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Yield components of the new seedless table grape 'BRS Ísis' as affected by the rootstock under semi-arid tropical conditions

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ABSTRACT

The new seedless table grape cultivar BRS Ísis has high bud fertility, yield and tolerance to downy mildew; its planted area is rapidly increasing in the Vale do São Francisco region in the Northeast of Brazil. The aims of the present study were to evaluate the yield performance, yield components, physical and chemical characteristics of the fruit of the cultivar BRS Ísis grafted onto different rootstocks in irrigated growing in the semi-arid region of Brazil. The experiment was conducted in a commercial vineyard in Petrolina, Pernambuco, over six production cycles in the period 2015-2018. The treatments were represented by the rootstocks IAC 572, IAC 766, IAC 313, Freedom, Harmony, Paulsen 1103, and SO4 in a randomized block design with four replications. There was a greater effect of the production cycle than of the rootstock on all the variables studied, with significant differences between rootstocks in some cycles and/or in the overall mean of the production cycles. Mean production of the six cycles was greatest for IAC 572, at 27 Kg (45 ton/ha/cycle) and 100 clusters per grapevine. The physical characteristics of the clusters and berries and chemical composition of the grape achieved the standards described for the cultivar BRS Ísis and market demands for all the rootstocks.

1. Introduction

Table grape production in Brazil is concentrated in the Northeast region, where 10,807 ha of vineyards were harvested (Agrianual, 2018), with exported grape volume of 83.64 thousand tons in 2017 (Brasil, 2019).

The Vale do São Francisco is between the 9th and 10th south latitude and is the grape- and wine-growing region nearest the equator in the world. It is characterized by a semi-arid tropical climate associated with availability of water for irrigation, which favors development of a viticulture with particular characteristics in relation to the traditional grape- and wine-growing regions throughout the world.

Diversification of grapevine cultivars and advancement of seedless grape cultivation has been observed in recent decades in the Vale do São Francisco, and recently, the substitution of traditional cultivars, such as 'Italia', 'Thompson Seedless', 'Sugraone', and 'Crimson Seedless', with new seedless grape cultivars coming from public and private plant breeding programs.

In Brazil, the most important grapevine breeding program is conducted by Embrapa with the aim of developing new cultivars with different purposes, such as table grapes, juices, and wines, with adaptation to the different climate conditions of the country and tolerance to the main diseases that affect the crop (Ritschel et al., 2015).

The cultivar BRS Isis, released in 2013, is characterized as a red table grape with traces of seeds, elongated berries, medium size, and firm and crisp texture. Its grapevines have high vigor and tolerance to downy mildew (*Plasmopora vitícola*), high bud fertility, and yields greater than 30 ton/ha/cycle in the Vale do São Francisco (Leão et al., 2016). This cultivar is adapted to a production system with two harvests per year under the subtropical conditions of Brazil, recommending crop load management for a density of 5 cluster/m^2, aiming to ensure stable production in the two harvests (Ahmed et al., 2019).

Grafting is a practice extensively used in viticulture worldwide to prevent biotic problems arising from pest and pathogen infections that affect the root system of the plant, as well as abiotic problems, such as adaptation to low fertility soils, soil subject to excess or deficiency of water, saline soils, lime soils, and other adverse conditions (Peterson and Walker, 2017).

In addition, the specific relationship of compatibility and interaction of the scion cultivar and rootstock can affect the growth and vigor of the grapevine (Ollat et al., 2003; Cookson et al., 2012). A positive correlation between vigor and yield related to the rootstock has been

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reported by some authors (Paranychianakis et al., 2004; Jones et al., 2009), but in other studies, this correlation was not observed (Keller et al., 2012; Kidman et al., 2013). In 'Thompson Seedless', differences in yield among rootstocks were the result of variations observed in the size and number of berries (Paranychianakis et al., 2004). The effect of the rootstock on the chemical composition of grape has shown varied results – the scion cultivar and seasonal climate variations seem to have greater influence on these variables than the rootstock (Tandonnet et al., 2010; Keller et al., 2012).

The main rootstocks used in the Vale do São Francisco belong to the IAC group (IAC 313, IAC 766, and IAC 572), developed by the Instituto Agronômico de Campinas, São Paulo, in the 1950s, obtained from crosses between *V. caribaea* x 101-14 Mgt (IAC 572 or Jales), *V. cinerea* x Golia (IAC 313 or Tropical), and *V. caribaea* x 103-8 Mgt (IAC 766 or Campinas). Besides them, in recent years there has been an increase in areas using the rootstocks Paulsen 1103 (*V. rupestris* x *V. berlandieri*) and SO4 (*V. riparia* x *V. berlandieri*) and, in lower proportion, Freedom and Harmony [C1613 (Solonis Othello) X Dogridge] (Leão, 2018).

