Australian Journal of Crop Science AJCS

Aust J Crop Sci. 18(10):650-657 (2024) | https://doi.org/10.21475/ajcs.24.18.10.p57 ISSN:1835-2707

Table grape harvested sequentially twice a year in a subtropical climate

Lenon Romano Modesto, Luiz Antonio Junqueira Teixeira, José Luiz Hernandes[1)], Armando Reis Tavares, Mara Fernandes Moura Furlan*

Instituto Agronômico (IAC), Centro APTA de Frutas, Avenida Luiz Pereira dos Santos, 1500, Corrupira, 13214-820 - Jundiaí, SP, Brazil

***Corresponding author: Mara Fernandes Moura Furlan**✉

***Submitted:* 27/11/2023**

***Revised:* 20/03/2024**

***Accepted:* 25/03/2024**

Abstract: Harvesting table grapes twice yearly presents a viable opportunity for winegrowers seeking to increase profitability and extend fruit availability in the market. In this study, we aimed to assess the production and quality of the seeded grape Niagara Rosada, a table grape resulting from a natural mutation of Niagara with red fruit. The vineyard was 14 years old and not irrigated; the soil is classified as dystrophic Tb Haplic Cambisol, and the climate is humid subtropical with dry winter and warm summer. Vines were pruned twice a year, leading to harvests in 2015 and 2016 in both summer and winter (a total of 760 days). Throughout the experiment, we monitored various climatic conditions, such as rainfall, air temperature, photosynthetically active radiation (PAR), temperature range, degree-day accumulation, and Huglin index values. We evaluated yield and fruit quality, including the number of branches and bunches, as well as the weight and size of the bunches and berries. Additionally, we assessed the quality of the must, examining soluble solids, acidity, and the maturation index for each harvest. We observed that higher rainfall and PAR during the summer harvest resulted in increased grape production compared to winter harvest. Niagara Rosada produced two branches and four bunches more per plant during the summer than in the winter crop, increasing by 71.2% of grape production. Interestingly, however, fruit harvested in winter displayed better quality with a higher maturation index. Despite these differences, both summer and winter harvests met the quality standards for commercialization. In conclusion, our findings suggest that winegrowers can successfully harvest Niagara Rosada grapes twice a year under subtropical conditions, offering a feasible approach for increasing productivity and fruit availability within the market.

Keywords: *Vitis* sp., climate, crop season, grape quality, double pruning

Abbreviations: ADG_accumulated degree-days; BeL_ten berries length; BeW_ ten berries width; BM_beginning of maturation; Br_number of branches; Bu_number of bunches; BuL_bunch length; BuW_bunch width; D_day length; F_flowering; FWBe_fresh mass of ten berries; FWBu_fresh mass of bunches; FWS_fresh mass of rachis; HI_Huglin index; M_Maturation; MI_maturation index; P_pruning; PAR_ photosynthetically active radiation; Prod_production; Rain_rainfall; S_budburst; S_summer crop season; SSC_solid soluble contents; Ta_tartaric acid; TA_thermal amplitude; T_{ave}_average temperatures; T_{max}_ maximum temperatures; T_{min}_minimum temperatures; W_winter crop season.

Introduction

Grapevines are grown for various purposes, including wine, juice, and table grapes, and they grow on a total of 7.3 million hectares of vineyards worldwide (OIV, 2020). Brazil produced 1.4 million tons of grapes in 2022, including *Vitis vinifera*, *Vitis labrusca* and hybrids (IBGE, 2022). In São Paulo State, one of the largest table grape regions in Brazil, the main cultivar is Niagara Rosada (Mello and Machado, 2022). Niagara Rosada is a seeded grape variety originated in 1933 from a natural somatic mutation of the Niagara (*Vitis labrusca* x *Vitis vinifera*) in Brazil. Niagara Rosada is known for its ease of cultivation, tolerance to diseases and pests, and popularity among consumers owing to its appealing pink color and sweet flavor (Camargo, 1998).

To achieve high grape quality and production, different types of vineyard management can be used, depending on the region where the vineyard is located (Qiu et al., 2019). In tropical and subtropical regions, high temperatures around 25 °C and consistent rainfall throughout the year create favorable conditions for at least two grapevine cycles per year (Hernandes et al., 2013; Scapin-Buffara et al., 2018; Leão et al., 2020). Grapevine double cropping represents a valuable technique that allows grape growers to maximize production efficiency, manage market dynamics, and increase both yield and fruit quality (Lu et al., 2023). Double pruning is a viticultural practice employed in spur-pruned vineyards to optimize the timing of final pruning. This technique involves conducting two pruning sessions during the growing season. The first occurs in late winter (late August and September in Brazil), and the second takes place in late summer, usually between late December and January in Brazil. During this stage, vines are rapidly and selectively pruned to achieve the desired bud count for optimal vine balance and grape production (Weber et al., 2007). By implementing summer pruning techniques, such as single or double cropping within the same season, growers can effectively manage vine vigor, canopy density, and fruit load to optimize grape quality and yield. This approach allows growers to adapt to shifts in temperature, precipitation patterns, and growing seasons to harness the potential benefits of climate change while mitigating associated risks (Poni et al., 2023).

