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Influência de diferentes porta-enxertos nas características de vinhos Vermentino em altitude de Santa Catarina

Influence of different rootstocks on the characteristics of Vermentino wines at altitudes in Santa Catarina

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O objetivo deste estudo foi determinar o melhor porta-enxerto que aprimora as características enológicas da variedade de uva Vermentino cultivada na região de alta altitude de Santa Catarina ao longo de três safras (2018, 2019 e 2020). Quatro porta-enxertos foram avaliados: '101-14 Mgt', 'Harmony', 'Paulsen 1103' e 'VR 043-43'. As propriedades físico-químicas e sensoriais dos vinhos foram analisadas.Os resultados revelaram que os porta-enxertos '101-14 Mgt', 'Harmony', 'Paulsen 1103' e 'VR 043-43' produziram vinhos com a menor acidez total na safra de 2019. O teor alcoólico foi notavelmente mais baixo nos vinhos produzidos com 'VR 043-43' em 2021. A análise sensorial indicou que os vinhos feitos com os porta-enxertos '101-14 Mgt' e 'Harmony' na safra de 2019 apresentaram maior turbidez. O caráter herbáceo foi mais pronunciado na safra de 2019, com um aroma herbáceo mais intenso, independentemente do porta-enxerto utilizado. Os níveis de acidez foram mais altos nos vinhos da safra de 2021, particularmente naqueles produzidos com os porta-enxertos 'Harmony' e 'VR043-43'.
Palavras-chave: *Vitis vinifera*, enologia, alta altitude.

The objective of this study was to determine the best rootstock that enhances the enological characteristics of the Vermentino grape variety cultivated in the high-altitude region of Santa Catarina, Brazil, over three vintages (2018, 2019, and 2020). Four rootstocks were evaluated: '101-14 Mgt', 'Harmony', 'Paulsen 1103', and 'VR 043-43'. The physicochemical and sensory properties of the wines were assessed. The findings revealed that the rootstocks '101-14 Mgt', 'Harmony', 'Paulsen 1103', and 'VR 043-43' produced wines with the lowest total acidity in the 2019 vintage. The alcohol content was notably lower in wines produced with 'VR 043-43' in 2021. Sensory analysis indicated that wines made with the '101-14 Mgt' and 'Harmony' rootstocks in the 2019 vintage exhibited higher turbidity. The herbaceous character was most pronounced in the 2019 vintage, with a stronger herbaceous aroma regardless of the rootstock used. Acidity levels were highest in the wines from the 2021 vintage, particularly in those made with the 'Harmony' and 'VR043-43' rootstocks.
Keywords: *Vitis vinifera*, enology, high altitude.

1. INTRODUCTION

In Brazil, grapevine cultivation plays a significant role across various markets, ranging from small family farmers to the development of wine and gastronomic tourism. It serves as a significant tool for supporting family agriculture and territorial development. Approximately 30,000 families rely on grape production as their primary source of income, which includes table grapes, fine wines, sparkling wines, and vinegar [1]. Moreover, wine holds a strong cultural significance, deeply rooted in Brazilian heritage and tradition [2].

Santa Catarina state stands out as the fifth largest grape producer in Brazil and the second largest processor of wines and musts. Most of the production is concentrated in the Vale do Rio do Peixe and Vales da Goethe regions, where common grapes (*Vitis labrusca*) and hybrids are extensively cultivated due to their ease of management [3]. However, there's been a rising trend in the cultivation of fine grapes (*Vitis vinifera*) for producing high-quality wines and sparkling

wines, especially in high-altitude regions, to meet the increasing demand in Brazil [3].

The high-altitude regions of Santa Catarina are among the premier areas in Brazil for cultivating vinifera grapes intended to produce fine wines and sparkling wines. These regions confer unique characteristics to the wines, setting them apart from other wine-producing areas in the country, thereby facilitating the production of high-quality products with notable enological potential [4, 5]. Within this context, policies promoting the development of high-altitude viticulture in Santa Catarina have enabled the introduction of Italian grape varieties known for their promising agronomic and enological attributes [6]. Therefore, it is essential to investigate the compatibility of each grape variety with various rootstocks and their subsequent impact on the final wine quality.

