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Alternative budburst management in Campanha Gaúcha vineyards

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Abstract – Seeking a less toxic alternative to budburst management than hydrogen cyanamide, doses of the mineral-organic product Erger® were tested in combination with calcium nitrate ($Ca(NO_3)_2$). The experiment was conducted in Santana do Livramento, southern Brazil, during the 2013/14 and 2014/15 growth cycles, in a 'Merlot' vineyard conducted in a vertical trellis system, pruned in double Guyot, with SO4 rootstock. Treatments were: Control (unsprayed); 5.0% $Ca(NO_3)_2$; 2.5% Erger® + 5.0% $Ca(NO_3)_2$; 5.0% Erger® + 5.0% $Ca(NO_3)_2$; 7.5% Erger® + 5.0% $Ca(NO_3)_2$; 3.5% Dormex® (positive control). All Erger® treatments stimulated budbreak, increasing budburst from 68% (unsprayed and calcium nitrate means) to 83% (Erger® means) in the first cycle and from 85% to 96% in the second one, with no difference among doses. Plants treated with Dormex® had budburst similar to Erger® in the first cycle (85%), but budburst in the second cycle was only 72%, possibly due to burned buds. Therefore, Erger®, in concentrations of 2.5% or more with 5% calcium nitrate, may be a promising alternative to induce budburst in regions with restrictions in cold availability.

Index terms: bud dormancy, hydrogen cyanamide, Erger®, Merlot, *Vitis vinifera*.

Manejo alternativo da brotação em vinhedos da Campanha Gaúcha

Resumo - Buscando uma alternativa menos tóxica que a cianamida hidrogenada para o manejo da brotação, doses do produto organomineral Erger® foram testadas em combinação com nitrato de cálcio ($Ca(NO_3)_2$). O experimento foi conduzido em Santana do Livramento, região Sul do Brasil, durante os ciclos de 2013/2014 e 2014/2015, em um vinhedo 'Merlot', conduzido em espaldeira, podado em Guyot duplo e enxertado sobre SO4. Os tratamentos testados foram: Controle (sem aplicação); 5,0% $Ca(NO_3)_2$; 2,5% Erger® + 5,0% $Ca(NO_3)_2$; 5,0% Erger® + 5,0% $Ca(NO_3)_2$; 7,5% Erger® + 5,0% $Ca(NO_3)_2$; 3,5% Dormex® (controle positivo). Todos os tratamentos com Erger® estimularam a quebra de dormência, aumentando a brotação de 68% (média dos controles sem aplicação e nitrato de cálcio) para 83% (média dos tratamentos com Erger®), no primeiro ciclo, e de 85% para 96%, no segundo, sem diferença entre as doses. Plantas tratadas com Dormex® tiveram brotação semelhante ao Erger® no primeiro ciclo (85%), mas a brotação no segundo ciclo foi de apenas 72%, possivelmente devido à queima de gemas. Portanto, Erger®, na concentração de 2,5% ou superior, combinado com 5% de nitrato de cálcio, pode ser uma alternativa promissora para induzir brotação em regiões com restrições na disponibilidade de frio.

Termos para indexação: dormência de gemas, cianamida hidrogenada, Erger®, Merlot, *Vitis vinifera*.

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Introduction

The Campanha Gaúcha has been ranked among the most promising wine producing regions in Brazil, due to climate and soil conditions which restrict water availability to the vine (MOTA, 1992). Although the first vineyards were installed in the 1970s, further expansion in vineyards and wine production was boosted in the early 2000s, counting with more than 1,500 ha in 2015 (MACHADO et al., 2017). Most grape growers have adopted vineyard management procedures imported from other regions (e.g.: Serra Gaúcha) without proper adaptation to local soil and climate.

Grapevines require a chilling exposure, depending on genotype, ranging between 50 and 400 chilling hours (CH, sum of hours with air temperature below 7.2°C) for normal budburst (TREJO-MARTÍNEZ et al., 2009). 'Merlo' (*Vitis vinifera* L.) is a cultivar that demands an average of 300 CH during the winter period to overcome bud endodormancy (ANZANELLO et al., 2018). The average number of CH from May to September in Santana do Livramento varied from 340 CH, based on a 1966-2003 data series (MATZENAUER et al., 2005), to 364 CH, based on a 1981-2010 data series (ALVES et al., 2019). However, cold accumulation varies and problems in overcoming bud dormancy may occur in some years. This scenario can be even more restrictive if we consider the predictions of climate change for this region. Wrege et al. (2010) predicted the impacts of air temperature increases of 1°C, 3°C and 5.8°C on cold accumulation in the south of Brazil. An increase of only 1°C would cause a reduction of up to 40% in winter CH, while a 5.8°C rise in temperature would completely eliminate CH availability in this region.

