Ciências Agrárias
SEMINA

DOI: 10.5433/1679-0359.2023v44n4p1441

Influence of rootstocks for Sangiovese vineyards in a high-altitude region of Santa Catarina State, Brazil: Impact on sensory and quality characteristics of wines

Influência de porta-enxertos para vinhedos cv. Sangiovese em região vitivinícola de altitude em Santa Catarina, Brazil: Impacto nas características sensoriais e de qualidade dos vinhos

Izabel Camacho Nardello[1]; Marines Batalha Moreno Kirinus[2]*; André Luiz Kulkamp de Souza[3]; Vinícius Caliari[3]; Marcelo Barbosa Malgarim[4]

Highlights

'101-14 Mgt' and 'Harmony' rootstocks improve wine quality, alcohol and phenols.
Polyphenol and anthocyanin vary with rootstock and harvest, affect color and flavor.
SO2 differs with rootstocks, affecting bacterial proliferation and wine stability.
Color and turbidity vary with rootstocks and harvests, grape health and phenols.
Sensory evaluation unchanged by rootstocks, but harvests show differences.

Abstract

Adapting grape varieties to new viticultural regions requires studying the influence of rootstock on wine quality. This study aimed to identify rootstocks that most enhance the enological characteristics of grapes of the Sangiovese variety grown in the high-altitude region of Santa Catarina. The experiment was set up as a completely randomized design in a factorial scheme. Factor A represented the vintages (2019 and 2020), while Factor B denoted the rootstocks: '101-14 Mgt', 'Harmony', 'IAC 572', 'Paulsen 1103', and 'VR 043-43'. We assessed the physicochemical and sensory characteristics of wines from both vintages. Wines from the 'IAC 572' and 'VR 043-43' rootstocks had the lowest alcohol concentrations. The 'VR

[1] Dr[a] from the Postgraduate Program in Agronomy, Universidade Federal de Pelotas, UFPEL, Pelotas, RS, Brazil. E-mail: izabelnardello@gmail.com
[2] Postdoctoral Researcher from the Postgraduate Program in Agronomy, UFPEL, Pelotas, RS, Brazil. E-mail: marineskirinus@gmail.com
[3] Researcher at the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, EPAGRI, Videira, SC, Brazil. E-mail: andresouza@epagri.sc.gov.br; caliari@epagri.sc.gov.br
[4] Prof. PhD in Agronomy and from the Postgraduate Program in Agronomy, UFPEL, Pelotas, RS, Brazil. E-mail: malgarim@ufpel.edu.br
* Author for correspondence

Received: Mar. 26, 2023 Approved: Sept. 22, 2023

043-43’ rootstock contributed to the highest titratable acidity in the 2020 vintage wines. Additionally, wines from 2020 displayed a more vivid red color than their 2019 counterparts. We deduced that the Sangiovese wine quality is affected by the cultivation year. Sensory evaluations revealed that the tested rootstocks did not considerably alter the overall balance of the wine. However, the ‘101-14 Mgt’ and ‘Harmony’ rootstocks notably increased the alcohol concentration and phenolic compound levels in Sangiovese wines.
Key words: *Vitis vinifera.* Altitude wines. Viticulture.

Resumo

Na adaptação de variedades de videiras em novas áreas vitícolas é necessário o estudo da influência do uso de porta-enxertos sobre a qualidade dos vinhos. Nesse sentido, o objetivo do presente estudo foi determinar o porta-enxerto que melhor contribua para as características enológicas da variedade Sangiovese, cultivada em região de altitude de Santa Catarina. O experimento contou com delineamento inteiramente casualizado, em esquema bifatorial, onde o fator A trata das safras (2019 e 2020) e o fator B dos porta-enxertos (‘101-14 Mgt’, ‘Harmony’, ‘IAC 572’, ‘Paulsen 1103’ e ‘VR 043-43’). Avaliou-se as características físico-químicas e sensoriais dos vinhos provenientes das duas safras. A menor concentração alcoólica foi obtida nos vinhos dos porta-enxertos ‘IAC 572’ e ‘VR 043-43’. A maior acidez titulável foi proporcionada pelo porta-enxerto ‘VR 043-43’ nos vinhos da safra 2020. Os vinhos da safra 2020 apresentaram tonalidade de cor mais vermelha que os vinhos da safra 2019. Conclui-se que a qualidade dos vinhos de Sangiovese são influenciadas pela safra de cultivo; sensorialmente os diferentes porta-enxertos testados na produção de Sangiovese não alteram de forma global o equilíbrio dos vinhos e, os porta-enxertos ‘101-14 Mgt’ e ‘Harmony’ contribuem para a maior concentração alcoólica e de compostos fenólicos nos vinhos de Sangiovese.
Palavras-chave: *Vitis vinifera.* Vinhos de altitude. Viticultura.

Introduction

Southern Brazil is renowned for its grape production and its derivatives, producing over one million tons in 2021 across 54 thousand hectares. Of this, Rio Grande do Sul contributed 951.3 thousand tons from 46,300 hectares, Santa Catarina produced 59.1 thousand tons from 3,900 hectares, and Paraná added 46 thousand tons from 3,500 hectares. Together, these figures account for 60% of the Brazilian total grape production, which stands at 1.75 million tons (Instituto Brasileiro de Geografia e Estatística [IBGE], 2023).

Efforts have been made to expand viticultural production within Santa Catarina State by exploring new areas suitable for viticulture, such as the Serra Catarinense. Commercial viticulture in Santa Catarina began in the 1970s, driven by Italian immigrants from the Serra Gaúcha region. This region remains the primary wine-producing area in Brazil (Costa, 2020). However, recent decades have seen a surge in exploring uncharted terroirs (Zanus, 2015). Among these, the Serra Catarinense, with its altitude exceeding 800 meters, has become prominent for producing premium wines. Its unique climatic conditions promote the full ripening of grapes, endowing them with attributes distinct from those grown elsewhere in Brazil. Such distinctiveness is leveraged to produce fine wines and effervescent varieties (Malinovski et al., 2012; Caliari, 2018).

In light of this potential, public initiatives have fostered viticulture development in Santa Catarina, particularly within its high-altitude areas. This expansion has enabled the introduction of Italian grape varieties like Sangiovese, which showcases promising agronomic and oenological prospects in these areas (Porro & Stefanini, 2016). However, introducing a new cultivar typically necessitates investigating its interaction with various rootstocks to maximize productivity and oenological qualities (Li et al., 2019).

The Sangiovese cultivar, believed to originate in Tuscany, Italy, is among the most cultivated varieties in Italy and is internationally acclaimed (Rinaldi et al., 2020). These wines exhibit a deep ruby-red color with floral aromas of violets and notes of red fruits and ripe plum. Their taste is rich yet velvety, underpinned by a solid structure (Porro & Stefanini, 2016). However, Sangiovese exhibits considerable adaptability, with aromatic and flavor profiles of its wines varying depending on the production region and techniques (Puccioni et al., 2013).

Rootstocks play a pivotal role in the overall growth of grapevines, functioning as their subterranean base. Changes in rootstock genetics can influence water and nutrient uptake, hormone regulation, and other signals affecting the growth of grafts and fruit quality (Rossdeutsch et al., 2021). This, in turn, impacts the sensory and quality attributes of resultant wines.

Additionally, rootstocks offer a solution to mitigate damages in the Southern region of Brazil caused by ground pearls or root mealybugs (*Eurhizococcus brasiliensis*). These pests facilitate the invasion of pathogenic fungi, such as *Cylindrocarpon, Phaeoacremonium,* and others, a concern that underscores the interplay of multiple environmental factors. In this sense, the use of resistant or tolerant rootstocks can manage this problem.

