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Article

EFFECT OF ANTI-HAIL NET ON PRODUCTION AND QUALITY OF 'ROSE NIAGARA' GRAPES GROWN IN SERRA GAÚCHA REGION, SOUTH BRAZIL

EFEITO DO USO DE TELA ANTIGRANIZO SOBRE A PRODUÇÃO E QUALIDADE DE UVAS 'NIÁGARA ROSADA' NA REGIÃO DA SERRA GAÚCHA, SUL DO BRASIL

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SUMMARY

In the Serra Gaúcha region, South Brazil, the occurrence of hail is common due to relief and the cold air currents coming from polar regions. Nowadays, the use of anti-hail nets to protect fruit production is increasing, but the real effects of using this coverture on vines are largely unknown. Thus, this work aimed to evaluate the impact of the use of an anti-hail net on the productivity and quality parameters of 'Rose Niagara' grapes grown in the region, in the 2019/2020 and 2020/2021 harvests. The studied parameters were production, number of bunches per plant, bunch length, berry diameter, mass of 100 berries, average bunch mass, juice pH, titratable acidity, soluble solids, phenolic compounds content, total anthocyanins content, and photosynthetically active radiation. The results showed that the anti-hail net influenced some quality parameters, but this change was not consistent in the two harvests, indicating a larger influence of edaphoclimatic conditions than of the use of the net. Thus, the anti-hail net may be an alternative to protect vineyards from hail and other bad weather conditions, without having important negative impacts on the production and quality of 'Rose Niagara' grapes.

RESUMO

Na região da Serra Gaúcha, Sul do Brasil, é comum a ocorrência de granizo devido ao relevo e às correntes de ar frio que vêm das regiões polares. Atualmente vem crescendo o uso de telas antigranizo para proteger a produção frutícola, mas os reais efeitos do uso deste tipo de cobertura nas videiras são desconhecidos. Desta forma, o presente trabalho teve como objetivo avaliar o impacto do uso de tela antigranizo sobre a produtividade e os parâmetros de qualidade de uvas 'Niágara Rosada' cultivadas na região, nas vindimas de 2019/2020 e 2020/2021. Os parâmetros estudados foram a produção, o número de cachos por planta, o comprimento do cacho, o diâmetro dos bagos, a massa de 100 bagos, a massa média dos cachos, o pH do mosto, a acidez titulável, o teor de sólidos solúveis, o teor de compostos fenólicos, o teor de antocianinas totais e a intensidade de radiação fotossinteticamente ativa. Os resultados mostraram que a tela antigranizo influenciou alguns parâmetros de qualidade, mas estas alterações não foram consistentes nas duas vindimas, indicando uma maior influência das condições edafoclimáticas do que do uso da tela. Assim, a tela antigranizo pode ser uma alternativa para proteger os vinhedos do granizo e outras intempéries sem causar impactos negativos na produção e qualidade de uvas 'Niágara Rosada'.

Keywords: inclement weather, productivity, fruit quality, *Vitis labrusca*.
Palavras-chave: intempéries, produtividade, qualidade dos frutos, *Vitis labrusca*.

INTRODUCTION

According to the International Organisation of Vine and Wine (OIV), there was a wine production of 260 million hectoliters worldwide, corresponding to 7.40 million hectares of vineyards, in the 2019/2020 harvest, whereas Brazil produced 1.92 million hectoliters of wine in the same period (OIV, 2021). Regarding the Brazilian production, at about 55 % of grape production is used for winemaking, 35 % is destined for *in natura* consumption, 6 % is used for juice production, 2 % for the production of raisins, and 2 % is used in the production of teas, infusions, and essences (Mello, 2017).

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Currently, Brazilian viticulture is concentrated in the states of Rio Grande do Sul, São Paulo, Santa Catarina, Minas Gerais, Bahia, and Pernambuco (Mello and Machado, 2020). The most favorable environmental conditions for vineyard development and production occur in South Brazil, and this region has the biggest vineyard area in the country, totaling 55,501 ha, which represented 73.3 % of the Brazilian vineyard area in 2019. Rio Grande do Sul is the main producer in South Brazil, accounting for 62.7% of the entire vineyard area of the country. In Rio Grande do Sul, the Serra Gaúcha region stands out as the main regional and, consequently, as the national viticultural center (IBGE, 2020).