Vermentino variety, cultivated in Santa Catarina, demonstrates medium to high yields with large clusters of medium to high weight. The wines produced from this variety exhibit a straw-yellow color with greenish reflections, accompanied by fine and delicate aromas, and a subtle bitter note [6]. However, when introducing new varieties, it is imperative to consider not only their adaptation to the edaphoclimatic conditions influenced by the rootstock but also the specific attributes the rootstock imparts on the wines, as these factors significantly affect the plant's overall development [7].

High-quality wines originate from quality grapes, which depend on various edaphoclimatic and cultivation factors [8]. Chemical composition of wine is highly variable, consisting of water (approximately 85%) and ethanol (approximately 12%), produced by yeasts during the fermentation process. The remaining 3% consists of a multitude of other compounds [9], which are all influenced by various factors, including the interaction between the canopy and rootstock [7].

Typically, the selection of a rootstock is based on its specific attributes, such as tolerance to fungi and nematodes, soil properties, cultivation conditions, and production objectives. However, the characteristics that this interaction impacts on the canopy and, consequently, on the grape and wine must also be considered [10]. The vigor of the above-ground part of the plant, influenced by the rootstock, is crucial as it is closely tied to fruit productivity and quality, potentially affecting the composition of sugars and phenolic compounds in the fruit [11].

In this regard, the aim of this study is to identify the rootstock that best enhances the enological characteristics of the Vermentino variety cultivated in the high-altitude region of Santa Catarina.

2. MATERIAL AND METHODS

The vineyard was established in 2016 in the municipality of Água Doce, Santa Catarina (26°42'33.8"S and 51°29'26.8"W; 1250 meters above sea level), at the Villaggio Grando winery. It consists of the Vermentino grape variety grafted onto four different rootstocks (101-14 Mgt, Harmony, Paulsen 1103, and VR 043-43). The plants were trained using a trellis system with spur-pruned cordons, spaced 2.9 meters between rows and 1.2 meters between plants, resulting in a population density of 2,874 plants per hectare. The region has a Cfb climate classification according to the Köppen system, characterized as mesothermal, humid, without a dry season, and with a cool summer [12].

Monthly averages of precipitation and air temperature were collected from the onset of berry color change until maturity using the weather station located at Villaggio Grando winery in Água Doce, based on the Epagri/Ciram database (Figure 1).

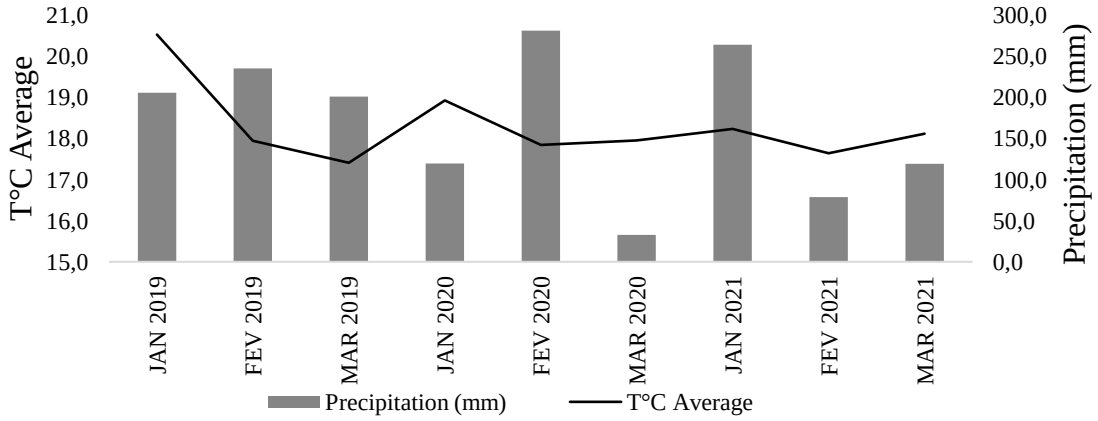

Figure 1: Monthly means of air temperature and precipitation during the grape maturation period in the 2019, 2020, and 2021 harvests. Água Doce - SC / Brazil.