Studies performed in Brazil with different combinations of rootstocks and cultivars of table grapes (Leão et al., 2011; Feldberg et al., 2007), juice grapes (Nassur et al., 2014; Borges et al., 2014), and wine grapes (Orlando et al., 2008; Dias et al., 2012; Miele and Rizzon, 2017) have highly variable results. This reinforces that specific behavior results from the scion × rootstock interaction, associated with the edaphic and climatic conditions of each producing region, which emphasizes the need for localized studies for recommendation of rootstocks for each grapevine scion cultivar.

The aim of the present study was to evaluate the yield performance, yield components, and physical and chemical characteristics of the fruit of the new table grape cultivar BRS Ísis grafted onto different rootstocks in irrigated fields in the semi-arid region of Brazil.

2. Materials and methods

2.1. Location and climate

The study was carried out over six production cycles in the period 2015–2018. Each production cycle is indicated by the year followed by semester of the year, for example 2017.1 means cycle carried out in the first semester of 2017. The pruning and harvest dates for each production cycle are presented in Table 1.

The experiment was set up in a commercial vineyard in the Senador Nilo Coelho irrigation project (N8) in the municipality of Petrolina, Pernambuco (09°09′S, 40°18′W and 369 m AMSL). The climate was classified according to Köppen-Geiger as semi-arid tropical, BSwh', hot and dry (Reddy and Amorim Neto, 1983), with mean annual temperature of about 26 °C and mean annual rainfall of approximately 500 mm, concentrated from the months of January to April. The mean monthly values of mean, maximum, and minimum air temperature (°C), global solar radiation (MJ/m^2), and rainfall (mm) were obtained from the Automatic Agricultural Weather Station at the Bebedouro Experimental Field, 34 km from the location of the experiment, and are shown in Fig. 1.

Table 1
Pruning and harvest dates for the six production cycles evaluated.

Production Cycle	Pruning Date	Harvest Date
2015.2	06/05/2015	10/25/2015
2016.2	05/23/2016	10/13/2016
2017.1	11/28/2016	04/03/2017
2017.2	05/22/2017	10/13/2017
2018.1	12/03/2017	04/12/2018
2018.2	06/11/2018	10/19/2018

2.2. Plant material and experimental design

Grapevines one year old of the cultivar BRS Ísis grafted onto rootstocks IAC 313, IAC 572, IAC 766, Paulsen 1103, SO4, and Freedom were trained in a horizontal trellis system at a spacing of 3 m x 4 m, with localized drip irrigation. The grapevines were pruned in a unilateral cordon, with lateral canes maintained with 3–5 buds in the production pruning. During the all six vegetative cycles, the canopy management consisted of removing unnecessary shoots, lopping branches and buds, removal of the end or top of the branches, thinning of bunches and berries, besides weed control by herbicide application, skimming between the lines and occasional hoeing. Common pests and diseases in the São Francisco Valley region were controlled by preventive chemical spraying. The experimental design was in randomized blocks with four replications, and a plot was composed of six vines, using the two center vines for data collection. The total amount of vines were 42 per replication (7 rootstocks x 6 vines) which corresponds to 168 vines in each season. Fruits was harvested when in full maturity, with adequate soluble solids content and titratable acidity according to the characteristics of the cultivar BRS Ísis in the Vale do São Francisco (Leão et al., 2016).

2.3. Variables analyzed

The following variables were evaluated during four growing: a) fresh matter of the branches and leaves, determined after pruning through weighing the fresh matter on a digital electronic balance (Ramuza DCR-15), expressed in kilograms (kg) (pruning weight); b) sprouting: determined in the phenological phase of 4–6 expanded leaves by counting all the buds and sprouts and calculated by the following equation: (number of sprouts / number of buds) X 100, expressed in percentage (%); c) bud fertility index: obtained through counting of sprouts and clusters, and calculated by the equation (number of clusters / number of shoots) and expressed in cluster.shoot^{-1}). However most of the variables were evaluated during six production cycles: d) production: evaluated at harvest through weighing all the clusters harvested on a digital electronic balance, expressed in kilograms (kg); e) yield: estimated through multiplication of mean production per vine by density of vines per hectare, expressed in tons per hectare (ton. ha^{-1}); f) number of clusters: obtained by counting all the clusters; g) cluster weight: determined by dividing the total weight of clusters by the number of clusters per vine, expressed in grams (g); h) length and width of the cluster: measured in a sample of five clusters per plot, using a ruler and expressed in centimeters (cm); i) berry weight: determined in a sample of 10 berries harvested from each cluster, for a total of 50 berries per plot, by means of a digital electronic balance, expressed in grams (g); j) berry length and diameter: evaluated in the same sample of berries as the previous item, using a ruler, expressed in millimeters (mm); k) total soluble solids content: readings made in the must extracted from 50 berries per plot, using a digital refractometer with automatic temperature adjustment (ATAGO, Digital Pocket Refractometer, model PAL-1) and expressed in °Brix; and l) titratable acidity: through dilution of 5 ml of grape pulp in 50 ml of distilled water together with 0.1 N NaOH solution using an automatic titrator, Metrohm brand (model 848 Titrino plus) (AOAC, 2010), and the results were expressed in g tartaric acid.100 mL^{-1}.