It is worth noting the distinct qualities of several rootstocks. The 101-14 Mgt variety provides substantial protection against *Phylloxera,* tends to reduce vigor, and might hasten maturation. Additionally, it adapts well to clayey soils that retain a high amount of water (Dry, 2007). On the other hand, the Paulsen 1103 variety boasts resistance to both *Xiphinema* and *Meloidogyne,* demonstrates moderate resistance to *Phylloxera* and *Fusarium* wilt, and adapts seamlessly to soils ranging from sandy to clayey. This variety also bestows medium to high vigor upon its scion (Giovannini, 2014). The Harmony variety is recognized for its moderate resistance to *Phylloxera* and nematodes and is well-suited for sandy soils, providing the grafted scion with moderate vigor (Leão et al., 2020). The IAC 572 variety stands out due to its resistance to a variety of diseases. It exhibits high vigor and shows versatility in its adaptability to different soil types (Pommer, 2000). Lastly, the 043-43 variety is resistant to *Fusarium* wilt and possesses a high tolerance to challenges posed by ground pearls and nematodes (Bernd et al., 2007).

Considering the significant impact of environmental variability and phytosanitary resistance, the synergy between canopy and rootstock is crucial in determining vine productivity and quality. Hence, field trials with different rootstocks in high-altitude areas are essential to discern their viticultural potential.

Given the above, this study aimed to identify the most suitable rootstock for enhancing the enological characteristics of the Sangiovese variety in the high-altitude region of Santa Catarina State, Brazil.

Materialsand Methods

Orchard characteristics

The vineyard was established in 2016 in the municipality of Água Doce - SC (26°42'33.8"S and 51°29'26.8"W; 1,250 meters above sea level) at the Villaggio Grando winery. The Sangiovese canopy variety was planted on five different rootstocks: '101-14 Mgt', 'Harmony', 'IAC 572', 'Paulsen 1103', and 'VR 043-43'. This vineyard was developed in an area previously unused for grape cultivation. The rootstock seedlings, obtained from a certified parent company, were transplanted 4 to 6 months before field grafting. The cleft grafting technique was utilized at the top of the rootstocks.

The vines were trained on a trellis system with spur-pruned bilateral cordons (pruned to two buds). The vineyard rows had a north-south orientation and were spaced at 2.9 meters apart with 1.2 meters between individual plants. This layout yielded a density of 2,874 plants per hectare. No artificial bud induction was used, allowing for natural sprouting. The topping was done once per cycle at the height of the last wire, which is approximately 2.1 meters. The canopy height was maintained at 1.20 meters (ranging from 0.90 to 2.10 meters from the ground). Defoliation was conducted immediately after the completion of flowering.

Climate and soil conditions

The region's climate, according to the Köppen classification, is type Cfb: mesothermal, humid, without a dry season, and with cool summers (Pessenti et al., 2021). The soil is a clayey dystrophic Red Nitosol. Monthly averages of rainfall and air temperature were sourced from the Água Doce weather station located at the Villaggio Grando winery via the Epagri/Ciram database (Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina [CIRAM], 2023) (Figure 1). It is noteworthy that the ÁguaDoce meteorological station did not have enough data to establish a climatological norm during this study. Thus, the data from 2018-2020 was compared to the climatological norm (1991-2020) from the adjacent Campo Novo/SC region.

Ciências Agrárias
SEMINA

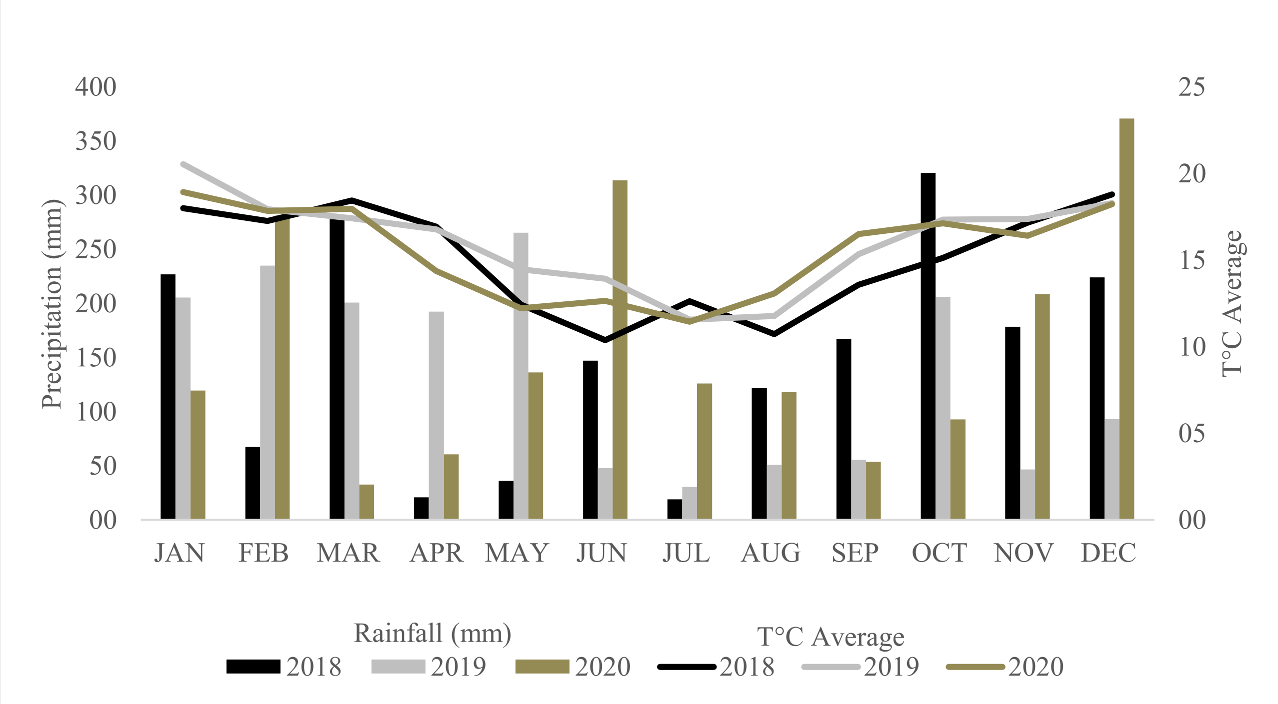

Figure 1. Monthly averages of air temperature and rainfall during the 2019 and 2020 harvests in Água Doce - SC / Brazil.

Plant material

Scions used for grafting were derived from the Sangiovese grape variety. This genotype is believed to have originated in Tuscany, Italy. It is characterized by semi-erect growth, considerable vigor, good fertility, and medium to high-weight grape clusters. The wines produced are intensely ruby-red with pronounced aromas of violets, red flowers, red fruits, and ripe plum. Their taste is velvety and smooth, yet structured.

Sangiovese is among the most cultivated varieties in Italy. When blended with Montepulciano or Cabernet Sauvignon, it results in wines with more stable aging coloration, heightened aromas, and acidity. This variety is the primary component in several wines with *Denominazione di Origine Controllata e Garantita* - DOCG (Controlled and Guaranteed Designation of Origin), like Brunello di Montalcino, Carmignano, Chianti, Chianti Classico, Vino Nobile di Montepulciano, among others. It also features in many wines with DOCG, such as Bardolino, Valpolicella, Sangiovese di Romagna, Montefalco, Rosso Piceno, Garda Orientale, and Valdadige (Calò et al., 2006).

Rootstocks for this experiment were selected based on their particular characteristics, including vigor, disease tolerance, and productivity. The varieties used are the following:

Variety 101-14 Mgt: A cross between *Vitis* riparia and *V. rupestris,* this variety was developed in France in 1882 by Alexis

Millardet and Charles de Grasset (Maul et al. 2020). It offers good phylloxera protection and is known for its ease of rooting and grafting success (Cousins, 2005). Its roots are well-branched but shallow, making it ideal for clayey soils but unsuited for dry soils (Dry, 2007). In combination with scion, it is known to reduce vigor and hasten ripening (Dry, 2007).

