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Post-harvest conservation of 'Rubi' grapes treated with abscisic acid

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Loss of mass, shatter and decay are undesirable for fresh grapes, as they decrease the cluster quality during post-harvest conservation. The objective of this study was to assess the effect of abscisic acid (*S*-ABA) application on 'Rubi' grapes' loss of mass, shatter, decay incidence and conservation periods. 'Rubi' grapes' clusters used in the experiment were gotten from a commercial vineyard located in the town of São Miguel Arcanjo, SP, Brazil (23° 31' S, 47° 35' W and 660 m above sea level). The experimental design was completely randomized with subdivided plots and six replicates; the plots represented the concentration levels of *S*-ABA and the subplots represented the assessment days, starting on the day of harvest, extending up to 18 days after harvest. The concentrations of the isomer (*S*)-cis-abscisic acid (*S*-ABA) used were: Control (0 mg L^{-1}); 400 mg L^{-1} of *S*-ABA at the beginning of maturation (BM); 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 days after the first application (25 DAFA); and 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA. The clusters were placed in expanded polystyrene trays and stored at room temperature (25.0 ± 5°C and 50 to 85% relative humidity (RH)). The loss of mass, berry shatter and decay incidence were assessed over the post-harvest conservation periods. The *S*-ABA influenced the evaluated characteristics. One application of *S*-ABA reduced shatter and decay incidence, while two applications (400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA) reduced the loss of mass.

Key words: Post-harvest conservation, grapes, abscisic acid, shatter, decay incidence, cluster quality.

INTRODUCTION

In Brazil, table grapes have increased their importance in national and international markets in recent years, the trend has been observed since the mid-1990s (Agrianual, 2015). Nowadays, however, there is a high demand for fruits of differentiated quality, especially from people of high purchasing power that seek not only healthy foods,

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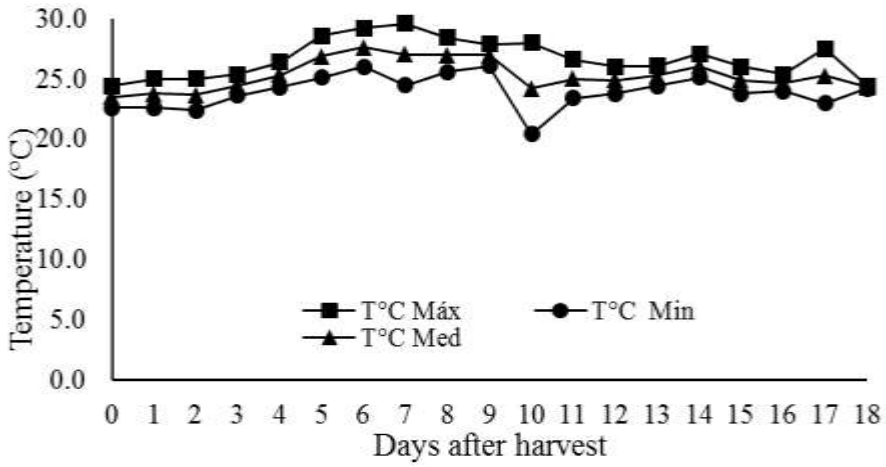

Figure 1. Maximum (Max), average and low (Min) temperatures for 'Rubi' grape stored 18 days at room temperature (25 ± 5°C and 50-85% RH) treated with *S*-ABA in different concentrations.

but also flavor,color, appearance, scent, texture, and freshness (Lulu et al., 2005).

During post-harvest conservation, table grape deterioration is fast, limiting their shelf-life (Crisoto and Mitchell, 2000). The cluster loss of the quality is, partially, caused by its loss of water, senescence or necrosis and the berry softening, color changes, shatter and decay incidence (Carvajal-Millan et al., 2001; Youssef and Roberto, 2014a,b). The occurrence of these changes in grape post-harvest quality varies according to the cultivar, cultural practices adopted in the vineyard, and storage conditions (Carvajal-Millan et al., 2001; Crisosto et al., 2002).