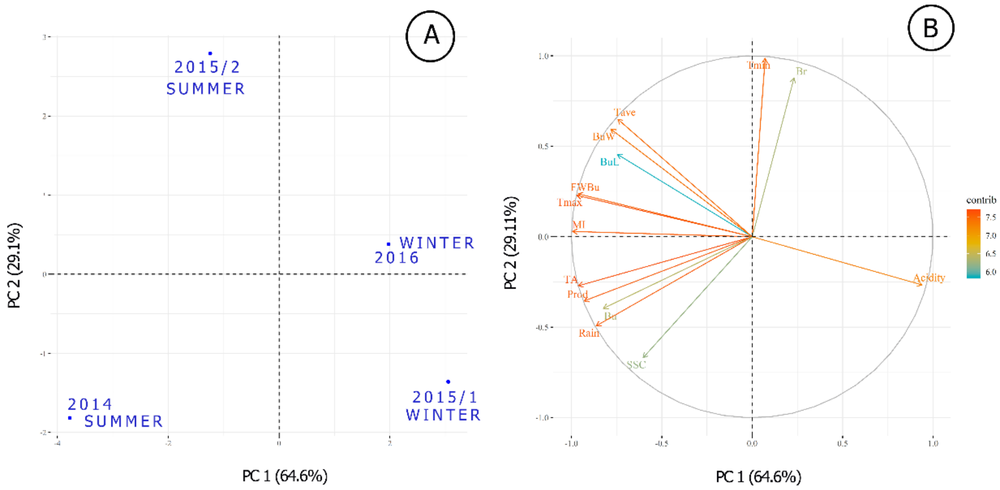

Fig 1. Principal components analysis. (A) Cycles 2014, 2015/1, 2015/2, and 2016, during summer and winter crop seasons. Crop seasons with a similar profile are grouped on the same side of the graph. (B)Variables used to characterize seasons and cycles. Variables with orange arrows indicate high contributions to explaining the principal component. Variables with arrows in yellow, brown, and blue, respectively, indicate low contributions to explaining the principal component. Note Production (Prod), number of branches (Br) and bunches (Bu) per plant, fresh mass of bunch (FWBu), bunch length (BuL) and width (BuW), fresh mass of ten berries (FWBu), ten berries length (BeL) and width (BeW), fresh mass of rachis (FWS), solid soluble contents (SSC), acidity, maturation index (MI), thermal amplitude (TA), average temperature (Tave), minimum temperature (T_{min}), maximum temperature (T_{max}) and rainfall (rain).

For two grapevine cycles per year, the double pruning technique is performed, resulting in two harvests per year, one in winter and the other in summer (Favero et al., 2011; Lu et al., 2022). However, grape production is seasonally affected by climatic factors, such as air temperature, rainfall, wind, humidity, thermal amplitude, and photosynthetically active radiation (Nunes et al., 2016). Therefore, grapevines cultivated twice a year may exhibit differences in terms of the number of branches and bunches, fruit weight and size, soluble solids content, and titratable acidity of the must in both crop cycles (Ricce et al., 2013; Mirdehghan and Rahimi, 2016; Nan et al., 2018). Nonetheless, double pruning still faces challenges due to its adaptability to different climatic regions and grape varieties, resulting in different yields and fruit quality (Lu et al., 2023). By altering the grapevine cycle, the double pruning technique can help avoid spring frost injury in grapevines (Centinari, 2023), reduce grape diseases like *Eutypa lata* in spur-pruned vineyards (Weber et al., 2007), and mitigate challenges related to the rainy season in tropical regions such as Brazil and Thailand, thereby improving grape quality (Camargo et al., 2012).
Accordingly, this study aimed to evaluate the production of table grapes, specifically the Niagara Rosada variety, during both winter and summer crop cycles under subtropical growing conditions. Despite climatic differences between the two seasons, our hypothesis holds that the production of high-quality table grapes is feasible in both summer and winter, highlighting the adaptability and potential of Niagara Rosada in Brazil.

Results

Performance of Niagara Rosada during the winter and summer cycles

The cultivar Niagara Rosada produced two branches and four bunches more per plant during the summer compared to such production in the winter crop, increasing grape production by 71.2% (+6 ton ha^{-1}) during the summer crop season under a subtropical climate (Table 1). High production during the summer, which is the usual crop season, was the result of heavier and bigger fruits compared to fruits harvested in the winter. FWBu, FWBe, and FWS increased by 49.9 g, 7.78 g, and 2.05 g, respectively, during the summer. Also, when comparing cycles in the summer season, the 2014 cycle produced more bunches per plant, and during the second summer crop cycle (2015/2), the grapevine produced more branches (21 branches) with berries (FWBe = 43.44 g) and heavier rachis (FWS = 6.35 g). Comparing the 2014 and 2015/1 winter crop cycles with the 2015/1 and 2016 winter cycles, the grapevine produced smaller and lighter fruits, resulting in lower production.
Grapes from summer crop cycles (2014 and 2015/2) showed higher MI with lower must acidity than grapes from winter crop cycles (2015/1 and 2016). Must acidity increased by 0.14, and both SSC and MI decreased by 0.25°. Brix and MI decreased by 0.25 and 18.8, respectively, during both winter crop cycles (Table 2). Must presented a higher SSC in the 2014 summer cycle compared to the 2016 winter cycle.

Characterizing crop seasons with Principal Components Analysis (PCA)

The first principal component explaining 64.6% of total experimental variation and it was related to grape production, Bu, FMBu, WBu, LBu, SSC, MI, must acidity, rainfall, thermal amplitude, and average and maximum temperature characterizing the differences between winter and summer seasons (Figure 3). During the summer season, the grapevines were cultivated under higher rainfall, thermal amplitude, and average and maximum temperature, resulting in higher grape production with heavier and larger bunches (FMBu, WBu, Bu and BuL) compared to the winter crop under subtropical conditions. In addition, the summer season produced must with lower acidity and higher SSC, resulting in higher MI than in the winter season (Figures 3A and B).
The second principal component explained 29.1% of the total experimental variation related to minimum temperature and the number of branches, which characterized the cycles. During the cycles 2015/2 and 2016, the grapevine was cultivated under higher minimum temperature, resulting in higher branch production per plant, compared to the cultivation in cycles 2014 and 2015/1 (Figures 3A and B).

