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Research Article

The increase in bud load of Sauvignon Blanc affects the temporal dynamics of Botrytis bunch rot (*botrytis cinerea*)

O aumento da carga de gemas da videira Sauvignon Blanc afeta a dinâmica temporal da podridão cinzenta (botrytis cinerea)

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ABSTRACT

The objective of this work is to evaluate the effect of increasing bud load on the temporal dynamics of Botrytis bunch rot in Sauvignon Blanc vines. This work was conducted in the 2017 and 2018 harvests, in a commercial vineyard, in São Joaquim – SC. Sauvignon Blanc plants subjected to four different bud load levels were used: 15, 30, 50 and 75 buds/plant. The disease epidemic was evaluated using the variables: beginning of symptom appearance (BSA), time to reach maximum disease incidence and severity (TRMDI and TRMDS), maximum disease incidence and severity (Imax and Smax), and areas under disease incidence and severity progress curves (AUDIPC and AUDSPC). The increase in bud load, above 50 buds/plant, resulted in an increase in incidence and severity of the disease, in addition to AUDIPC and AUDSPC. There was an influence on the onset of symptoms, with the disease occurring early in plants with loads above 50 buds/plant. No effect was observed for the TRMDI and TRMDS variables. It is concluded that when adopting bud loads greater than 50 buds/plant, it is necessary to adopt complementary integrated disease management measures, to reduce the damage resulting from the occurrence of the disease.

KEYWORDS: *Vitis vinifera* L. Grapevine diseases. Winter pruning. Integrated disease management.

RESUMO

Tem-se como objetivo deste trabalho avaliar o efeito do aumento da carga de gemas na dinâmica temporal da podridão cinzenta na videira Sauvignon Blanc. O presente trabalho foi realizado nas safras 2017 e 2018, em um vinhedo comercial, no município de São Joaquim – SC. Utilizou-se plantas de Sauvignon Blanc submetidas a quatro diferentes níveis de carga de gemas: 15, 30, 50 e 75 gemas/planta. Avaliou-se a epidemia da doença através das variáveis: início do aparecimento dos sintomas (IAS); tempo para atingir a máxima incidência e severidade da doença (TAMID e TAMSD); valor máximo de incidência e severidade (Imax e Smax); área abaixo da curva do progresso da severidade e incidência doença (AACPSD e AACPID). O aumento da carga de gemas, acima de 50 gemas/planta, resultou aumento da incidência e severidade da doença, além da AACPID e AACPSD. Houve influência no início do aparecimento dos sintomas, com a doença ocorrendo precocemente em plantas com cargas acima de 50 gemas /planta. Não se observou efeito para as variáveis TAMID e TAMSD. Conclui-se que ao adotar cargas de gemas superiores a 50 gemas/planta, faz-se necessário a adoção de medidas complementares de manejo integrado de doença, a fim de reduzir os danos resultantes da ocorrência da doença.

PALAVRAS-CHAVE: *Vitis vinifera* L. Doenças da videira. Poda invernal. Manejo integrado de doenças.

INTRODUCTION

The high-altitude regions of the state of Santa Catarina, Brazil, are characterized by having vineyards between 900 and 1,400 m above sea level (WURZ et al. 2017a), and this region has the characteristic of presenting longer phenological cycles when compared to other viticultural regions in Brazil (BRIGHENTI et al. 2013), presenting a higher availability of solar radiation and lower nighttime temperatures in the final stage of maturation (MALINOVSKI et al. 2016).

However, the high rainfall levels (above 1,000 mm/year) observed in this region (BITENCOURT et al. 2021), and extensive use of vigorous rootstocks (MARCON FILHO et al. 2021), in addition to grapevine production based on vertical shoot position trellis (VSP), and vines pruned in spur cordon (VIANNA et al. 2016), result in high vineyard vigor, lower bud fruitfulness, and, thus, reduced productive potential (WÜRZ et al. 2018). To overcome the problems of excessive vegetative vigor, an increase in the bud load during winter pruning is a viable alternative.

