

Defoliation, application of *S*-ABA and vegetal extracts on the quality of grape and wine Malbec cultivar

Isabela Leticia Pessenti¹, Ricardo Antonio Ayub², Renato Vasconcelos Botelho³

Abstract-High rainfall and low temperatures can cause grapes not to reach adequate maturation indexes. The aim of this work was to evaluate the effect of leaf removal, hormonal regulator and vegetable extracts on the quality of grape and wine. An experiment was conducted in a vineyard of Malbec cv. in southern Brazil by two consecutive seasons. Treatments were: 1) control, 2) manual defoliation in early maturation; 3) defoliation 15 days after the first defoliation; 4) *S*-ABA 200 mg L⁻¹; 5) *S*-ABA 400 mg L⁻¹; 6) *S*-ABA 600 mg L⁻¹. 7) vegetal *Stachytarpheta cayenensis* extract (100 g L⁻¹) and 8) *Cymbopogon citratus* 100 g L⁻¹. Diameter and length of canes, soluble solids, titratable acidity, anthocyanins and polyphenols in berry and wine, photosynthetically active radiation (PAR), chlorophyll index, defoliation percentage and leaf chlorosis and color index of berry skin were evaluated. Defoliation and *S*-ABA increased PAR. *S*-ABA provided leaf chlorosis and lowered the chlorophyll content, causing senescence. Defoliation and *S*-ABA increased the levels of total polyphenols, anthocyanins both in berry skin and wine of grapes Malbec cv. Vegetal extracts applied did not influence physical and chemical analyses, neither in anthocyanins and total polyphenols.

Index terms: *Vitis vinifera* L., berry skin, total polyphenols, anthocyanins.

Desfolha, aplicação de *S*-ABA e extratos vegetais sobre a qualidade da uva e do vinho da cv. Malbec

Resumo- A alta taxa de chuvas e baixas temperaturas podem fazer com que as uvas não atinjam índices adequados de maturação. O objetivo deste trabalho foi avaliar a remoção de folhas, regulador hormonal e extratos vegetais na qualidade da uva e do vinho. Um experimento foi conduzido em um vinhedo com a cv. Malbec, no Sul do Brasil, por duas safras consecutivas. Os tratamentos foram: 1) controle; 2) desfolha manual no início da maturação; 3) desfolha 15 dias após a primeira desfolha; 4) *S*-ABA 200 mg L⁻¹; 5) *S*-ABA 400 mg L⁻¹; 6) *S*-ABA 600 mg L⁻¹; 7) Extrato vegetal de *Stachytarpheta cayenensis* (100 g L⁻¹), e 8) *Cymbopogon citratus* 100 g L⁻¹. Avaliaram-se o diâmetro e o comprimento de ramos, sólidos solúveis, acidez titulável, antocianinas e polifenóis em bagas e no vinho, radiação fotossinteticamente ativa (PAR), índice de clorofila, porcentagem de desfolha e clorose foliar, e índice de cor de frutos da casca. A desfolha e o *S*-ABA aumentaram a PAR. O *S*-ABA proporcionou clorose nas folhas, seguido de baixo teor de clorofila, causando a senescência. A desfolha e o *S*-ABA aumentaram os níveis de polifenóis totais, antocianinas, tanto na casca das bagas como no vinho das uvas da cv. Malbec. Os extratos vegetais aplicados não influenciaram nas análises físico-químicas, nem em antocianinas e polifenóis totais.

Termo de indexação: *Vitis vinifera* L.; casca; polifenóis totais; antocianinas.

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Introduction

High rainfall incidence and low thermal amplitude may lead grapes not to reach adequate maturation indexes (GARDIN et al., 2012). In many Brazilian regions, climatic conditions do not allow adequate fruit ripening for wine red grapes, decreasing quality.

According to Mandelli et al. (2008), defoliation consists of removing leaves to facilitate aeration and insolation in grape clusters to provide better conditions for maturation and reduction of diseases. The exposure of clusters to solar radiation is related to greater accumulation of soluble solids. Abe et al. (2007) reported that it is the most important phenomenon of grape maturation, including other compounds such as polyphenols and anthocyanins.

Exogenous application of (*S*)-*cis*-abscisic acid (*S*-ABA) isomer provides an increase in the amount of anthocyanins in grape skin, hastening the harvest season. Some studies have demonstrated that *S*-ABA and Ethephon hasten the harvest time and increase the concentration of anthocyanins and proanthocyanins, in grape skin, improving their color (CANTÍN; FIDELIBUS; CRISOSTO, 2007); (LACAMPAGNE; GAGNÉ; GÉNY, 2010).