However, the Serra Gaúcha region has a high incidence of hailstorms during the period between the vegetative growth of vines and the harvest, which causes insecurity and economic damage to the regional grape production. Aiming to mitigate this situation, anti-hail nets are being used in the region as an alternative to protect the vineyards against damage caused by this phenomenon and reduce the risk of losses (Castellano *et al.*, 2008).

The damage caused by hail consists of variable lesions, depending on hail size and terminal speed, density of the affected area, time and speed of winds, age of the affected plants, time of occurrence, and the phenological phase of the vineyard (Cera *et al.*, 2016).

Fruticulture is experiencing a new technological phase, resulting from the increase in the occurrence of inclement weather in the last decades, resorting to the installation of anti-hail nets in several regions worldwide, in which apple orchards stand out (Blanke, 2008). The photoselective anti-hail nets started to have greater importance in fruit industry, aiming to mitigate the effects of hail and reduce the incidence of direct sunlight by the shade of the net on the plants (Shahak, 2014). This shadowing has a protective effect, increasing the efficiency of light-dependent processes, and helping the plants to complete their cycle (Rajapakse, 2007; Basile *et al.*, 2012). In the last few years, many kinds of photoselective nets, with several color and mesh options, have become better accepted by the specific market and by farmers in general, increasing the area covered by these nets (Abdel-Ghany *et al.*, 2011).

Currently, there is a great technical and economic interest in the use of anti-hail nets, especially in horticulture and fruticulture. Different colors of photoselective nets can be applied, including red, yellow, blue, gray, and pearl colors. Thus, nets are used not only for protection against hail but also for their shadowing effect, with a reduction of the incident sunlight by up to 45 %, such as the black net. The color of the net has an important influence on both the transmission of photosynthetically active radiation – PAR – (shadowing) and the spectrum of the transmitted light (Castellano *et al.*, 2008). The effect on agricultural parameters depends on plant species that grow under the covering, but yield, soluble solids, color, and secondary metabolites (phenolic compounds, pigments, phytohormones) can be affected by the net color (Shahak, 2014; Buthelezi *et al.*, 2016; Aras and Estiken, 2019).

Buthelezi *et al.* (2016), evaluating the effect of net color on PAR transmittance and spectrum composition, observed that black nets had the highest PAR transmission, followed by pearl and red nets, respectively. On the other hand, the black and pearl nets had similar blue/red ratios, which were much lower in the red nets. These authors also reported that the presence of the net did not affect both the temperature and relative humidity of the crops, regardless of net color. Aras and Estiken (2019) obseved a different behavior: the use of photoselective nets (green, red, and black, all with 40% shading) increased the air temperature in the strawberry cultivation.

Excessive shadowing may have deleterious effects on plant development by increasing the vegetative growth and decreasing the capacity of bud differentiation, reducing both productivity and fruit quality. The intensity of this effect is related to the shadowing degree, which is dependent on the net color and also on the variety/rootstock combination, plant density and management, and the productive region (Mello, 2017).

The present work aimed to evaluate the effect of the use of an anti-hail net on the production and quality parameters of ‘Rose Niagara’ (*Vitis labrusca* L.) table grapes, analyzing the effects of shadowing on the vineyard.

MATERIALS AND METHODS

Vineyard conditions and grape harvest

The experiment was carried out in a vineyard located in the municipality of Antônio Prado, South Brazil (28°89' S 51°23' W, 690 m above sea level). The climate of the region is classified as Cfb according to the Köppen classification, being characterized by a hot climate in summer and temperate in the rest of the year, with an average annual rainfall of 1,801 mm.

The vineyard was established in 2009, on a leptosol (EMBRAPA, 2006). Soil fertility parameters were analyzed and were within the appropriate ranges for vineyard cultivation, according to the Commission of Chemistry and Soil Fertility (CQFS, 2016), in the two studied areas and harvests.

The grape variety studied was ‘Rose Niagara’ (*Vitis labrusca* L.), grafted on the Paulsen 1103 (*Vitis berlandieri x Vitis rupestris*) rootstock, with a plant density of 1,344 plants/ha, and 2.5 x 3.0 m spacing. Vineyard production is destined for *in natura* consumption (table grapes), with an average productivity of 10 t/ha, under a trellis training system.