In order to compensate for the lack of CH, grape growers usually spray chemical budburst inducers, to increase uniformity and maximum number of sprouted buds (OR et al., 2002). Lower budburst has a direct and negative impact on vineyard yield, while low budburst uniformity causes contrasts in maturation level and enological quality among clusters. In addition, irregular budburst promotes an imbalance between production and vegetative growth, restricting the number of fertile shoots per plant and stimulating individual shoot vigor and canopy shade, requiring more labor to manage vineyards and ensure enological quality (CONDE et al., 2007; KELLER, 2015).

Few commercial options have recognized effectiveness in budbreak control (MOHAMED, 2008). Like other temperate fruit species, grapevines are very responsive to cyanamide, commercially employed as a liquid formulation of hydrogen cyanamide, H_2CN_2 (CITADIN et al., 2006), classified as highly toxic and banned in European Union countries since 2008 (EFSA, 2010). Thus, an alternative treatment to overcome bud dormancy is in high demand. Preliminary studies have identified a commercial product called Erger® as a less dangerous option to stimulate budburst in temperate fruit species. According to manufacturer's guidelines, this product is an organic nitrogen compound which, when mixed with calcium nitrate ($Ca(NO_3)_2$), has budbreaking effects on apples (HAWERROTH et al., 2010b; PETRI et al., 2014) and blackberries (SEGANTINI et al., 2015). Therefore, this product could be an alternative with lower environmental risk for dormancy control in the Campanha Gaúcha region.

Despite these advances, the use of Erger® in grapevine budburst management is still restricted. As observed with hydrogen cyanamide, the action of Erger® can be influenced by climatic conditions (BOTELHO et al., 2010; RUFATO et al., 2010; WERLE et al., 2008), and its use needs local adjustments. This work evaluates the effect of different doses of Erger® associated with calcium nitrate on budburst, phenology, and yield components of 'Merlot' grapevines grown in the Campanha Gaúcha climatic conditions, in an attempt to identify an alternative to hydrogen cyanamide.

Materials and methods

The work was carried out in a commercial 'Merlot' vineyard located in Santana do Livramento, Rio Grande do Sul (30°44'53"S, 55°23'49"W), 180 meters above sea level, planted in 2005 on SO4 rootstock with 1.0 x 2.8 m spacing. Vines were conducted in a vertical trellis system with double Guyot pruning, leaving two canes (8 buds each) and 2 spurs (2 buds each) per plant. The standard management practices adopted in the region were used, with twenty-one sprays per cycle to prevent diseases (mainly anthracnose, downy mildew and fruit rot) and pests (mainly *Cryptoblabes gnidiella* and thrips). No irrigation or fertilization was necessary during the experiment and the weeds were controlled by three mows in each cycle.

According to the Köppen (1948) classification, the local climate is Cfa, subtropical with hot humid summers and mild winters, with uniform precipitation throughout the year. Vineyard soil was classified as a dystrophic red-yellow ultisol (SANTOS et al., 2018).

Six treatments were tested in two consecutive growing cycles (2013/14 and 2014/15), based on the dosages of two commercial products (Dormex® – 52% hydrogen cyanamide, and Erger® – an organic fertilizer with 5.8% nitric N, 3.1% ammonia N, 6.1% urea N, 6.5% CaO, enriched with diterpenes, and mono and polysaccharides): Control (unsprayed); 5.0% $Ca(NO_3)_2$ (calcium nitrate); 2.5% Erger® + 5.0% $Ca(NO_3)_2$; 5.0% Erger® + 5.0% $Ca(NO_3)_2$; 7.5% Erger® + 5.0% $Ca(NO_3)_2$; 3.5% Dormex® (positive control). All treatments were applied (without adjuvant) using 20 L knapsack sprayers fitted with a deflector nozzle, spraying until complete wetting of buds (equivalent to 300 L/ha). The experiment was set up in randomized blocks with five repetitions distributed in two central lines of the vineyard. The useful plot to collect data was composed of two plants. All plants were pruned and submitted to spray treatments (between 3 and 5 pm) on the same day. In the first cycle, pruning and sprays were performed on 12 August 2013, while, in the next cycle, the same procedures were performed on 13 August 2014.

