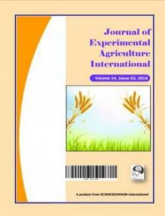

Journal of Experimental Agriculture International

20(1): 1-7, 2018; Article no.JEAI.38512
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Evaluation of the Effect of Different Budbreak Promoters on Apple Trees 'Eva' and 'Castel Gala' in Mild Winter Climate Conditions

E. S. Abreu[1*], B. Carra[1], D. Spagnol[1], J. D. Schmitz[2], T. A. Silva[1], C. G. Hellwig[1] and J. C. Fachinello[1]

[1]Faculty of Agronomy 'Eliseu Maciel', Federal University of Pelotas, Pelotas, RS, Brazil.
[2]Federal Institute of Santa Catarina, Concórdia, SC, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. Authors ESA, BC, DS and TAS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JDS and JCF managed the study analyzes. Authors ESA and JDS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/38512
Editor(s):
(1) Claude Bakoume, Professor, Institute of Agricultural Research for Development, Cameroon.
Reviewers:
(1) Sultan Filiz Güçlü, Süleyman Demirel University, Turkey.
(2) Zeynel Dalkiliç, Turkey.
(3) Margaret H. N. Mollel, University of Limpopo, South Africa.
Complete Peer review History: http://www.sciencedomain.org/review-history/22826

Original Research Article

Received 29th October 2017
Accepted 12th January 2018
Published 23rd January 2018

ABSTRACT

This study aimed to evaluate the effect of different budbreak promoters on low chilling apple trees, Eva and Castel Gala, in mild winter conditions of Southern Brazil. An experimental design was randomised blocks, with four replications, and the experimental unit was composed of two plants, on 4x2 factorial arrangement (four treatments and two cultivars). This research was carried out during growing season 2014/2015, in an experimental apple orchard located at Palma Agriculture Center, Federal University of Pelotas, Southern Brazil. Four treatments were applied: Erger 3% + calcium nitrate 3%; Erger 5% + calcium nitrate 5%; hydrogen cyanamide 1.5% + mineral oil 3% and control. It was recorded phenological stages: beginning, full and the end of blooming; budbreak of axillary buds and fruit set. The productive parameters were analysed: average fruit weight (g), yield efficiency (kg-cm^{-2}) and yield (Mg ha^{-1}). All treatments reduced blooming period and improved the

**Corresponding author: E-mail: sozodeabreu@hotmail.com;*

synchronisation in both cultivars. There was an increase in budbreak of axillary 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'. The combination of Erger and calcium nitrate showed 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 [1]. National production is concentrated in the states of Santa Catarina and Rio Grande do Sul, where ‘Gala’ and ‘Fuji’ represent 90% of production [2,3].

‘Gala' and ‘Fuji' clones, selected for intense red epidermis color, predominate from the 1990's [4], which present high chilling requirements to overcome dormancy and consequent induction and standardisation of budburst and blooming [5]. Thus, these cultivars have poor climatic adaptation under low chilling winter regions [6]. Therefore, the implantation of orchards with low chilling requirement cultivars is the main measure to enable apple production in these regions [7].

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 7.2ºC of chilling to overcome dormancy [8]. Another alternative is ‘Castel Gala', which originates from a spontaneous mutation of ‘Gala' and it is characterised by precocity in production, requiring around 400 chilling hours to overcome the dormancy period [9].

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 [6,10,11,12,13]. Therefore, even cultivars with low chilling requirements may require some intervention for overcoming dormancy and to enable fruit production in these regions [14].

Among the chemical budbreak promoters, the most employed is hydrogen cyanamide (HC), marketed as Dormex® [15]. 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 [16].

Due to the high toxicity of HC [17], alternatives for induction and standardisation 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. The previous study has shown that this product is effective 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 [18].

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. MATERIALS AND METHODS

The experiment was performed in an experimental orchard in Capão do Leão city, state of Rio Grande do Sul, Brazil (latitude 31º 52'S, longitude 52º 21'W, 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℃ relative humidity of 80.7%, and 238 chill hours (CH) below 7.2ºC

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 MO, 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℃ had accumulated, and the buds were between the physiological stages A and B according to the scale shown in Iuchi [19]. 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℃, 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.