The wines were produced in the 2019, 2020, and 2021 vintages at the experimental winery of Epagri - Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, at the Videira Experimental Station, located in Videira, Santa Catarina, Brazil. Vinifications were carried out individually for each rootstock.

The grapes were manually harvested and stored in a cold room at 2°C for 24 hours. Following this period, destemming and immediate pressing were conducted. The must was subjected to cold settling with bentonite (AEB Spa - Brescia, Italy) for 24 hours, followed by inoculation with selected yeast *Saccharomyces cerevisiae* PB2019 (Fermol Blanc-AEB - Brescia, Italy). Alcoholic fermentation took place at a temperature of 17°C in stainless steel tanks, without undergoing malolactic fermentation. After cold stabilization, sulfur dioxide (Vino Aromax AEB Spa - Brescia, Italy) was added, and bottling was carried out.

The experiment followed a completely randomized design with three replications, each represented by a randomly selected bottle for the physicochemical analyses. The experimental design was a two-factorial arrangement (3 × 4), with factor A representing the vintages (2019, 2020, and 2021) and factor B representing the rootstocks (101-14 Mgt, Harmony, Paulsen 1103, and VR 043-43). This resulted in a total of 36 experimental units, and the physicochemical analyses were performed in triplicate.

Wine hydrogenionic potential (pH) was measured using a pH meter (AD1030®), and the total acidity (TA) was determined by titrating the sample with a standardized 0.1N NaOH solution, using a pH of 8.2 as the endpoint. Results were expressed in $mEq.L^{-1}$. Volatile acidity (VA) was obtained by distilling the sample using a Gibertini® apparatus. A 100 mL aliquot of the distillate was collected and titrated with 0.1N NaOH, with the endpoint determined by the appearance of a pink color, expressed in $mEq.L^{-1}$. The alcohol content was measured using a hydrostatic balance after distillation with an electronic enological distiller (Gibertini®), with results expressed as percentage. The reducing sugars ($g.L^{-1}$) were determined using the DNS method described by Rizzon (2010) [13]. Density was established using an Anton Paar® glass hydrometer, expressed in $g.cm^{-3}$. The levels of free and total SO_2 were determined according to the Ripper method (1892), with results expressed in $mg.L^{-1}$ of free and total SO_2. Ash analyses were conducted according to methodology proposed by Rizzon (2010) [13], with results expressed in $g.L^{-1}$.

The sensory evaluation was performed by a panel of 10 trained judges, using wines from the 101-14Mgt, Harmony, Paulsen 1103, and VR043-43 rootstocks from the 2019, 2020, and 2021 vintages. The study received approval from the Human Research Ethics Committee of the Federal University of Pelotas, under protocol CAAE 62015922.0.0000.5317. For wine characterization, four ISO glasses were used, each containing wine from a different rootstock. The glasses were randomly arranged and coded with three digits on the evaluation bench. The procedure was repeated for each vintage, resulting in 12 tastings per judge. Evaluations were conducted using a quantitative scale, with scores ranging from 0 (imperceptible) to 10 (very intense), for visual attributes such as turbidity and brightness, color tone (ranging from 0 - greenish-yellow to 10 - golden yellow), olfactory attributes including floral, spice, fruity, defects, and herbaceous notes,

as well as taste attributes such as acidity, sweetness, bitterness, aftertaste (ranging from 0 - little to 10 - very persistent), and overall balance, which was rated from 0 (poor) to 10 (liked very much). The sensory evaluation inquiry form is shown in Figure 2.

Final data were subjected to analysis of variance (ANOVA), and when treatment effects were detected, a Tukey's test was performed for mean comparison at a 5% probability of error.

