Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga
ISSN 1983-2125 (online)

http://dx.doi.org/10.1590/1983-21252025v3812736rc

Scientific Article

Compatibility of Pathogen-Resistant Melon Rootstocks: Effects on Fruit Yield, Quality, and Biometric Traits

Compatibilidade de Porta-Enxertos Resistentes em Melão: Efeitos na Produtividade, Qualidade dos Frutos e Parâmetos Biométricos

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ABSTRACT – Grafting is an effective method for pathogen control in various crops and improved several plant and fruit characteristics. This technique has been successfully adopted in melon cultivation, particularly using rootstocks resistant to multiple diseases. The objective of this study was to evaluate the compatibility of melon scions with rootstocks resistant to *Stagonosporopsis cucurbitacearum*, *Meloidogyne incognita*, *M. javanica*, and *M. enterolobii*, and to assess the effects of grafting on rootstock biometry, fruit yield, and fruit quality. The experiment was conducted in a randomized block design with four replications, 16 treatments, and seven plants per plot. Production, quality, and biometric parameters were assessed. Grafting increased epicarp and mesocarp firmness, fruit shape index, and vitamin C content, while reducing fruit length, fruit width, and locule length. Compatibility analysis revealed variability in the effects on measured traits, based on the general combining ability observed for scions JAB20-11 and 'Olimpic Express'. Grafting did not affect the total number of fruits or total fruit weight, while rootstock PI482398 exhibited the most favorable general combining ability for fruit length.

Keywords: *Cucumis melo* L.. *Didymella bryoniae*. Grafting. Root-knot nematodes.

RESUMO – A enxertia é uma estratégia eficaz para o controle de patógenos em diversas culturas, além de promover melhorias em características agronômicas e de qualidade de frutos. Essa técnica tem sido amplamente empregada no cultivo de melão, especialmente com o uso de porta-enxertos resistentes a múltiplas doenças. O objetivo deste estudo foi avaliar a compatibilidade de enxertos de melão com porta-enxertos resistentes a *Stagonosporopsis cucurbitacearum*, *Meloidogyne incognita*, *M. javanica* e *M. enterolobii*, bem como investigar os efeitos da enxertia sobre a biometria dos porta-enxertos, a produtividade e a qualidade dos frutos. O experimento foi conduzido em delineamento de blocos ao acaso, com quatro repetições, 16 tratamentos e sete plantas por parcela. Foram avaliados parâmetros produtivos, de qualidade e biométricos. A enxertia promoveu aumento na firmeza do epicarpo e mesocarpo, no índice de formato do fruto e no teor de vitamina C, além de reduzir o comprimento, a largura dos frutos e o comprimento do lóculo. A análise de compatibilidade revelou variabilidade nos efeitos sobre as variáveis analisadas, baseada na capacidade geral de combinação observada para os enxertos JAB20-11 e 'Olimpic Express'. O enxerto não influenciou o número total de frutos e o peso total de frutos, enquanto o porta-enxerto PI482398 destacou-se para a capacidade geral de combinação para o comprimento do fruto.

Palavras-chave: *Cucumis melo* L.. *Didymella bryoniae*. Enxertia. Nematóides-de-galhas.

Conflict of interest: The authors declare no conflict of interest related to the publication of this manuscript.

Received for publication in: June 7, 2024.
Accepted in: July 1, 2025.

Editor in Chief: Aurélio Paes Barros Júnior
Section Editor: Lindomar Maria da Silveira

Data Availability: The data that support the findings of this study can be made available, upon reasonable request, from the corresponding author.

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INTRODUCTION

Melon (*Cucumis melo* L.) is a widely cultivated fruit crop worldwide, with China being the leading producer (FAOSTAT, 2024. Brazil is a major melon producer and exporter, with production primarily concentrated in the state of Rio Grande do Norte (361,600 Mg), followed by Bahia (86,900 Mg) and Ceará (70,700 Mg) (HORTIFRUTI BRASIL, 2024).

Melon can be cultivated under different production systems. In the Northeast region of Brazil, it is predominantly grown in open fields, while in the Southeast region, it is cultivated in protected environments, particularly in São Paulo for noble melon varieties (CARVALHO et al., 2017).

Intensive cultivation in the same area, whether in protected environments or open fields, has led to a higher incidence of pathogens in melon crops, posing significant challenges to producers. Key pathogens, including *Stagonosporopsis cucurbitacearum* and root-knot nematodes (*Meloidogyne* spp.), are responsible for substantial yield losses in melon crops (CANDIDO et al., 2017; LIU et al., 2017).

Given the economic importance of melon, developing strategies to prevent or mitigate pathogen incidence in production areas is critical, as these pathogens (*Stagonosporopsis cucurbitacearum* and root-knot nematodes) are difficult to control and available management alternatives are often ineffective. Control of *Meloidogyne incognita* through genetic resistance is complex because resistance is polygenic, controlled by six loci, with incomplete dominance of the resistance allele and epistatic gene interactions (CANDIDO et al., 2017). Consequently, introgression of resistance genes for developing resistant cultivars is time-consuming and increases the costs of breeding programs. Thus, grafting has been proposed as an effective alternative.

Grafting is widely adopted globally, contributing to improvements in several agronomic traits of grafted plants. Advantages of grafting include enhanced fruit quality under abiotic stress conditions (BAYOUMI et al., 2021), increased yields (MUSA et al., 2020), and improved resistance to pathogens (SANTOS et al., 2020; DUAN et al., 2022). Thus, selecting resistant rootstocks is essential for managing pathogens that affect melon production. Additionally, compatibility between rootstock and scion is a fundamental factor in grafting studies, determining the success of the graft union. Consequently, numerous studies have focused on identifying optimal grafting methods for various crops (GUAN et al., 2025; ZEIST et al., 2017).

Thus, the objective of this study was to evaluate the compatibility of melon scions with rootstocks resistant to *Stagonosporopsis cucurbitacearum*, *Meloidogyne incognita*, *M. javanica*, and *M. enterolobii*, and to assess the effects of grafting on rootstock biometry, fruit yield, and fruit quality.

MATERIAL AND METHODS

Experimental Area Characterization

The experiment was conducted from October 2019 to March 2020 in a greenhouse located in Jaboticabal, São Paulo, Brazil (21°14'05"S, 48°17'09"W, 614 m altitude). The climate of the region is classified as Aw, transitioning to Cwa (KÖPPEN, 1948), characterized by a tropical climate with dry winter, transitioning to a subtropical climate with rainy summers and relatively dry winters.

