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Article

Agronomic performance of table grape cultivars affected by rootstocks in semi-arid conditions

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ABSTRACT: The aim of the present study was to investigate the effect of the grape cultivar combined with rootstocks on yield and fruit traits of grapevine in the São Francisco Valley, in the Northeast of Brazil. The experiment was carried out over eight growing seasons (2014 to 2018) in Petrolina, Pernambuco, Brazil. The treatments were represented by five seedless table grape cultivars (A Dona, Arizul, Marroo Seedless, BRS Clara, and BRS Maria Bonita) and six rootstocks (IAC 313, IAC 766, IAC 572, SO4, Harmony, and Paulsen 1103) in a randomized block experimental design with three replicates. Principal component analysis showed that 59.2% of the variation found in the data was related to principal component (PC) 1 (42.76%) associated with the number of bunches and berry weight, length, and diameter variables; and PC 2 (16.4%) correlated with yield per vine. The yield per vine showed a significant positive correlation with number of bunches, bunch length, soluble solids content, and titratable acidity, and showed a negative correlation with berry length. A Dona and Marroo Seedless grapes had the highest yield, regardless of the rootstocks they were grafted onto, whereas BRS Clara had high values for soluble solids content and titratable acidity and a balanced SS/TA ratio. In contrast, BRS Maria Bonita had the lowest yielding grape cultivar, although it had the greatest bunch weight and berry length. The rootstocks affected the agronomic performance of the table grape cultivars in most variables, depending on the effect of different grape cultivars × rootstock combinations.
Key words: *Vitis* spp., tropical viticulture, scion, grafting, seedless grapes.

INTRODUCTION

The Lower-Middle São Francisco River Valley is the main region for production and export of table grapes in Brazil. The volume of grapes exported in 2021 reached 76.6 thousand metric tons, and the main destination was Europe (Comex Stat 2022). The semi-arid tropical climate that characterizes this grape and wine growing region stands out for its intense solar radiation and temperature, which favor continuous vegetative growth of the grapevines, such that they do not pass through a dormant or resting period. This physiological response of the grapevine under tropical conditions, combined with irrigation and pruning practices, makes for at least two crops per year for most cultivars. Thus, the ideal rootstock for this region should not only have the ability of expressing the yield and quality potential of the vine, but also gather necessary traits, such as vigor, nematode tolerance, and edaphic and climatic adaptation (Costa et al. 2020).

The use of rootstocks in grape growing began in the middle of the 19th century with the aim of preventing damage caused by phylloxera, a pest that attacks the root system of the grapevine (Arnold and Schnitzler 2020). The first rootstocks used were accessions of the species *Vitis riparia*; however, they induced limited vigor in the grapevine canopy. Thus, other more vigorous American species were selected, such as *V. rupestris* and *V. berlandieri*, with wide acceptance in many grape-growing zones (Fregoni 2005). Currently, most of the rootstocks used are hybrids obtained from these three species (Berdeja

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et al. 2015). The effect of the canopy × rootstock relationship came to be extensively studied because this interaction can affect vigor, yield components, and grape quality (Brighenti et al. 2021).

The main rootstocks used in different table grape cultivars in the São Francisco Valley are IAC 313, IAC 766, and IAC 572, which were obtained by the Instituto Agronômico de Campinas (IAC) using grapevine species from Central America, whereas others, such as Paulsen 1103, SO4, and 101-14 Mgt, were introduced in the region through Embrapa Uva e Vinho (Mello and Machado 2020). In addition, the rootstocks Freedom and Ramsey (Salt Creek) were introduced in the past decade for grafting of foreign grape cultivars (Leão 2020).

The interaction of physiological, morphological, and agronomic variables in a single scion (Leão and Chaves 2019, 2021, Ferreira et al. 2020, Leão et al. 2020a, 2020b, Costa et al. 2021, Edwards et al. 2022, Leão et al. 2022) has been extensively studied in different growing regions. Nevertheless, the recommendation in relation to the best rootstock or group of rootstocks cannot be generalized to other situations, since the interactions between different grape cultivar × rootstock combinations have not been evaluated (Serra et al. 2014). Therefore, it is necessary to understand the phenotypic correlations among the diverse variables studied, what the causes of the correlations among the variables are, and their importance, indicating which are related to the main trait, that of yield, as well as if they remain stable in the different grape cultivar × rootstock combinations.