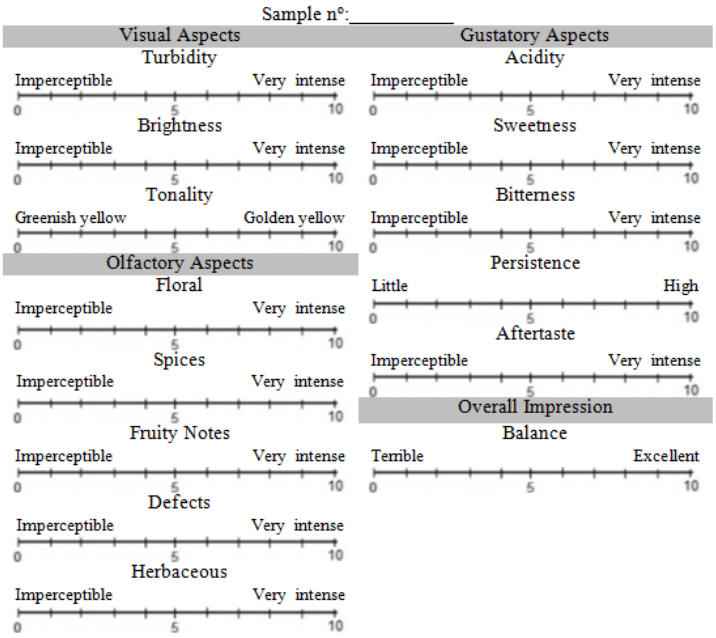

Figure 2: Vermentino Sensory Profile inquiry.

3. RESULTS AND DISCUSSION

The interaction effect between treatments was observed for the evaluated physicochemical variables, except for reducing sugars, which showed statistical significance only for the vintage (Table 1). Total acidity exhibited a significant interaction among the evaluated rootstocks. The VR 043-43 rootstock showed the highest total acidity compared to the other rootstocks in all three vintages. Furthermore, wines from the 2021 vintage displayed the highest total acidity among all evaluated wines. Total acidity is related to the degree of grape ripening, tending to decrease as maturity progresses [14]. Elevated levels of total acidity ensure the refreshing characteristics of the beverage and may be influenced by the grape variety and the must extraction method [15].

The VR 043-43 rootstock is considered high vigor compared to the others and tends to delay ripening. Nevertheless, according to Brazilian legislation [16], the accepted range for total acidity is a minimum of 40 and a maximum of 130 $mEq.L^{-1}$, and all wines were within the established standards.

Table 1: Analytical characteristics of Vermentino wines on different rootstocks and vintages. Água Doce - SC / Brazil.

	2019	2020	2021	2019	2020	2021
Rootstocks	TA			VA		
101-14 Mgt	85,86^{cC}	99,17^{bB}	105,69^{bA}	4,43^{aB}	8,34^{aA}	8,32^{aA}
Harmony	89,68^{bB}	94,24^{cB}	105,77^{bA}	4,51^{aC}	8,68^{aA}	7,35^{bB}
Paulsen 1103	86,37^{bcC}	94,88^{cB}	103,73^{cA}	4,24^{aC}	7,79^{bA}	7,00^{bB}
VR 043-43	98,66^{aC}	103,32^{aB}	108,41^{aA}	4,70^{aC}	7,04^{cB}	7,60^{bA}
	Total SO_2			Free SO_2		
101-14 Mgt	26,08^{cC}	154,08^{bA}	72,00^{aB}	9,76^{bC}	39,20^{abA}	20,00^{aB}
Harmony	62,48^{aB}	175,04^{aA}	69,60^{aB}	15,20^{aB}	47,60^{aA}	16,50^{bB}
Paulsen 1103	41,39^{bC}	122,40^{dA}	64,00^{bB}	9,04^{bC}	37,28^{bA}	16,00^{bB}
VR 043-43	28,40^{bc}C	137,44^{cA}	72,80^{aB}	9,60^{bC}	34,80^{bA}	17,60^{abB}
	Density			Alcohol		
101-14 Mgt	991,0^{bB}	993,3^{aA}	993,0^{abA}	11,72^{abB}	11,85^{aB}	12,25^{abA}
Harmony	991,5^{bA}	991,3^{bA}	992,5^{bA}	11,55^{bB}	12,10^{aA}	12,48^{aA}
Paulsen 1103	991,3^{bB}	991,5^{abB}	993,5^{abA}	11,90^{aAB}	11,55^{aB}	12,03^{bA}
VR 043-43	993,0^{aAB}	992,0^{abB}	994,0^{aA}	11,30^{cB}	12,02^{aA}	11,65^{cAB}
	pH			Ashes			Reducing
	2019	2020	2021	2019	2020	2021	Sugars
101-14 Mgt	3,28aA	3,22aA	3,25aA	1,69bB	1,85aA	1,66aB	2,10ns
Harmony	3,22aA	3,14bB	3,24aA	1,59bcA	1,61bA	1,61aA	2,14
Paulsen 1103	3,29aA	3,20aB	3,19aB	1,83aA	1,69bB	1,73aAB	2,08
VR 043-43	3,22aA	3,18abA	3,24aA	1,54cA	1,81aA	1,52aA	2,07
Vintage							
2019	-	-	-	-	-	-	1,84b
2020	-	-	-	-	-	-	2,60a
2021	-	-	-	-	-	-	1,85b

