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Performance of 'Fuji Suprema' apple trees treated with budbreak promoters, in São Joaquim-SC

Mateus da Silveira Pasa[1], João Felippeto[2], Gilberto Nava[3], Carina Pereira da Silva[4], Alberto Fontanella Brighenti[1], Marlise Nara Ciotta[5]

Abstract - The application of rest breaking agents to overcome the lack of chilling is a common practice in apple orchards in southern Brazil. However, its necessity in areas of greater chilling accumulation, like in the city São Joaquim, Santa Catarina State (SC), has been questioned over the years. The aim of this study was to evaluate the effect of different budbreak promoters, on the performance of 'Fuji Suprema' apple trees, in the region of São Joaquim/SC. The study was performed at the Experimental Station of São Joaquim - Santa Catarina Agricultural Research and Extension Agency (EPAGRI), in the growing seasons of 2013/2014, 2014/2015, and 2015/2016. Plant material consisted of 10-year-old 'Fuji Suprema apple trees grafted on the rootstock 'M.9' and arranged in a randomized complete block design with five replicates. Treatments consisted of a nutrient solution containing soluble nitrogen and calcium (NCaS), combined with either calcium nitrate or mineral oil, at different rates; and hydrogen cyanamide combined with mineral oil. The time of application was 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 and fruit quality were little affected by treatments. In the other hand, the budbreak promoters consistently improved axillary budbreak in two out of three seasons.

Index terms: *Malus domestica*, dormancy, flowering, yield, hydrogen cyanamide, nitrogen-calcium solution.

Desempenho de macieiras 'Fuji Suprema' tratadas com indutores de brotação, em São Joaquim-SC

Resumo – A aplicação de indutores de brotação para superar o baixo acúmulo de frio é uma prática comum em pomares de macieira na região Sul do Brasil. No entanto, sua necessidade em áreas com maior acúmulo de frio, como na cidade de São Joaquim, do Estado de Santa Catarina (SC), tem sido questionada ao longo dos anos. O objetivo deste trabalho foi avaliar o efeito de diferentes indutores de brotação no desempenho de macieiras 'Fuji Suprema' na região de São Joaquim-SC. O estudo foi desenvolvido na Estação Experimental de São Joaquim – Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina, nas safras de 2013/2014, 2014/2015 e 2015/2016. Foram utilizadas plantas da cultivar 'Fuji Suprema', com 10 anos de idade, enxertadas no porta-enxerto 'M.9'. O delineamento experimental foi de casualização por blocos, com cinco repetições. Os tratamentos consistiram em solução nutritiva contendo nitrogênio solúvel e cálcio (SNCa), 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, produção e qualidade do fruto. A floração e a qualidade do fruto foram pouco influenciadas pelos tratamentos. Por outro lado, a brotação de gemas laterais foi consistentemente aumentada pelos produtos testados em duas das três safras em que o estudo foi realizado.

Termos para indexação: *Malus domestica*, dormência, floração, produtividade, cianamida hidrogenada, solução de nitrogênio e cálcio.

Corresponding author:
E-mail: mateuspasa@epagri.sc.gov.br

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[1]Agronomist, PhD. Researcher – Empresa de Pesquisa Agropecuária e Extensão Rural. São Joaquim-SC, Brazil. E-mail: mateuspasa@epagri.sc.gov.br; alberto-brighenti@epagri.sc.gov.br
[2]Enologist, M.Sc., Researcher - Empresa de Pesquisa Agropecuária e Extensão Rural. São Joaquim-SC, Brazil. E-mail: joaofelippeto@epagri.sc.gov.br
[3]Agronomist, PhD. Researcher – Embrapa Clima Temperado. Pelotas-RS, Brazil. E-mail: gilberto.nava@embrapa.br
[4]Biologist, PhD. São Joaquim-SC, Brazil. E-mail: carpers.rs@gmail.com
[5]Agronomist, PhD. Researcher – Empresa de Pesquisa Agropecuária e Extensão Rural. São Joaquim-SC, Brazil. E-mail: marlise@epagri.sc.gov.br

Introduction

Perennial crops, such as apple (*Malus domestica* Borkh.), suitable for growing in temperate climate regions, have to satisfy their chilling requirements to initiate spring bud break, shoot meristematic extension growth and anthesis (ATKINSON et al., 2013). However, when grown in regions of inadequate chilling accumulation, such as in Southern Brazil, apple budbreak and flowering is lacking and not uniform (PETRI; LEITE, 2004), which may ultimately reduce yield and fruit quality (HAWERROTH et al., 2010).