Long-term studies of the interactions between different canopy × rootstock combinations on yield and yield components are necessary since most of the results report the response conferred by the rootstock or differences in the establishment of the grapevine over only one or a few crops, that is, short-term studies (Edwards et al. 2022). However, canopy × rootstock relationships are affected by factors such as yield, vineyard management, water availability, and climate conditions, variables that change for each crop or production cycle (Edwards and Clingeleffer 2013). Thus, long-term studies or studies repeated in various production cycles are necessary for estimating the real contribution of the rootstocks in the diverse combinations with grape cultivars.

The aims of this study were to identify which morpho-agronomic traits contribute to production of grapes using diverse grape cultivar × rootstock combinations and to identify rootstocks that lead to gains in fruit yield and quality in different table grape cultivars.

MATERIALS AND METHODS

Site

The study was conducted over eight production cycles from 2014 to 2018 in an experiment set up at the Bebedouro Experimental Field of Embrapa Semiárido, in the municipality of Petrolina, Pernambuco, Brazil (09°09'S, 40°22'W, and mean altitude of 365.5 m). The soils of the site were classified as *argissolo vermelho eutrófico abrúptico plíntossólico*, with a moderate A horizon, medium texture, and flat topography (Cunha et al. 2008). Climate in the region can be classified, according to Köppen, as Bswh, which corresponds to a very hot semi-arid region (Alvares et al. 2014), with historical averages recorded by the Bebedouro Agro-Meteorological Station. The mean annual temperature is around 26°C, relative humidity of 64%, annual rainfall of 549 mm, global solar radiation of 18 $MJ{\cdot}m^{-2}{\cdot}day^{-1}$, wind speed of 2 $m{\cdot}s^{-1}$, and reference evapotranspiration of 6 $mm{\cdot}day^{-1}$ (Embrapa 2022).

Material and experimental design

Five seedless table grapes cultivars named A Dona (IAC, Brazil), Arizul (INTA, Argentina), Marroo (CSIRO, Australia), and BRS Clara and BRS Maria Bonita (EMBRAPA, Brazil) were grafted on six rootstocks (table grafted): IAC 572 (Jales), IAC 766 (Campinas), IAC 313 (Tropical), Paulsen 1103 (P1103), and SO4 (Harmony). The genetic origin, vigor response, degree of resistance/tolerance to phylloxera, nematodes, drought, and salinity of the rootstocks are shown in Table 1. Grafting was performed in a nursery, and the seedlings were planted in the field around 60 days after grafting.

Table 1. Origin, vigor, and degree of resistance/tolerance of rootstocks to phylloxera, nematodes, drought, and salinity.

Rootstock	Origin	Vigor	Degree of resistance/tolerance			
			Phylloxera	Root-knot nematodes	Drought	Salinity
IAC 572	*V. caribaea* and (*V. riparia* × *V. rupestris*, R. R. 101-14)	High	High	High	High	High
IAC 766	(*V. riparia-V. rupestris* × *V. cordifolia*, 106-8 Mgt) × *V. caribaea*	Medium to high	High	High	Unknown	High
IAC 313	(*V. riparia-Carignane* × *V. rupestris* du Lot) x *V. cinerea*	Medium to high	High	High	Unknown	Medium
Paulsen 1103	*V. berlandieri* × *V. rupestris*	Medium to high	High	Medium to high	Medium to high	Medium
SO4	*V. berlandieri* × *V. riparia*	Low to medium	High	Medium to high	Low to medium	Low to medium
Harmony	C1613 (Solonis × Othello) × Dog Ridge	Low to medium	Low to medium	Medium to high	Low to medium	Low to medium

Source: Viana et al. (2001), Christensen et al. (2003), Souza et al. (2009), Hermínio et al. (2018).

A randomized block experimental design was used with four replications and split plots, with the grapevines separated by cultivars as the main plot, and rootstocks constituting the split plots. The experimental unit was composed of four plants.

Vineyard management

The grapevines were planted in 2013 at a spacing of 3 m between rows and 2 m between plants, using a trellis training system. Drip irrigation was performed based on reference evapotranspiration information collected from the agrometeorological station of the Bebedouro Experimental Field. The nutrients were applied through irrigation as necessary when indicated by soil and plant tissue analysis. The grapevines were pruned twice a year into canes with five to seven buds and spurs at the base of the branches with two to three buds. The fertility of buds varied among grape cultivars, but the length of canes pruned were the same for all the vines. The index of fertile buds (bunches per shoot) varied among grape cultivars according to previous studies in the same region: 0.78 for Marroo seedless, 0.54 for BRS Maria Bonita, 0,48 for Arizul, 0.95 for A Dona, and 0.84 for BRS Clara (Leão et al. 2017), but the location of fertile buds for all the cultivars was between the 4th and the 7th buds. Then, the canes were pruned with seven or eight buds per cane.

