ISSN 0100-2945 DOI: http://dx.doi.org /10.1590/0100-29452018537

Revista Brasileira de Fruticultura

Crop production

Performance of 'Maxi Gala' apple trees as affected by budbreak promoters, in São Joaquim-SC

Mateus da Silveira Pasa[1], João Felippeto[2], Gilberto Nava[3], André Luiz Kulkamp de Souza[4], Alberto Fontanella Brighenti[5], José Luiz Petri[6]

Abstract - The application of rest breaking agents to compensate the lack of chilling is a common practice in apple orchards in Southern Brazil. However, its necessity in areas of greater chilling accumulation has been questioned over the years. The aim of this study was to investigate the performance of 'Maxi Gala' apple in response to different budbreak promoters in São Joaquim, SC. The study was performed in the growing seasons of 2013/2014, 2014/2015, and 2015/2016. Plant material consisted of 10-year-old 'Maxi Gala' apple trees grafted on the rootstock 'M.9', arranged in a randomized complete block design with five replicates in the 2013/2014 and 2014/2015 growing seasons and six replicates in the 2015/2016 season. Treatments consisted of Erger®, combined with either calcium nitrate or mineral oil, at different rates; and hydrogen cyanamide combined with mineral oil. Treatments were applied when buds were between the stages A (dormant bud) and B (swollen bud; silver tip). The influence of treatments on flowering, budbreak, yield components, and fruit quality was assessed. Flowering was little affected by treatments, while axillary budbreak was consistently improved in the year of insufficient chilling accumulation. Besides, the combination Erger® (2% and 3%) + calcium nitrate (2% and 3%) and Erger® (1%) + mineral oil (3%) induced similar axillary budbreak as hydrogen cyanamide + mineral oil. Fruit quality attributes were not affected by treatments.

Index terms: *Malus domestica*, dormancy, flowering, hydrogen cyanamide.

Desempenho de macieiras 'Maxi Gala' em resposta a indutores de brotação, em São Joaquim-SC

Resumo – A aplicação de indutores de brotação para compensar a falta de frio é uma prática comum em pomares de macieira no Sul do Brasil. Porém, sua necessidade em áreas com maior acúmulo de frio nessa região, como em São Joaquim-SC, tem sido questionada ao longo dos anos. O objetivo deste trabalho foi estudar o desempenho de macieiras 'Maxi Gala' em resposta à aplicação de diferentes indutores de brotação em São Joaquim-SC. O estudo foi desenvolvido na Estação Experimental da EPAGRI, nas safras de 2013/2014, 2014/2015 e 2015/2016. Foram utilizadas plantas da cultivar Maxi Gala, com 10 anos de idade, enxertadas no porta-enxerto 'M.9'. O delineamento experimental foi de casualização por blocos, com pelo menos cinco repetições. Os tratamentos consistiram em Erger®, combinado com nitrato de cálcio ou óleo mineral, em diferentes concentrações; e cianamida hidrogenada combinada com óleo mineral. A aplicação foi realizada quando as gemas estavam entre os estádios A (gema dormente) e B (gema inchada; ponta prateada). Foi avaliada a influência dos tratamentos na floração, brotação, componentes produtivos e qualidade dos frutos. A floração foi pouco influenciada pelos tratamentos, enquanto a brotação de gemas laterais foi aumentada no ano com acúmulo de frio insuficiente. Além disso, as combinações de Erger® (2% e 3%) + nitrato de cálcio (2% e 3%) e Erger® (1%) + óleo mineral (3%) induziram brotação de gemas laterais semelhante à cianamida hidrogenada + óleo mineral. Os atributos de qualidade dos frutos não foram afetados pelos tratamentos.

Termos para indexação: *Malus domestica*, dormência, floração, cianamida hidrogenada, retorno de floração.

Corresponding author:
pasam@oregonstate.edu

Received: December 04, 2017.
Accepted: March 26, 2018.

[1]Agronomist, PhD. Assistant Professor – Pomology/Mid-Columbia Agricultural Research and Extension Center, Department of Horticulture, Hood River, OR, United States,. E-mail: pasam@oregonstate.edu

[2]Enologist, M.Sc., Researcher - Enology. Santa Catarina Agricultural Research and Extension Agency/Experimental Station of São Joaquim, São Joaquim-SC, Brazil. E-mail: joaofelippeto@epagri.sc.gov.br.

[3]Agronomist, PhD. Researcher – Temperate Fruit Trees/Soil and Plant Nutrition Department. Embrapa Temperate Climate, Pelotas-RS, Brazil. E-mail: gilberto.nava@embrapa.br.

[4]Agronomist, PhD. Researcher – Temperate Fruit Trees/Crop Science Department. Santa Catarina Agricultural Research and Extension Agency/Experimental Station of Videira, Videira, SC, Brazil. E-mail: andresouza@epagri.sc.gov.br;

[5]Catarina Agricultural Research and Extension Agency/Experimental Station of São Joaquim, São Joaquim- SC, Brazil. albertobrighenti@epagri.sc.gov.br.

