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AGROMETEOROLOGY - Article

Cycle, physicochemical characterization and climatic adaptation of a white hybrid grape on different rootstocks

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ABSTRACT: This study evaluated the cycle duration, physicochemical characteristics of fruits and climatic adaptation of the 'SR 501-17' hybrid grape grafted on four rootstocks for the production of white wine. We tested four rootstocks, 'IAC 766 Campinas', 'IAC 572 Jales', 'IAC 571-6 Jundiaí' and 'IAC 313 Tropical', planted in two climatic regions, Cfa and Aw, in the state of São Paulo, Brazil in the cultivation years 2014 and 2015. Cycle duration, production, cluster weight, number of berries per bunch, content of soluble solids, titratable acidity, a maturation index and the weight, length and width of berries were evaluated. A principal component analysis characterized the cultivar for both climatic regions and years. The rootstock did not influence the cycle, production or physicochemical characteristics of the 'SR 501-17' hybrid. The soluble-solid content in the must was higher and the production cycle in 2014 was longer for the Cfa climate. The production cycle was shorter and the weight and width of the berries were lower, mainly in 2015, for the Aw climate. The cycle was thus longer, production was higher and the chemical characteristics were better for the 'SR 501-17' hybrid under Cfa conditions, regardless of the rootstock.

Key words: canopy/rootstock, climate, principal component analysis, *Vitis*.

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INTRODUCTION

Grapes are an important fruit globally and can be used for making wine and oil or as table grapes and in other applications. The grape genus *Vitis* is highly variable, but *V. vinifera* is normally used for making wine in most countries because this species has better fruit for making high quality wines (Dolkar et al. 2017; Miele and Rizzon 2017; Laucou et al. 2018). In contrast, most *V. vinifera* varieties are susceptible to many common grape diseases, partly because grapes mature during the rainy season, which is ideal for the development of diseases (Guan et al. 2016; Santos et al. 2018a). Some breeding programs have therefore crossed *V. vinifera* with *V. labrusca* and *V. riparia*, native North American species, and other species to produce grape hybrids that are cultivated in unfavorable climatic conditions for the growth of *V. vinifera* (Kapusta et al. 2017). Brazil, however, has great potential for wine production, because new markets for white and sparkling wines are promising (OIV 2016). The grape cycle, though, is problematic in some wine regions due to high rainfall and the development of diseases such as powdery mildew, downy mildew and anthracnose, which reduce fruit quality and cause up to 100% crop loss (Amorim et al. 2016; Santos et al. 2018b). Some grape-breeding programs in Brazil have also developed new cultivars with good climatic adaptation and characteristics for making wine.

In addition to climatic adaption, the rootstock is another crucial factor for viticultural production. The use of a rootstock is mandatory in vineyards due to phylloxera, a soilborne pest. Rootstocks can provide tolerance against this pest, influence the yield, quality and vegetative growth of grapes (Hartmann and Kester 1990; Berdeja et al. 2015; Ollat et al. 2015). Good rootstocks are available, but each has limitations, so only regional experimentation can determine their suitability to different cropping conditions (Mota et al. 2009; Van Leeuwen and Destrac-Irvine 2016).

The selection of rootstocks is based on their adaptation to environmental conditions and to scions, which will directly affect yield and some chemical characteristics of the berries, such as acidity and content of soluble solids (Fraga et al. 2016; Southey and Jooste 1991). The composition of the berries at harvest affects the wine quality and will determine its distinctive character, which is directly associated with the genetic material of the cultivar, the cultural techniques adopted in a vineyard and the viticultural ecosystem (Miele and Rizzon 2017; Silva et al. 2015). The influence of climate is another fundamental factor that has a strong relationship with wine quality. The effects of climate change on the adaptability and yield of grapes have been studied (Salinger et al. 2015; Bonfante et al. 2017).

The aim of this study was to evaluate the performance of the 'SR 501-17' white hybrid grape grafted onto four rootstocks and to characterize this genotype in two climatic regions and years of cultivation.

MATERIAL AND METHODS

Experiments were carried out with the 'SR 501-17' white hybrid grape, developed by Wilson Corrêa Ribas from an unknown parent in the IAC grapevine program in São Roque (Fig. 1). The experimental site in the Cfa climatic region (23°17′ S, 46°09′ W; 715 m a.s.l.) has a humid temperate climate with dry winters and hot summers. Rainfall during cultivation in this region was 810 mm in 2014 and 1750 mm in 2015. The temperature ranged from 7 to 30 °C, with an average temperature of 22 °C (Fig. 2). The experimental site in the Aw climatic region (20°15′ S, 50°30′ W; 483 m a.s.l.) has a tropical climate with dry winters. Rainfall during cultivation in this region was 740 mm in 2014 and 630 mm in 2015. The average temperature during grape growth was 26 °C, varying between 13 and 35 °C (Fig. 2). Neither site was irrigated.

