Original Research Article

Bluprins® as Alternative Bud Break Promoter for 'Maxi Gala' and 'Fuji Suprema' apple trees

ABSTRACT

Aims: Evaluate the effect of Bluprins® at different concentrations combined with calcium nitrate and ammonium nitrate on phenology, bud break induction and fruit production of 'Maxi Gala 'and' Fuji Suprema' apple tree cultivars, in mild winter conditions. **Study design:** The experiment was arranged in a randomized block design and replicated five times. **Place and Duration of Study:** The experiment was carried out in the municipality of Caçador, Brazil, during the growing seasons of 2013/2014, 2014/2015, 2015/2016 and 2016/2017. **Methodology:** The study considered 'Maxi Gala' and 'Fuji Suprema' apple trees. The treatments evaluated were: 1. Control (untreated); 2. Mineral oil 3.5% + hydrogen cyanamide 0.35%; 3. Bluprins® 3.0% + calcium nitrate 3.0%; 4. Bluprins® 5.0% + calcium nitrate 3.0%; 5. Bluprins® 3.0% + calcium nitrate 5.0%; 6. Bluprins® 5.0% + calcium nitrate 5.0%; 7. Bluprins® 3.0% + calcium nitrate 3.0% + ammonium nitrate 3.0%; 8. Bluprins® 5.0% + calcium nitrate 4.0% + ammonium nitrate 4.0%. Phenology, axillary and terminal bud break, fruit set, fruit production and average fruit weight were evaluated. The phenological stage of green tip (C-C3) and the beginning of bud break and flowering were anticipated by the application of Bluprins® and hydrogen cyanamide in comparison to the control. The axillary and terminal bud break were increased by the application of bud break promoters for both cultivars considering the four growing seasons studied. The average fruit weight did not show significant differences between treatments in the growing seasons of 2013/2014 and 2015/2016. Bluprins®, in combination with calcium nitrate and ammonium nitrate, proved effective in inducing bud break, anticipating bud break and flowering and reducing the flowering period, and does not compromise the fruit set and fruit production of 'Maxi Gala' and 'Fuji Suprema' apple tree cultivars under mild winter conditions.

Keywords: Malus domestica Borkh.; Dormancy; Mild winter chilling; Bud break induction.

1. INTRODUCTION

Apple trees (*Malus domestica* Borkh.) present suspension of vegetative growth in winter, which is called dormancy. This mechanism allows it to survive periods of low temperatures [1]. To overcome dormancy, plants have to satisfy their chilling requirements to initiate spring bud break, shoot meristematic extension growth and anthesis [2]. Chilling requirements vary depending on the cultivar [3]. The insufficient chilling accumulation in a specified cultivar results mainly in reduction of bud break and uneven flowering [4,5]. These dysfunctions have economic consequences due to the impact on fruit production and quality, may compromise management orchard techniques such as chemical thinning and influence the next harvest by reducing the production due to lower formation of reproductive structures in the plants [6,7].

In some subtropical climate countries such as Brazil, a few regions present favorable conditions to overcome apple tree dormancy [8,9]. In these areas, the solution for the cultivation has been the selection of cultivars with low chilling requirement combined with the application of bud break promoters and cultural practices to break dormancy, providing adequate bud brake and flowering [10,11].

The main desirable characteristics of chemical substances are good efficiency for the bud break induction, low cost and minimum toxicity to plants and environment [12]. Despite the existence of a large number of effective substances for bud break induction, only a few are used commercially. The high cost of application and the high toxicity of the compounds are the main limiting factors [13]. Hydrogen cyanamide combined with mineral oil is the most effective compound for bud break induction and is extensively used in the cultivation of apple trees and other temperate climate fruit trees for more than 20 years in Brazil [14,15]. However, the toxicity of hydrogen cyanamide is diversifying the standard recommendation to break dormancy of apple trees by alternative substances less harmful to the agrochemical applicator and environment [16].

Organic nitrogen compounds has shown potential for commercial use. The combination of these inducers with calcium nitrate has proved promising for bud break induction of apple trees [17,7].