A ChromatiNet® anti-hail net was used, with pearl color (5.3 mm x 2.1 mm, 16-20 % shadowing, with no change in RGB ratio). The net was installed in April 2019, following the planting line, in the north-south orientation, using an adaptation of the ‘chapel’ system. Fruiting pruning for both treatments was carried out between 2019-08-03 and 2019-08-14 (2019/2020 harvest), and between 2020-08-05 and 2020-08-09 (2020/2021 productive cycle), being of the mixed type, leaving sticks and spurs.

The evaluations were carried out between November 2019 and February 2020, being repeated between November 2020 and February 2021. Both harvests were carried out when the bunches reached the ripening point for *in natura* consumption, that is, when the soluble solids content stabilized, reaching 14-16 °Brix. A field refractometer (Lorbem, Brazil), with a scale of 0-32 °Brix and a resolution of 0.25 °Brix, was used to measure this parameter.

Determination of production and quality parameters

The number of bunches per plant was determined by collection and individual counting of the production of each plant in each treatment. The determination of the average bunch length was carried out by measuring all bunches collected from each plant, in the vertical direction, from the rachis insertion point to the end of the lowest berry. The measurements were carried out using a digital caliper (MTX, Brazil), with a measurement capacity of 0-150 mm and a resolution of 0.01 mm. The average bunch mass was determined by the individual weighing of the collected bunches for each treatment using a digital scale (Marte, Brazil) model AL500C, with a measurement capacity of 1.0 kg and a resolution of 0.01 g. The results were expressed as grams per bunch.

To determine the average mass of 100 berries, they were randomly chosen among the bunches in each treatment and weighed in an analytical balance (Marte, Brazil). The average berry diameter was determined by randomly choosing 60 berries among the bunches from each treatment, and berry diameter was measured using a digital caliper (MTX, Brazil).

Determination of titratable acidity, soluble solids content and pH of the juice/must was carried out using 30 berries for each replicate from all bunches. The berries were pressed manually, the juice was collected and filtered on a 2.0 mm (Tyler 9) mesh sieve. The filtered juice was homogenized and used in the analyses.

Juice/must pH (free acidity) was determined by direct measurement of juice pH using a pH meter (DM-22, Digimed, Brazil) with an Ag/AgCl glass electrode. Titratable acidity was determined according to the IAL 310/IV method (IAL, 2008); the results were expressed as grams equivalent of tartaric acid per 100 mL of juice/must (eq. $g_{\text{tartaric acid}}$/100 mL). The soluble solids content was determined by the method IAL 315/IV (IAL, 2008), using an analogic refractometer (Petrodidática, Brazil), with a measurement range of 0-30 °Brix and resolution of 0.5 °Brix.

For the determination of phenolic compounds and total anthocyanins contents, 15 g of berries were weighed and transferred to a mortar, and macerated with 20 mL of a hydroalcoholic solution (ethanol 70% v/v). After, the mixture was transferred to a 125 mL Erlenmeyer and 30 mL of the hydroalcoholic solution were added, totaling 50 mL of solution. The mixture was thoroughly shaken, and kept at rest for 24±2 h at 20±2 °C in the dark. The supernatant was used in the analyses. Phenolic compounds content was determined by the Folin-Ciocalteu method, following the procedures of Pereira *et al.* (2018); the results were expressed as grams equivalent of gallic acid per 100 g of berries (mg eq. gallic acid·100/g). Total anthocyanin content was determined by the differential pH method, according to the AOAC procedure 2005.02 (Lee *et al.*, 2005); the results were expressed as milligram equivalent of cyanidin-3-glycoside per 100 g of berries (mg eq. cyanidin-3-glycoside/100 g).

PAR was measured using a ceptometer (AccuPAR LP-80, Decagon Devices, USA). The measurements were carried out in ten random places in the experimental areas at 8:00 h, 10:00 h, 12:00 h, 14:00 h, and 16:00 h, on 2020-02-01 and 2021-02-04. The equipment was positioned immediately above vine leaves, at the same relative positions inside the experimental areas. The same points were marked and used again in the measurement carried out in the second harvest. The results were expressed as micromoles of PAR photons per square meter per second (μmol/m^2/s).

Experimental design and statistical analysis

The experiment was composed of two treatments: with an anti-hail net; without the net. The experimental design included four rows (replicates), with five vines each, corresponding to 20 plants per treatment in each area. The same plants were evaluated in two consecutive harvests (2019/2020 and 2020/2021, respectively).