Roberto et al. (2012) observed lower luminosity values (L^*) in two consecutive seasons, with two applications of *S*-ABA at 200 or 400 mg L⁻¹, 7 DAV (days after veraison) and 15 DBH (days before harvest) in 'Benitaka' table grapes (*Vitis vinifera*), indicating that berries were darker. For the same doses, a color improvement increase was observed through the CIRG index. In 'Rubi' table grapes, Roberto et al. (2013) also found lower luminosity values with two *S*-ABA applications (400 mg L⁻¹, 7 DAV, and 15 DBH) and higher CIRG index.

Silva et al. (2017) used *S. cayenensis*, lemongrass (*C. citratus*), *Gallesia integrifolia* at 12% and grape pomace powder, each extract was directly applied in clusters 10 days before harvest, and the other application after harvest in Ives and Niagara Branca cultivars (*V. labrusca*). Lemongrass and *S. cayenensis* extracts applied before and after harvest maintained higher content of phenolic compounds.

The aim was to evaluate defoliation, application of *S*-ABA and lemongrass (*Cymbopogon citratus* (DC) Stapf L.) (CC) and *Stachytarpheta cayenensis* (L.C. Rich.) Vahl. (SC) vegetable extracts on the quality of grape and wine Malbec cv. (*Vitis vinifera* L.).

Materials and Methods

The experiment was conducted in a commercial vineyard at Água Doce, State of Santa Catarina, Southern Brazil (26°43'53" S and 51°30'26" W; 1,300 m a.s.l.) with Malbec cv. (*Vitis vinifera*) for two consecutive cycles 2015/2016 and 2016/2017.

Fourteen-year-old grapevines were grafted on 'Paulsen 1103' rootstock and conducted in an espalier system, with 1.5m spacing between plants and 3.0 m between rows. The site has subtropical humid climate (Cfa), according to Köppen classification, with annual rainfall of 1,433 mm, relative humidity 77.3% and annual temperature 14.6°C (VILLAGGIO, 2017).

The experimental design was randomized blocks, with 8 treatments, 4 replicates and 3 plants per plot, evaluating the central plant. Treatments were the following: 1) control (no treatment); 2) manual defoliation in early maturation (DEM); 3) manual defoliation 15 days after the first defoliation (D15); 4) *S*-ABA 200 mg L⁻¹ (*S*-ABA200); 5) *S*-ABA 400 mg L⁻¹ (*S*-ABA400); 6) *S*-ABA 600 mg L⁻¹ (*S*-ABA600), 7) SC vegetal extract 100 g L⁻¹, 8) CC vegetal extract 100 g L⁻¹.

Applications of *S*-ABA aqueous solutions (Valent BioSciences Corporation, Libertyville, IL, USA, 2010) were performed at the beginning of berry maturation (veraison) using a costal sprayer to the point of drainage, being directly applied to bunches. Manual defoliation was performed at the beginning of maturation and 15 days after the date of first defoliation up to the height of bunches, and 6 leaves per cane were collected. SC and CC vegetal extracts at 10% were prepared according to Santos et al. (2014), with adaptations. Previously air dried shoot leaves (13% humidity) were cut into small pieces, then mixed with 1000 mL of distilled water heated to 70 °C in the proportion of 1:10 (w/v) for 10 minutes. Subsequently, extracts were filtered with Whatman n°. 1 filter, stored in glass containers sealed with PVC film for 24 hours. Extracts were applied on the same date when the second manual defoliation was performed, 15 days after the first one. Vegetal extracts were grown on a rural property in Santa Catarina (26°89'09" S and 51°36'83" W).

Evaluations of plant traits were performed soon after harvest, on February 19 and 22, in 2016 and 2017, respectively. The diameter (mm) and length of canes (cm) were measured with digital caliper and tape-measure, respectively. Defoliation was evaluated counting the number of knots without leaves. Leaves with the presence of chlorosis were also counted. Defoliation and chlorosis data were transformed into percentage (%).

In the second cycle (2016/2017), photosynthetically active radiation (PAR) was measured using Pyranometer ProCheck® software Version 7 (Decagon Devices, Pullman, Washington, USA), from 10:00 am to 2:00 pm. Measurements were performed at the height of clusters,

and result expressed in $\mu\text{mol m}^{-2} \text{s}^{-1}$. Additionally, chlorophyll meter CFL 1030 (ClorofiLOG, Porto Alegre, RS, Brazil) was used to measure the Chlorophyll Index. For each replicate, two readings were performed on a fully expanded leaf.

At harvest, samples of 60 berries were collected from each experimental plot. Berries were collected from different portions of bunches, weighed and separated from the skin. Pulp was macerated, and most was analyzed for soluble solids content ($^{\circ}\text{Brix}$), with manual refractometer Model 103 (Biobrix, São Paulo, Brazil). Titratable acidity (% tartaric acid) was analyzed by mini titrator model HI 84532 (Hanna, Woonsocket, Rhode Island, USA).

Total polyphenol content of berry skin was analyzed according to method of Singleton and Rossi (1965) using Folin Ciocalteu reagent and calibration curve with gallic acid. Then, absorbance readings of samples were performed at 760 nm in UV 1650 PC spectrophotometer (Shimadzu, Kyoto, Japan). Results were expressed in mg gallic acid equivalent L^{-1} .