Pruning is one of the main factors in plant management that allows the winegrower to manipulate vine balance and grape composition (ALLEBRANDT et al. 2017). The adaptive processes by which vines respond to increased bud numbers have been described and include reduced vegetative growth, reduced bud fertility, shorter branches with shorter internodes, increased productivity and greater number of clusters per plant, presenting longer clusters and smaller berries (GREVEN et al. 2014, GREVEN et al. 2015, WURZ et al. 2020a). Work conducted by WURZ et al. (2023), with Sauvignon Blanc plants in an altitude region of southern Brazil, demonstrate that increasing bud load, results in an increased productivity, improving vegetative-productive balance, maintaining a similar cluster architecture and technological maturation levels between the different loads of buds per plant.

However, according to WURZ et al. (2017b) and WURZ et al. (2020a), increasing the bud load in grapevines can result in a denser canopy with an increase in the number of clusters per plant, affecting the occurrence of fungal diseases. According to work done by WURZ et al. (2021), with 'Cabernet Franc' plants, when adopting a high number of buds per plant, it is necessary to adopt complementary integrated disease management to reduce the damage caused by gray mold in the vine clusters. MOSSETTI et al. (2016), describes that the occurrence of gray mold is strongly influenced by the microclimate in the cluster zone.

Botrytis bunch rot can significantly reduce both grape yield and quality (DE BEM et al. 2017). Botrytis bunch rot, caused by *Botryotinia fuckeliana* (de Bary) Whetzel, the sexual phase of *Botrytis cinerea* Persoon ex Fries (ELLIS 1971), is a critical grape disease and a problem in regions with cool and wet macroclimates, common in the highland regions of Southern Brazil. In general, fungal infection is most likely to occur in poorly exposed and dense clusters (DE BEM et al. 2015). According to WURZ et al. (2020b), Sauvignon Blanc plants have a compact cluster, and its ripening-harvest phase typically occurs in the period of high rainfall (monthly average of 195 mm) in the highland regions of Southern Brazil. Sauvignon Blanc plants are very vigorous and tend to exhibit excessive vegetative growth.

In this context, the literature indicates an increased productivity with higher bud numbers that need to be balanced with vine management to prevent phytosanitary problems. Therefore, the objective of this work is to evaluate the effect of increasing the bud load on the occurrence of gray mold in clusters of 'Sauvignon Blanc' grown in high altitude regions.

MATERIAL AND METHODS

This work was performed during the 2016/2017 and 2017/2018 vintages, in a commercial vineyard, located in the municipality of São Joaquim (28°17'39" S and 49°55'56" W), at 1230 meters above sea level. Sauvignon Blanc plants grafted on 'Paulsen 1103' rootstock were used. The experimental design used was randomized blocks, with four blocks and ten plants per replication.

The vineyards were established in 2004. The vineyard is characterized by having plants spaced by 3.0 x 1.5m, in rows arranged in the N-S direction, trained in VSP, pruned in a double spur cordon, at 1.2m in height and covered with anti-hail protection net. The climate of the region is classified as 'Cold, Cold Nights and Humid', Heliothermal Index of 1.714, average annual rainfall of 1,621 mm and average annual relative humidity of 80% (TONIETTO & CARBONNEAU 2004), and the soils in the region are considered Humic Cambisol, Litholic Neosol and Haplic Nitosol, developed from rhyodacite and basalt rocks (SANTOS et al. 2018).

The treatments consisted of four different levels of bud load: 15, 30, 50 and 75 buds per plant. After pruning 8, 15, 25 spurs with two buds each were left for treatments of 15, 30 and 50 buds per plant; and for the treatment 75 buds per plant, 30 spurs were left with two buds, and two canes with 8 buds each, therefore, this treatment was pruned in the mixed pruning system, characterized by the presence of spurs and canes. Pruning was done on September 1, 2016, and August 31 of 2017.

