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Article

ROOTSTOCK COMPETITION AND PLANTING SPACING FOR CV. 'VERMENTINO' IN AN ALTITUDE REGION OF SANTA CATARINA

COMPETIÇÃO DE PORTA-ENXERTOS E ESPAÇAMENTO DE PLANTAÇÃO PARA A CV. 'VERMENTINO' EM REGIÃO DE ALTITUDE DE SANTA CATARINA

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SUMMARY

Rootstock adequacy and planting density are necessary for new grapevine varieties in new regions. The objective of this work was to select the rootstock that confers the best productive performance to the 'Vermentino' variety, and to adjust the ideal spacing for this combination. The experimental design used was randomized blocks in a 5x3 factorial scheme, in which the treatments studied consisted of the combination of five rootstocks ('101-14 Mgt', 'Harmony', 'IAC 572', 'Paulsen 1103', and 'VR 043-43') and three spacings between plants (1.0, 1.2 and 1.5 m). The phenological cycle of the plants and the productive and quality characteristics of the grapes were evaluated during 2018/19, 2019/20, and 2020/21 harvests. Bud break of 'Paulsen 1103' and 'VR 043-43' rootstocks occurred the latest in 2019/20 and 2020/21. '101-14 Mgt' and 'Paulsen 1103' rootstocks induced the highest yields in 2019/20 and 2020/21. The 1.0 m spacing between plants provided the highest productivity in all seasons. Thus, it can be concluded that the 'Paulsen 1103' and 'VR 043-43' rootstocks delayed bud break and decreased phenological sub-periods. 'Paulsen 1103' and '101-14 Mgt' rootstocks contributed to increase the productivity; the 'IAC 572' rootstock presented the lowest contribution to the polyphenols content and antioxidant activity, and the 1.0 m spacing between plants resulted in greater productivity of the vineyard.

RESUMO

A adequação do porta-enxerto e da densidade de plantação é necessária para novas variedades de videira em novas regiões. O objetivo deste trabalho foi selecionar o porta-enxerto que confere o melhor desempenho produtivo para a variedade 'Vermentino', bem como ajustar o compasso ideal para essa combinação. O delineamento experimental utilizado foi o de blocos casualizados, em esquema fatorial 5x3, em que os tratamentos estudados consistiram na combinação de cinco porta-enxertos ('101-14 Mgt', 'Harmony', 'IAC 572', 'Paulsen 1103', e 'VR 043-43') e três espaçamentos entre plantas (1,0, 1,2 e 1,5 m). Procedeu-se à avaliação do estado fenológico das plantas, bem com das características produtivas e de qualidade da uva durante as vindimas 2018/19, 2019/20 e 2020/21. Os porta-enxertos 'Paulsen 1103' e ''VR 043-43'' apresentaram os abrolhamentos mais tardias em 2019/20 e 2020/21. O porta-enxerto '101-14 Mgt' e 'Paulsen 1103' induziram as maiores produtividades em 2019/20 e 2020/21. O espaçamento de 1,0 m entre plantas proporcionou a maior produtividade em todas as safras. Assim, conclui-se que os porta-enxertos 'Paulsen 1103' e 'VR 043-43' atrasaram os abrolhamentos e atrasaram os subperíodos fenológicos; os porta-enxertos 'Paulsen 1103' e '101-14 Mgt' contribuiram para a maior produtividade; o porta-enxerto 'IAC 572' apresentou a menor contribuição para a acumulação de polifenóis e para a atividade antioxidante, e o espaçamento de 1,0 m entre plantas contribuiu para a maior produtividade do vinhedo.

Keywords: Vitis vinifera, rootstock, planting density.
Palavras-chave: Vitis vinifera, porta-enxerto, densidade de plantio.

INTRODUCTION

Vine cultivation is practiced in different regions of the world, where it consolidates and moves the market, generating wealth and income for the population. The altitude regions of Santa Catarina – Brazil, have stood out in the cultivation of fine wine grapes (Brighenti *et al*., 2014; Brighenti *et al*., 2015; Brighenti *et al*., 2016; Vianna *et al*., 2016; Nodari and Frank, 2019). In this sense, partnerships between the state government and the Autonomous Province of Trento made it possible to develop the project "Technology for the Development of Santa Catarina Vitiviniculture", to study and indicate grapevine varieties for the altitude regions of the state of Santa Catarina (Palladini *et al*., 2021). This project selected Italian varieties with the best enological and agronomic performance, which included the 'Vermentino' variety.

However, further research was necessary to choose the best spacing and rootstock combination for these varieties since this can influence the phenological and productive characteristics of the vineyard, as well as the quality characteristics of the wines (Brighenti *et al*., 2011).

The 'Vermentino' variety, also known as 'Pigato', 'Favorita', 'Piccabon', and 'Formentino', is recommended for the production of wines and sparkling wines (Souza *et al*., 2017), and can also be used as a table grape and for the production of homemade candies (Calò *et al*., 2006). When cultivated in Santa Catarina, its phenology is marked by medium budding and flowering, late veraison, and medium ripening (Porro and Stefanini, 2016). It has shown good productivity in regions above 900 m of altitude (Souza et al., 2017).

The appropriate rootstock combination contributes to the adaptation to different types of soil, and also influences the phenology of the plant, being an alternative adaptation to the climate specificities of each region (Hartmann and Kester, 1975; Tecchio *et al*., 2013; Allebrandt *et al*., 2015). In addition, rootstocks interfere with the vigor characteristics of plants grafted onto them, which is reflected in the vineyard productivity and management (Dalbó and Souza, 2019; Tecchio *et al*., 2019).

The different levels of vigor conferred by the rootstocks, in turn, require an adjustment in the density of plants in the vineyard since, with vigorous rootstocks, greater spacing between the plants is recommended so that there is space to hold a more significant load of buds per plant without excessive shading conditions (Santos, 2006).

Hence, the objective of the work was to select the rootstock that provides the best productive performance to the 'Vermentino' variety, and to adjust the ideal spacing for this combination.

