

Diallel analysis for yield and quality characteristics in melon

ABSTRACT

Aims: To estimate the effects of general and specific combinatorial fitness in parents and progeny on yield and fruit quality related traits of melon.

Study design: A completely randomized block design with three replications was used to estimate the analysis of variance and the effects of general combining ability (GCA) and specific combining ability (ACE). The genetic analysis was carried out based on the Griffing Method II diallelic design (1956) with fixed effects model. Tukey $P=0.05$ mean comparison analysis.

Place and Duration of Study: The research was conducted in two stages. In stage 1, seed production of the parents and crosses was carried out at the Physiotechnical Greenhouse of the of the Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila. Mexico, between April and July 2021. In stage 2, the evaluation of the parents and progeny was carried out between August and November 2021 in the agricultural field "La Jaroza", Paila, Coahuila. México.

Methodology: In the present study, seven melon parents were analyzed. The parents were crossed in all possible combinations, without reciprocal crosses, resulting in 21 progenies, a total of 28 genotypes evaluated.

Results: The results showed significant differences between genotypes, general and specific combining ability effects (GCA and SCA) for almost all variables, except fruit number. The parent "(E x L)" showed the best yield and GCA effects, and participated in most of the outstanding crosses in yield, average fruit weight, fruit length, fruit width, flesh thickness, seed cavity and soluble solids. The "N x (E x L)" progeny excelled in yield and average fruit weight in SCA.

Conclusion: The parent "(E x L)" showed the best yield and GCA effects and participated in most of the outstanding crosses in yield, average fruit weight, fruit length, fruit width, flesh thickness, seed cavity and soluble solids. The progeny "N x (E x L)" excelled in yield in SCA.

Keywords: Cucumis melo, genetic effects, yield.

1. INTRODUCTION

The melon (*Cucumis melo* L.) belonging to Cucurbitaceae family is an important horticultural crop of economically importance worldwide [1]. China, Turkey, India, Iran and Kazakhstan are the main producers of melon, with Mexico in tenth place [2]. Melon is one of the crops of great economic and social importance in Mexico, which is grown approximately 15,600 ha with a production of 483,500 t [3, 4]. Comarca Lagunera, formed by Durango and Coahuila in north of Mexico, stands out as an important melon-producing region in country with a planted area of 4,900 ha with a production of 169, 247 t, representing 35% of national production [4].

Melon breeding programs have as objective to increase yield, precocity, fruit quality and improve resistance to diseases and pests [5]. Selection of parents is essential to obtain competitive hybrids with quality and yield [6]. Melon fruit quality is related to characteristics such as total soluble solids concentration, internal and external appearance of the fruit, flesh thickness and flavor, which determine consumer acceptability [7]. In this sense, adoption of diallel cross design is useful to estimate capacity of general combining ability (GCA) of parents and specific combining ability (SCA) of progeny [8]. Therefore, objective of this study was to estimate effects of general and specific combining ability in parents and progeny on yield and quality-related characteristics of melon fruit.

2. MATERIALS AND METHODS

2.1 Experiment location

The investigation was carried out in two stages. Stage 1. The production of the seed of parents and crosses was carried out in Invernadero de Fisiotecnia of Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, México, between April and July 2021. Located at 25° 21' 19.29" North latitude and 101° 01' 49.07" West longitude, 1,777 m.a.s.l. Stage 2. Evaluation of parents and progeny was carried out between August and November 2021 in agricultural field "La Jaroza", Paila, Coahuila. Located at 25°45'08.6" North latitude and 102°09'31.3" West longitude, 1,129 m.a.s.l.

2.2 Vegetal material

In present study, seven progenitors of melon in F₆, cantaloupe type, were analyzed. Parents "K", "N", "E x L", "H x B", "J x K", "L x M" and "H", were crossed in all possible combinations, without reciprocal crosses, resulting in 21 progenies, a total of 28 genotypes evaluated.