The main apple growing areas in Southern Brazil are climatically marginal regarding chilling accumulation; the average registered is 500 h below 7.2°C (PETRI et al., 2008). Among these areas, the region of São Joaquim - Santa Catarina State, shows the best conditions for growing apples (IUCHI et al., 2002), with an average of 900 h below 7.2°C. In such conditions, trees usually show a fair performance without the use of rest breaking agents. However, previous results have shown positive response to the application of these substances regarding lateral budbreak of shoots in this region (IUCHI et al., 2002). The greater number of lateral buds breaking dormancy will ultimately result in greater number of spurs, and potentially increasing the yield in the next seasons. Besides, the use of rest breaking agents may have significant effect in other important practices, like chemical thinning. The timing of application is one of the main factors influencing the efficiency of chemical thinning, 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 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. Besides, they also may have negative effects on fruit set (HAWERROTH et al., 2009), which is closely related with chemical thinning planning.

Several rest breaking compounds have been tested over the last years, 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%), thidiazuron (TDZ), gibberellic acid (PETRI et al, 2014), NCaS, and calcium nitrate (HAWERROTH et al., 2010). Even though hydrogen cyanamide is still the most effective and widely used compound for breaking dormancy (MOHAMED, 2008) its high toxicity is a limiting factor (PETRI et al., 2014). According to Erez (2000), the main desirable features in chemical substances are their 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 the apple industry.

The objective of this study was to evaluate the effect of different budbreak promoters on the performance of ‘Fuji Suprema’ apple trees, in the region of São Joaquim/SC.

Materials and Methods

The study was performed at the experimental orchard of the Santa Catarina Agricultural Research and Extension Agency, located in the municipality of São Joaquim, in Santa Catarina State, 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 mesothermal humid (Cfb) according to Köppen-Geiger classification, i.e, temperate climate constantly humid, without dry season, and cool summer. Average accumulation of temperatures bellow 7.2 ºC 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 field is a Cambissolo Húmico (Inceptisol), according to the Brazilian soil classification system (SANTOS et al., 2013).

Plant material consisted of ‘Fuji Suprema’ apple trees grafted on the rootstock ‘M.9’. The cultivar ‘Maxi Gala’ was used as pollinator, in the proportion of 50%, i.e., for two rows of ‘Fuji Suprema’, other two rows of ‘Maxi Gala’ were planted. Single axis trees were planted in the winter of 2006 and trained as a central leader system. Soil fertility was previously corrected according to soil analysis. Trees were spaced at 4m between rows and 1m within the row, totalizing 2,500 trees per hectare. Trees were arranged in a randomized complete block design with five replicates of three trees each. Only the central tree was used for evaluation, leaving one at each end as border.

In the 2013/2014 and 2014/2015 growing seasons treatments were sprayed to the same trees and consisted of: 1) Control; 2) NCaS 2% + Calcium Nitrate (CaN) 2%; 3) NCaS 4% + CaN 4%; 4) NCaS 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) NCaS 2% + CaN 2%; 3) NCaS 3% + CaN 3%; 4) NCaS 1% + MO 2%; 5) NCaS 1% + MO 3%; 6) Hydrogen Cyanamide (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.), Iharol (76% a.i., w/v; Iharabras S.A. Indústria Químicas), and YaraLiva™ Calcinit™ (15.5% N and 19% Ca, w/w; Yara Brasil Fertilizantes S.A.), respectively. The NCaS source was the trade product Erger® (Valagro do Brasil Ltda.), a nutrient solution consisting on the combination of water soluble nitrogen (18.7%, w/v) and calcium (4.2%, w/w). Treatments were sprayed when buds were between the stages A (dormant bud) and B (swollen bud; silver tip), according to the phenological scale of Epagri (2006).