Genetic Material

Rootstocks and scions were selected based on prior research identifying sources of resistance to *Stagonosporopsis cucurbitacearum*, *Meloidogyne incognita*, *M. javanica*, and *M. enterolobii*. Compatibility was evaluated using rootstocks from melon genotypes PI482398, PI140471, and PI42045 (resistant to *D. bryoniae*), 'Ouro' (resistant to *M. enterolobii*), AC-09 (resistant to *M. incognita*), and PI157082 (resistant to *Stagonosporopsis cucurbitacearum* and *M. javanica*) (SILVA, 2021; GOMES, 2018; WOLUKAU et al., 2007; SILVA et al., 2022). The scions comprised a cross between the lines JAB 20 and JAB 11 (JAB20-11), susceptible to *D. bryoniae*, *Meloidogyne incognita*, *M. javanica*, and *M. enterolobii*, and the hybrid 'Olimpic Express' (susceptible to *D. bryoniae*).

Experimental Design

The experiment was conducted using a randomized block design with four replications, 16 treatments, and seven plants per plot. The treatments included 12 rootstock-scion grafting combinations (six rootstocks × two scions), the two scions (JAB20-11 and 'Olimpic Express') as self-rooted and as self-grafted. Plants at the ends of the rows in each plot were deemed as borders, and JAB20-11 plants served as a general border for all plots. The rootstock-scion grafting combinations of melon genotypes evaluated as treatments are shown in Figure 1.

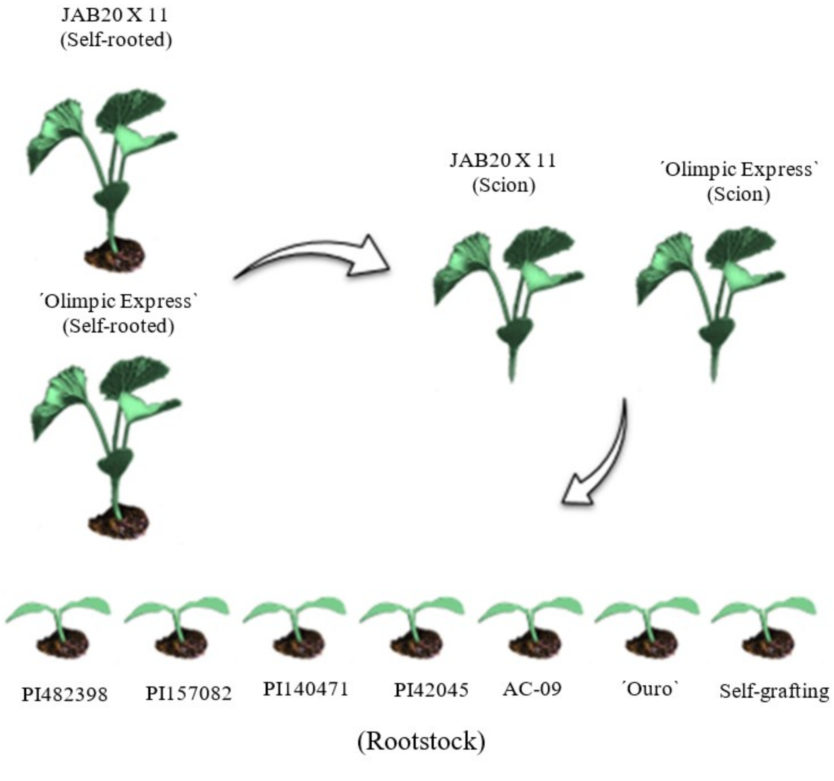

Figure 1. Rootstock-scion grafting combinations of melon (*Cucumis melo* L.) genotypes evaluated in the experiment.

Seedling Production and Grafting

Seedlings were cultivated in polystyrene trays containing a commercial substrate (Bioplant®) composed of autoclaved coconut husk fiber and maintained in a greenhouse under a micro-sprinkler irrigation system.

Scions and 'Ouro' were sown seven days after sowing the other genotypes. Grafting was conducted 28 days after sowing, using the full cleft grafting method with a standardized scion length of 3 cm (Figure 2). A plastic clip was used to secure the graft union until healing was achieved. Post-grafting, the plants were transferred to a floating-type humid chamber (OLIVEIRA et al., 2009), maintained at temperatures ranging from 17.1 to 47.6 °C and relative humidity from 15.9% to 97%. The plants remained in the humid chamber for 15 days, with the chamber kept completely closed for the first 12 days, with acclimatization beginning on the 13th day, during which the chamber was opened during the day and closed at night.

The plants were transplanted into 13-liter pots filled with a mixture of soil, sand, and cattle manure (3:1:1), previously autoclaved at 120 °C and 1 atm for 1 hour. Drip irrigation was used, and fertilization was administered through a nutrient solution, with a spacing of 50 cm between pots and 1 m between rows.

Melon plants were vertically trained on strings, with weekly pruning of shoots up to the 8th node. Self-pollination of flowers was performed on all plants to produce two fruits per plant, followed by pruning of branches after fruit set, with the apical meristem excised upon reaching a height of two meters.