To obtain better experimental control, the vine management (pruning, thinning, training, leaf removal and harvesting) was conducted by the Fruit Production team of the Agroveterinary Sciences Center of Santa Catarina State University. All management was done in accordance with the standards of the company that provided the vineyards for the experiment.

During the vegetative cycle, fungicides effective against Botrytis bunch rot and other fungal diseases were used: mancozeb/DITHANE NT (dithiocarbamate, 800 mL a.i./Kg^{-1}, 350 g/c.p./ha); iprodione/ROVRAL (Dicarboximida, 500g a.i./kg^{-1}, 150 g/c.p./ha), methyl thiophanate/CERCOBIN 700WP (benzimidazole, 700 g/a.i./kg^{-1}, 70 g/c.p./ha), Chlorothalonil/ BRAVONIL 720 (Tetrachloroisophthalonitrile, 123 g a.i./kg^{-1}, 150 g/c.p./ha).

The incidence of *Botrytis cinerea* was obtained through visual assessment, verifying the presence or absence of symptoms. The incidence was calculated by the percentage of clusters that had at least one lesion in relation to the total number of clusters. For the severity of *Botrytis cinerea*, assessments began at the appearance of the first symptoms, at intervals of 10 to 15 days, under conditions of natural infection. Then, 20 clusters per plot were marked, totaling 80 clusters for each bud load, marked randomly, and evaluations were done using a diagrammatic scale as proposed by HILL et al. (2010).

With the data obtained from Botrytis bunch rot incidence and severity, the progression curves of were constructed, and the epidemic was compared in relation to: beginning of symptom appearance (BSA) (days), time to reach maximum disease incidence/severity (TRMDI and TRMDS) (days), maximum disease incidence (Imax) (%) and maximum disease severity (Smax) (%), area under disease incidence (AUDIPC) and disease severity (AUDSPC) progress curve. To calculate the Area Under the Disease Progression Curve (AUDPC) the following formula was used: AUDPC = Σ ((Yi+Yi+1)/2)(ti+1–ti), where Y represents disease intensity (incidence and severity), t the time and i the number of evaluations in time (CAMPBELL & MADDEN 1990).

The meteorological data was obtained from a meteorological station from CIRAM (Center of Environmental Resources Information and Hydrometeorology of Santa Catarina) located near the vineyard. The daily precipitation (mm) and average temperature (°C) data was registered during the months of August 2016 to April 2017 and August 2017 to April 2018, corresponding to vine vegetative growth period.

The average disease incidence data was transformed by arc sine of the square root to normalize the statistical distribution. Averages were submitted to analysis of variance (ANOVA) and the detection of significant differences between treatments was obtained through Tukey test ($p < 0.05$).

RESULTS AND DISCUSSION

Climatic conditions favorable to the development of Botrytis bunch rot occurred in both of the evaluated vintages (Figure 1). During the period of intense vegetative growth, in 2016/2017, the average temperature was 17.3 °C. In 2017/2018, during the same period, the average temperature was 16.1 °C. The precipitation from December to April 2016/2017 was 532.7 mm, while in 2017/2018 it was 519.8 mm. The average relative humidity in the period was 81.2% and 79.4% in the 2016/2017 and 2017/2018 cycles, respectively.

The combination of high volumes of rainfall, high relative humidity are factors that favor the onset of the disease, especially during spring and summer for *B. cinerea* (DE BEM et al. 2015), in addition, for the progression of the disease, there is a range of 15-23ºC as the optimal temperature for the development of the disease (HED et al. 2009), therefore, during the evaluation period, favorable conditions for the disease occurrence were observed.

The effect of bud load on the epidemiological variables of gray mold is described in Table 1. No effect of bud load per plant was observed for the variables time to reach maximum disease incidence and severity (TRMDI and TRMDS) (days), in both vintages. The beginning of symptom appearance (BSA) showed similar behavior in both evaluated vintages, with loads of 50 and 75 buds per plant presenting symptoms earlier when compared to loads of 15 and 30 buds per plant (Table 1).