2.3 Variables to be evaluated

The fruits were harvested at the physiological maturity stage, making four cuts, at 71, 75, 79 and 83 days after sowing (das). Variables evaluated were number of fruit (NF); precocity (PREC) number of days to harvest; yield (YIELD, t ha⁻¹) tons per hectare; average fruit weight (AFW, Kg); fruit length (FL, cm); fruit width (FW, cm); pulp thickness (PT, cm); seed cavity diameter (SCD, cm) and total soluble solids (TSS, °Brix).

2.4 Statistic analysis

A completely randomized block design with three replications was used to estimate analysis of variance and effects of GCA and SCA, genetic analysis was performed based on diallelic design Method II [8] with a fixed effects model, using AGD-R program (Analysis of Genetic Designs with R for Windows) Version 5.0 [9]. Tukey $P=0.05$ mean comparison analysis was performed with R Core Team (2022) statistical program, using ExpDes.pt version 1.2 package [10].

3. RESULTS AND DISCUSSION

The results showed significant differences ($P=0.01$) between genotypes, effects of GCA and SCA for almost all variables, except in number of fruits (Table 1). Differences of genotypes are associated with variability that exists between materials ([11]. Response of additive effects (GCA) and non-additive effects

(SCA) is involved in genetic control of trait [12]. Results of general and specific combining ability provide relevant information on parents and progeny to continue advancing in breeding program.

Table 1. Mean squares of analysis of variance of seven parents and 21 crosses for yield and quality characteristics in melon.

| Source of Variation | DF | PREC | YIELD | NF | AFW | FL | FW | PT | DSC | TSS |
|---------------------|----|---------|----------|---------|--------|---------|---------|--------|--------|---------|
| Repetition | 2 | 0.57ns | 55.54ns | 0.011ns | 0.10ns | 0.67ns | 1.63ns | 0.56* | 0.49ns | 1.00ns |
| Genotypes | 27 | 27.40** | 275.42** | 0.04ns | 0.49** | 14.92** | 9.73** | 0.64** | 1.35** | 3.87** |
| GCA | 6 | 33.72** | 658.83** | 0.04ns | 1.07** | 30.14** | 24.09** | 1.53** | 2.81** | 10.87** |
| SCA | 21 | 25.59** | 165.88** | 0.04ns | 0.33** | 10.57** | 5.62** | 0.39** | 0.93** | 1.86** |
| Error | 54 | 7.49 | 28.50 | 0.049 | 0.06 | 1.71 | 1.55 | 0.17 | 0.32 | 0.83 |
| CV % | | 3.63 | 19.73 | 21.12 | 21.34 | 8.70 | 8.82 | 12.21 | 10.24 | 15.21 |

*, **= significant at 0.05, 0.01, ns= not significant differences; PREC= precocity; YIELD=yield; NF= number of fruits; AFW= average fruit weight; FL= fruit length; FW= fruit width; PT= pulp thickness; DSC= Diameter of the seed cavity; TSS= total soluble solids.

3.1 Precocity

The precocity, is one of the objectives of many breeding programs [5]. Great majority of farmers prefer early varieties with high yields to enter to market quickly and obtain high prices [13]. Analysis of variance showed significant differences ($P=0.01$) between genotypes (Table 1) in precocity. Parent "K" (72.33 das) presented better precocity followed by "H x B" and "L x M" (73.67 das) in progeny of materials "(E x L) x (H x B)", "(E x L) x H", "(H x B) x (L x M)" and "(L x M) x H" (71.00 das) with best precocity (Table 4). Values of GCA for precocity in different parents are presented in Table 2. Parent "H x B" (-1.44) with negative values in GCA, could be used for formation of early varieties, where negative values in certain variables are desirable as precocity [14, 15]. SCA values in progeny are presented in Table 3, where crosses "N x (E x L)" (-4.67) and "N x (L x M)" (-4.37) with negative values, SCA significantly affects differences in precocity [16].

