Original Research Article

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 3 threereplications 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 dialelic design (1956) with fixed effects model. Tukey *P*=.05 mean comparison analysis.

Place and Duration of Study: The research was conducted in two stages. In Sstage 1.-, sSeed production of the parents and crosses was carried out at the Physiotechnical Greenhouse of the of the Universidad AutónomaAgraria Antonio Narro, Saltillo, Coahuila. Mexico, between April and July 2021. In Sstage 2.-, Tthe 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 "(ExL)" 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 "Nx(ExL)" progeny excelled in yield and average fruit weight in SCA.

Conclusion: The parent "(ExL)" 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 "Nx(ExL)" 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, Iranand 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 andCoahuila 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].

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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]. 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 [7]. 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. Stage1. The production of the seed of parents and crosses was carried out in Invernadero de Fisiotecnia of Universidad AutónomaAgraria 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 F_6, cantaloupe type, were analyzed. Parents “K”, “N”, “(ExL)”, “(HxB)”, “(JxK)”, “(LxM)” 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 3 threereplications was used to estimate analysis of variance and effects of general combining ability (GCA) and specific combining ability (SCA), genetic analysis was performed based on diallelic design Method II [7] with a fixed effects model, using AGD-R program (Analysis of Genetic Designs with R for Windows) Version 5.0 [8]. Tukey *P*=.05 mean comparison analysis was performed with R Core Team (2022) statistical program, using ExpDes version 1.2 package [9].

3. RESULTS AND DISCUSSION

The results showed significant differences (P=.01) between genotypes, effects of general and specific combining ability (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 ([10]. Response of additive effects (GCA) and non-additive effects (SCA) is involved in genetic control of trait [11]. 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 7 sevenparents and 21 crosses for yield and quality characteristics in melon.

Source of Varation	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 [12]. Analysis of variance showed significant differences (*P*=.01) between genotypes (Table 1.) in precocity. Parent "K" (72.33 das) presented better precocity followed by "(HxB)" and "(LxM)" (73.67 das) in progeny of materials "((ExL))x((HxB))", "((ExL))xH", "((HxB))x((LxM))" and "((LxM))xH" (71.00 das) with best precocity (Table 4). Values of GCA for precocity in different parents are presented in Table 2. Parent "(HxB)" (-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 [13, 14]. SCA values in progeny are presented in Table 3, where crosses "Nx((ExL))" (-4.67) and "Nx((LxM))" (-4.37) with negative values, SCA significantly affects differences in precocity [15].

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
(ExL)	-0.25ns	8.46**	0.07ns	0.31**	0.80**	1.12**	0.38**	0.47**	0.52*
(HxB)	-1.44*	1.90ns	-0.04ns	0.12*	1.38**	0.69*	0.04ns	0.14ns	-0.59**
(JxK)	0.93ns	-2.82*	-0.01ns	-0.13*	-0.21ns	-0.38ns	0.09ns	-0.36**	0.90**
(LxM)	-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
KxN	1.85ns	3.37ns	-0.07ns	0.22ns	1.05ns	1.14ns	0.41ns	0.12ns	0.65ns
Kx(ExL)	1.41ns	8.43**	0.19ns	0.15ns	0.15ns	0.45ns	-0.41ns	1.05**	1.29**
Kx(HxB)	-0.07ns	1.96ns	-0.04ns	0.13ns	0.04ns	-0.73ns	0.27ns	0.18ns	0.20ns
Kx(JxK)	-2.44ns	8.74**	0.26*	0.16ns	3.57**	1.74**	0.26ns	0.41ns	-0.01ns

