Ciência Rural, Santa Maria, v.54:06, e20230207, 2024 http://doi.org/10.1590/0103-8478cr20230207
ISSNe 1678-4596
CROP PROTECTION

Ethephon effect on defoliation of cluster zone, *Botrytis* bunch rot, and viticultural performance of 'Cabernet Sauvignon' grapevine in highland region of southern Brazil

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ABSTRACT: Phytoregulators have been used as grapevine defoliants in cluster zones to manage and improve grape quality and production. The present study evaluated the effect of the phytoregulator ethephon on the grapevine defoliation of the cluster region, *Botrytis* bunch rot (BBR) epidemiology, and the viticultural performance of 'Cabernet Sauvignon', during the 2018/2019 and 2019/2020 growing seasons, in the highland region of the Santa Catarina State, Southern Brazil. Ethephon was applied in the bunch region of both sides of the grapevine vegetative canopy, at the phenological stage of beginning of ripening (BBCH-81) in five active ingredient doses (0 mg L^{-1} (control); 720 mg L^{-1}; 1,440 mg L^{-1}; 2,160 mg L^{-1}; and 2,880 mg L^{-1}), following a randomized block design with four replications and five plants per replication. The following parameters were evaluated: BBR epidemiology, vegetative, productive, and technological and phenolic maturation. The increasing ethephon doses significantly reduced the linear leaf drop and affected the technological and phenolic grape maturation parameters, improving the must pH, total polyphenols, color 420, 520, and 620 ηm, color intensity (°hue angle), and anthocyanin, and reducing the total solubre solids in the 'Cabernet Sauvignon' grapevine. However, this significant effect on the linear leaf drop and the technological and phenolic maturation parameters did not interfere with other vegetative, productive, and BBR epidemiology parameters evaluated in the edaphoclimatic conditions of the highland region of southern Brazil.
Key words: *Vitis vinifera*, epidemiology, *Botrytis cinerea*, ethrel®, agronomic performance.

Efeito do Ethephon na desfolha da zona de cacho, podridão cinzenta de cachos e desempenho vitícola da uva 'Cabernet Sauvignon' em região serrana do sul do Brasil

RESUMO: Fitorreguladores tem sido usado como desfolhante na região dos cachos de videira no processo de manejo para melhoria da qualidade e produção de uva. O presente estudo objetivou avaliar o efeito do fitorregulador etefon na desfolha localizada na região dos cachos, a epidemiologia da podridão cinzenta de cachos (PCC) e desempenho vitícola da cultivar "Cabernet Sauvignon", durante as safras 2018/2019 e 2019/2020, na região de altitude do estado de Santa Catarina, sul do Brasil. O etefon foi aplicado na região dos cachos nos dois lados da copa vegetativa, no estádio fenológico de início da maturação (BBCH 81) em cinco doses do ingrediente ativo (0 mg L^{-1} (control); 720 mg L^{-1}; 1,440 mg L^{-1}; 2,160 mg L^{-1}; and 2,880 mg L^{-1}), seguindo um delineamento experimental em blocos ao acaso com quatro repetições e cinco plantas por repetições. Foram avaliados os parâmetros da epidemiologia da PCC e parâmetros vegetativos, produtivos e maturação tecnológica e fenólica. O aumento das doses de ethephon significativamente reduziu a queda linear de folhas na região dos cachos e afetou os parâmetros tecnológicos e fenológicos de maturação, melhorando o pH do mosto, polifenóis totais, coloração a 420, 520 e 630 nm, intensidade de cor (angulo °hue), antocianina e reduziu os sólidos solúveis totais na cultivar 'Cabernet Sauvignon'. Contudo, este efeito significativo na queda linear das folhas e nos parâmetros tecnológicos e fenológicos não houve interferência com os outros parâmetros vegetativos, produtivos e epidemiológicos da PCC, avaliados nas condições edafoclimáticas de regiões de altitude do sul do Brasil.
Palavras-chave: *Vitis vinifera,* epidemiologia*, Botrytis cinerea,* ethrel®, performance agronômico.

INTRODUCTION

The "Cabernet Sauvignon" grape (*Vitis vinifera* L.) is one of the most cultivated grapevine in Brazil and in the highland regions of the Santa Catarina State it is used in fine wines production (VIANNA et al., 2016). In southern Brazilian regions, the "Cabernet Sauvignon" phenological cycle used to be long, and, particularly in rainy and cold years, there was a risk of incomplete maturation due to a lack of thermal requirements (BRIGHENTI et al., 2013).

Vegetative canopy management is adequate to minimize the biotic and abiotic problems caused by climate adversities. Leaf removal in the grapevine bunch region is used to improve maturation conditions (COSTA et al., 2016; COSTA et al., 2016a; WURZ et al., 2018) and microclimates around the cluster, reducing

Received 04.17.23 Approved 08.30.23 Returned by the author 11.07.23
CR-2023-0207.R2
Editors: Leandro Souza da Silva Leonardo Araujo

the development of pathogens, such as the fungus *Botrytis cinerea* Pers. Fr, which affects the quality of grapes. The development of *B. cinerea* is favored by high humidity above 80% and long wetting periods over 4 hours on the surface of berries. The grapevine leaves removed in the cluster region by chemical, or manual defoliation increases the temperature and reduces the relative humidity and wetting period of the grape berries, reducing the damage caused by *B. cinerea* (HILL et al., 2010) and increasing the viticultural performance. However, defoliation in the cluster region demands excessive labor, resulting in prolonged labor times and increased production costs (SILVA et al., 2016; GONZALES et al., 2018).