[6]Agronomist, M.Sc. Researcher – Temperate Fruit Trees/Crop Science Department. Santa Catarina Agricultural Research and Extension Agency/Experimental Station of Caçador, Caçador-SC, Brazil. E-mail: petri@epagri.sc.gov.br

Introduction

Mosto of the apple growing areas in Southern Brazil are climatically marginal regarding chilling accumulation for most apple varieties, including Gala and its clones; the average chilling accumulation registered is 500 h below 7.2°C (45 °F) (PETRI et al., 2008). In this situation, apple budbreak and flowering are deficient and not uniform (PETRI; LEITE, 2004), which may ultimately reduce yield and fruit quality (HAWERROTH et al., 2010). Among the apple growing regions in Brazil, São Joaquim, in Santa Catarina State, shows the best chilling conditions for apple cultivation, accumulating an average of 900 h below 7.2°C. In such conditions, trees usually show a satisfactory performance without the use of rest breaking agents. However, previous results have shown positive response to the application of these substances regarding shoot axillary budbreak in this region (IUCHI et al., 2002).

A greater number of lateral buds may ultimately result in greater number of spurs, and potentially increasing the yield the next seasons. Besides, the use of rest breaking agents may have significant effects in other important practices, like chemical thinning. The time of application is one of the main factors influencing the efficiency of chemical thinning (GREENE, 2002), and it is usually set by the phenological stage or fruit size. However, trees normally do not open all flowers at the same time; so by the time of chemical thinning treatment, there will be structures at different stages that may reduce its efficiency. The use of rest breaking agents usually result in greater uniformity of flowering, so facilitating chemical thinning. On the other hand, they may have negative effects on fruit set (HAWERROTH et al., 2009), which is closely related to chemical thinning planning.

Several rest breaking compounds have been tested over the last decades, such as mineral oil, calcium cyanamide, potassium nitrate, hydrogen cyanamide, dinitro-orthocresol (DNOC), dinitro-ortho-butyl-phenol (DNOPB), dinitro-butylphenol (DNBP), thiourea, sodium pentachlorophenate, TCMTB (2-thiocyanomethylthio), benzothiazole (30%), thiadizuron (TDZ), gibberellic acid (PETRI et al, 2014; SAGREDO et al., 2005), Erger®, and calcium nitrate (HAWERROTH et al., 2010). Even though hydrogen cyanamide is still the most effective and widely used compound for breaking bud dormancy (MOHAMED, 2008), its high toxicity is a limiting factor (PETRI et al., 2014). The most desirable features in chemical substances to overcome dormancy are the combination of high efficacy, low cost, and minimum toxicity to plants and environment. Then, studies with rest breaking compounds of low toxicity and good efficiency to induce budbreak are very important for apple industry. Despite being relatively new, some studies have shown that Erger® is a potential product to replace hydrogen cyanamide when used in combination with calcium nitrate at concentrations ranging from 3% to 7% (HAWERROTH et al., 2010).

The objective of this study was, therefore, to investigate the performance of 'Maxi Gala' apple trees in response to the application of budbreak promoters in São Joaquim, SC.

Material and methods

The study was performed at the Experimental Station of the Santa Catarina Agricultural Research and Extension Agency, located in the municipality of São Joaquim, in the State of Santa Catarina, Brazil (28º17'39"S, 49º55'56"W, at 1,415 m of altitude), in the growing seasons of 2013/2014, 2014/2015, and 2015/2016. The climate of the region is a mesothermal humid (Cfb) according to Köppen-Geiger classification, i.e, humid subtropical, oceanic climate, without dry season, with temperate summer (ALVARES et al., 2014). Average accumulation of temperatures below 7.2 ºC (45 °F) is 900 hours. Minimum and maximum daily temperatures shortly before and after application of treatments are shown in Figure 1. The soil of the experimental orchard is a "Cambissolo Húmico" (Inceptisol) (PASA et al., 2018). Plant material consisted of 'Maxi Gala' apple trees grafted on the dwarfing rootstock 'M.9'. The cultivar 'Fuji Suprema' was used as pollinator, in the proportion of 50%, i.e., two rows of 'Fuji Suprema' for each two rows of 'Maxi Gala' were planted. Single axis trees were planted in the winter of 2006 and trained in a central leader system. Soil fertility was previously corrected according to soil analysis. Trees were spaced at 4m between rows and 1m between trees in the rows, totalizing 2,500 trees per hectare. Trees were arranged in a randomized complete block design with five replicates of three trees each in the 2013/2014 and 2014/2015 growing seasons, and six replicates in the 2015/2016 season. Only the central tree was used for evaluation, leaving one at each end as border. Orchard management was performed according to recommendations of the apple production system and were similar for all treatments.