The budbreak in three branches of each plant was evaluated at 28 days after application of budbreak promoters to determine the budbreak percentage. Fruit set was obtained from the relation between the number of flower clusters counted during full bloom and the number of fruits at 40 days after full bloom, using the formula ([number of fruits / flower clusters] x100).

In the physiological maturation, the fruits were harvested in January 6, 2015 for 'Eva' and 'Castel Gala'. The total number of fruit per tree were counted and weighed. Estimated yield was calculated based on the yield per tree and the number of trees per ha. The average fruit weight was calculated using the yield per tree and the number of fruits per tree. The productive efficiency was calculated using the mean plant yield divided by the mean trunk section, expressed in kg cm^{-2}.

The statistical analysis was performed using the software R [20]. Analysis of variance (ANOVA) was performed by F test and, when significant, the data were submitted to mean comparison by Tukey's test at 5% of significance.

3. RESULTS AND DISCUSSION

The blooming period varied between cultivars and levels of budbreak promoters used (Fig. 1). When not employed the budbreak promoters blooming period lasted 23 days in 'Eva', 5 days longer than trees where budbreak promoters were applied, while in 'Castel Gala', the untreated trees showed a blooming period of 19 days, two to three days more than treated trees (Fig. 1), however, the beginning bloom in untreated trees was later. This typical symptom of winter chilling lack may make it difficult to perform cultural practices such as thinning and disease control due to the presence of different phenological stages within the same plant [6]. Budbreak promoters applications reduced blooming period to 18 days and 16 to 17 days in 'Eva' and 'Castle Gala', respectively, resulting in a higher blooming uniformity.

The beginning bloom, on 'Eva' apple trees, occurred between August 17 and August 19, 2014 and was not affected by budbreak promoters applications. In untreated trees and treated with HC, beginning bloom was observed on August 17, 2014. In trees subjected with Erger (3% and 5%), beginning bloom occurred on August 18 and August 19, 2014, respectively.

In 'Castel Gala' apples, budbreak promoters anticipated blooming 4 to 5 days, compared to control trees, which began on August 30, 2014, while trees subjected with Erger (3% and 5%) started on August 26, 2014 and with HC on August 25, 2014 (Fig. 1). According to Tooke and Battey [21], in temperate fruit, when the chilling requirements are not completely satisfied, a prolongation can occur in the blooming time, which can affect orchard productivity due to bloom between producing cultivars and their pollinators do not occur simultaneously.

Without the use of budbreak promoters blooming asynchrony was observed between cultivars, which can be observed in control trees (Fig. 1), where 'Castel Gala' full bloom occurred 1 day before the end of 'Eva' bloom, similar results were observed by Denardi and Stuker [22], where the beginning of bloom in 'Castel Gala' apple trees occurred 1 day before the full bloom of 'Eva' apple trees, and full bloom of 'Castel Gala' occurred after end bloom of 'Eva'. The different Erger and calcium nitrate rates as well as MO associated with HC resulted in an increase blooming synchrony among the cultivars studied, since the full bloom of 'Eva' occurred after the beginning of bloom in 'Castel Gala', and the full bloom of 'Castel Gala' when there were still 'Eva' flowers open.

The pollen of the cultivars under study has high compatibility with each other, both being used for the commercial pollination of each other, but its blooming has great temporal variability [22], so these results evidenced the need to use budbreak promoters for blooming synchrony between the cultivars studied, so that both can be used as pollinators of each other, especially in 'Castel Gala' apples, which has later budbreak and blooming period.