For the variable maximum incidence (Imax) of Botrytis bunch rot, the highest values were observed in both vintages for loads of 30, 50 and 75 buds per plant. In both of the evaluated vintages, the load of 15 buds per plant presented the lowest values for the incidence of gray mold, with 71.9 and 68.7%, in the 2017 and 2018 vintages, respectively. For the maximum gray mold severity variable (Smax), similar behavior was observed, that is, the lowest values were found at a load of 15 buds per plant, in 2017 and 2018 vintages, presenting disease values of 6.0 and 2.1%, respectively (Table 1).

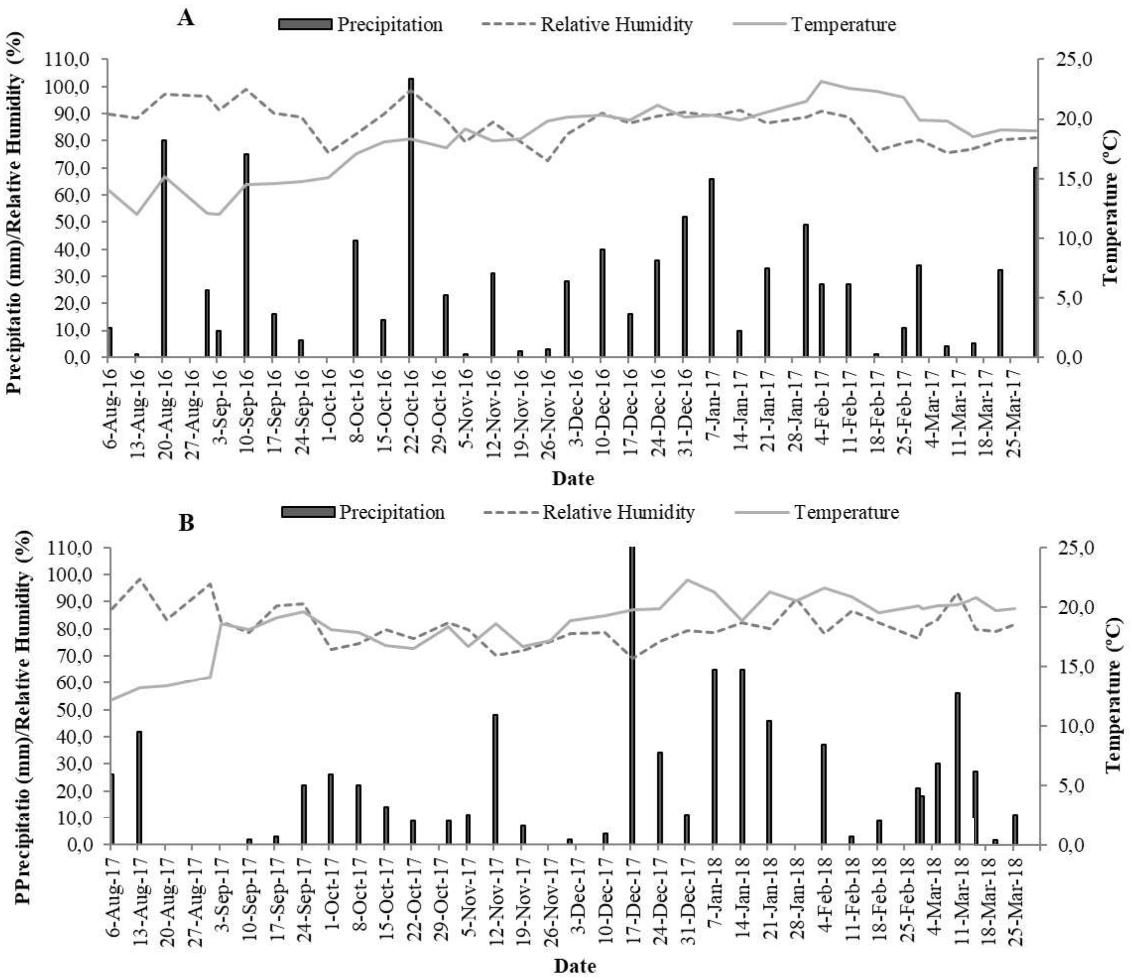

Figure 1. Accumulated precipitation (mm), relative humidity (%) and average air temperature (ºC) in São Joaquim/SC during the 2016/2017 (A) and 2017/2018 (B) vintages.