In the 2013/2014 and 2014/2015 growing seasons, the treatments were sprayed to the same trees and consisted of: 1) Control; 2) Erger® 2% + calcium nitrate (CaN) 2%; 3) Erger® 4% + CaN 4%; 4) Erger® 6% + CaN 6%; 5) Hydrogen Cyanamide (HC) 0.34% + Mineral Oil (MO) 3.2%; 6) CaN 6%. In the 2015/2016 growing season, different trees were selected and treatments were: 1) Control; 2) Erger® 2% + CaN 2%; 3) Erger® 3% + CaN 3%; 4) Erger® 1% + MO 2%; 5) Erger® 1% + MO 3%; 6) HC 0.25% + MO 3 %. The source of HC, MO and CaN were the commercial products Dormex® (52% a.i., w/v; BASF S.A. – São Paulo, SP), Iharol (76% a.i., w/v; Iharabras S.A. Indústria Químicas, Sorocaba, SP), and

YaraLiva™ Calcinit™ (15.5% N and 19% Ca, w/w; Yara Brasil Fertilizantes S.A, Porto Alegre, RS), respectively. Erger® (Valagro do Brasil Ltda, São Paulo, SP) is a nutrient solution consisting of the combination of water-soluble nitrogen (18.7%, w/v) and calcium (4.2%, w/w). Treatments were sprayed in 08/29/2013, 08/21/2014 and 08/21/2015, when buds were between the stages A (dormant bud) and B (swollen bud; silver tip), according to the phenological scale of Iuchi (2006). The accumulation of chilling hours (≤ 7.2°C) at the time of application was 872 h, 623 h, and 559 h, and of chilling units according to North Carolina Model (SHALTOUT; UNRATH, 1983) was 1414.5, 1309.0, and 1232.5, for 2013, 2014, and 2015, respectively. Trees were sprayed to the point of runoff with a motorized hand-gun backpack sprayer (Stihl SR 450, Stihl Ferramentas Motorizadas Ltda, São Leopoldo, RS), with a flow rate of 2.64 L min^{-1}.The pH of the water used was ~5.95. Trees were sprayed during the morning, with temperature ranging from 20 to 25 °C, relative humidity of 70-75% and wind speed 1.8-2.1 km h^{-1}.

The dates of initial, full and end of bloom were recorded, and analyzed as the period of time (days) from application to initial bloom (Spraying - F), initial bloom to full bloom (F-F2), full bloom to end of bloom (F2-G), and initial bloom to end of bloom (F-G); the letters within parentheses refers to the phenological phases described by Iuchi (2006). The initial bloom was considered when 5% of flowers were opened, full bloom when 70% were opened, and the end of bloom when the last flowers were opened. Six uniform one-year-old shoots were selected to evaluate the axillary budbreak, which was expressed as the ratio between buds breaking dormancy 30 days after treatment and the total number of buds (%). From these six one-year-old shoots, the standard deviation (std) within treatments was determined and then the variation coefficient was calculated [VC= (std/average axillary budbreak) *100] for each treatment, which was named as heterogeneity index of axillary budbreak (HIAB). A lateral scaffold branch was selected to evaluate terminal budbreak and fruit set. Terminal budbreak was calculated as the ratio between the number of terminal buds breaking dormancy and the total number of buds.

Fruit set was determined by counting the total number of flower clusters per scaffold branch and the number of fruits 40 days after full bloom, then calculated as number of fruit.number of flower $clusters^{-1}$. Return bloom was determined by counting all flower clusters per tree the year following application of treatments. Trees were hand thinned at 42 days after full bloom, leaving one fruit per cluster and the total number of fruits thinned per tree was counted. Trees were harvested at commercial maturity: 02/17/2014, 02/10/2015 and 02/11/2016. At harvest, the total number of fruits per tree was counted and weighed (kg), resulting in the production per tree (kg). From the division of production per tree by number of fruits per tree, the average fruit size (g) was obtained. Estimated yield (t ha^{-1}) was calculated through the multiplication of production per tree by the number of trees per hectare (2,500).

At harvest, in the 2013/2014 and 2014/2015 growing seasons, samples of 15 fruit per replicate (tree) were taken for fruit quality analysis. Fruit firmness was measured in Newton with a digital firmness tester, Fruit Texture Analyzer (Güss Manufacturing, Strand, South Africa), using an 11 mm diameter probe. Sections of skin (2 cm in diameter) were removed at the widest point of the fruit on opposite sides prior to the determination of fruit firmness. After fruit firmness measurements, a composite sample per replicate was juiced, and 0.5 mL of juice was placed onto a digital refractometer (Model PR−32 - Atago Co., Tokyo, Japan) to determine soluble solids contents, expressed as ºBrix. The starch-iodine index was determined by the reaction of starch with a solution containing 12 g of metallic iodine and 24 g of potassium iodine diluted in 1 liter of distilled water. The fruits of each replicate were cut in two halves and one of them was soaked into the iodine solution. The reaction of the starch in the fruit with the iodine solution resulted in a color pattern, which was compared with a scale ranging from 1 to 9, where 1 and 9 represents the lowest and the highest fruit ripening stage, respectively (ARGENTA, 2006).

Statistical analyses were performed using the R software (R CORE TEAM, 2014). Data expressed as percentage or counts were transformed by arcsin [square root (n + 1)] and square root (n + 1) analysis, respectively, in order to meet the assumptions of analysis of variance. Data were analyzed for statistical significance by means of F test. Duncan’s test was performed to compare treatments when analysis of variance showed significant differences among means.

