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CROP PRODUCTION

Performance of interstocks in the plant development and fruit quality of plum trees

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ABSTRACT. The production of compact plants, which are slightly lacking in vigor and as productive as conventionally sized plants, is a trend in fruit growing. The objective of this study was to evaluate the vegetative performance and fruit quality of Gulfblaze and Reubennel plums intergrafted into two peach genotypes (UFV 186 and UFV 286). The experiment was arranged in a randomized block design using a 3x2 factorial arrangement (interstocks x cultivar) with four replications and one plant per plot. The non-intergrafted treatment was considered the control. Ten fruits were collected per plot for physical and chemical analyses. The evaluations were performed in the years 2014 and 2015. The interstock UFV 286 produced Gulfblaze trees with lower height in the two years of evaluation. When using the UFV 286 interstock, the trunk diameters were 50.2% smaller in Gulfblaze and 44.25% smaller in Reubennel than the control cultivars. Intergrafting had no influence on the fruit mass of Reubennel. In general, the peach genotypes UFV 186 and UFV 286 can be recommended as interstocks for reducing plant size in the plums studied. Intergrafting had no effect on fruit quality of Reubennel plums.

Keywords: *Prunus salicina*; rootstock; vigor control; antioxidant.

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Introduction

The annual consumption of plums in Brazil is estimated to be approximately 50,000 tons, of which 30% is imported primarily from Chile and Argentina (Fachinello, Pasa, Schmtiz, & Betemps, 2011). Plum is among the fruits of a temperate climate that need technological development due to the scarcity of cultivars with good climatic adaptation, phytosanitary problems, and low yields (Oliveira et al., 2011).

The production of compact plants, which are slightly lacking in vigor and as productive as conventionally sized plants, is a trend in fruit growing, attempting to achieve high yields per area by a possible densification of plants in orchards. The use of phyto-regulators, dwarfing rootstocks, branch and trunk girdling, and production of intergrafted seedlings may have an effect on plant vigor (Rufato, Rossi, Giacobbo, & Fachinello, 2006). The relative decrease in vigor of the plants also facilitates cultural treatments throughout the crop cycle, (training, pruning, disbudding, thinning and phytosanitary treatments) and even at harvest (Scarpare Filho, Kluge, Victória Filho, Neto, & Jacomino, 2000).

Intergrafting consists of the use of an intermediate stem fragment or compatible interstock between the rootstock and the scion, which may influence the development of the crown and roots (Fachinello, Hoffmann, & Nachtgal, 2005; Hartmann, Kester, Davies Junior, & Geneve, 2011). This technique aims to reduce the vigor of plants, increase yield efficiency, and improve fruit quality. These effects have already been verified in several fruit species, such as peach (Rufato et al., 2006; Scarpare Filho et al., 2000; Telles, Biasi, Mindello Neto, & Peters, 2006; Tomaz, Schuch, Peil, & Timm, 2014), orange (Guilherme, Marinho, Biazatt, Campos, & Bremenkamp, 2014), pear (Baciu, Achim, & Cosmulescu, 2008), apple (Marcon Filho, Rufato, Rufato, Kretzschmar, & Zancan, 2009; Vaio, Cirillo, Buccheri, & Limongelli, 2009), cherry (Magyar & Hrotkó, 2008), and mango (Posada & Guzmán, 2009). Theoretically, rootstocks may indirectly affect fruit quality by several mechanisms, including budburst, time and abundance of scion flowering and flower quality (Daza, Galavis, Grande, & Santamaria, 2008).

Scarpare Filho et al. (2000) reported that the use of Januária plum interstock anticipated flowering and sprouting of the peach cultivars Tropical and Ouromel-2, enabling early harvesting and showing that each cultivar or species behaves differently. Telles et al. (2006) observed that using Irati and Reubennel plums as interstock in the production of peach seedlings proved to be compatible and reduced crown growth.

However, there is little information in the literature regarding the use of intergrafting in plums relating the technique to fruit quality. Therefore, the objective of this work was to evaluate the vegetative performance and fruit quality of Gulfblaze and Reubennel plums intergrafted with two peach genotypes (*Prunus persica*).

Material and methods

The experiment was conducted in the orchard of the Department of Plant Science, Federal University of Viçosa, in the municipality of Viçosa, Minas Gerais State, Brazil (20°45'48" South Latitude and 42°51'1.7" West Longitude) at an altitude of 618 m. The municipality has a humid subtropical climate with cold and dry winter and hot and humid summer, classified as tropical Cwa. The soil of the experimental area is a Red-Yellow Latosol. Climatological data recorded during the experiment are presented in Figure 1.