MATERIALS AND METHODS

The experiment was conducted in a vineyard installed in 2016, located in the municipality of Água Doce - SC (1250 m of altitude), at the Villaggio Grando winery, in 2018/19, 2019/20, and 2020/21 cycles. The plants of the 'Vermentino' variety were conducted in an espalier with a spur cord pruning system. A 2.9 m spacing was used between rows, while the distance between plants varied according to the treatment. The climate of the region, according to the Koeppen classification, is Cfb, mesothermic, humid, without a dry season, and with a cool summer (Pessenti *et al*., 2019).

The experimental design used was randomized blocks, in a 5 x 3 factorial scheme (five rootstocks and three spacings), with four replications evaluated at two plants per plot. The treatments studied are a combination of five rootstocks ('101-14 Millardet et de Grasset' (Mgt) (*Vitis riparia* x *Vitis rupestris*), 'Harmony'(*Vitis champinii* x *Vitis vinifera* x *Vitis labrusca* x *Vitis riparia*), 'IAC 572'(*Vitis caribaea* × '101-14 Mgt'), 'Paulsen 1103'(*Vitis berlandieri* x *Vitis rupestris*), and 'VR 043-43' (*Vitis rotundifolia* x *Vitis vinífera*)) and three plant spacings of 1.0 m (3448 plants/ha), 1.2 m (2874 plants/ha) and 1.5 m (2298 plants/ha).

The phenological cycle was evaluated through the observation of the main stages - after the winter solstice (21/06/2018, 21/06/2019, and 20/06/2020) the budburst; full flowering; color change (veraison); harvest date - according to the scale of Baggiolini (1952). Pruning was carried out by observing the swelling of the buds (a sign of breaking dormancy) on 09/12/2018, 09/12/2019 and 08/10/2020.

The monthly and weekly precipitation and air temperature averages, as well as the accumulated cold hours (≤ 7.2 °C), were obtained by the Água Doce meteorological station, located at the Villaggio Grando winery, through the EPAGRI/CIRAM database.

To assess the productive parameters, fertility evaluations were carried out through: i) the direct counting of the number of branches and bunches per plant; ii) average pruning mass, obtained by weighing the branches pruned per plant in winter (g); iii) Ravaz index, by dividing the mass of bunches (yield, g) by the pruning mass (g); iv) number of bunches, counted individually on the marked plants and averaged per plant; v) the average mass of the bunch, obtained by the average weight of the bunches harvested per plant (g); vi) production per plant, based on weighing the bunches at the time of harvest (kg); vii) estimated productivity per hectare, by multiplying the production per plant by the number of plants per hectare (t/ha).

The harvests were carried out considering the health of the bunches and the ripeness of the grapes

according to the total soluble solids content and total acidity.

The harvests took place on 18/03/2019, 03/03/2020, and 04/03/2021. Regarding the physicochemical parameters of the must, the total soluble solids content was evaluated and determined in a digital benchtop refractometer with automatic temperature compensation (QUIMIS®, Nova instruments, WYA -2S, Brazil), and the results were expressed as °Brix. In addition, the pH was determined directly in the must by a potentiometer (Meter AD1030, Adwa Instruments, Hungary), and total acidity was assessed by titration of the sample (Mettler 8603-Toledo, Switzerland) with a standardized solution of NaOH 0.1N, adopting pH = 8.2 as the endpoint of the titration, and the results were expressed as mEq/L.

Total polyphenols of the must (mg/L) were determined by the Folin-Ciocalteu method (Singleton and Rossi, 1965) and the antioxidant activity of the must (µmol/L) was based on the DPPH assay according to the methodology described by Kim *et al*. (2002), using a UV-2601 spectrophotometer (Beijing Rayleigh Analytical Instrument Corporation, China).

Measurements of the chromatic characteristics of the must were performed using a spectrophotometer (Konica Minolta, CM 5, Japan): L* (represents lightness, ranging from fully opaque/dark = 0 % to fully transparent/bright = 100%); a* and b* (represents chromatic coordinates, in which a* varies from +a* red to –a* green, and b* varies from +b* yellow to –b* blue); chroma and hue (°Hue), obtained by the following formulas C= [(a*)2+(b*)2]1/2 and H°= 1/tan b*/a*, respectively, as recommended by McGuire (1992).

The ANOVA assumptions were evaluated in the statistical analysis, with normality analyzed using the Shapiro-Wilk test and homoscedasticity using the Bartlett test. If the assumptions were not met, data transformation was performed. In the 2018/2019 harvest, the variables that required transformation were: yield, Ravaz index, total polyphenols, and DPPH. In the 2019/2020 harvest, the total polyphenols and pruning mass variables required transformation. In the 2020/2021 harvest, the total polyphenols variable was transformed. The transformations were carried out according to the method described by Box and Cox (1964).

The results were submitted to analysis of variance. and, in case of statistical significance, to an analysis of means by Duncan's test ($p \leq 0.05$).

RESULTS AND DISCUSSION

The vineyard's first harvest, 2018/19, was marked by frequent rains throughout the vine's reproductive period and mild temperatures during the fruiting period. The 2019/20 harvest was characterized by a drought that occurred in the months before the bud break and frequent rains during the months of grape ripening, together with mild temperatures. The 2020/21 harvest presented drought in September and October; however, it had frequent rains in November, December, and January, a period of flowering and development of the bunches, with mild temperatures for this period (Figure 1). The weeks that preceded the evaluated crops' harvest showed a predominance of cloudy days with frequent rains until harvest (Figure 2). The frequency and distribution of rainfall are essential elements in fruit growing since the free water on leaves, flowers, and fruits is the main factor that can trigger the development of fungal diseases in the vine (Chavarria *et al*., 2007), indicating the need for alertness in the control of fungal diseases in the cultivation of the 'Vermentino' variety for this region In 2018/19, the sum of cold hours was 680 hours; in 2019/20, it was 405 hours; in 2020/21, it was 575 hours (Figure 3). The species regulate the cold hours needed to overcome dormancy when this requirement is met. Dormancy depends on an environmental stimulus, mainly temperature and water availability, which provides adequate conditions for the beginning of bud break (Anzanello and Christo, 2020).