Results and discussion

Significant differences were found for evolution of flowering. The treatments Erger® (4% and 6%) + CaN (4% and 6%) delayed initial bloom approximately 5.4 days in the growing season of 2013/2014, relative to control, while in the 2015/2016 season Erger® (2% and 3%) + CaN (2% and 3%) delayed initial bloom in 4 days, relative to control (Table 1). These results are contradictory with those found by Hawerroth et al. (2010), which observed an advance of flowering of approximately 5.5 days in ‘Fuji Suprema’ apple trees treated with Erger® + CaN and HC + MO. We have observed the opposite, where budbreak promoters, mainly the combination of Erger® + CaN, delayed initial flowering in two out of three seasons studied. The anticipation of flowering induced by budbreak promoters is greater the earlier the sprayings are performed after the completion of endodormancy. In our study, we have sprayed the compounds between the stages A (dormant bud) and B (swollen bud; silver tip), when most of the buds had already started the physiological processes to release dormancy and grow. Then, the budbreak promoters tested would have little effect to accelerate these processes.

It is important to emphasize that in regions of higher altitudes in Southern Brazil (with higher chilling accumulation) like São Joaquim, the promotion of axillary budbreak is the main goal when spraying budbreak promoters, and not the anticipation of flowering. Indeed, in such conditions, the anticipation of flowering is usually not desired and delaying flowering might in fact be an important result, given the frequent occurrence of late frost events, which may ultimately damage fruits and reduce yield.

In the growing season of 2014/2015, Erger® (4% and 6%) + CaN (4% and 6%) reduced the period of time between full bloom and end of bloom, while in 2015/2016 the period of time between initial bloom and full bloom was reduced by Erger® (2%) + CaN (2%) (Table 1). While the greater uniformity of phenological stages provided by the shortening of the flowering period is beneficial for some cultural practices like thinning and disease control (PETRI; LEITE, 2004), it might indeed increase the risk of losing in areas prone to late frost events, since the resistance to frost is different according to the stage of fruit development.

Significant differences in axillary budbreak and HIAB were observed only in the growing season of 2015/2016, when all treatments increased axillary budbreak and reduced HIAB relative to control trees (Table 2). The reason differences in axillary budbreak and HIAB were found only in the 2015/2016 growing season is probably due the lower chilling accumulation (559 h; 1232.5 CU) in 2015, compared to 2014 (623 h; 1309.0 CU) and 2013 (872 h; 1414.5 CU). In that case (2015/2016 season), the chilling requirement of the trees was not totally fulfilled, so the treatments with budbreak promoters showed positive effects on breaking dormancy. Iuchi et al. (2002) found that adult apple trees in areas at altitudes higher than 1360m in São Joaquim, usually do not need chemical treatments to induce budbreak. Indeed, in the first and the second growing seasons of the present study, the percentage of budbreak of control trees was similar to the other treatments. However, in the last season, when chilling accumulation was lower than necessary, axillary budbreak of treated trees was up to 72.5%, while that of control trees was only 35.6% (Table 2). Although the increased budbreak of axillary buds may not show any visible results in the short term (year of application), it may increase the long term productive potential of the trees by increasing the number of spurs, since more lateral buds are released from dormancy. Failure of lateral buds to break dormancy results in problems of bare wood, i.e., failure to occupy the canopy volume with an adequate number of fruit bearing long shoots and spurs (JACKSON, 2003) Terminal budbreak did not differ among treatments in any of the growing seasons (Table 2), probably because terminal buds on 1-year-old shoots have a much lower chilling requirement than axillary buds (NAOR et al., 2003).

Fruit set in the tree growing seasons and number of fruits thinned in the last seson, did not differ among treatments (Table 2). Hawerroth et al. (2010) and Petri et al. (2014) observed that treatments with budbreak promoters have often resulted in reduction of apple fruit set. However, in our study the compounds tested did not show such negative effect on fruit set of 'Maxi Gala'. Since fruit set was not reduced, the number of fruits thinned also should not differ among treatments, exactly as we have found.

Number of fruits per tree, yield per tree and estimated yield did not differ among treatments in any of the growing seasons (Table 3). According to Iuchi et al. (2002), the positive effect of budbreak promoters on yield components is usually observed after the second year from application or even later. This effect would be a result of a greater number of spurs formed due to greater axillary budbreak. Since it was affected in only one growing season, positive effects in the years coming should not be expected, unless a greater frequency of lack of chilling is observed in the years coming. Fruit weight was affected only in the 2015/2016 growing season, where the treatments HC (0.25%) + MO (3%) and Erger® (2%) + CaN (2%) resulted in bigger fruits than control (Table 3). Petri et al. (2010) observed that the combination of Erger® (5%) + CaN (5%), sprayed in August 30, resulted in fruits with greater fruit weight than the other treatments. These authors argue that the greater budbreak promoted by this treatment might have resulted in increased leaf area, then more assimilates would be available to support fruit growth. This would partly explain the results we have found, since the treatments with the greater fruit size showed an axillary budbreak nearly two-fold greater than control (Table 2).