Ethylene-releasing ethephon has been reported to be a synthesis inducer of pathogenesis-related proteins (PRs), β-1,3-glucanase, and increased sucrose content (COSTA et al., 2016a). Ethylene has a dual function in plant-pathogen interactions. Like defense regulatory compounds, such as salicylic acid and jasmonic acid, plant-derived ethylene is generally involved in plant resistance (UZQUIZA et al., 2015). However, it has been indicated in some reports that ethylene can promote increased intensity of certain diseases and not reduction (RAVANBAKHSH et al., 2018).

The management of leaf removal in the cluster region in some tropical and subtropical regions has been minimized by mechanical defoliation (COSTA et al., 2016). However, in some highland areas in southern Brazil, most vineyards were implanted in rugged terrain with medium slopes, conducted either with an anti-hail net or a Y-trellis training system, which made mechanical defoliation difficult. Based on this situation, phytoregulators can be an alternative to mechanical defoliation, triggering a series of physiological processes, such as leaf senescence, via an ethylene-based regulator that activates enzymes that degrade cell walls in the leaf abscission region, promoting leaf fall. Additionally, ethylene can anticipate or accelerate the maturation process, increasing the effect of chemical defoliation (COSTA et al., 2016; COSTA et al., 2016a; RAVANBAKHSH et al., 2018; XU et al., 2019).

The profile of technological and phenolic compounds in grapes and wines varies with the harvest, ripening time, edaphoclimatic conditions, and vineyard management (SCAVRONI et al., 2018; SUSIN et al., 2022). The occurrence of high concentrations of technological and phenolic compounds is characteristic, especially in berry skin in some red wine grapes (SUSIN et al., 2022). Ethephon has been related to the increase some technological and phenolic maturation parameters as berry coloration and the number, since it is involved in the increased synthesis of pigments such as anthocyanins, leading to higher uniformity in the coloration of berries (SCAVRONI et al, 2018).

Therefore, the present study evaluated the effect of the phytoregulator ethephon on the grapevine defoliation of the cluster region, *Botrytis* bunch rot (BBR) epidemiology, and the viticultural performance of vegetative, productive and technological and phenolic maturation parameters of ‘Cabernet Sauvignon’ cultivar in the highland region of the state of Santa Catarina, southern Brazil.

MATERIALS AND METHODS

Experimental area

Experiments were conducted in a commercial vineyard (*V. vinifera* L.) located in the municipality of São Joaquim (28°17′39″ S and 49°55′56″ W), Santa Catarina State, Southern Brazil, and conducted during the 2018/2019 and 2019/2020 growing seasons. The vineyard was located at an altitude of 1,430 m above sea level. The regional climate is humid mesothermal (Cfb), according to the Köppen classification (PEEL et al., 2007), and the soil type is cambisol, with a high clay (417 g kg^{-1}) and organic matter (81 g kg^{-1}) content. In this region, high precipitation occurs from October to March, during which rainfall averages approximately 130 mm per month. Daily rainfall, relative humidity, and hourly temperatures were recorded at the Santa Catarina Hydrology and Environmental Resources Center (Epagri) (Figure 1). The climate data were recorded from September to February, corresponding to the interval of the phenological stages from sprouting (BBCH 07; September) to harvest (BBCH-89; February).

The vineyard comprised around 1,500 vines (15 rows of approximately 100 vines) of 17-year-old “Cabernet Sauvignon” cultivar grafted onto “Paulsen 1103” rootstock. The vineyard was conducted in vertical shoot positioning, trained at distances of 3.0 m × 1.5 m, arranged along a single east/west-oriented row, and pruned to a double spur cordon at the height of 1.0 m. The vineyard was covered by a white-colored anti-rail net. Irrigation was usually unnecessary because of the adequate rainfall, since the annual rainfall in this region was between 1,450–1,550 mm and was regularly distributed throughout the year. The “Cabernet Sauvignon” cultivar is susceptible to BBR, and disease outbreaks have occurred every year in the study region without exception because climatic conditions that promoted