Kx(LxM)	4.37**	4.55ns	-0.04ns	0.25ns	0.95ns	1.21ns	0.10ns	-0.63*	0.26ns
KxH	0.37ns	0.50ns	-0.07ns	0.09ns	-0.20ns	0.42ns	0.27ns	0.22ns	-0.81ns
Nx(ExL)	-4.67**	15.50**	-0.11ns	0.79**	2.92**	3.14**	0.38ns	1.15**	0.86ns
Nx(HxB)	3.19*	-0.66ns	0.00ns	-0.04ns	1.64*	-0.83ns	-0.14ns	-0.22ns	-0.29ns
Nx(JxK)	0.81ns	1.14ns	-0.04ns	0.07ns	-0.70ns	0.30ns	0.25ns	0.51ns	0.36ns
Nx(LxM)	-4.37**	-6.98*	0.00ns	-0.33*	-0.36ns	-1.13ns	-0.08ns	0.03ns	-0.64ns
NxH	3.63*	-2.21ns	0.30*	-0.25ns	-2.51**	-1.91**	-0.54*	-0.28ns	-0.57ns
(ExL)x(HxB)	-2.59ns	4.08ns	-0.07ns	0.26ns	0.38ns	0.20ns	0.15ns	-0.12ns	1.02*
(ExL)x(JxK)	-0.96ns	-3.99ns	-0.11ns	-0.07ns	1.13ns	0.24ns	-0.30ns	-0.56ns	-1.00*
(ExL)x(LxM)	4.52**	-2.80ns	-0.07ns	-0.05ns	-0.72ns	-1.02ns	0.18ns	-0.20ns	0.20ns
(ExL)xH	-3.48*	-3.53ns	-0.11ns	-0.07ns	1.16ns	0.69ns	0.45*	-0.61*	-1.26**
(HxB)x(JxK)	0.22ns	-3.04ns	0.00ns	-0.13ns	-1.01ns	-0.24ns	-0.22ns	0.04ns	-0.42ns
(HxB)x(LxM)	-2.30ns	1.06ns	0.04ns	0.02ns	-0.06ns	0.40ns	-0.14ns	0.43ns	-1.02*
(HxB)xH	-0.96ns	11.81**	0.00ns	0.52**	3.02**	1.81**	0.56*	0.75*	0.38ns
(JxK)x(LxM)	2.00ns	8.96**	0.00ns	0.41**	1.26ns	0.77ns	0.54*	0.26ns	1.17*
(JxK)xH	2.00ns	-0.44ns	-0.04ns	0.00ns	0.07ns	0.25ns	0.08ns	-0.15ns	0.37ns
(LxM)xH	-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=.01) betweengenotypes (Table 1.). Parent "(ExL)" (35.14 $t.ha^{-1}$) presented best yield, in progeny "Nx((ExL))" (47.64 t ha^{-1}, Table 4.). Significant variations (P=.01) of GCA and SCA for yield indicate importance of dominant additive and non-additive effects being controlled for this trait [16],where parent (ExL) (8.46, Table 2) manifests effect of GCA for yield (YIELD) with high values in additive effects [17, 18], in Table 3 they present the SCA values in progeny, where cross "Nx((ExL))" (15.50, Table 3) manifests additive, non-additive and epistatic genetic effects to control this trait [19].