Variety IAC 572: A product of a three-way cross between *V. caribaea* and *V. riparia* x *V. rupestris* ('101-14 Mgt'), this variety was developed in 1954 at the Agronomic Institute of Campinas - IAC by Santos Neto (Camargo, 2003). It has a high success rate for rooting and survival after transplanting (Nachtigal, 2000). Additionally, it exhibits vigorous growth, adapts well to a variety of soils, including acidic and nutrient-depleted ones (Camargo, 2003; Pommer, 2000), and resists major diseases. This variety is frequently planted in southeastern Brazil (Camargo, 2003; Pommer, 2000).

Variety Paulsen 1103: Originating from southern Italy in 1895, this variety is a cross between *V. berlandieri* and *V. rupestris* (Jahnke et al., 2011). Vigorous and adaptable, it thrives in varied soil types (from sandy to clayey) and has optimal take rates for field and bench grafting, conferring moderate to high scion vigor (Camargo, 2003). It is resistant to drought, high humidity, active limestone (up to 20%), aluminum toxicity, and magnesium deficiency. The ideal pH range varies from 5.5 to 7.0. Moreover, the genotype has moderate resistance to phylloxera, *Xiphinema, Meloidogyne,* and *Fusarium* wilt (Christensen, 2003; Giovannini, 2014). It is recommended for American and hybrid cultivars grown in low to medium-fertility soils, as well as for vinifera cultivars in medium-fertility soils. Overall, it is the most recommended rootstock for the states of Rio Grande do Sul and Santa Catarina (Giovannini, 2014).

Variety Harmony: A hybrid between Solonis x Courdec 1613 and Dog Ridge (*V.champinii*) selections in 1955, Harmony shows moderate resistance to phylloxera and high resistance to nematodes. It is best suited to sandy soils and provides moderate vigor to scions (Leão et al., 2020).

Variety 043-43: A Californian release, this hybrid is between *V. vinifera* and *V. rotundifolia.* It has resistance to *Fusarium* wilt and high tolerance to root-knot nematodes and grape phylloxera (Bernd et al., 2007). Torregrosa and Bouquet (1995) noted a genetic incompatibility of the *V. rotundifolia* species (2n=40) as rootstock for commercial grapevine varieties (2n=38). This issue has been addressed through interspecific hybrids.

Experimental design

The experimental unit in the field was arranged using a completely randomized block design. It comprised four blocks, each containing six plots. In each plot, two plants were evaluated, leading to a total grape collection exceeding 40 kg for wine production. The experiment followed a completely randomized design with three repetitions. Each repetition involved a bottle selected at random for triplicate physical-chemical analyses. Treatments under study combined five rootstocks ('101-14 Mgt', 'Harmony', 'IAC 572', 'Paulsen 1103', and 'VR 043-43') and two vintages (2019 and 2020), i.e., harvest years, in a 2x5 bifactorial scheme.

Harvesting, grape processing, and vinification process

All the evaluated plots were harvested simultaneously, adhering to the harvesting schedule of the Villaggio Grando winery, during both the 2019 and 2020 seasons. Ripe grapes were handpicked, boxed, and promptly transported to the vinification facility. For each rootstock assessed, around 10-15 kg of Sangiovese grapes were harvested. Vinification took place at the experimental winery of Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI) located at the experimental station in Videira, SC/Brazil. Each rootstock's wines were produced individually for the two vintages.

Post the cold storage phase, 10kg of Sangiovese grapes from every evaluated rootstock were sent to the vinification facility, serving as the sample unit for vinification. The process began with destemming, followed by immediate pressing. Sulfur dioxide (SO_2) was introduced into the must at a concentration of 50mg.L^{-1} (Vino Aromax AEB Spa - Brescia, Italy), along with 20 g.hL^{-1} of selected yeast *Saccharomyces cerevisiae* PB2019 (Fermol Blanc-AEB - Brescia, Italy). Throughout the maceration phase, daily pumping over was done, and the temperature (maintained between 20°C and 24°C) and density were monitored. Once a density around 1020 was achieved, the wine underwent racking and was transferred for completing both alcoholic and malolactic fermentations in sealed containers equipped with a hydraulic valve. Subsequently, processes like transfers, SO_2 adjustments, tartaric stabilization, filtration, and bottling were executed.

Physicochemical parameters

Wine pH was directly ascertained using an AD1030® pH meter. Total acidity (TA) was measured by titrating the sample with a standardized 0.1N NaOH solution, reaching an endpoint of pH = 8.2, with results presented in mEq.L^{-1}. Using Cazenave-Ferré® equipment, the sample was distilled to determine the Volatile Acidity (VA); 100 mL of this distillate, combined with phenolphthalein, was titrated with 0.1N NaOH until a pink color appeared, indicating the endpoint, and results are shown in mEq.L^{-1}. The Gibertini® electronic oenological still was used post-distillation to gauge the alcohol content, expressed as a percentage (%). Reducing sugars (g/L^{1}) and density (g/cm^{3}) were determined using the DNS method described by Rizzon (2010) and an Aton Paar® glass densimeter, respectively. Both free and total SO_2 concentrations were deduced using the method proposed by Ripper (1892) and expressed in mg.L^{-1}. Ash content analyses followed the protocol of Rizzon (2010), with the results expressed in g/L^{1}.

For color measurements, a Konica Minolta CM-5 spectrophotometer was employed. The parameters included lightness (L* from black to white; 0-100) and chromatic coordinates a* (from red-purple to green-blue; a* to a*) and b* (from yellow to blue; b* to b*), in the horizontal and vertical axes, respectively. From these, chroma and hue were derived based on the formulas by McGuire (1992): C* = [(a*)2+(b*)2]1/2 and H° = tan^{-1} b*/a*. Total polyphenols (mg.L^{-1}), antioxidant activity (μmol.L^{-1}), and total anthocyanins (mg.L^{-1}) were determined through the Follin-Ciocalteu method (Singleton & Rossi, 1965), the DPPH method (Kim et al., 2002), and the differential pH method (Wrolstad, 1993), respectively. All spectrophotometric evaluations were conducted using a UV-2601 model spectrophotometer (Beijing Ray Leigh Analytical Instrument Co. Ltd., China).

Sensory parameters

Sensory evaluation was undertaken by a panel of ten judges, all of whom underwent prior training. The Ethics Committee for Research with Human Beings at the Federal University of Pelotas approved their participation, as reflected by protocol CAAE 62015922.0.0000.5317. To characterize each wine, five ISO glasses were used, each filled with wine from a distinct rootstock. These glasses were randomly arranged on the evaluation table and marked with a three-digit code. This procedure was replicated for both harvests, resulting in ten tastings per judge. The wine was assessed using a quantitative scale:

Two visual attributes were assessed, turbidity and color. Turbidity scores ranged from 0 (imperceptible) to 10 (very intense), while intensity scores were between 0 (low intensity) and 10 (high intensity). Olfactory attributes comprised aromas, such as red fruits and spices, and the presence of defects; for these traits, scores ranged from 0 (imperceptible) to 10 (very intense). Gustatory attributes included acidity, tannicity, bitterness, persistence, and aftertaste, with scores ranging from 0 (low) to 10 (extremely high). Allied to that, gustatory body perception was rated between 0 (light) and 10 (full). Finally, for the overall balance aspect, the scale spanned from 0 (extremely poor) to 10 (excellent).

Statistical analysis

Physicochemical parameters were subjected to analysis of variance (ANOVA). When treatment effects were significant, Tukey's test was applied to compare means at a 5% error probability. For the sensory parameters, data from all ten assessors were subjected to ANOVA. Any significant effects identified were further analyzed using the Tukey test to compare means at a 5% significance level.