Total anthocyanins were analyzed according to method described by Lee and Francis (1972). An aliquot of 1g of berry skin was macerated in porcelain crucibles together with 10 mL extractive solution (50% ethanol 95%+ 50% 1.5 M hydrochloric acid). With fully macerated samples, liquid contents were stored in test tube protected from light (covered with foil), followed by washing of macerate remaining in the crucible, adding another 15 mL.

Then, test tubes received all macerated solution and were allowed to cool at 4°C for 20 hours. Then, the extract was filtered, washed with 25 mL extractive solution, leaving the total extract in a jar covered with aluminum foil for two hours. Then, 2 mL of extract were collected, adding 10 mL of extractive solution and subsequent shaking in vortex.

Samples were read in 1650 UVPC spectrophotometer (Shimadzu, Kyoto, Japan) at 535 nm and values were expressed in mg of anthocyanins per 100 g of plant material. For quantification of anthocyanin content, $(\text{FD} * \text{VA}) * 98.2^{-1}$ equation was used, where VA = absorbance value and FD = dilution factor.

Berry color was analyzed using Minolta® CR-400/410 colorimeter (Minolta, Osaka, Japan) to obtain the following variables from the equatorial portion of berries ($n = 2$ per berry): L^* (lightness), C^* (chroma), and h° (hue) (CANTÍN; FIDELIBUS; CRISOSTO, 2007). Lightness values may range from 0 (black) to 100 (white). Chroma indicates color purity or intensity, the distance from gray (achromatic) toward a pure chromatic color, and is calculated from a^* and b^* values of the CIELab color system, starting from zero for a completely neutral color, and does not have an arbitrary end, but intensity increases with magnitude. Hue refers to the color wheel and is measured in angles; green, yellow, and red correspond to 180° , 90° , and 0° , respectively. Color index for red

grapes (CIRG), colorimetric values were calculated using the $\text{CIRG} = 180 - \text{hue} * / (\text{L} * + \text{C} *)$ equation, where C^* is calculated with $C^* = (a^{*2} + b^{*2})^{1/2}$ and hue^* is the angle calculated with $\text{hue}^* = \text{tang}^{-1}(b^*/a^*)$ (CARREÑO et al., 1995).

After separation of berry samples for technological and phenolic maturation analyses, approximately 2 kg of grapes from each experimental plot were used for microvinification. After harvest and transport, grapes were kept in cold room for three hours until grapes reached around 10 to 12°C and manually crushed. During this process, potassium metabisulphite was added at a concentration of 0.12 g kg^{-1} of grape dissolved in mineral water and Fermol Rouge yeast (AEB, USA), selected *Saccharomyces cerevisiae* strain at ratio of 200 mg L^{-1} . Fermentation was monitored by measuring density at 20°C twice a day, when berry reassembly was also carried out.

After malolactic fermentation was concluded, wines were manually bottled, and bottles were stored in horizontal position and protected from light. Then, total anthocyanins and polyphenols analysis was carried out.

Data were submitted to Shapiro-Wilk normality test, followed by analysis of variance, and if significant, subject to average Scott Knott test ($p \geq 0.05$) using the R software (R CORE TEAM, 2018).

Results

For the chemical analyses of the must of Malbec grapes, no significant differences were verified in any of cycles evaluated. For soluble solids content and titratable acidity, mean values were 16.28 and 16.36%; and 0.69 and 0.44% tartaric acid, for both consecutive cycles, respectively.

In the first cycle, grapes Malbec cv. obtained the highest anthocyanin content ($571 \text{ mg } 100\text{g}^{-1}$) with S-ABA400 treatment (Fig. 1a), followed by S-ABA600 ($534 \text{ mg } 100\text{g}^{-1}$). In the second cycle, the highest total anthocyanin content was also verified for S-ABA treatment (Fig. 1b). The lowest value was verified for defoliation treatment, and did not differ from control.

In the first cycle, for total polyphenol content, S-ABA200 treatment presented the highest content (1484 mg L^{-1}) followed by D15, DEM, S-ABA400 (1096 ; 1029 and 1117 mg L^{-1} , respectively) and SC vegetal extract treatments (998 mg L^{-1}) (Fig. 1c). CC treatment presented the lowest content, differing from all treatments. In the second cycle (2016/2017), defoliation in early maturation (veraison) (DEM), fifteen days after the first defoliation (D15) and S-ABA treatments presented the highest total polyphenol contents (Figure 1d).