According Table 1, the application of budbreak promoters in Eva and Castel Gala apple trees presented significant interaction for the variables of this study. Budbreak promoters provided a significant increase in axillary bud burst relative to control trees in both cultivars evaluated (Table 2). 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

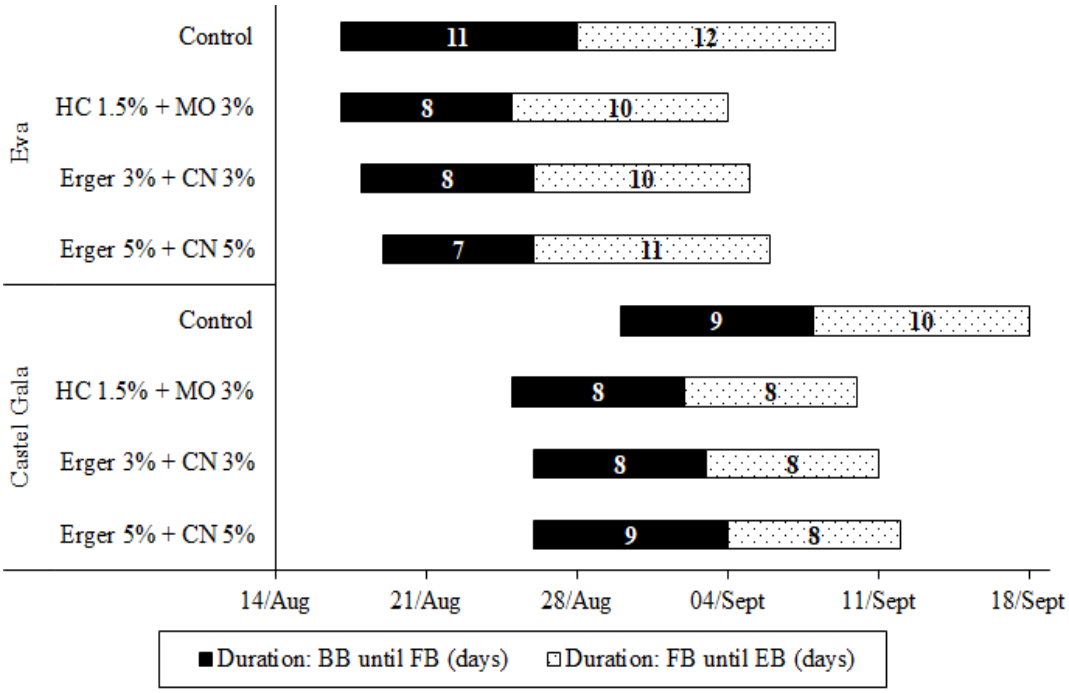

Fig. 1. Duration of blooming period in 'Eva' and 'Castel Gala' apple trees treated with different budbreak promoters

(BB = Beginning bloom, FB = Full bloom, EB = End bloom, HC = Hydrogen cyanamide, MO = Mineral oil, CN = Calcium nitrate)

than the results obtained with hydrogen cyanamide (Table 2). In 'Castel Gala' the treatments with Erger and hydrogen cyanamide did not differ among them, and showed budbreak percentage above 40% (Table 2). These results corroborate with those found by Petri et al. [23], 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 2). 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.

Regarding the productive variables, there were no significant difference for the three evaluated parameters in 'Castel Gala' (Table 3). 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 3).

This effect may be related primarily to the greater fruit set in control trees, which led to a greater

Table 1. Analysis of variance, summary for budbreak, fruit set, average fruit weight, yield efficiency and yield of 'Eva' and 'Castel Gala' apple trees treated with different budbreak promoters

Source of variation	DF	Mean square				
		Budbreak	Fruit set	Average fruit weight	Yield efficiency	Yield
Cultivar	1	4005.27*	603.87*	3961.81*	0.055*	260.86*
Promoter	3	1504.19*	64.34*	905.63*	0.014*	16.86*
CxP	3	152.96*	241.11*	371.48	0.011	5.05
Error	21	21.72	21.39	154.23	0.004	3.00
P>F		<0.0001	<0.0001	<0.0001	0.0033	<0.0001
Mean		48.87	23.95	128.78	0.47	12.06
CV (%)		9.54	19.31	9.64	13.53	14.35

**significant differences ($p \leq 0.05$). DF = Degrees of freedom*

Table 2. 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

Table 3. 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

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.