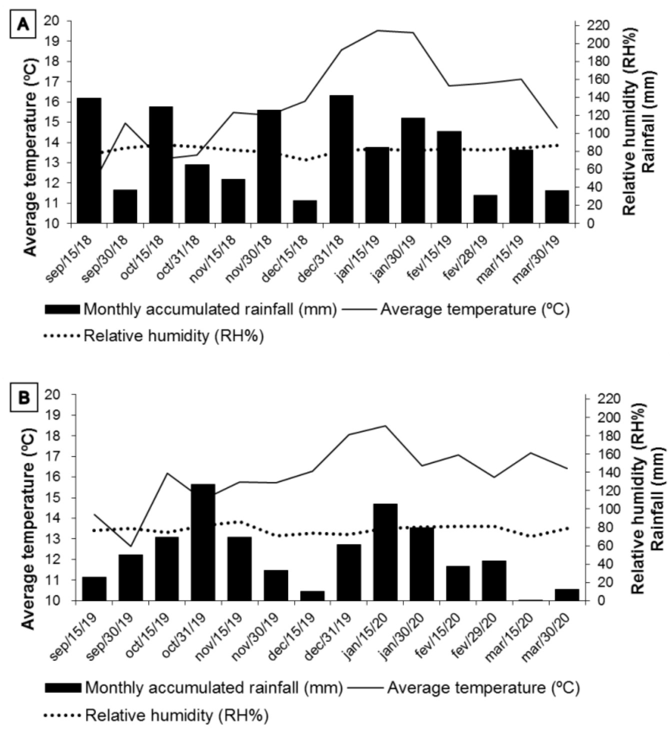


Figure 1 - Average monthly accumulated rainfall (mm), relative humidity (RH%) and average temperature (ºC) at the São Joaquim municipality, State of Santa Catarina, across both 2018/2019 (A) and 2019/2020 (B) growing seasons.

these pathogens were present most of the time. Therefore, there was no need to inoculate crops with pathogens before the proposed study was performed.

To protect the vineyard against the diseases, downy mildew (*Plasmopara viticola* [Berk et Curt.] Berl. et de Toni), powdery mildew (*Erysiphe necator* Schw.) and anthracnose (*Elsinoe ampelina* Shear), cymoxanil (150 mL of active ingredient (AI) L^{-1}), fenarimol (500 mL of AI L^{-1}) and folpet (67 g of AI L^{-1}) applications, respectively, were performed during the 2018/2019 and 2019/2020 growing seasons. However, low rates of captan (125 g of AI L^{-1}) and Metalaxyl + mancozeb (24 + 192 g and mL of AI L^{-1}) were applied in rotation by spray from September (beginning of bud burst; BBCH-07) to February/March (beginning of ripening; BBCH-81) to maintain BBR at low levels, and yet still allow sufficient amounts of disease to evaluate the effect of the ethephon doses.

Ethephon was applied as ethrel® (240 g L^{-1} of ethephon) adjusted to a volume of 1.000 L ha^{-1} at five doses (g ha^{-1}) of ethephon AI at the phenological stage of the beginning of ripening. During this period, berries begin to develop variety-specific color (BBCH-81), according to the International grapevine BBCH scale (LORENZ et al., 1995). The five applied doses were: a) 0 g ha^{-1} (control); b) 720 g ha^{-1}; c) 1,440 g ha^{-1}; d) 2,160 g ha^{-1}; and e) 2,880 g L^{-1}. Ethephon was applied on both sides of the leaves canopy at the grape cluster region, wetting the entire vine, and sprayed with an 18L Pulvimat® atomizer (Canada). The spray gun used a cone nozzle 1.5 mm in diameter, allowing a liquid flow rate of 0.85 (± 0.02) L min^{-1}. Ethephon was sprayed early in the morning, without adjuvant, when no rain was predicted for at least 24 h. The ethephon spraying session was conducted on February 13, 2019, and February 7, 2020.

Botrytis buch root (BBR) epidemiology

The incidence and severity of BBR were assessed weekly from the beginning of symptom appearance (BSA) at the end of ripening (February) until harvest (April). This procedure was performed during the 2018–2019 and 2019–2020 growing seasons. The incidence of BBR was evaluated by counting disease clusters per five replicates per treatment. Severity was determined by rotted berries per cluster, according to HILL et al. (2010), based on 12 levels of disease severity: 1%, 5%, 10%, 15%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90%. For each plot, 30 random clusters were evaluated per parcel.

The BBR disease progress curve was constructed, and its epidemiology was compared using four epidemiological measures: beginning symptoms appearance (BSA), time to reach maximum disease incidence/severity (TRMD*I* and TRMD*S*), maximum disease incidence/severity (*I*max and *S*max), and areas under the severity disease progress curves (AUDPC). The incidence percentage data were transformed to arcsine multiplied by the square root of the percentage to normalize the data (JEAGER, 2008). The AUDPC was calculated as $\Sigma[(Yi + Yi + 1)/2)(ti + 1 - ti]$, where Y is the disease intensity (severity), t is time, and i is the cumulative number of evaluations. These areas represented the trapezoidal integration value of severity (CAMPBELL & MADDEN, 1990).

Viticultural performance

The viticultural performance was determined by the following parameters: vegetative, productive, and technological and phenolic maturation, as follows:

Vegetative parameters

a) Leaf fall (%): leaf drop was performed weekly, from the seventh day after the date of ethephon dose sprayings (February 20, 2019, and February 12, 2020), until harvest. In three different plants, five leaves per selected branch/plant containing at least one grape bunch were market by color tape, totaling 15 marked leaves;

b) Berry fall (%): three bunches of three plants per repetition were bagged with tubular plastic mesh bags. The fall of berries was measured weekly, from the seventh day after the date of the ethephon dose application (February 20, 2019, and February 12, 2020), until the harvest.