The treatment Erger® (3%) + CaN (3%) increased return bloom relative to the other treatments (Table 3). The increase in return bloom is a desired result, since the greater number of flower cluster will potentially increase return yield. According to Duyvelshoff and Cline (2013), enhancing flowering has demonstrated to significantly increase the number of fruit and yield per tree at harvest. Other results with Erger® regarding its effect on return bloom are not available, probably because this is a relatively new compound and most of the studies have focused mainly on its effects on budbreak rather than other aspects. A possible explanation is the change on nutritional status of the trees, since Erger® and CaN are sources of nitrogen (N) containing 18.7% and 15.5% of N, respectively. Return bloom of 'Golden Delicious' apple trees was increased with the higher rates of soil applied nitrogen (DRAKE et al., 2007).

Fruit quality attributes were not affected by treatments (Table 4). The effect of budbreak promoters in fruit quality of apples has been rarely reported. Bound and Jones (2004) found no significant effects of hydrogen cyanamide on fruit quality of 'Fuji' apples. Any treatment sprayed to the trees should not negatively influence fruit quality, since que quality of the fruit is a key factor to achieve reasonable prices in the market.

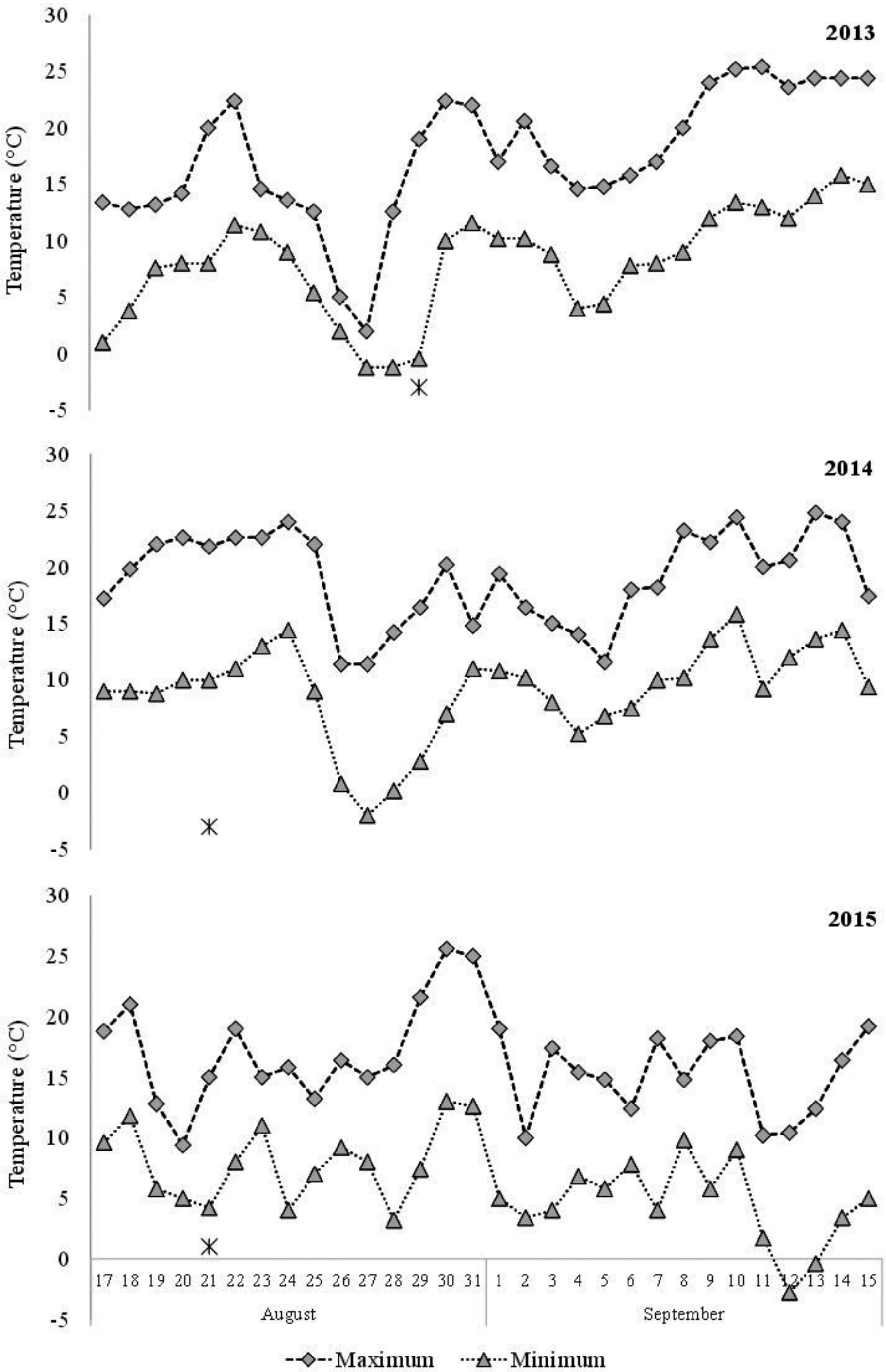

Figure 1. Daily maximum and minimum temperatures before and following the application of the tested substances. Asterisks at the bottom of graphics denotes the time of application in each growing season. Data obtained from the weather station located at the Experimental Station of São Joaquim, Santa Catarina, Brazil.