(1) Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly from each other according to the Tukey test at a 5% probability. ns: Non-significant. TA - Titratable acidity (mEq.L^{-1}), VA - Volatile acidity (mEq.L^{-1}), Density (g.cm^{-3}), Free and total SO2 (mg.L^{-1}), Alcohol (%), pH - Hydrogen ion potential, Reducing sugars (g.L^{-1}), Ashes (g.L^{-1}).

Volatile acidity showed significant differences on 2019 vintage among the wines from different rootstocks, with the lowest values observed. In contrast, the 101-14 Mgt rootstock exhibited the highest volatile acidity in the 2021 vintage. This indicates that the conditions for wine production were better in the 2019 vintage, likely related to better grape health conditions.

Volatile acids are formed during alcoholic fermentation, with most being acetic acid. The amount of volatile acids produced depends on the must composition (acidity, sugar, nitrous substances), yeast strain, and fermentation conditions [8]. Regardless of the treatment evaluated, all the values found indicate the good health of the products. According to the Brazilian Normative Instruction No. 14 of 2018, the content of volatile acids should not exceed 20 mEq.L^{-1} for table, fine, and noble wines, and all values found in this study are within the legally required parameters.

Regarding the density of the wines, statistical significance was observed in the wines from the VR 043-43 rootstock in the 2019 vintage, with higher density. However, there were no differences between Paulsen 1103 and 101-14 Mgt in 2020 and 2021. According to Wurz et al. (2021) [17], for dry wines, the density should be between 993 and 996 when fermentation is complete.

The analysis of reducing sugars did not show statistical significance among wines from different rootstocks, with only the effect of the vintage being significant, with the highest concentration of reducing sugars observed in 2020. This evaluation is important as it provides information about the classification of wines based on residual sugar content after stabilization: dry (0-4 g.L^{-1}), medium-dry (4-12 g.L^{-1}), medium-sweet (12-48 g.L^{-1}), and sweet (>48 g.L^{-1}) [17]. All the residual sugar content from wines produced in this study were below 4 g.L^{-1}, classified as completely fermented dry wines.

Furthermore, alcohol content and relative density are related in the sense that as relative

density decreases, alcohol content increases. In completely fermented and sugar-free wines, the density is lower than 1000, and the alcohol content is higher [17]. Brazilian legislation establishes minimum and maximum limits for alcohol content between 8.6% and 14% for fine and table wines, and all wines from the evaluated rootstocks are within the legally required parameters.

Regarding the influence of the rootstock on the alcohol content of the wines, the VR 043-43 rootstock stood out in 2019 and 2021 with the lowest values. This indicates that, in addition to the vintage effect, the vigor of these rootstocks may have contributed to lower grape ripeness, which is related to the higher total acidity observed earlier. This suggests that the contribution of sugars for fermentation in the wines obtained from these rootstocks was lower, resulting in lower alcohol content.

The highest concentration of total sulfur dioxide (SO_2) was observed in wines from the 2020 vintage. The dose of SO_2 to be applied in wines depends on the sanitary condition of the grapes, temperature, sugar content, and pH of the must or wine, and can vary from vintage to vintage. Brazilian legislation no longer establishes a maximum limit for total SO_2 in wines [18]. Under the previous legislation, the maximum allowed limit was up to 350 $mg.L^{-1}$ [17] and all evaluated wines comply with the previously required standards.