Productive parameters

Two vines from each treatment per plot were selected at the harvest. The branches and bunches were assessed using the following productive parameters:

a) Production (kg $plant^{-1}$): total bunches weighed per plant at the harvest;

b) Productivity (kg ha^{-1}): the multiplication of plant production per vine density (1,500 plants ha^{-1});

c) Ravaz index: the estimated relationship between production and pruning weight. The pruning weight was assessed in the winter during the dormant period;

The following parameters were assessed in five randomized bunches per plot, reaching a total of 20 bunches:

d) Berry diameter (cm): a transversal diameter measure of 50 berries per plot, using a digital caliper;

e) Bunch length (cm);

f) Bunch mass (g); and,

h) Bunch compactness index (BCI), where BCI = [(bunch mass)/(bunch length) 2], according to Tello and Ibanez (2014).

The bud fertility index (no. of bunches/shoot) was evaluated by counting the number of buds, shoots, and bunches. Counting was performed for each bud position from the basal bud to the terminal bud of the cane. As a means to determine bud fertility, in August 2019 and August 2020, after the winter pruning, 15 cane cuttings of “Cabernet Sauvignon” containing 10 buds were sampled and placed in a growth chamber with a controlled temperature of 25 °C (± 1°C), photoperiod 12 h of light at 300–400 $\mu E \cdot m^{-2} \cdot s^{-1}$, and 60% relative humidity (Andreini et al. 2009). The cane cuttings were cut on one-node segments, and their buds were separated in positions 1–10. Each cane segment was placed in hydrated phenolic foam and arranged in ascending order of 1–10 according to the bud position in the cane. After bud break, the buds were evaluated until their visible inflorescence phenological stage (Baillod and Baggiolini 1993). Buds were classified as fertile or non-fertile according to the presence or absence of inflorescence. Buds in positions 1–3 were classified as basal, buds in positions 4–6 were considered medium, and buds in positions 7–10 were classified as apical. The fertility percentages of the basal, median, and apical buds and the total bud fertility were calculated at the end of the evaluation.

Techno logical and phenolic maturation parameters

The monitoring of grape ripening began at veraison (March 25, 2019, and March 11, 2020), when approximately 50% of the berries had changed color. Each sample consisted of 10 clusters and 150 berries randomly collected per plot/treatment from different bunch portions (e.g., basal, median, and apical) of the vines on both sides of the rows. All berries were manually crushed one by one to obtain grape must and skin separately. The extracts from grape skin macerated for 24 h at 30 °C ± 0.5 °C were washed with methanol: HCl (at a 99:1 ratio).

a) The total soluble solid (TSS) content (°Brix): determined using a digital temperature-compensated refractometer (model Pal^{-1}; Atago, Saitama, Japan);

b) Titratable acidity (TA) - (meq L^{-1}): mg of tartaric acid 100 g^{-1} grape skin (Oiv, 2008);
c) pH was measured with a potentiometer (Impac, São Paulo, Brazil);
d) Total polyphenols (TP): mg gallic acid 100 g^{-1} grape skin (concentration), using a spectrophotometric method described by SINGLETON & ROSSI (1965) and using the Folin–Ciocalteu reagent with an absorbance of 760 nm. The phenolic content was determined using a gallic acid calibration curve;
e) Total monomeric anthocyanins (TMA): mg malvidin 3-glucoside 100 g^{-1} grape skin, using a spectrophotometric method described by RIBÉREAU-GAYON et al. (2010);
f) Hue angle (°hue): the fruit skin color was determined using a spectrophotometric method described by RIBÉREAU – GAYON (2010). The extract was diluted with distilled water at a ratio of 1:10 and analyzed in a spectrophotometer at wavelengths of 420, 520, and 620 um. The fruit skin color was measured by the intensity parameter using the following formulas: intensity = wavelengths of 420 + 520 + 620 um.

A second extraction using the remains of the skin was performed using the same method. Both extracts were homogenized and filtered through Whatman 01 filter paper. Both must extracts were homogenized, and the final must was assessed using the latter parameters.

Statistical Analysis

This study used a completely randomized experimental block consisting of 10 vines along the rows. These conditions were replicated four times for each treatment, and the buffer rows separated each treatment. The three vines on each end of the vine lines that formed a plot were excluded from the analyses, as well vines at each end of each row, and all vines in border rows.

The data for each growing season were analyzed separately, and the results were submitted to Shapiro-Wilk normality tests. Abnormal data were transformed using the following formula: arc-sen [root(x+0.5)/100] and submitted to an analysis of variance, followed by regression analysis using the Sisvar Program (JOHNSON & WICHERN, 1998).

RESULTS

Weather conditions were satisfactory for the cultivation of the grapevine and despite of different rainfall disponibility, the temperature and relative humidity were similar in both (Figure 1). The phenological stages of flowering - BBCH 60 (first and second halves of November) and maturation - BBCH 85 (between the second week of February and the second week of March) were the most critical periods for disease occurrence. The rainfall volume, relative humidity, and temperature in these two phenological stages of flowering and maturation were, respectively, 125 mm and 92.8 mm, 79.4% and 83.7%, 15.3 ºC and 14.3 ºC, and 38.8 mm and 41.4 mm, 71% and 78.7%, and 15.7 ºC and 16.8 ºC, at the 2018/2019 and 2019/2020 growing seasons (Figure 1).