Results of the color index of red grapes (CIRG) in the first cycle are presented in Fig. 1e. DEM, S-ABA200, S-ABA400 and S-ABA600 treatments (3,8; 4,0; 3,9

and 3,7, respectively) presented the highest values and differed from the other treatments. CC and SC treatments showed lower values, not differing from control (3,2; 3,1 and 3,1, respectively). In the second cycle, the highest CIRG value was verified for *S*-ABA600 treatment, which statically differed from the other treatments (Fig. 1f). After *S*-ABA600 (4,7), *S*-ABA200 (4,3) and *S*-ABA400 (4,4) treatments were significant. The lowest value was verified for defoliation treatment (D15) (3,9).

For the analysis of total anthocyanins of wines in the first cycle (2015/2016), *S*-ABA600 (207 mg 100g⁻¹) presented the highest anthocyanin content. After *S*-ABA600, treatments with D15, *S*-ABA200, *S*-ABA400 (145, 141 and 150mg 100 g⁻¹) were significant, followed by other treatments (Fig. 2a). In the second cycle (2016/2017), *S*-ABA200, *S*-ABA400, and *S*-ABA600 (160, 165 and 186 mg 100g⁻¹, respectively) presented the highest values and differed from the other treatments (Fig. 2b).

For total polyphenols in wine in the first cycle (2015/2016), *S*-ABA400 treatment (1656 mg GAE L⁻¹) presented the highest content but was not statistically different from *S*-ABA200 (1556 mg GAE L⁻¹) (Fig. 2c). The control had the lowest content of polyphenols, not differing only from SC. In the second cycle, the treatments *S*-ABA200, *S*-ABA400 and *S*-ABA600 (1425, 1476 and 1502 mg GAE L⁻¹, respectively) presented higher levels and differed from the other treatments. The lowest levels were verified for control and CC (961 and 1089 mg GAE L⁻¹, respectively), which did not differ significantly from the DEM, D15 and SC (1174, 1117 and 1212 mg GAE L⁻¹, respectively) (Fig. 2d).

For measurements of cane diameter in the first cycle, control presented the highest value and statistically different from DEM, *S*-ABA400 and *S*-ABA600 treatments (7.4, 6.4 and 6.9 mm) (Fig. 3a). For cane length, control, *S*-ABA200 and both vegetal extracts were significantly higher than the other treatments (158,175, 157 and 162 cm) (Fig. 3b). In the second cycle (2016/2017), no statistical differences were verified for these variables (data not shown).

For the results of percentage of leaves with chlorosis (%), the highest values were verified for *S*-ABA400 and *S*-ABA600 treatments (40 and 39%, respectively), followed by *S*-ABA200 (24%), which also differed significantly from the other treatments (Fig.3c). For the defoliation percentage (%) in the evaluation performed in the second cycle, DEM, D15, *S*-ABA400, and *S*-ABA600 treatments (40, 49, 46 and 60%, respectively) significantly reduced these values in relation to control (Fig. 3d).

For data of photosynthetically active radiation (PAR) incident on clusters of Malbec grape in the first cycle, D15 treatment (205 μmol/m² s⁻¹) was statistically superior, followed by DEM, *S*-ABA400 and *S*-ABA600

(143, 111 and 119 μmol/m² s⁻¹, respectively). The lowest levels were verified for control, ABA200, SC and CC vegetal extract (77, 65, 66 and 72 μmol/m² s⁻¹, respectively) (Fig. 4a). In the second cycle, DEM, D15, and *S*-ABA600 treatments (1132, 1144 and 980 μmol/m² s⁻¹, respectively) were statistically superior, followed by *S*-ABA400 and SC vegetal extract (809 and 727 μmol/m² s⁻¹, respectively). The lowest levels were verified for control, *S*-ABA200, CC vegetal extract (592 and 648 μmol/m² s⁻¹, respectively) (Fig. 4b). Total chlorophyll measured in leaves of Malbec grapevines in both cycles (2015/2016 and 2016/2017), was statistically lower for *S*-ABA200, *S*-ABA400, and *S*-ABA600 treatments (first cycle: 33, 29 and 30; second cycle: 35, 30 and 32, respectively) (Fig. 4c and 4d).

Discussion

For results of chemical analyses of must of Malbec grapes, no significant differences among treatments were verified for both cycles. Similarly, Bledsoe et al. (1988) observed no statistical differences in the chemical characteristics by three seasons and three defoliation intensities performed in Sauvignon Blanc grapevines. Kataoka et al. (1982) reported that exogenous application of *S*-ABA combined with defoliation did not improve the chemical characteristics of 'Kyoho' grapes.

Sandhu et al. (2011) also did not find significant differences for chemical analyses in 'Noble' table grapes and 'Alachua' wine grapes, with *S*-ABA applications. Rufato et al. (2016) observed no statistical differences in the chemical characteristics of berries with exogenous applications of different *S*-ABA doses in Cabernet Sauvignon grapes. Soluble solids contents and total acidity were also not affected in Merlot and Cabernet Sauvignon cultivars by defoliation in the pre-ripening stage of fruits (ANZANELLO; SOUZA; COELHO, 2011). Silva (2017) found no significant differences for pH and TSS / TA ratio in 'Niagara Branca' grapes (*Vitis labrusca*), with the pre and post-harvest application of different vegetal extracts.