Table 1. Production, number of branches (Br) and bunches (Bu) per plant, fresh mass of bunch (FWBu), bunch length (BuL) and width (BuW), fresh mass of ten berries (FWBu), length of ten berries (BeL) and width (BeW), and the fresh mass of rachis (FWS) of cv. Niagara Rosada cultivated during four cycles in the winter and summer crop seasons under subtropical conditions.

Characteristic	Crop season			Cycle				
	Summer	Winter	p-value	2014	2015/1	2015/2	2016	p-value
Prod (ton ha^{-1})	14.10 ± 3.51 a	8.36 ± 1.11 b	<0.001	17.35 ± 0.47 a	8.97 ± 0.92 c	10.35 ± 1.29 b	7.75 ± 0.99 c	<0.001
Br (un)	16 ± 5.2 a	14 ± 0.9 b	<0.001	11 ± 0.30 c	15 ± 0.80 b	21 ± 1.1 a	14 ± 0.9 b	<0.001
Bu (un)	15 ± 2.1 a	11 ± 1.4 b	<0.001	17 ± 0.30 a	13 ± 0.60 b	13 ± 0.60 b	10 ± 1.3 c	<0.001
FWBu (g)	189.0 ± 4.21 a	139.1 ± 3.36 b	<0.001	198.0 ± 0.36 a	126.9 ± 0.54 c	180.0 ± 0.45 a	151.2 ± 0.80 b	<0.001
BuL (cm)	11.42 ± 0.76 a	10.63 ± 0.36 b	<0.001	11.47 ± 0.33 a	10.08 ± 0.38 b	11.38 ± 0.42 a	11.18 ± 0.52 a	<0.001
BuW (cm)	5.97 ± 0.41 a	5.46 ± 0.10 b	0.001	5.88 ± 0.26	5.41 ± 0.06	6.06 ± 0.54	5.51 ± 0.11	0.541
FWBe (g)	43.44 ± 1.44 a	35.66 ± 3.39 b	<0.001	-	36.17 ± 3.84	43.44 ± 1.44	35.15 ± 3.14	0.603
BeL (cm)	20.80 ± 0.39 a	19.21 ± 1.31 b	0.021	-	18.75 ± 0.49	20.80 ± 0.39	19.67 ± 1.75	0.198
BeW (cm)	18.64 ± 0.25 a	17.22 ± 0.22 b	<0.001	-	17.22 ± 0.31 b	18.64 ± 0.25 a	17.22 ± 0.07 b	0.900
FWS (g)	6.35 ± 0.37 a	4.30 ± 0.55 b	<0.001	-	3.82 ± 0.22 c	6.35 ± 0.37 a	4.77 ± 0.30 b	<0.001

Values after means are the deviation using 95% of interval confidence. Different letters in the row indicate significance according to the Scott-Knott test (p≤0.05).

Table 2. Solid soluble contents (SSC), acidity and maturation index (MI) of cv. Niagara Rosada´s must cultivated during four cycles in the winter and summer crop seasons under subtropical conditions.

Characteristics	Crop Season			Cycle				
	Summer	Winter	P-value	2014	2015/1	2015/2	2016	P-value
SSC (°Brix)	16.72 ± 0.37 a	16.47 ± 0.32 b	0.024	17.0 ± 0.20 a	16.7 ± 0.29 ab	16.4 ±0.27 bc	16.2 ± 0.14 c	<0.001
Acidity (g 100 g^{-1} ta)	0.30 ± 0.03 b	0.44 ± 0.05 a	<0.001	0.27 ± 0.02 d	0.48 ± 0.02 a	0.32 ± 0.01 c	0.39 ± 0.02 b	<0.001
MI (SSC/Acidity)	56.4 ± 7.9 a	37.6 ± 3.9 b	<0.001	62.8 ± 6.0 a	34.3 ± 1.3 d	50.1 ±2.5 b	41.1 ±1.9 c	<0.001

Values after means are the deviation using 95% of interval confidence. Different letters on the row indicate significance according to the Scott-Knott test (p ≤ 0.05). ta = tartaric acid.

Discussion

Our results demonstrated a higher production of branches and fruits for Niagara Rosada during the summer crop compared to the winter crop under a subtropical climate. Nevertheless, berries from both summer (20.8 mm) and winter (19.21 mm) seasons reached the minimum diameter required for table grape commercialization at between 14 and 17 mm (Brasil, 2002). On the other hand, the variety Isabel exhibited consistent fruit production and berry mass during both summer and winter crop seasons (Santos et al., 2011a), indicating that different vine cultivars are affected in distinct ways by variable growing conditions. Fruit taste and quality of the second harvest of grapes from the grapevine are generally superior to those of the initial fruit (Ahmed et al., 2019). In our study, however, grapes from both crop seasons achieved the minimum SSC required for the market at 14°C Brix (Benato, 2002; Maia, 2002). Niagara Rosada from the summer crop showed higher MI (maturation index) with lower must acidity than grapes from the winter crop. However, varieties such as Syrah and Bôrdo produced larger bunches and berries during the summer crop compared to the winter crop, while higher sugar content (SSC) and anthocyanins were observed during the winter crop season compared to summer (Santos, 2011b). During our experiment, we observed higher PAR from the beginning of grape maturation to harvest during the summer crop, resulting in higher MI, compared to the winter crop. In addition, higher rainfall during the summer crop, compared to the winter crop, improved grape production. The low water availability in soil during the winter limits fruit production (Martínez-Lüscher et al., 2016). The varieties Syrah and Bôrdo produced fewer fruits owing to lower water availability during the summer when compared to the winter crop season (Santos et al., 2011b). However, *V. labrusca* varieties, such as Niagara Rosada and Bôrdo, are more adapted to tropical and subtropical conditions than *V. vinifera* cultivars (Hernandes et al., 2013; Duchêne, 2016).