Studies carried out in different countries have shown promising results of Bluprins® bio-stimulant on bud break induction and flowering uniformity for trees of table grapes, cherries and kiwifruit. Preliminary positive results were also obtained for apple and peach trees [18]. Bluprins® is a concentrated gel formulation for breaking bud dormancy of temperate fruit trees containing polysaccharides, amino acids, nitrogen and organic carbon [19].

In this context, the aim of this study was to test the efficiency of Bluprins® combined with calcium nitrate and ammonium nitrate as an alternative to hydrogen cyanamide in relation to bud break induction in 'Maxi Gala' and 'Fuji Suprema' apple tree cultivars.

2. MATERIAL AND METHODS

The experiment was carried out in an experimental orchard located in the municipality of Caçador, Santa Catarina State, Brazil (26º50'S, 50º58'O, 941 m a.s.l) during the 2013/2014, 2014/2015, 2015/2016 and 2016/2017 growing seasons. Eight-year-old plants of 'Maxi Gala' and 'Fuji Suprema' apple trees were grafted on rootstock Marubakaido and M-9 as interstock. The orchard density was about 2,500 plants ha^{-1} and the plants were trained to a central leader system. Orchard management practices were applied according to recommendations for the apple production system [20].

The experimental design was a randomized blocks with five replications of a single tree. The treatments evaluated were: 1. Control (untreated); 2. Mineral oil 3.5% + hydrogen cyanamide 0.35%; 3. Bluprins® 3.0% + calcium nitrate [$Ca(NO_3)_2$] 3.0%; 4. Bluprins® 5.0% + calcium nitrate 3.0%; 5. Bluprins® 3.0% + calcium nitrate 5.0%; 6. Bluprins® 5.0% + calcium nitrate 5.0%; 7. Bluprins® 3.0% + calcium nitrate 3.0% + ammonium nitrate [$NH_4(NO_3)$] 3.0%; 8. Bluprins® 5.0% + calcium nitrate 4.0% + ammonium nitrate 4.0%.The bio-stimulant used is the commercial product Bluprins®, composed of water, ammonium nitrate, sugar cane molasses, amino acids, citric acid, sodium hydroxide, supplying 4% ammoniacal N, 4% nitric N, 0.7% organic N and 5.5% organic C. The commercial product Dormex®, which has 52% of active ingredient, was used as source of hydrogen cyanamide. The commercial product Assist® was used as source of mineral oil (75.6%). Compounds were applied with a motorized backpack sprayer. Application time was performed on 06/09/2013, 03/09/2014, 26/08/2015 and 25/08/2016 for the growing seasons of 2013/2014, 2014/2015, 2015/2016 and 2016/2017, respectively.

The phenology, axillary and terminal bud break and fruit set were evaluated. The evaluation of flowering phenology consisted of determining the dates of occurrence of the green tip stage (C-C3), start of flowering, full bloom and end of flowering [20, 16]. The start of flowering was considered when the plants had 5% of the flowers open, full bloom more than 80% and the end of flowering was defined when the last flowers were open.

The axillary bud break was obtained by counting both burst and dormant buds in five one-year-old shoots previously selected, located in the middle third of the plant. A scaffold branch was selected to estimate the percentage of terminal bud break. These data were collected at 30 and 60 days after dormancy breaking (DADB). The fruit set was obtained as a percentage in 100 flower cluster in the same scaffold branch used to estimate terminal bud break. Fruit production per tree and average fruit weight were also measured.

The data were submitted to analysis of variance (ANOVA). Percentage data were transformed by the formula arcsine [(x + 1) / 100] 1/2 before being submitted to ANOVA. Treatment means were compared using the Scott-Knott test at 5% probability. The statistical analysis were performed by the Sisvar program version 5.6 [21].