Chilling accumulation (hours ≤ 7.2°C) at the time of applicaton was 872 h, 623 h, and 559 h, and chilling units (CU) according to North Carolina model (SHALTOUT; UNRATH, 1983) 1414.5 CU, 1309.0 CU, and 1232.5 CU, in 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.), with a flow rate of 2.64 L min^{-1}. The application water pH 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 early, full and end of bloom were recorded, and analyzed as the period of time (days) from application to start of bloom (Application - F), start of bloom to full bloom (F-F2), full bloom to end of bloom (F2-G), and start of bloom to end of bloom (F-G). The start of 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-shoots, the standard deviation (std) within treatment was determined and then calculated the coefficient of variation [CV= (std/ average axillary budbreak)*100] for each treatment, which was named as heterogeneity index of axillary budbreak (HIAB). A lateral scaffold was selected to evaluate terminal budbreak and fruit set. Terminal budbreak was 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 and the number of fruit ~40 days after full bloom, then calculated by number of fruit/number of flower clusters, and expressed as number of fruit per flower cluster. Return bloom was determined by counting all flower clusters per tree the year following application of treatments.

Fruit were harvested at commercial maturity: 04/16/2014, 04/03/2015, 03/15/2016. The total number of fruit per tree was counted and weighed (kg). From these data, the following parameters were calculated: yield per tree (kg); average fruit size (g); and estimated yield (t ha^{-1}).

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), 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.) 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 fruit of each replicate were cut in two halves and one of them was soaked in the iodine solution. The reaction of the starch in the fruit with the iodine solution resulted in a color pattern, which was compared with the scale developed by Epagri (EPAGRI, 2006), ranging from 1 to 9, where 1 and 9 represents the lowest and the highest ripening stage, respectively.

Statistical analyses were performed using the R software (R CORE TEAM, 2014), with package ExpDes (FERREIRA et al., 2013). 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

Flowering was little affected by treatments. The only significant effect was observed for the period of time from application to early bloom in 2014/2015, where HC (0.34%) + MO (3.2%) and CaN (6%) advanced approximately 2 days the start of flowering, relative to the other treatments (Table 1). These results are probably due to the adequate amount of accumulated chilling in the areas of higher altitudes in São Joaquim city, Santa Catarina State (>1200m), resulting in adequate flowering of non-treated trees. However, in regions of lower altitudes and chilling accumulation, the effects on flowering are more significant. Hawerroth et al. (2009) observed a shortening of the flowering period of approximately 3 days in 'Fuji Suprema' apple trees treated with HC + MO in Caçador city, Santa Catarina State (altitude: 960 m). In a second study, Hawerroth et al. (2010) observed an anticipation of flowering of approximately 5.5 days in 'Fuji Suprema' apple trees treated with NCaS + CaN and HC + MO, but no differences in the flowering period were found. 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 loss in areas prone to late frost events, since the resistance to frost is different according to the stage of fruit development.

