

Original Research Article

Budbreak promoters increases percentage, standardization and synchrony of budbreak in 'Eva' and 'Castel Gala' apple trees in mild winter climate conditions

ABSTRACT

Aims: The aim of this study was to evaluate the effect of different budbreak promoters on low chilling apple cultivars, Eva and Castel Gala, in mild winter conditions of the Southern Brazil.

Study design: Experimental design was randomized blocks, with four replications, and the experimental unit was composed by two plants, on 3x2 factorial arrangement (three treatments and two cultivars).

Place and Duration of Study: This research was carried out during growing season 2012/2013, in an experimental apple orchard located at Palma Agriculture Center, Federal University of Pelotas, Southern Brazil.

Methodology: Three treatments were applied: Erger® 3% + calcium nitrate 3%; Erger® 5% + calcium nitrate 5%; And hydrogen cyanamide 1.5% + mineral oil 3%. It was recorded phenological stages: beginning, full and the end of blooming; budbreak of axillaries buds and fruit set. The productive parameters were analysed: average fruit weight, yield efficiency and yield.

Results: All treatments reduced blooming period and improved the synchronization in both cultivars. There was increase in budbreak of axillaries buds, whereas in 'Eva' apple trees, the treatments with Erger® had higher budbreak rates than hydrogen cyanamide. In 'Eva', the application of budbreak promoters reduced fruit set and increased the average fruit weight, yield and yield efficiency, when compared to control trees. However, these results were not observed in 'Castel Gala'.

Conclusion: The combination of Erger® and calcium nitrate showed a similar and higher performance than the combination of hydrogen cyanamide and mineral oil in the budbreak percentage in 'Castel Gala' and 'Eva', respectively.

Keywords: *Malus domestica* Borkh., dormancy, phenology, blooming period.

1. INTRODUCTION

Apple (*Malus domestica* Borkh.) is widely cultivated worldwide. Brazil was the 12th largest apple producer in 2013 with 1.23 million tons of harvested fruit (FAO, 2016). National production is concentrated in the states of Santa Catarina and Rio Grande do Sul, where 'Gala' and 'Fuji' represent 90% of production (Petri and Leite 2008; Fachinello et al., 2011).

'Gala' and 'Fuji' clones, selected for intense red epidermis color, predominate from the 1990's (Petri et al., 2011), which present high chilling requirements to overcome dormancy and consequent induction and standardization of budburst and blooming (Putti et al., 2003). Thus, these cultivars have poor climatic adaptation under low chilling winter regions (Petri and Leite, 2004). Therefore, the implantation of orchards with low chilling requirement cultivars is the main measure to enable apple production in these regions (Pommer and Barbosa, 2009).

Among low chilling requirement cultivars, the most outstanding in Brazil is 'Eva' (IAPAR-75), obtained from the cross between 'Gala' and 'Anna', which requires between 300 and 350 hours below 7.2 °C of chilling to overcome dormancy (Hauagge and Tsuneta, 1999). Another alternative is 'Castel Gala', which originates from a spontaneous mutation of 'Gala' and it is characterized by precocity in production, requiring around 400 chilling hours to overcome the dormancy period (Holz 2005).

In regions of mild winter conditions and in years that does not occur the adequate chilling accumulation, several problems can occur, such as erratism of budbreak, non-coincident blooming

between pollinating and producing cultivars, fruit deformity, poor budbreak and plant architecture disorders (Petri et al., 2004, Petri et al., 2006, Cook 2010, Maguylo et al., 2012, Schmitz et al., 2014). Therefore, even cultivars with low chilling requirements may require some intervention for overcoming dormancy and to enable fruit production in these regions (Citadin et al., 2006).

Among the chemical budbreak promoters, the most employed is hydrogen cyanamide (HC), marketed as Dormex® (Mohamed 2008). In addition to HC, mineral oil (MO) is widely used, which allows the reduction of the HC concentration used, reducing expenses and maintaining results similar to those obtained only with HC (Hawerroth et al., 2009).

Due to the high toxicity of HC (Haro 2009), alternatives for induction and standardization of budbreak and blooming in temperate fruit production have been sought, one of them is the commercial product Erger®, compound based on nitrogen, which is used together with calcium nitrate. Previous study has shown that this product is efficient in regions with a higher accumulation of chilling and in cultivars of greater chilling requirement, promoting budbreak similar to that obtained by the use of HC and MO (Hawerroth et al., 2010).