For the 'Vermentino' variety, the cold requirement was sufficient throughout the seasons, where the budburst is seen to occur in the first half of October in 2018, in the second half of September in 2019, and in the first half of September in 2020. Flowering occurred in the second half of November in 2018, in the first half of November in 2019, and in the second half of October in 2020; while the veraison took place between the end of January and the beginning of February in all crops, while the harvests happened in the beginning of the second half of March 2019 and in the first half of March in 2020 and 2021 (Table I).

No studies comparing rootstocks with the variety 'Vermentino' in Água Doce-SC were found in the literature; however, the commonly used rootstock is 1103P. For this scion-rootstock combination, Würz *et al*. (2017) observed average bud break, flowering, and veraison around September 20, November 24, and February 8 in São Joaquim-SC, respectively. Brighenti *et al*. (2014) observed the same region's mean dates between September 18, December 6, and February 9 for the bud break, flowering, and veraison, respectively.

Budburst occurred latest in the vines grafted onto 'Paulsen 1103' and 'VR 043-43' rootstocks in 2019/20 and 2020/21 (S-B) (Table II). This result is interesting because the classification based on the bud break can be used to choose varieties less prone to late frost risks (Würz *et al*., 2017).

The sub-period between budburst and flowering (B-F) was anticipated by these rootstocks, with an average difference of 4.5 days between the latest and the earliest rootstocks.

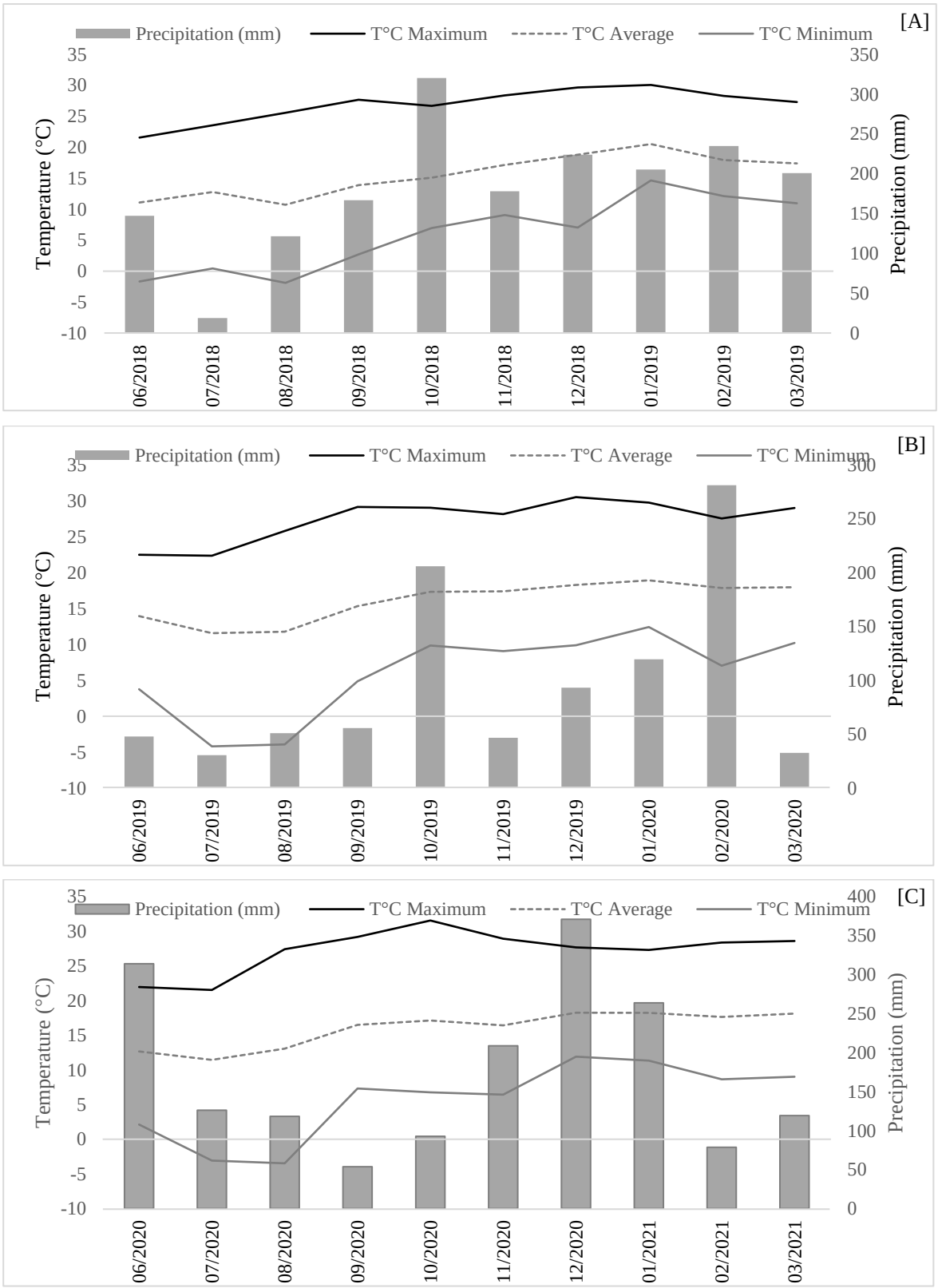

Figure 1. Monthly averages of temperature and precipitation, Água Doce - SC, Villaggio Grando Winery. Crops [A] 2018/19, [B] 2019/20 and [C] 2020/21.