2.4. Statistical analyses

Analysis of variance (ANOVA) was conducted on the mean data of all the variables, using the SAS statistical program (Statistical Analysis System, version 9.2), comparing the means by the Tukey test at the level of 5 % probability.

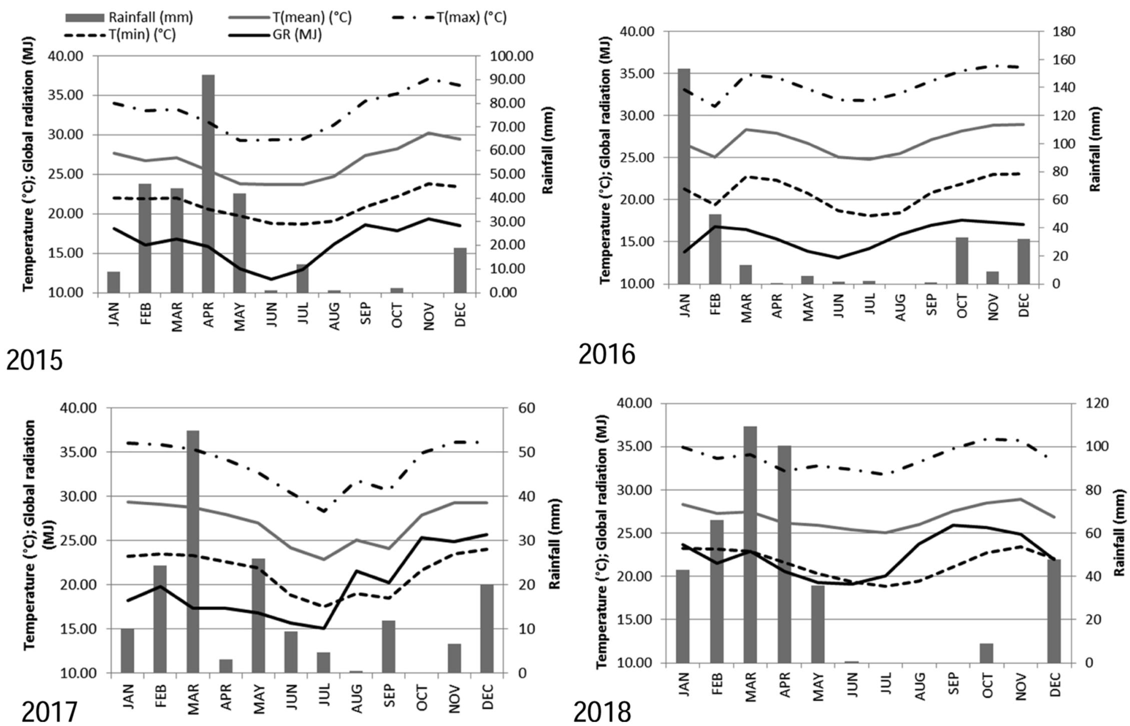

Fig. 1. Seasonal variations of rainfall (mm); mean, maximum, and minimum air temperature (°C); and global solar radiation (MJ m^2) in the period 2015–2018, Petrolina, PE, Brazil.

3. Results and discussion

The variables studied, in general, were more affected by the seasonal variations of the climate and of the vineyard management practices that characterized each production cycle than by the rootstock. Significant differences among production cycles were observed in the yield components and chemical composition of the grape. Variation and irregularity from one harvest to the next is a common phenomenon in wine grape (Trought and Bramley, 2011) and table grape cultivars. According to Oag (2007), table grape yields above 20 ton/ha in Australia lead to draining of stored carbohydrate reserves, which results in reduction in production levels of the grapevines in the following crop season. Variation in the yield of the cultivar Menindee Seedless was mainly explained by the variation in the number of clusters (90 %), in part caused by temperatures of October in Australia, which affected floral differentiation (Dahal et al., 2019).

The fresh matter of the branches eliminated after pruning (pruning weight) indicated irregularity in vigor of the grapevines among production cycles. Greater vigor was observed in the second semester 2017 in grapevines of 10 months of age, and this was the only production cycle in which there was an effect of the rootstock on vigor, obtaining more vigorous grapevines grafted onto the rootstock Paulsen 1103 compared to ‘IAC 572’, ‘IAC 313’, and ‘Freedom’. Grapevines grafted onto ‘Paulsen 1103’ were also more vigorous, according to Koundouras et al. (2008) and Aly et al. (2015), but these results are not in agreement with those obtained in ‘Crimson Seedless’ and ‘Superior Seedless’, where greater vigor was found in grapevines grafted onto ‘IAC 572’ (Feldberg et al., 2007). Differences were not observed among rootstocks in the mean values of the four production cycles evaluated in this study (Table 2), which may be attributed to the fact that under optimal conditions of supply of water and nutrients, and considering that BRS Ísis grapevines have naturally high vigor, the rootstocks responded in a similar manner.