There was no significant effect of the increasing ethephon doses on the BBR epidemiological parameters compared with the control plot in either the 2018/2019 or 2019/2020 growth seasons (Table 1). None of the ethephon doses applied at the phenological stages of the beginning of ripening – BBCH 81 showed a significant effect on BSA, TRMD*I* and TRMD*S*, *I*max and Smax, and AUDPC (Table 1) when compared with the control plot. This indicates no effect of ethephon on BBR epidemiology and control.

There was a significant difference in the vegetative parameter for only leaf fall and not for berry fall in both the 2018/2019 and 2019/2020 growing seasons (Figure 2). The leaf fall rate caused by ethephon increased linearly with increasing ethephon doses (Figure 2). Despite the significant effect of ethephon on leaf fall, the average leaf fall ranged between 15%–20% and such defoliation was considered less unreasonable.

The accumulated rainfall during January and February of the 2018/2019 and 2019/2020 growing seasons were approximately 330 and 260 mm, respectively. In this period, characterized by berries change color and increase soluble solids content, there was a significant increase, reduction, and non-effect in the technological maturation parameters for pH, TSS (Figure 3), and TA with increased ethephon doses. The pH increased from around 2.90–2.95 to 3.25–3.35, and the TSS decreased by approximately 0.5% in both the 2018/2019 and 2019/2020 growing seasons (Figure 3).

There was a significant increase in the phenolic maturation parameters for TP, °hue (color at 420, 520, and 620 um), and anthocyanin (TMA) with increasing ethephon doses (Figure 4). The TP, color intensity, and TMA increased around 20 mg L^{-1}, 1 um of °hue angle, and 125 mg L^{-1}, respectively, compared with the control plot in the 2018/2019 and 2019/2020 growing seasons (Figure 4). However, the increase in the former phenolic maturation parameters did not affect and not showed any significance on the

Table 1 - Effect of different ethephon doses on epidemiological parameters of Botrytis bunch rot of beginning of symptoms appearance (BSA), time to reach maximum disease incidence/severity (TRMDI and TRMDS), maximum disease incidence/severity (*I*max and *S*max), and areas under the disease progress curves (AUSDPC) 'Cabernet Sauvignon' grape during the 2018/2019 and 2019/2020 growing seasons at São Joaquim municipality, State of Santa Catarina, Southern Brazil.

	------------------------	------------------------	Ethephon doses mg L^{-1}	------------------------	------------------------	------------------------
Parameters	0	720	1440	2160	2880	CV[d](%)
BSA (days)	19.5*	15.5*	15.1*	13.7*	18.0*	17.1
TRMD*I* (days)	27.0*	25.5*	26.5*	24.0*	22.0*	12.3
TRMDS (days)	25.0*	21.0*	29.0*	27.0*	27.0*	22.0
*I*max. (%)[a]	45.0*	38.0*	41.0*	37.0*	39.0*	19.0
*S*max. (%)[b]	1.4*	2.2*	1.8*	2.1*	1.2*	14.5
AUDPC[c]	42.0*	47.5*	32.6*	33.0*	31.5*	15.1

*Not significant.
[a]Average incidence estimated in berry with symptoms.
[b]Average severity estimated by infection class according to HILL et al. (2010).
[c]Area calculated by trapezoidal integration value according to CAMPBELL & MADDEN (1990).
[d]Coefficient of variation.

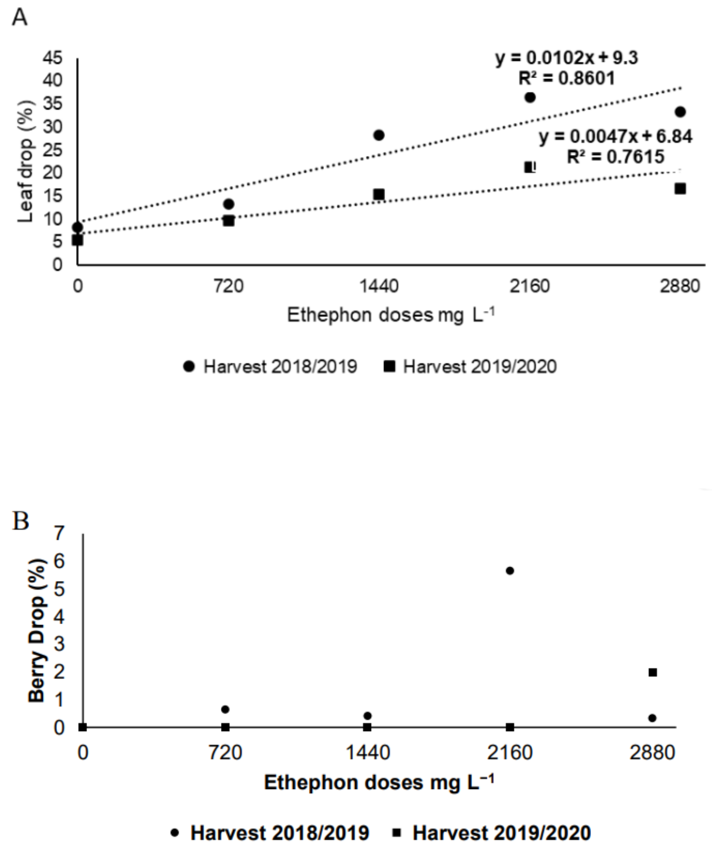
productive parameters of bunch size and mass, number and diameter of berries, production and productivity, BCI, and Ravaz index , or bud fertility parameters of the apical, median, and basal buds per bunch.