Table 2. Estimation of the general combining ability (ACG) of 7 melon parents for yield and quality characteristics.

| PROGENITOR | PREC | YIELD | NF | AFW | FL | FW | PT | DSC | TSS |
|------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| K | -0.11ns | 1.65ns | 0.03ns | 0.03ns | 0.20ns | 0.52* | 0.10ns | 0.14ns | 0.27ns |
| N | 1.97** | -3.39** | -0.01ns | -0.13* | -1.40** | -1.15** | -0.33** | 0.21ns | 0.10ns |
| (E x L) | -0.25ns | 8.46** | 0.07ns | 0.31** | 0.80** | 1.12** | 0.38** | 0.47** | 0.52* |
| (H x B) | -1.44* | 1.90ns | -0.04ns | 0.12* | 1.38** | 0.69* | 0.04ns | 0.14ns | -0.59** |
| (J x K) | 0.93ns | -2.82* | -0.01ns | -0.13* | -0.21ns | -0.38ns | 0.09ns | -0.36** | 0.90** |
| (L x M) | -0.55ns | 1.11ns | -0.04ns | 0.09ns | 0.57* | 0.49ns | -0.02ns | -0.34** | -0.30ns |
| H | -0.55ns | -6.92** | -0.01ns | -0.29** | -1.34** | -1.29** | -0.26* | -0.27* | -0.90** |

*, **= significant at 0.05, 0.01, ns= not significant differences; PREC= precocity; YIELD= yield; NF= number of fruits; AFW= average fruit weight; FL= fruit length; FW= fruit width; PT= pulp thickness; DSC= diameter of the seed cavity; TSS= total soluble solids.

Table 3. Estimation of the specific combining ability (ACE) of 21 melon crosses for yield and quality characteristics.

| PROGENY | PREC | YIELD | NF | AFW | FL | FW | PT | DSC | TSS |
|-------------|---------|--------|---------|--------|--------|---------|---------|--------|---------|
| K x N | 1.85ns | 3.37ns | -0.07ns | 0.22ns | 1.05ns | 1.14ns | 0.41ns | 0.12ns | 0.65ns |
| K x (E x L) | 1.41ns | 8.43** | 0.19ns | 0.15ns | 0.15ns | 0.45ns | -0.41ns | 1.05** | 1.29** |
| K x (H x B) | -0.07ns | 1.96ns | -0.04ns | 0.13ns | 0.04ns | -0.73ns | 0.27ns | 0.18ns | 0.20ns |
| K x (J x K) | -2.44ns | 8.74** | 0.26* | 0.16ns | 3.57** | 1.74** | 0.26ns | 0.41ns | -0.01ns |