In subtropical regions, such as São Miguel Arcanjo, SP, the colored grapes present an undesirable color intensity at harvest, mainly due to the low thermal amplitude and high rainfall rate in the harvest period. Plant regulators have been used in several grape growing regions around the world in order to overcome color problems. Recently, it has been demonstrated that the exogenous application of (*S*)-cis-abscisic acid (*S*-ABA) can overcome the lack of color in colored grapes through the synthesis of anthocyanins, which are pigments that impart color to the fruits (Roberto et al., 2012; Koyama et al., 2014).

Although the main objective of using *S*-ABA on grapes is to promote better berry color uniformity, it was observed that grapes treated with this regulator present reduction of loss of mass, shatter and decay incidence (Silva et al., 2011). However, it is necessary to assess grapes treated with *S*-ABA from the region of São Miguel Arcanjo, SP, because it is located in São Paulo State, the main producer area of fine table grapes, and because there are no studies regarding this plant regulator on the decrease of post-harvest losses.

Thus, the objective of this study was to assess the effect of the *S*-ABA application on loss of mass, shatter, and decay during the conservation of 'Rubi' grapes.

MATERIALS AND METHODS

Assessment took place in a commercial 8-year old 'Rubi' grapevine (*Vitis vinifera* L.) grafted on the 420-A rootstock, spaced at 4 × 2 m and trained in pergola system, located in São Miguel Arcanjo, SP, Brazil, located at 23° 31' S, 47° 35' W and altitude of 660 m.

A completely randomized block design was used, with six replications, in a split-plot experiment, and each plot consisted of one cluster. The plots represented the concentration levels of *S*-ABA and the subplots represented the assessment days after the harvest (starting at the harvest day, extending up until the 13 and 18th day, for the loss of mass, shatter and decay, respectively).

The concentrations of the isomer *S*-ABA (100 g L^{-1} active ingredient, Valent BioSciences Co.) were: Control (0 mg L^{-1}); 400 mg L^{-1} of *S*-ABA at the beginning of maturation (BM); 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 days after the first application (25 DAFA); and 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA.

Harvesting was performed 40 days after the first application of *S*-ABA. The period from pruning to harvest was 150 days. After the harvest, the clusters were taken to the Fruit and Vegetable Post-Harvest Laboratory, Agronomic Sciences School, UNESP, Botucatu, SP, Brazil where the experiment was carried out. The clusters were placed in expanded polystyrene trays and stored at room temperature (25 ± 5°C and 50 to 85 RH) (Figures 1 and 2).

The assessed variables were: loss of mass, berry shatter, decay, and conservation periods. The loss of mass loss was assessed daily until the 13th day after harvest, by weighing the clusters on a semi-analytical scale with 0.1 g accuracy and the results expressed as loss of mass percentage, using the formula:

Loss of mass (%) = IM - MA/IM × 100

Where IM = initial mass (harvesting day) and MA = mass on assessment day.

The reference cluster fresh mass was obtained on the day of harvest. In order to determine berry shatter, the clusters were slightly agitated, twice, and the shatter berries were weighed. The shatter was determined in a cumulative way over assessment days and the results were expressed as a percentage, using the

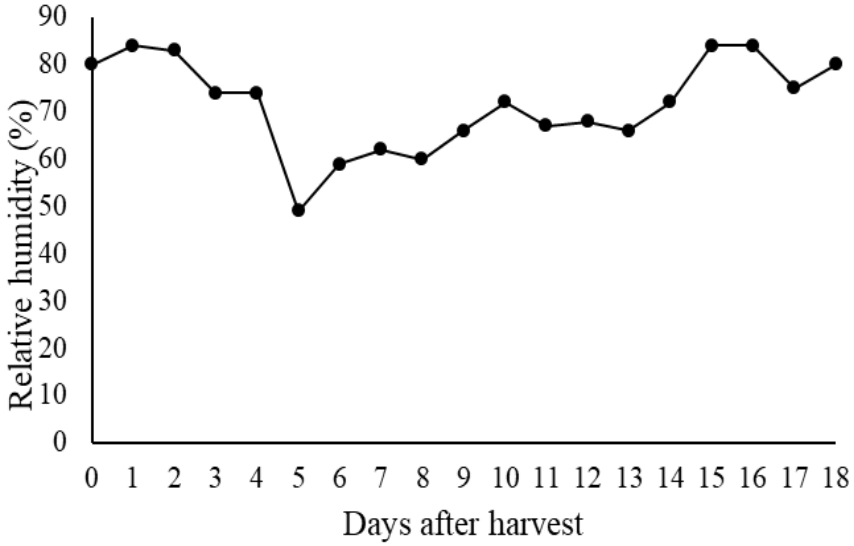

Figure 2. Relative humidity (%) for 'Rubi' grape stored 18 days at room temperature (25 ± 5°C and 50-85% RH) treated with *S*-ABA in different concentrations.

equation:

Shatter (%) = SAM×100/CIM

Where CIM = cluster initial mass (harvest day) and SAM = shatter accumulated mass on the assessment days.