The obtained data was analyzed by Levene’s test (homoscedasticity) and Shapiro-Wilk’s test (homogeneity of residuals), followed by Analysis of Variance, and Tukey’s multiple range test at 95 % probability. The statistical analyses were carried out using Statistica 12 software (Statsoft, EUA).

RESULTS AND DISCUSSION

Edaphoclimatic conditions of the harvest

Regarding the climatic conditions of the harvests analyzed in this work, it was observed a total of 322 chilling hours for the 2019/2020 harvest, and 373 chilling hours for the 2020/2021 harvest (Jungues *et al.*, 2020), supplying the chilling requirement of the vines, which is about 100 h for the 'Rose Niagara' (Cardoso *et al.*, 2008).

The variation of the maximum and minimum temperatures in the two crop cycles is presented in Figure 1, showing that the thermal amplitude was similar in both harvests. In 2020/2021 harvest the temperatures were lower in November, January, and February, whereas in 2019/2020 the months of August and September were colder.

In the period between August and February occurs the formation and distribution of the nutritional reserves in the vines. This also fosters bud development, flowering, and berry growth (Pommer *et al.*, 2003; Borghezan, 2017). Thus, the temperature during this period has a direct influence on the production and quality of the grapes. The historical series of maximum and minimum average temperatures and rainfall of the region where this study took place is shown in Table I.

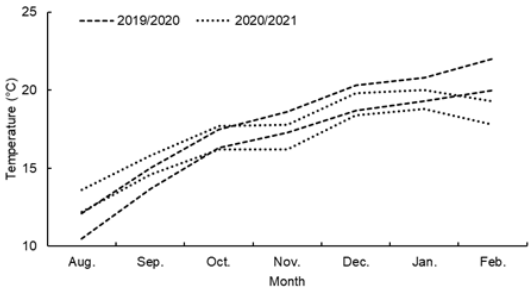

Figure 1. Variation of maximum and minimum monthly temperatures for 2019/2020 (dashed lines) and 2020/2021 (dotted lines) harvests. Adapted from INMET (2022).

The results show that average maximum and minimum temperatures in the two harvests remained within the historical climatic series. The data on monthly rainfall and average temperature for the two harvests are presented in Figure 2.

Regarding the two harvests, the average temperatures differed most in August and February, being more similar in October and December. The average monthly temperatures in August, time of vine pruning, were 10.8 ºC and 12.9 °C for 2019/2020 and 2020/2021 harvests, respectively. In November, time of vine flowering and start of bunch development, the average temperatures were 17.9 ºC and 17.0 °C in 2019/2020 and 2020/2021 harvests, respectively. In February, when veraison and harvest time occur, the average temperatures were 21.0 °C for 2019/2020 harvest and 18.5 °C for 2020/2021 harvest. The thermal amplitude in January and February, which influence the organoleptic characteristics of the grape, was 2.0 °C in 2019/2020 and 1.5 °C in 2020/2021 (INMET, 2021).

Table I

Historical series from 1988 to 2018 (last 30 years) of monthly average maximum and minimum temperatures and rainfall for the municipality of Antônio Prado, South Brazil

Month	Minimum temperature (°C)	Maximum temperature (°C)	Rainfall (mm)
January	16.2	25.0	161
February	16.4	25.1	159
March	15.3	23.8	109
April	12.9	21.0	120
May	10.3	17.5	143
June	9.0	16.4	158
July	8.1	16.0	190
August	9.0	18.1	146
September	9.6	18.5	166
October	12.0	20.8	187
November	13.4	22.8	153
December	15.0	24.4	143
Mean	12.3	20.8	153

Adapted from INMET (2022).

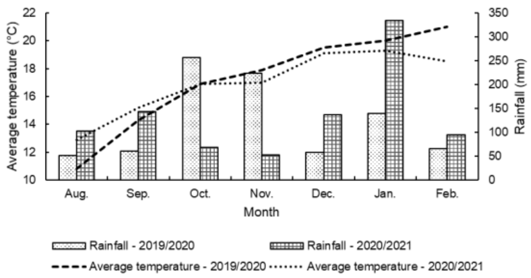

Figure 2. Variation of average monthly temperature and rainfall for 2019/2020 and 2020/2021 harvests in the region of the study. Adapted from INMET (2022).