For the anthocyanin content in Malbec grapes, *S*-ABA treatments at 400 or 600 mg L⁻¹ were the most effective, leading to an increase between 117 and 192%. Similarly, Domingos et al. (2017) observed an increase in total anthocyanin content, regardless of applied *S*-ABA doses. Similar results were also found by Koyama et al. (2014a), Koyama et al. (2014b) and Yamamoto et al. (2015), who verified an increase in total anthocyanin contents in berries of 'Isabella' (*V. labrusca*) juice grapes. Rufato et al. (2016) observed 48% and 80% increase in anthocyanin content for 600 and 800 mg L⁻¹ *S*-ABA doses, respectively. Maximum total polyphenols concentration was 600 mg L⁻¹ in 'Isabella' grapes.

Kataoka et al. (1982) observed significant differences in anthocyanin content when *S*-ABA was applied; however, when combined with defoliation, no

increase was observed. The authors claim that S-ABA is suppressed due to high temperatures, inhibiting its accumulation in berry and skin. Almeida and Ono (2017) found higher concentrations of phenolic compounds in defoliation of 3 to 4 leaves in Syrah grapes, while control and treatment with the highest defoliation showed smaller contents. These same authors suggest that slight defoliation may be positive to increase the concentration of these compounds, important to the elaboration of red wines.

Both defoliation and S-ABA applications led to an increase in total polyphenol content in at least one of the cycles. Accordingly, Rufato et al. (2016) verified an increase in the total polyphenol content in 'Isabella' grapes treated with S-ABA at 600 mg L⁻¹.

Total anthocyanin and polyphenol values of Malbec grapes were lower when compared to values found by Silva et al. (2017), whose post-harvest applications of *S. cayenensis* extract provided higher values in Ives grapevines (*V. labrusca*). For anthocyanins, these authors observed higher values for treatments with SC and CC extracts when applied in pre and post-harvest (SILVA et al., 2017).

According to Almeida and Ono (2017), Ives grapes have anthocyanin content of 2.295 mg kg⁻¹, 95 to 98% in skin and the remaining in the stalk. The way anthocyanin pigments evolve in grapes skin during maturation is influenced by many factors (plant genetic, environmental conditions, cultural practices, water regime). Light and temperature are the most important climatic factors in anthocyanin biosynthesis, with light increasing the sugar content of skin and inducing anthocyanin accumulation (PIRIE; MULLINS, 1977; ALMEIDA; ONO, 2017).

The evolution of anthocyanin content is characterized by three stages: first, it presents a slight increase, the second stage is characterized by more pronounced increase and in the last stage, stabilization followed by decrease until the end of technological maturation (RIBÉREAU-GAYON, 1982). In *Vitis vinifera* L. varieties, anthocyanins are produced during the maturation period in the painter phase.

This stage is characterized by a change in berry color and texture due to the anthocyanin accumulation in the skin of red grapes. Cultural practices that increase direct exposure of clusters to the sun, in addition to increasing temperature, favors the synthesis of anthocyanins, increases total phenolic compounds and the color density of wines (PIRIE; MULLINS, 1977; ALMEIDA; ONO, 2017). In this experiment, defoliation, even when caused by exogenous S-ABA application, may have increased the anthocyanin and total polyphenol content present in grape skin, as well as the CIRG index. Many studies have demonstrated that exogenous application of an isomer of this plant growth regulator, (*S*)-*cis*-ABA (S-ABA), increases anthocyanin concentration in grape skin.

S-ABA applications promoted higher CIRG index values. Similar results were found in Rubi table grapes (ROBERTO et al., 2013) and 'Cabernet Sauvignon' wine grapes (GARDIN et al., 2012). This index demonstrates that S-ABA exerts an effect on grape maturation, mainly for modifying their coloration, increasing the anthocyanin content and CIRG index. In this experiment, vegetal extracts presented lower values but did not differ from control, in the first cycle. In the second cycle, values were lower than control.

For the analysis of wines from Malbec grapes, defoliation or S-ABA applications increased total anthocyanins and total polyphenols in at least one of the seasons. Rufato et al. (2016) observed increases in total polyphenols and anthocyanins in wines from grapes treated with S-ABA. These improvement could be of great commercial interest considering that polyphenols are the main compounds responsible for aroma, flavor and color of red wines according to Kennedy (2008).

Deis et al. (2011) also observed that exogenous S-ABA application significantly increased the phenolic content of grapes and wine produced from Cabernet Sauvignon grapes in Mendoza, Argentina. In the present work, increase in anthocyanin and total polyphenol contents was verified in grapes treated with exogenous S-ABA application in pre-harvest and by defoliation, which was also transferred to Malbec wine, providing higher quality to wine produced by the improvement in phenolic composition.