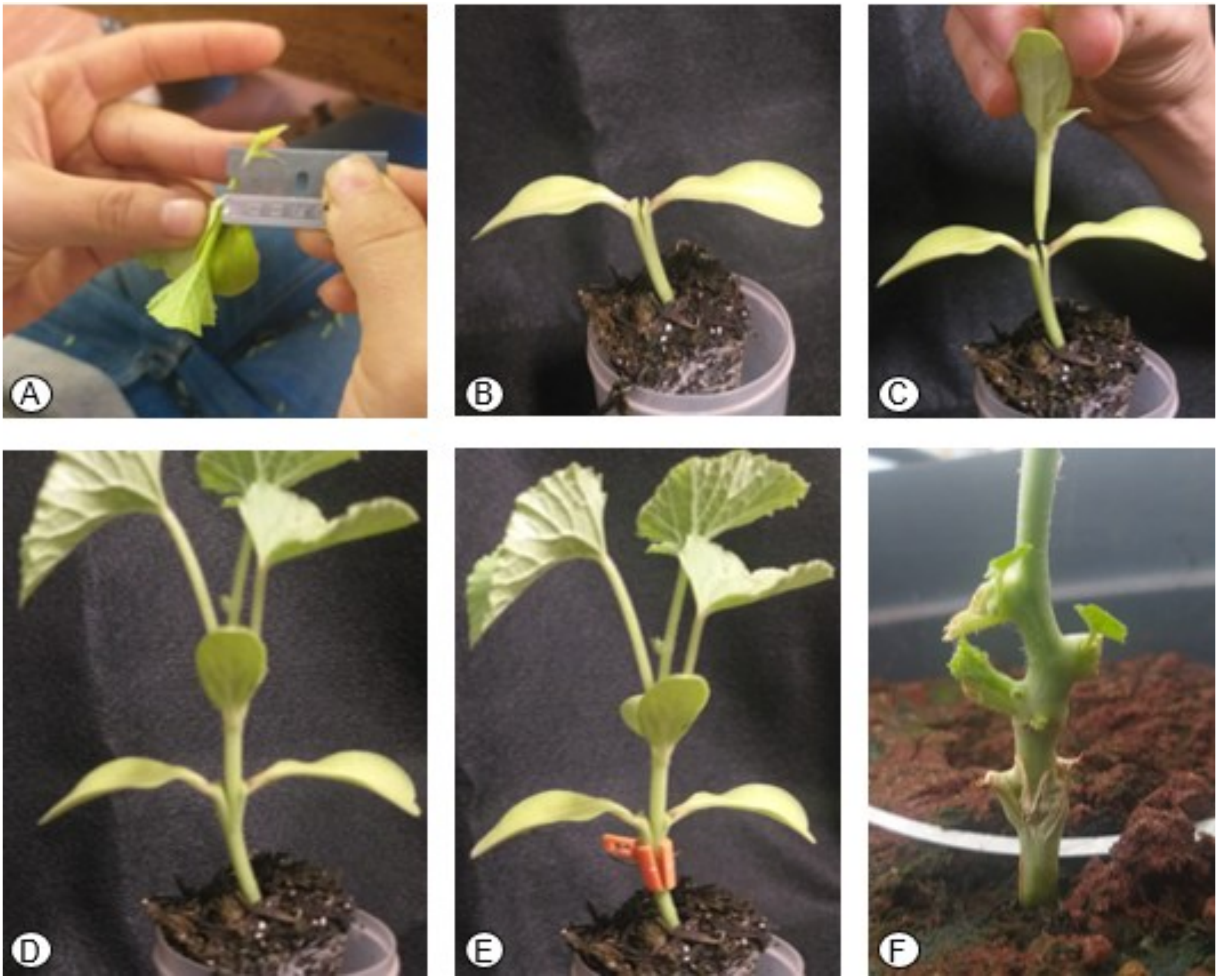

Figure 2. Full cleft grafting method performed used melon plants. Obtaining the wedge (A); Cleft made in the rootstock (B); Fitting of the scion into the rootstock (C-D); Placement of the grafting clip (E); Healing of the graft (F).

Evaluations of Grafted Plants

Grafting success and sprouting emergence percentages were assessed prior to transplanting. Rootstock diameter was measured 1 cm below, 1 cm above, and at the grafting point after the melon plants reached a height of two meters.

Production Variables

Production variables comprised total fruit weight (Mg ha^{-1}), calculated as the mean weight of all fruits in each plot; total number of fruits; fruit length (mm), determined by measuring the longitudinal diameter of the fruits; fruit width (mm), obtained by measuring the transverse diameter of the fruits; fruit shape index, calculated as the ratio of mean longitudinal to transverse diameters; locule length (mm), determined by measuring the longitudinal diameter of the locule; locule width (mm), determined by measuring the transverse diameter of the locule using a digital caliper; locule shape index, calculated as the ratio of mean longitudinal to transverse diameters of the locules; and epicarp width (mm), which was measured using a digital caliper.

Quality Variables

Quality variables included mesocarp thickness (mm); epicarp firmness and mesocarp firmness, assessed using a digital penetrometer, with results expressed in newtons (N); epicarp netting, evaluated visually according to the scoring scale adopted by Rizzo and Braz (2004); soluble solids content (SS), measured with a digital refractometer corrected for the ambient temperature and expressed as °Brix; vitamin C content, quantified by titration with 2,6-dichlorophenol indophenol sodium (2,6-DINa) and expressed as mg of ascorbic acid per 100 mL of juice; titratable acidity (TA), determined using a 1% phenolphthalein solution and expressed as g of citric acid; and the maturation index, calculated as the SS-to-TA ratio.

Statistical Analyses

Analysis of contrasts was performed using the Student's t-test at a 5% significance level to compare means. The analyses were conducted using GENES software (CRUZ, 2013). Adapted diallel analysis models were employed to evaluate general combining ability and specific combining ability of the rootstock and scion (TOMAZ et al., 2006), with the objective of validating the contrast analysis results and identifying the optimal rootstock and scion genotypes.

RESULTS AND DISCUSSION

Grafting Success and Sprouting Percentages in Rootstocks

The highest grafting success were observed for the scion JAB20-11 grafted onto rootstocks PI140471 and PI157082 and the scion 'Olimpic Express' grafted onto PI157082, each showing a 100% grafting success rate (Figure 3).

The sprouting emergence percentages of JAB20-11 were below 10%, regardless the rootstock used, with self-grafted scions exhibiting no sprouting. Rootstock genotypes 'Ouro', PI157082, PI482398, and PI42045 combined with 'Olimpic Express', each showing exhibited the lowest sprouting percentages.

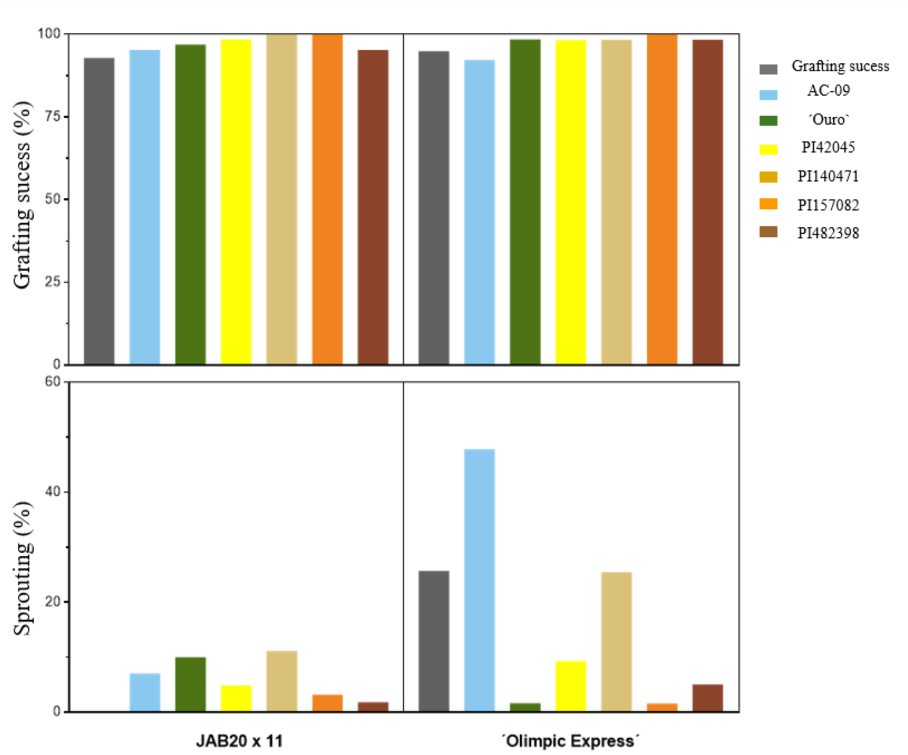

Figure 3. Grafting success and sprouting emergence percentages in melon genotypes.