Canopy management also included sprout thinning, defoliation, berry thinning, tying, and shoot topping. Growth regulators for berry growth or grape coloring were not applied.

Measurements

Grapes were harvested from all the cultivars when the soluble solids content exceeded 15 °Brix or the SS/TA ratio was greater than 20. All the bunches from two plants used for data collection in the plot were counted and weighed on a digital electronic balance. The mean results obtained were expressed in kg per vine. The mean bunch weight, expressed in grams, was obtained by dividing the total weight of the bunches by the number of bunches per vine. A sample of five bunches per plot was harvested for evaluation of bunch length and width using a scale ruler and expressed in centimeters.

Physical and physicochemical analyses of the berries were performed on a 10-berry sample taken from each bunch, for a total of 50 berries per plot, for determination of mean weight (g), length (mm), and diameter (mm) of the berry. The must extracted from 50 berries per plot was used for determination of total soluble solids (SS) content and titratable acidity (TA). The SS content was measured in a digital refractometer and expressed in °Brix, while titration with 0.1 N NaOH was performed for determination of titratable acidity (AOAC 2016), and the results were presented in percentage of tartaric acid (%). These results were used for calculation of the SS/TA ratio.

Statistical analysis

The results were evaluated for normal distribution using the Shapiro-Wilk test, and, if they were in conformity with the presupposition of normality, analysis of variance was performed using the F test, comparing the mean values of plot and split plot effects, as well as possible interactions between them, using Tukey's test ($p < 0.05$). The data regarding the number of bunches, bunch weight, bunch length and width, berry weight and length, total soluble solids, and titratable acidity traits did not exhibit normal distribution of the data. Then, they were transformed using $\sqrt{(x+1)}$. The data were analyzed using the SISVAR computational program (Ferreira 2011).

Principal component analysis (PCA) ('prcomp' library on R) was carried out using the mean values of the production cycles to segregate the effects of the rootstocks and grape cultivars on yield and its components. Analysis of phenotypic correlation ('corrplot' library on R) was carried out to determine the contribution of each variable to production. Pathway analysis was based on the phenotypic correlation matrix of the variables studied using the 'ggplot2' package on R, considering yield as the main variable and the other variables as independent or explanatory. Analyses were performed using the R statistical software (R Development Core Team 2018).

RESULTS AND DISCUSSION

The effect of six different rootstocks on 11 morpho-agronomic variables was evaluated in five table grape cultivars over eight production cycles. The distribution of the results in the PCA quadrants indicated greater variability among cultivars than among rootstocks and production cycles in each cultivar (Fig. 1), and these results are in agreement with Ibacache et al. (2016) and Silva et al. (2018), who also found greater variability among cultivars than among rootstocks in each cultivar.

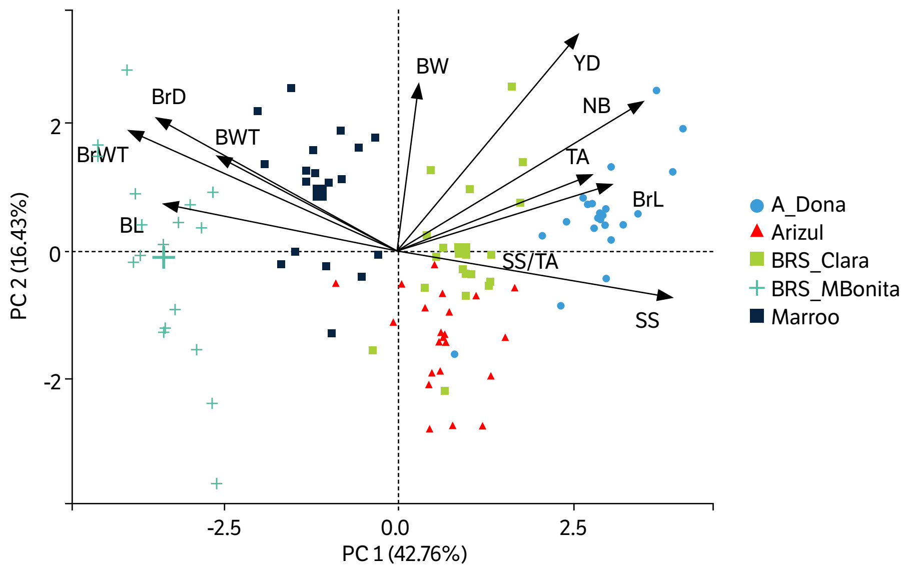
The first and second principal components explained 59.2% of the variation found in the data, in which CP 1 (42.76%) was associated with the number of bunches (NB), bunch weight (BWT), berry length (BrL), and berry diameter (BrD) variables, while CP 2 (16.4%) was associated with yield per vine (YD). The number-of-bunches variable was also identified by Ibacache et al. (2016), with greater contribution to the seasonal variability in the cultivars Flame seedless, Red Globe, and Thompson seedless on different rootstocks. However, the percentage values associated with the principal components and the contribution of the variables to the total variation depend on the nature of the data (cultivars, clones, number of samples, crop seasons, variables, etc.). Leão et al. (2010) studying the genetic diversity of two groups of cultivars for table grapes and for processing from a Germplasm Bank mentioned that four principal components were necessary to explain more than 80% of the variation observed, but the relative contribution of the variables to the total variation was different as a result of the type of grape used in each group (table grape, wine or juice grape), considering the same experimental conditions and methodology.