In both cycles, phenological stage of buds and shoots was evaluated weekly, according to the scale proposed by Eichhorn and Lorenz (1977). Total budburst (green-tip buds) per plant was registered until no more buds sprouted (14 October 2013 and 10 October 2014). In the second cycle, due to the occurrence of bud damage by the Dormex® treatment, the number of fertile shoots (with at least one bunch) and total number of shoots were also counted (90 days after pruning), as were measured, at harvest (9 February 2015), number of bunches per plant and production per plant (kg). A sample of three bunches per plant was collected randomly, counting the number of berries of each bunch. Percentage of fertile shoots was calculated by dividing the number of fertile shoots by the total number of shoots. Number of berries per plant was calculated by multiplying number of bunches per plant by number of berries per bunch. Yield (t/ha) was estimated by dividing production per plant by the area occupied by each plant (2.8 m²), adjusting the units.

Temperature, humidity, rainfall and wind speed were recorded with a Campbell Scientific automatic weather station installed 50 meters from the vineyard. Accumulated winter chilling hours (CH) before each growth cycle were calculated applying the method used by Matzenauer et al. (2005). Cumulative heat sum after the pruning date of each cycle was calculated using a base temperature of 9.4°C (POUGET, 1988), according to the methodology described by Villa Nova et al. (1972).

Production cycle was divided into five periods, starting at the pruning date: Dormant (before budburst), Vegetative growth (before beginning of flowering), Flowering (before fruit set), Fruit development (before color change) and Ripening (EICHHORN & LORENZ, 1977). All fruits were harvested on the same day within each cycle (14-Feb-2014 and 16-Feb-2015), after all treatments reached 20°Brix. Dates of the five transitions between these periods were estimated by interpolation, considering the observed phenological stages, and compared using the Tukey test at 5% probability. Measured variables were tested with an orthogonal contrast analysis with 5 degrees of freedom: controls vs. chemical spraying; Erger® vs. Dormex®; linear effect of Erger® dose; quadratic effect of Erger® dose; control vs. $Ca(NO_3)_2$. Budburst means were also compared using the Tukey test at 5% probability. All statistical analysis were performed using R software package (R Development Core Team, 2018).

Results and discussion

Meteorological data measured in both cycles during the growth and production period (15-24 °C, 64-83 % RH, 148 mm/month rain, 3 m/s average wind speed, during the September-February period) were within normal values for the region (ALVES et al., 2019). However, there was a marked difference in cold accumulation between cycles. Registered cold accumulation from May to September in 2013 and 2014 was 641 CH and 374 CH, respectively. Despite the strong contrast between winters, this was within the expected range for Campanha Gaúcha (ALVES et al., 2019), in which the climatic average is 364 CH. As seen on Figure 1, cold accumulation in both years was similar until the end of July. However, cold fronts between 9 and 28 August 2013 resulted in over 230 additional CH, and lasted through September. This caused a delay of 12.5 days in budburst in the first cycle, compared to 2014/15, which could be related to heat availability. ‘Merlot’ has a chilling requirement of 300 CH to overcome endodormancy (ANZANELLO et al., 2018) and a base temperature (Tb) of 9.4°C (POUGET, 1988). Cumulative heat sum after the pruning date in each cycle was calculated in both years and plotted on Figure 1. Although 300 CH was reached earlier in 2013 (25 Jul) than in 2014 (9 Aug), budburst occurred later, due to slower heat accumulation in 2013, which impacts grapevine development (ZAPATA et al., 2015).

In addition to delaying budburst, the colder spring of 2013 also reduced the percentage of sprouted buds (68%) in control treatments, compared to the 2014/15 cycle (85%), as seen on Figure 2. This could be also related to the cold period immediately following the mean budburst date, in Sep 2013 (Figure 1), which inhibited further budburst. When this frostless cold front ended, existing sprouts were already more developed, possibly inhibiting some of the remaining buds from sprouting, due to apical dominance (HAWERROTH et al., 2010a).