Results and Discussion

The average temperatures during the evaluated period (Figure 1) closely resembled the climatological normal for the region (Figure 2). In 2018, average temperatures in May, June, and August saw a slight decline. Conversely, in 2019, April to July experienced slightly warmer temperatures. Average temperatures in 2020 closely resembled normal conditions. Regarding precipitation, 2018 witnessed reduced rainfall, except for January, March, October, November, and December. In 2019, a dry spell occurred from June to December, with October being the exception. This pattern repeated in 2020 from March to November, except for June. Nevertheless, the cycles remained quite similar, with consistent average temperatures and rainfall throughout the annual cycle.

The hydrogen potential exhibited no statistical differences among treatments, but differences emerged between the evaluated years. In the 2019/2020 harvest, there were higher pH, soluble solids, and titratable acidity levels post-harvest (Table 1). This variance could be attributed to climatic influences throughout the cycle, including elevated temperatures and precipitation in February and December (Figure 1), which aided grape maturation. Previous studies involving grapevines have also noted the impact of established edaphoclimatic conditions, such as those with 'Isabel Precoce' in the Western region of Paraná (Miranda et al., 2020).

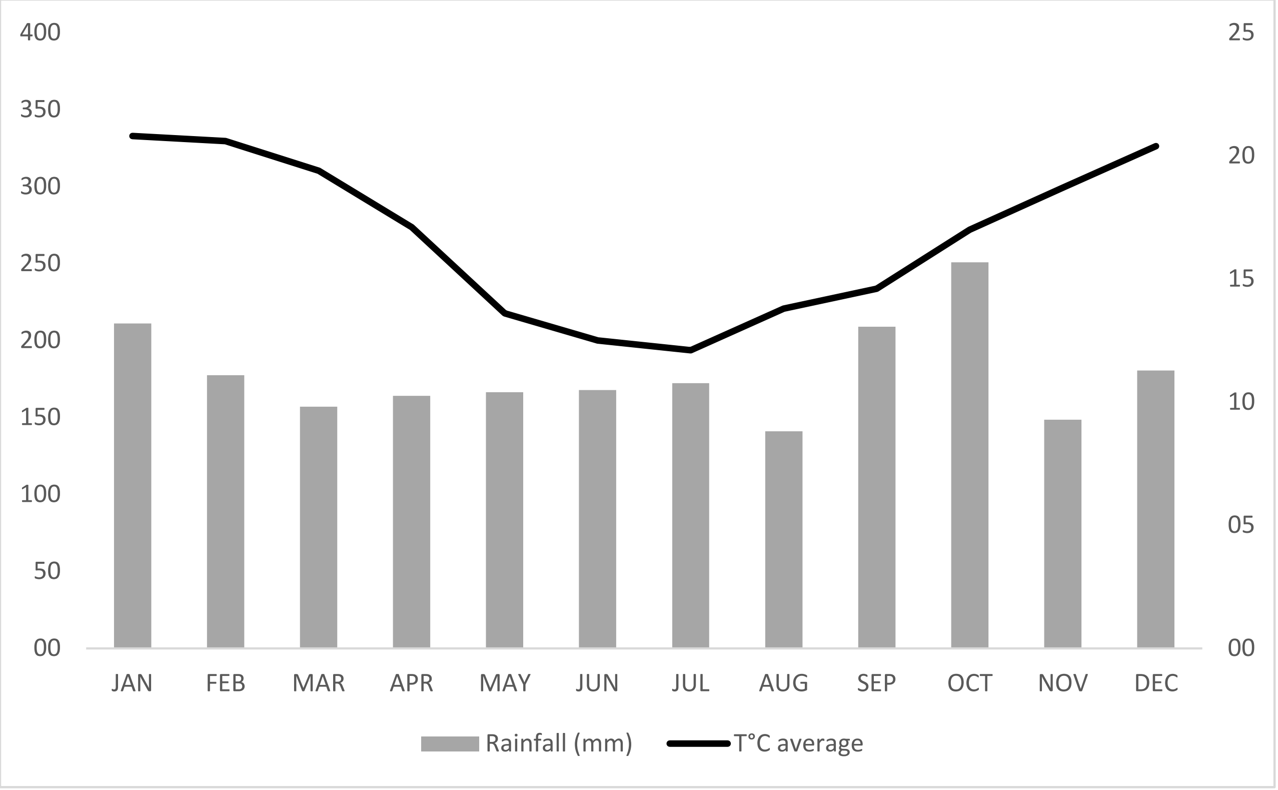

Figure 2. Climatological normals of rainfall (mm) and average temperatures (°C) sourced at the Campo Novo gauge station, Santa Catarina State, Brazil, from 1991 to 2020. (Instituto Nacional de Meteorologia [INMET], 2020).

Table 1
Physicochemical parameters of Sangiovese must as a function of the rootstock used for the 2018/19 and 2019/20 vintages

Rootstock[(1)]	pH	SS (°Brix)	TA	L	°Hue	C*
			2018/19			
'101-14 Mgt'	3.14^{ns}B	17.6aB	85.06bB	42.64^{ns}	11.98a ^{ns}	62.62^{ns}A
'Harmony'	3.13B	17.3abB	84.48bB	45.96	11.56a	60.47A
'IAC 572'	3.11B	16.2cB	86.86bB	47.62	9.87ab	58.91A
'Paulsen 1103'	3.14B	17.1bB	85.34bB	46.31	8.90b	60.30A
'VR 043-43'	3.11B	16.4cB	92.74aB	43.99	11.39a	62.09A
			2019/20			
'101-14 Mgt'	3.47^{ns}A	21.2aA	90.82bA	49.03ab ^{ns}	9.08b ^{ns}	56,05aB
'Harmony'	3.45A	21.1abA	90.76bA	48.50b	10,67ab	56,12aB
'IAC 572'	3.49A	20.5bA	92.04abA	46.84b	11.66a	53,29abB
'Paulsen 1103'	3.51A	20.7abA	88.61bA	55.29a	7.24b	48,44bB
'VR 043-43'	3.48A	20.5bA	96.54aA	49.06ab	9.47ab	53,36abB

[(1)] Means followed by the same lowercase letter in the column do not differ from each other by Tukey's test at 5% probability. ns - non-significant.

Soluble solids measured in the grape must (Table 1) reveal that the '101-14 Mgt' and 'Harmony' cultivars significantly outperformed others in both harvests, reaching an average of 16.9ºBrix in the first harvest and 20.8ºBrix in the second. These levels exceeded those found by Bender et al. (2019) in the Summit variety (14ºBrix). Post-harvest, the total titratable acidity in both harvests was noteworthy for the 043-43 variety, averaging 94.6, displaying higher acidity than the Summit variety studied by Bender et al. (2019) with an average of 62.6 across the evaluated harvests.

Regarding the coloration of the must, no significant differences were observed between the evaluated years, except for chroma, which indicates color saturation. The tested varieties, 101-14 Mgt, Paulsen 1103, and 043-43, exhibited higher luminosity in Sangiovese must, while hue and saturation were significant for all, except for 'Paulsen 1103'. Luzio et al. (2021) analyzed red varieties in the southern Mediterranean region of Portugal, ranging from 25.80 to 29.27 in luminosity values. A higher luminous intensity is evident in this experiment due to the edaphoclimatic conditions of the region, and the characteristics expressed by the Sangiovese variety.

The interaction between rootstock and vintage had a discernible impact on the physicochemical parameters post-vinification, except for pH, density, sugars, and ashes. These variables exhibited no statistically significant variations across treatments (Table 2), with no disparities established.