Dispersion of the data in the upper left quadrant indicates that the cultivar A Dona stood out regarding yield per vine, number of bunches per vine, bunch length, titratable acidity, and total soluble solids (Fig. 1).

The mean values of BRS Maria Bonita were distributed in the upper and lower right quadrants and are associated with bunch weight, berry weight, and berry size, in spite of having low yield potential. The table grapes Arizul, BRS Clara, and Marroo, whose mean values were distributed nearer the central axes, had intermediate values for most of the variables studied (Fig. 1).

When the analysis was conducted individually in each grape cultivar, the effect of the two principal components was greatest for BRS Maria Bonita (77.24%), whereas for A Dona, Arizul, BRS Clara, and Marroo the two principal components had values of 59.53, 50.59, 63.26, and 56.25%, respectively, that is, values near that obtained using the combined data.

Most of the phenotypic correlations between the morpho-agronomic variables were significant ($p < 0.05$) (Table 2), indicating that yield per vine (YD) is positively correlated with number of bunches (NB), bunch length (BL), soluble solids content (SS), and titratable acidity (TA). Only berry length (BrL) had significant negative correlation with yield per vine. The significant negative correlation between berry length and yield per vine can be explained by considering that in vines whose bunches had longer berries the number of bunches per vine was reduced ($R2 = -0.537$), as well as the bunch length ($R2 = -0.466$).



YD: yield; NB: number of bunches per vine; BWT: bunch weight; BL: bunch length; BW: bunch width; BrWT: berry weight; BrL: berry length; BrD: berry diameter; SS: soluble solids content; TA: titratable acidity; SS/TA: soluble solids content / titratable acidity ratio.

Figure 1. Principal component analysis (PCA) biplot on 11 grape traits over eight crop seasons of five cultivars grafted onto six rootstocks under semi-arid conditions. Arrowed lines represent vectors that quantify the magnitude and direction of a trait contribution.

Table 2. Phenotypic correlation coefficient (above diagonal) and estimates of indirect effects (below diagonal) and direct effects through path analysis of five seedless table grapes and six rootstocks over eight production cycles.

Trait	NB	BWT	BL	BW	BrWT	BrL	BrD	SS	TA	SS/TA
YD	0.869*	-0.060	0.435*	0.283	-0.177	-0.387*	-0.042	0.301*	0.487*	0.155
NB		-0.416*	0.418*	0.177	-0.382*	-0.537*	-0.237	0.507*	0.620*	0.282
BWT	-0.148		0.059	0.089	0.472*	0.261	0.491*	-0.549*	-0.437*	-0.269
BL	-0.013	-0.002		0.314*	-0.554*	-0.466*	-0.511*	0.582*	0.330*	0.114
BW	0.013	0.006	0.023		0.074	0.160	0.063	-0.015	-0.037	0.183
BrWT	0.007	-0.009	0.011	-0.001		0.768*	0.847*	-0.704*	-0.268	-0.360*
BrL	-0.031	0.015	-0.027	0.009	0.044		0.477*	-0.464*	-0.125	-0.566*
BrD	0.000	-0.001	0.001	0.000	-0.002	-0.001		-0.761*	-0.406*	-0.052
SS	0.004	-0.004	0.004	0.000	-0.005	-0.003	-0.005		0.613*	0.146
TA	-0.013	0.009	-0.007	0.001	0.006	0.003	0.009	-0.013		-0.351*
SS/TA	-0.012	0.011	-0.005	-0.008	0.015	0.024	0.002	-0.006	0.015	
Direct	1.062	0.356	-0.03	0.072	-0.019	0.058	-0.002	0.007	-0.021	-0.042
R^2	0.875								¥RVE	0.353

YD: yield; NB: number of bunches per vine; BWT: bunch weight; BL: bunch length; BW: bunch width; BrWT: berry weight; BrL: berry length; SS: soluble solids content; TA: titratable acidity ratio; R^2: coefficient of determination; *significant at 0.05 probability level.