Rootstocks and interstocks were obtained from seedlings produced in the UFV Experimental Orchard. Okinawa seedlings were used as rootstocks one year after planting, measuring 25-30 cm in height. The seedlings were grafted with buds of Gulfblaze and Reubennel plums to form the crown varieties. To obtain intergrafted seedlings, forks of the peach genotypes UFV 186 and UFV 286 were grafted onto the Okinawa rootstock by full cleft grafting and then the plum crowns were grafted by inverted 'T' budding. The planting of the seedlings was carried out in October 2012 at a spacing of 3.0 x 3.0 m (1,111 plants ha^{-1}) in an experimental area of 0.2 ha. The experiment was conducted in pots, and the cultural treatments that were performed were split fertilization, pruning, irrigation, breaking of dormancy with hydrogen cyanamide (1.2%) combined with mineral oil (1%), fruit thinning, and routine phytosanitary treatments for cultivation in subtropical climates.

The experiment was arranged in a randomized complete block design in a 3 x 2 factorial arrangement (interstocks x crown cultivar) with four replications, one plant per plot and ten fruits per replicate. Two peach interstocks from the UFV Peach Improvement Program (UFV 186 and UFV 286) were tested, and a treatment without intergrafting was performed as a control.

The characteristics related to the vegetative growth were trunk diameter (mm) at 10 cm above the intergrafting point and plant height (m) measured from the ground level to the tip of the central branch.

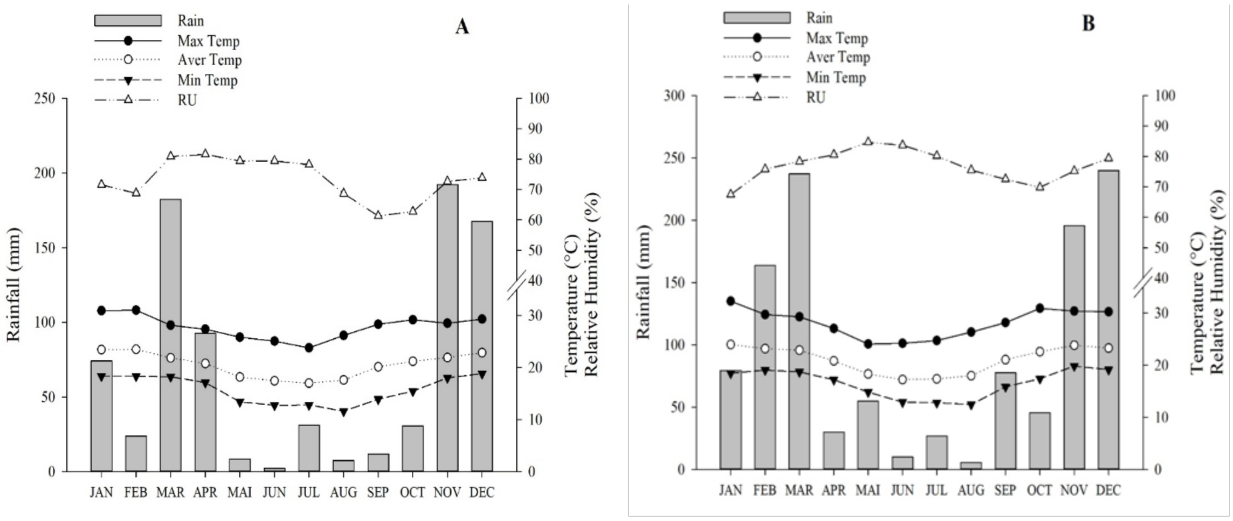

Figure 1. Rainfall, relative humidity, maximum, average, and minimum temperature for the 2014 (A) and 2015 (B) harvest years. Source: Weather station of the Federal University of Viçosa, Viçosa, Minas Gerais State, Brazil.

Ten fruits per plot were collected for physical and chemical analyses based on a change in the characteristic background skin color of each variety studied. The variables evaluated were skin color given by the coordinates a* and b* and the Hue angle (h°) using a Minolta CR-10 colorimeter (the skin color was measured on the equatorial region of opposite fruit sides); fruit mass (FM), in grams (g), measured to the nearest 0.1 kg with a digital scale; fruit equatorial diameter (ED), in mm, maximum transversal distance perpendicular to the suture, using a digital caliper; pulp firmness (FIR), measured on the equatorial region of one of the faces of each fruit after skin removal, using a digital Effegi penetrometer (TF-011) with an 8 mm diameter plunger tip, and expressed as Newtons (N); soluble solids (SS), using a digital refractometer and expressed as Brix; titratable acidity (TA), by titrating 5 g of ground pulp plus 95 mL distilled water with NaOH solution and expressed as a percentage of malic acid.