Rainfall for the two harvests evaluated was within the historical series, especially in October and November, when the flowering period begins. This period is the most prone to damage caused by excessive rainfall, which causes flower abortion due to hindered pollination. The accumulated rainfall in the flowering phase was 481.0 mm for 2019/2020 harvest and 108.5 mm for 2020/2021 harvest.

In the veraison phase and increase in soluble solids content in the grapes, the accumulated rainfall was 206.0 mm in 2019/2020 and 427.8 mm in 2020/2021. Both harvests had rainfall above the water requirements for vines, which, according to Manica and Pommer (2006), is 384 mm. The total accumulated rainfall between pruning and harvest in 2019/2020 cycle was 857 mm and 930 mm in 2020/2021 cycle.

Effect of the anti-hail net on grape production

The average production in 2019/2020 harvest was 9.0 kg/plant for the area with the anti-hail net and 7.8 kg/plant for the area without the net. In 2020/2021 harvest, the average production in the area with the anti-hail net was 12.8 kg/plant, greater than the production in the previous cycle. On the other hand, the average production in the area without the net in 2020/2021 was 5.8 kg/plant, 35% lower than the production in the previous cycle in the same condition.

The estimated average production for 'Rose Niagara' grapes in tropical climates, as cited by Mota *et al.* (2010), is about 10.8 kg/plant, observed in a vineyard in Caldas (Southeast Brazil). Gonçalves (2007) reported a decrease in the productivity of 'Rose Niagara' vines from 2.0 kg/plant without the anti-hail net to 0.6 kg/plant in the plants covered with black anti-hail net with shading of 70%. Genta *et al.* (2010) observed productivity in the range of 10.9 and 22.9 kg/plant for 'BRS Clara' vines covered with an anti-hail net (18% shading, color not specified). Ferreira *et al.* (2004) observed that the use of plastic covering (polyethylene diffusor film DTR Nortene®) reduced the productivity of 'Rose Niagara' grapes grown in Minas Gerais state (Southeast Brazil), reporting that the average production of this cultivar for Southeast Brazil is about 6.0 kg/plant.

Borghezan *et al.* (2011) reported productivity in the ranges of 2.0-2.7 kg/plant, 0.9-1.2 kg/plant, and 0.8-1.2 kg/plant for the cultivars 'Sauvignon Blanc', 'Merlot', and 'Cabernet Sauvignon', respectively, in 2005/2006 and 2006/2007 harvests, all grown covered with anti-hail and anti-UV polyethylene nets (9% shading, color not specified). These authors also stated that the harvest significantly influenced the productivity of the three studied cultivars, while the net did not affect this parameter.

Thus, the use of coverture as an anti-hail net may cause an increase in the production of vines. This may be the result of a reduction of excessive sunlight, although the differences in latitude and other edaphoclimatic factors inherent to the harvest can also influence, potentiating or reducing the impact caused by the use of the anti-hail coverture (Gonçalves, 2007; Genta *et al.*, 2010).

Influence of the anti-hail net on grape quality parameters

Concerning the biometric parameters in the two harvests, no statistical difference between treatments for the number of bunches per plant and average berry diameter, with averages of 38.68 and 17.96 mm, respectively, were observed. The number of bunches per plant were statistically different between treatments in 2019/2020 harvest, which was not observed in 2020/2021 cycle (Table II).

Table II

Number of bunches per plant, average bunch length, and average berry diameter of 'Rose Niagara' grapes grown under different coverture systems in the 2019/2020 and 2020/2021 harvests in the municipality of Antônio Prado, South Brazil.

Harvest	**2019/2020**			**2020/2021**		
Treatment	**Bunches per plant**	**Bunch length (mm)**	**Berry diameter (mm)**	**Bunches per plant**	**Bunch length (mm)**	**Berry diameter (mm)**
With anti-hail net	43.12 a	103.10 a	19.69 a	34.25 a	101.44 a	16.44 a
Without anti-hail net	41.50 a	88.81 b	19.34 a	35.87 a	107.68 a	16.35 a
Coefficient of variation (%)	18.49	4.84	2.07	22.95	5.89	2.52

Means in a column followed by the same letter did not differ statistically with $p > 0.05$).