The berry decay was assessed after weighing the rotten berries, cumulatively, over the assessment days, and the results were expressed as a percentage, using the equation:

Decay (%) = DAM×100/CIM

Where CIM = cluster initial mass (harvest day) and DAM = decay accumulated mass on the assessment days. In both cases, a semi-analytical scale with 0.1 g accuracy was used to weigh the berries.

At the end of the assessments, it was daily determined, the conservation periods, analyzing the clusters, and discarding those clusters that presented more than 50% of decay or wilting.

The data were submitted for analysis of variance (F test) and polynomial regression analysis in order to present the behavior of the variables as a function of days after harvest.

For the shatter, the segmented linear regression model with plateau (LRQ) was determined using the software R.

RESULTS AND DISCUSSION

The linear regression model was significant to express the loss of mass of 'Rubi' grapes (LM) over the postharvest periods (Figure 3A, B, C, and D). It was observed that the lowest LM during storage was obtained with the application of 400 mg L^{-1} of *S*-ABA in the BM + 400 mg L^{-1} at 25 DAFA, evidenced by presenting the lowest value of the equation's angular coefficient (1.17), followed by the control treatment (1.31); 400 mg L^{-1} in the BM (1.34); and 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 DAFA (1.52). After applying 400 mg L^{-1} in the BM + 400 mg L^{-1} to 25 DAFA, every day in storage there was 1.17% of LM, 12% below the values that had been obtained in the control treatment, 1.31% of LM was added every day in storage.

The loss of mass is one of the limiting factors to vegetables useful life, being related to the loss of water, the main cause of deterioration, which in turn, results in quantitative losses, hinder the appearance, such as berry wilting and wrinkling, the texture and nutritional quality (Carvalho, 2000; Vilas Boas, 2000).

The importance of assessing the loss of mass in table grapes, such as 'Rubi', is then emphasized, since the grapes usually do not reach the consumer on the same day of the harvest, and they are commercialized according to the weight. The lower the LM is during storage, the better is the price. For 'Crimson Seedless' grapes, the lowest clusters loss of mass occurred in grapevines submitted to irrigation, interrupted during maturation, and treated with 0.04 g 100 g^{-1} of abscisic acid split into two applications, the first during the berry softening and the second 15 days before harvest (Silva et al., 2011).

Regarding berry shatter, the plateau formation was observed as the treatment response, in which for the control treatment, it can be inferred that until the 5th day, there was an average of 1.04%, from which the linear effect on the berry shatter occurred. The *S*-ABA 400 mg L^{-1} treatment in the BM presented a 0.3% of the berry shatter by the 4th day; for the *S*-ABA 400 mg L^{-1} treatment in the BM + 200 mg L^{-1} of *S*-ABA at 25 DAFA, there was a 0.78% of the berry shatter by the 3rd day; and for the S-ABA 400 mg L^{-1} treatment in the BM + 400 mg L^{-1} of S-ABA at 25 DAPA, there was a berry shatter of 0.98% by the 2nd day. From the days the plateau was