Given the limited availability of information on the use of budbreak promoters in apple trees in mild winter conditions like in Southern Brazil and its potential benefits to budbreak uniformity, blooming synchrony and yield increase, research of this nature is essential as an attempt to increase apple production in mild winter regions like Brazil. The objective of this study was, therefore, to evaluate the effect of budbreak promoters in low chilling requirement cultivars, Eva and Castel Gala, in mild winter climate condition.

2. MATERIAL AND METHODS

The experiment was performed in an experimental orchard in Capão do Leão city, state of Rio Grande do Sul, Brazil (latitude 31° 52 'S, longitude 52° 21'O, altitude 13m) during the 2014/2015 growing season. According to Köppen-Geiger classification, i.e., the climate of the studied region is Cfa, humid subtropical with the following annual averages: rainfall of 1,367 mm, temperature of 17.8 °C relative humidity of 80.7 %, and 238 chill hours (CH) below 7.2 °C according to data provided by the Embrapa Clima Temperado Terras Baixas weather station.

Plant material consisted of three-year-old 'Eva' and 'Castel Gala' apple trees grafted onto 'Marubakaido' rootstock with a 15 cm long 'M-9' filter. Trees were spaced 0.9 m between trees and 5 m between rows, totalling 2,222 trees ha⁻¹, and trained to a central-leader system. Cultural practices during the experiment were similar to all treatments and were performed according to commercial standards.

The experiment was arranged in a randomized block design, following the 4x2 factorial arrangement (four levels of budbreak factor and two levels of cultivar factor). Four replications were used, where each replicate was composed of two plants. The levels studied for the budbreak factor were: 1) control (untreated); 2) Erger 3% + calcium nitrate 3%; 3) Erger® 5% + calcium nitrate 5%; 4) hydrogen cyanamide 1.5% + mineral oil 3%. As a source of HC and OM, the commercial products Dormex® (active ingredient 49%) and Triona® (active ingredient 80%), were used, respectively.

The application of budbreak promoters was performed when 185 CH below 7.2 °C had accumulated, and the buds were between the physiological stages A and B according to the scale shown in Iuchi (2006). All products were sprayed using a backpack sprayer Jacto model PJH20. The application water pH was ~6.5. Trees were sprayed during the morning, with temperature ranging from 20 to 25 °C, relative humidity of 85-95% and wind speed not exceeding 7 km h⁻¹. At the time of application, the limit volume applied was the runoff point.

From budbreak beginning, phenological evaluations were carried out to determine the occurrence dates of beginning, full and end bloom for each treatment. The beginning bloom was considered when the plants had 5% of open flowers, the full bloom when 70% of flowers were open and the end bloom was given when the last flowers were open. From the phenological data, the interval, in days, between the application of budbreak promoters and the date of bud burst beginning and duration of bloom periods, was calculated. Phenological observation was used to verify the blooming coincidence between the cultivars studied within each level of the budbreak factor.

79 The budbreak in three branches of each plant was evaluated at 28 days after application of budbreak
80 promoters to determine the budbreak percentage. Fruit set was obtained from the relation between
81 the number of flower clusters counted during full bloom and the number of fruits at 40 days after full
82 bloom, using the formula $[(\text{number of fruits} / \text{flower clusters}) \times 100]$.

83 In the physiological maturation, the fruits were harvested in January 6 for 'Eva' and 'Castel Gala'. The
84 total number of fruit per tree were counted and weighed. Estimated yield was calculated based on the
85 yield per tree and the number of trees per ha. The average fruit weight was calculated using the yield
86 per tree and the number of fruits per tree. The productive efficiency was calculated using the mean
87 plant yield divided by the mean trunk section, expressed in kg cm⁻².

88 The statistical analysis was performed using the software R. Analysis of variance (ANOVA) was
89 performed by F test and, when significant, the data were submitted to mean comparison by Tukey's
90 test at 5% of significance.

91 3. RESULTS AND DISCUSSION

92 The blooming period varied between cultivars and levels of budbreak promoters used (Figure 1).
93 When not employed the budbreak promoters blooming period lasted 23 days in 'Eva', 5 days longer
94 than trees where budbreak promoters were applied, while in 'Castel Gala', the untreated trees
95 showed a blooming period of 19 days, two to three days more than treated trees (Figure 1), however,
96 the beginning bloom in untreated trees was later. This typical symptom of winter chilling lack may
97 make it difficult to perform cultural practices such as thinning and disease control due to the presence
98 of different phenological stages within the same plant (Petri and Leite, 2004). Budbreak promoters
99 applications reduced blooming period to 18 days and 16 to 17 days in 'Eva' and 'Castle Gala',
100 respectively, resulting in a higher blooming uniformity.