On the other hand, these last two variables have a positive and significant correlation with yield per vine. The bunch weight variable had positive correlation with berry weight (BrWT) and berry diameter (BrD). The number of bunches per vine (NB) and bunch length (BL) had significant negative correlation with the morphological variables of the berry, except between number of bunches and berry diameter, which, though negative, was not significant. Berry weight (BrWT), berry length (BrL), and berry diameter (BrD) had negative correlations with the physical-chemical traits (SS, TA, and SS/TA). These results confirm those obtained by different authors that also studied correlations between variables in the grape crop (Akram et al. 2021, Khalil et al. 2017, Vujović et al. 2017) and observed significant correlations of high magnitude between variables of the same category (for example, between yield components, bunch weight, and bunch size; berry weight and berry size and physical-chemical traits).

Pathway analysis based on the phenotypic correlation matrix (Table 2) showed that a large part of the variation in grape yield (YD) in different grape cultivar × rootstock combinations was explained by the effect of ten morpho-agronomic traits evaluated ($R^2 > 0.875$). The phenotypic correlation did not exhibit a significant linear association between the bunch weight (BWT) and yield per vine (YD) variables; however, through pathway analysis, it was possible to confirm the direct and significant contribution between these variables (0.356 > RVE). Fanizza et al. (2005) used pathway analysis to show that the number of bunches per vine, number of berries per bunch, and berry weight had a positive correlation with yield, but number of bunches per vine had a significant negative correlation with the number of berries per bunch and berry weight. Pathway analysis also made it possible to identify that the number of bunches per vine made a greater contribution to grapevine yield in different environments (Rasoli et al. 2015) than other yield components did.

The table grapes A Dona and Marroo seedless had the highest yields, regardless of the rootstock used (Table 3), in agreement with Oliveira et al. (2017), who also found greater yield per vine in A Dona in this same region. The cultivar A Dona also had the highest mean values for number of bunches per vine, bunch width, soluble solids content, and titratable acidity.

BRS Maria Bonita had the highest mean values for bunch weight and physical traits of the berry (BrWT, BrL, and BrD) (Table 3); however, the greater bunch weight and berry size occurred in detriment to the physical-chemical variables (SS, TA, and SS/TA). The negative and significant relationship between these variables was observed in the phenotypic correlation (Table 1).

Arizul is part of the group of grapes that had the highest mean values for bunch weight and length (Table 3), although their berries have lower weight and size than those of the other cultivars.

BRS Clara stands out for bunch size (BL and BW) and high soluble solids content (Table 3). Oliveira et al. (2017) compared these cultivars under the same experimental conditions and concluded that the cultivars A Dona and BRS Clara stood out for high soluble sold content too.

Table 3. Mean* values for yield per vine (YD), number of bunches per vine (NB), bunch weight (BWT), bunch length (BL), bunch width (BW), berry weight (BrWT), berry length (BrL), berry diameter (BrD), soluble solids content (SS), titratable acidity (TA), and soluble solids content/titratable acidity ratio (SS/TA) of the cultivars on different rootstocks.

Cultivar		YD (kg·vine^{-1})	NB	BWT (g)	BL (cm)	BW (cm)
A Dona		10.63a	65.46a	171.00c	16.86a	9.38c
Arizul		6.45bc	36.10c	227.50ab	16.81a	9.16c
BRS Clara		7.44bc	43.78b	181.51bc	16.49a	11.61a
BRS Maria Bonita		5.51c	25.89d	240.82a	14.19b	9.20c
Marroo		8.55ab	48.16b	210.83abc	14.85b	10.74b
Mean		7.72	43.88	206.33	15.84	10.02
Cultivar	**BrWT (g)**	**BrL (mm)**	**BrD (mm)**	**SS (ºBrix)**	**TA (g·100 mL^{-1})**	**SS/TA**
A Dona	2.46c	17.85cd	15.25b	21.06a	0.64a	40.75b
Arizul	2.23c	17.44d	15.14b	18.98b	0.46c	43.91ab
BRS Clara	2.59c	20.33b	14.93b	19.86ab	0.54b	40.83b
BRS Maria Bonita	3.70a	22.25a	17.01a	16.89c	0.49c	30.44c
Marroo	3.21b	19.08bc	17.20a	16.62c	0.45c	49.65a
Mean	2.84	19.39	15.91	18.68	0.51	41.12

*Means followed by the same letters do not differ from each other using Tukey's test ($p < 0.05$).