Seasonal pruning for grape production needs to be planned based on climatic conditions and the characteristics of the variety to be cultivated (Gu et al., 2012; Duchêne, 2016). The ideal climatic conditions for growing grapevine allow varieties to achieve maximum genetic potential, resulting in high fruit production and quality (Duchêne, 2016; Wu et al., 2016). In our study, the summer crop resulted in higher production and MI of Niagara Rosada as a result of higher rainfall during fruit development and higher PAR during maturation compared with the winter crop. The winter crop is, nonetheless, an alternative for producing marketable table grapes (Ras and Vermeulen, 2009; Hernandes et al., 2013; da Silva et al., 2018), commanding correspondingly high prices (Ras and Vermeulen, 2009; Ricce et al., 2013; Frölech et al., 2019). Grapevine varieties, such as Isabel, Niagara Rosada, Niagara, Concord, Bôrdo, BRS Carmen, and BRS Rúbea, presented enough accumulated degree-days to be cultivated twice a year in subtropical and tropical regions during summer and winter crops (Ricce et al., 2013). Moreover, grapes harvested in both seasons present the minimum standard in berry size and SSC to meet market requirements (Benato, 2002; Maia, 2002), such as that found in Ordinance nº 371 of the Ministry of Agriculture (Brasil, 2002) and different international commercialization standards (Kader, 1992; Barros et al., 1995).

The infographic in Figure 2 was created to explain table grape production and quality during winter and summer crops under subtropical conditions. From budburst to flowering, the grapevine needs high thermal amplitude, lower PAR, and rainfall, when compared to those values from the beginning of grape maturation. At the first phenological stages, from budburst to flowering, low PAR and rainfall decrease the vegetative growth of tendrils and branches, resulting in more bunches and fresh mass of bunches. Moreover, high thermal amplitude results in standard budburst (Antivilo et al., 2017). From fruit development to color change of fruit (‘veraison’), temperatures above 25 °C, high PAR, and rainfall increase grape size. From ‘veraison’ to harvest, the decrease in rainfall and increase in temperature increase SSC, MI, and phenolic compounds on the must, but decrease must acidity (Zhang

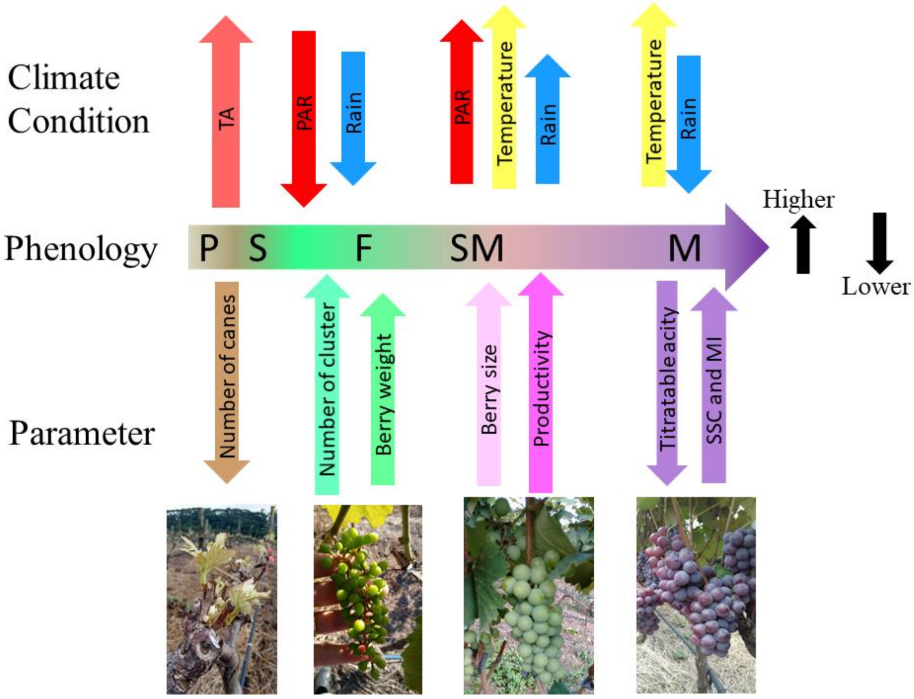

Fig 2. Effect of climate on table grape production and quality during the main phenological stages. Note: Up arrows (↑) correspond to higher values, and down arrows (↓) represent lower values for evaluated variables during summer and winter crop seasons. (P) Pruning, (S) Budburst, (F) Flowering, (SM) Start of maturation, (M) Maturation, (SSC) solid soluble contents, (MI) maturation index, (PAR) photosynthetically active radiation, and (TA) thermal amplitude.

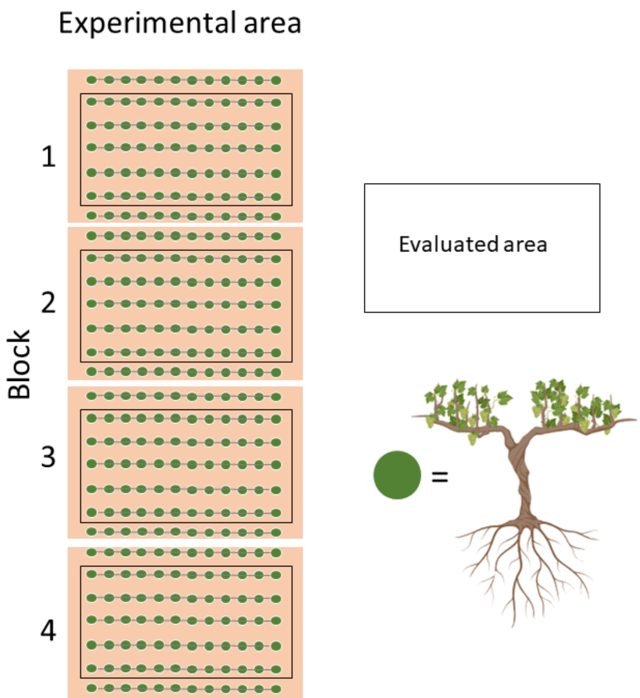

Fig 3. Design of experimental area. The experiment was performed in a completely randomized block design, consisting of four blocks with seventy-two grapevines per block. Only the forty-eight central grapevines were considered for evaluation in each season (n=192 grapevines evaluated in four blocks). Black squares indicate the evaluated area in each block, and green circles represent individual grapevine plants.