Ciências Agrárias
SEMINA

Table 2
Analytical characteristics of Sangiovese wines from different rootstocks and vintages. ÁguaDoce - SC / Brazil

Rootstock[1]	2019	2020	2019	2020	2019	2020
	TA		VA		Total SO_2	
'101-14 Mgt'	73.5cA	67.6bcB	8.6dA	7.6abB	31.6aB	43.8cA
'Harmony'	87.6abA	69.4abB	9.1cdA	7.2bB	38.2aA	32.5dB
'IAC 572'	81.3bA	67.0cB	9.4bcA	7.6abB	34.5aB	52.6bA
'Paulsen 1103'	89.7aA	68.7abcB	18.1aA	7.3bB	34.7aB	57.4aA
'VR 043-43'	70.5cA	69.5aA	9.9bA	8.2aB	32.3aA	33.1dA
	Free SO_2		Alcohol		Polyphenols	
'101-14 Mgt'	15.8bB	23.7bA	11.2aB	13.3aA	861.1abB	1251.5aA
'Harmony'	18.6bA	16.5cA	11.2aB	12.9abA	876.5abB	1297.7aA
'IAC 572'	23.5aB	27.8abA	11.1aB	12.0dA	965.0aB	1165.0aA
'Paulsen 1103'	18.4bB	30.6aA	10.9abB	12.5bcA	790.0bB	991.9bA
'VR 043-43'	16.9bA	16.7cA	10.6bB	12.3cdA	863.0abA	965.0bA
	Anthocyanins		Antioxidant activity		*L	
'101-14 Mgt'	0.402bB	1.710aA	12497abA	12995aA	79.3aA	72.0bB
'Harmony'	0.503aB	1.176cA	11217bcB	13462aA	76.9bA	67.1cB
'IAC 572'	0.542aB	1.351bA	13047aA	12522aB	73.3cB	76.9aA
'Paulsen 1103'	0.329cB	1.441bA	10857cA	9757cA	78.9abA	76.9aB
'VR 043-43'	0.373bcB	0.920dA	11550abcA	10975bA	79.8aA	73.0bB
	°Hue		C*			
'101-14 Mgt'	33.9aA	14.6bB	19.6cB	27.8bA		
'Harmony'	25.3bA	11.0cB	21.6bB	31.6aA		
'IAC 572'	21.8cA	16.9aB	23.9aA	20.2dB		
'Paulsen 1103'	34.0aA	17.2aB	18.5cB	21.2dA		
'VR 043-43'	32.9aA	16.2aB	18.3cB	23.8cA		

[1] Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ from each other by Tukey's test at 5% probability. ns - non-significant. TA - Titratable acidity ($mEq.L^{-1}$), VA - Volatile acidity ($mEq.L^{-1}$), Free and total SO_2 ($mg.L^{-1}$), Alcohol (%), Total anthocyanins ($mg.L^{-1}$), Total polyphenols ($mg.L^{-1}$), Antioxidant activity ($\mu mol.L^{-1}$), *L - lightness, C* - color intensity, hue angle (Hue).

Total acidity emerged as a differentiating factor among the assessed wines in the 2019 harvest. It was notably pronounced in the 'Paulsen 1103' and 'Harmony' rootstocks across both harvests. Yet, in 2020, 'VR 043-43' showed no significant differences in total acidity from the aforementioned rootstocks. Total acidity represents the concentration of organic acids found in both grapes and wines, and it is influenced by a variety of factors, including the physiological aspects of maturation, soil composition, climatic conditions, and agronomic practices. Specifically, cooler temperatures and heightened freshness during the harvest tend to increase total acidity in the wine produced (Chavarria et al., 2011).

Differences attributed to the harvest can be explained by the elevated precipitation in February 2020, which encouraged greater potassium (K) absorption by the roots, subsequently facilitating the conversion of tartaric acid and resulting in a reduction in total acidity (Pasquier et al., 2021). Additional contributing factors could include the grape maturation stage, malic acid content reductions during malolactic fermentation, and precipitation of tartrates (Rizzon et al., 2012). It is worth noting that the wines subjected to scrutiny adhere to the standards prescribed by Brazilian legislation, stipulating a minimum threshold of 40 and a maximum threshold of 130 mEq.L^{-1} (Lei nº 13.648, 2018).

Among the rootstocks evaluated, Harmony and Paulsen 1103 exhibited higher titratable acidity in both vintages, averaging 78.5 and 79.2mEq.L^{-1}, respectively. On the other hand,'IAC 572'had the lowest acidity in the 2019/2020 harvest (67.0 mEq.L^{-1}). Similarly, volatile acidity (Table 2) varied among the rootstocks in the 2019 harvest, with 'Paulsen 1103' showing the highest values. The 2019 vintage marked the vineyard's initial productive harvest, characterized by elevated rainfall accumulations that compromised grape health, consequently leading to an increase in volatile acidity in the wines. Volatile acids are formed during alcoholic fermentation and depend on the must composition, yeast strain, and fermentation conditions (Bayram & Kayalar, 2018). Brazilian regulations set a maximum limit of 20 mEq.L^{-1} for the table, fine, and noble wines (Instrução Normativa, 2018), and all the tested wines fell within these prescribed limits.

The 'Paulsen 1103' rootstock displays a medium to high level of canopy vigor (Giovannini, 2014). This vigor can lead to a delay in the phenological cycle due to prevailing climatic conditions, which in turn may impact alcohol concentration and sugar levels (Grigolo et al., 2021). The data for all grape varieties in this study adhere to the regulatory limits, where the threshold is set at 20 mEq.L^{-1} (Instrução Normativa, 2018). The low alcohol content of the wine could have amplified this limit. However, for sensory purposes, an acceptable limit is 12 mEq.L^{-1} (Ribéreau-Gayon et al., 2006), which can be subjected to the individual organoleptic perception of each taster. Notably, Goode (2022) has cautioned that a high concentration of volatile acids could be associated with acetic acid formation and the presence of bacteria (such as Acetobacter and Gluconobacter) during the fermentation in winemaking. Conversely, more vigorous rootstocks, which tend to delay the phenological cycle, may result in reduced sugar accumulation in berries and, consequently, lower alcohol concentration (Grigolo et al., 2021).

Concentrations of SO2 (Table 2) were noticeably diminished for all wines during the 2019 vintage. These reduced values may have increased the proliferation of bacteria that foster volatile acidity. An exception was noted in the wines from ‘Harmony’ rootstock, which had higher SO2 concentrations in 2019 compared to 2020. SO2 applications have a dual role: they protect wine from bacterial influence and inhibit the activity of oxidative enzymes, all the while acting as an antioxidant agent (Diniz et al., 2010). The ideal dose to be applied may vary depending on factors such as plant health, ambient temperature, sugar content, and pH of must or wine (Bortoletto et al., 2015). Free SO2is crucial in its role as a protective agent, and it is recommended to maintain an optimal concentration of around 30 $mg.L^{-1}$ for preservation (Silva et al., 2015). As an example, the 'Paulsen 1103' rootstock displayed a concentration of 30.6 $mg.L^{-1}$ in the 2019/2020 vintage; therefore, the dosage applied to wines might have been higher during the 2019 vintage, possibly due to the health condition of grapevines.

In the 2019 vintage, wines across various rootstocks had lower alcohol content (Table 2). In 2020, 'IAC 572' wines showed reduced alcohol content compared to the 2019 vintage but higher levels when compared to 2018/2019, without statistical distinction from ‘VR 043-43’. It is noteworthy that the vintage's impact on rootstocks is influenced by climatic conditions affecting grape maturation. The vintage in question experienced the least solar radiation duration (Pedro-Júnior et al., 2020). Since these were the initial plants, this could be due to the juvenile phase influencing the accumulation of soluble solids, as photoassimilates were preferentially allocated to plant establishment (Dalbó & Feldberg, 2019).

In terms of the impact of rootstocks on wine characteristics, 'IAC 572' and 'VR 043-43' emerge as strong contenders, lengthening the grapevine's growth cycle. This characteristic can result in reduced sugar accumulation in grapes and, consequently, wines with lower alcohol levels (Grigolo et al., 2021). Nonetheless, it is worth noting that the wines produced from the studied rootstocks remained within the allowable alcohol content range specified by Brazilian regulations, which falls between 8.6% and 14% for fine and table wines (Lei nº 13.648, 2018).