In the first cycle (2015/2016), S-ABA higher doses reduced cane length and diameter, and defoliation treatment reduced cane length. vegetative growth reduction may be related to S-ABA application, which acts as inhibitor of the growth of plant organs, in addition to being related to physiological processes of stomatal closure, bud dormancy, seed germination, leaf and fruit abscission and plant responses to water stress.

It was also verified that total chlorophyll content decreased in Malbec grape leaves with S-ABA application when compared to control. S-ABA applications led to increased defoliation and chlorosis rates. For the SPAD index, values below 40 indicate senescent leaves, the process of abscission layer formation. In this experiment, with increasing S-ABA doses, the chlorophyll index decreased with values below 40. S-ABA promotes reduction of chlorophyll index and consequently accelerates the process of leaf senescence.

S-ABA has also been associated with the physiological process of grape maturation, including accumulation of anthocyanins in berry skin (KATAOKA et al., 1982). It is known that the expression of anthocyanins depends on internal factors, such as abscisic acid (S-ABA), which induces the MYB1A transcription factor, protein that regulates the transcription of genes that make up the biosynthetic route of anthocyanins (JEONG et al., 2004).

In addition to providing better color of berries, S-ABA can be used for defoliation, to increase solar radiation in clusters and to reduce production costs.

Luminosity features influence the physiology control of grapevine and grape quality. Luminosity increases of the content of total monomeric anthocyanins in grapes; however, this compound is reduced when clusters are submitted to high temperatures. In this stage of grape maturation, clusters more exposed to the sun can contain up to ten times more total flavonos than those in the shade. This is due to the increase in 3-glycoside concentration of quercetin, campherol, and myricetin (SPAYD et al., 2002).

The results of photosynthetically active radiation (PAR) on the surface of clusters showed increases 4 and 6 times for treatments with hand-defoliation or S-ABA applications at 400 and 600 mg L⁻¹ (Figure 5). High levels of photosynthetically active radiation (PAR, 400 - 700 nm) incident on the canopy, especially at the height of clusters, is very important in determining the composition of grapes (COMIRAN et al., 2012).