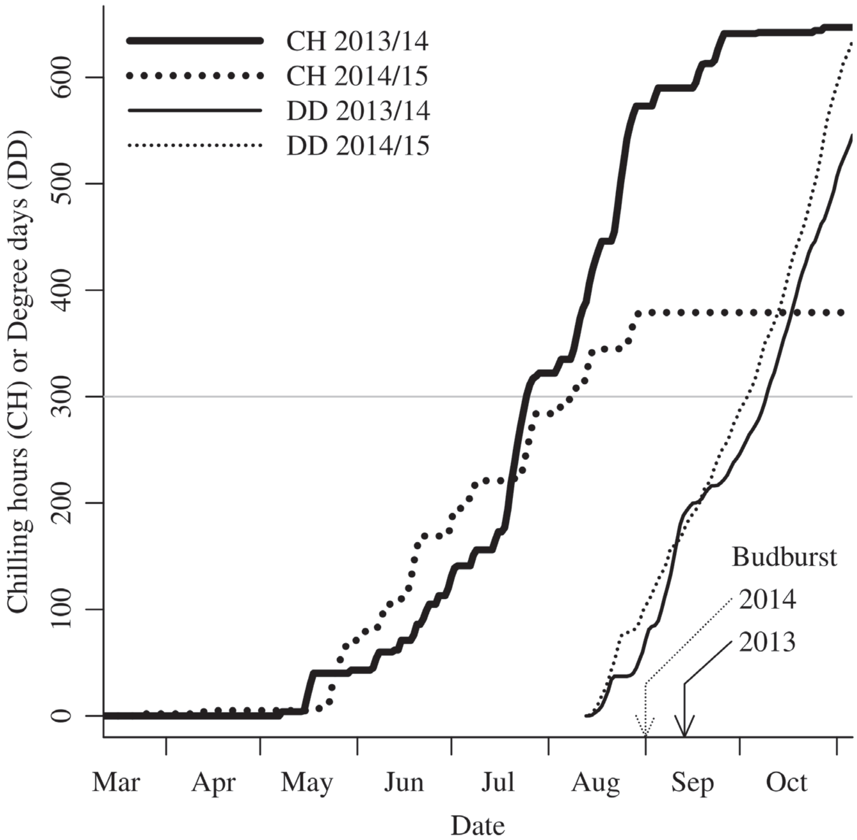

Figure 1. Chilling hours (CH, number of hours with temperature < 7.2°C) and cumulative heat sum after pruning (DD, degree-days above a base temperature of 9.4°C) in 'Merlot' vineyards during two cycles (2013/14 and 2014/15). Temperature data was registered using a Campbell Scientific automatic station located 50 m from the vineyard, in Santana do Livramento, RS. The horizontal gray line represents the 'Merlot' chilling requirement of 300 CH. Budburst dates of each cycle (13/09/2013 and 31/08/2014) is indicated by the arrows.