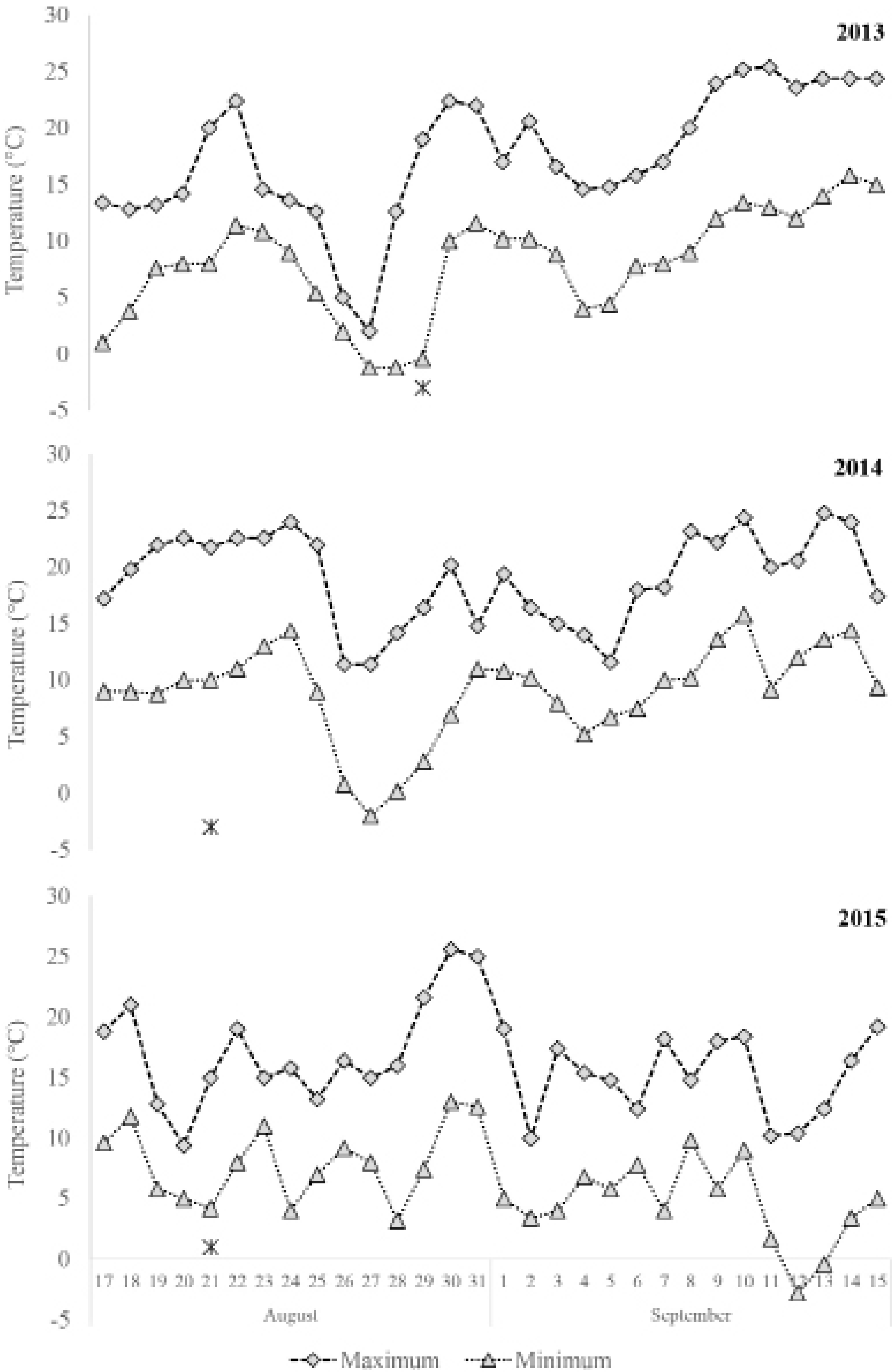

Figure 1. Daily maximum and minimum temperatures before and following the application of the tested substances. Asterisks at the bottom of graphics denotes time of application in each growing season. Data obtained from the weather station located at the experimental station of São Joaquim/SC, Brazil.