The ascorbic acid content in the pulp (Vit C) was determined by titration with Tillman's reagent [2,6-dichlorophenolindofenol (0.1% sodium salt)] according to methodology described by Instituto Adolfo Lutz (2008) and expressed as mg of ascorbic acid per 100 g of pulp.

Total carotenoids were determined according to Higby (1962). Samples of 2 g of the pulp were added to 20 mL of PA acetone and processed in an Ultra Stirrer homogenizer for 6 min. The extract was vacuum filtered on a Büchner funnel using filter paper, and the volume was raised to 25 mL. The absorbance was read at 450 ηm in a spectrophotometer. Total carotenoid content was estimated using the equation described below, with the results expressed as milligrams per 100 g of pulp. Total Carotenoids = A450 x 100/250 x L x W, where A450 is the absorbance at 450 nm; 250 is absorptivity; L is cell length in cm; and W is the amount of sample, in grams, in the final dilution volume (5/25 mL).

Data were examined with an analysis of variance and F test, and means were compared with Tukey's test at 5% probability using the statistical program GENES (Cruz, 2016).

Results and discussion

Plant height of the two plum cultivars was significantly influenced by the interstocks (Table 1). The interstock derived from cv. UFV 286 reduced plant height in the two years of evaluation with values 28.6% and 36.1% lower on average than the control (without interstock) for both cvs. Gufblaze and Reubennel, respectively.

The trunk diameters were significantly lower in intergrafted plants than in non-intergrafted plants (Table 1) in both cultivars and harvest years. When using the interstock derived from cv. UFV 286, trunk diameters were 50.2% and 44.3% lower than the control for cvs. Gufblaze and Reubennel, respectively. Scarpare Filho et al. (2000) observed that the interstock of cv. Januaria reduced the trunk diameter of two peach cultivars. These results showed that the use of interstocks can reduce plant growth and vigor and corroborated other authors (Tomaz et al., 2010; Marcon Filho et al., 2009; Vaio et al., 2009).

Table 1. Plant height, trunk diameter, fruit mass and fruit diameter of Gulfblaze (GFB) and Reubennel (REUB) plums as a function of peach interstocks.

Interstock	Plant height (m)				Trunk diameter (mm)			
	2014		2015		2014		2015	
	GFB	REUB	GFB	REUB	GFB	REUB	GFB	REUB
UFV 186	3.10 Aa	3.35 Ba	3.68 Aa	4.05 Aa	66.1 Aa	64.5 ABa	86.6 Aa	99.6 Aa
UFV 286	2.21 Ba	2.62 Ca	2.32 Bb	3.01 Ba	37.5 Ba	47.8 Ba	50.9 Ba	64.7 Ba
Control	3.13 Ab	4.13 Aa	3.21 Ab	4.67 Aa	77.2 Aa	86.7 Aa	99.7 Aa	114.8 Aa
CV(%)	12.28		13.17		21.88		15.28	
Interstock	Fruit mass (g)				Fruit diameter (mm)			
	2014		2015		2014		2015	
	GFB	REUB	GFB	REUB	GFB	REUB	GFB	REUB
UFV 186	38.5 Bb	56.8 Aa	54 Aba	40.5 Ab	39.6 Ba	44.1 Aa	45.6 ABa	40.5 Ab
UFV 286	36. Bb	51.5 Aa	43.8 Ba	40.2 Aa	40.1 Ba	43.3 Aa	41.9 Ba	41.5 Aa
Control	60.0 Aa	41.1 Ab	59.6 Aa	39.7 Ab	47.5 Aa	40.5 Ab	47.3 Aa	40.7 Ab
CV(%)	18.68		15.15		7.21		4.85	

Means followed by the same capital letter in the column and the same small letter in the row were not significantly different at 5% probability according to a Tukey's test.

Reduction in the area of the trunk section is probably a symptom of physiological incompatibility. In certain cases, the interstock effect on growth is due to the introduction of an additional grafting union with possible translocation restriction. In turn, there are data indicating that the observed effects are due more to the influence of the interstock than to abnormalities in the graft union (Hartmann et al., 2011). Thus, the interstock changes the distribution of phytoregulators, such as gibberellins in the branches and leaves, which can reduce plant growth (Richards, Thompson, & Pharis, 1986) and modify the nutrient contents of the crown.