3.1 RESULTS AND DISCUSSION

For ‘Maxi Gala’ apple trees, the phenological stage C-C3 was different between the control treatment and the other treatments. The application of mineral oil + hydrogen cyanamide advanced this stage 19 days, 21 days, 24 days and 23 days compared to the control treatment in the growing seasons of 2013/2014, 2014/2015, 2015/2016 and 2016/2017, respectively. The treatments containing Bluprins® also advanced this stage from 5 to 15 days in 2013/2014, from 13 to 19 days in 2014/2015, from 5 to 7 days in 2015/2016 and from 14 to 17 days in comparison to the control treatment in 2016/2017 (Table 1). In the 2013/2014 growing season, for ‘Fuji Suprema’ apple trees, there was not a defined period that characterized the C-C3 stage for the control treatment. Considering the other treatments, this stage occurred practically at the same date. In the 2014/2015 growing season, the treatments containing Blueprins® advanced the C-C3 stage from 1 to 8 days in relation to the control treatment, and delayed this stage from 2 to 5 days in relation to mineral oil + hydroxygen cyanamide. In the 2015/2016 and 2016/2017 growing seasons, all the treatments advanced this stage from 2 to 8 days and from 4 to 10 days, respectively, in relation to the control treatment (Table 2).

Table 1 – Phenological stages of ‘Maxi Gala’ apple trees under the influence of compounds for bud break in four growing seasons (Date/Month). Caçador, SC, 2016.

Treatments	C–C3	Bud break	Flowering		
			Start	Full bloom	End
	2013/2014				
1. Control	10/10	14/10	14/10	21/10	28/10
2. MO 3,5% + HC 0,35%	21/09	06/10	08/10	12/10	19/10
3. B 3% + $Ca(NO_3)_2$ 3%	05/10	08/10	08/10	20/10	23/10
4. B 5% + $Ca(NO_3)_2$ 3%	25/09	08/10	08/10	18/10	23/10
5. B 3% + $Ca(NO_3)_2$ 5%	05/10	08/10	08/10	20/10	23/10
6. B 5% + $Ca(NO_3)_2$ 5%	25/09	06/10	08/10	12/10	23/10
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	25/09	06/10	08/10	18/10	25/10
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	05/10	12/10	12/10	21/10	26/10
	2014/2015				
1. Control	12/10	12/10	12/10	24/10	28/10
2. MO 3,5% + HC 0,35%	21/09	25/09	28/09	03/10	14/10
3. B 3% + $Ca(NO_3)_2$ 3%	29/09	02/10	04/10	12/10	20/10
4. B 5% + $Ca(NO_3)_2$ 3%	26/09	29/09	29/09	12/10	18/10
5. B 3% + $Ca(NO_3)_2$ 5%	26/09	29/09	30/09	12/10	21/10
6. B 5% + $Ca(NO_3)_2$ 5%	23/09	25/09	30/09	08/10	18/10
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	28/09	01/10	01/10	12/10	21/10
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	29/09	03/10	04/10	12/10	21/10

	2015/2016				
1. Control	10/10	-	10/10	28/10	05/11
2. MO 3,5% + HC 0,35%	16/09	21/09	21/09	24/09	30/09
3. B 3% + $Ca(NO_3)_2$ 3%	23/09	25/09	27/09	08/10	26/10
4. B 5% + $Ca(NO_3)_2$ 3%	23/09	25/09	25/09	01/10	04/10
5. B 3% + $Ca(NO_3)_2$ 5%	21/09	22/09	25/09	28/09	04/10
6. B 5% + $Ca(NO_3)_2$ 5%	21/09	25/09	26/09	11/10	26/10
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	21/09	24/09	25/09	30/09	09/10
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	21/09	22/09	25/09	28/09	04/10
	2016/2017				
1. Control	05/10	08/10	08/10	16/10	20/10
2. MO 3,5% + HC 0,35%	12/09	17/09	21/09	30/09	06/10
3. B 3% + $Ca(NO_3)_2$ 3%	21/09	30/09	30/09	08/10	10/10
4. B 5% + $Ca(NO_3)_2$ 3%	19/09	30/09	30/09	06/10	10/10
5. B 3% + $Ca(NO_3)_2$ 5%	21/09	30/09	30/09	06/10	10/10
6. B 5% + $Ca(NO_3)_2$ 5%	21/09	30/09	30/09	05/10	15/10
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	18/09	22/09	30/09	06/10	10/10
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	18/09	20/09	25/09	21/10	08/10

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®.

Table 2 – Phenological stages of 'Fuji Suprema' apple trees under the influence of compounds for bud break in four growing seasons (Date/Month). Caçador, SC, 2016.