Significant differences in axillary budbreak were observed in all growing seasons (Table 2). In the 2013/2014 and 2014/2015 growing seasons the greatest axillary budbreak was observed with HC (0.34%) + MO (3.2%), followed by NCaS + CaN (4 and 6%). In 2015/2016 all treatments improved axillary budbreak relative to control. Similar results were observed by Petri et al. (2014), which observed greater percentage of axillary budbreak of 'Fuji Suprema' apples treated with HC (0.34%) + MO (3.5%), and NCaS (3%, 4%, and 6%) + CaN (3%). In the other hand, Iuchi et al. (2002) found that adult apple trees in areas at altitudes higher than 1360 m in São Joaquim city, do not need chemical treatments to induce budbreak. Indeed, the percentage of budbreak of control trees is not too low (~50%), but the best treatments showed axillary budbreak of up to 80%. Although it may not show any visible results in the short term (year of application), it may increase the productive potential of the trees by increasing the number of spurs, since more lateral buds are released from dormancy. Failure of lateral budbreak in orchard trees results in problems of bare wood, i.e., failure to occupy the canopy volume with an adequate number of long shoots and spurs bearing fruit. All treatments reduced HIAB relative to control in the 2015/2016 growing season (Table 2). The higher the HIAB the more heterogeneous the budbreak, which is not desirable. The reason differences in HIAB were found only in the 2015/2016 growing season is probably due the lower chilling accumulation (559 h) in 2015, compared to 2014 (623 h) and 2013 (872 h), reducing the homogeneity of

Table 1. Flowering of 'Fuji Suprema' apple trees, treated with budbreak promoters, in the growing seasons of 2013/2014, 2014/2015, and 2015/2016.

Treatment	Date			Period of time (days)			
	Early bloom (F)	Full bloom (F2)	End of bloom (G)	Apl.-F	F-F2	F2-G	F-G
				2013/2014			
Control	25-Sep	8-Oct	14-Oct	27.4	12.6	6.0	18.6
NCaS + CaN 2%	27-Sep	8-Oct	14-Oct	29.8	10.2	6.0	16.2
NCaS + CaN 4%	29-Sep	8-Oct	14-Oct	31.6	8.4	6.0	14.4
NCaS + CaN 6%	29-Sep	8-Oct	14-Oct	31.6	8.4	6.0	14.4
HC 0.34 % + MO 3.2 %	26-Sep	8-Oct	14-Oct	28.0	12.0	6.0	18.0
CaN 6%	23-Sep	2-Oct	14-Oct	25.0	9.6	11.4	21.0
p	-	-	-	0.156	0.383	0.055	0.192
				2014/2015			
Control	24-Sep	1-Oct	5-Oct	35.8 a	7.2	5.4	12.6
NCaS + CaN 2%	24-Sep	1-Oct	4-Oct	35.8 a	7.2	4.8	12.0
NCaS + CaN 4%	25-Sep	29-Sep	3-Oct	36.2 a	5.8	4.6	10.4
NCaS + CaN 6%	25-Sep	30-Sep	3-Oct	36.2 a	5.8	4.0	9.8
HC 0.34 % + MO 3.2 %	22-Sep	26-Sep	2-Oct	33.8 b	4.8	6.6	11.4
CaN 6%	22-Sep	26-Sep	3-Oct	33.8 b	4.6	8.0	12.6
p	-	-	-	0.002	0.056	0.078	0.116
				2015/2016			
Control	23-Sep	28-Sep	1-Oct	34.2	5.8	4.0	9.8
NCaS + CaN 2%	24-Sep	28-Sep	1-Oct	35.4	4.6	4.8	9.4
NCaS + CaN 3%	24-Sep	28-Sep	1-Oct	35.4	4.6	4.0	8.6
NCaS 1% + MO 2%	23-Sep	28-Sep	2-Oct	34.4	5.6	5.6	11.2
NCaS 1% + MO 3%	24-Sep	28-Sep	4-Oct	35.0	5.0	7.2	12.2
HC 0.25% + MO 3%	24-Sep	28-Sep	1-Oct	35.8	4.2	4.8	9.0
p				0.289	0.316	0.053	0.068

*Different letters within columns indicate significant differences according to Duncan's test ($p < 0.05$). Apl.-F: application to start of bloom; F-F2: start of bloom to full bloom; F2-G: full bloom to end of bloom; F-G: start of bloom to end of bloom.

axillary budbreak of control trees. Hawerroth et al. (2009) also observed a great reduction of HIAB in 'Fuji Suprema' apple trees in response to budbreak promoters, in a region of insufficient chilling accumulation. Terminal budbreak did not differ among treatments in any of the seasons (Table 2), probably because terminal buds have a much lower chilling requirement than axillary buds (NAOR et al., 2003).