et al., 2016). Low rainfall after 'veraison' results in grapes with higher quality owing to less incidence of rip rot (*Glomerealla cingulata*) and *Botrytis cinerea* (Echeverrigaray et al., 2020; Fedele et al., 2020). Nonetheless, in order to maintain active vegetation during the summer under a double reproductive cycle, vines require substantial vigor and abundant resources, including nutrients and water (Poni et al., 2023).

Materials and methods

Experimental area

This study was conducted in Jundiaí, São Paulo State, Brazil (23°07'S and 46°56'W), 750 m (a.m.s.l.). According to Köppen-Geiger, the climate is classified as humid subtropical with dry winter and warm summer (Cfa). The soil of the experimental area was classified as dystrophic Tb Haplic

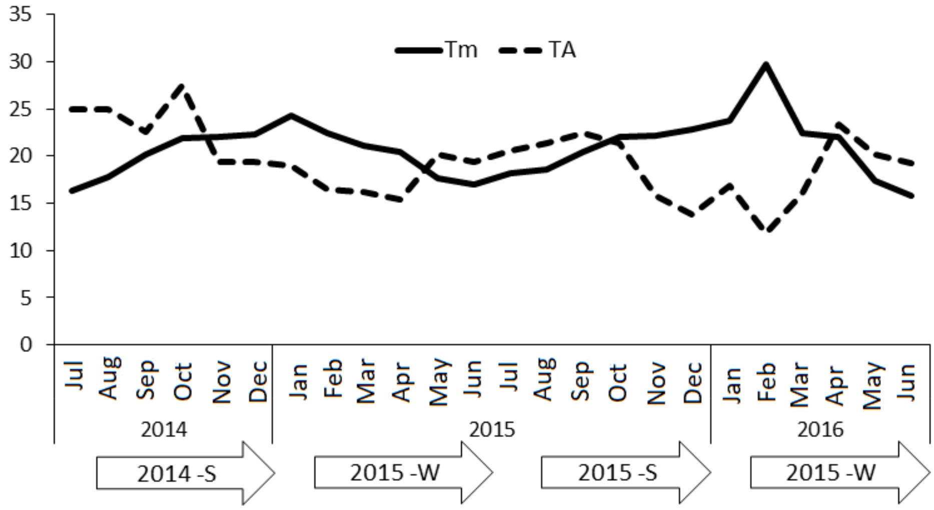

Fig 4. Average temperature (T_{ave}) and thermal amplitude (TA) during four grapevine cycles, from August 2014 to June 2016, in a subtropical climate. Summer crop season (S) from August to December. Winter crop season (W) from February to June. July and January were intervals between cycles before grapevine pruning.