Similarly, free SO_2 was higher in the wines from the 2020 vintage. Sulfur dioxide serves to protect the wine from bacterial action, inhibit the activity of oxidative enzymes, and act as an antioxidant, preserving polyphenols and esters from oxidation processes, thus ensuring the overall quality and longevity of the wines [19]. Although there are no legally established minimum and maximum values for free SO_2 in wines, this evaluation is interesting as it contributes as a protective agent. The wines produced in the 2020 vintage had values ranging from 47.6 to 34.8 $mg.L^{-1}$, which are close to the considered ideal range for preservation, around 30 $mg.L^{-1}$ [20]. However, the wines from the 2019 and 2021 vintages fell below the ideal range.

The pH values of the wines varied among different rootstocks in the 2020 vintage, with Harmony and VR 043-43 showing the lowest pH. The limited variation in pH can be explained by the buffering effect of wines, where relative differences in the concentration of organic acids may not affect pH in the same proportion. Additionally, wines are naturally acidic, so minimal differences of 0.1 can cause changes in visual appearance, aroma profile, flavor, and wine stability [17].

Ash analysis showed variation among rootstocks in the 2019 and 2020 vintages but no difference when comparing the same rootstock between vintages. In the 2019 vintage, VR 043-43 stood out with the lowest value, while Harmony and Paulsen 1103 had the lowest values in the 2020 vintage. Ash corresponds to the mineral elements present in wine. Brazilian legislation establishes a minimum value of 1.0 $g.L^{-1}$ for white and rosé wines, and all the wines in this study meet the required parameters.

Regarding sensory analysis, no significant differences were found between rootstocks and vintages for visual aspects (brightness), olfactory aspects (floral, spice, and fruity notes), gustatory aspects (sweetness, bitterness, persistence, and aftertaste), and overall impression. Only significant results are presented.

Turbidity showed significant results in the 2019 vintage when using the 101-14Mgt and Harmony rootstocks, with the cloudiest wines. However, the same trend was not observed in the 2020 and 2021 vintages, with differences only associated with the vintages and not the rootstocks (Figure 3A). Turbidity refers to the reduction of transparency in a liquid due to the presence of undissolved substances. The presence of turbidity can lead to sensory defects in the wine and instability in the color of white wine [21].

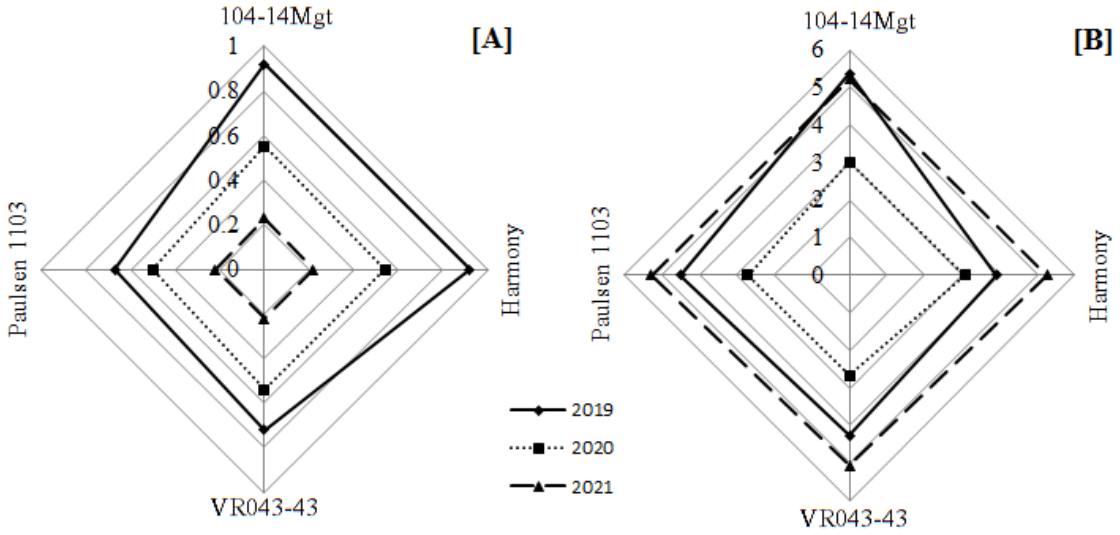

Figure 3: Visual parameters of Vermentino wines on different rootstocks and vintages. [A] Turbidity, [B] Hue.