Comparisons between Self-Rooted and Grafted Plants

Regarding quality variables, plants with scions JAB20-11 and 'Olimpic Express' did not differ significantly in epicarp netting and epicarp firmness. Mesocarp firmness was positively influenced by grafting JAB20-11 onto AC-09; JAB20-11 onto PI140471; 'Olimpic Express' onto 'Ouro'; 'Olimpic Express' onto PI42045; and 'Olimpic Express' onto PI482398 (Table 1).

Evaluating quality variables in melon fruits is critical, particularly epicarp and mesocarp firmness, which are vital for fruit transport and shelf life (Table 1). Epicarp and mesocarp firmness contribute to a more resistant pericarp, protecting melon fruits against damages caused by vibrations and impacts during transport, which could compromise fruit quality. Therefore, selection for these variables targets fruits with greater mesocarp firmness, improving post-harvest quality and extending shelf life (COSTA, 2017).

Grafting 'Olimpic Express' onto PI482398 produced longer fruits compared to self-rooted plants. Fruits from JAB20-11 grafted onto PI157082 were smaller compared to those from other combinations and self-rooted plants. However, grafting had no effect on locule width, locule shape index, and epicarp thickness (Table 1).

Table 1. Mean epicarp netting (EN), epicarp firmness (EF; N), mesocarp firmness (MF; N), fruit length (FL; mm), fruit width (FW; mm), fruit shape index (FI), locule length (LL; mm), locule width (LW; mm), locule shape index (LI), and epicarp thickness (ET; mm) in grafted melon genotypes.

Contrasts (scion × rootstock)	EN	EF	MF	FL	FW
JAB20-11 (self-rooted)	1.35^{ns}	14.23^{+++}	0.73^{ns}	125.3^{+}	129.0^{ns}
vs. JAB20-11 (self-grafted)	1.41^{ns}	14.49^{ns}	0.77^{ns}	122.3^{ns}	125.5^{ns}
vs. JAB20-11 × AC-09	1.42^{ns}	15.04^{ns}	0.94*	125.3^{ns}	126.3^{ns}
vs. JAB20-11 × 'Ouro'	1.42^{ns}	14.45^{ns}	0.90^{ns}	117.8*	120.0*
vs. JAB20-11 × PI42045	1.70^{ns}	15.02^{ns}	0.84^{ns}	122.6^{ns}	123.8^{ns}
vs. JAB20-11 × PI140471	1.83^{ns}	15.25^{ns}	1.06***	121.6^{ns}	123.1^{ns}
vs. JAB20-11 × PI157082	1.73^{ns}	15.33^{ns}	0.90^{ns}	116.1**	116.4***
vs. JAB20-11 × PI482398	1.66^{ns}	14.44^{ns}	0.91^{ns}	124.7^{ns}	124.4^{ns}
'Olimpic Express' (self-rooted)	1.96^{ns}	5.69^{+++}	0.63^{ns}	132.2^{+}	125.1^{ns}
'Olimpic Express' (self-grafted)	1.61^{ns}	6.19^{ns}	0.66^{ns}	130.9^{ns}	121.2^{ns}
vs. 'Olimpic Express' × AC-09	1.64^{ns}	5.85^{ns}	0.66^{ns}	139.7*	130.4^{ns}
vs. 'Olimpic Express' × 'Ouro'	1.71^{ns}	6.99^{ns}	0.86*	135.2^{ns}	125.9^{ns}
vs. 'Olimpic Express' × PI42045	1.84^{ns}	7.37*	0.84*	139.4*	129.1^{ns}
vs. 'Olimpic Express' × PI140471	1.44^{ns}	5.71^{ns}	0.66^{ns}	141.0*	127.5^{ns}
vs. 'Olimpic Express' × PI157082	1.63^{ns}	6.87^{ns}	0.78^{ns}	140.8*	131.3^{ns}
vs. 'Olimpic Express' × PI482398	1.94^{ns}	6.87^{ns}	0.80*	144.5***	131.7^{ns}
Mean square of the residue	0.093^{ns}	1.223***	0.016***	22.89***	23.95**
Overall mean	1.644	10.612	0.809	129.956	125.663
Coefficient of variation (%)	18.52	10.426	15.418	3.682	3.894

Contrasts	FI	LL	LW	LI	ET
JAB20-11 (self-rooted)	0.971^{+++}	75.34^{+++}	61.07^{ns}	1.239^{+++}	5.88^{ns}
vs. JAB20-11 (self-grafted)	0.975^{ns}	71.87^{ns}	57.54^{ns}	1.250^{ns}	5.77^{ns}
vs. JAB20-11 × AC-09[1]	0.992^{ns}	72.88^{ns}	58.37^{ns}	1.250^{ns}	5.52^{ns}
vs. JAB20-11 × 'Ouro'	0.982^{ns}	69.62^{ns}	55.67^{ns}	1.251^{ns}	5.34^{ns}
vs. JAB20-11 × PI42045	0.989^{ns}	72.17^{ns}	57.37^{ns}	1.258^{ns}	5.19^{ns}
vs. JAB20-11 × PI140471	0.989^{ns}	73.44^{ns}	56.76^{ns}	1.296^{ns}	5.33^{ns}
. JAB20-11 × PI157082	0.998^{ns}	68.24*	53.41^{ns}	1.280^{ns}	5.47^{ns}
JAB20-11 × PI482398	1.002*	72.39^{ns}	55.99^{ns}	1.295^{ns}	5.36^{ns}
'Olimpic Express' (self-rooted)	1.057^{+++}	87.43^{+++}	53.58^{ns}	1.634^{+++}	5.32^{ns}
vs. Self-grafting 'Olimpic Express '	1.080^{ns}	88.16^{ns}	52.27^{ns}	1.690^{ns}	4.96^{ns}
vs. 'Olimpic Express' × AC-09	1.070^{ns}	93.11^{ns}	57.71^{ns}	1.613^{ns}	5.61^{ns}
vs. 'Olimpic Express' × 'Ouro'	1.074^{ns}	89.99^{ns}	54.17^{ns}	1.664^{ns}	5.81^{ns}
vs. 'Olimpic Express' × PI42045	1.080^{ns}	92.09^{ns}	52.95^{ns}	1.744^{ns}	5.67^{ns}
vs. 'Olimpic Express' × PI140471	1.107***	92.66^{ns}	55.80^{ns}	1.664^{ns}	5.57^{ns}
vs. 'Olimpic Express' × PI157082	1.072^{ns}	94.26*	55.74^{ns}	1.691^{ns}	5.46^{ns}
vs. 'Olimpic Express' × PI482398	1.097**	96.97**	56.92^{ns}	1.706^{ns}	5.66^{ns}
Mean square of the residue	0.0004***	18.06***	13.57^{ns}	0.0065***	0.2211^{ns}
Overall mean	1.0336	81.9147	55.9572	1.4702	5.4953
Coefficient of variation (%)	1.8615	5.1882	6.5858	5.4619	8.5528

*, **, ***, and ^{ns} = contrasts significant at 5%, 1%, 0.1%, and not significant at 0.1%, by Student's t-test, respectively; + contrasts between self-rooted plants.