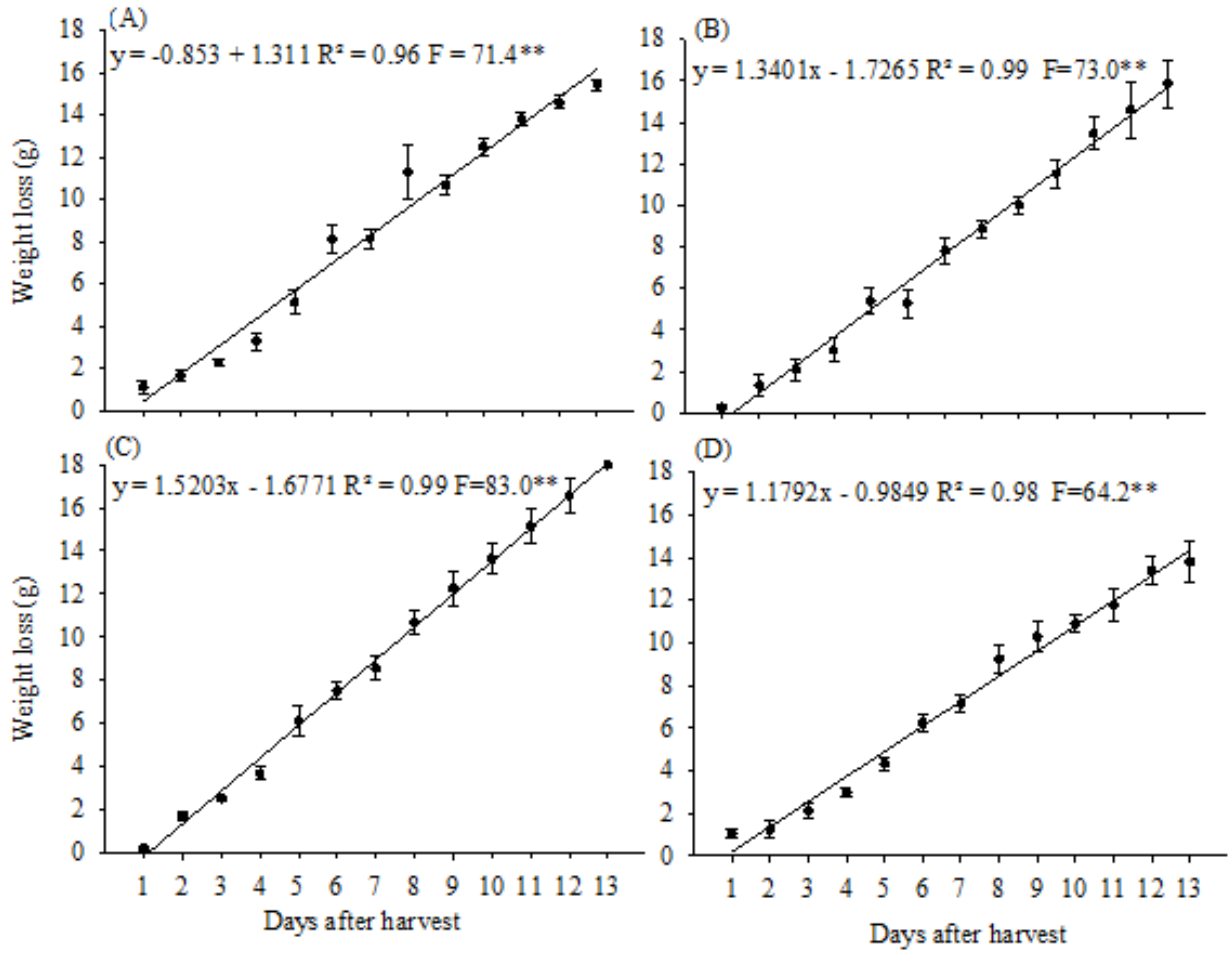

Figure 3. Loss of mass (%) of the 'Rubi' grape, during storage for 13 days at room temperature (25 ± 5°C and 50-85% RH) treated with S-ABA at different concentrations. A: Control (0 mg L^{-1}); B: 400 mg L^{-1} of S-ABA at the beginning of maturation (BM); C: 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 days after the first application (25 DAFA); and D: 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA. Error bars indicate the standard error of the mean (n = 6).

observed, the linear effect occurred (Figure 4A, B, C, and D).

The control treatment and 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA presented the highest berry shatter, evidenced by presenting the highest value of the angular coefficient equation (0.11), meaning that, every day, around 0.11% of the berries were dehydrated (Figure 4A and D). The lowest angular coefficients (0.07) were found in the 400 mg L^{-1} treatments in the BM and 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 DAFA (Figures 4B and C), showing that these treatments presented about 0.07% of shatter every day in storage. This is explained by the fact that these treatments had delayed rachis tissues senescence, increasing their resistance to shatter during storage (Kuhn et al., 2014; Padmalatha et al., 2017). It is also important to mention that a hormonal balance controls the senescence process, so, it is possible that the *S*-ABA regulated this balance, decreasing the shatter (Raban et al., 2013; Ferrara et al., 2016).