Frequent rainfall throughout the grape ripening period in the 2019 vintage may have compromised berry health. Additionally, the 101-14Mgt and Harmony rootstocks are known to have lower vigor and tend to ripen earlier [22], which could be related to the protein stability of the wines, considering that most of the proteins in wine come from the grape pulp [23]. Despite the wines from the 2019 vintage showing higher statistical intensity, the judging panel gave scores below 1 (one), indicating low turbidity in all evaluated rootstocks and vintages.

The hue of the wines varied according to the vintages. The wines from the 2020 vintage had yellow-greenish hues with scores below 4, while the wines from the 2021 vintage had scores above 5, indicating a yellow hue with golden reflections. In 2019, the hue of the wines varied according to the rootstock used, with the 101-14Mgt rootstock showing a yellow hue with golden reflections and an average score above 5, while the Harmony rootstock had a yellow hue with greenish reflections and scores below 4 (Figure 3B).

Vermentino wines are characteristically straw-yellow with greenish reflections [24]. This research shows that the evaluated wines had hues close to the expected range for this variety, indicating minimal influence from the evaluated rootstocks. However, there may be greater variation in relation to production vintages. According to Urvieta et al. (2021) [25], climate is likely the most important specific factor affecting fruit quality at harvest, and the analysis of multiple vintages should be incorporated to isolate this factor for wine characterization.

In terms of olfactory parameters, the variable "defects" showed higher intensity in wines produced with the Paulsen 1103 rootstock. However, the same rootstock did not exhibit aroma defects in the 2019 vintage. For this vintage, the 101-14Mgt and VR043-43 rootstocks had the highest intensity of aromatic defects (Figure 4A). This characteristic is crucial for consumer appreciation. Several factors are related to the aromatic composition of wines, including vine metabolism or fermentative metabolism related to microorganisms, which can undergo transformations or be revealed during alcoholic fermentation [26].

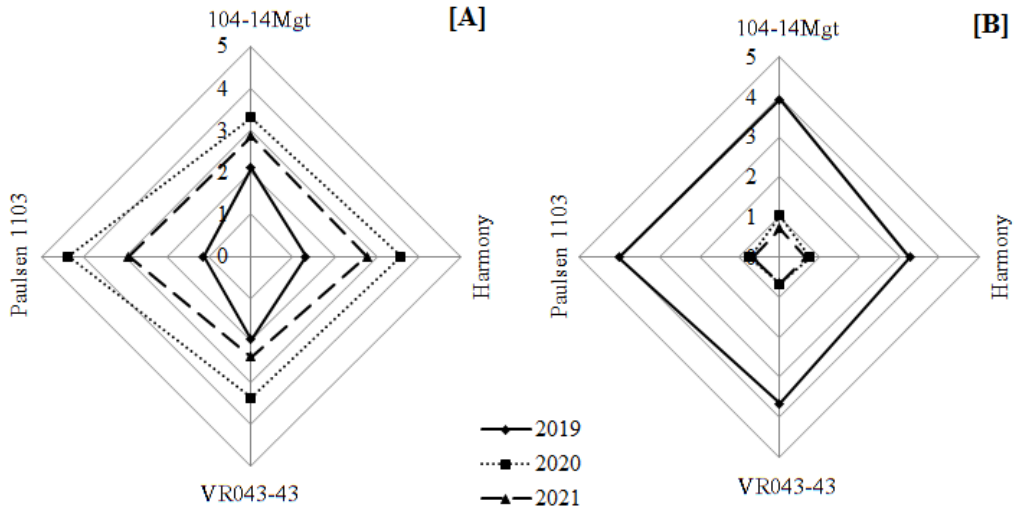

Figure 4: Olfactory parameters of Vermentino wines on different rootstocks and vintages. [A] Defects, [B] Herbaceous.

The herbaceous character stood out in the 2019 vintage, with a higher intensity of herbaceous aroma regardless of the rootstock used (Figure 4B). This outcome may be linked to the early harvest and/or the vineyard's youthfulness, given that it was the first productive vintage. Additionally, various factors can influence the aromatic profile of wines. Environmental conditions, such as thermal variation and hours of sun exposure, significantly impact grape taste and quality, influencing the ripening process. Many compounds of interest are synthesized in the grape skins, affecting the chemical composition and subsequently the accumulation of aromas in wines [26].