Grafting 'Olimpic Express' onto PI42045 resulted in significant effect on mesocarp thickness, with no significant impact on other variables (Table 2).

The contrasting effects of grafting on the evaluated variables are attributed to scion-rootstock interactions, as various biological mechanisms involved in these interactions can positively or negatively influence the traits, depending on the genotypic response and the substances translocated from the rootstock to the scion (WANG; JIANG; WU, 2016). Fruit size, shape, firmness, texture, and flavor can be modified by grafting (GARCIA-LOZANO et al., 2019).

Rootstock biometric measurements indicated that grafting had no effect on stem diameter measured 1 cm below, 1 cm above, and at the grafting point (Table 2). According to Gaion et al. (2017), these variables reflect compatibility between scion and rootstock, linked to morphological factors involved in callus formation.

Total number of fruits, total fruit weight, vitamin C content, titratable acidity, and soluble solids were not significantly affected by the treatments. However, all combinations using the scion JAB20-11 exhibited soluble solids content exceeding the minimum export requirement of 10 °Brix (NUNES et al., 2016) (Table 2).

Table 2. Mesocarp thickness (MT; mm), stem diameter measured 1 cm below (SDB; cm), 1 cm above (SDA; cm), and at the grafting point (SDG; cm), total number of fruits (TNF), total fruit weight (TFW; Mg ha^{-1}), vitamin C content (VCC), titratable acidity (TA), soluble solids (SS), and maturation index (MI) in grafted melon genotypes.

Contrasts (scion × rootstock)	MT	SDB	SDG	SDA	TNF
JAB20-11 (self-rooted)	29.28^{ns}	9.426^{ns}	12.60^{ns}	8.397^{ns}	33.250^{ns}
vs. JAB20-11 (self-grafted)	28.66^{ns}	9.540^{ns}	12.94^{ns}	8.219^{ns}	30.000^{ns}
vs. JAB20-11 × AC-09[1]	28.36^{ns}	8.637^{ns}	12.46^{ns}	9.051^{ns}	36.000^{ns}
vs. JAB20-11 × 'Ouro'	27.21^{ns}	9.304^{ns}	12.13^{ns}	8.962^{ns}	33.000^{ns}
vs. JAB20-11 × PI42045	28.10^{ns}	9.333^{ns}	12.47^{ns}	9.651^{ns}	28.000^{ns}
vs. JAB20-11 × PI140471	28.30^{ns}	7.833^{ns}	10.99^{ns}	7.885^{ns}	27.500^{ns}
vs. JAB20-11 × PI157082	27.60^{ns}	9.344^{ns}	11.76^{ns}	9.808^{ns}	33.000^{ns}
vs. JAB20-11 × PI482398	28.75^{ns}	8.356^{ns}	11.28^{ns}	8.947^{ns}	35.750^{ns}
'Olimpic Express' (self-rooted)	30.18^{ns}	8.092^{ns}	11.16^{ns}	8.043^{ns}	37.000^{ns}
vs. 'Olimpic Express' (self-grafted)	29.39^{ns}	7.229^{ns}	11.72^{ns}	7.735^{ns}	33.000^{ns}
vs. 'Olimpic Express' × AC-09	32.43^{ns}	7.256^{ns}	10.61^{ns}	7.740^{ns}	37.000^{ns}
vs. 'Olimpic Express' × 'Ouro'	31.28^{ns}	8.499^{ns}	12.27^{ns}	8.905^{ns}	35.000^{ns}
vs. 'Olimpic Express' × PI42045	33.22*	8.490^{ns}	11.80^{ns}	7.992^{ns}	38.000^{ns}
vs. 'Olimpic Express' × PI140471	31.23^{ns}	8.093^{ns}	11.89^{ns}	8.080^{ns}	34.000^{ns}
vs. 'Olimpic Express' × PI157082	32.76^{ns}	8.546^{ns}	12.32^{ns}	9.236^{ns}	38.000^{ns}
vs. 'Olimpic Express' × PI482398	32.43^{ns}	7.961^{ns}	11.17^{ns}	8.295^{ns}	36.500^{ns}
Mean square of the residue	3.596***	1.189^{ns}	1.614^{ns}	0.9798^{ns}	26.530.6^{ns}
Overall mean	29.9494	8.4961	11.8487	8.5597	34.062.5
Coefficient of variation (%)	6.3331	12.8410	10.7229	11.5604	15.1216

Contrasts	TFW (Mg ha^{-1})	VCC (mg)	TA (g)	SS Brix°	MI (SS/TA)
JAB20-11 (self-rooted)	104.10^{ns}	22.17^{ns}	0.1104^{ns}	11.02^{+++}	105.80^{++}
vs. JAB20-11 (self-grafted)	105.50^{ns}	19.90^{ns}	0.1158^{ns}	10.85^{ns}	98.40^{ns}
vs. JAB20-11 × AC-09[1]	93.86^{ns}	22.30^{ns}	0.1125^{ns}	11.27^{ns}	104.40^{ns}
vs. JAB20-11 × 'Ouro'	85.06^{ns}	21.64^{ns}	0.1098^{ns}	11.41^{ns}	110.00^{ns}
vs. JAB20-11 × PI42045	83.86^{ns}	23.29^{ns}	0.1154^{ns}	11.27^{ns}	102.40^{ns}
vs. JAB20-11 × PI140471	89.14^{ns}	21.13^{ns}	0.1128^{ns}	10.99^{ns}	102.30^{ns}
vs. JAB20-11 × PI157082	93.15^{ns}	23.46^{ns}	0.1109^{ns}	10.40^{ns}	96.76^{ns}
vs. JAB20-11 × PI482398	76.61^{ns}	22.70^{ns}	0.1202^{ns}	10.78^{ns}	93.93^{ns}
'Olimpic Express' (self-rooted)	104.20^{ns}	22.59^{ns}	0.1149^{ns}	8.568^{+++}	79.35^{++}
vs. 'Olimpic Express' (self-grafted)	110.50^{ns}	21.32^{ns}	0.1073^{ns}	9.211^{ns}	90.53^{ns}
vs. 'Olimpic Express' × AC-09	80.76^{ns}	23.15^{ns}	0.1056^{ns}	8.379^{ns}	87.97^{ns}
vs. 'Olimpic Express' × Ouro'	77.33^{ns}	24.76^{ns}	0.1136^{ns}	9.032^{ns}	88.81^{ns}
vs. 'Olimpic Express' × PI42045	102.80^{ns}	21.07^{ns}	0.1146^{ns}	8.672^{ns}	81.95^{ns}
vs. 'Olimpic Express' × PI140471	99.58^{ns}	22.86^{ns}	0.1040^{ns}	8.164^{ns}	85.95^{ns}
vs. 'Olimpic Express' × PI157082	97.30^{ns}	24.57^{ns}	0.0932^{ns}	9.168^{ns}	107.70**
vs. 'Olimpic Express' × PI482398	84.99^{ns}	22.77^{ns}	0.1062^{ns}	8.170^{ns}	87.87^{ns}
Mean square of the residue	320.1371^{ns}	11.07^{ns}	0.0001094^{ns}	0.666***	146.6**
Overall mean	93.0525	22.4806	0.1108	9.8336	95.2698
Coefficient of variation (%)	19.2282	14.8020	9.8036	8.3024	12.7082

