	-39
36.1	26	22.6	32	12
-17.5	-47	10.6	-27	-35
-34.2	-33	-14.9	19	-38

1- Sefidak 2- Jajrood 3- Shadegan 4- Qasri 5- Ghaenat 6- Dargazi 7- Green-striped 8- Yellow Ivaneki.

Table 7. Additive and dominance variances, broad sense heritability (H^2b) and narrow sense heritability (H^2n)

Genetic parameters	Fruit length	Fruit width	Number of fruit per plant	Cavity length	Cavity width
Additive variance	15.43	7.45	0.26	3.58	3.29
Dominance variance	92.7	37.98	0.87	5.12	9.38
H^2b	0.95	0.93	0.98	0.88	0.7
H^2n	0.38	0.26	0.29	0.62	0.26

Table 7. (Continued).

Genetic parameters	Total soluble solids	Plant length	Durability	Flesh thickness	Yield
Additive variance	34.4	2709	0.35	0.61	84970106
Dominance variance	2.21	9786	0.31	0.8	251640872
H^2b	0.46	0.91	0.56	0.59	0.99
H^2n	0.59	0.15	0.12	0.34	0.3

CONCLUSION

Results showed the significance of both the additive and the non-additive effects in the inheritance of the evaluated traits. Furthermore, it was shown that total yield was more dependent on non-additive variance than additive variance. The additive effects of genes on cavity diameter, total soluble solids, and shelf life were observed, expressing the possibility of selection in early generations for these traits. Durability or shelf life is the most important trait in vegetables especially in melon so, based on these results cross Sefidak × Yellow ivaneki was the best cross for improvement of this trait in Sefidak for its weakness in shelf life. Also, cross Qasri × green stripped was the best cross regarding to their specific combining ability based on positive feedback in all traits.

Conflict of interest

The authors have no conflict of interest to report.

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