Moving on to polyphenol contents (Table 2), wines from all rootstocks exhibited higher concentrations in the 2020 harvest. Notably, 'Paulsen 1103' and 'VR 043-43' displayed the lowest polyphenol concentrations in this vintage. 'Paulsen 1103' consistently showed the least polyphenol concentration across both vintages, averaging at 890.9 $mg.L^{-1}$, followed by 'VR 043-43' with 914.0 $mg.L^{-1}$. These polyphenolic compounds are mainly found in grape skins and seeds and significantly influence sensory aspects such as color, flavor, texture, structural characteristics, and functional attributes in wines. Furthermore, their evolution during aging can be influenced by factors such as climate, atmospheric conditions, soil properties, grape variety, and winemaking techniques (Felippeto et al., 2020).

Regarding total anthocyanins (Table 2), wines from all rootstocks showed an increase in the 2020 harvest, with the lowest concentrations observed in 'VR 043-43' wines during both vintages, averaging at 0.6465 $mg.L^{-1}$. In contrast, '101-14 Mgt' exhibited the highest anthocyanin concentration in both vintages, averaging at 0.8552 $mg.L^{-1}$. This observation may be attributed to the adaptability of rootstocks to environmental conditions, potentially affecting the synthesis of anthocyanins (Pozzan et al., 2012). Additionally, the stability of anthocyanins depends on several factors related to cultivation, climate conditions, processing, pH, and storage temperature (Pessenti et al., 2021).

When it comes to antioxidant activity (Table 2), minimal variation was observed across vintages, except in wines from 'Harmony' and 'IAC 572' rootstocks. Among wines derived from the 'Paulsen 1103' rootstock, both the 2019 and 2020 vintages displayed the lowest antioxidant activity. The antioxidant capacity of wines is determined by a complex mix of antioxidant compounds, which encompass anthocyanins, proanthocyanidins, and phenolic acids like catechin, epicatechin, rutin, quercetin, and others. Their composition depends on vine metabolism, growing conditions, and winemaking processes (Nemzer et al., 2021). These compounds play a significant role in wine color and its transformation during aging.

In terms of color parameters (Table 2), luminosity (*L) decreased in wines from the 2020 harvest, except 'IAC 572', which exhibited lower luminosity in 2019, indicating darker wines. This observation is consistent with the color angle (Hue°), which showed that wines in the 2020 harvest had a more subdued hue, aligning closely with the 0° axis (red). This outcome is in line with the higher anthocyanin concentration observed in the 2020 harvest, as anthocyanins from the polyphenol group contribute to red hues in wines (Pessenti et al., 2021). However, wines from all rootstocks generally displayed increased color intensity in the 2020 harvest, as evidenced by saturation assessments, except for 'IAC 572', which showed lower color intensity (*C). Additionally, 'Paulsen 1103' exhibited lower saturation compared to the other rootstocks across both vintages. Wine color can be influenced by factors such as pigments, pH, and SO_2 concentration, as these factors can affect anthocyanin color (Escobar et al., 2021).

As for sensory parameters, there were no significant differences observed in terms of olfactory aspects (red fruits, defects, and spices), gustatory dimensions (acidity, tannicity, persistence, and body), and overall appearance balance. However, distinct variations were noted in visual attributes related to color intensity and turbidity, as well as in gustatory aspects of bitterness and aftertaste (Table 3). Notably, the sensory attribute of color intensity showed differences among wines originating from various rootstocks during the 2019 vintage, with 'IAC 572' wines receiving the highest scores, statistically similar to '101-14 Mgt' and 'Harmony' wines in that particular vintage. In 2020, no such differences were observed among wines from different rootstocks; however, when considering the vintages, wines from the 'IAC 572' rootstock received lower scores in 2020 compared to the 2019 vintage, while wines from 'VR 043-43' received higher scores in 2020.

It is essential to recognize that color is a crucial factor in determining the quality of red wines. Sangiovese wines are known for their unique pigment composition, characterized by relatively lower anthocyanin content compared to other grape varieties (Arapitsas et al., 2012). Color intensity variations in wines during the 2019 harvest, as perceived by the panel, could potentially be attributed to plant immaturity. It is plausible to consider that this phenomenon was not replicated in the subsequent harvest, as wines exhibited similarity in color.

Turbidity exhibited differences solely between the harvests, with notably higher scores observed in the 2019 harvest. However, this difference was absent in wines from the 'Harmony' and 'VR 043-43' rootstocks, which displayed consistent turbidity across harvests. The 2019 vintage was characterized by unfavorable climatic conditions, including frequent rainfall during the harvest and ripening period, which could have compromised grape health and consequently impacted wine protein stability. It is worth noting that the majority of proteins in wine originate from grape pulp (Pasquier et al., 2021).

In terms of gustatory attributes, bitterness, and aftertaste showed no variation among wines sourced from the different rootstocks. However, a difference was observed only between vintages for wines from the '101-14 Mgt' rootstock in 2020, where a lower bitterness score was noted, and for 'VR 043-43' in 2019, which was marked by a reduced aftertaste score. A key determinant of wine quality lies in the composition of phenolic compounds, which contribute to astringency, bitterness, and color (Canuti et al., 2020). While wines from the 2020 harvest displayed an increased concentration of these compounds, the perception of bitterness and aftertaste may also be influenced by olfactory attributes, sweetness, and alcohol content (Lesschaeve & Noble, 2005).

In summary, the assessment of Sangiovese wines highlights the influence of the harvest on wine quality. However, the use of specific rootstocks can enhance wine quality by affecting the growth cycle of grapevines and adaptation to local environmental conditions. Notably, rootstocks with lower vigor, such as '101-14 Mgt' and 'Harmony', contributed to higher alcohol concentrations, polyphenol accumulation, and antioxidant activity. These rootstocks exhibit the unique trait of extending the growth cycle of grapevines (Nardello et al., 2022), which aligns well with the consistent rainfall patterns at ripening and harvesting in the high-altitude regions of Santa Catarina.

Table 3
Sensory parameters of Sangiovese cultivar wine as a function of the rootstock used for the 2019 and 2020 vintages

Rootstock[1]	2019	2020	2019	2020	2019	2020
	Visual aspects				Overall appearance	
	Color intensity		Turbidity		Balance	
'101-14 Mgt'	5.91abA	6.03aA	2.22aA	1.08aB	6.65ns	6.47ns
'Harmony'	6.62abA	6.91aA	1.91aA	1.15aA	6.79	6.74
'IAC 572'	7.22aA	5.92aB	3.41aA	1.14aB	6.65	6.98
'Paulsen 1103'	5.15bA	5.28aA	2.45aA	1.04aB	6.23	6.56
'VR 043-43'	5.00bB	6.70aA	1.79aA	1.19aA	5.77	6.45
	Olfactory Aspects					
	Red fruits		Defects		Spices	
'101-14 Mgt'	5.91ns	5.80ns	4.72ns	5.58ns	1.75ns	0.50ns
'Harmony'	6.40	5.91	5.62	4.93	1.08	0.66
'IAC 572'	6.33	5.98	5.12	4.75	0.91	0.47
'Paulsen 1103'	6.10	6.24	5.08	4.99	2.35	1.19
'VR 043-43'	6.20	6.06	3.92	5.52	1.77	0.66
	Gustatory aspects					
	Acidity		Tannicity		Bitterness	
'101-14 Mgt'	5.40ns	5.55ns	6.29ns	5.91ns	4.44aA	3.04aB
'Harmony'	5.66	5.34	6.64	6.40	4.20aA	3.54aA
'IAC 572'	4.87	5.32	6.30	5.79	3.95aA	3.30aA
'Paulsen 1103'	5.12	5.90	4.95	5.43	3.50aA	3.14aA
'VR 043-43'	5.48	5.44	5.76	6.16	4.13aA	3.30aA
	Persistence		Body		Aftertaste	
'101-14 Mgt'	5.92ns	5.84ns	5.51ns	5.98ns	5.45aA	5.70aA
'Harmony'	6.22	6.45	5.94	6.55	5.43aA	5.92aA
'IAC 572'	6.66	6.20	6.00	5.60	5.76aA	5.47aA
'Paulsen 1103'	5.37	5.97	5.14	5.27	5.60aA	5.70aA
'VR 043-43'	5.28	5.96	4.91	5.79	4.60aB	6.02aA

[1] Means followed by the same lowercase letter in the column or uppercase in the row do not differ from each other by Tukey's test at 5% probability. ns - non-significant.