*, **, ***, and ^{ns} = contrasts significant at 5%, 1%, 0.1%, and not significant at 0.1%, by Student's t-test, respectively; + contrasts between self-rooted plants.

The absence of significant effects on most variables does not imply that grafting did not provide benefits, as it is essential to recognize that this technique offers additional advantages, such as its applicability in pathogen-infested soils (Tables 1 and 2).

Compatibility of Scion and Rootstock Combinations

Rootstocks should demonstrate not only genetic resistance but also graft compatibility with the scion. Compatibility analyses, conducted to assess the general combining ability (GCA) and specific combining ability (SCA) of scions, revealed significant effects according to the F-test at 1% and 5% for various variables (Tables 3, 4, 5, and 6). The results indicate differences in scion GCA for each variable, presenting positive values. Thus, variables should be evaluated individually when selecting scions, based on the specific selection objective. Positive GCA values suggest that a given parent (rootstock or scion) is likely to contribute favorably to the average performance of the trait. For instance, selection of the rootstock PI42045, which showed a positive value for epicarp firmness (0.4319), may enhance this attribute regardless of the scion combination (Table 3).

However, caution is required when interpreting negative GCA values, as these may be advantageous in certain cases, such as when smaller and more uniform fruits are desired to meet specific market demands.

Positive SCA values indicate a favorable interaction between the two studied genotypes, which can be exploited in genetic breeding programs. Negative SCA values, as observed for fruit length in the combination 'Olimpic Express' and PI42045 (-2.2056), necessitate careful consideration of evaluated characteristics before discarding such a combination (Table 3).

Table 3. Analysis of variance and estimates of general (GCA) and specific combining ability (SCA) in grafted melon genotypes for the variables: epicarp netting (EN), epicarp firmness (EF; N), mesocarp firmness (MF; N), fruit length (FL; mm), and fruit width (FW; mm).

Source of variation	Mean square					
	DF	EN	EF	MF	FL	FW
Treatments	11	0.1115^{ns}	76.4161**	0.0518*	424.7956**	85.8082**
GCA (Scion)	1	0.0668^{ns}	828.5903**	0.3024**	4219.3125**	585.4827**
GCA (Rootstock)	5	0.0917^{ns}	0.7963^{ns}	0.0059^{ns}	65.8363*	38.7738^{ns}
SCA (S × R)	5	0.1403^{ns}	1.6012^{ns}	0.0476*	24.8515^{ns}	32.9077^{ns}
Residue	45	0.0927	1.223	0.0157	22.89	23.95
Effect of scion GCA						
JAB20-11		-0.0373	4.1548	0.0794	-9.3756	-3.4925
'Olimpic Express'		0.0373	-4.1548	-0.0794	9.3756	3.4925
Standard error (Gi):		0.0439	0.1597	0.0180	0.6907	0.7064
Effect of rootstock GCA						
PI482398		0.1360	-0.1081	0.0110	3.8473	2.1954
PI157082		0.0148	0.3344	-0.0027	-2.2452	-1.9696
PI140471		-0.0265	-0.2869	0.0110	0.5835	-0.5708
PI42045		0.1048	0.4319	-0.1021	0.2460	0.6567
AC-09		-0.1327	-0.3206	-0.0452	1.7798	2.5579
'Ouro'		-0.0965	-0.0506	0.0360	-4.2114	-2.8696
Standard error (Gj):		0.0982	0.3571	0.0402	1.5444	1.5795
Effect of SCA						
JAB20-11 × PI482398		-0.1002	-0.3710	-0.0281	-0.5344	-0.1675
JAB20-11 × PI157082		0.0836	0.0739	-0.0169	-2.9794	-3.9675
JAB20-11 × PI140471		0.2298	0.6127	0.1244	-0.3331	1.2913
JAB20-11 × PI42045		-0.0315	-0.3286	-0.0819	0.9743	0.8587
JAB20-11 × AC-09		-0.0764	0.4390	0.0581	2.2056	1.4524
JAB20-11 × 'Ouro'		-0.1052	-0.4261	-0.0556	0.6669	0.5325
'Olimpic Express' × PI482398		0.1003	0.3711	0.0282	0.5344	0.1675
'Olimpic Express' × PI157082		-0.0834	-0.0740	0.0169	2.9794	3.9675
'Olimpic Express' × PI140471		-0.2297	-0.6127	-0.1243	0.3332	-1.2912
'Olimpic Express' × PI42045		0.0315	0.3285	0.0819	-0.9744	-0.8588
'Olimpic Express' × AC-09		0.0766	-0.4389	-0.0581	-2.2056	-1.4525
'Olimpic Express' × 'Ouro'		0.1053	0.4260	0.0557	-0.668	-0.5325
Standard error (Sij)		0.0982	0.3571	0.0402	1.5444	1.5795

DF = degrees of freedom; *, **, and ^{ns} = significant at 5% and 1%, and not significant, by the F-test, respectively.

The rootstocks significantly influenced fruit length, with PI482398 showing superior performance compared to the others (Table 3). SCA analyses indicated a significant effect on mesocarp firmness, with the combination JAB20-11 and PI140471 yielding the highest value, confirming the results of the contrast analysis (Tables 1 and 3). Effects of SCA involving scion and rootstock on the other variables was not significant (Tables 3 and 4).