Table 1. Evolution of flowering of 'Maxi Gala' apple trees, treated with budbreak promoters, in the growing seasons of 2013/2014, 2014/2015, and 2015/2016.

Treatment	Date			Period of time (days)			
	Initial bloom (F)	Full bloom (F2)	End of bloom (G)	S - F	F-F2	F2-G	F-G
				2013/2014			
Control	19-Sep	26-Sep	8-Oct	21.4 b	7.4^{ns}	11.8 a	19.2^{ns}
Erger 2% + CaN 2%	20-Sep	27-Sep	8-Oct	22.6 ab	6.6	10.8 a	17.4
Erger 4% + CaN 4%	24-Sep	3-Oct	9-Oct	26.8 a	8.4	6.6 b	15.0
Erger 6% + CaN 6%	24-Sep	5-Oct	11-Oct	26.8 a	10.8	5.4 b	16.2
HC 0.34 % + MO 3.2 %	21-Sep	27-Sep	8-Oct	23.2 ab	6.0	11.4 a	17.4
CaN 6%	18-Sep	26-Sep	8-Oct	20.8 b	7.2	12.0 a	19.2
p	-	-	-	0.029	0.652	0.032	0.279
				2014/2015			
Control	22-Sep	28-Sep	3-Oct	33.0^{ns}	7.2^{ns}	6.2^{ns}	13.4^{ns}
Erger 2% + CaN 2%	22-Sep	28-Sep	3-Oct	31.4	7.8	6.0	13.8
Erger 4% + CaN 4%	21-Sep	28-Sep	2-Oct	29.0	7.4	8.0	15.4
Erger 6% + CaN 6%	22-Sep	28-Sep	3-Oct	29.8	8.4	7.4	15.8
HC 0.34 % + MO 3.2 %	21-Sep	27-Sep	2-Oct	28.2	8.2	8.0	16.2
CaN 6%	20-Sep	27-Sep	2-Oct	30.2	7.6	8.0	15.6
p	-	-	-	0.126	0.980	0.249	0.446
				2015/2016			
Control	15-Sep	22-Sep	28-Sep	26.8 c	8.0 a	6.8^{ns}	14.8^{ns}
Erger 2% + CaN 2%	19-Sep	23-Sep	30-Sep	30.4 ab	5.0 b	8.0	13.0
Erger 3% + CaN 3%	20-Sep	25-Sep	1-Oct	31.2 a	6.4 ab	6.4	12.8
Erger 1% + MO 2%	16-Sep	23-Sep	30-Sep	27.4 bc	7.8 a	8.2	16.0
Erger 1% + MO 3%	17-Sep	23-Sep	30-Sep	28.2 abc	7.4 a	7.8	15.2
HC 0.25% + MO 3%	15-Sep	22-Sep	29-Sep	26.8 c	8.0 a	8.0	16.0
p				0.027	0.047	0.634	0.151

*Different letters within columns indicate significant differences according to Duncan's test ($p < 0.05$). S.: Spraying; ns: not significant.

Table 2. Axillary and terminal budbreak, heterogeneity index of axillary budbreak (HIAB) and fruit set of 'Maxi Gala' apple trees, treated with budbreak promoters in the growing seasons of 2013/2014, 2014/2015, and 2015/2016

Treatment	Axillary budbreak (%)	Terminal budbreak (%)	HIAB (%)	Fruit set[1]	Number of fruit thinned
		--------------------------2013/2014-------------------------			
Control	60.8^{ns}	100.0^{ns}	25.0^{ns}	2.5^{ns}	-
Erger 2% + CaN 2%	63.1	100.0	26.6	2.0	-
Erger 4% + CaN 4%	68.6	100.0	28.3	2.1	-
Erger 6% + CaN 6%	67.5	100.0	17.3	2.2	-
HC 0.34 % + MO 3.2 %	66.9	100.0	18.0	2.2	-
CaN 6%	61.5	100.0	32.4	2.2	-
p	0.370	0.443	0.196	0.863	-
		--------------------------2014/2015-------------------------			
Control	63.8^{ns}	95.9^{ns}	36.5^{ns}	2.4^{ns}	-
Erger 2% + CaN 2%	63.4	95.3	22.0	2.5	-
Erger 4% + CaN 4%	63.3	100.0	19.9	1.6	-
Erger 6% + CaN 6%	67.9	98.2	17.8	1.4	-
HC 0.34 % + MO 3.2 %	67.5	99.0	23.1	1.6	-
CaN 6%	54.0	98.8	38.9	2.1	-
p	0.333	0.321	0.170	0.206	-
		--------------------------2015/2016-------------------------			
Control	35.6 c	90.6^{ns}	43.1 a	1.5^{ns}	155.0^{ns}
Erger 2% + CaN 2%	68.4 ab	91.8	22.0 b	0.8	107.4
Erger 3% + CaN 3%	72.5 a	92.4	19.0 b	1.3	141.8
Erger 1% + MO 2%	58.1 b	86.1	24.0 b	1.1	120.4
Erger 1% + MO 3%	62.0 ab	94.0	23.5 b	1.4	139.0
HC 0.25% + MO 3%	64.2 ab	97.9	30.1 b	1.1	136.8
p	>0.001	0.082	0.004	0.180	0.735

*Different letters within columns indicate significant differences according to Duncan's test ($p < 0.05$). [1]Expressed as number of fruit.flower cluster^{-1}; ns: not significant.