Separate evaluation of the different rootstocks in each cultivar shows a significant effect of the rootstock on the cultivar A Dona only in the number of bunches per vine, in which IAC 572 (76.03 ± 4.06) was superior to SO4 (56.76 ± 10.85). Tecchio et al. (2009) observed that A Dona grown on the rootstock IAC 766 in the state of São Paulo had greater bunch weight and berry size than those found in this study, which may be explained by the treatments with gibberellic acid. In contrast, results obtained in the same experimental area by Brito et al. (2019) indicate similar values for berry weight, but lower values for bunch weight and titratable acidity than those observed in this study.

The effect of the rootstock on Arizul was significant for the bunch weight (BWT), bunch length (BL), berry diameter (BrD), and titratable acidity (TA) variables (Fig. 2), with higher values on the rootstocks IAC 766, IAC 313, and IAC 572 compared to SO4 for each variable, respectively. The rootstock IAC 313 led to grapes with greater acidity compared to Paulsen 1103. Brito et al. (2019) observed the effect of the crop season and of the rootstock on this same cultivar and experimental area, with better results in relation to the quality attributes in the grapes harvested in June 2017. However, the mean bunch weight in that crop season was less than that observed in this study, whereas the titratable acidity values were higher in all the rootstocks.

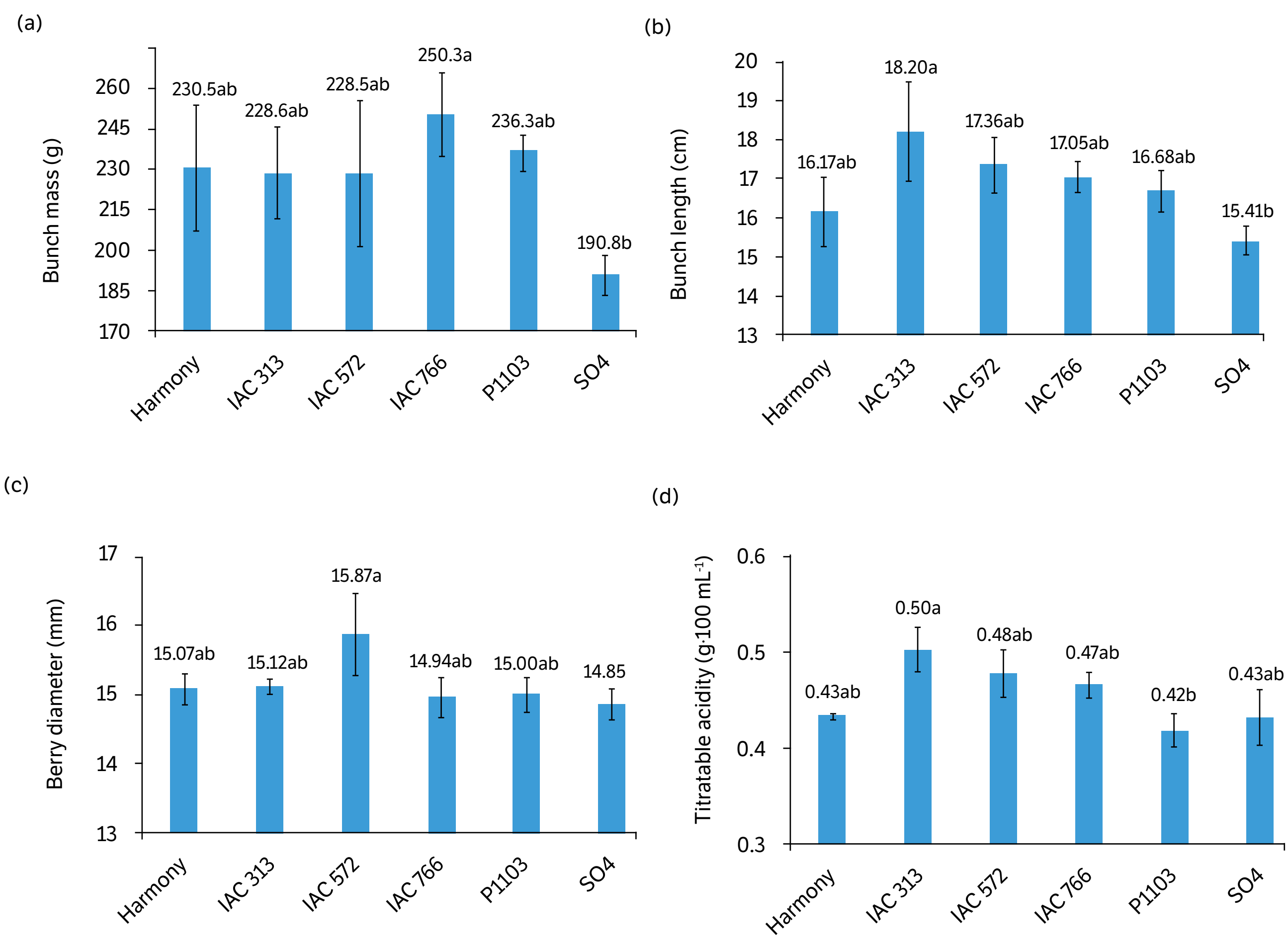


Figure 2. Mean values of the Arizul cultivar on different rootstocks. (a) Bunch weight. (b) Bunch length. (c) Berry diameter. (d) Titratable acidity. Each bar shows the mean ± standard error. Different letters among the rootstocks denote significant differences by Tukey's test ($p < 0.05$).

For BRS Clara, a significant effect of the rootstock was observed in yield per vine, in which the rootstocks Harmony, Paulsen 1103, and SO4 were superior to the other ones (Table 4). The rootstock IAC 572 reduced the number of bunches per vine (NB), bunch weight (BWT), bunch width (BW), and bunch length (BL) compared to the Paulsen 1103. This can be explained by the excessive vigor of this rootstock, which favored flower abortion and low fruit