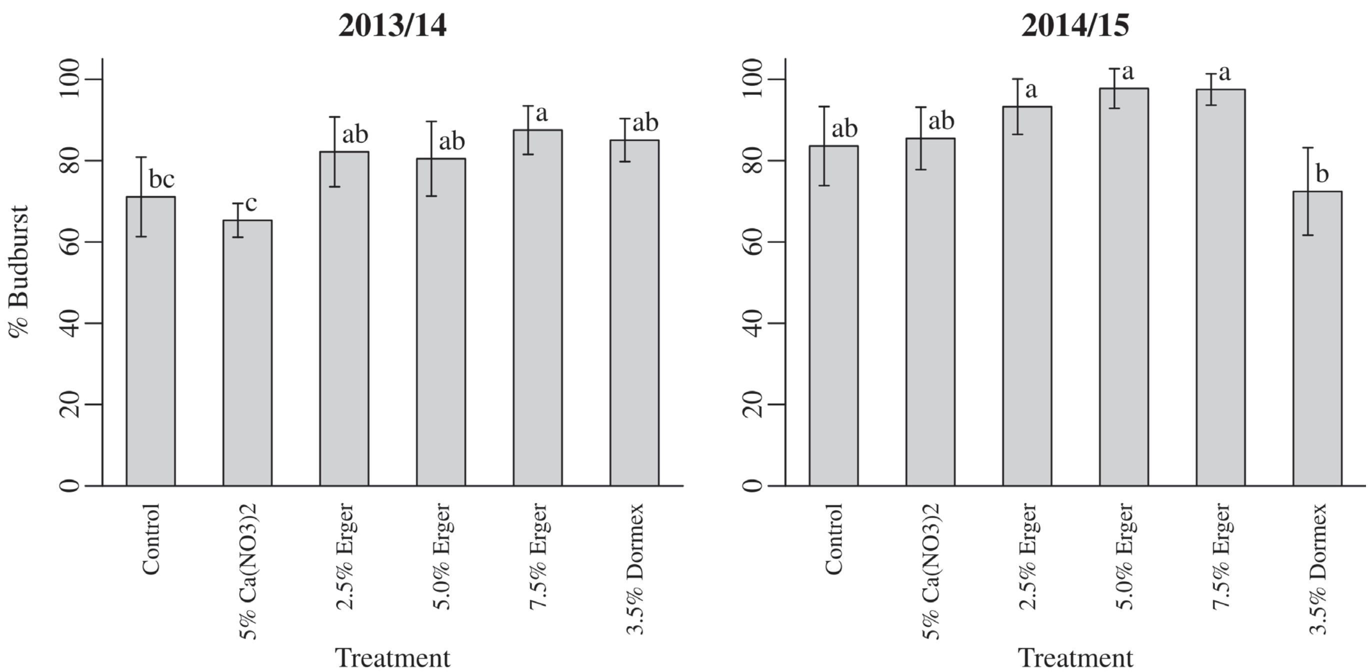

Figure 2. Observed budburst (%) in 'Merlot' grapevines treated with different doses of Erger®+ $Ca(NO_3)_2$ during two cycles, in Santana do Livramento, RS. Two negative control treatments (untreated or sprayed with $Ca(NO_3)_2$) and one positive control (Dormex®) were included for comparison. All Erger® treatments were sprayed combined with 5% $Ca(NO_3)_2$. Vertical bars represent the 95% confidence interval of the mean. Within each cycle, treatments with the same letters do not differ (Tukey test, at 5% probability).

Pruning in canes (Guyot), a common practice in Campanha Gaúcha, tends to worsen this situation, because long canes favor sprouting of basal and apical buds, restricting the number and synchronism of medium positioned buds (MANFROI et al., 1997). This could be seen in the 2014/15 cycle, in which, although total budburst was higher, an irregular pattern was clearly visible in control and 5% $Ca(NO_3)_2$ treated plants, which manifested greater apical dominance and unsprouted intermediate buds (Figure 3A).

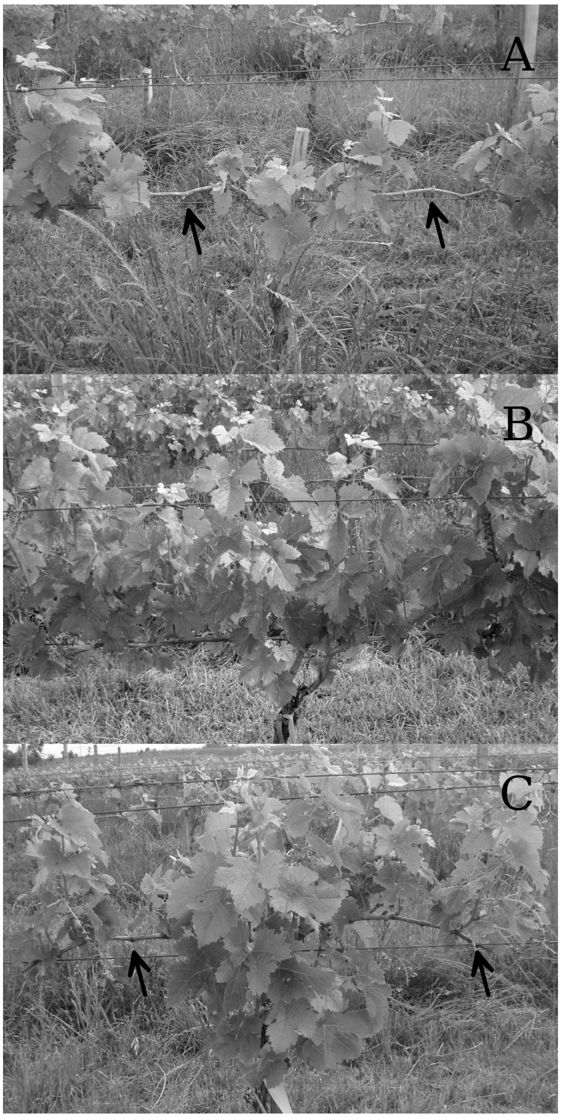

Figure 3. Visual contrast of observed budburst in 'Merlot' grapevines pruned in double Guyot, in control plants (a) and plants treated with 5% Erger® (b) or 3.5% Dormex® (c), during the 2014/15 cycle in Santana do Livramento-RS. Arrows indicate budburst failures, due to sustained dormancy (control) or burned buds (Dormex®).