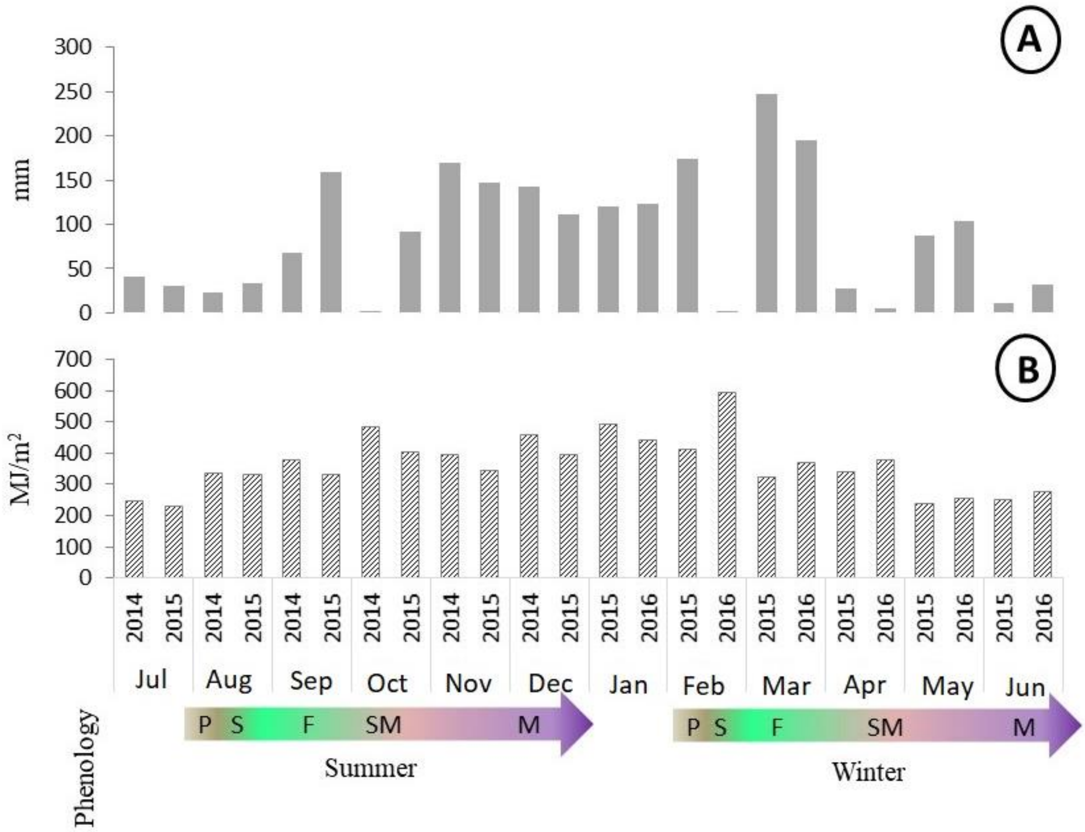

Fig 5. Rainfall accumulation (A) and photosynthetically active radiation (B) during each phenological phase of the grapevine Niagara Rosada cultivated in a subtropical climate during summer and winter crop seasons. The summer crop season was from August to December. The winter crop season was from February to June. July and January were intervals between cycles before grapevine pruning. (P) Pruning, (S) Budburst, (F) Flowering, (BM) Beginning of maturation, and (M) Maturation.

Table 3. Rainfall, minimum (T_{min}), maximum (T_{max}), and average (T_m) temperature, accumulated degree-days (ADG), and Huglin index (HI) of cv. Niagara Rosada cultivated during four cycles in the winter and summer crop seasons under subtropical conditions.

	Temperature				ADG	HI
	Average	Minimum	Maximum	Amplitude		
Crop season	-----------------°C-------------------					
Summer	22.1	4.6	37.8	33.2	1853	2243
Winter	21.6	2.4	33.9	31.5	1648	2157

Cambisol. The soil of the experimental area was classified as dystrophic Tb Haplic Cambisol. Chemical analysis of the soil was conducted before the experiment installation, following the methodology proposed by Raij et al. (2001). The soil in the 0-20 cm layer exhibited the following values for chemical attributes organic matter (O.M.): 16 g kg^{-1}; pH ($CaCl_2$): 5.0; base saturation: 68%; P: 388 mg dm^{-3}; K: 4.8 $mmol_c$ dm^{-3}; Ca: 40 $mmol_c$ dm^{-3}; Mg: 10 $mmol_c$ dm^{-3}; H+Al: 25 $mmol_c$ dm^{-3}; B: 0.28 mg kg^{-1}; Cu: 6.6 mg kg^{-1}; Fe: 76 mg kg^{-1}; Mn: 7.7 mg kg^{-1}; Zn: 7.5 mg kg^{-1}, and in the 20-40 cm layer exhibited organic matter (O.M.): 12 g kg^{-1}; pH ($CaCl_2$): 5.1; base saturation: 67%, P: 250 mg dm^{-3}; K: 5.2 $mmol_c$ dm^{-3}; Ca: 34 $mmol_c$ dm^{-3}; Mg: 9 $mmol_c$ dm^{-3}; H+Al: 24 $mmol_c$ dm^{-3}; B: 0.25 mg kg^{-1}; Cu: 4.8 mg kg^{-1}; Fe: 54 mg kg^{-1}; Mn: 4.7 mg kg^{-1}; Zn: 4.2 mg kg^{-1}.

The rootstock IAC 766 Campinas was planted in 2010, spaced 1.8 m between rows and 1.0 m between plants (Figure 3). The cultivar Niagara Rosada was grafted onto the rootstocks in 2011. The grapevines were conducted under a vertical trellis system, the soil was fertilized, adventitious and apical shoots were removed, and diseases, such as anthracnose, downy and powdery mildew, were controlled according to technical recommendations for the region.

Treatments and experimental design

The treatments were summer and winter crops in a subtropical climate (Brazil). The summer crop was conducted during the 2014 and 2015 (2015/1) cycles with pruning in August and harvesting in December. The winter crop was conducted during the 2015 (2015/2) and 2016 cycles with pruning in February and harvesting in June. The experimentation period lasted a total of 760 days. In all cycles, 5 % of hydrogen cyanamide (Dormex®, 52 %, m/v CH_2N_2) was sprayed on the buds after pruning to standardize the budburst. After pruning, in all cycles, hydrogen cyanamide (Dormex®, 52 %, m/v CH_2N_2) at 5 % was again sprayed on buds to standardize the budburst. The experiment was performed in a completely randomized block design, consisting of four blocks with seventy-two grapevines per block. Only the forty-eight central grapevines were considered for evaluation (n = 192 grapevines evaluated in four blocks).

Grape production and quality

The number of branches (Br) and bunches (Bu) was counted at the veraison stage. Production and fruit quality were evaluated at physiological maturation (purple fruits). Production was estimated in tons per hectare. Grape size was evaluated using 480 bunches per experimental block (n = 1920 bunches in four blocks). Fresh mass of bunches (FWBu), ten berries (FWBe), and rachis (FWS) were weighed, and bunch length (BuL), bunch width (BuW), and both BeL (length of ten berries) and BeW (width of ten berries) were measured. Must was extracted (4,800 berries per experimental block), and solid soluble contents (SSC) were measured by a digital refractometer (ATAGO®), while acidity was assessed by adding NaOH 0.1N to the must until reaching pH 8.2. The maturation index (MI) was calculated as the ratio between SSC and titratable acidity of the must.

Climatic conditions

Total rainfall, photosynthetically active radiation (PAR), minimum (T_{min}), maximum (T_{max}), and average (T_{ave}) temperatures were monitored at a meteorological station next to the experimental area during all crop seasons. Thermal amplitude (TA) was calculated using maximum and minimum temperatures. The accumulated degree-days (ADG) and Huglin index (HI) were calculated using data from budburst to harvest for each crop season (Huglin, 1978; Tonietto and Carbonneau, 2004), as

$$ADG = \sum\left[\frac{(Tmax + Tmin)}{2}\right] - 10$$

$$HI = \frac{\sum[(Tmax - 10)] + [Tave - 10]}{2d}$$

Day length (d) was 1 since the experimental area was located below 40° latitude (Tonietto and Carbonneau, 2004).