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

GENOTYPES	PREC	YIELD	NF	AFW	FL	FW	PT	DSC	TSS
(ExL)	77.67ab	35.14a-d	1.33a	1.29b-f	14.10b-f	14.50a-f	3.90ab	6.10abc	6.47a-g
(ExL)x(HxB)	71.00b	41.51abc	1.00a	1.87ab	17.57abc	16.13abc	3.93a	6.00abc	6.93a-g
(ExL)x(JxK)	75.00ab	28.72b-g	1.00a	1.29b-f	16.73a-d	15.10a-e	3.53a-d	5.07c	6.40a-g
(ExL)x(LxM)	79.00ab	33.83a-e	1.00a	1.52a-d	15.67a-e	14.70a-f	3.90ab	5.43bc	6.40a-g
(ExL)xH	71.00b	25.08c-h	1.00a	1.13b-g	15.63a-e	14.63a-f	3.93a	5.10c	4.33fg
(HXB)	73.67ab	23.25d-h	1.00a	1.05c-g	15.77a-e	15.20a-e	3.20a-d	5.27c	4.87b-g
(HxB)x(JxK)	75.00ab	23.1d-h	1.00a	1.04c-g	15.17a-f	14.20a-f	3.27a-d	5.33c	5.87a-g
(HxB)x(LxM)	71.00b	31.12a-g	1.00a	1.40a-e	16.90abc	15.70a-d	3.23a-d	5.73abc	4.07g
(HxB)xH	72.33ab	33.85a-e	1.00a	1.52a-d	18.07ab	15.33a-e	3.70abc	6.13abc	4.87b-g
(JxK)	76.33ab	15.75fgh	1.00a	0.71efg	12.43efg	11.83d-g	3.23a-d	4.53c	7.53abc
(JxK)x(LxM)	77.67ab	34.31a-d	1.00a	1.54a-d	16.63a-d	15.00a-e	3.97a	5.07c	7.73ab
(JxK)xH	77.67ab	16.89e-h	1.00a	0.76d-g	13.53c-g	12.70b-g	3.27a-d	4.73c	6.33a-g
(LxM)	73.67ab	26.89c-h	1.00a	1.21b-g	15.30a-f	14.83a-e	3.03a-d	4.73c	5.40a-g
(LxM)xH	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
Kx(ExL)	76.33ab	45.61ab	1.33a	1.66abc	16.17a-e	16.20abc	3.43a-d	7.17ab	8.07a
Kx(HxB)	73.67ab	32.58a-f	1.00a	1.47a-e	16.63a-d	14.60a-f	3.77abc	5.97abc	5.87a-g
Kx(JxK)	73.67ab	34.63a-d	1.33a	1.24b-g	18.57a	16.00abc	3.80abc	5.70abc	7.13a-f
Kx(LxM)	79.00ab	34.37a-d	1.00a	1.55a-d	16.73a-d	16.33ab	3.53a-d	4.67c	6.20a-g
KxH	75.00ab	22.29d-h	1.00a	1.00c-g	13.67c-g	13.77a-f	3.47a-d	5.60abc	4.53efg
KxN	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
Nx(ExL)	72.33ab	47.64a	1.00a	2.14a	17.33abc	17.23a	3.80abc	7.33a	7.47a-d
Nx(HxB)	79.00ab	24.92c-h	1.00a	1.12b-g	16.63a-d	12.83b-g	2.93a-d	5.63abc	5.20a-g
Nx(JxK)	79.00ab	22.00d-h	1.00a	0.99c-g	12.70d-g	12.90b-g	3.37a-d	5.87abc	7.33a-e
Nx(LxM)	72.33ab	17.81d-h	1.00a	0.80d-g	13.83c-g	12.33c-g	2.93a-d	5.40bc	5.13b-g
NxH	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*=.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*=.01) in average fruit weight between genotypes is presented in Table 1. Parents with best average fruit weight were “~~(~~ExL~~)~~ and ~~(~~LxM~~)~~” (1.29 and 1.21kg), in progeny “Nx (~~(~~ExL)~~)~~ and (ExL)x(HxB)” (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 “~~(~~ExL~~)~~”. Similar results were reported in previous studies~~(0.31, Table 2)~~ [20].The SCA values of 0.79was recorded in “Nx(ExL)” progeny ~~(0.79) are presented in (~~Table 3).

3.4 Fruit length and fruit width

In length and width characteristic of fruit, parent "~~(~~HxB~~)~~" (15.77 and 15.20 cm) resulted with greater length and with high values in fruit width. The ~~P~~progeny "Kx(JxK)" (18.57 cm) ~~was~~ showed thelongest ~~cross~~ fruitand the "Nx(ExL)" cross showed the ~~(17.23 cm) was~~ greatest for fruit width(17.23 cm) (Table 4). In GCA for fruit length, parent "(HxB)" (1.38) and for fruit width “(ExL)” (1.12) with additive characteristics for trait. In the SCA, it was “Kx(JxK)” (3.57) for fruit length and “Nx(ExL)” (3.14) for fruit width [16].

3.5 Pulp thickness

There was significant difference (*P*=.05, Table 1) in thickness of pulp of parent “(ExL)” (3.90 cm) and in crosses “(JxK)x(LxM)” (3.97 cm), “(ExL)x(HxB)” and “(ExL)xH” (3.93 cm), (Table 4). In GCA values in terms of thickness of pulp, parent (ExL) (0.38, Table 2), is controlled by additive effect [16,20]. In SCA, crosses “(HxB)xH” (0.56) and “(JxK)x(LxM)” (0.54, Table 3) show dominance effects [15].

3.6 Seed cavity

In characteristics of seed cavity, we selected parents with low values, where parent “(JxK)” (4.53 cm) has a small seed cavity, followed by cross “Kx(LxM)” (4.67 cm). In GCA, we obtained parents “(JxK) and (LxM)” (-0.36 and -0.34, respectively), and in SCA, crosses “Kx(LxM) and (ExL)xH” (-0.63 and -0.61, respectively).

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3.7 Total soluble solids

The parent "(JxK)" (7.53 °Brix) presented the highest values in total soluble solids, in cross "Kx(ExL)" (8.07 °Brix). In GCA values, the parent "(JxK)" (0.90) and progeny "Kx(ExL)" (1.29).

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4. CONCLUSIONS

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

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