Following the same trend as the maximum disease incidence variable, the loads of 30, 50 and 75 buds per plant presented the highest AUDIPC values, while the load of 15 buds per plant presented the lowest values in the 2017 and 2018 vintages, with values of 1159.3 and 780.6, respectively. As for the AUDSPC, the highest values were observed in loads of 50 and 75 buds per plant, in both evaluated vintages, while the load of 30 buds per plant presented intermediate AUDSPC values, and the load of 15 buds per plant presented the lowest values of AUDSPC, in both evaluated vintages.

It was observed that the increase in bud load resulted in an increase in the intensity of gray mold, which can be explained by the favorable microclimate that occurs as a result of the cluster density. For O'DANIEL et al. (2012), increasing the bud load results in an increase in the number of shoots per hectare and decrease the spacing between shoots. These responses indicate a denser canopy, with less penetration of solar radiation, reduced efficiency of phytosanitary treatments and reduced air flow in the vegetative canopy, creating a microclimate with high humidity, which can influence fungal diseases occurrence and berry quality (SMART 1985).

Table 1. Effect of bud load on beginning of symptom appearance (BSA), time to reach maximum disease incidence (TRMDI) and severity (TRMDS), maximum incidence (Imax), maximum severity (Smax), and area under disease incidence (AUDIPC) and severity (AUDSPC) progress curves on Sauvignon Blanc clusters in high altitude region of Santa Catarina. Vintages 2017 and 2018.

	Bud Load				CV
	15	30	50	75	(%)
2017					
BSA (days)	14.0 a	12.2 a	5.2 b	5.2 b	14.4
TRMDI (days)	31.5 ns	33.2	33.2	35.0	12.1
TRMDS (days)	35.0 ns	35.0	35.0	35.0	0.0
Imax (%)	71.9 b	96.9 a	90.6 a	98.4 a	7.7
Smax (%)	6.0 c	12.1 b	16.2 a	16.9 a	9.8
AUDIPC	1159.3 b	1607.8 a	1707.8 a	1908.6 a	12.9
AUDSPC	82.7 b	156.8 ab	183.6 a	193.0 a	22.3
2018					
BSA (days)	28.0 a	15.0 ab	12.0 b	10.0 b	17.7
TRMDI (days)	49.0 ns	49.0	49.0	49.0	0.0
TRMDS (days)	49.0 ns	49.0	49.0	49.0	0.0
Imax (%)	68.7 b	82.8 ab	93.7 a	98.4 a	10.2
Smax (%)	2.1 c	5.0 bc	7.2 ab	9.2 a	24.4
AUDIPC	780.6 c	1208.3 b	1733.1 a	1759.8 a	8.3
AUDSPC	15.0 c	34.8 b	61.7 a	63.4 a	9.6

* Averages followed by the same letter, on the line, do not differ from each other by the Tukey test ($p < 0.05$).ns = not significant by analysis of variance (ANOVA) ($p < 0.05$).

Furthermore, WURZ et al. (2021), highlights that with an increase in bud load, there is a greater number of structures left at the pruning time, and consequently, there may be a greater source of inoculum in plants subjected to higher bud loads, which could influence the beginning of the epidemic in the vineyard.

Work done by WURZ et al. (2017c) and WURZ et al. (2019), studying the increase in bud load and the occurrence of the fungal disease anthracnose and WURZ et al. (2021) and WURZ et al. (2023), evaluating downy mildew, observed a similar behavior to the occurrence of gray mold, in which the increase in the bud load per plant resulted in an increase in the occurrence of fungal diseases, with emphasis on loads greater than 50 buds per plant.