The experimental design was randomized blocks with four replicates. Treatments consisted of combinations of the 'SR 501-17' hybrid grafted onto the four rootstocks, 'IAC 313 Tropical', 'IAC 572 Jales', 'IAC 766 Campinas' and 'IAC 571-6 Jundiaí, in two production cycles, 2014 and 2015, in the two climatic regions, Cfa and Aw. The support system for the grapevines during training was a traditional vertical-trellis system. The row × plant spacing was 2 × 1 m in the Cfa region and 2 × 1.5 m in the Aw region. Each plot consisted of six and four vines per rootstock in the Cfa and Aw regions, respectively. Rootstocks were planted in September 2008, and the 'SR 501-17' hybrid was grafted onto them in June 2009. The vines were short-pruned in July 2014 and 2015, leaving one or two buds per spur.

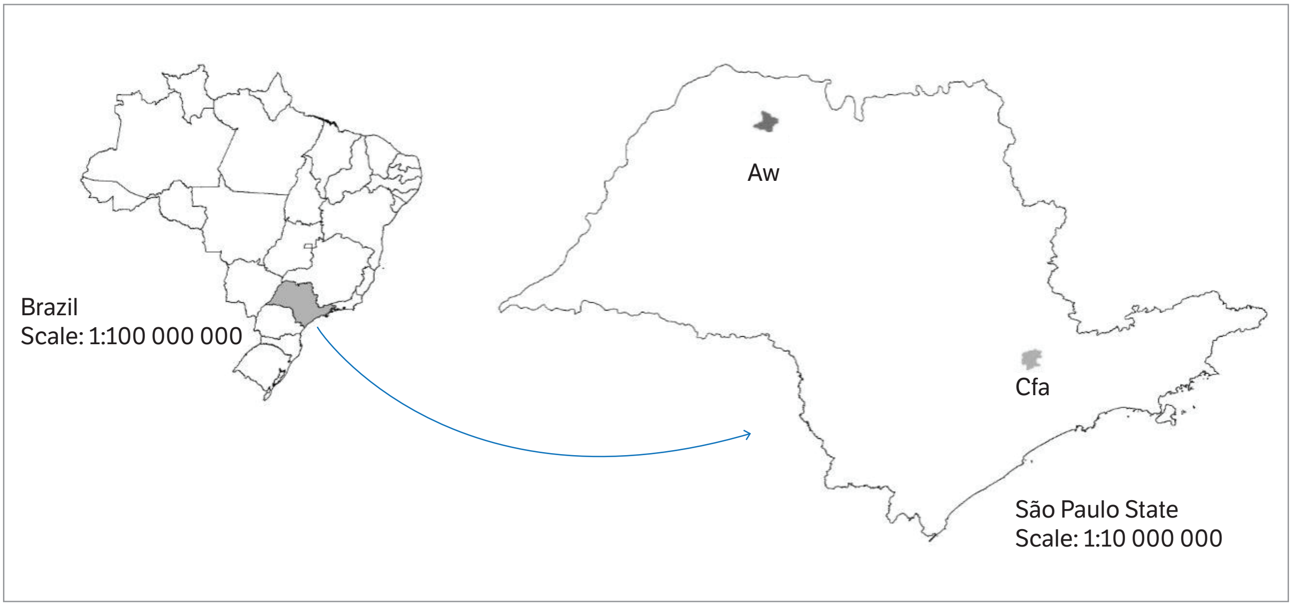

Figure 1. Locations of the two climatic regions in Brazil.