| | | | | | | | | | |
|-------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| K x (L x M) | 4.37** | 4.55ns | -0.04ns | 0.25ns | 0.95ns | 1.21ns | 0.10ns | -0.63* | 0.26ns |
| K x H | 0.37ns | 0.50ns | -0.07ns | 0.09ns | -0.20ns | 0.42ns | 0.27ns | 0.22ns | -0.81ns |
| N x (E x L) | -4.67** | 15.50** | -0.11ns | 0.79** | 2.92** | 3.14** | 0.38ns | 1.15** | 0.86ns |
| N x (H x B) | 3.19* | -0.66ns | 0.00ns | -0.04ns | 1.64* | -0.83ns | -0.14ns | -0.22ns | -0.29ns |
| N x (J x K) | 0.81ns | 1.14ns | -0.04ns | 0.07ns | -0.70ns | 0.30ns | 0.25ns | 0.51ns | 0.36ns |
| N x (L x M) | -4.37** | -6.98* | 0.00ns | -0.33* | -0.36ns | -1.13ns | -0.08ns | 0.03ns | -0.64ns |
| N x H | 3.63* | -2.21ns | 0.30* | -0.25ns | -2.51** | -1.91** | -0.54* | -0.28ns | -0.57ns |
| (E x L) x (H x B) | -2.59ns | 4.08ns | -0.07ns | 0.26ns | 0.38ns | 0.20ns | 0.15ns | -0.12ns | 1.02* |
| (E x L) x (J x K) | -0.96ns | -3.99ns | -0.11ns | -0.07ns | 1.13ns | 0.24ns | -0.30ns | -0.56ns | -1.00* |
| (E x L) x (L x M) | 4.52** | -2.80ns | -0.07ns | -0.05ns | -0.72ns | -1.02ns | 0.18ns | -0.20ns | 0.20ns |
| (E x L) x H | -3.48* | -3.53ns | -0.11ns | -0.07ns | 1.16ns | 0.69ns | 0.45* | -0.61* | -1.26** |
| (H x B) x (J x K) | 0.22ns | -3.04ns | 0.00ns | -0.13ns | -1.01ns | -0.24ns | -0.22ns | 0.04ns | -0.42ns |
| (H x B) x (L x M) | -2.30ns | 1.06ns | 0.04ns | 0.02ns | -0.06ns | 0.40ns | -0.14ns | 0.43ns | -1.02* |
| (H x B) x H | -0.96ns | 11.81** | 0.00ns | 0.52** | 3.02** | 1.81** | 0.56* | 0.75* | 0.38ns |
| (J x K) x (L x M) | 2.00ns | 8.96** | 0.00ns | 0.41** | 1.26ns | 0.77ns | 0.54* | 0.26ns | 1.17* |
| (J x K) x H | 2.00ns | -0.44ns | -0.04ns | 0.00ns | 0.07ns | 0.25ns | 0.08ns | -0.15ns | 0.37ns |
| (L x M) x H | -3.19* | -0.01ns | 0.00ns | -0.02ns | 0.65ns | 0.29ns | -0.05ns | 0.27ns | -0.03ns |

*, **= significant at 0.05, 0.01, ns= not significant differences; PREC= precocity; YIELD= yield; NF= number of fruits; AFW= average fruit weight; FL= fruit length; FW= fruit width; PT= pulp thickness; DSC= diameter of the seed cavity; TSS= total soluble solids.

3.2 Yield

The analysis of variance for yield shows significant differences ($P=0.01$) between genotypes (Table 1). Parent "E x L" (35.14 t ha^{-1}) presented best yield, in progeny "N x (E x L)" (47.64 t ha^{-1} , Table 4), similar results were reported in previous studies [17], where the significance of GCA and SCA values for yield indicate the importance of additive and non-additive dominant effects is controlling for yield [18], where parent E x L (8.46, Table 2) manifests effect of GCA for yield (YIELD) with high values in additive effects [19, 20], in Table 3 they present the SCA values in progeny, where cross "N x (E x L)" (15.50 , Table 3) manifests additive, non-additive and epistatic genetic effects to control this trait [21].

Table 4. Means of the parents and progeny in melon yield and quality characteristics.