Sprouting and bud fertility are important characteristics because they affect grapevine production. Small differences in sprouting were observed among the rootstocks in the cycles of the second semester

Table 2
Mean values and coefficients of variation (CV) for pruning weight, sprouting, and bud fertility of the cultivar BRS Ísis grafted onto seven rootstocks over four production cycles, 2015–2018, Petrolina, PE, Brazil.

Rootstock	Pruning Weight (kg)				
	2015.2	2016.2	2017.1	2017.2	Mean
Freedom	4.49^{b1}	1.11^{ns2}	3.46^{ns}	1.85^{ns}	3.85^{ns}
Harmony	7.01^{ab}	1.46	4.02	1.80	4.49
IAC 313	4.95^{b}	1.19	4.33	2.00	3.61
IAC 572	4.79^{b}	1.65	4.88	1.92	4.58
IAC 766	7.85^{ab}	1.21	4.61	2.16	4.63
P1103	8.62^{a}	1.39	5.26	2.08	4.75
SO4	6.65^{ab}	1.38	4.29	2.24	3.95
Mean	**6.34^{A}**	**1.34^{C}**	**4.41^{B}**	**2.01^{C}**	**4.27**
CV (%)	**24.16**	**32.98**	**16.82**	**25.38**	**13.66**
	Sprouting (%)				
Freedom	65.72^{ab}	77.49^{ab}	72.46^{ns}	79.89^{ns}	74.72^{ns}
Harmony	59.62^{b}	78.20^{ab}	73.31	77.79	71.47
IAC 313	73.81^{ab}	62.20^{b}	77.97	80.83	79.54
IAC 572	65.93^{ab}	81.53^{a}	70.36	74.18	72.78
IAC 766	79.83^{a}	72.90^{ab}	77.8	77.93	73.88
P1103	63.32^{b}	70.47^{ab}	75.84	82.61	72.66
SO4	61.20^{b}	70.47^{ab}	76.25	82.13	71.18
Mean	**67.06^{B}**	**73.32^{AB}**	**74.85^{A}**	**79.34^{A}**	**73.75**
CV (%)	**10.19**	**11.24**	**18.06**	**13.81**	**10.33**
	Bud Fertility (cluster.shoot^{-1})				
Freedom	0.84^{ns}	0.18^{ns}	0.73^{ns}	0.93^{ns}	0.78^{ns}
Harmony	0.87	0.28	0.70	0.84	0.82
IAC 313	0.92	0.34	0.78	0.87	0.86
IAC 572	0.81	0.27	0.91	0.87	0.90
IAC 766	0.92	0.26	0.77	0.87	0.82
P1103	0.90	0.29	0.70	0.80	0.90
SO4	0.89	0.29	0.86	0.96	0.85
Mean	**0.88^{A}**	**0.27^{B}**	**0.78^{A}**	**0.88^{A}**	**0.84**
CV (%)	**14.05**	**24.57**	**17.98**	**15.76**	**9.09**

[1]Mean values followed by the same lowercase letter in the column and uppercase letter in the row do not differ by the Tukey test at the level of 5 % probability; [2]ns: not significant.

Table 3
Mean values and coefficients of variation (CV) for yield components of the cultivar BRS Isis grafted onto seven rootstocks over six production cycles, 2015-2018. Petrolina, PE, Brazil.