In general, the reduction in plant height and trunk diameter was provided by the UFV 286 interstock, which shows the potential of this genotype for intergrafting plums. Moreover, this reduction in plant size, besides increasing the yield efficiency, enables the use of higher densities and facilitates the cultural treatments, especially pruning, thinning, phytosanitation, and harvesting operations.

The fruit mass of non-intergrafted Gulfblaze plums was 37.9% and 18% higher on average than the intergrafted treatments in 2014 and 2015, respectively (Table 1). However, fruit mass of cv. Reubennel was not influenced by the intergrafting, which shows the potential of the interstocks tested to maintain the fruit mass compared to the control in this cultivar. Silva, Silva, Costa, and Ramos (2008) reported an average fruit weight below 50 g for cvs. Harry Pickstone and Reubennel, in Caldas, Minas Gerais. In Pelotas, Rio Grande do Sul, Danner, Raseira, Sasso, Citadin, and Scariot (2010) found an average of 68 g for cv. Reubennel. In this study, we observed a mean of 46.17 g, which was lower than that reported previously.

Intergrafting significantly influenced the fruit diameter of cv. Gulfblaze, which was 16.1% and 7.5% lower on average than the control treatment in 2014 and 2015, respectively (Table 1). Conversely, no significant differences were found between the treatments for cv. Reubennel in the two years of evaluation, which showed the potential of the interstocks that were tested to maintain fruit diameters in this cultivar.

Regarding the skin color, there was no effect of the interstocks on the red (a*) and yellow (b*) colors of Guflblaze fruits in the two years of evaluation (Table 2). However, in 2014, the non-intergrafted plants showed a lower h°. Reubennel plants intergrafted with the interstock UFV 186 produced greener fruits with a lower b*. In general, intergrafting did not affect fruit visual quality.

Table 2. Skin color (a*, b* and hue angle) and firmness of Gulfblaze (GFB) and Reubennel (REUB) fruit pulp as a function of peach interstocks.

Interstock	a*				b*			
	2014		2015		2014		2015	
	GFB	REUB	GFB	REUB	GFB	REUB	GFB	REUB
UFV 186	5.84 Aa	6.54 Aa	5.21 Aa	2.12 Ab	2.35 Ab	26.1 Ba	4.47 Ab	23.4 Ba
UFV 286	4.72 Aa	1.82 Ba	4.14 Aa	3.23 Ab	3.31 Ab	29.5 ABa	4.38 Ab	24.8ABa
Control	4.65 Aa	5.68ABa	4.92 Aa	3.22 Ab	2.26 Ab	31.3 Aa	4.18 Ab	25.6 Aa
CV(%)	34.16		35.15		13.61		6.15	
Interstock	Hue angle				Pulp firmness (N)			
	2014		2015		2014		2015	
	GFB	REUB	GFB	REUB	GFB	REUB	GFB	REUB
UFV 186	41.2ABb	75.5 Ba	44.1 Ab	94.6 Aa	20.9 Aa	25.4 Aa	9.1 Ab	22.8 Aa
UFV 286	50.4 Ab	88.3 Aa	48.1 Ab	96.6 Aa	18.4 Ab	29.4 Aa	6.4 Ab	19.2 Aa
Control	35.1 Bb	91.7 Aa	44.1 Ab	96.1 Aa	22.7 Ab	36.5 Aa	6.5 Ab	19.3 Aa
CV(%)	10.22		7.53		26.63		18.39	

Means followed by the same capital letter in the column and the same small letter in the row are not significantly different at 5% probability according to a Tukey's test.

Pulp firmness showed no significant differences between the interstocks and the control treatment for the two plum cultivars in the two years of evaluation, demonstrating that intergrafting had no effect on fruit firmness. However, comparing the cultivars, Reubennel fruits showed greater firmness. In 2015, Reubennel fruits reached greater pulp firmness for all of the combinations tested with the interstocks with an average of 20.45 N. Steffens, Amarante, Chechi, Silveira, and Corrêa (2011), working with cv. Laetitia, reported firmness of 3.46 N, which was well below the values obtained in this study, indicating that the use of interstock in the cultivars tested in this study can provide the market with fruits of greater firmness. Silva, Matias, Silva, Salazar, and Bruckner (2016), working with different peach cultivars, argued that firmer fruits may reach more distant markets as, under these conditions, they remain marketable for a longer time.