Hernandes *et al.* (2011), in an experiment with 'Rose Niagara' grapes in Jundiaí (Southeast Brazil), reported 22 bunches per plant, a smaller value than the one observed in the present study, in which the smallest number of bunches per plant was 34, in 2020/2021 harvest and with the anti-hail net. On the other hand, Terra *et al.* (2003) observed that, for 'Rose Niagara' grapes grown under the vertical trellis training system in the municipality of Monte Alegre do Sul (Southeast Brazil) between 1996 and 2001, an average number of 14 bunches per plant. Gonçalves (2007) reported averages of 10 and 3 bunches per plant of 'Rose Niagara' vines without and with anti-hail coverture, respectively.

According to Pedro Júnior and Sentelhas (2003) and Gonçalves (2007), the number of bunches per branch is directly influenced by the temperatures during the budding phase and also by the incidence of sunlight on the developing buds, which may explain the higher number of bunches per plant in the treatment without coverture than in the vines under the anti-hail net.

Bunch length ranged between 101.4 mm and 103.1 mm in the two cycles in the area with the anti-hail net. In the area without the net, the bunch length ranged between 88.8 mm and 107.7 mm in the two harvests. Hernandes *et al.* (2011) reported that the average bunch length of 'Rose Niagara' vines was 139.0 mm, which was higher than the lengths observed in this work. Gonçalves (2007) observed, for 'Rose Niagara' grapes, bunch lengths ranging between 91–114 mm and 89-120 mm for plants without and with anti-hail net, respectively.

Frölech *et al.* (2018), evaluating the physicochemical characteristics of 'Rose Niagara' grapes in an open field in Pelotas (South Brazil), observed that the average berry diameter was 19.5 mm, similar to the values observed in 2019/2020 harvest in both treatments, which were 19.7 mm with the anti-hail net and 19.3 mm without the net. However, in 2020/2021 cycle, the average berry diameter was lower than in the previous cycle in both treatments, suggesting an important effect of the edaphoclimatic conditions of each harvest regardless of the presence of the anti-hail coverture.

Table III shows the results of mass of 100 berries, average bunch mass, and of the pH of the juice/must of the grapes grown with and without the anti-hail net in 2019/2020 and 2020/2021 harvests.

Table III

Mass of 100 berries, average bunch mass, and pH of the juice/must of 'Rose Niagara' grapes grown under different coverture systems in 2019/2020 and 2020/2021 harvests in the municipality of Antônio Prado, South Brazil

Harvest	**2019/2020**			**2020/2021**		
Treatment	**Mass of 100 berries (g)**	**Average bunch mass (g)**	**pH**	**Mass of 100 berries (g)**	**Average bunch mass (g)**	**pH**
With anti-hail net	397.25 a	207.20 a	3.33 a	447.75 a	172.12 a	3.22 a
Without anti-hail net	371.75 b	220.31 a	3.30 a	502.25 a	159.02 b	3.14 b
Coefficient of variation (%)	3.49	8.35	1.16	5.61	10.43	1.01

Means in a column followed by the same letter did not differ statistically with $p > 0.05$.

According to the results of Table III, the mass of 100 berries was greater in the first harvest with the anti-hail net (397.3 g) when compared to the area without the net (371.8 g). However, in 2020/2021 harvest, there was no statistical difference between the treatments, with 447.8 g in the area with the anti-hail net and 502.3 g without the net. Martins *et al.* (2014), in a trial with the same grapevine variety in Santa Rita do Araguaia (North Brazil) in an open field, reported a mass of 100 berries of 440 g, similar to the values observed in this work.

For 2019/2020 cycle, there was no significant statistical difference between the treatments regarding average bunch mass, whereas in 2020/2021 harvest the plants with the anti-hail net had a greater average bunch mass (172.1 g) than the plants without the coverture (159.0 g). Martins *et al.* (2014) observed an average bunch mass of 183 g. Gonçalves (2007) reported an average bunch mass in the range of 107– -130 g in 2005/2006 cycle, with no influence from the net. However, in 2006/2007 cycle, the average bunch mass ranged between 137.8 g and 196.8 g; the bunches grown under the anti-hail net had a smaller average mass.

In this work, in 2019/2020 harvest, the pH values for both treatments did not differed significantly. However, in 2020/2021 cycle, the opposite behavior was noted. The treatment with the anti-hail net had the highest pH value (3.22) and the treatment without the net had the lowest one (3.14).