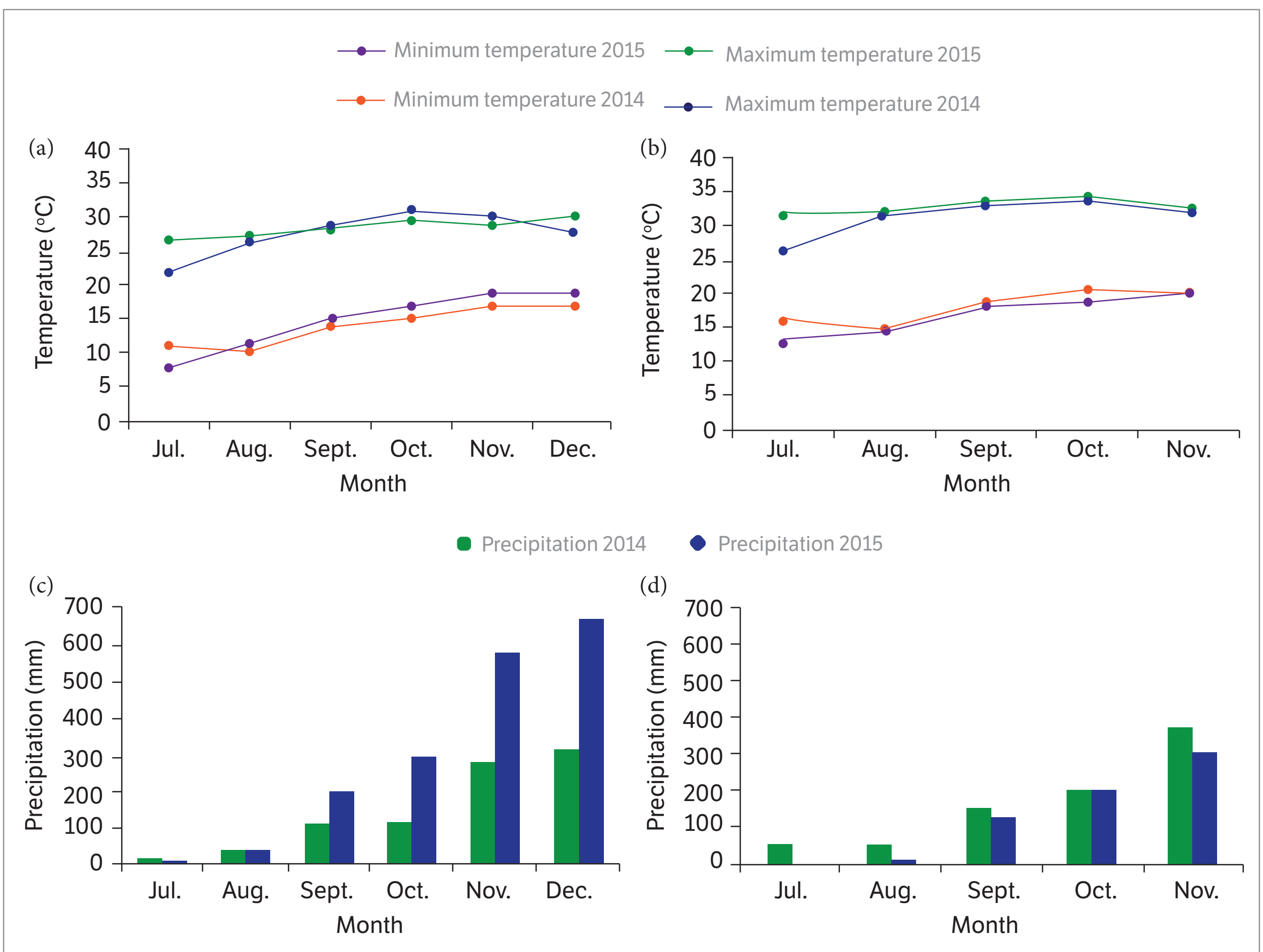

Figure 2. Maximum and minimum temperatures per month in the Cfa (a) and Aw (b) climatic regions and rainfall per month in the Cfa (c) and Aw (d) climatic regions.

Production was measured at harvest, sampling 10 representative clusters per experimental plot. The number of days to maturation (NDM) and cycle duration was recorded at harvest, which was determined by the stabilization of the content of soluble solids and pH (< 3.5) of the cultivar. We recorded the fresh mass of a cluster (FMC), the fresh mass of berries (FMB), berry length (BL) for 10 berries, berry width (BW) for 10 berries and the number of berries per cluster (NB). The chemical composition of the juice was characterized by the soluble-solid content (SSC) (°Brix) and titratable acidity (TA) of the juice, and a maturity index (MI) was calculated based on the SSC/TA ratio (Instituto Adolfo Lutz 1985).

Statistical analysis was carried out using Statistical Analysis Software (SAS Institute 2002). Data were submitted to an analysis of variance with the comparison of means using Tukey's test ($p < 0.05$) to evaluate the rootstock and climatic interaction. A multivariate analysis of the correlations between the variables ($p < 0.01$) and a principal component analysis (PCA) were used to characterize the performance of the hybrid in the climatic regions and production years. Efforts were made to follow the criterion of the sum of variances of the first principal component exceeding 80% of the total variance of the original data.