The effect of bud load on the area under the disease incidence progress curve (AUDIPC) during the 2017 vintage is described in Figure 2 (A). The first assessment took place on 02/02/2017 and the last assessment happened on 03/09/2017.

After 7 days of the first evaluation, an increase in AUDIPC was observed for loads of 50 and 75 buds per plant, while loads of 15 and 30 buds per plant remained at zero for the AUDIPC variable. However, from 02/09 onwards, an increase in AUDIPC values was observed for all bud loads, increasing up to the moment of harvest. It is noteworthy that despite the beginning of the evaluations, the load of 30 buds per plant presented low AUDIPC values at the time of harvest, values like the load of 75 buds per plant were observed, while the smallest increase in AUDIPC was observed at a load of 15 buds per plant.

Data relating to the vintage 2018 on the effect of bud load on AUDIPC are described in Figure 2 (B). The first evaluation took place on 12/14/2017, and the last evaluation was done on the day of harvest, on 02/08/2018. Seven days after the start of the evaluations, a significant increase in the variable was observed for loads of 30, 50 and 75 buds per plant, while the load of 15 buds per plant showed a slow increase in AUDIPC until 01/09/2018. For all bud loads, an exponential increase was observed from 01/18/2018 to 01/25/2018, and from then on, the increase in AUDIPC was less significant.

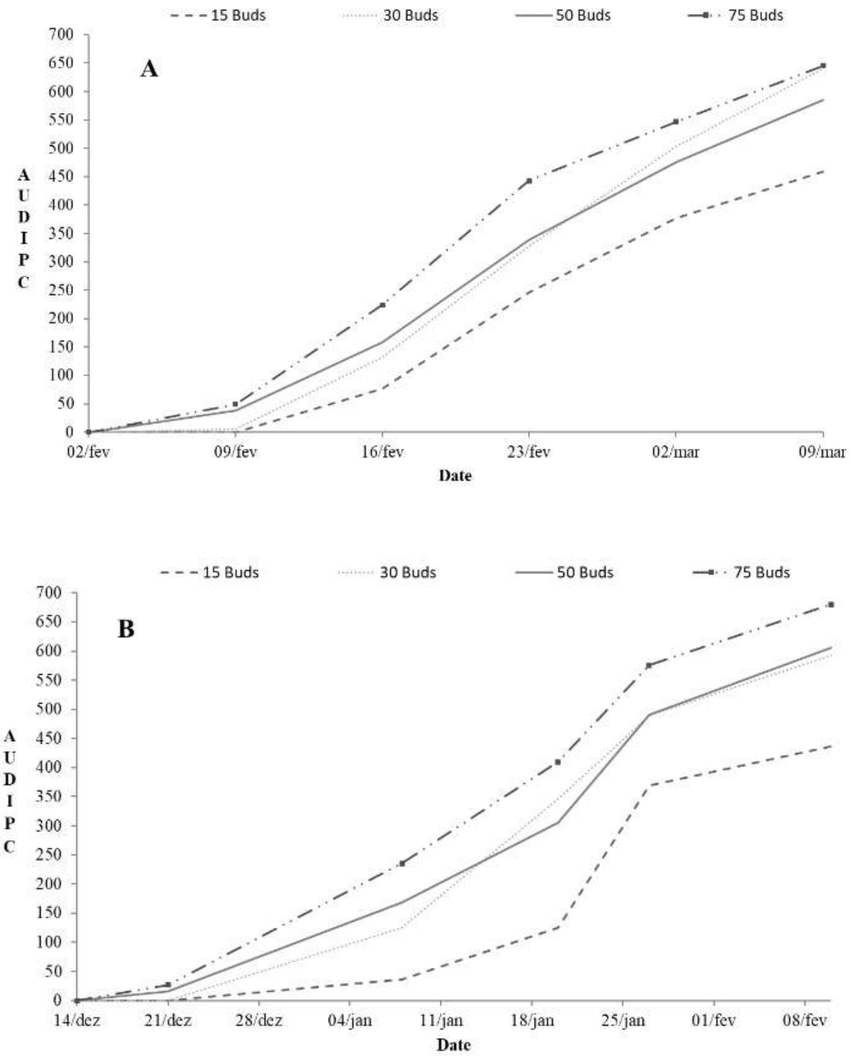

Figure 2. Effect of bud load on the area under Botrytis bunch rot incidence progress curve for Sauvignon Blanc (*Vitis vinifera* L.) plants in high altitude region of Santa Catarina State. Vintage 2017 (A) and 2018 (A).