set. IAC 313 and IAC 572 led to an increase in the berry size of BRS Clara, as a result of less competition for photoassimilates in bunches with low fruit set and a smaller number of berries. Brito et al. (2019) found values for bunch weight similar to those observed in this study, although with marked differences between two production cycles in the same cultivar and experimental area. In addition to the rootstock, bunch management practices considerably affect berry weight and size in the BRS Clara; bunch thinning and two applications of 30 mg·L^{-1} gibberellic acid are recommended to increase bunch weight and berry diameter (Formolo et al. 2009). In relation to the physical-chemical variables (SS, TA, and SS/TA), there were no significant effects of the rootstocks on this cultivar.

Table 4. Mean* values for yield per vine (YD), number of bunches per vine (NB), bunch weight (BWT), bunch width (BW), bunch length (BL), berry weight (BrWT), berry length (BrL), and berry diameter (BrD) of BRS Clara on different rootstocks.

Rootstock	YD (kg·vine^{-1})	NB (unit)	BWT (cm)	BW (cm)	BL (cm)	BrWT (g)	BrL (mm)	BrD (mm)
Harmony	8.21ab	48.35a	195.37ab	11.57ab	10.57ab	2.65ns	20.04b	15.45ns
IAC 313	6.22bc	38.19ab	174.69ab	12.05ab	12.05ab	2.50	20.48ab	14.81
IAC 572	4.30c	30.88b	152.06b	10.56b	10.56b	2.62	21.64a	14.83
IAC 766	6.76bc	45.17a	174.41ab	11.74ab	11.74ab	2.60	19.80b	14.70
P1103	10.20a	51.31a	205.13a	12.60a	12.60a	2.64	20.10b	15.12
SO4	8.94ab	48.78a	187.44ab	11.12ab	11.12 ab	2.52	19.91b	14.69
Mean	7.44	43.78	181.51	11.61	15.79	2.59	20.33	14.93

*Means followed by the same letters do not differ from each other using Tukey's test ($p < 0.05$).

For cultivar BRS Maria Bonita, there was a significant effect of the rootstock on all the variables evaluated. The rootstocks IAC 313, IAC 572, and IAC 766 stood out with the highest mean values for the eight variables evaluated, especially IAC 766, which led to an increase of 56% in yield per vine compared to SO4 (Table 5).

Table 5. Mean* values for yield per vine (YD), bunch weight (BWT), bunch length (BL), bunch width (BW), berry weight (BrWT), berry length (BrL), berry diameter (BrD), and titratable acidity (TA) of BRS Maria Bonita on different rootstocks.