Motta (2009) observed that 'Rose Niagara' variety, grown in an open field, had a pH value of 3.30. Ferreira *et al.* (2004) reported pH values in the juice ranging between 3.10 and 3.18, with no statistical difference between treatments. Moreover, Bordignon *et al.* (2011) showed the effect of harvest on the pH values of 'Sauvignon Blanc', 'Merlot', and 'Cabernet Sauvignon' grapes grown under anti-hail coverture, with variations up to 0.3 pH units, suggesting a high susceptibility of this parameter to edaphoclimatic conditions inherent to each harvest.

The titratable acidity had similar behavior in both harvests, and the highest values occurred in the treatments with the anti-hail net, differing statistically from the plants without the coverture in both cycles. On the other hand, there was no statistical difference in soluble solids content between the treatments in both harvests (Table IV).

In 2019/2020 cycle, soluble solids contents were below the average values for this cultivar, whose range is 14-16 °Brix. In 2020/2021 cycle, the observed values were within the average values, with no statistical differences occurring in both harvests.

High rainfall volumes near the harvest period may have influenced these results (Pedro Júnior *et al.*, 2020), as well as changes in PAR levels, as can be seen in Table VI.

Table IV

Titratable acidity and soluble solids content of 'Rose Niagara' grapes grown under different coverture systems in the 2019/2020 and 2020/2021 harvests in the municipality of Antônio Prado, South Brazil

Harvest	**2019/2020**		**2020/2021**	
Treatment	**Titratable acidity (% w/v)***	**Soluble solids (°Brix)**	**Titratable acidity (% m/v)***	**Soluble solids (°Brix)**
With anti-hail net	0.37 a	13.60 a	0.67 a	14.35 a
Without anti-hail net	0.28 b	13.37 a	0.57 b	15.12 a
Coefficient of variation (%)	10.06	11.40	6.33	7.66

Means in a column followed by the same letter did not differ statistically with $p > 0.05$. *grams equivalent of tartaric acid per 100 mL of must/juice.

According to the Brazilian Normative Instruction nº 1, of February 1st, 2002, rustic grapes must have a minimum soluble solids content of 14 °Brix (BRASIL, 2002). However, Ferreira *et al.* (2004) observed soluble solids content ranging between 11.6 °Brix and 13.4 °Brix in 'Rose Niagara' grapes grown in Caldas (Southeast Brazil). Gonçalves (2007) also observed soluble solids content in the range of 12.0 °Brix and 14.2 °Brix, with no significant influence of anti-hail net on this parameter.

In 2019/2020 cycle, the higher titratable acidity content (0.37% w/v) was probably related to the presence of the anti-hail net, unlike the area without it, which presented a titratable acidity of 0.28% w/v. In 2020/2021 harvest, the behavior was similar, with titratable acidity of 0.67% w/v in the area with the anti-hail net and 0.57% w/v in the area without the net.

Frölech *et al.* (2018) reported a titratable acidity of 0.65% w/v for 'Rose Niagara' grapes, whereas Ferreira *et al.* (2004) observed 0.81% w/v. These values were greater than the ones observed in this work for 2019/2020 harvest but similar to the values found in the 2020/2021 cycle, in both treatments. Borghezan *et al.* (2011) also reported an influence of harvest on the titratable acidity of 'Sauvignon Blanc' and 'Merlot' grapes, whereas the 'Cabernet Sauvignon' cultivar was not affected.

Considering that soluble solids content was not significantly influenced by the anti-hail net in both harvests whereas titratable acidity was affected. This suggests that the shadowing effect caused by the net may have had a direct influence on increasing the acidity of the grapes.

According to Table V, the phenolic compounds and total anthocyanin contents differed statistically between treatments in 2019/2020 harvest, which did not repeat in the 2020/2021 cycle.

Regarding the phenolic compounds content, in 2019/2020 harvest the treatment with the anti-hail net had 24.54 mg/100 g, while the treatment without the coverture had statistically smaller contents, with an average of 19.66 mg/100 g. In 2020/2021 cycle, the phenolic compounds content did not differed between treatments, with 37.54 mg/100 g in the area with the anti-hail net and 31.70 mg/100 g in the area without the net, respectively.

For total anthocyanin contents, 2019/2020 harvest had a different behavior, with 8.23 mg/100 g in the treatment with the anti-hail net and 4.36 g/100 g without the net. In 2020/2021 harvest, no statistical difference occurred, with a total anthocyanin content of 4.98 g/100 g with the anti-hail net coverture and 4.91 g/100 g without it.