Table 3. Yield components of 'Maxi Gala' apple trees treated with budbreak promoters in the growing seasons of 2013/2014, 2014/2015, and 2015/2016

Treatment	Number of fruit per tree	Yield per tree (kg)	Estimated Yield (t ha^{-1})[1]	Fruit weight (g)	Return bloom[2]
		------------------------------2013/2014----------------------------			
Control	134.6^{ns}	16.6^{ns}	41.6^{ns}	123.5^{ns}	-
Erger 2% + CaN 2%	146.0	16.8	41.9	113.9	-
Erger 4% + CaN 4%	123.0	14.2	35.4	116.2	-
Erger 6% + CaN 6%	164.6	19.9	49.8	120.7	-
HC 0.34 % + MO 3.2 %	137.6	16.5	41.2	116.5	-
CaN 6%	140.6	18.6	46.5	134.8	-
p	0.434	0.504	0.504	0.763	-
		------------------------------2014/2015----------------------------			
Control	130.6^{ns}	19.0^{ns}	47.4^{ns}	146.6^{ns}	-
Erger 2% + CaN 2%	130.4	18.3	45.7	141.0	-
Erger 4% + CaN 4%	149.5	20.8	52.0	140.3	-
Erger 6% + CaN 6%	145.8	18.7	46.8	130.3	-
HC 0.34 % + MO 3.2 %	141.9	19.7	49.4	139.6	-
CaN 6%	133.6	19.4	48.5	146.4	-
p	0.811	0.910	0.910	0.437	-
		---------------------2013/2014 - 2014/2015---------------------			
		Cumulative		Average	-
Control	265.2^{ns}	35.6^{ns}	88.9^{ns}	133.4^{ns}	-
Erger 2%+ CaN 2%	276.4	35.0	87.6	123.5	-
Erger 4% + CaN 4%	272.5	35.0	87.4	121.5	-
Erger 6% + CaN 6%	310.4	38.6	96.6	126.3	-
HC 0.34 % + MO 3.2 %	279.5	36.2	90.5	124.5	-
CaN 6%	274.2	38.0	95.0	138.6	-
p	0.739	0.941	0.941	0.291	-
		------------------------------2015/2016----------------------------			
Control	148.2^{ns}	17.9^{ns}	44.7^{ns}	116.9 ab	217.0 b
Erger 2% + CaN 2%	161.4	21.2	52.9	136.8 a	283.6 b
Erger 3% + CaN 3%	182.4	21.8	54.4	120.5 ab	354.8 a
Erger 1% + MO 2%	150.6	18.3	45.7	120.7 bc	249.6 b
Erger 1% + MO 3%	177.8	20.5	51.2	113.1 c	249.6 b
HC 0.25% + MO 3%	153.8	19.6	49.1	128.7 a	243.2 b
p	0.754	0.877	0.877	0.208	0.006

*Different letters within columns indicate significant differences according to Duncan's test ($p < 0.05$). [1]Calculated through the multiplication of production per tree by the number of trees per hectare (2,500); [2]Number of flower clusters per tree; ns: not significant.

Table 4. Firmness, total soluble solids and starch-iodine index of 'Maxi Gala' apple fruits treated with budbreak promoters in the growing seasons of 2013/2014 and 2014/2015.

Treatment	Firmness (N)	Total Soluble solids (°brix)	Starch-iodine index
		2013/2014	
Control	76.4^{ns}	11.3^{ns}	4.0^{ns}
Erger + CaN 2%	80.6	11.6	4.1
Erger + CaN 4%	75.0	11.9	5.1
Erger + CaN 6%	74.6	13.4	4.5
HC 0.34 % + MO 3.2 %	76.3	11.6	4.9
CaN 6%	76.1	12.8	5.0
p	0.142	0.477	0.574
		2014/2015	
Control	72.4^{ns}	12.5^{ns}	8.4^{ns}
Erger + CaN 2%	73.3	13.0	8.5
Erger + CaN 4%	73.8	12.4	8.3
Erger + CaN 6%	74.6	12.4	8.1
HC 0.34 % + MO 3.2 %	74.1	13.1	8.2
CaN 6%	72.4	12.1	8.5
p	0.977	0.399	0.950

ns: not significant.

Conclusions

The application of budbreak promoters in areas of higher chilling accumulation in Southern Brazil, like in São Joaquim-SC, is necessary only in years of insufficient chilling accumulation.

Axillary budbreak of 'Maxi Gala' apple trees is improved by the budbreak promoters tested in years of insufficient chilling accumulation.