4. CONCLUSION

Budbreak promoters tested promoted greater budbreak, blooming uniformity and synchronisation 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Food and Agriculture Organization of the United Nations Statical Databases. Production crops. (Accessed 01 June 2016) Available:http://www.faostat.fao.org
2. Petri JL, Leite GB. Apple tree. Revista Brasileira de Fruticultura. 2008;30:851-853.
3. Fachinello JC, Pasa MS, Schmitz JD, Betemps D L. Situation and prospects of temperate fruit crops in Brazil. Revista Brasileira de Fruticultura. 2011;33:109-120. Portuguese.
4. Petri JL, Leite GB, Couto M, Francescatto P. Advances of the apple crop in Brazil. Revista Brasileira de Fruticultura. 2011; 33:48-56. Portuguese.
5. Putti GL, Petri JL, Mendez ME. Effect of the cold intensity in time and percentage of shoot buds in apple trees. Revista Brasileira de Fruticultura. 2003;25:199-202. Portuguese.
6. Petri JL, Leite GB. Consequences of insufficient winter chilling on apple tree budbreak. Acta Horticulturae. 2004;662:53-60.
7. Pommer CV, Barbosa W. The impact of breeding on fruit production in warm climates of Brazil. Revista Brasileira de Fruticultura. 2009;31:612-634.
8. Hauagge R, Tsuneta M. IAPAR 75 - 'Eva', IAPAR 76 - 'Anabela' and IAPAR 77 - 'Carícia' – New low chilling requirements apple cultivars. Revista Brasileira de Fruticultura. 1999;21:239-242. Portuguese.
9. Hollz C. Castel Gala: New early apple cultivar. Agropecuária Catarinense. 2005; 18:22-26. Portuguese.
10. Petri JL. Dormancy and budbreak in apple trees. In: Epagri (Org.). A cultura da macieira. Florianópolis: GMC/Epagri; 2006.
11. Cook NC. Apple production under conditions of sub-optimal winter chilling in South Africa. Acta Horticulturae. 2010;872: 199-204.
12. Maguylo K, Cook NC, Theron KI. Environment and position of first bud to break on apple shoots affects lateral outgrowth. Trees. 2012;26:663-675.
13. Schmitz JD, Guédon Y, Herter FG, Leite GB, Lauri P-É. Exploring bud dormancy completion with a combined architectural and phenological analysis: The case of apple trees in contrasting winter temperature conditions. American Journal of Botany. 2014;101:398–407.
14. Citadin I, Bassani MH, Danner M., Mazaro SM, Gouvêa A. Use of hydrogen cyanamid and mineral oil in blooming, budding and production of peach 'Chiripá'. Revista Brasileira de Fruticultura. 2006;28:32-35. Portuguese.
15. Mohamed AKA. The effect of chilling, defoliation and hydrogen cyanamide on dormancy release, bud break and fruiting of Anna apple cultivar. Scientia Horticulturae. 2008;118:25-32.
16. Hawerroth FJ, Petri JL, Leite GB, Herter FG. Budbreak in 'Imperial Gala' and 'Fuji Suprema' apples by using Erger® and calcium nitrate. Revista Brasileira de Fruticultura. 2010;32:342-350. Portuguese.
17. Haro L. Disulfiram-like syndrome after hydrogen cyanamide professional skin exposure: Two case reports in France. Journal of Agromedicine. 2009;14:382-384.
18. Hawerroth FJ, Petri JL, Herter FG, Leite GB, Leonetti JF, Marafon AC, Simões F. Phenology, budbreak and apple fruit production by hydrogen cyanamide and mineral oil application. Bragantia. 2009; 68:961-971. Portuguese.
19. Iuchi VL. Botany and physiology. In: Epagri (Org.). A cultura da macieira. Florianópolis: GMC/Epagri; 2006.

20. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing; 2016.
(Accessed 5 March 2016)
Available:http://www.R-project.org
21. Tooke F, Battey NH. Temperate flowering phenology. Journal of Experimental Botany. 2010;61:2853-2862.
22. Denardi F, Stuker H. Efficiency of different cultivars as pollinizers for 'Castel Gala' and 'Condessa' apples. Agropecuária catarinense. 2008;21:79-83. Portuguese.
23. Petri JL, Leite GB, Putti GL. Apple tree budbreak promoters in mild winter conditions. Acta Horticulturae. 2008;774: 291-296.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/22826