The soluble solids content was not affected by intergrafting (Table 3). Reubennel fruits produced a higher soluble solids content with an overall mean of 15.26 °Brix. Benato, Castro, Sigrist, Anjos, and Valentini (2015) reported 11.4 °Brix for Reubennel plum in Campinas-SP, which was well below the values observed in this study. According to Silva et al. (2016), the content of soluble solids in peach depends on several factors, such as genetic variety, ripening stage, post-harvest storage, processing, and nutrition.

Titratable acidity of Gufblaze plum fruits was significantly influenced by the use of interstocks, with UFV 286 producing fruits with higher acid content in 2014 (Table 3). Conversely, for the Reubennel cultivar, there was no significant difference in fruit acidity independent of the interstock evaluated. On average, Reubennel fruits showed mean titratable acidity of 0.78 g 100 g^{-1}, whereas Benato et al. (2015) reported mean titratable acidity of 1.27 100 g^{-1} for Reubennel plums in Campinas, São Paulo State, which was were well above the results found in the present study.

Cultivar Reubennel showed a significant difference for vitamin C content only in the year 2014 at the interstock evaluation (Table 3). This same cultivar in the year 2015 and cv. Gufblaze in the two years of evaluation showed no significant difference between the treatments, demonstrating that the use of the interstock had no effect on vitamin C content. Vitamin C and carotenoids are among the antioxidants that have received greater attention for their possible beneficial action on the body (Cao et al., 2017; Chacón-Ordóñes et al., 2017; Guedes et al., 2017).

Table 3. Soluble solids content, titratable acidity, vitamin C and total carotenoids of Gulfblaze (GFB) and Reubennel (REUB) fruits as a function of peach interstocks.

Interstock	Soluble solids content (°Brix)				Titratable acidity (%)			
	2014		2015		2014		2015	
	GFB	REUB	GFB	REUB	GFB	REUB	GFB	REUB
UFV 186	13.8 Ab	15.5 Aa	12.9 Ab	15.3 Aa	1.35 Ba	1.26 Aa	1.19 Aa	0.30 Ab
UFV 286	13.3 Ab	16.2 Aa	12.6 Ab	15.1 Aa	1.69 Ab	1.19 Aa	1.08 ABa	0.32 Ab
Control	13.6 Aa	14.5 Aa	12.7 Ab	15.1 Aa	1.48 Ba	1.27 Ab	0.90 Ba	0.34 Ab
Interstock	Vitamin C (mg 100 g^{-1})				Total carotenoids (mg 100 g^{-1})			
	2014		2015		2014		2015	
	GFB	REUB	GFB	REUB	GFB	REUB	GFB	REUB
UFV 186	17.1 Aa	17.1ABa	14.2 Aa	9.9 Ab	1.17 Aa	0.59 Ab	0.70 Ba	0.59 Aa
UFV 286	18.3 Aa	14.1 Bb	13.1 Aa	11.4 Aa	0.89 Aa	0.49 Ab	1.12 Aa	0.52 Ab
Control	19.1 Aa	18.7 Aa	14.1 Aa	9.7 Ab	0.93 Aa	0.56 Ab	0.70 Ba	0.53 Ab

Means followed by the same capital letter in the column and the same small letter in the row are not significantly different at 5% probability according to a Tukey's test.

Gulfblaze fruits had a higher carotenoid content in 2015 when grafted with the UFV 286 interstock (Table 3). Several carotenoid compounds have been reported to exert beneficial effects on the prevention of certain cancer cardiovascular diseases (Yuan, Zhang, Nageswaran, & Li, 2015). The carotenoid content in plants depends on, among other factors, the genetic variety, ripening stage, post-harvest storage, and processing (Llorente, Garcia, Stange, & Concepcion, 2017, Matias et al., 2016a). Matias et al. (2016b) noted that the concentration of total carotenoid contents accounted for the yellow coloration of the pulp and Faraoni, Ramos, Stringheta, and Laureano (2008) mentioned that in the pulp and by-products, the color, besides influencing quality, is an important parameter used for the quality control of these products.

Conclusion

The peach genotypes UFV 186 and UFV 286 can be recommended as interstocks for the plum cvs. Reubennel and Gulfblaze when attempting to reduce plant size.

Under the conditions employed in this study, the use of intergrafting had no effect on the quality of Reubennel plum fruits.

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