Rootstock	2015.2	2016.2	2017.1[3]	2017.2[3]	2018.1	2018.2	Mean
	Production per vine (kg)						
Freedom	9.12^{ns2}	20.49^{ns}	20.52 ^{b1}	36.28^{ns}	30.78^{ns}	16.31^{ns}	23.41^{ab}
Harmony	10.41	15.39	21.64 ^{b}	40.08	36.58	16.13	23.72^{ab}
IAC 313	11.33	16.11	22.02 ^{b}	39.16	29.31	15.08	21.69^{ab}
IAC 572	13.99	20.39	35.89 ^{a}	43.26	35.57	16.46	27.06^{a}
IAC 766	14.46	20.84	24.21 ^{a}	42.19	31.04	15.94	24.27^{ab}
P1103	8.84	16.06	30.38 ^{a}	36.19	34.82	14.69	23.50^{ab}
SO4	7.95	11.66	28.23 ^{a}	32.70	31.49	13.10	20.86^{b}
Mean	**10.87^{E}**	**17.28^{D}**	**26.13^{C}**	**38.55^{A}**	**32.80^{B}**	**15.58^{D}**	**23.50**
CV (%)	**17.44**	**27.71**	**21.68**	**14.59**	**18.28**	**15.38**	**11.26**
			Number of clusters per vine				
Freedom	33^{ns}	62^{ns}	93^{ns}	98^{b}	86^{s}	83^{ns}	80^{ab}
Harmony	28	53	95	145^{a}	133	80	87^{ab}
IAC 313	32	45	123	127^{ab}	118	81	83^{ab}
IAC 572	43	59	142	124^{ab}	137	76	100^{a}
IAC 766	46	67	117	134^{ab}	118	85	93^{ab}
P1103	30	51	130	104^{ab}	123	76	86^{ab}
SO4	30	40	120	96^{b}	111	75	78^{b}
Mean	**34^{D}**	**54^{C}**	**117^{A}**	**118^{A}**	**118^{A}**	**79^{B}**	**87**
CV (%)	**20.07**	**33.11**	**23.48**	**15.89**	**21.12**	**15.14**	**10.78**
			Cluster Weight (g)				
Freedom	345.67^{ns}	345.00^{ns}	256.00^{b}	403.72^{ns}	292.08^{ns}	418.75^{ns}	346.28^{ab}
Harmony	348.86	302.07	320.06^{ab}	343.36	294.46	377.49	321.71^{b}
IAC 313	344.92	357.99	297.98^{ab}	361.44	391.79	461.08	357.16^{a}
IAC 572	363.50	342.65	330.08^{ab}	365.83	347.40	433.07	347.32^{ab}
IAC 766	357.05	312.20	328.68^{ab}	374.19	335.48	389.85	326.77^{ab}
P1103	325.29	329.18	355.91^{a}	376.09	319.90	364.15	326.24^{ab}
SO4	298.74	290.88	319.71^{ab}	389.96	351.59	426.41	331.59^{ab}
Mean	**340.58^{BC}**	**325.71^{BC}**	**315.49^{C}**	**373.51^{AB}**	**333.24^{BC}**	**410.11^{A}**	**336.72**
CV (%)	**19.47**	**10.51**	**10.46**	**6.39**	**12.98**	**16.39**	**3.96**
			Cluster Width (cm)				
Freedom	11.62^{ns}	9.99^{bc}	8.58^{ns}	10.00^{ns}	8.49^{ns}	11.18^{ns}	9.97^{ab}
Harmony	10.64	9.37^{bc}	9.35	9.25	9.39	8.85	9.47^{b}
IAC 313	9.33	11.68^{ab}	9.03	10.84	8.67	10.15	9.95^{ab}
IAC 572	10.85	13.50^{a}	9.24	9.90	8.07	10.78	10.39 ^{a}
IAC 766	10.67	10.71^{abc}	9.48	9.76	10.26	9.15	10.00^{ab}
P1103	10.27	8.50^{c}	9.13	9.22	9.50	10.88	9.58^{ab}
SO4	9.94	9.14^{bc}	9.33	10.29	10.94	11.55	10.20^{ab}
Mean	**10.47^{A}**	**10.41^{AB}**	**9.16^{B}**	**9.89^{AB}**	**9.33^{AB}**	**9.03^{AB}**	**9.94**
CV (%)	**10.92**	**12.75**	**9.45**	**10.69**	**13.47**	**10.36**	**3.87**

[1]Mean values followed by the same lowercase letter in the column and uppercase letter in the row do not differ by the Tukey test at the level of 5 % probability; [2]ns: not significant; [3]Data from production of 2017.1 and 2017.2 were transformed into (√X) + 1.

2015 and 2016 (Table 2); however, this tendency was not confirmed in the following cycles and in the overall mean of the cycles. There was no effect of the rootstock on bud fertility, with mean values ranging from 0.78 cluster.shoot^{-1} on 'Freedom' up to 0.90 cluster.shoot^{-1} on rootstocks IAC 572 and Paulsen 1103. The high bud fertility of the cultivar BRS Ísis stands out as an important characteristic of this cultivar, achieving values from 1.0 to 2.0 cluster.shoot^{-1} (Ritschel et al., 2015), greater than other traditional cultivars, such as Crimson Seedless and Thompson Seedless, in the Vale do São Francisco (Leão et al., 2017).

Mean production per vine ranged from 10.87 kg in the first cycle in 2015 up to a maximum of 38.55 kg in the second semester 2017, corresponding to mean yields estimated in ton/ha from 18 (2015.2) to 64 (2017.2). The high yield capacity of this cultivar, which remained stable over three consecutive production cycles in 2017 and 2018, is noteworthy (Table 3). The mean yield of the six production cycles was estimated at 39 ton/ha/cycle, greater than that reported for this cultivar by Leão et al. (2016) and Ritschel et al. (2015), representing an increase of 68 % in relation to mean annual yield of 25 ton/ha/year in this region (Leao et al., 2018). High yield and bud fertility are prominent advantages of this new seedless grape cultivar, drawing the interest of growers and, consequently, rapidly increasing the area in which it is grown in this region.