RESULTS

The climatic regions interacted with the rootstocks for variable SSCs (Table 1). SSC did not differ among the rootstocks in the Cfa region but was higher for 'IAC 313 Tropical' and 'IAC 571-6 Jundiaí' than 'IAC 572 Jales' in the Aw region. 'IAC 766 Campinas' and 'IAC 572 Jales' influenced the variety in the Cfa region, producing more soluble solids. The cycle was 20 days longer in the Cfa than the Aw region (Table 2) because the Cfa region received more rain and less sunlight than the Aw region (Fig. 2). The more days to harvest in the Cfa than the Aw region led to higher SSC, FMB, BL and NB, demonstrating a better adaptation of the

Table 1. Soluble-solid content (SSC) assessed for the 'SR 501-17' white hybrid grape grafted onto the four rootstocks in the two regions for two cycles.

Rootstock × Climate	SSC (°Bx)	
	Cfa	Aw
'IAC 766 Campinas'	19.9 a	18.7ABb
'IAC 572 Jales'	20.6 a	17.9 Bb
'IAC 313 Tropical'	20.2	19.3A
'IAC 571-6 Jundiaí'	19.9	19.1A

Different lowercase letters within a row and uppercase letters within a column indicate significant differences ($p < 0.05$).

Table 2. Cycle, mean production (Prod), soluble-solid content (SSC), titratable acidity (TA), maturity index (MI), fresh mass of cluster (FMC), fresh mass of berries (FMB), berry length (BL), berry width (BW) and number of berries per cluster (NB) for the 'SR 501-17' white hybrid grape grafted onto the four rootstocks in the two climatic regions.

Rootstock	Cycle (d)	Prod (t/ha)	SSC (°Bx)	TA	MI	FMC (g)	FMB (g)	BL (cm)	BW (cm)	NB
'IAC 766 Campinas'	136.25	7.04	19.33	0.72	27.37	146.14	19.04	14.94	14.10	74.2
'IAC 572 Jales'	137.75	5.64	19.26	0.73	26.68	146.23	19.25	15.02	14.15	73.6
'IAC 313 Tropical'	136.25	7.05	19.76	0.74	27.04	146.43	19.57	14.94	14.13	72.3
'IAC 571-6 Jundiaí'	136.25	7.77	19.51	0.69	28.64	157.97	19.38	14.94	14.09	78.8
Climate										
Cfa	147.0 a	8.69 a	20.16 a	0.71	29.0	165.8 a	20.4 a	15.4 a	14.3 a	78.6 a
Aw	126.3 b	5.57 b	18.77 b	0.74	25.8	132.5 a	18.2 b	14.6 b	13.9 a	70.9 b
p										
Block	1.000	0.007	0.680	0.165	0.423	0.023	0.172	0.300	0.699	0.004
Climate	< 0.001	< 0.001	< 0.001	0.073	0.001	< 0.001	< 0.001	< 0.001	0.002	0.012
Block × Climate	1.000	0.020	0.675	0.108	0.294	0.006	0.108	0.243	0.216	0.208
Rootstock	0.758	0.070	0.424	0.279	0.491	0.384	0.479	0.618	0.976	0.451
Climate × Rootstock	0.0758	0,860	0.009	0.830	0.773	0.254	0.201	0.959	0.517	0.478
CV (%)	3.50	36.95	4.65	10.38	13.74	22.98	4.98	3.22	3.29	15.74

Different letters within a column indicate significant differences ($p < 0.05$). CV = coefficient of variation.

'SR 501-17' cultivar. 'SR 501-17' produced more fruits in the humid temperate climate than in the tropical climate.

The rootstocks did not influence the parameters of the white hybrid grape 'SR 501-17' (Table 2). The 'IAC 766 Campinas', 'IAC 572 Jales', 'IAC 313 Tropical' and 'IAC 571-6 Jundiai' rootstocks, though, are most commonly used in temperate and tropical regions such as Cfa, Cfb and Aw. The grapevine-breeding program of the Agronomic Institute of Campinas was responsible for creating the white hybrid grape and the four rootstocks, so these rootstocks have been adapted to many varieties in these regions.

Cycle and SSC were positively correlated (Table 3 and Fig. 2). A shorter cycle provided higher MI, FMC and FMB, but MI, the interaction between two chemical variables (SSC and TA), was higher when TA was lower and BW was higher (Table 3). The physical variable FMC was correlated with FMB, BL and NB because the cluster size was proportional to the weight, size and number of the berries.