DISCUSSION

The main grape-producing regions in southern Brazil are characterized by a grapevine cycle that initiates in September and ending in early March, with the ripening and harvesting of late varieties. In this period adequate rainfall volume occurred in the both 2018/2019 and 2019/2020 growing seasons, surpassed the water requirements of the vines throughout the cycle. The environmental conditions during the ethephon application at the phenological stage of flowering (BBCH-60) and beginning of ripening (BBCH-81) allowed the *B. cinerea* infection despite not being the ideal condition for the germination of fungus spores of 18 ºC to 24 ºC, with a period of 2 hours of free water on the plant surface (LATORRE et al., 2015). Environmental conditions during the flowering period are determinants of grape sanity. During this period, the opening of the floral stigma and the infection by *B. cinerea* are favored by free water and high humidity. The fungus may remain latent until maturation, when it can find favorable conditions for BBR development (LATORRE et al., 2015). A low rainfall rate found in the phenological stage of maturation (BBCH 85) around February and March 2020 (Figure 1) helped to reduce pathogen infection and; consequently, the occurrence of BBR and the ethephon non effect (Figure 1). Average rainfall during maturation may disrupt the berry skin and facilitate *B. cinerea* infection. Still; although, this general condition occurred on average, there was no effect of the ethephon on BBR epidemiological parameters (LATORRE et al., 2015; COSTA et al., 2016).

The effect of ethephon on defoliation was significant and showed a crescent leaf fall rate with increasing ethephon doses (Figure 2). Ethephon absorption is easily influenced by changes in temperature, relative humidity, pH of the diluent solution, and the leaf surface where the phytoregulor solution is applied (RAVANBAKHSH et al., 2018). Temperatures lower than 25 °C–27 °C and high humidity, around 80%–100%, are favorable to ethephon absorption by plants and degradation of cell walls in the leaf abscission region (UZQUIZA et al., 2015; COSTA et al., 2016; COSTA et al., 2016a; RAVANBAKHSH et al., 2018; XU et al., 2019). The ethephon absorption is less efficient in summer, especially when plants are sprayed on hot days with temperatures higher than 25 °C–27 °C and rainfall and humidity restrictions. In such conditions, approximately 30% and 60% of the ethephon volume applied is absorbed by the leaves between 4 h and 24 h, respectively (COSTA et al., 2016a). These enviroumental conditons associated with low leaf fall rate caused by the different doses of ethephon may be the reason of the non effect of ethephon on the BBR epidemiological paramentrs.

The rainfall and temperature rates were slightly lower and higher in the maturation period



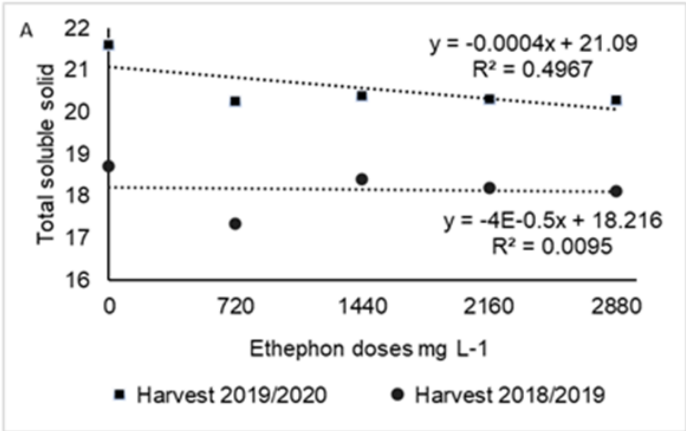
Trend line shows significant difference amongst treatments at 5% probability.

Figure 2 - Effect of different doses of ethephon on leaf (A) and berry (B) fall of 'Cabernet Sauvignon' grapevine during the 2018/2019 and 2019/2020 growing seasons at São Joaquim municipality, State of Santa Catarina, Southern Brazil.

during the 2019/2020 growing season compared with the former 2018/2019 growth season. These conditions could interfere with the absorption of the ethephon product because absorption occurs by the cuticle and, probably, by the stomatic openings (RAVANBAKHSH et al., 2018; XU et al., 2019). Despite this, ethephon significantly affected leaf fall, with a 15%–20% percentage of defoliation in both the 2018/2019 and 2019/2020 growing seasons. This percentage is still considered low and unsatisfactory for replacing manual defoliation, which reaches almost 100% of the leaves in the cluster region. The exposure of clusters to the natural conditions of solar radiation, ventilation, and a low period of free water can help prevent pathogen infections (COSTA et al., 2016; COSTA et al., 2016a; RAVANBAKHSH et al., 2018).

There was no significant influence of ethephon on the berries fall in either the 2018/2019 and 2019/2020 growing seasons. The non-effect on the berries fall is considered a positive factor because the interference should be on the leaf fall and not on the initial phase of berry formation. FERRARA et al. (2016) showed that the applications of 1,445 and 2,890 mg L^{-1} of etephon were responsible for 90% and 49% of the fall of berries in the "Thompson Seedless" and "Crimson Seedless" cultivars, respectively.