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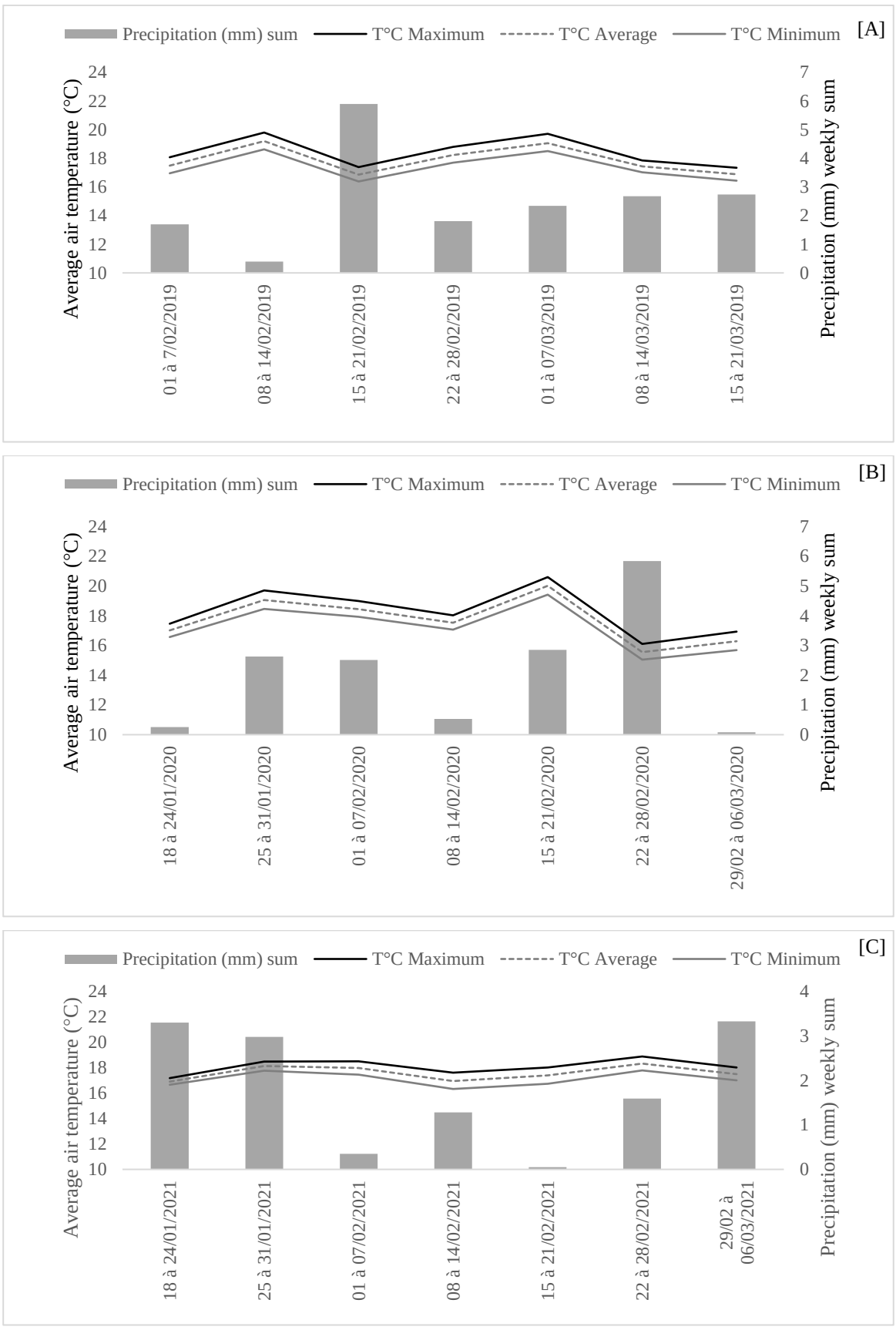

Figure 2. Weekly averages of temperature and precipitation, Água Doce - SC, Villaggio Grando Winery. Crops [A] 2018/19, [B] 2019/20 and [C] 2020/21.

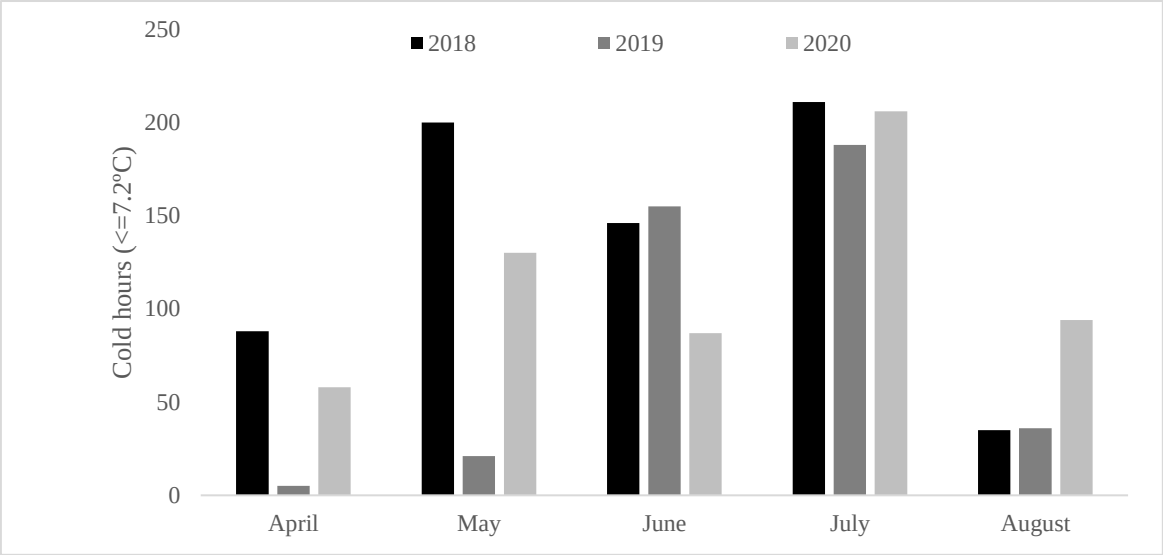

Figure 3. Accumulated cold hours, Água Doce – SC, Villaggio Grando Winery.