The average temperature during the summer crop was 0.5 °C higher than that during the winter crop season (Table 3 and Figure 4). Thermal amplitude during summer was 1.7 °C higher compared to the winter crop. During the winter crop, the average minimum temperature was 2.2 °C lower than that of the summer crop. The maximum temperature average in the summer crop was 3.9 °C higher than that of the winter crop, increasing the accumulated degree-days and Huglin Index. Before grapevine pruning, during the winter crop in July (Table 3), the plants were exposed to higher PAR than before pruning in the summer crop in January (Figure 5B). On the other hand, compared to the winter crops, grapevines were exposed to higher PAR from the beginning of grape maturation to maturation during the summer crop (Figure 5B). Rainfall accumulation in the summer crop was 50 mm higher at grape maturation than that during the winter crop (Figure 5A).

Statistical analysis

Data from seasons and cycles were analyzed by variance analysis, and the means were ranked by the Scott-Knott test (α = 0.05). Crop seasons were characterized by principal component analysis. Statistical analyses were performed using the statistical packages Agricolae (Mendiburu, 2020) and Factoextra (Kassambara and Mundt, 2020) in R software (R Core Team, 2019).

Conclusions

Our results demonstrate that the management system can effectively be employed for Niagara Rosada grapes in São Paulo State, ensuring high-quality production of grapes that can be brought to market in both seasons. This approach also increases annual grapevine production. The production and quality of Niagara Rosada grapes were influenced by climatic conditions during different crop seasons, with a higher number of fruits exhibiting a correspondingly higher MI during the summer compared to the winter crop. The development of a double cropping system per year represents a significant advancement, improving the quality and yield of out-of-season grapes.

Acknowledgments

The authors are grateful to CAPES (Coordination for the Improvement of Higher Education Personnel) for the scholarships to LRM and TSS.

References

Ahmed S, Roberto SR, Shahab M, Colombo RC, Silvestre JP, Koyama R, Souza RT (2019) Proposal of double-cropping system for 'BRS isis' seedless grape grown in subtropical area. Sci Hortic. 251:118-126.

Antivilo FG, Paz RC, Keller M, Borgo R, Tognetti J, Juñent FR (2017) Macro-and microclimate conditions may alter grapevine deacclimation: variation in thermal amplitude in two contrasting wine regions from North and South America. Int. J. Biometeorol. 61:2033-2045.

Barros JCSM, Ferri CP, Okawa H (1995) Qualidade da uva fina de mesa comercializada na Ceasa de Campinas. Inf Econ. 25(7):53-61.

Benato EA (2002) Cuidados na colheita, manuseio e conservação de uvas de mesa. In: Regina MA (Ed).