| GENOTYPES | PREC | YIELD | NF | AFW | FL | FW | PT | DSC | TSS |
|-------------------|---------|----------|-------|---------|----------|----------|---------|---------|---------|
| (E x L) | 77.67ab | 35.14a-d | 1.33a | 1.29b-f | 14.10b-f | 14.50a-f | 3.90ab | 6.10abc | 6.47a-g |
| (E x L) x (H x B) | 71.00b | 41.51abc | 1.00a | 1.87ab | 17.57abc | 16.13abc | 3.93a | 6.00abc | 6.93a-g |
| (E x L) x (J x K) | 75.00ab | 28.72b-g | 1.00a | 1.29b-f | 16.73a-d | 15.10a-e | 3.53a-d | 5.07c | 6.40a-g |
| (E x L) x (L x M) | 79.00ab | 33.83a-e | 1.00a | 1.52a-d | 15.67a-e | 14.70a-f | 3.90ab | 5.43bc | 6.40a-g |
| (E x L) x H | 71.00b | 25.08c-h | 1.00a | 1.13b-g | 15.63a-e | 14.63a-f | 3.93a | 5.10c | 4.33fg |
| (H x B) | 73.67ab | 23.25d-h | 1.00a | 1.05c-g | 15.77a-e | 15.20a-e | 3.20a-d | 5.27c | 4.87b-g |
| (H x B) x (J x K) | 75.00ab | 23.1d-h | 1.00a | 1.04c-g | 15.17a-f | 14.20a-f | 3.27a-d | 5.33c | 5.87a-g |
| (H x B) x (L x M) | 71.00b | 31.12a-g | 1.00a | 1.40a-e | 16.90abc | 15.70a-d | 3.23a-d | 5.73abc | 4.07g |
| (H x B) x H | 72.33ab | 33.85a-e | 1.00a | 1.52a-d | 18.07ab | 15.33a-e | 3.70abc | 6.13abc | 4.87b-g |
| (J x K) | 76.33ab | 15.75fgh | 1.00a | 0.71efg | 12.43efg | 11.83d-g | 3.23a-d | 4.53c | 7.53abc |
| (J x K) x (L x M) | 77.67ab | 34.31a-d | 1.00a | 1.54a-d | 16.63a-d | 15.00a-e | 3.97a | 5.07c | 7.73ab |
| (J x K) x H | 77.67ab | 16.89e-h | 1.00a | 0.76d-g | 13.53c-g | 12.70b-g | 3.27a-d | 4.73c | 6.33a-g |
| (L x M) | 73.67ab | 26.89c-h | 1.00a | 1.21b-g | 15.30a-f | 14.83a-e | 3.03a-d | 4.73c | 5.40a-g |
| (L x M) x H | 71.00b | 21.24d-h | 1.00a | 0.96c-g | 14.90a-f | 13.60a-g | 3.03a-d | 5.17c | 4.73c-g |
| H | 75.00ab | 10.18h | 1.00a | 0.46g | 11.23fg | 10.77fg | 2.47cd | 4.87c | 5.13b-g |

| | | | | | | | | | |
|-------------|---------|----------|-------|---------|----------|----------|---------|---------|---------|
| K | 72.33ab | 16.59e-h | 1.00a | 0.75d-g | 12.63d-g | 13.03b-g | 3.10a-d | 5.10c | 5.73a-g |
| K x (E x L) | 76.33ab | 45.61ab | 1.33a | 1.66abc | 16.17a-e | 16.20abc | 3.43a-d | 7.17ab | 8.07a |
| K x (H x B) | 73.67ab | 32.58a-f | 1.00a | 1.47a-e | 16.63a-d | 14.60a-f | 3.77abc | 5.97abc | 5.87a-g |
| K x (J x K) | 73.67ab | 34.63a-d | 1.33a | 1.24b-g | 18.57a | 16.00abc | 3.80abc | 5.70abc | 7.13a-f |
| K x (L x M) | 79.00ab | 34.37a-d | 1.00a | 1.55a-d | 16.73a-d | 16.33ab | 3.53a-d | 4.67c | 6.20a-g |
| K x H | 75.00ab | 22.29d-h | 1.00a | 1.00c-g | 13.67c-g | 13.77a-f | 3.47a-d | 5.60abc | 4.53efg |
| K x N | 79.00ab | 28.69b-g | 1.00a | 1.29b-f | 14.87a-f | 14.63a-f | 3.53a-d | 5.97abc | 7.00a-f |
| N | 79.00ab | 15.21gh | 1.00a | 0.68efg | 11.20fg | 11.47efg | 2.57bcd | 5.27c | 6.00a-g |
| N x (E x L) | 72.33ab | 47.64a | 1.00a | 2.14a | 17.33abc | 17.23a | 3.80abc | 7.33a | 7.47a-d |
| N x (H x B) | 79.00ab | 24.92c-h | 1.00a | 1.12b-g | 16.63a-d | 12.83b-g | 2.93a-d | 5.63abc | 5.20a-g |
| N x (J x K) | 79.00ab | 22.00d-h | 1.00a | 0.99c-g | 12.70d-g | 12.90b-g | 3.37a-d | 5.87abc | 7.33a-e |
| N x (L x M) | 72.33ab | 17.81d-h | 1.00a | 0.80d-g | 13.83c-g | 12.33c-g | 2.93a-d | 5.40bc | 5.13b-g |
| N x H | 80.33a | 14.55gh | 1.33a | 0.50fg | 9.77g | 9.77g | 2.23d | 5.17c | 4.60d-g |