There was a linear increase in the berry decay percentage over the days after harvest for all the treatments (Figure 5A, B, C and D).

The lowest decay during storage was obtained on the treatment with only one application of *S*-ABA (Figure 5B), and this treatment presented 5.60% of decay; 35.18% less than the control treatment that presented an 8.64% of decay.

Treatments with 400 mg L^{-1} of *S*-ABA in the BM + 200 mg L^{-1} at 25 DAFA presented the highest LM during storage (8.97%) and differed from the other treatments. Loss of mass is one of the main causes of grapes post-harvest life reduction (Youssef and Roberto, 2014a, b), and it was verified in this study that because this treatment presented the highest LM, it resulted in the shortest conservation period (16 days) (Table 1).

This lowest mean was found in treatments of 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA (7.27%) and 400 mg L^{-1} in the BM (7.65%). The higher concentration of water

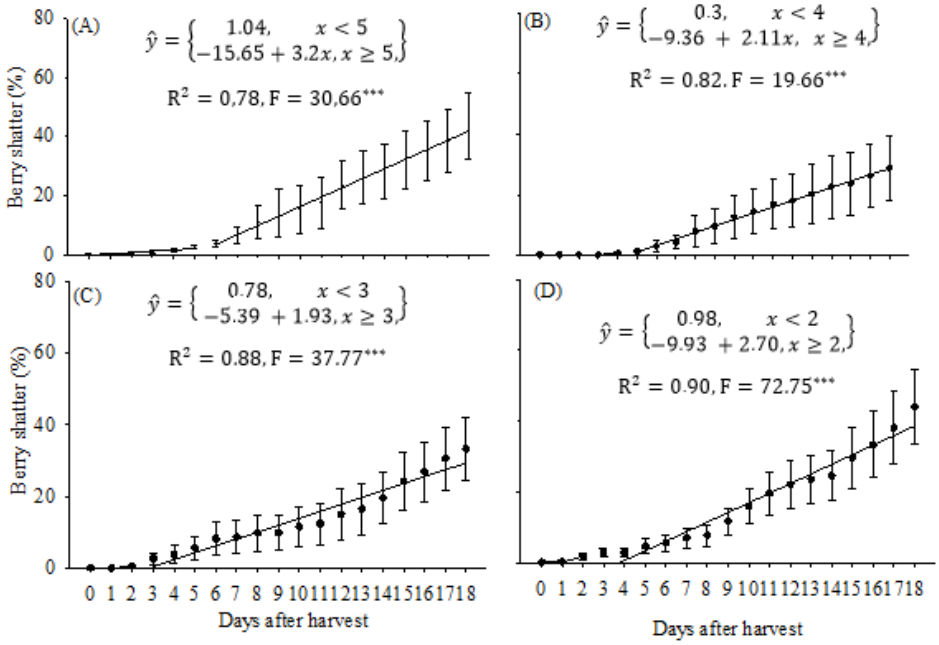

Figure 4. Berry shatter (%) of 'Rubi' grape, during storage for 18 days at room temperature (25 ± 5 °C and 50-85 % RH) treated with S-ABA in different concentrations. A: Control (0 mg L^{-1}); B: 400 mg L^{-1} of S-ABA at the beginning of maturation (BM); C: 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 days after the first application (25 DAFA); and D: 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA. Error bars indicate the standard error of the mean (n = 6).