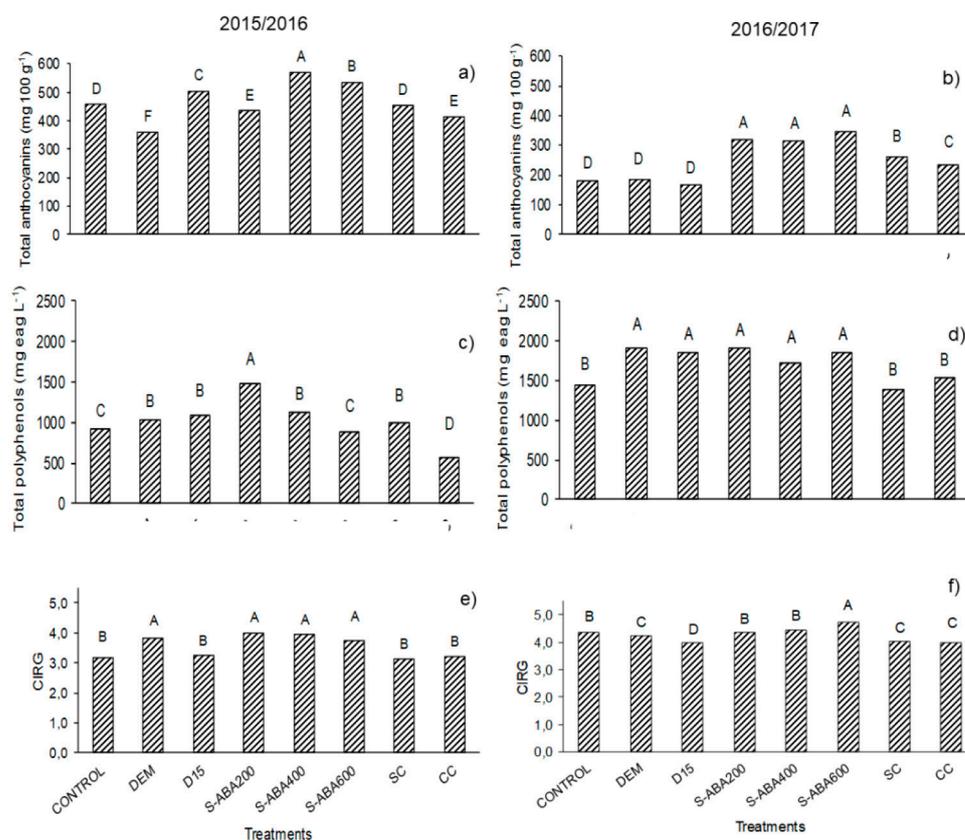


Figure 1 - Total anthocyanins (mg 100 g⁻¹) (a), total polyphenols (mg gallic acid equivalent L⁻¹) (c), color index for red grapes (CIRG) (e) in 2015/2016, total anthocyanins (mg 100 g⁻¹) (b), total polyphenols (mg GAE L⁻¹) (d) and CIRG (f) in 2016/2017 of Malbec grape. Test: control; DEM: manual defoliation in early maturation; D15: manual defoliation fifteen days after the first defoliation; S-ABA200: S-ABA 200 mg L⁻¹; S-ABA400: S-ABA 400 mg L⁻¹; S-ABA600: S-ABA mg 600L⁻¹; SC: *Stachytarpheta cayennensis* vegetal extract 100 g L⁻¹; CC: *Cymbopogon citratus* vegetal extract 100 g L⁻¹. Means followed by the same letter do not differ by the Scott Knott test ($p \leq 0.05$). Vertical bars represent standard deviation (n = 4).

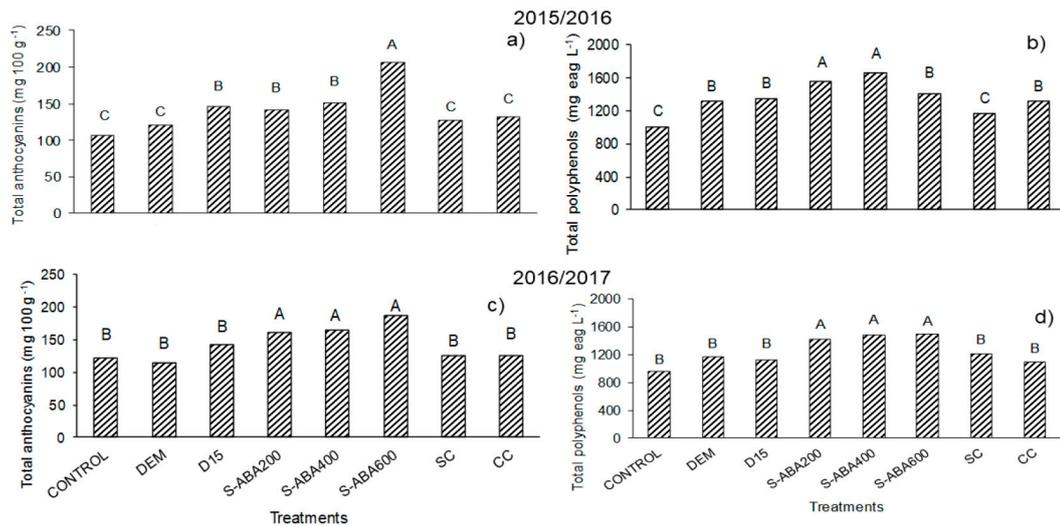


Figure 2 - Total anthocyanins (mg 100 g⁻¹) (a), total polyphenols (mg gallic acid equivalent L⁻¹) (b) in 2015/2016, total anthocyanins (mg 100 g⁻¹) (c) and total polyphenols (mg GAE L⁻¹) (d) in 2016/2017 of the wine of grapes cv. Malbec. Test: control; DEM: manual defoliation in early maturation; D15: manual defoliation fifteen days after the first defoliation; S-ABA200: S-ABA 200 mg L⁻¹; S-ABA400: S-ABA 400 mg L⁻¹; S-ABA600: S-ABA mg 600L⁻¹; SC *Stachytarpheta cayennensis* vegetal extract 100 g L⁻¹; CC: *Cymbopogon citratus* vegetal extract 100 g L⁻¹. Means followed by the same letter do not differ by the Scott Knott test ($p \leq 0.05$). Vertical bars represent standard deviation (n = 4).