Rootstock	YD (kg·vine^{-1})	BWT (g)	BL (cm)	BW (cm)	BrWT (g)	BrL (mm)	BrD (mm)	TA (g·100 mL^{-1})
Harmony	4.63ab	216.82b	14.15a	8.82bc	3.66a	22.15ab	17.05a	0.42b
IAC 313	6.26ab	268.10ab	14.70a	10.79a	3.75a	22.53ab	17.12a	0.46ab
IAC 572	6.00ab	276.30a	14.74a	9.62ab	3.94a	22.96a	17.48a	0.51a
IAC 766	7.37a	273.66a	15.29a	9.58ab	3.94a	22.32ab	17.45a	0.49ab
P1103	5.61ab	248.25ab	14.48a	8.82bc	3.75a	22.22ab	16.92ab	0.51a
SO4	3.21b	161.83c	11.79b	7.57c	3.13b	21.33b	16.05b	0.54a
Mean	5.51	240.82	14.19	9.20	3.70	22.25	17.01	0.49

*Means followed by the same letters did not differ from each other using Tukey's test ($p < 0.05$).

Marroo seedless had one of the highest yielding (8.55 ± 0.46 kg·vine^{-1}) and had the greatest bunch weight (210.83 ± 7.11 g), regardless of the rootstock used. However, the rootstock affected bunch length (BL) and total soluble solids content (SS) (Fig. 3). IAC 572 favored the development of bunches with greater length in relation to the rootstocks Harmony and SO4, neither of which differed from the other rootstocks. The grapes harvested from grapevines grafted on IAC 313 had greater soluble solids content.

The results obtained in this trial showed that the rootstock affected each table grape cultivar in a different way, confirming a genotype-dependent response already shown in different studies conducted on table grape (Leão et al. 2020a, 2020b), juice (Leão et al. 2022), and wine (Leão and Chaves 2019, 2021) cultivars in the São Francisco Valley.

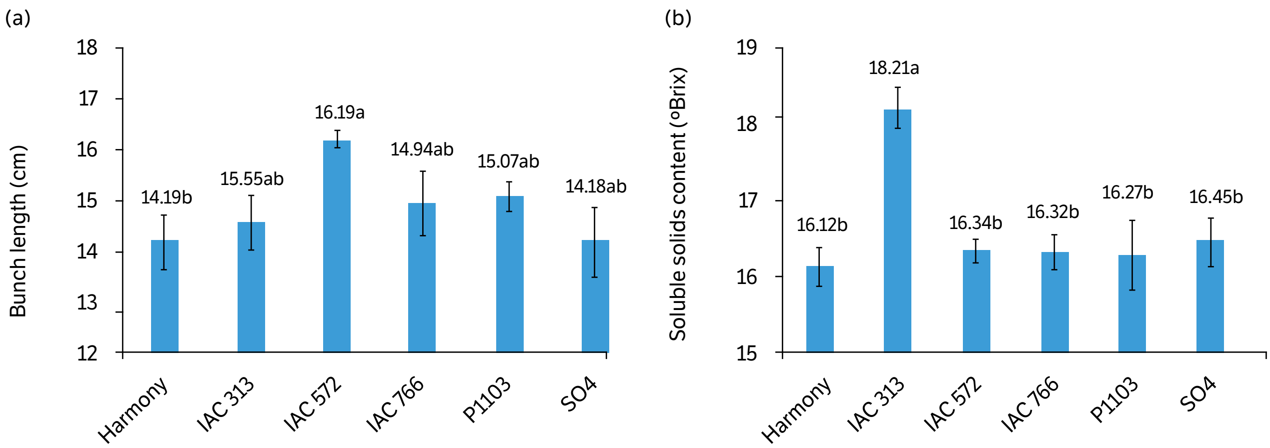


Figure 3. Mean values of the Marroo cultivar on different rootstocks. (a) Bunch length. (b) Soluble solids content. Each bar shows the mean ± standard error. Different letters among the rootstocks denote significant differences by Tukey's test ($p < 0.05$).

CONCLUSION

A Dona and Marroo seedless table grapes stood out for higher yield and larger number of bunches per vine. BRS Clara had high soluble solids content, with a balanced SS/TA ratio, and stood out for quality attributes, while BRS Maria Bonita had greater berry weight and berry size.

The agronomic performance of the grapevines was affected in different ways as a result of the cultivar × rootstock combinations.

PCA and phenotypic correlations showed that the number of bunches per vine trait is highly correlated with yield; however, berry weight, length, and diameter were negatively correlated with soluble solids content, titratable acidity, and the SS/TA ratio.

AUTHORS' CONTRIBUTION

Conceptualization: Leão, P. C. de S.; **Investigation:** Leão, P. C. de S.; **Writing – Original Draft:** Leão, P. C. de S. and Oliveira, C. R. S. de; **Writing – Review and Editing:** Leão, P. C. de S. and Oliveira, C. R. S. de; **Funding Acquisition:** Leão, P. C. de S; **Supervision:** Leão, P. C. de S.

DATA AVAILABILITY STATEMENT

All dataset were generated and analyzed in the current study.

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