Table I

Dates of the main phenological occurrences of the 'Vermentino' cultivar in 2018/19, 2019/20, and 2020/21 cycles in Água Doce/SC

Rootstock	Bud break	Flowering	Veraison	Harvest
		2018/19 Crop		
'101-14 Mgt'	09/10/2018	26/11/2018	02/02/2019	18/03/2019
'Harmony'	10/10/2018	25/11/2018	29/01/2019	18/03/2019
'IAC 572'	12/10/2018	27/11/2018	02/02/2019	18/03/2019
'Paulsen 1103'	16/10/2018	30/11/2018	29/01/2019	18/03/2019
'VR 043-43'	12/10/2018	30/11/2018	01/02/2019	18/03/2019
		2019/20 crop		
'101-14 Mgt'	24/09/2019	12/11/2019	01/02/2020	03/03/2020
'Harmony'	24/09/2019	12/11/2019	27/01/2020	03/03/2020
'IAC 572'	24/09/2019	13/11/2019	29/01/2020	03/03/2020
'Paulsen 1103'	29/09/2019	14/11/2019	28/01/2020	03/03/2020
'VR 043-43'	28/09/2019	13/11/2019	02/02/2020	03/03/2020
		2020/21 Crop		
'101-14 Mgt'	05/09/2020	23/10/2020	25/01/2021	04/03/2021
'Harmony'	04/09/2020	24/10/2020	24/01/2021	04/03/2021
'IAC 572'	05/09/2020	25/10/2020	25/01/2021	04/03/2021
'Paulsen 1103'	10/09/2020	27/10/2020	28/01/2021	04/03/2021
'VR 043-43'	09/09/2020	27/10/2020	28/01/2021	04/03/2021

The value of recognition of growth stages for the grapevine is indispensable for implementing cultural operations in the vineyard and providing a unanimous understanding among workers (Gökbayrak and Engin, 2019). The sub-period between flowering and veraison (F-V) was

significantly influenced by the rootstocks in the first crop only, with 'Paulsen 1103', 'VR 043-43', and 'Harmony' inducing the smallest sub-period.

The difference in color change and harvest (V-C) subperiod was observed only in the 2020/21 harvest, for the 'Paulsen 1103' and 'VR 043-43' rootstocks. Brighenti *et al*. (2015) stated that in colder climate regions, varieties that have early ripening are indicated, while in warmer climates, varieties of late ripening are preferable because they have climatic conditions to complete maturation.

These differences may be related to variations in rootstock vigor levels, considering that vigorous rootstocks can prolong the vegetative cycle (Brighenti *et al*., 2011). Malinovski et al. (2016) observed an average cycle of 179 days for the 'Vermentino' variety in Água Doce-SC, which is similar to that observed in the present study in the 2020/21 harvest with 'Paulsen 1103' and 'VR 043-43' rootstocks.

Table II

Days between stages of the main phenological occurrences of the cultivar 'Vermentino' in the 2018/19, 2019/20 and 2020/21 cycles in Água Doce/SC

Rootstock	S-B	B-F	F-V	V-C
2018/19 Crop				
'101-14 Mgt'	111b	47ns	69a	43ns
'Harmony'	111b	47	63b	47
'IAC 572'	113b	45	66ab	43
'Paulsen 1103'	117a	45	62b	47
'VR 043-43'	112b	48	62b	45
2019/20 Crop				
'101-14 Mgt'	96b	48ab	83ns	29ns
'Harmony'	96b	48ab	79	33
'IAC 572'	95b	49a	81	29
'Paulsen 1103'	100a	46b	79	31
'VR 043-43'	100a	46b	79	31
2020/21 Crop				
'101-14 Mgt'	75c	51a	94ns	38a
'Harmony'	77b	50a	92	39a
'IAC 572'	77b	51a	92	38a
'Paulsen 1103'	83a	47b	92	35b
'VR 043-43'	82a	48b	93	34b

Means followed by the same lowercase letter in a column do not differ by Duncan's test (p>0.05); ns, not significant. S-B (Solstice- Bud break), B-F (Bud break-Flowering), F-V (Flowering -Veraison), V-C (Veraison-Harvest).

Evaluating the productive parameters of the first crop (2018/19), no difference in the fertility index caused by the rootstocks and the spacing was found. Fertility is a genetic characteristic of grapevine varieties, and reflects the ability to differentiate vegetative buds from fruiting buds, which will determine their productivity (Meneguzzi *et al*., 2020).

Pruning mass was higher by using 'IAC 572' and 'Paulsen 1103' rootstocks. These rootstocks are considered vigorous (Dalbó and Feldberg, 2019); however, the Ravaz index indicates that only 'IAC 572' showed excessive vigor in this crop, with a 3.7 Ravaz index, and 'Paulsen 1103' was slightly above, which is accepted as appropriate for optimal ripening (Würz *et al*., 2020). Despite the low Ravaz index presented by the 'IAC 572', the production in several bunches did not show a significant difference, indicating that the vigor did not interfere with the fertility of the branches. The cluster mass was higher for Paulsen1103 rootstock, affecting production per plant and estimated yield (Table III).

Table III

Productive parameters of the 'Vermentino' variety in relation to the rootstock and spacing in the 2018/19 crop

	Fertility index	**Pruning mass** (g)	**Ravaz index**	**Number of bunches**	**Bunch weight** (g)	**Production per plant** (kg)	**Estimated yield** (ton/ha)
Rootstock							
'101-14 Mgt'	1.27ns	280bc	5.53b	10.00ns	170b	1.94b	6.19b
'Harmony'	1.43	238c	5.51b	7.91	170b	1.47b	4.61b
'IAC 572'	1.36	429a	3.73b	10.67	170b	1.92b	5.90b
'Paulsen 1103'	2.07	365ab	10.71a	16.25	230a	3.80a	10.89a
'VR 043-43'	1.45	301bc	5.32b	10.58	150b	1.80b	5.48b
Spacing							
1.0 m	1.74ns	329ns	8.61a	13.95ns	210a	2.97a	10.23a
1.2 m	1.55	339	5.69ab	10.35	170b	2.02ab	5.82b
1.5 m	1.30	301	4.67b	9.06	150b	1.61b	3.69c

Means followed by the same lowercase letter in a column do not differ by Duncan's test ($p>0.05$); ns, not significant.