At the time of harvest, the highest AUDIPC values were observed for the load of 75 buds per plant, while the load of 15 buds per plant presented the lowest values, and the loads of 30 and 50 buds per plant, presented intermediate AUDIPC values. The fungus can attack almost all floral organs, and the attacks on clusters, during maturation, assume greater occurrence, which is evident in this study, with increased disease growth and progress at the beginning of berry maturation.

The area under the disease severity progress curve (AUDSPC) was influenced by the different bud loads, as described in Figure 3. In the 2017 vintage, until 02/09/2017, that is, 07 days after the first evaluation of gray rot, all bud loads presented AUDSPC values, close to zero, however, from then on, loads of 30, 50 and 75 buds per plant showed an exponential increase in the values of the AUDSPC variable.

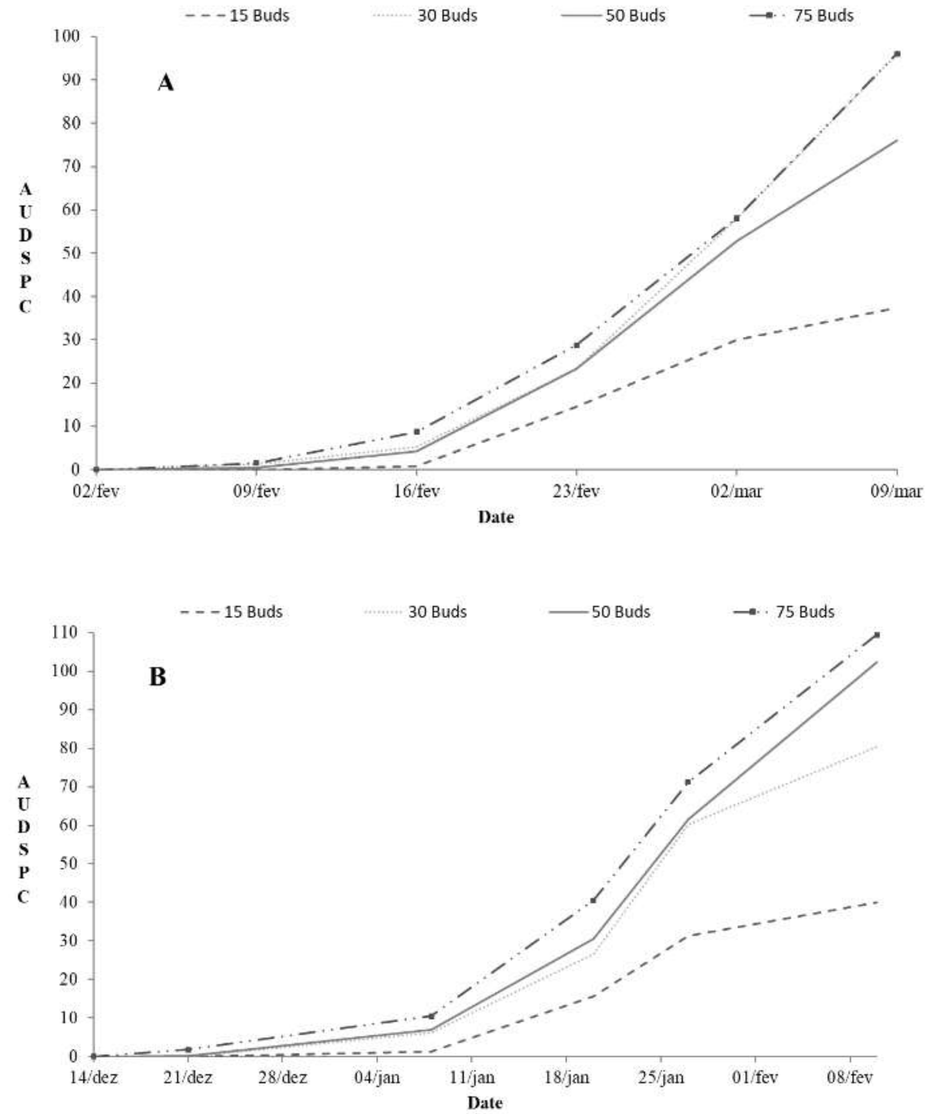

Figure 3. Effect of bud load on the area under Botrytis bunch rot severity progress curve of Sauvignon Blanc (*Vitis vinifera* L.) plants in high altitude region of Santa Catarina State. Vintage 2017 (A) and 2018 (A).

For the load of 15 buds per plant, a more significant increase was observed in the AUDSPC variable, between 02/16/2017 and 03/02/2017, and from then on, there was a stabilization of its values, while the other bud loads showed an increase in AUDSPC in all evaluations performed throughout the maturation period of the Sauvignon Blanc plants.

For vintage 2018, the effect of the bud load regarding AUDSPC was similar to the vintage 2017, with the exception of the load of 30 buds per plant, which showed similar behavior to the load of 15 buds per plant.

It was observed for loads of 15 and 30 buds per plant, between 01/25/2018 and 02/08/2018, a tendency towards stabilization of AUDSPC values, while loads of 50 and 75 buds per plant showed exponential increase in the values of AUDSPC. It is noteworthy that the increase in values of AUDSPC was lower in the load of 15 buds per plant compared to other bud loads.

In the work by WURZ et al. (2021), with the 'Cabernet Franc' plants, it observed similar behavior to the present work, indicating that plants left with more than 50 buds result in a greater occurrence of the disease, with the need for preventive control measures, such as green pruning.