Significant effects of the rootstock were found on production per vine in the first semester 2017 cycle, as well on the mean values of the cycles, and the rootstock IAC 572 led to greater production, but differing only from 'SO4' (Table 3). Higher yields in grapevines grafted onto 'IAC 572' were also found in the cultivars Niágara Rosada and Folha de Figo in the South of Minas Gerais (Mota et al., 2009). However, other authors reported an increase in production in 'Crimson Seedless', 'Sugraone', and 'Flame Seedless' on the rootstock Paulsen 1103 (Feldberg et al., 2007; Leão et al., 2011; Aly et al., 2015), which also exhibited high production, similar to 'IAC 572' in this study. Greater production in the cultivar Red Globe grafted onto 'Harmony' and 'Salt Creek' in an arid region in Chile was positively correlated with greater leaf area, photosynthesis, sugars content in the leaves, carbohydrate reserves in the roots, and chlorophyll *a/b* and total chlorophyll content in the leaves (Bascunan-Godoy et al., 2017).

The number of clusters responded in a way similar to production, which was expected, because of the positive and high correlation between these two variables ($r = 0.82$, $P < 0.0001$, data not shown). This positive correlation between production and number of clusters was also observed in other table grape cultivars (Bascunán-Godoy et al., 2017; Ibacache et al., 2016) and cultivars for preparation of juices (Silva et al., 2018). Variation was found among production cycles, from 34 clusters per vine in young plants of the first cycle (2015.2) up to 117 and 118 clusters in the 3rd, 4th, and 5th production cycles (2017.1, 2017.2, and 2018.1).

Significant differences among rootstocks were obtained in the second semester 2017 and in the overall mean, with a higher number of clusters in the grapevines grafted onto IAC 572 compared to 'SO4' (Table 3).

The clusters of the cultivar BRS Ísis had mean weight of 337 g, with significant differences among production cycles. The highest values were obtained in the second semester 2018, when the clusters achieved a mean value of 410 g, which was near the values of mean cluster weight reported by Ritschel et al. (2015) and Leão et al. (2016) for this same cultivar. The rootstock Paulsen 1103 favored clusters with greater weight than the rootstock Freedom, but this response was observed only in the first semester 2017, while in the mean of the production cycles, clusters of greater weight were found on 'IAC 313' compared to the rootstock Harmony, and differences were not found between these and the other rootstocks.

There was no effect of the rootstock on cluster length (data not shown). However, greater width of the cluster was obtained on the rootstock IAC 572 compared to 'Paulsen 1103', 'SO4', 'Freedom', and 'Harmony' in the 2nd production cycle (2016.2); but in the overall mean of the cycles, significant differences were found only between the rootstocks IAC 572 and Harmony. Therefore, the rootstock Harmony reduced the weight and width of the clusters of 'BRS Ísis'.

The 'BRS Ísis' grapevines had wider clusters in the cycle of the second semester 2015, which differed only from those of the first semester 2017, when clusters with the smallest width and weight among all the production cycles evaluated in this study were harvested.

The physical characteristics of the berry were little influenced by the rootstock, with a response observed in a single production cycle and in the overall mean of the cycles. Other authors showed significant effects of the rootstock on the weight and size of the berry of different table grape cultivars when compared to non-grafted or own-rooted grapevines (Ibacache et al., 2016; Aly et al., 2015; Satisha et al., 2010).

The rootstock SO4 reduced the weight, length, and diameter of the berry compared to the rootstock IAC 313, but significant differences between these rootstocks and the other rootstocks were not found (Table 3). Table 4 shows that lower berry weight and size were obtained in the production cycles of the second semester 2017 and the first semester 2018, which were also the cycles of highest yield and number of clusters. This can be explained by the negative correlation between production and berry weight ($r = -0.35$, $p < 0.0001$, data not shown), production and berry diameter ($r = -0.29$, $p < 0.05$, data not shown), and production and berry length ($r = -0.18$, $p < 0.001$, data not shown), i.e., the higher the production, the smaller the berry size, the result of competition for photoassimilates and imbalance in the source-drain relationship.

Mean soluble solids content of the 'BRS Ísis' grapes was 16.41 °Brix, which is in agreement with the soluble solids contents found by Leão et al. (2016) and Ritschel et al. (2015), but these contents were higher than the values of about 14 °Brix obtained by Ahmed et al. (2019) for the cultivar BRS Ísis in a subtropical region of the South of Brazil.

Variations from 15.49 °Brix (2017.2) to 18.91 °Brix (2018.2) were observed among production cycles, and the lowest values were obtained in the cycles with the largest number of clusters and production per vine (Table 5). This may be explained by the negative correlation between production and soluble solids content ($r = -0.61$, $p < 0.0001$, data not shown) and number of clusters and soluble solids content ($r = -0.52$, $p < 0.0001$).