In 2018/19, pH variation promoted by the rootstocks was observed. However, all the musts had fair quality fermentation values (Brighenti *et al*., 2014). Higher total acidity and lower concentration of soluble solids were associated with 'IAC 572' and 'VR 043-43' rootstocks (Table IV). However, it is worth mentioning that the whole experiment was harvested on the same date, and this behavior may be related to the need for a longer period for grape ripening using these rootstocks due to their high vigor. Lower total polyphenols content and antioxidant activity were obtained with '101-14 Mgt' and 'IAC 572' rootstocks. Nevertheless, the amount and phenolic composition may vary according to different factors, such as grapevine variety, grape maturity, climate conditions, and exposure to ultraviolet light (Da Costa *et al.*, 2021), and therefore its behavior over the years should be observed. Regarding the chromatic characteristics, differences were only observed for the Hue; higher values were related with '101-14 Mgt' and 'IAC 572' rootstocks (Table IV). This result may be related to the lower concentration of phenolic compounds associated with these rootstocks, considering that such compounds have an essential role in the color of wines acting as pigments (Bender *et al*., 2020).

The second crop of the vineyard (2019/20) presented the lowest fertility rate for the 'IAC 572' and 'VR 043-43' rootstocks. On the other hand, the pruning mass was superior to the 'IAC 572' rootstock in the spacings of 1.2 and 1.5 m between plants, following the exact behavior of the first crop. However, even with a statistical difference between the rootstocks, the Ravaz index values indicate an excessive vegetative vigor (Würz *et al*., 2020), especially in 'IAC 572' that presented the lowest index value, thus being seen again as the rootstock that confers more significant imbalance between vegetation and production.

In 2019/20, an increase in the number of bunches was observed when using the 'Paulsen 1103' rootstock followed by 'Harmony'. The lowest value of bunch mass was related to 'IAC 572'. These results demonstrate the need for adjustment in management to adapt to the vigor conferred by the rootstocks since excess or lack of vigor can lead to lower productivity (Grigolo *et al*., 2021), as observed in 'IAC 572' (Table V).

Grapes produced in 2019/20 with 'IAC 572', VR 043-42, and 'Paulsen 1103' rootstocks had a lower concentration of soluble solids content and higher total acidity regardless of the spacing used. As a result, these rootstocks are considered to be of increased vigor, and a more extended period may be necessary for grape ripening (Dalbó and Feldberg, 2019).

Table IV

Physicochemical parameters of 'Vermentino' must in relation to rootstock and spacing in the 2018/19 crop

	pH	**TSS** (°Brix)			TA
		1.0 m	**1.2 m**	**1.5 m**	
Rootstock					
'101-14 Mgt'	3.16ab	16.3aB	16.8aAB	17.3aA	84.92b
'Harmony'	3.13b	16.2abA	16.7aA	16.6aA	82.73b
'IAC 572'	3.14ab	15.0bA	16.1abA	15.3bA	92.60a
'Paulsen 1103'	3.18a	15.9abA	14.1cB	16.6aA	84.50b
'VR 043-43'	3.12b	15.5abA	15.1bcB	15.2bA	95.07a
Spacing					
1.0 m	3.16ns	-	-	-	86.78ns
1.2 m	3.15	-	-	-	87.05
1.5 m	3.13	-	-	-	90.05
	Polyphenols (mg gallic acid /L)	**Antioxidant activity** (µM/mL)	**L***	**°Hue**	**Chroma**
Rootstock					
'101-14 Mgt'	664b	10103bc	95.33ns	95.13a	7.13ns
'Harmony'	848a	12866a	94.99	93.74b	8.83
'IAC 572'	601b	10261c	95.38	95.33a	7.01
'Paulsen 1103'	817a	12948a	95.05	93.93b	8.28
'VR 043-43'	776a	12126ab	95.15	94.7ab	8.15
Spacing					
1.0 m	734a	11825ab	95.22ns	94.63ns	7.83ns
1.2 m	807a	12356a	95.07	94.41	8.34
1.5 m	679b	10694b	95.26	94.66	7.48

Means followed by the same lowercase letter in a column do not differ by Duncan's test (p>0.05); ns, not significant. TSS – total soluble solids; TA – total acidity; L* - lightness.

Lower pH, in turn, was associated with 1.0 m spacing between plants when using the 'IAC 572' and 'Paulsen 1103' rootstocks, but in practice, this difference is not enough to change the quality of the must (Table VI).

The chromatic characteristics were not affected by the spacing between plants. The lightness of the sample, demonstrated that the musts have a clear and limpid aspect. The hue indicated that the musts exhibited a greenish yellow color when '101-14 Mgt', 'IAC 572' and 'VR 043-43' rootstocks were used, and greenish yellow with straw tones when 'Harmony' and Paulsen1103 rootstocks were used. The highest color chroma was verified in the musts associated with 'Harmony' rootstock (Table VI). Polyphenol content and antioxidant activity were influenced by the interaction between rootstock and spacing; the lowest levels in the 1.0 meter spacing between plants were observed when using '101-14 Mgt' and 'Harmony' rootstocks (Table VI). Despite the lack of information on the influence of these rootstocks on the polyphenol content and antioxidant activity of 'Vermentino' scion, Brighenti *et al*. (2014), studying Italian varieties in an altitude region of Santa Catarina, found higher levels of polyphenols in the 'Vermentino' variety and ascribed them to the influence of altitude and low temperature.

In 2020/21 there was no interaction between the factors spacing and rootstock on the vineyard production variables (Table VII). Following the behavior of the previous crop, the fertility index was lower, and the pruning mass was higher when using the 'IAC 572' rootstock, this same rootstock presented the lowest Ravaz index value, indicating excess vigor conferred by the rootstock.