Significant effects of chemical spraying were observed on budburst in both cycles, specially activating intermediate buds, but the response depended on the chemical used. Treating plants with Erger® increased budburst from 68% to 83% in the first cycle, compared to controls, and from 85% to 96% in the second one, with no significant differences between doses (Figures 2 and 3B). Although 2.5% Erger® was able to induce sufficient budburst, the amount of cold in both cycles was enough to overcome dormancy, and higher doses of Erger® may be necessary in milder winters.

Plants treated with Dormex® had budburst similar to Erger® in the first cycle (85%), but budburst in the second cycle was only 72%. Considering that hydrogen cyanamide causes oxidative burning of meristematic tissues when buds are not protected by closed scales (OR et al., 1999), a possible explanation for the reduced budburst in the 2014/15 cycle is the fact that it occurred earlier, and that some buds may have been partially open when spraying occurred (Figure 3C). Since Erger® did not reduce budburst in these conditions, one may conclude that the mechanisms by which it promotes meristematic growth are different from those of hydrogen cyanamide. Furthermore, Erger® is more cost effective, considering that spraying at the 7.5% dose would cost US$ 510/ha (against US$ 910/ha of Dormex® at 3.5%), and higher doses may be used with little risk of burning buds.

Phenology evolution was directly affected by budburst date in both cycles (Figure 4). In the colder conditions of the first cycle, chemically treated plants sprouted significantly earlier than controls, with a larger effect of Dormex® (13.8 days) than Erger® (5.2 days). However, on the second cycle, Dormex® induced budburst 8.9 days earlier, but Erger® had no significant effect. In both cycles, the flowering period was affected by Dormex®, but not by Erger®.

Despite the initial differences in budburst (Figure 2), no significant effect was observed in the ratio between fertile shoots (with at least one bunch) and total number of shoots in the second cycle (Table 1). However, number of bunches per plant increased significantly in sprayed plants ($p=0.0048$), which caused a reduction in number of berries per bunch ($p<0.0001$). These two factors compensated for each other, and the total number of berries per sprayed plant did not differ from controls.

According to Keller (2015), leaving more clusters per plant will increase sink strength for carbohydrates, decreasing shoot vigor and number of berries, favoring enological quality. Berry mass is not directly related to treatments affecting budburst, because it depends on environmental conditions which occur later in the cycle (CARREÑO et al., 1999), and was not considered in this study. A slight effect of Erger® dose was observed, with 5% Erger® resulting in 271 (14.9%) more berries per plant than the average of the other treatments. However, this did not impact yield, which was 10.97 t/ha, on average, with no significant difference between treatments ($p=0.10$).