Conclusions

From a sensory perspective, using different rootstocks for Sangiovese cultivation does not fundamentally alter wine balance. However, it maintains compliance with legal standards while showcasing distinct terroir characteristics. The wines consistently featured a high level of soluble solids, with an average of 18.9 ºBrix across rootstocks and vintages.

The '101-14 Mgt' and 'Harmony' rootstocks excelled in this experiment, with 'Harmony' particularly standing out. These rootstocks promoted increasing alcohol and phenolic compound contents in Sangiovese wines, which are crucial for the sensory appreciation of consumers.

References

Arapitsas, P., Perenzoni, D., Nicolini, G., & Mattivi, F. (2012). Study of sangiovese wines pigment profile by UHPLC-MS/MS. *Journal of Agricultural and Food Chemistry, 60*(42), 10461-10471. doi: 10.1021/jf302617e

Bayram, M., & Kayalar, M. (2018). White wines from narince grapes: impact of two different grape provenances on phenolic and volatile composition. *OENO One, 52*(1), 81-92. doi: 10.20870/oeno-one.2018.52.1.2045

Bender, A., Souza, A. L. K., Caliari, V., Souza, E. L., Malgarim, M. B., & Camargo, S. S. (2019). Physicochemical characteristics of whole grape juices elaborated from Vitis rotundifolia species. *Brazilian Journal of Food Technology, 22*(2019), e2018310. doi: 10.1590/1981-6723.31018

Bernd, R. B., Trivilin, A. P., Camargo, U. A. & Czermainski, A. B. C. (2007). Micro propagation of hybrids of *Vitis labrusca* x *Vitis rotundifolia* rootstocks with resistance to perola-da-terra (*Eurhizococcu brasiliensis* Hempel, Hemiptera: Margarodidae). *Revista Brasileira de Fruticultura. 29*(2), 350-354. doi: 10.1590/S0100-29452007000200031

Bortoletto, A. M., Alcarde, A. R., Carazzato, C., Mendonça, J. A., & Scarpare-Filho, J. A. (2015). *Produção de vinho de qualidade.* ESALQ.

Caliari, V. (2018). *Uva e vinho.* EPAGRI/Cepa. (Síntese Anual 2017-2018).

Calò, A., Scienza, A., &Costacurta, A. (2006). *Vitignid'Italia* (2nd ed.). Edagricole-New Business Media.

Camargo, U. A. (2003). Porta-enxertos e cultivares de videira. In G. B. Kuhn (Org.), *Uvas viníferas para processamento em regiões de clima temperado* (pp. 167-170). Brasília.

Canuti, V., Cantu, A., Picchi, M., Lerno, L. A., Tanabe, C. K., Zanoni, B., Heymann, H., & Ebeler, S. E. (2020). Evaluation of the intrinsic and perceived quality of sangiovese wines from California and Italy. *Foods, 9*(8), 1088. doi: 10.3390/foods9081088

Chavarria, G., Santos, H. P. D., Zanus, M. C., Marodin, G. A. B., & Zorzan, C. (2011). Cobertura plástica sobre o vinhedo e suas influências nas características físico-químicas do mosto e do vinho. *Revista Brasileira de Fruticultura, 33*(3), 809-815. doi: 10.1590/s0100-29452011000300014

Christensen, L. P. (2003). Rootstockselection. In L. J. Bettiga (Ed.), *Wine grape varieties in California* (pp. 12-15). Oakland: University of California (System), Division of Agriculture and Natural Resources.

Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina (2023). *Dados climáticos para a região de água doce.* CIRAM. https://ciram.epagri.sc.gov.br/index.php/solucoes/ tempo-e-clima/

Costa, F. S. (2020). Análise mensal - uva industrial. Cia. Nac. Abast. CONAB. http://www.conab.gov.br

Cousins, P. (2005). Evolution, genetics, and breeding: viticultural applications of the origins of our rootstocks. *Proceeding of the 2005 Rootstock Symposium,* Osage Beach, MO, USA.

Dalbó, M. A., & Feldberg, N. P. (2019). Comportamento agronômico de porta-enxertos de videira com resistência ao declínio de plantas jovens nas condições do estado de Santa Catarina. *Agropecuária Catarinense, 32*(2), 68-72. doi: 10.22491/RAC.2019.v32n2.10

Diniz, B. C. R., Araújo, A. J. B., Oliveira, V. S., Oliveira, J. B., Costa, T. R., Nascimento, R. L., Quintino, C., Alves, L. A., & Pereira, G. E. (2010). Evolução das características físico-químicas de vinhos Syrah no Submédio do Vale do São Francisco. *Anais da Jornada de Iniciação Científica da Embrapa Semiárido,* Petrolina, PE, Brazil.

Dry, N. (2007). *Grapevine rootstocks: selection and management for south Australian Vineyard.* Lythrum Press.

Escobar, R. G., González, M. J. A., & Villar, E. C. (2021). Wine polyphenol content and its influence on wine quality and properties: a review. *Molecules, 26*(3), 718. doi: 10.3390/molecules26030718

Felippeto, J., Caliari, V., & Guerra, C. C. (2020). Perfil físico-químico dos vinhos finos produzidos nas regiões de altitude de Santa Catarina. In C. Pandolfo, & L. F. de N. Vianna (Orgs.), *Vinhos de altitude de Santa Catarina* (pp. 171-179). Florianópolis.

Giovannini, E. (2014). *Manual de viticultura* (Série Tekne). Bookman.

Goode, J. (2022). *Regenerative viticulture.* Kindle Edition.

Grigolo, C. R., Citadin, I., Feldberg, N. P., Scariotto, S., Pertille, R. H., Santos, E. P., & Takeshita, K. C. C. (2021). Compatibility and initial development of grapevines 'BRS Magna' grafted on different rootstocks. *Ciência Rural, 51*(7), e20200913. doi: 10.1590/0103-8478cr202190939

Instituto Brasileiro de Geografia e Estatística (2023). *Produção agropecuária do Brasil.* https://www.ibge.gov.br/explica/producao-agropecuaria/uva/br

Instituto Nacional de Meteorologia (2020). Normais climatológicas do Brasil período de 1991 - 2020. https:// portal.inmet.gov.br/normais

Instrução Normativa N° 14, Ministério da Agricultura, Pecuária e Abastecimento (2018). Fica estabelecido a complementação dos padrões de identidade e qualidade do vinho e derivados da uva e do vinho.

DOU, 09/03/2018, seção 4. https://www.agricultura.rs.gov.br/upload/arquivos/202008/17121016-instrucao-normativa-14-de-2018-piqs-vinhos-e-derivados-da-uva-e-do-vinho.pdf

Jahnke, G., Molnár, G. K., Májer, J., Szöke, B., Tarczal, E., Varga, P., & Kocsis, L. (2011). Analysis of grape rootstocks by SSR markers. *Journal International dês Sciences de la Vigne et du Vin, 45*(3), 199-210.

Kim, D. O., Lee, K. W., Lee, H. J., & Lee, C. Y. (2002). Vitamin C equivalent antioxidant capacity (VCEAC) of phenolic phytochemicals. *Journal of Agricultural and Food Chemistry, 50*(13), 3713-3717. doi: 10. 1021/jf020071c

Leão, P. C. de S., Chaves, A. R. de M., & Silva, D. J. (2020). *Porta-enxertos e sua influência na produtividade e desempenho agronômico de videiras 'Syrah' e 'Chenin Blanc' no Vale do São Francisco.* (Circular Técnica, 125). EMBRAPA Semiárido.