101 The beginning bloom, on 'Eva' apple trees, occurred between August 17 and 19 and was not affected
102 by budbreak promoters applications. In untreated trees and treated with HC, beginning bloom was
103 observed on August 17. In trees subjected with Erger® (3% and 5%), beginning bloom occurred on
104 August 18 and 19, respectively. In 'Castel Gala' apples, budbreak promoters anticipated blooming 4
105 to 5 days, compared to control trees, which began on August 30, while trees subjected with Erger (3%
106 and 5%) started on August 26 and with HC on August 25 (Figure 1). According to Tooke and Battey
107 (2010), in temperate fruit, when the chilling requirements are not completely satisfied, a prolongation
108 can occur in the blooming time, which can affect orchard productivity due to bloom between producing
109 cultivars and their pollinators do not occur simultaneously.

110 Without the use of budbreak promoters blooming asynchrony was observed between cultivars, which
111 can be observed in control trees (Figure 1), where 'Castel Gala' full bloom occurred 1 day before the
112 end of 'Eva' bloom, similar results were observed by Denardi and Stuker (2008), where the beginning
113 of bloom in 'Castel Gala' apple trees occurred one day before the full bloom of 'Eva' apple trees, and
114 full bloom of 'Castel Gala' occurred after end bloom of 'Eva'. The different Erger® and calcium nitrate
115 rates as well as MO associated with HC resulted in an increase blooming synchrony among the
116 cultivars studied, since the full bloom of 'Eva' occurred after the beginning of bloom in 'Castel Gala',
117 and the full bloom of 'Castel Gala' when there were still 'Eva' flowers open.

118 The pollen of the cultivars under study has high compatibility with each other, both being used for the
119 commercial pollination of each other, but its blooming has great temporal variability (Denardi and
120 Stuker, 2008), so these results evidenced the need to use budbreak promoters for blooming
121 synchrony between the cultivars studied, so that both can be used as pollinators of each other,
122 especially in 'Castel Gala' apples, which has later budbreak and blooming period.

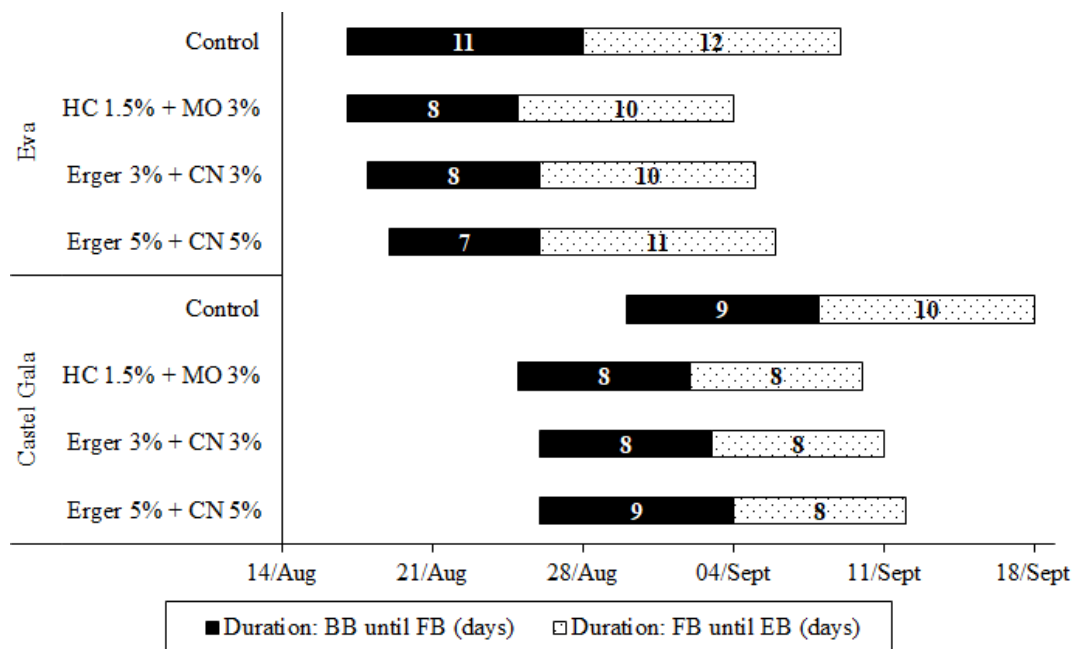


Fig. 1. Duration of blooming period in 'Eva' and 'Castel Gala' apple trees treated with different budbreak promoters. (BB = beginning bloom, FB = full bloom, EB = end bloom, HC = hydrogen cyanamide, MO = mineral oil, CN = calcium nitrate).