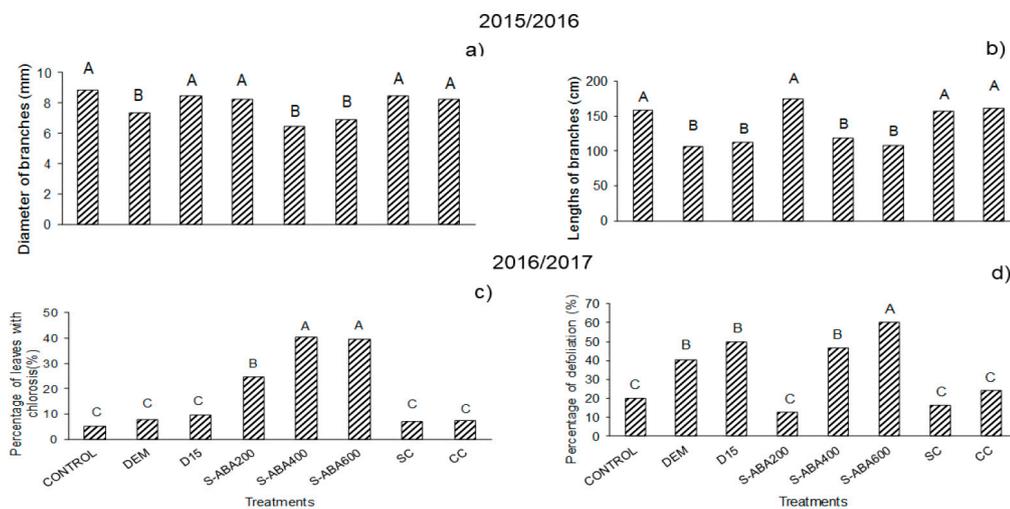


Figure 3 – Diameter (mm) (a) and length (cm) (b) of branches in 2015/2016, percentage of leaves with chlorosis (%) (c) and defoliation percentage (%) (d) in 2016/2017 for Malbec grapes. Test: control; DEM: manual defoliation in early maturation; D15: manual defoliation fifteen days after the first defoliation; S-ABA200: S-ABA 200 mg L⁻¹; S-ABA400: S-ABA 400 mg L⁻¹; S-ABA600: S-ABA mg 600L⁻¹; SC: *Stachytarpheta cayennensis* vegetal extract 100 g L⁻¹; CC: *Cymbopogon citratus* vegetal extract 100 g L⁻¹. Means followed by the same letter do not differ by the Scott Knott test ($p \leq 0.05$). Vertical bars represent standard deviation (n = 4).

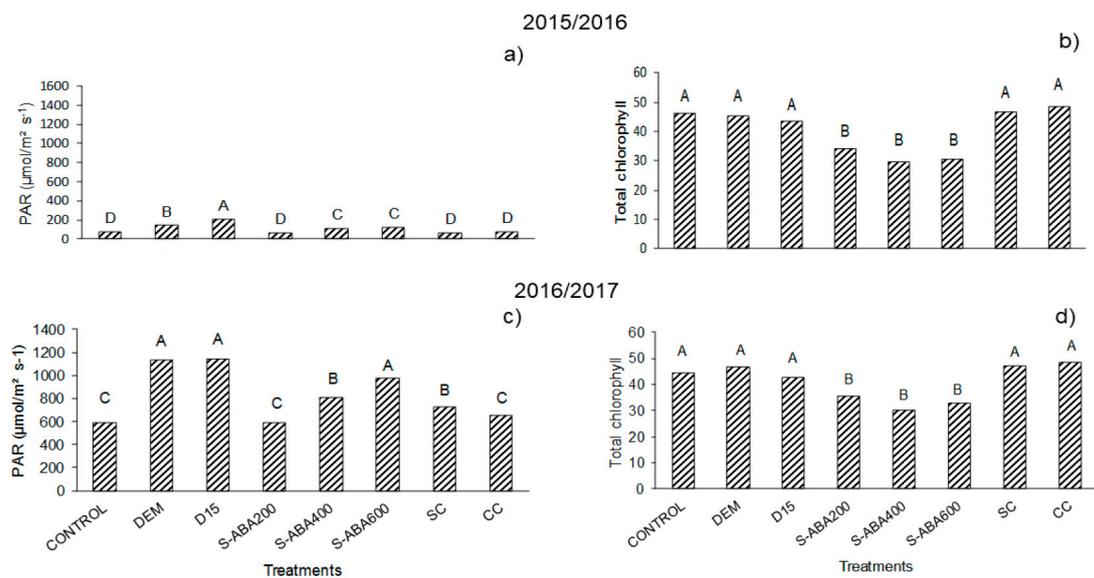


Figure 4 –Photosynthetically active radiation (PAR) (a) and total chlorophyll (b) in 2015/2016 and PAR (c) and total chlorophyll (d) in 2016/2017. Test: control; DEM: manual defoliation in early maturation; D15: manual defoliation fifteen days after the first defoliation; S-ABA200: S-ABA 200 mg L⁻¹; S-ABA400: S-ABA 400 mg L⁻¹; S-ABA600: S-ABA mg 600L⁻¹; SC: *Stachytarpheta cayennensis* vegetal extract 100 g L⁻¹; CC: *Cymbopogon citratus* vegetal extract 100 g L⁻¹. Means followed by the same letter do not differ by the Scott Knott test ($p \leq 0.05$). Vertical bars represent standard deviation (n = 4).



Figure 5 – S-ABA application at 600mg L⁻¹.

Conclusion

Defoliation provides an increase in total anthocyanin and polyphenol contents in Malbec berries; however, in the wine, an increase of polyphenols was observed, which may be related to the higher incidence of radiation caused by the removal of leaves. Defoliation and S-ABA application do not promote effect on soluble solids and total acidity in Malbec grapes. Vegetal extracts had little influence on the physicochemical characteristics, total anthocyanins and polyphenols.

Exogenous S-ABA application provides higher levels of total polyphenols, anthocyanins, and CIRG in Malbec grapes and also in the wine. In general, S-ABA application is a promising tool for viticulture, since it adds value to the final product. S-ABA application promoted defoliation at 600 mg L⁻¹, and can be applied to reduce production costs.

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