These results indicate that variations in quality attributes, such as soluble solids content, commonly observed between production cycles, occur not only under the influence of climate conditions of each period of the year on evolution of grape maturation and accumulation of sugars, but also from management of the vineyard and cluster density, where an excessive number of clusters not only reduces berry size but also reduces sugars content and grape quality. Thus, excessive production, as observed in 2017 and the first semester 2018, should be

Table 4
Mean values and coefficients of variation (CV) for physical characteristics of berries of 'BRS Isis' grafted onto seven rootstocks over six production cycles, 2015-2018. Petrolina, PE, Brazil.

Rootstock	Berry Weight (g)						
	2015.2	2016.2	2017.1	2017.2	2018.1	2018.2	Mean
Freedom	6.09^{ns2}	7.07^{ns}	5.96^{ab1}	5.87^{ns}	5.16^{ns}	6.96 ^{ns}	6.18^{ab}
Harmony	5.74	6.56	6.47^{a}	5.92	5.07	7.59	6.22^{ab}
IAC 313	6.32	7.14	6.29^{ab}	5.94	5.74	7.03	6.41^{a}
IAC 572	6.42	6.91	6.45^{a}	6.02	5.13	6.81	6.29^{ab}
IAC 766	5.91	6.50	6.23^{ab}	5.66	5.19	6.75	6.04^{ab}
P1103	5.87	6.66	6.21^{ab}	5.78	5.23	6.84	6.10^{ab}
SO4	5.64	6.38	5.51^{b}	5.98	5.46	6.68	5.94^{b}
Mean	**6.00^{B}**	**6.75^{A}**	**6.16^{B}**	**5.88^{B}**	**5.28^{C}**	**8.47^{A}**	**6.17**
CV (%)	**12.72**	**6.30**	**5.87**	5.58	**10.36**	**6.95**	**2.87**
Berry Length (mm)							
Freedom	27.37^{ns}	29.3^{ns}	28.16^{ns}	28.87^{ns}	25.72^{ns}	28.11^{ns}	28.35^{ab}
Harmony	27.03	28.69	29.03	28.42	25.75	26.06	28.37^{ab}
IAC 313	27.75	29.4	28.18	28.17	28.11	26.32	28.94^{a}
IAC 572	28.28	29.09	28.80	28.47	26.06	25.72	28.51^{ab}
IAC 766	28.22	27.57	28.23	28.43	26.32	25.75	28.11^{ab}
P1103	27.1	28.26	28.23	28.41	26.20	26.20	28.14^{ab}
SO4	26.26	28.27	27.65	28.58	26.57	26.57	27.81^{b}
Mean	**27.43^{BC}**	**28.65^{B}**	**28.32^{B}**	**28.48^{B}**	**26.39^{C}**	**26.39^{A}**	**28.32**
CV (%)	**5.79**	**3.41**	**3.57**	**2.93**	**5.34**	**5.34**	**1.30**
Berry Diameter (mm)							
Freedom	18.91^{ns}	20.34^{ab}	20.25^{ns}	18.45^{ns}	18.11^{ns}	19.68^{ns}	19.29^{ns}
Harmony	19.05	19.87^{ab}	20.53	18.53	17.96	19.48	19.21
IAC 313	19.01	20.40^{a}	20.39	18.13	18.57	19.50	19.39
IAC 572	19.57	20.15^{ab}	20.38	18.48	17.74	19.70	19.34
IAC 766	19.54	20.32^{ab}	20.52	18.38	18.08	19.58	19.36
P1103	18.59	19.68^{ab}	20.58	18.24	18.13	19.45	19.11
SO4	18.7	19.20^{b}	20.08	19.11	18.75	19.40	19.20
Mean	**19.05^{CD}**	**19.99^{AB}**	**20.39^{A}**	**18.47^{DE}**	**18.19^{E}**	**19.54^{BC}**	**19.27**
CV (%)	**4.16**	**2.57**	**2.94**	**3.55**	**4.70**	**2.76**	**1.20**

[1]Mean values followed by the same lowercase letter in the column and uppercase letter in the row do not differ by the Tukey test at the level of 5 % probability; [2]ns: not significant.

Table 5
Mean values and coefficients of variation (CV) for chemical composition of the 'BRS Isis' grapes grafted onto seven rootstocks over six production cycles, 2015-2018. Petrolina, PE, Brazil[1].