Table V

Contents of phenolic compounds and total anthocyanins of 'Rose Niagara' grapes grown under different coverture systems in the 2019/2020 and 2020/2021 harvests in the municipality of Antônio Prado, South Brazil

Harvest	**2019/2020**		**2020/2021**	
Treatment	**Phenolic compounds[1] (mg/100 g)**	**Total anthocyanins[2] (mg/100 g)**	**Phenolic compounds[1] (mg/100 g)**	**Total anthocyanins[2] (mg/100 g)**
With anti-hail net	24.54 a	8.23 a	37.54 a	4.98 a
Without anti-hail net	19.66 b	4.36 b	31.70 a	4.91 a
Coefficient of variation (%)	10.19	18.27	16.53	19.56

Means in a column followed by the same letter did not differ statistically with $p > 0.05$. [1]Milligram equivalent of gallic acid per 100 g of berries; [2]Milligram equivalent of cyanidin-3-glycoside per 100 g of berries.

The 2019/2020 harvest had the lowest rainfall (206.0mm) in veraison (January and February), when there is the accumulation of anthocyanins in berries. On the other hand, in 2020/2021 cycle, there was the highest rainfall (427.8 mm), which may have influenced the quality of grapes. Soares *et al.* (2008) reported phenolic compounds content ranging between 219.6 and 1,242.8 mg/100 g, whereas total anthocyanin contents ranged between 7.0 and 82.2 mg/100 g.

The PAR intensity measured at grape harvesting in both harvests is compiled in Table VI. It should be noted that in 2020/2021 harvest there was a higher incidence of sunlight during harvest time in the vines covered with the anti-hail net.

Regarding PAR intensity, the treatments differed in both cycles. In the areas with the anti-hail net, PAR incidence was lower due to the shadowing effect caused by light dispersion and absorption by the net, as expected.

Table VI

Photosynthetically active radiation (PAR; µmol/m^2/s) incident on 'Rose Niagara' grapes grown under different coverture systems in 2019/2020 and 2020/2021 harvests in the municipality of Antônio Prado, South Brazil.

Treatment	**Harvest**	
	2019/2020	**2020/2021**
With anti-hail net	223.80 b	469.15 b
Without anti-hail net	1,294.95 a	1,272.50 a
Coefficient of variation (%)	15.71	2.94

Means in a column followed by the same letter did not differ statistically with $p > 0.05$).

Mota *et al.* (2009) found a 30% reduction in PAR intensity due to plastic coverture, from 1,754 μmol/m^2/s in the uncovered vines to 1,236 μmol/m^2/s in the vines covered with raffia plastic net. Cardoso *et al.* (2008), studying the effect of coverture in vineyards in the Serra Gaúcha region, South Brazil, stated on the joint effect of the plastic coverture and the vegetative growth on the reduction of the incident sunlight on the bunches, though the authors also pointed out that the attenuating effect was not constant throughout the productive cycle of the vines.

The anti-hail net has the objective of forming a physical barrier to protect the plants from the damage caused by hail and photooxidative stress. However, the interaction between the plants under coverture and the environment occurs differently from the ones in full sun due to changes in microclimatic conditions, such as insolation degree, sunlight intensity, and exposition time of the berries to light. These factors can influence fruit quality (Bosco *et al.*, 2014).

According to Genta *et al.* (2010) and Jungues *et al.* (2020), the use of an anti-hail net alters the vineyard exposition to sunlight, prolonging the vegetative cycle and delaying fruit ripening, also mitigating oscillations in sunlight incidence, which helps standardize berry color. However, Gonçalves (2007) highlighted the reduction in productivity and quality of grapes grown under an anti-hail net, commenting on the effect of the lower sunlight incidence and alterations in vineyard microclimate due to the presence of the net.

CONCLUSIONS

The vines under the anti-hail net had greater production in both harvests, suggesting that the net may have had a protective effect on the developing berries. Regarding the quality parameters, there was a wide variation between harvests. This indicates that the presence of the net have not caused an important effect on the development and quality of the grapes. It also did not eliminate nor mitigate the microclimatic alterations inherent to each harvest. Despite this, the vines under the anti-hail coverture had higher titratable acidity contents in both cycles and higher contents of phenolic compounds and anthocyanins in 2019/2020 harvest. This findings indicate that the use of a pearl anti-hail net may be an alternative of protection against hail and other storms, with no important negative effects on the development and quality of 'Rose Niagara' grapes.

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