Budbreak promoters provided a significant increase in axillary bud burst relative to control trees in both cultivars evaluated (Table 1). In 'Eva', treatments with Erger® at concentrations of 3% and 5% plus calcium nitrate at 3% and 5%, respectively, showed budbreak rates above 70%, which were significantly higher than the results obtained with hydrogen cyanamide (Table 1). In 'Castel Gala' the treatments with Erger® and hydrogen cyanamide did not differ among them, and showed budbreak percentage above 40% (Table 1). These results corroborate with those found by Petri et al. (2008), where 'Gala' treated with Erger® and calcium nitrate showed no significant difference compared with trees treated with HC and MO at 0.5 and 4.0% in the budbreak of axillary buds.

For fruit set, different results were obtained in each cultivar. While in 'Castel Gala' there was no significant difference between the treatments, in 'Eva' the application of budbreak promoters significantly reduced the fruit set compared to control trees (Table 1). This effect may be related first to the rapid leaf development competing with the bloom and fruit development, and also to the short blooming period, which impaired pollination and the activity of pollinating insects.

Table 1. Percentage of budbreak and fruit set of 'Eva' and 'Castel Gala' apple trees treated with different budbreak promoters.

Treatment	Budbreak (%)		Fruit Set (%)	
	'Eva'	'Castel Gala'	'Eva'	'Castel Gala'
Control	40.55 c	16.12 b	31.46 a	24.15 ^{ns}
HC 1.5% + MO 3%	59.40 b	49.91 a	14.77 b	29.72
Erger® 3% + CN 3%	70.10 a	42.91 a	16.22 b	26.67

Erger® 5% + CN 5%	70.18 a	41.79 a	15.95 b	32.62
CV (%)	7.84	13.01	19.01	22.83

CN – calcium nitrate; MO – mineral oil; HC - hydrogen cyanamide; Means followed by the same letter in the column do not differ statistically by the Tukey test at 5% of error probability. ns - non-significant interaction, by F test, 5% probability of error.

Regarding the productive variables, there were no significant difference for the three evaluated parameters in 'Castel Gala' (Table 2). In 'Eva', budbreak promoters increased average fruit weight, yield efficiency and yield, where in the latter parameter, trees subjected with HC and MO showed no significant difference between untreated trees (Table 2).

This effect may be related primarily to the greater fruit set in control trees, which led to a greater number of fruits per plant, increasing competition for carbohydrates and reducing their caliber. In a second moment, the smaller leaf area of control trees (data not showed), which would mean a lower contribution of carbohydrates to the fruits, consequently, hampering their development.

Table 2. Average fruit weight, yield efficiency and yield of 'Eva' and 'Castel Gala' apple trees treated with different budbreak promoters.

Treatment	Average fruit weight (g)		Yield efficiency (kg cm ⁻²)		Yield (mg ha ⁻¹)	
	'Eva'	'Castel Gala'	'Eva'	'Castel Gala'	'Eva'	'Castel Gala'
Control	95.41 b	136.85 ^{ns}	0.40 b	0.43 ^{ns}	12.34 b	8.26 ^{ns}
HC 1.5% + MO 3%	125.67 a	135.50	0.53 a	0.39	14.99 ab	10.03
Erger® 3% + CN 3%	116.23 a	139.02	0.57 a	0.48	17.18 a	10.70
Erger® 5% + CN 5%	133.87 a	150.27	0.52 a	0.38	15.11 a	7.53
CV (%)	7.53	8.24	8.52	14.9	17.2	20.44

CN – calcium nitrate; MO – mineral oil; HC - hydrogen cyanamide; Means followed by the same letter in the column do not differ statistically by the Tukey test at 5% of error probability. ns - non-significant interaction, by F test, 5% probability of error.

4. CONCLUSION

Budbreak promoters tested promoted greater budbreak, blooming uniformity and synchronization in both cultivars. The combination of Erger® and calcium nitrate in the two rates tested presented similar performance to HC and MO in budbreak, showing to be an alternative for bud induction with good prospects for use in mild climate conditions.

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