Fruit set was reduced by the application of HC (0.34%) + MO (3.2%), relative to control, in the 2014/2015 growing season, and by NCaS + CaN (2 and 3%) in 2015/2016, which did not differ of HC (0.25%) + MO (3%) (Table 2). Reduction of apple fruit set as a result of treatments with budbreak promoters have been reported in other studies (HAWERROTH et al., 2010; PETRI et al., 2014). Flowering and fruit set normally occur before leaf buds break and growth starts. If shoot growth occurs before flowering, reserve-carbohydrates are not sufficient for a high rate of fruit set and shoot growth (FAUST, 2000). Then, the greater axillary budbreak of treated trees possibly resulted in more competition of young growing shoots with developing fruit, reducing fruit set. According to Hawerroth et al. (2010) there is a negative relationship between the intensity of budbreak and fruit set. Additionally, in a study with HC in 'Fuji' apple, Bound and Jones (2004) showed that the application of HC increased the percentage of dead or damaged buds, even when applied 40 days before budburst. They also observed that the closer the application to budburst the greater the negative effect. The number of fruit hand thinned was evaluated only in 2015/2016, where all treatments, but NCaS (1%) + MO (3%), showed lower number of fruit thinned than control (Table 2). This is probably a direct effect of the reduction in fruit set and is an important result to be considered in orchard management, since it may change chemical thinning planning.

Table 2. Axillary and terminal budbreak, heterogeneity index of axillary budbreak (HIAB) and fruit set of 'Fuji Suprema' 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[2]
			2013/2014		
Control	51.1 bc	100.0	35.6	3.0	-
NCaS + CaN 2%	50.0 bc	100.0	33.7	3.5	-
NCaS + CaN 4%	59.4 b	100.0	37.8	3.7	-
NCaS + CaN 6%	57.9 b	100.0	34.8	2.5	-
HC 0.34 % + MO 3.2 %	73.9 a	100.0	22.2	2.2	-
CaN 6%	47.6 c	100.0	43.1	3.3	-
p	<0.001	0.443	0.234	0.069	-
			2014/2015		
Control	53.9 c	92.3 ab	35.4	3.6 ab	-
NCaS + CaN 2%	52.0 c	84.8 b	34.6	4.6 a	-
NCaS + CaN 4%	70.1 b	100.0 a	23.0	2.7 bc	-
NCaS + CaN 6%	67.0 b	95.4 ab	26.6	2.1 bc	-
HC 0.34 % + MO 3.2 %	81.2 a	100.0 a	15.3	2.0 c	-
CaN 6%	53.4 c	89.01 b	33.0	3.4 ab	-
p	<0.001	0.047	0.187	0.005	-
			2015/2016		
Control	47.8 b	82.0	57.7 a	2.0 a	167.5 a
NCaS + CaN 2%	76.9 a	91.6	23.6 b	1.1 b	54.5 c
NCaS + CaN 3%	77.5 a	84.5	15.7 b	0.6 b	103.2 bc
NCaS 1% + MO 2%	74.8 a	88.3	19.4 b	1.9 a	87.5 c
NCaS 1% + MO 3%	73.8 a	93.6	21.5 b	2.1 a	146.2 ab
HC 0.25% + MO 3%	81.9 a	87.1	14.3 b	1.3 ab	68.7 c
p	<0.001	0.788	<0.001	0.003	0.002

*Different letters within columns indicate significant differences according to Duncan's test ($p < 0.05$). [1]Number of fruit per flower cluster; [2]Fruit hand thinned approximately 40 days after full bloom.