The first two components of the PCA accounted for 83.43% of the variation, demonstrating the influence of climate and year on the hybrid/rootstock combination (Fig. 3). The first component was associated with the →

Table 3. Correlations between cycle, soluble-solid content (SSC), titratable acidity (TA), maturity index (MI), fresh mass of cluster (FMC), fresh mass of berries (FMB), berry length (BL), berry width (BW) and number of berries per cluster (NB) for the 'SR 501-17' white hybrid grape grafted onto the four rootstocks in the two climatic regions.

	Cycle	SSC	TA	MI	FMC	FMB	BL	BW	NB
Cycle	1	0.78*	–0.39	0.58*	0.69*	0.75*	0.44	0.13	0.44
SSC		1	–0.55*	0.79*	0.36	0.41	0.08	–0.18	0.20
TA			1	–0.94*	–0.05	0.12	0.37	0.67*	–0.16
MI				1	0.16	0.66	–0.23	–0.55*	0.18
FMC					1	0.80*	0.74*	0.47	0.88*
FMB						1	0.85*	0.62*	0.42
BL							1	0.87*	0.44
BW								1	0.21
NB									1

*Significant correlations at $p < 0.01$.

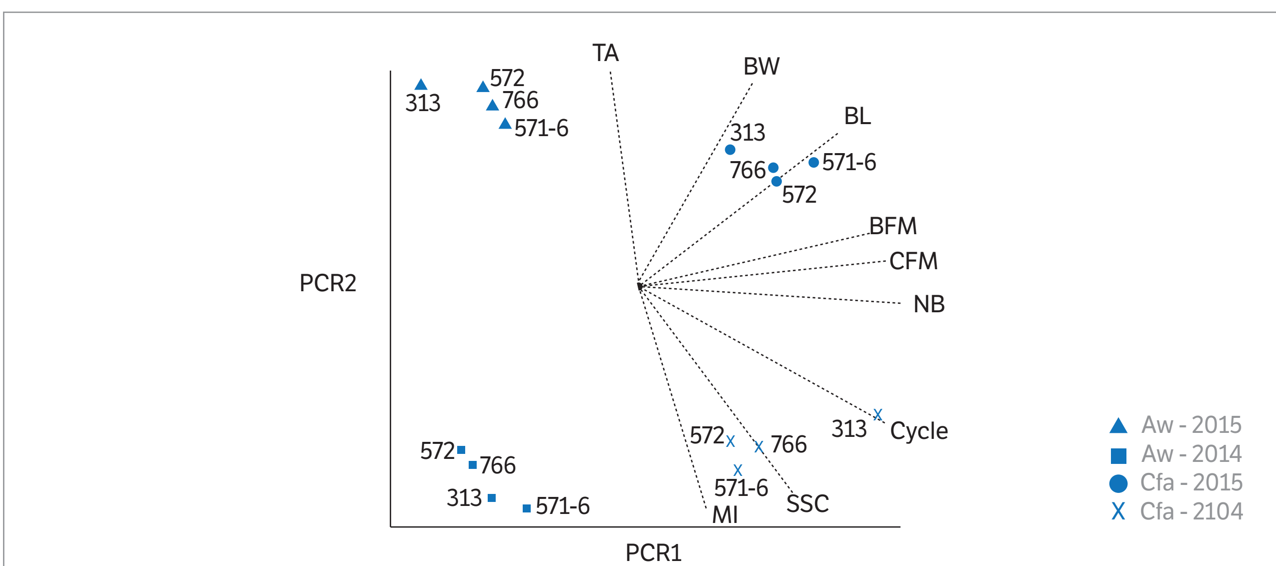

Figure 3. Principal component regression (PCR) of cycle, soluble-solid content (SSC), titratable acidity (TA), maturity index (MI), fresh mass of cluster (FMC), fresh mass of berries (FMB), berry length (BL), berry width (BW) and number of berries per cluster (NB) of the 'SR 501-17' white hybrid grape grafted onto the four rootstocks, 'IAC 766 Campinas' (766), 'IAC 572 Jales' (572), 'IAC 571-6 Jundiaí' (571-6) and 'IAC 313 Tropical' (313), in the two climatic regions, Aw and Cfa, and years, 2014 and 2015.

climatic region, characterized by values of variables production, cycles, FMC, FMB, BL and NB. The second component was associated with year by means of TA, MI, SSC and BW.