UZQUIZA et al. (2015) and FERRARA et al. (2016) showed that ethephon could be potentially used in mechanical grape harvest because it may help develop scars at the junction of the pedicel berry, reducing the infection or contamination of berries. This maintains the integrity of berries for winemaking



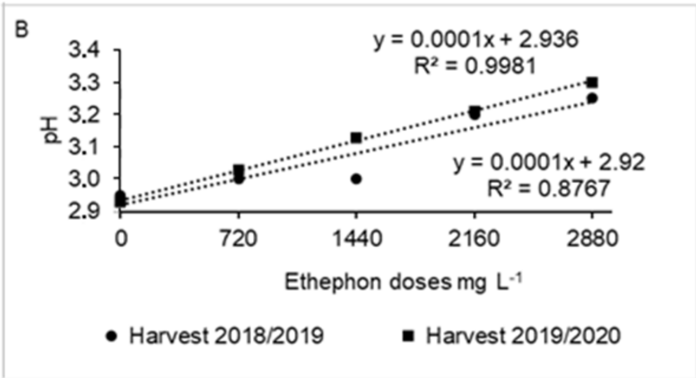


Figure 3 - Effect of different ethephon doses on the technological maturation parameters of total soluble solid (A) and pH (B) of 'Cabernet Sauvignon' grape during the 2018/2019 and 2019/2020 growing seasons at São Joaquim municipality, State of Santa Catarina, Southern Brazil.

and increases the quality of the final product. Increasing ethephon doses had several effects on the technological and phenolic maturation parameters of grapes. In this particular study, there was no significant effect on Titratable acidity (TA). Still, a significant impact of ethephon on Total soluble solid (TSS) and pH in both the 2018/2019 and 2019/2020 growing seasons was significant observed. The significance of the ethephon effect on TSS contents in different growing seasons was also reported by OBREQUE-SLIER et al. (2014), SCAVRONI et al. (2018), and SUSIN et al (2022). These researchers observed a data alternation in different growth seasons due to different environmental conditions.

The reduction in TSS accumulation can be caused by the fact that ethephon is an ethylene precursor, influencing the acceleration process of maturation and reducing the time of TSS accumulation. TSS accumulation was dependent on leaf photoassimilates in the maturation period. Another possibility was the effect of ethephon on increasing respiration and, consequently, higher consumption of sugars because ethylene accelerates ripening metabolism (UZQUIZA et al., 2015), justifying the significant increase in the must pH values with the increase in ethephon doses (Figure 3). This same effect was also reported by ABREU et al. (2017), in the "Isabel" cultivar and SCAVRONI et al. (2018), in the 'Rubi' cultivar. However, there was no significant difference in the TA values among treatments in the growing seasons evaluated. This effect was also reported by UZQUIZA et al. (2015) and WURZ et al. (2018).

The increase in all phenolic maturation parameters according to the increase in ethephon