The combination Erger® (2% and 3%) + Calcium Nitrate (2% and 3%) and Erger® (1%) + mineral oil (3%) shows similar axillary budbreak as hydrogen cyanamide (0.25%) + mineral oil (3%).

The budbreak promoters tested have little effect on flowering and terminal budbreak.

Fruit quality is not affected by the budbreak promoters studied.

References

ALVARES, C.A.; STAPE, J.L.; SENTELHAS, P.C.; GOLÇALVES, J.L.M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrif**, Stuttgart, v.22, p.711-728, 2014.

ARGENTA, L.C. Fisiologia pós-colheita: Maturação, colheita e armazenagem dos frutos. In: EPAGRI. **A cultura da macieira**. Florianópolis: Epagri, 2006. p.691-732.

BOUND S.A.; JONES, K.M. Hydrogen cyanamide impacts on flowering, crop load, and fruit quality of red 'Fuji' apple (*Malus domestica*). **New Zealand Journal of Crop and Horticultural Science**, New Zealand, v.32, p.227-234, 2004.

DRAKE, S.R.; RAESE, J.T.; SMITH, T.J. Time of nitrogen application and its influence on 'Golden Delicious' apple yield and fruit quality. **Journal of Plant Nutrition**, London, v.25, p.143-157, 2007.

DUYVELSHOFF, C.; CLINE, J.A. Ethephon and prohexadione-calcium influence the flowering, early yield, and vegetative growth of young 'Northern Spy' apple trees. **Scientia Horticulturae**, Amsterdam, v.151, p.128-134, 2013.

GREENE, D.W. Chemicals, timing, and environmental factors involved in thinner efficacy on apple. **HortScience**, Alexandria, v.37, p.477-481, 2002.

HAWERROTH, F.J.; PETRI, J.L.; HERTER, F.G.; LEITE, G.B.; LEONETTI, J.F.; MARAFON, A.C.; SIMÕES, F. Fenologia, brotação de gemas e produção de frutos de macieira em resposta à aplicação de cianamida hidrogenada e óleo mineral. **Bragantia**, Campinas, v.68, p.961-971, 2009.

HAWERROTH, F.J.; PETRI, J.L.; LEITE, G.B.; HERTER, F.G. Brotação de gemas em macieiras 'Imperial Gala' e 'Fuji Suprema' pelo uso de Erger® e nitrato de cálcio. **Revista Brasileira de Fruticultura**, Jaboticabal, v.32, n.2, p.343-350, 2010.

IUCHI, V.L. Botânica e Fisiologia. In: EPAGRI. **A cultura da macieira**. Florianópolis: Epagri, 2006. p.59-104.

IUCHI, V.L.; IUCHI, T.; BRIGHENTI, E.; DITRICH, R. Quebra da dormência da maciera (***Malus domestica*** Borkh) em São Joaquim-SC. **Revista Brasileira de Fruticultura**, Jaboticabal, v.24, n.1, p.168-174, 2002.

JACKSON, J. E. **Biology of apples and pears**. London: Cambridge University Press, 2003. 488p.

MOHAMED, A.K.A. The effect of chilling, defoliation and hydrogen cyanamide on dormancy release, budbreak and fruiting of Anna apple cultivar. **Scientia Horticulturae**, Amsterdam, v.118, p.25-32, 2008.

NAOR, A.; FLAISHMAN, M.; STERN, R.; MOSHE, A.; EREZ, A. Temperature effects on dormancy completion of vegetative buds in apple. **Journal of the American Society for Horticultural Science**, Alexandria, v.128, p.636-641, 2003.

PASA, M.S.; FELIPPETO, J.; NAVA, G.; SILVA, C.P.; BRIGHENTI, A.F.; CIOTTA, M. Performance of 'Fuji Suprema' apple trees treated with budbreak promoters, in São Joaquim-SC. **Revista Brasileira de Fruticultura**, Jaboticabal, v.40, n.1, e-325, 2018.

PETRI, J.L.; LEITE, G.B. Consequences of insufficient winter chilling on apple tree bud-break. **Acta Horticulturae**, The Hague v.662, p.53-60, 2004.

PETRI, J.L.; LEITE, G.B.; COUTO, M.; GABARDO, G.C.; HAWERROTH, F.J. Chemical induction of budbreak: new generation products in replacement of hydrogen cyanamide. **Acta Horticulturae**, The Hague, v.1042, p.159-166, 2014.

PETRI, J.L.; LEITE, G.B.; PUTTI, G.L. Apple tree budbreak promoters in mild winter conditions. **Acta Horticulturae**, The Hague, v.774, p.291-296, 2008.

R CORE TEAM. **R:** A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. 2014. Disponível em: <http://www.R-project.org/>.

SAGREDO, K.X.; THERON, K.I.; COOK, N.C. Effect of mineral oil and hydrogen cyanamide concentration on dormancy breaking in 'Golden Delicious' apple trees, **South African Journal of Plant and Soil**, Noordstad, v.22, p.251-256, 2005.

SHALTOUT, A.D.; UNRATH, C.R. Rest completion prediction model for 'Starkrimson Delicious' apples. **Journal of the American Society for Horticultural Science**, Alexandria, v.108, p.957-961, 1983.