Except for the 2013/2014 growing season, number of fruit per tree was significantly affected by treatments (Table 3). In 2014/2015, HC (0.34%) + MO (3.2%) and NCaS + CaN (4%) induced higher number of fruit per tree than control and CaN (6%), similarly as observed for cumulative number of fruit. In the 2015/2016 growing season, the lowest number of fruit was observed with NCaS + CaN (2%), which did no differ of HC (0.25%) + MO (3.0%). Yield per tree and estimated yield were affected only in 2015/2016, where differences were similar to those found for number of fruit per tree. According to Iuchi et al., (2002) the positive effect of increasing budbreak is usually observed after the second year. This is exactly what was observed in the present study, where the treatments HC (0.34%) + MO (3.2%) and NCaS + CaN (4%) increased the number of fruit after the second year of application (2014/2015). Hawerroth et al. (2009) did not found differences in the number of fruit per tree of 'Fuji Suprema' treated with budbreak promoters, but they reported only the results of the year of application. The reduction in the yield per tree and estimated yield in the 2015/2016 growing season of trees treated with NCaS + CaN (2%) and HC (0.25%) + MO (3.0%), might be due to the mild winter conditions in this season associated with intrinsic characteristics of the trees chosen for these treatments (probably a lower content of carbohydrate reserve). In such conditions, after some chilling accumulation, if long periods of higher temperatures take place in the winter, trees spend reserves to start its metabolic process to grow out, but then temperatures drop again and this process is stopped, depleting tree reserves and potentially decreasing the yield.

Return bloom was not significantly affected by treatments (Table 3), indicating that the greater number of fruit per tree induced by some treatments did not have negative effects on flowering the following season. Higher crop load of apple trees are often associated with alternate bearing (MELAND, 2009) mainly with susceptible cultivars like Fuji (ATAY et al., 2013).

Significant differences in fruit weight were observed in the 2013/2014, 2014/2015 growing seasons, and the average between them (Table 3). In the 2013/2014 growing season fruit size was reduced by the application of HC (0.34%) + MO (3.2%), not differing of NCaS + CaN (6%). In 2014/2015, the treatment NCaS + CaN (4%) resulted in smaller fruit, relative to control. The average fruit weight between the 2013/2014 and 2014/2015 growing seasons was reduced by HC (0.34%) + MO (3.2%) and NCaS + CaN (4 % and 6%), relative to control. Fruit size reduction has been commonly associated with higher crop load (ROBINSON, 2011). However, this effect would only partly explain the results observed, like the fruit weight in the 2014/2015 growing season and the average fruit weight between the first two seasons where the treatments with higher cumulative number of fruit per tree also had the lowest fruit weight compared to control. However, it does not explain the smaller fruit weight observed in the 2013/2014 growing season, where fruit weight was reduced by HC (0.34%) + MO (3.2%) and number of fruit per tree was similar among treatments. Similar results were observed in 'Fuji Suprema' apples (PETRI et al., 2014; HAWERROTH et al., 2009), where the it was observed reduction in fruit size induced by treatments with several budbreak promoters but not in crop load. In this case, a hypothesis is that the great axillary budbreak provided by the treatment with HC (0.34%) + MO (3.2%) might have impaired early fruit cell division. Apple fruit weight variation at harvest is about 85% explained by cell number, which is directly related to cell division (LAKSO; GOFFINET, 2013). The majority of cell division takes place from about 1 week after bloom until about 4-5 weeks after bloom, coinciding with budbreak of axillary buds. Then, one might speculate that the greater number of axillary buds growing due to treatment with a given budbreak promoter would compete for resources with fruit cell division, reducing its fruit weight at harvest. While this is just a hypothesis, further studies should be performed in order to investigate more deeply the effects of budbreak promoters on fruit size.

Fruit quality parameters (flesh firmness, soluble solids and starch-iodine index) were not affected by treatments (Table 4). The effect of budbreak promoters in apple fruit quality has been little reported. Bound and Jones (2004) also found no differences in fruit quality of 'Fuji' apples treated with hydrogen cyanamide. Since fruit quality is a key factor to achieve reasonable prices, any treatment sprayed to the trees should not negatively influence fruit quality.