Lei nº 13.648, de Abril de 2018. Dispõe sobre a produção de polpa e suco de frutas artesanais em estabelecimento familiar rural e altera a Lei nº8.918, de 14 de julho de 1994. http://www.planalto.gov.br/ ccivil_03/_Ato2015-2018/2018/Lei/L13648.htm

Lesschaeve, I., & Noble, A. C. (2005). Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. *The American Journal of Clinical Nutrition, 81*(1), 330-335. doi: 10.1093/ajcn/81.1.330S

Li, M., Guo, Z., Jia, N., Yuan, J., Han, B., Yin, Y., Sun, Y., Liu, C., & Zhao, S. (2019). Evaluation of eight rootstocks on the growth and berry quality of 'Marselan' grapevines. *Scientia Horticulturae, 248*(2019), 58-61. doi: 10.1016/j.scienta.2018.12.050

Luzio, A., Bernardo, S., Correia, C., Moutinho-Pereira, J., & Dinis, L. T. (2021). Phytochemical screening and antioxidant activity on berry, skin, pulp and seed from seven red Mediterranean grapevine varieties (Vitis vinifera L.) treated with kaolin foliar sunscreen. *Scientia Horticulturae, 281*(2021), 109962. doi: 10.1016/j.scienta.2021.109962

Malinovski, L. I., Welter, L. J., Brighenti, A. F., Vieira, H. J., Guerra, M. P., & Silva, A. L. da. (2012). Highlands of Santa Catarina/Brazil: a region with high potential for wine production. *Acta Horticulturae, 933*(1), 433-439. doi: 10.17660/ActaHortic.2012.933.57

Maul, E., Röckel, F., & Töpfer, R. (2020). *Wiederentdecktetraditionelle Rebsorten und die Einordnung ihrer geographischenund zeitlichen Entstehung.* Deutsches Weinbau-Jahrbuch.

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience, 27*(12), 1254-1255. doi: 10.21273/hortsci.27.12.1254

Miranda, J., Detoni, A. M., Lima, C. S. M., Forlin, D., & Cottica, S. M. (2020). Microclimatic characteristics on behavior agronomic and qualitative of 'Isabel precose' grapes in different driving systems in Santa Tereza do Oeste - PR. *Brazilian Journal of Development, 6*(7), 1-32. doi: 10.34117/bjdv6n7-821

Nachtigal, J.C. (2000). Propagação e instalação da cultura da videira. In A. C. Boliani, & L. de S. Corrêa (Orgs.), *Cultura de uvas de mesa - do plantio à comercialização* (pp. 81-106). Jaboticabal.

Nardello, I. C., Souza, A. L. K. de, Pasa, M. da S., Dalbó, M. A., & Malgarim, M. B. (2022). Initial performance of 'Rebo' wine grapes on different rootstocks and at various planting densities. *Pesquisa Agropecuária Brasileira, 57*(2022), e02426. doi: 10.1590/S1678-3921.pab2022.v57.00009

Nemzer, B., Kalita, D., Yashin, A. Y., & Yashin, Y. I. (2021). Chemical composition and polyphenolic compounds of red wines: their antioxidant activities and effects on human health a review. *Beverages, 8*(1), 1-18. doi: 10.3390/beverages8010001

Pasquier, G., Feilhes, C., Dufourcq, T., & Geffroy, O. (2021). Potential contribution of climate change to the protein haze of white wines from the French Southwest region. *Foods, 10*(6), 1355. doi: 10.3390/foods 10061355

Pedro-Júnior, M. J., Hernandes, J. L., & Silva, T. S. (2020). Maturação de uvas rústicas cultivadas em safras sequenciais de verão-inverno e sua relação com a pluviosidade. *Scientia Vitae, 10*(31), 23-37. doi: 10.23876/svitae.v10i2.1512

Pessenti, I. L., Ayub, R. A., Melo, H. F., Martins, W. S., Wiecheteck, L. H., & Botelho, R. V. (2021). Qualidade fenólica em cultivares de uvas submetidas à poda verde e regulador hormonal. *Research, Society and Development, 10*(4), e39310414227. doi: 10.33448/rsd-v10i4.14227

Pommer, C. V. (2000). Cultivares de uva produzidos ou introduzidos pelo IAC. In A. C. Boliani, & L. de S. Corrêa (Orgs.), *Cultura de uvas de mesa - do plantio à comercialização* (pp. 51-68). Jaboticabal.

Porro, D., & Stefanini, M. (2016). *Tecnologias para o desenvolvimento da vitivinicultura de Santa Catarina: relatório das atividades desenvolvidas.* EPAGRI.

Pozzan, M. S. V., Braga, G. C., & Salibe, A. B. (2012). Teores de antocianinas, fenóis totais, taninos e ácido ascórbico em uva "bordô" sobre diferentes porta-enxertos. *Revista Ceres, 59*(6), 701-708. doi: 10.1590/S0034-737X2012000600006

Puccioni, S., Zombardo, A., Epifani, A. M., & Giannetti, F. (2013). Caratterizzazione della composizione fenólica di vini rossi da varietá autóctone toscane. *Rivista Internet di Viticoltura ed Enologia, 7*(1), 1-7. doi: 10.5281/zenodo.59623

Ribéreau-Gayon, P., Dubourdieu, D., Donèche, B., & Lonvaud, A. (2006). *Handbook of enology: the chemistry of wine and stabilization and treatments* (2nd ed.). Wiley and Sons.

Rinaldi, A., Moine, V., & Moio, L. (2020). Astringency subqualities and sensory perception of Tuscan Sangiovese wines. *One one, 54*(1), 75-85. doi: 10.3390/oenology2010007

Ripper, M. (1892). Die schweflige Säure im Weine und deren Bestimmung. *JournalfürPraktische Chemie, 46*(1), 428-473. doi: 10.1002/prac.18920460132

Rizzon, L. A. (2010). Metodologia para análise de vinho. EMBRAPA.

Rizzon, L. A., Miele, A., & Scopel, G. (2012). Características analíticas de vinhos Riesling Itálico da Serra Gaúcha. *Current Agricultural Science and Technology, 17*(2), 273-276. doi: 10.18363/rvst.v17 i0.1509

Rossdeutsch, L., Schreiner, R. P., Skinkis, P. A., & Deluc, L. (2021). Nitrate uptake and transport properties of two grapevine rootstocks with varying vigor. *Frontiers in Plant Science, 11*(2020), 1-15. doi: 10.3389/fpls.2020.608813

Silva, M. J. R. da, Tecchio, M. A., Moura, M. F., Brunelli, L. T., Imaizumi, V. M., & Venturini, W. G., Fº. (2015). Composição físico-química do mosto e do vinho branco de cultivares de videiras em resposta a porta-enxertos. *Pesquisa Agropecuária Brasileira, 50*(11), 1105-1113. doi: 10.1590/S0100-204X201500 1200011

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture, 16*(1), 144-158. doi: 10.5344/ajev.1965.16. 3.144

Torregrosa, L. & Bouquet, A. (1995). In vitro propagation of Vits x Muscadinia hybrids by microcuttings or axillary budding. *Vitis, 34*(4), 237-238. http://www.core. ac.uk/reader/235692480

Wrolstad, R. E. (1993). *Color and pigment analyses in fruit products.* Oregon Agricultural Experimental Station.

Zanus, M. C. (2015). Panorama da vitivinicultura brasileira. *Anais do Congresso Latino-americano de Viticultura e Enologia, Congresso Brasileiro de Viticultura e Enologia,* Bento Gonçalves, RS, Brasil, 15, 8.