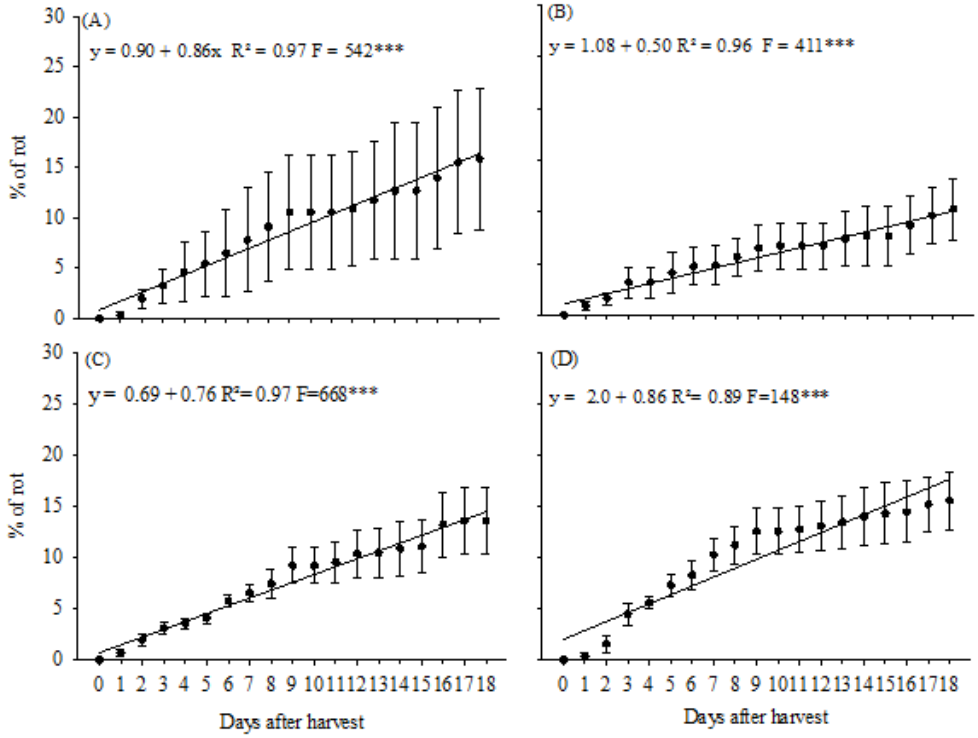

Figure 5. Decay (%) on berries of 'Rubi' grape, during storage for 18 days at room temperature (25 ± 5 °C and 50-85 % RH) treated with S-ABA in different concentrations. A: Control (0 mg L^{-1}); B: 400 mg L^{-1} of S-ABA at the beginning of maturation (BM); C: 400 mg L^{-1} in the BM + 200 mg L^{-1} at 25 days after the first application (25 DAFA); and D: 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA. Error bars indicate the standard error of the mean (n = 6).

Table 1. Loss of mass (LM), shatter and decay incidence of berries and conservation period (CP) of 'Rubi' grape, during storage at room temperature (25 ± 5°C and 50-85% RH) treated with *S*-ABA in different concentrations (São Miguel Arcanjo, SP, Brazil, 2016).

Treatment (*S*-ABA mg L^{-1})	LM (%)	Shatter (%)	Decay (%)	CP (Days)
Control (0)	8.32[b]	15.90[NS]	8.64[ab]	17[NS]
400 (BM)	7.65[c]	11.12	5.60[b]	16
400 (BM) + 200 (25 DAFA)	8.97[a]	12.60	7.60[ab]	16
400 (BM) + 400 (25 DAFA)	7.27[c]	15.70	9.82[a]	18
CV (%)	16.2	89.0	55.0	10.0

Means followed by the same letter in the column do not show any significant difference by the Tukey's test at 5% probability. NS: Non-significant. BM: Beginning of maturation; 25 DAFA: 25 days after the first application (DAFA).

in the clusters, evidenced by the lowest values of LM from the treatment of 400 mg L^{-1} in the BM + 400 mg L^{-1} at 25 DAFA, resulted in the highest berry decay (9.82%).

When stored under room temperature, berries tend to have their skins wrinkled, making them opaque and turgid, causing browning of rachis and pedicel dryness (Ginsburg et al., 1978), favoring shatter, and these factors contribute to form an out of standard product for commercialization. The highest shatter incidence observed (15.90%) was found in the control treatment, probably, due to a higher rachis browning caused by the high loss of mass (8.32%). The lowest shatter incidence was obtained with only one application of *S*-ABA and this is explained by the fact that the rachis of these treatments had not presented browning once; this treatment also presented a low loss of mass (7.65%), and it is concluded that the rachis water loss was lower.

The conservation period was not significant among the *S*-ABA concentrations, with average values being taken in between the 16 and 18 days treatments.

Conclusion

The *S*-ABA decreases the 'Rubi' grape loss of mass, the berry shatter and decay incidence over the post-harvest conservation periods, thus, it provides a longer time for the commercialization of these grapes, which usually do not reach their final destination on the day of harvest.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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