The productive behavior for most rootstocks was adequate, showing that in the third year of vineyard production, the plants are already better established; even when young, the Ravaz index shows the best balance between vegetative and grape production (Würz *et al*., 2020).

Table V

Productive parameters of the 'Vermentino' variety in relation to the rootstock and spacing in the 2019/20 crop

	Fertility index	**Ravaz Index**	**Pruning mass** (g)		
			1.0 m	**1.2 m**	**1.5 m**
Rootstock					
'101-14 Mgt'	1.00ab	3.25b	603aA	503bAB	400cB
'Harmony'	1.09a	4.83a	473abA	396bAB	317cB
'IAC 572'	0.73c	1.63c	554abB	904aA	826aA
'Paulsen 1103'	1.00ab	4.64a	441bA	517bA	561bA
'VR 043-43'	0.89bc	3.12b	503abA	510bA	552bA
Spacing					
1.0 m	0.87ns	3.88ns	-	-	-
1.2 m	0.97ns	3.57	-	-	-
1.5 m	0.97ns	3.02	-	-	-

	Number of bunches	**Bunch weight** (g)	**Production per plant** (kg)	**Estimated yield** (ton/ha)
Rootstock				
'101-14 Mgt'	10.64b	160ab	2.08ab	5.46ab
'Harmony'	11.70ab	150ab	1.94ab	5.40ab
'IAC 572'	10.14b	130b	1.24c	3.24c
'Paulsen 1103'	12.92a	170a	2.29a	6.67a
'VR 043-43'	9.67b	170a	1.68bc	4.77bc
Spacing				
1.0 m	11.11ns	190a	2.05ns	6.72a
1.2 m	11.08	150b	1.91	5.18b
1.5 m	10.83	130c	1.55	3.32c

Means followed by the same lowercase letter in a column do not differ by Duncan's test ($p>0.05$); ns, not significant.

The number of bunches was lower when using the 'Harmony' rootstock, and this rootstock provided the lowest bunch mass, followed by 'VR 043-43' and 'Paulsen 1103', which was reflected in the production per plant and estimated productivity, where 'Harmony' and 'VR 043-43' had the lowest averages (Table VII). Regarding the spacing, a relationship between the number of bunches and bunch mass was observed; as the spacing increased, an increase in the number of bunches and the inverse in bunch mass occurred, evidencing the high fertility of buds (Porro and Stefanini, 2016). However, the highest estimated productivity was obtained with the spacing of 1.0 m between plants due to the greater number of productive plants with heavier bunches. The 'Vermentino' variety originally had medium vigor and produced bunches with medium to high mass (180-300 g), showing good productivity in the altitude regions of Santa Catarina (Palladini *et al*., 2021).

Table VI

Physicochemical parameters of 'Vermentino' must in relation to rootstock and spacing of the 2019/20 crop

	pH			TSS (°Brix)	TA	L*	°Hue	Chroma
	1.0 m	**1.2 m**	**1.5 m**					
Rootstock								
'101-14 Mgt'	3.36abA	3.36aA	3.38aA	18.9a	87.37c	94.47a	92.19a	10.59b
'Harmony'	3.41aA	3.36aAB	3.32bB	19.5a	80.58d	93.88b	90.49b	13.68a
'IAC 572'	3.28cB	3.37aA	3.39aA	17.2c	99.13a	94.5a	92.04a	10.3b
'Paulsen 1103'	3.32bcB	3.35aAB	3.38aA	17.6bc	90.51bc	94.32a	90.68b	11.4b
'VR 043-43'	3.41aA	3.37aA	3.38aA	18.1b	93.77ab	94.11ab	91.51a	11.87b
Spacing								
1.0 m	-	-	-	17.9ns	91.08ns	94.34ns	91.44ns	11.14ns
1.2 m	-	-	-	18.1	89.88	94.25	91.32	11.63
1.5 m	-	-	-	18.7	89.56	94.15	91.30	12.04

	Polyphenols (mg gallic acid/L)			**Antioxidant activity** (µM/mL)		
	1.0 m	**1.2 m**	**1.5 m**	**1.0 m**	**1.2 m**	**1.5 m**
Rootstock						
'101-14 Mgt'	668bB	821bcA	764cAB	743cB	1020bA	1082bcA
'Harmony'	832aB	1393aA	1748aA	1018abB	1397aA	1395aA
'IAC 572'	888aA	707cB	744bcAB	1220aA	793cB	919cB
'Paulsen 1103'	891aA	882bA	909bcA	961bcA	1073bA	1014bcA
'VR 043-43'	751abA	868bA	925bA	845bcB	1080bA	1180bA

Means followed by the same lowercase letter in a column do not differ by Duncan's test (p>0.05); ns, not significant.
TSS – total soluble solids; TA – total acidity; L* - lightness.

Table VII

Productive parameters of the 'Vermentino' variety in relation to rootstock and 2020/21 crop spacing

	Fertility index	Pruning mass (g)	Ravaz Index	Number of bunches	Bunch weight (g)	Production per plant (kg)	Production per plant (ton/ha)
Rootstock							
'101-14 Mgt'	1.38a	433b	7.90a	18.70a	186.50a	3.31a	9.73a
'Harmony'	1.21ab	291c	8.22a	14.45b	150.01c	2.37b	6.71c
'IAC 572'	1.12b	759a	4.06c	18.41a	166.93b	2.96a	8.61ab
'Paulsen 1103'	1.39a	453b	7.08ab	19.75a	158.41bc	3.11a	8.74ab
'VR 043-43'	135a	437b	6.46b	17.21a	163.40bc	2.78ab	7.95bc
Spacing							
1.0 m	1.29ab	456ns	6.68ns	17.11b	170.93a	2.88ns	10.02a
1.2 m	1.21b	467	6.51	16.42b	167.70a	2.75	7.92b
1.5 m	1.38a	474	7.13	19.55a	155.31b	3.08	7.07b

Means followed by the same lowercase letter in a column do not differ by Duncan's test (p>0.05); ns, not significant.