Viticultura e enologia: atualizando conceitos. EPAMIG-FECD, Caldas.
Brasil (2002). Instrução Normativa nº1 de 1º de fevereiro de 2002. Anexo III - Regulamento técnico de identidade e de qualidade para a classificação da uva rústica. Diário Oficial da União, Seção 1, 24, 6-7.
Camargo UA, Mandelli F, Conceição MAF, Tonietto J (2012). Grapevine performance and production strategies in tropical climates. As J Food Ag-Ind 5(04):257-269.
Camargo UA (1998) Cultivares para a viticultura tropical no Brasil. Inf Agropec 19:15-19.
Centinari M (2023) Understanding and preventing spring frost and freeze damage to grapes. The Pennsylvania State University, University Park.
da Silva MJR, Paiva APM, Junior AP, Sanchez CAPC, Lima GPP, Leonel S, Tecchio MA (2018) Shoot topping of'Niagara Rosada'grapevine grafted onto different rootstocks. Aust J Crop Sci. 12(3):496-504.
Duchêne E (2016) How can grapevine genetics contribute to the adaptation to climate change?. Oeno One 50(3):113-124.
Echeverrigaray S, Scariot FJ, Fontanella G, Favaron F, Sella L, Santos MC, Schwambach J, Pedrotti C, Delamare APL (2020) *Colletotrichum* species causing grape ripe rot disease in *Vitis labrusca* and *V. vinifera* varieties in the highlands of southern Brazil. Plant Pathol. 69(8):1504-1512.
Favero AC, Amorim DA, Mota RV, Soares AM, Souza CR, Regina MA (2011) Double-pruning of 'Syrah' grapevines: a management strategy to harvest wine grapes during the winter in the Brazilian Southeast. Vitis 50:151-158.
Fedele G, Brischetto C, Rossi V (2020) Biocontrol of Botrytis cinerea on grape berries as influenced by temperature and humidity. Front Plant Sc. 11:1232.
Frölech DB, Assis AMD, Nadal MC, Mello LLD, Oliveira BADS, Schuch MW (2019) Chemical and sensory analysis of juices and cuts of 'Bordô'and 'Niágara Rosada'grapes. 3Chemical and sensory analysis of juices and cuts of 'Bordô' and 'Niágara Rosada' grapes. Rev Bras Frutic. 41:e-141.
Gu S, Jacobs SD, McCarthy BS, Gohil HL (2012) Forcing vine regrowth and shifting fruit ripening in a warm region to enhance fruit quality in 'Cabernet Sauvignon'grapevine (*Vitis vinifera* L.). J Hortic Sci Biotechnol. 87(4):287-292.
Hernandes JL, Pedro Júnior MJ, Blain GC, Rolim GDS (2013) Comportamento produtivo da videira 'Niagara Rosada' em diferentes sistemas de condução, com e sem cobertura plástica, durante as safras de inverno e de verão. Rev Bras Frut. 35: 123-130.
Huglin M (1978) Nouveau mode d'évaluation des possibilités héliothermiques d'un milieu viticole. C R Séances Acad Agric Fr. 64:1117-1126.
IBGE (Instituto Brasileiro de Geografia e Estatística) (2022) Produção de Uva. Available at: https://www.ibge.gov.br/explica/producao-agropecuaria/uva/br. Accessed on: Oct. 18th 2023.
Kader AA (1992) Postharvest tecnology of horticultural crops. University of California, Davis.
Kassambara A, Mundt F (2020) Package factoextra. Extract and Visualize the Results of Multivariate Data Analyses. R package version, 1-2. R Foundation for Statistical Computing, Vienna.
Leão PC, do Nascimento JHB, de Moraes DS, de Souza ER (2020) Yield components of the new seedless table grape 'BRS Ísis' as affected by the rootstock under semi-arid tropical conditions. Sc Hort. 263:109114.
Lu G, Zhang K, Que Y, Li Y (2023) Grapevine double cropping: a magic technology. Frontiers in Plant Science, 14, 1173985.
Lu HC, Chen WK, Wang Y, Bai XJ, Cheng G, Duan CQ, Wang J, He F (2022) Effect of the seasonal climatic variations on the accumulation of fruit volatiles in four grape varieties under the double cropping system. Front Plant Sc. 12:809558.
Maia JDG (2002) Manejo da videira Niagara Rosada em regiões tropicais. In: Regina MA (Ed). Viticultura e enologia: atualizando conceitos. EPAMIG-FECD, Caldas.
Martínez-Lüscher J, Kizildeniz T, Vučetić V, Dai Z, Luedeling E, Van Leeuwen C, Gomès E, Pascual I, Irigoyen JJ, Morales F, Delrot S (2016) Sensitivity of grapevine phenology to water availability, temperature and CO_2 concentration. Front Environ Sc. 4:48.
Mello LMR, Machado CAE (2022) Vitivinicultura brasileira: panorama 2021. Comunicado Técnico 226. EMBRAPA, Bento Gonçalves,
Mendiburu F (2020) Package 'agricolae'. 2020. Available at: <https://cran.r-project.org/web/packages/agricolae/agricolae.pdf>. Accessed on: Aug. 18th 2022.
Mirdehghan SH, Rahimi S (2016) Pre-harvest application of polyamines enhances antioxidants and table grape (*Vitis vinifera* L.) quality during postharvest period. Food Chem. 196:1040-1047.
Nan L, Li Y, Cui C, Huang J, Liu Y, Xu C, Fan S, Wang H, Li H (2018) Maturation of shoots, leaves and fruits of Ecolly grape in response to alternative new pruning system and harvesting times in China. Sc Hort. 231:108-117.
Nunes NAS, Leite AV, Castro CC (2016) Phenology, reproductive biology and growing degree days of the grapevine 'Isabel'(*Vitis labrusca*, Vitaceae) cultivated in northeastern Brazil. Braz J Biol. 76:975-982.
OIV (International Organisation of Vine and Wine) (2020) State of the world vitivinicultural sector in 2020. Available at: <https://www.oiv.int/public/medias/7909/oiv-state-of-the-world-vitivinicultural-sector-in-2020.pdf>. Accessed on: Aug. 18th 2022.
Poni S, Frioni T and Gatti M (2023) Summer pruning in Mediterranean vineyards: is climate change affecting its perception, modalities, and effects? Front Plant Sci. 14:1227628.
Qiu Z, Chen G, Qiu D (2019) Pruning and dormancy breaking make two sustainable grape-cropping productions in a protected environment possible without overlap in a single year. PeerJ 7:e7412.
R Core Team (2019) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Viena.
Raij Bv, Alcarde Jc, Cantarella H, Quaggio Ja (2001) Análise química para avaliação da fertilidade de solos tropicais. Instituto Agronômico, Campinas.
Ras PJ, Vermeulen WJ (2009) Sustainable production and the performance of South African entrepreneurs in a global supply chain. The case of South African table grape producers. Sustain Dev. 17(5):325-340.
Ricce WDS, Caramori PH, Roberto SR (2013) Potencial climático para a produção de uvas em sistema de dupla poda anual no Estado do Paraná. Bragantia 72:408-415.
Santos AO, Hernandes JL, Pedro Jr MJ, Rolim GS (2011b) Parâmetros fitotécnicos e condições microclimáticas para videira vinífera conduzida sob dupla poda sequencial. Rev. Bras Eng Agr Amb. 15:1251-1256.
Santos AO, Hernandes JL, Pedro Junior MJ, Pereira SE (2011a) Composição da produção e qualidade da Uva em videira cultivada sob dupla poda e regime microclimático estacional constrastante. Rev. Bras Frut. 33:1135-1154.
Scapin-Buffara CR, Angelotti F, Dufault NS, Pereira CB, Tessmann DJ (2018) Seasonal progression of leaf rust in 'Niagara Rosada'grapevine in a biannual crop system in Brazil. Eur J Plant Pathol. 152:589-597.

Tonietto J, Carbonneau A (2004) A multicriteria climatic classification system for grape-growing regions worldwide. Agr Forest Meteor. 124(1-2):81-97.

Weber EA, Trouillas FP, Gubler WD (2007). Double pruning of grapevines: a cultural practice to reduce infections by *Eutypa lata*. American Journal Of Enology and Viticulture 58(1):61-66.

Wu Y, Duan S, Zhao L, Gao Z, Luo M, Song S, Xu W, Zhang C, Ma C, Wang S (2016) Aroma characterization based on aromatic series analysis in table grapes. Scientific Rep 6(1):1-16.

Zhang L, Xu, YS, Jia Y, Wang JY, Yuan Y, Yu Y, Tao JM (2016) Effect of floral cluster pruning on anthocyanin levels and anthocyanain-related gene expression in 'Houman'grape. Hort Res. 3:16037.