Rootstock	SS (°Brix)						
	2015.2	2016.2	2017.1	2017.2	2018.1	2018.2	Mean
Freedom	18.25^{ns}	17.53^{ab}	17.40 ^{ns}	15.44^{ns}	16.06^{a}	19.10^{ns}	17.41^{ns}
Harmony	17.18	17.98^{ab}	16.70	15.60	15.65^{ab}	19.35	16.84
IAC 313	17.13	17.50^{ab}	15.90	15.19	14.78^{b}	18.60	16.56
IAC 572	17.68	17.48^{ab}	16.58	16.11	16.11^{a}	17.60	16.84
IAC 766	16.88	16.50^{b}	15.35	14.21	15.76^{ab}	19.60	16.55
P1103	18.43	19.05^{a}	15.87	15.91	15.94^{ab}	18.93	17.15
SO4	16.43	19.13^{a}	16.08	15.99	15.24^{ab}	19.20	17.01
Mean	17.42^{B}	17.88^{B}	16.09^{C}	15.49^{C}	15.65^{C}	18.91^{A}	**16.91**
CV (%)	**8.90**	**5.85**	**8.82**	**5.44**	**3.49**	**6.47**	**2.33**
TA (g tartaric acid / 100 mL)							
Freedom	0.33^{c}	0.36^{ns}	0.28^{ns}	0.41^{b}	0.46^{ns}	0.33^{ns}	0.37^{ns}
Harmony	0.32^{c}	0.39	0.30	0.47^{ab}	0.47	0.39	0.39
IAC 313	0.34^{bc}	0.36	0.28	0.43^{ab}	0.43	0.35	0.36
IAC 572	0.39^{ab}	0.41	0.27	0.45^{ab}	0.36	0.42	0.39
IAC 766	0.39^{ab}	0.39	0.26	0.47^{ab}	0.40	0.40	0.38
P1103	0.41^{a}	0.41	0.27	0.48^{ab}	0.40	0.38	0.39
SO4	0.39^{ab}	0.39	0.30	0.49^{a}	0.41	0.45	0.40
Mean	**0.36^{C}**	**0.39^{BC}**	**0.28^{D}**	**0.46^{A}**	**0.42^{AB}**	**0.39^{BC}**	**0.38**
CV (%)	**6.88**	**9.84**	**10.17**	**6.76**	**14.18**	**22.89**	0.37

[1] Mean values followed by the same lowercase letter in the column and uppercase letter in the row do not differ by the Tukey test at the level of 5 % probability; [2]ns: not significant.

avoided by adoption of practices such as control of cluster density, to allow development of fruit with desirable berry size and soluble solids content.

An effect of the rootstock on soluble solids content was observed in two production cycles (2016.2 and 2018.1); in the second semester 2016, values of around 19 °Brix were obtained on the rootstocks Paulsen 1103 and SO4, higher than those on 'IAC 766' (16.5 °Brix). However, in the first semester 2018, greater soluble solids content was found in grapes on the rootstock IAC 572 compared to 'IAC 313'. These differences among rootstocks were isolated cases and were not repeated in other production cycles or in the overall mean of the cycles, which shows that other aspects of vineyard management must be considered. Responses in soluble solids content as a result of the rootstock are associated with factors such as the genetics of the cultivar, seasonal variations, and vineyard management, and there are contradictory results in the literature. According to Satisha et al. (2010), the rootstock did not affect the soluble solids content of 'Thompson Seedless' grapes; however, in 'Flame Seedless', higher sugars content was found in the grapevines grafted onto 'Paulsen 1103' (Lo'ay and El-khateeb, 2017).

The 'BRS Ísis' grapes had moderate titratable acidity, which varied as a result of the production cycle (Table 5) % (2017.1) to 0.46. These values were lower than the values of 0.6 % and 0.8 % obtained for this same cultivar by Ahmed et al. (2019) in the South of Brazil, but are in agreement with the titratable acidity reported by Leão et al. (2016) and Ritschel et al. (2015) for the cultivar BRS Ísis.

Effects of the rootstock on titratable acidity were observed in two production cycles. In the second semester 2015, the rootstock Paulsen 1103 favored higher acidity in the fruit compared to the rootstocks IAC 313, Harmony, and Freedom, while in the second semester 2017, grapes with higher titratable acidity were harvested from grapevines grafted onto 'SO4′, with significant differences for 'Freedom'. Therefore, the response in titratable acidity of the fruit, as well as in the soluble solids content, had little effect from the rootstock, and it was not possible to observe a tendency over the production cycles.

4. Conclusions

Seasonal variations of the climate and vineyard management practices among production cycles had a greater impact than the rootstock in the response of the 'BRS Ísis' grapevine in relation to all the variables evaluated in this study.

The effect of the rootstock on vigor, yield components, and physical and chemical characteristics of 'BRS Ísis' grapes occurred in an isolated manner in some cycles and/or in the mean of the production cycles, but this did not allow a specific rootstock with better performance to be distinguished for the set of variables analyzed.

The cultivar BRS Ísis, regardless of the rootstock used, had high bud fertility and yield, as well as characteristics of the clusters and chemical composition of grapes that meet the requirements of the most demanding consumer markets for table grapes.

CRediT authorship contribution statement

Patrícia Coelho de Souza Leão: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **José Henrique Bernardino do Nascimento:** Data curation, Investigation. **Dayane Silva de Moraes:** Data curation, Investigation. **Edimara Ribeiro de Souza:** Data curation, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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