BL, CFM, BFM and NB were lowest and the production cycle was shorter for 'SR 501-17' cultivated in the Aw climate in 2014, whereas all combinations had the highest values for these variables in the Cfa climate in 2015 (Fig. 3). The larger berry size in Cfa in 2015 may be a consequence of the longer cycle and the longer exposure of the fruit to a higher rainfall index in this climatic region (Fig. 2).

The number of berries per cluster was largest and FMC was highest in the Cfa climate in 2015 due to the larger and heavier berries (Table 2). All canopy/rootstock combinations in the hotter temperature of the Aw region in 2015 (Fig. 2) had the highest TA and the lowest MI and SSC, with a shorter production cycle (Fig. 3). All combinations in the milder temperature of the Cfa region in 2014 (Fig. 2), however, had inversely proportional values, i.e. TA was lowest and MI and SSC were highest with the longer production cycle. The higher SSC in the grapes harvested in 2014 was due to the slower maturation, probably caused by the characteristic lower nighttime temperatures and precipitation common in Cfa region (Fig. 2).

DISCUSSION

The interaction between rootstock and canopy is fundamental for the most important *V. vinifera* cultivars, such as Cabernet Sauvignon and Merlot, but it is less pronounced for interspecific hybrids because these materials are rustic (Barros et al. 2015; Phillips et al. 2015). Most cultivated hybrids are usually from crosses with North American species of *Vitis*, which provide better homogeneity when these varieties are grafted onto many rootstocks from the same region (Corso et al. 2015; Nimbolkar et al. 2016; Bascuñán-Godoy et al. 2017).

Climate influences the production of grapes in many parts of the world (Campos et al. 2016; Van Leeuwen and Darriet 2016; Pons et al. 2017). SSC and TA are typically the main chemical variables studied in the production of grapes for wine. Grape maturation increases SSC and decreases acidity in berries (Rombaldi et al. 2004). Higher SSC is mainly due to the accumulation of sugars, and lower acidity is mainly due to the reduction of the main organic acids involved in fruit maturation (Rizzon et al. 2000; Keller et al. 2015).

Increased berry weight and production are associated with the number of seeds per berry, the accumulation of sugar in the fruit, cluster compaction, number of berries and berry water content (Rizzon and Mieli 2002). Physical and chemical interactions are conditioned by factors such as dilution of organic acids and decreased acidity due to the increased berry size, from early maturation to ripening (Santos et al. 2011). Berry mass increases proportionally with berry length and width, which are correlated accounting for the correlation between FMB, BL and BW (Regina et al. 2010; Chialva et al. 2016).

Bunch weight directly depends on the number and size of berries (Rizzon and Miele 2004). Berry size is also an important characteristic for wine quality due to the relationship between the berry skin, a major source of aromatic compounds and tannins, and the juice, mainly composed of organic acids and sugars (Houel et al. 2010). Allowing clusters to remain on the plant longer due to the lower risk of losses by fungal diseases contributes to better berry composition (Mota et al. 2011).

Berry size is influenced by the availability of soil water (Mota et al. 2011). Excessive rainfall during ripening forms a fine moist layer on the surface on the berries, especially in compact clusters, which may be responsible for their larger diameters caused by the absorption of water through the skin (Blouin and Guimberteau 2004; Malinovski et al. 2016).

Prolonged periods with temperatures > 30 °C in the Aw climate, though, may have promoted vegetative growth. Consequently, the period of fruit maturation was shorted, affecting the accumulation of compounds in the berries and decreasing the quality of the raw material (Mullins et al. 1992; Borghezan et al. 2011; Nunes et al. 2016). The chemical characteristics of the juice were thus best and the cycle was longest for the 'SR 501-17' hybrid in the Cfa climatic region for all rootstocks.

CONCLUSION

The rootstocks did not influence the production or physicochemical parameters of the 'SR 501-17' genotype. The chemical characteristics of the juice was better, production →

was higher and the cycle was longer for the 'SR 501-17' white hybrid grape grown in the Cfa climatic region for all rootstocks.

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AUTHOR'S CONTRIBUTION

Conceptualization, Moura M. F., Hernandes J. L. and Tecchio M. A.; Methodology, Mattar G. S., Modesto L. R., Moura M. F. and Hernandes J. L. Investigation and Writing – Original Draft, Mattar G. S., Modesto L. R. and Moura M. F.; Writing – Review and Editing, Hernandes J. L. and Tecchio M. A.; Funding Acquisition, Resources and Supervision, Moura M. F.

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