The control of *Botrytis cinerea* usually requires excessive use of fungicides, especially in regions with a temperate rainy climate, to prevent epidemics and obtain quality grapes. However, an economically and environmentally sustainable viticulture demands the rational use of fungicides, in addition to alternative practices to prevent disease occurrence (DE BEM et al. 2020, BRIGHENTI et al. 2020). In this context, it is necessary to adopt preventive measures to obtain good cluster health in Sauvignon Blanc vineyards pruned with loads greater than 50 buds per plant, with emphasis on early management of leaf removal in the cluster zone.

CONCLUSION

Increasing bud load resulted in higher incidence and severity of Botrytis bunch rot on Sauvignon Blanc clusters.

Increased bud load, above 50 buds per plant, results in earlier beginning of symptom appearance.

Increased bud load does not influence the time to reach maximum disease incidence and severity.

Increasing the bud load, above 50 buds per plant, results in an increase in the area under disease incidence and severity progress curves.

When adopting bud loads greater than 50 buds per plant, it is necessary to adopt complementary integrated management measures in order to reduce damage resulting from the occurrence of the disease.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis Leo Rufato, Alberto Brighenti and Douglas Wurz; software and validation, Leo Rufato and Alberto Brighenti; investigation, Leo Rufato, Alberto Brighenti and Douglas Wurz; resources and data curation Leo Rufato, Alberto Brighenti; writing-original draft preparation, Alberto Brighenti and Douglas Wurz; writing-review and editing, Leo Rufato, Alberto Brighenti and Douglas Wurz; visualization, Leo Rufato, Alberto Brighenti and Douglas Wurz; supervision, Leo Rufato; project management, Leo Rufato; fundraising, Leo Rufato. All authors have read and agreed to the published version of the manuscript.

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INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable for studies not involving humans or animals.

INFORMED CONSENT STATEMENT

Not applicable as this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available upon request.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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