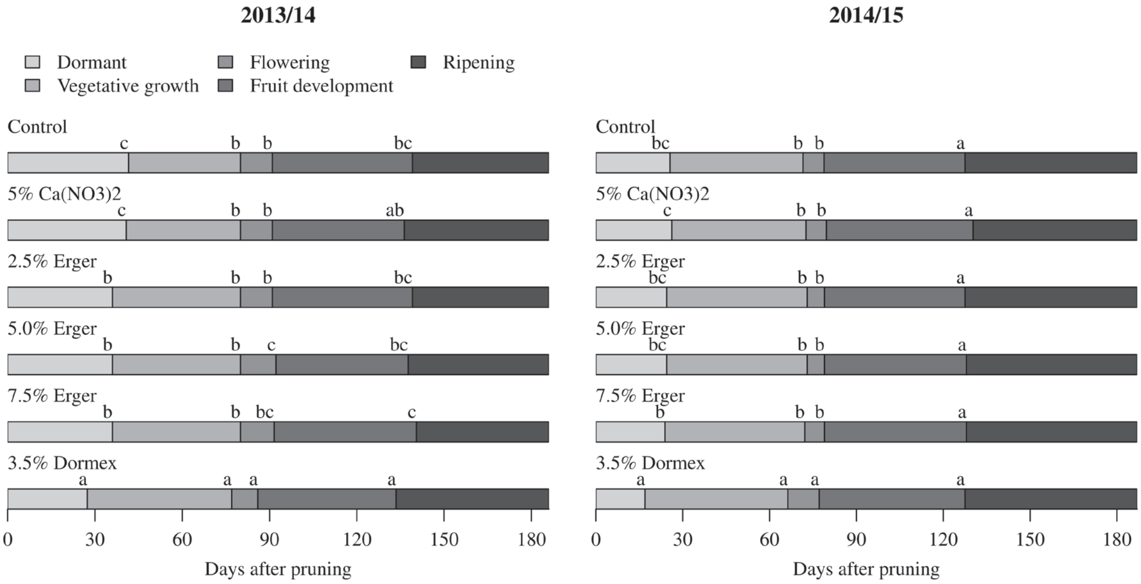

Figure 4. Phenology evolution of 'Merlot' variety conducted in Double Guyot pruning system resulted from treatments with Erger® and Dormex® in production cycles 2013/14 and 2014/15. Control treatments were unsprayed (Control) or sprayed with $Ca(NO_3)_2$, and all Erger® treatments were sprayed combined with 5% $Ca(NO_3)_2$. Santana do Livramento-RS, 2015. Within each cycle, treatments with the same letters do not differ (Tukey test, at 5% probability).

Table 1. Yield components related to number of berries of 'Merlot' grapevines treated with Erger® or Dormex® and meaningful contrasts defined in the statistical analysis. Control treatments were unsprayed (Control) or sprayed with $Ca(NO_3)_2$, and all Erger® treatments were sprayed combined with 5% $Ca(NO_3)_2$. Santana do Livramento, RS, Brazil, 2014/15 cycle.

Treatments[1]	Fertile shoots[2] (%)	Bunches per plant	Berries per bunch	Berries per plant
Control	67.9	20.4	96.9	1817
Control + 5% $Ca(NO_3)_2$	63.3	22.2	83.1	1799
2.5% Erger® + 5% $Ca(NO_3)_2$	70.0	26.2	67.4	1769
5.0% Erger® + 5% $Ca(NO_3)_2$	75.6	31.8	67.9	2093
7.5% Erger® + 5% $Ca(NO_3)_2$	70.5	30.2	62.3	1882
3.5% Dormex®	68.8	27.4	68.3	1843
Coefficient of variation (%)	18.2	23.4	19.4	17.1
Significance (*p<0.05; **p<0.01) of hierarchical orthogonal contrasts				
Controls vs. Chemicals[3]	p=0.12	p=0.0048**	p<0.0001**	p=0.22
Erger® vs. Dormex®	p=0.49	p=0.54	p=0.57	p=0.45
Erger® dose	p=0.55	p=0.36	p=0.51	p=0.022*

[1] Concentration of commercial product (v/v) and $Ca(NO_3)_2$ (w/v) in water.
[2] Number of shoots with at least one bunch divided by total number of shoots.
[3] Contrast of the two controls (no spraying and $Ca(NO_3)_2$) against dormancy breaking products (Erger® and Dormex®)

Hydrogen cyanamide is still widely used to break bud dormancy in fruit trees in many parts of the world. However, due to its high toxicity, its use is prohibited in Europe, and restrictions tend to increase worldwide (POTJANAPIMON et al., 2007; EFSA, 2010). Considering that climate changes tend to restrict cold availability, the dependency on bud breaking treatments tends to increase, and alternative products must be made available. Although further research is necessary to determine optimum doses (especially in warmer winter conditions), the results of this work show that Erger® may be a promising alternative to induce budburst, because it stimulates sprouting without negative impacts on open buds.

Conclusions

Erger® effectively induces grapevine budburst and may anticipate early phenological states. Although 2.5% Erger® with 5% calcium nitrate may be sufficient to induce budburst, higher doses may be necessary in mild winters. Both Erger® and Dormex® increase number of bunches per plant while reducing number of berries per bunch. Erger® is a viable alternative to hydrogen cyanamide for sustainable grapevine management in Campanha Gaúcha, and possibly other subtropical wine regions in the world.

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