Regarding gustatory aspects, acidity showed statistical significance in the wines from the 2021 vintage, with higher intensity for this parameter, particularly in the Harmony (6.96) and VR043-43 (6.90) rootstocks (Figure 5). These rootstocks represent opposite ends of the spectrum regarding inferred canopy vigor [22], and this outcome may be more attributed to the harvest timing rather than the rootstock's influence. The 2021 vintage was characterized by frequent rainfall during the grape ripening period, leading to an early harvest to minimize losses. The results of the sensory analysis align with the observations from the physicochemical analysis, where the 2021 vintage showed higher total acidity.

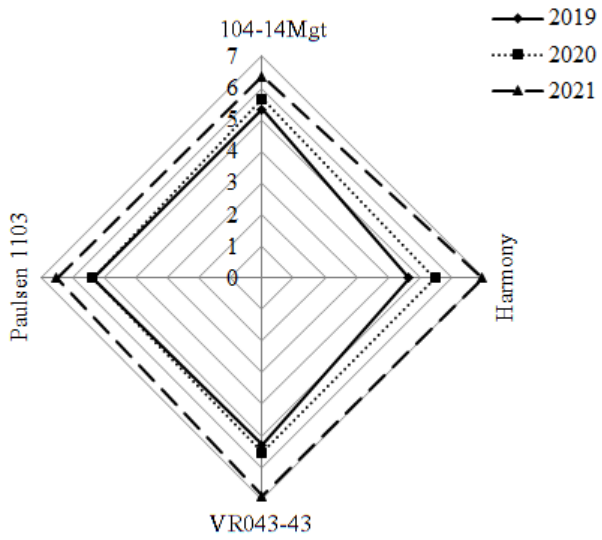

Figure 5: Gustatory parameter of acidity in Vermentino wines under different rootstocks and vintages.

The perception of acidity in wines is influenced by various factors, including the concentrations of malic, citric, and tartaric acids, which are the primary acids in wine grapes. These acids contribute significantly to the total acidity and are crucial in the sensory perception of wine, directly influencing its overall organoleptic character. Excessive acidity results in an overly sour and pronounced taste, while wines with low acidity taste flabby and flat, exhibiting a less defined flavor profile [27].

At the conclusion of the study, it is evident that the influence of rootstocks on wine quality is minimal, whereas the production vintage has a more significant impact. The different levels of vigor provided by the evaluated rootstocks affect grape ripening, either advancing or delaying the cycle. This factor is critical for harvesting healthy grapes in the high-altitude regions of Santa Catarina, where there is a higher frequency of rainfall during the ripening period, consequently affecting wine quality.

4. CONCLUSION

This study evaluated the impact of different rootstocks on the quality of Vermentino wines produced in the high-altitude regions of Santa Catarina. The findings suggest that while rootstocks do play a role in grape ripening and, consequently, in certain aspects of wine composition, their overall influence on the final wine quality is relatively minimal compared to the effect of the production vintage. The various rootstocks provided different levels of vigor, which either advanced or delayed grape ripening, a critical factor in regions with frequent rainfall during the ripening period.

Results indicate that the VR 043-43 rootstock tends to produce wines with higher total acidity and lower alcohol content, likely due to its higher vigor and delayed ripening effect. Conversely, the Harmony rootstock showed variations in pH and acidity levels, reflecting its influence on the sensory and physicochemical properties of the wines. Despite these differences, all wines produced adhered to the required legal standards for quality.

The study also highlighted the significant role of environmental conditions, particularly the vintage, in determining wine quality. Variations in rainfall, temperature, and other climatic factors during the grape ripening period had a more pronounced impact on the wine's sensory and physicochemical characteristics than the choice of rootstock.

Overall, this research underscores the importance of considering both rootstock selection and vintage conditions in the production of high-quality Vermentino wines. While rootstock selection remains a critical factor for viticultural management, especially in mitigating the effects of environmental variability, the vintage ultimately plays a more decisive role in shaping the wine's final quality.

5. ACKNOWLEDGMENTS

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