Table 4. Analysis of variance and estimates of general (GCA) and specific combining ability (SCA) in grafted melon genotypes for the variables: fruit shape index (FI), locule length (LL; mm), locule width (LW; mm), locule shape index (LI), and epicarp thickness (ET; mm).

Source of variation	DF	Mean square				
		FI	LL	LW	LI	ET
Treatments	11	0.0099**	532.3725**	11.3964^{ns}	0.1867**	0.1240^{ns}
GCA (Scions)	1	0.1027**	5663.0558**	6.1205^{ns}	2.0049**	0.8269^{ns}
GCA (Rootstocks)	5	0.0005^{ns}	22.4892^{ns}	13.2590^{ns}	0.0058^{ns}	0.0306^{ns}
SCA (S × R)	5	0.0006^{ns}	16.1192^{ns}	10.5890^{ns}	0.0040^{ns}	0.0768^{ns}
Residue	45	0.0004	18.06	13.57	0.0065	0.2211
Effect of scion GCA						
JAB20-11		-0.0462	-10.8619	0.3571	-0.2044	-0.1313
'Olimpic Express'		0.0462	10.8619	-0.3571	0.2044	0.1313
Standard error (Gi):		0.0028	0.6134	0.5319	0.0116	0.0678
Effect of rootstock GCA						
PI482398		0.0104	2.3615	0.5500	0.0240	0.0125
PI157082		-0.0033	-1.0685	-1.3288	0.0102	-0.0325
PI140471		0.0104	0.7302	0.3750	0.0027	-0.05
PI42045		-0.0021	-0.1873	-0. 7450	0.0252	-0.0725
AC-09		-0.0071	0.6765	2.1338	-0.0448	0.0687
'Ouro'		-0.0083	-2.5123	-0.9850	-0.0173	0.0738
Standard error (Gj):		0.0062	1.3716	1.1894	0.0259	0.1517
Effect of SCA						
JAB20-11 × PI482398		-0.0025	-1.4319	-0.8221	-0.007	-0.0175
JAB20-11 × PI157082		0.0087	-2.1493	-1.5259	-0.002	0.1326
JAB20-11 × PI140471		-0.0126	1.2544	0.1279	0.0205	0.015
JAB20-11 × PI42045		0.0025	0.9019	1.8554	-0.0394	-0.1099
JAB20-11 × AC-09		0.005	0.7456	-0.0284	0.0231	0.0838
JAB20-11 × 'Ouro'		-0.0013	0.6794	0.3929	-0.0019	-0.1037
'Olimpic Express' × PI482398		0.0024	1.4318	0.8221	0.0006	0.0175
'Olimpic Express' × PI157082		-0.0088	2.1494	1.5258	0.0018	-0.1324
'Olimpic Express' × PI140471		0.0124	-1.2544	-0.1279	-0.0207	-0.015
'Olimpic Express' × PI42045		-0.0025	-0.9019	-1.8554	0.0394	0.1101
'Olimpic Express' × AC-09		-0.005	-0.7457	0.0283	-0.0231	-0.0837
'Olimpic Express' × 'Ouro'		0.0012	-0.6794	-0.3929	0.0019	0.1038
Standard error (Sij)		0.0062	1.3716	1.1894	0.0259	0.1517

DF = degrees of freedom; *, **, and ^{ns} = significant at 5% and 1%, and not significant, by the F-test, respectively.

These results corroborate those from the contrast analysis, where the same combinations showed enhanced mesocarp firmness (Table 1). Negative SCA values for scions and rootstocks in compatibility analysis indicated that grafting had a detrimental effect compared to the self-rooted scions, potentially compromising the performance of the evaluated genotypes.

The scion JAB20-11 showed positive values compared to 'Olimpic Express' for epicarp firmness, mesocarp firmness, titratable acidity, soluble solids, and maturation index, and stem diameter measured 1 cm below, 1 cm above, and at the grafting point. The PI482398 rootstock exhibited positive values for most variables, demonstrating the potential of this genotype (Tables 5 and 6).

The non-significance of scion and rootstock GCA and SCA effects suggests that the optimal rootstock or the best scion-rootstock combination cannot be reliably determined for most variables (Tables 3, 4, 5, and 6). However, positive values should be considered during the selection process, and variables should be evaluated individually when selecting scions, based on the specific selection objective.

Table 5. Analysis of variance and estimates of general combining ability (GCA) and specific combining ability (SCA) in grafted melon genotypes for the variables: mesocarp thickness (MT; mm), stem diameter measured 1 cm below (SDB; cm), 1 cm above (SDA; cm), and at the grafting point (SDG; cm), and total number of fruits (TNF).

Source of variation	DF	Mean square				
		MT	SDB	SDG	SDA	TNF
Treatments	11	20.7094**	1.6511^{ns}	1.5291^{ns}	1.9452^{ns}	48869318.1818^{ns}
GCA (Scions)	1	208.669*	5.2404*	0.3451^{ns}	5.4607*	212520833.3334**
GCA (Rootstocks)	5	2.3645^{ns}	1.9790^{ns}	1.3626^{ns}	2.1763^{ns}	38387500.0000^{ns}
SCA (S × R)	5	1.4628^{ns}	0.6053^{ns}	1.9323^{ns}	1.0110^{ns}	26620833.3333^{ns}
Residue	45	3.596	1.189	1.614	0.9798	26530556.0000
Effect of scion GCA						
JAB20-11		-2.085	0.3304	0.0848	0.3373	-2104.1666
'Olimpic Express'		2.085	-0.3304	-0.0848	-0.3373	2104.1666
Standard error (Gi):		0.2738	0.1575	0.1834	0.1428	743.4513
Effect of rootstock GCA						
PI482398		0.4521	-0.3133	-0.5381	-0.0919	1812.5
PI157082		0.0421	0.4742	0.2756	0.8106	1187.5
PI140471		-0.3754	-0.5083	-0.3219	-0.7306	-3562.5
PI42045		0.5171	0.4404	0.3744	0.1081	-1312.5
AC-09		0.2571	-0.5246	-0.2269	-0.3169	2187.5
'Ouro'		-0.8929	0.4317	0.4369	0.2206	-312.5
Standard error (Gj):		0.6122	0.3521	0.4101	0.3194	1662.4077
Effect of SCA						
JAB20-11 × PI482398		0.2425	-0.1329	-0.0323	-0.0135	1729.1667
JAB20-11 × PI157082		-0.4925	0.0671	-0.3611	-0.051	-395.8333
JAB20-11 × PI140471		0.62	-0.4604	-0.5386	-0.4348	-1145.8333
JAB20-11 × PI42045		-0.4725	0.0933	0.2502	0.4915	-2895.8333
JAB20-11 × AC-09		0.05	0.3608	0.8364	0.3189	1604.1667
JAB20-11 × 'Ouro'		0.0525	0.0721	-0.1548	-0.311	1104.1667
'Olimpic Express' × PI482398		-0.2425	0.1329	0.0323	0.0136	-1729.1667
'Olimpic Express' × PI157082		0.4925	-0.0671	0.361	0.0511	395.8333
'Olimpic Express' × PI140471		-0.62	0.4604	0.5385	0.4348	1145.8333
'Olimpic Express' × PI42045		0.4725	-0.0934	-0.2502	-0.4914	2895.8333
'Olimpic Express' × AC-09		-0.05	-0.3609	-0.8365	-0.319	-1604.1667
'Olimpic Express' × 'Ouro'		-0.0525	-0.0721	0.1548	0.3111	-1104.1667
Standard error (Sij)		0.6122	0.3521	0.4101	0.3194	1662.4077

DF = degrees of freedom; *, **, and ^{ns} = significant at 5% and 1%, and not significant, by the F-test, respectively.