Different letters in the same column indicate significant differences, ($P=0.05$; Tukey); PREC= precocity; NF= number of fruits; AFW= average fruit weight; FL= fruit length; FW= fruit width; PT= pulp thickness; DSC= diameter of the seed cavity; TSS= total soluble solids.

3.3 Average fruit weight

The significant difference ($P=0.01$) in average fruit weight between genotypes is presented in Table 1. Parents with best average fruit weight were "E x L and L x M" (1.29 and 1.21kg), in progeny "N x (E x L) and (E x L) x (H x B)" (2.14 and 1.87 kg, respectively; Table 4) present highest values in average fruit weight. In highest positive GCA (0.31, Table 2) was found in "E x L". Similar results were reported in previous studies [22]. The SCA values of 0.79 was recorded in "N x (E x L)" progeny (Table 3).

3.4 Fruit length and fruit width

In length and width characteristic of fruit, parent "H x B" (15.77 and 15.20 cm) resulted with greater length and with high values in fruit width. The progeny "K x (J x K)" (18.57 cm) showed the longest fruit and the "N x (E x L)" cross showed the greatest for fruit width (17.23 cm) (Table 4). In GCA for fruit length, parent "(H x B)" (1.38) and for fruit width "(E x L)" (1.12) with additive characteristics for trait. In the SCA, it was "K x (J x K)" (3.57) for fruit length and "N x (E x L)" (3.14) for fruit width [18].

3.5 Pulp thickness

There was significant difference ($P=0.05$, Table 1) in thickness of pulp of parent "(E x L)" (3.90 cm) and in crosses "(J x K) x (L x M)" (3.97 cm), "(E x L) x (H x B)" and "(E x L) x H" (3.93 cm), (Table 4). In GCA values in terms of thickness of pulp, parent (E x L) (0.38, Table 2), is controlled by additive effect [18, 22]. In SCA, crosses "(HxB) x H" (0.56) and "(J x K) x (L x M)" (0.54, Table 3) show dominance effects [16].

3.6 Seed cavity

In characteristics of seed cavity, we selected parents with low values, where parent "(J x K)" (4.53 cm) has a small seed cavity, followed by cross "K x (L x M)" (4.67 cm), it important to select varieties with narrow seed cavity [23, 24]. In GCA the parentals "(J x K) and (L x M)" (-0.36 and -0.34, respectively) and in SCA, crosses "K x (L x M) and (E x L) x H" (-0.63 and -0.61, respectively). Therefore, "(J x K) and (L x M)" and "K x (L x M) and (E x L) x H" may be promising and agree with those reported in previous studies [24].

3.7 Total soluble solids

The percentage of total soluble solids is used to classify the melon according to its degree of sweetness; less than 9 °Brix is considered unmarketable, between 9 and 12 °Brix is considered marketable, and more than 12 °Brix is considered extra quality [25,26]. The parent "(J x K)" (7.53 °Brix) presented the highest values in total soluble solids, in cross "K x (E x L)" (8.07 °Brix). In GCA values, the parent "(J x K)" (0.90) and progeny "K x (E x L)" (1.29), genotypes in general did not meet the quality parameters, the parents should be further improved.

4. CONCLUSIONS

In present study, we found significant variation between parents and progeny in different characters evaluated, parent "(E x L)" presents interesting values in general and specific combining ability, and additive and non-additive effects can be used to form a variety synthetic. "N x (E x L)" cross highlighted in diallelic analysis in characteristics related to yield. Parents should be improved in terms of quality and continue advancing with competitive varieties.

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