Table 3. Yield components of 'Fuji Suprema' 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})	Fruit weight (g)	Return bloom[2]
			2013/2014		
Control	96.8	18.3	45.8	188.7 ab	-
NCaS + CaN 2%	78.2	14.5	36.3	187.1 ab	-
NCaS + CaN 4%	96.2	17.0	42.6	179.7 ab	-
NCaS + CaN 6%	107.2	18.9	47.2	175.9 bc	-
HC 0.34 % + MO 3.2 %	99.8	16.4	41.1	164.7 c	-
CaN 6%	91.2	17.5	43.9	193.4 a	-
p	0.434	0.573	0.573	0.006	-
			2014/2015		
Control	144.4 b	20.3	50.9	143.2 a	-
NCaS + CaN 2%	176.6 ab	23.5	58.7	133.0 ab	-
NCaS + CaN 4%	213.8 a	27.1	67.9	126.8 b	-
NCaS + CaN 6%	159.4 b	21.0	52.5	131.9 ab	-
HC 0.34 % + MO 3.2 %	211.4 a	28.1	70.2	132.4 ab	-
CaN 6%	149.0 b	21.2	53.1	142.5 a	-
p	0.017	0.075	0.075	0.021	-
			2013/2014 - 2014/2015		
	Cumulative	Cumulative	Cumulative	Average	-
Control	241.2 b	38.7	96.7	165.9 a	-
NCaS + CaN 2%	254.8 ab	38.0	94.9	160.1 ab	-
NCaS + CaN 4%	310.0 a	44.2	110.5	153.3 bc	-
NCaS + CaN 6%	266.6 ab	39.8	99.6	153.9 bc	-
HC 0.34 % + MO 3.2 %	311.2 a	44.5	111.2	148.6 c	-
CaN 6%	240.2 b	38.8	96.9	168.0 a	-
p	0.037	0.435	0.435	0.004	-
			2015/2016		
Control	121.2 ab	18.8 a	47.0 a	154.8	161.8
NCaS + CaN 2%	70.5 c	10.8 c	27.2 c	155.3	198.8
NCaS + CaN 3%	120.2 ab	17.3 ab	43.2 ab	144.4	231.4
NCaS 1% + MO 2%	126.2 a	18.1 a	45.3 a	143.5	156.4
NCaS 1% + MO 3%	125.8 a	18.1 a	45.2 a	147.0	187.6
HC 0.25% + MO 3%	88.6 bc	12.8 bc	32.1 bc	144.0	195.4
p	0.008	0.011	0.011	0.164	0.307

*Different letters within columns indicate significant differences according to Duncan's test ($p < 0.05$).[1]Total number of flower clusters per tree the year following application.

Table 4. Firmness, soluble solids and starch-iodine index of 'Fuji Suprema' apple fruit, treated with budbreak promoters, in the growing seasons of 2013/2014 and 2014/2015.

Treatment	Firmness (N)	Soluble solids (°brix)	Starch-iodine index
		2013/2014	
Control	68.7	14.7	4.7
NCaS + CaN 2%	69.7	14.3	4.9
NCaS + CaN 4%	71.0	14.3	4.8
NCaS + CaN 6%	71.3	14.8	4.8
HC 0.34 % + MO 3.2 %	72.5	15.0	4.9
CaN 6%	70.8	14.8	4.9
p	0.059	0.104	0.053
		2014/2015	
Control	75.3	12.3	6.6
NCaS + CaN 2%	76.3	12.8	6.1
NCaS + CaN 4%	75.6	12.3	6.4
NCaS + CaN 6%	76.0	12.9	6.5
HC 0.34 % + MO 3.2 %	75.3	12.3	6.5
CaN 6%	75.6	12.5	5.8
p	0.986	0.506	0.182

Conclusions

Axillary budbreak is improved by the budbreak promoters tested.

The combination of NCaS + CaN (4% and 6%) and NCaS (1%) + MO (2% and 3%) shows similar axillary budbreak as HC + MO.

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

HC + MO and NCaS + CaN (4%) increase the cumulative number of fruit per tree.

Fruit quality attributes are not affected by budbreak promoters.

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