Table 6. Analysis of variance and estimates of general combining ability (GCA) and specific combining ability (SCA) in grafted melon genotypes for the variables: total fruit weight (TFW), vitamin C content (VCC), titratable acidity (TA), soluble solids (SS), and maturation index (MI).

Source of variation	DF	Mean square				
		TFW (Mg ha^{-1})	VCC (mg)	TA (g)	SS (Brix°)	MI (SS/TA)
Treatments	11	301.0555^{ns}	5.5226^{ns}	0.0002^{ns}	6.9924*	353.3473*
GCA (Scions)	1	148.6848^{ns}	7.2075^{ns}	0.0006*	70.2526*	1615.9963**
GCA (Rootstocks)	5	347.0193^{ns}	4.3030^{ns}	0.0002^{ns}	0.5813^{ns}	151.1458^{ns}
SCA (S × R)	5	285.5657^{ns}	6.4053^{ns}	0.0002^{ns}	0.7515^{ns}	303.0190^{ns}
Residue	45	320.1371	11.07	0.0001	0.666	146.6
Effect of scion GCA						
JAB20-11		-1.760	-0.3875	0.0035	1.2098	5.8023
'Olimpic Express'		1.760	0.3875	-0.0035	-1.2098	-5.8023
Standard error (Gi):		2.5825	0.4803	0.0016	0.1178	1.7475

DF = degrees of freedom; *, **, and ^{ns} = significant at 5% and 1%, and not significant, by the F-test, respectively.

Table 6. Continuation.

Source of variation	DF	Mean square				
		TFW ($Mg\ ha^{-1}$)	VCC (mg)	TA (g)	SS (Brix°)	MI (SS/TA)
Effect of rootstock GCA						
PI482398		-7.9087	-0.0721	0.0023	-0.3340	-4.9490
PI157082		6.5187	1.2104	-0.0090	-0.0277	6.3960
PI140471		5.65	-0.8133	-0.0015	-0.2315	-1.7065
PI42045		4.645	-0.6308	0.0060	0.1648	-3.6565
AC-09		-1.395	-0.0846	-0.0002	0.0160	0.3585
'Ouro'		-7.51	0.3904	0.0023	0.4123	3.5573
Standard error (Gj):		5.7747	1.0740	0.0035	0.2635	3.9075
Effect of SCA						
JAB20-11 × PI482398		-2.4287	0.355	0.0014	0.0939	-2.7711
JAB20-11 × PI157082		-0.3137	-0.1675	0.0051	-0. 5973	-11.2861
JAB20-11 × PI140471		-3.4575	-0.4762	0.0027	0.2015	2.3865
JAB20-11 × PI42045		-7.735	1.4987	-0.0024	0.0902	4.434
JAB20-11 × AC-09		8.31	-0.0375	-0.0011	0.2339	2.4365
JAB20-11 × 'Ouro'		5.625	-1.1725	-0.0061	-0.0223	4.8002
'Olimpic Express' × PI482398		2.4288	-0.355	-0.0015	-0.094	2.771
'Olimpic Express' × PI157082		0.3138	0.1675	-0.0053	0.5973	11.286
'Olimpic Express' × PI140471		3.4575	0.4763	-0.0027	-0.2014	-2.3864
'Olimpic Express' × PI42045		7.735	-1.4988	0.0022	-0.0902	-4.4339
'Olimpic Express' × AC-09		-8.31	0.0375	0.001	-0.234	-2.4364
'Olimpic Express' × 'Ouro'		-5.625	1.1725	0.006	0.0223	-4.8002
Standard error (Sij)		5.7747	1.0740	0.0035	0.2635	3.9075

DF = degrees of freedom; *, **, and ^{ns} = significant at 5% and 1%, and not significant, by the F-test, respectively.

This study emphasizes important aspects of grafting. The first is that grafting did not negatively affect the primary variables evaluated, including mesocarp firmness, mesocarp thickness, total number of fruits, total fruit weight, vitamin C content, titratable acidity, and soluble solids content (Tables 1 and 2). This finding is significant, as grafting is also associated with the genetic resistance of the rootstocks, ensuring maintenance of key production and quality components of melon. Moreover, the grafting technique has expanded rapidly worldwide (FLORES-LEÓN et al., 2024; LECHOLOCHOLO et al., 2022), particularly due to its association with resistance to pathogens such as *Fusarium* spp., *Monosporascus* spp., and nematodes (YE; ZHANG; WANG, 2025; KYRIACOU et al., 2018). Once resistance sources are identified, the next step in the breeding programs involves transferring resistance genes to elite cultivars, typically through backcrossing, although this is a time-consuming process. The use of grafting reduces costs by eliminating the need for gene transfer and can enhance yield in pathogen-infested environments (BIE et al., 2017). The second aspect highlighted by this study is the compatibility test, which assesses the general and specific combining ability of scion-rootstock combinations. This test is crucial in determining grafting success and identifying combinations that may improve desirable traits, such as fruit quality.

Furthermore, analyzing GCA and SCA is essential for identifying and selecting rootstocks that, when combined with scions, yield optimal results. Thus, the positive and negative values of these estimates should be carefully interpreted, considering the trait being selected and the objectives of the breeding program. This analysis enables a more strategic interpretation of the results, facilitating the selection of the most promising combinations based on GCA and SCA.

This approach highlights the significance of evaluating rootstock and scion combinations, with the objective of achieving satisfactory results in large-scale production of grafted plants. The next stage of the study involves field tests of grafted plants to assess their performance under diverse environmental conditions.

CONCLUSIONS

Grafting had no effect on soluble solids content, indicating that this technique did not compromise melon fruit quality.

Total number of fruits and total fruit weight of melon were not affected by grafting, suggesting that the technique can be used without impacting crop yield.

The rootstock PI482398 exhibited the strongest general combining ability effects for fruit length among the evaluated genotypes.

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