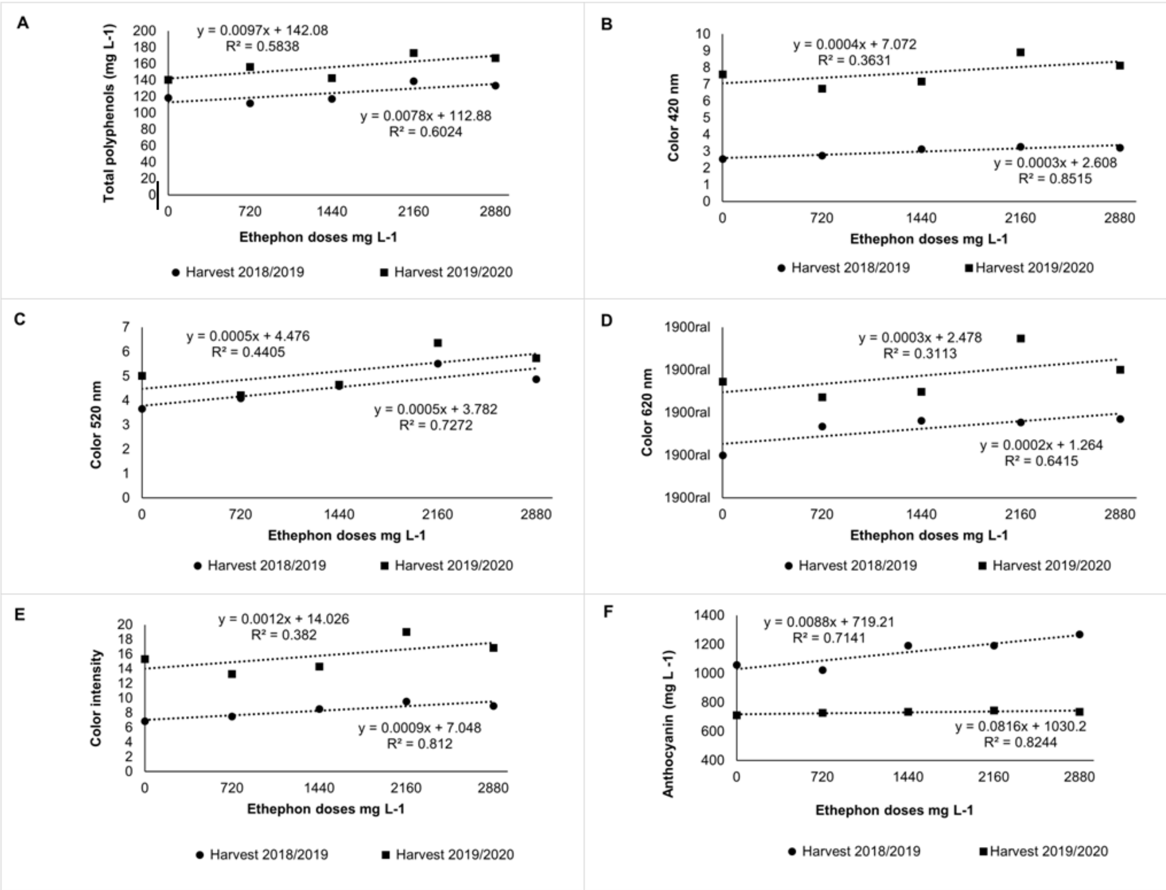


Figure 4 - Effect of different ethephon doses on the phenolic maturation parameters of ‘Cabernet Sauvignon’ grapevine during the 2018/2019 and 2019/2020 growing seasons at São Joaquim municipality, State of Santa Catarina, Southern Brazil.

doses was also reported by UZQUIZA et al. (2015), and FERRARA et al. (2016). These researchers demonstrated the potential of ethephon in improving phenolic maturation parameters to improve the quality of grapes, as they are attributes responsible for their longevity and conservation and wines, especially the red ones. Theoretically, such effects could help minimize the physical damage to berries and the final must volume released during mechanical harvesting, reducing undesirable oxidative processes before grapes come into the winery GONZÁLEZ et al, 2018).

The grape skin color intensity of the berries was obtained by the sum of the three tonalities/°hue (420, 520, and 620 ηm). There was an increase in color intensity content because of the increasing influence of pH. In this case, the higher the pH, the higher the color intensity (OBREQUE-SLIER et al., 2014; SCAVRONI et al., 2018). The increase in the must pH was also associated with the rise in °hue and anthocyanin content values as the ethephon doses increased. These data indicate that ethephon applications may have promoted the synthesis of positive compounds that give or improve grape color. Color is the first sensory attribute evaluated by wine consumers in a technical grape and wine evaluation (COSTA et al., 2016; RAVANBAKHSH et al., 2018). SCAVRONI et al. (2018) showed that ethephon associated with $CaCl_2$ can contribute to improve the post-harvest quality of ‘Rubi’ grape, since this association increased the accumulation of anthocyanins due to the higher activity of phenylalanine ammonia lyase and glutathione S-transferase, related to biosynthesis and storage of antocyanins, respectively.

The increasing ethephon doses did not show a significant difference in the productive parameters of bunch size and mass, berries number and diameter, BCI, production, productivity, and Ravaz index. COSTA et al. (2016) showed a production increase in the “Niagara Rosada” grape when it was treated with ethephon before pruning by inducing a higher sprouting rate without influencing the fertility rates of buds. These results are similar to the fertility parameters of the bud in this study, which were not affected by the ethephon application. Bud fertility is determined from one growing season to another because when the plant is in the phenological stage of fruit set (BBCH-71) (LORENZ et al., 1995), it takes place together with the process of production of primordium differentiation for the next growth season (RAVANBAKHSH et al., 2018; XU et al., 2019). Hormonal balance is crucial for the primordium differentiation process (UZQUIZA et al. 2015) because the ethephon spray in the phenological stage of color exchange at beginning of ripening (BBCH-81) has no effects on bud fertility. Similarly, the Ravaz index parameter depended on bud fertility and plant production, which were not affected by the increasing of ethephon doses.

CONCLUSION

There was a significant effect of increasing ethephon doses on leaf fall. However, the defoliation rate of 15%–20% was considerable less unreasonable compared with the leaf fall expectation for ´Cabernet Sauvignon´ cultivar in the edaphoclimatic conditions of highland regions of southern Brazil.

There was no significant effect of increasing ethephon doses on the epidemiological parameters of BBR, caused by *B. cinerea*.

There was a significant effect of increasing ethephon doses on the technological and phenolic grape maturation parameters, improving the must pH, TP, color 420, 520, and 620 ηm, color intensity (°hue angle), and anthocyanin, and reducing the total solubre solids. Based on this result, ethephon may be a positive product for enhancing grape maturation.

There was no significant effect of increasing ethephon doses on the productive parameters of bunch and berries size, mass and diameter, compactness and Ravaz index, production, productivity, and bud fertility.

ACKNOWLEDGEMENTS

The authors are grateful for the assistance and support given by Universidade do Estado de Santa Catarina (UDESC), Fundação de Amparo a Pesquisa e Inovação do Estado de Santa Catarina (FAPESC), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

DECLARATION OF CONFLICT OF INTERESTS

No potential conflict of interest was reported by the author(s).

AUTHORS’ CONTRIBUTIONS

AB, ROA and GF conceived and designed experiments. GF, JR and ROA performed the experiments, GF, AB and RTC carried out the lab analyses. . AB, DPR, FNS and RTCperformed statistical analyses of experimental data. AB prepared the draft of the manuscript. All authors critically revised the manuscript and approved of the final version.

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