The 2020/21 harvest showed low values of soluble solids (Table VIII). This crop was characterized by constant rains and predominance of cloudy days during the grape ripening. These factors hinder the accumulation of soluble solids in the berries since the photosynthetic rate is reduced (Taiz and Zeiger, 2004). Nevertheless, Brighenti *et al*. (2014), studying the 'Vermentino' variety in the altitude region of Santa Catarina, obtained adequate values for the production of quality wines (18 to 22 °Brix). The total acidity of the musts was lower when using the 'Harmony' and 'Paulsen 1103' rootstocks, however, in the case of white wines, higher acidity values are acceptable, in order to give freshness to the wines, in this context, it is considered that all rootstocks presented good acidity values for the production of young wines (Porro and Stefanini, 2016). Acidity are correlated the pH, which ranged from 3.27 to 3.32. This parameter is crucial in the biological stability and color of wines, and the ideal range is between 3.0 and 3.6, depending on the type of wine (Wurz *et al*., 2022), which indicates adequate pH values for all the evaluated musts.

Table VIII

Physicochemical parameters of 'Vermentino' must in relation to rootstock and spacing of the 2020/21 crop

	pH	TSS (°Brix)	TTA	L*		
				1.0 m	1.2 m	1.5 m
Rootstock						
'101-14 Mgt'	3.29ab	16.5b	100.4bc	95.01bAB	95.33bA	94.81bcB
'Harmony'	3.32a	17.5a	95.0d	95.04bA	94.60cB	94.48cdB
'IAC 572'	3.28b	16.2b	103.0ab	95.83aA	95.89aA	94.96bB
'Paulsen 1103'	3.30ab	16.4b	98.4cd	94.50cB	95.77aA	94.28dB
'VR 043-43'	3.27b	16.2b	105.2a	95.48abA	94.77cB	95.55aA
Spacing						
1.0 m	3.28ns	16.8ns	100.4ns	-	-	-
1.2 m	3.3	16.6	99.6	-	-	-
1.5 m	3.29	16.2	101.5	-	-	-
	°Hue			Chroma		
	1.0 m	**1.2 m**	1.5 m	1.0 m	1.2 m	1.5 m
Rootstock						
'101-14 Mgt'	93.69abA	94.27bA	93.13bA	8.7aA	7.3bA	9.0bA
'Harmony'	93.27bA	91.92cB	91.79cB	8.6aB	10.8aA	11.3aA
'IAC 572'	94.78aB	96.10aA	93.67bB	5.0cB	5.1cB	8.8bA
'Paulsen 1103'	91.99cB	95.45aA	91.49cB	10.0aA	5.6cB	11.4aA
''VR 043-43''	94.66aA	92.73cB	95.15aA	6.7bB	10.0aA	6.3cB
	Polyphenols (mg gallic acid/L)			Antioxidant activity (µM/mL)		
	1.0 m	1.2 m	1.5 m	1.0 m	1.2 m	1.5 m
Rootstock						
'101-14 Mgt'	478bA	421cA	435cA	1015bA	980cA	1010cA
'Harmony'	575aB	709aA	727aA	1348aA	1410aA	1424aA
'IAC 572'	341cB	321dB	455cA	902bB	942cB	1191bA
'Paulsen 1103'	580aA	427cB	612bA	1235aA	1180bA	1267bA
''VR 043-43''	437bB	590bA	392cB	990bB	1278abA	905cB

Means followed by the same lowercase letter in a column do not differ by Duncan's test (p>0.05); ns, not significant.

The chromatic characteristics showedinteraction between rootstock and spacing, the variable L* presented the highest values when using the 'IAC 572' rootstock with 1.0 and 1.2 m spacing between plants, although all the rootstocks were associated with clear musts. The hue, revealed musts of yellow color with greenish reflections, although 'IAC 572' presented the highest values in the 1.2 m spacing. Chroma, in turn, indicates musts with lower color intensity (Chitarra and Chitarra, 2005).

The lowest concentration of polyphenols was ascribed to the rootstock 'IAC 572' in the spacing of 1.0 and 1.2 m between plants. This rootstock, being vigorous, can lead to imbalance in the direction of carbohydrates, the main precursors of polyphenols, which are directed to the vegetative apex and not to the bunches (Marcon Filho *et al*., 2015).

Likewise, of antioxidant activity was lower for 'IAC 572' at 1.0 and 1.2 m between plants. Antioxidant activity is the ability of a compound to inhibit or delay oxidation and lipid peroxidation, with phenolic compounds being the primary natural antioxidants. Its determination is vital to assess a food's ability to protect against deterioration, reactions that can decrease its quality, and nutritional value (Taiz and Zeiger, 2004).

Over the three seasons assessed, the tendency of delay in bud break can be observed when using more vigorous rootstocks, as well as the shortening of subsequent periods. This is an interesting behavior in plants grown in the altitude regions of Santa Catarina, since the risk of late frosts is high and the rainy period during ripening can harm the health and quality of the grapes for these regions. On the other hand, the last crop evaluated showed interesting yield values when the '101-14 Mgt' rootstock, with lower vigor, was used.

CONCLUSIONS

Under these experimental conditions, 'Paulsen 1103' and 'VR 043-43' rootstocks delayed bud break and shorten phenological sub-periods in young vineyards of the 'Vermentino' variety.

'Paulsen 1103' and '101-14 Mgt' rootstocks contributed to increase productivity in young vineyards of the 'Vermentino' variety.

The 1.0 m spacing between plants contributed to greater productivity in vineyard of the 'Vermentino' variety.

The 'IAC 572' rootstock contributed the least to the increase in polyphenols and antioxidant activity of grapes from 'Vermentino' variety.

The 'Harmony' rootstock contributed to the greater accumulation of soluble solids in the grapes of the 'Vermentino' variety.

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