Treatments	**C–C3**	**Bud break**	**Flowering**		
			Start	**Full bloom**	**End**
	2013/2014				
1. Control	-	07/10	07/10	15/10	22/10
2. MO 3,5% + HC 0,35%	25/09	04/10	05/10	08/10	16/10
3. B 3% + $Ca(NO_3)_2$ 3%	25/09	06/10	06/10	15/10	22/10

4. B 5% + $Ca(NO_3)_2$ 3%	25/09	03/10	05/10	08/10	15/10
5. B 3% + $Ca(NO_3)_2$ 5%	25/09	04/10	05/10	08/10	16/10
6. B 5% + $Ca(NO_3)_2$ 5%	25/09	04/10	05/10	08/10	16/10
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	25/09	03/10	06/10	08/10	12/10
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	23/09	04/10	03/10	07/10	15/10
2014/2015					
1. Control	01/10	03/10	10/10	20/10	28/10
2. MO 3,5% + HC 0,35%	25/09	27/09	30/09	04/10	08/10
3. B 3% + $Ca(NO_3)_2$ 3%	30/09	02/10	06/10	10/10	18/10
4. B 5% + $Ca(NO_3)_2$ 3%	28/09	30/09	01/10	08/10	12/10
5. B 3% + $Ca(NO_3)_2$ 5%	28/09	01/10	03/10	10/10	18/10
6. B 5% + $Ca(NO_3)_2$ 5%	29/09	30/09	03/10	10/10	15/10
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	23/09	29/09	28/09	03/10	18/10
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	27/09	30/09	03/10	10/10	18/10
2015/2016					
1. Control	25/09	25/09	26/09	-	28/10
2. MO 3,5% + HC 0,35%	17/09	20/09	18/09	25/09	30/09
3. B 3% + $Ca(NO_3)_2$ 3%	23/09	23/09	22/09	27/09	30/09
4. B 5% + $Ca(NO_3)_2$ 3%	20/09	22/09	21/09	26/09	30/09
5. B 3% + $Ca(NO_3)_2$ 5%	19/09	21/09	21/09	26/09	30/09
6. B 5% + $Ca(NO_3)_2$ 5%	17/09	21/09	18/09	26/09	30/09
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	17/09	21/09	19/09	26/09	30/09
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	19/09	21/09	21/09	26/09	30/09
2016/2017					
1. Control	24/09	03/10	26/09	06/10	14/10
2. MO 3,5% + HC 0,35%	14/09	23/09	20/09	30/09	07/10
3. B 3% + $Ca(NO_3)_2$ 3%	20/09	26/09	26/09	04/10	12/10
4. B 5% + $Ca(NO_3)_2$ 3%	18/09	23/09	25/09	30/09	07/10
5. B 3% + $Ca(NO_3)_2$ 5%	14/09	25/09	25/09	01/10	05/10
6. B 5% + $Ca(NO_3)_2$ 5%	14/09	24/09	20/09	30/09	05/10

7. B 3%+Ca$(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	14/09	20/09	20/09	30/09	04/10
8. B 5%+Ca$(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	15/09	25/09	25/09	01/10	07/10

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®.

The bud break was also advanced in both cultivars by the application of bud break promoters. However, there were small differences between mineral oil + hydrogen cyanamide and the Bluprins® treatments. The start, full bloom and end of flowering were advanced in relation to the control treatment for 'Maxi Gala' and 'Fuji Suprema' cultivars in the four growing seasons, and the Bluprins® treatments showed a tendency to delay these phenological stages in a few days in relation to treatment mineral oil + hydrogen cyanamide (Tables 1 and 2).

In the 2013/2014 growing season, the flowering period was prolonged in the control treatment compared to the other treatments. For ‘Maxi Gala’, the flowering period comprised of 14 days in the control trees, whereas the other treatments varied between 11 to 15 days. For ‘Fuji Suprema’, the flowering period comprised of 15 days in the control trees, and varied between 6 to 16 days in the other treatments. In the 2014/2015, 2015/2016 and 2016/2017 growing seasons, the other treatments provide a shortened flowering period compared to the control treatment only for 'Fuji Suprema', varying from 8 to 12 days, and from 10 to 17 days, respectively in 2015/2016 and 2016/2017, while the control trees had a flowering period of 32 and 18 days, respectively. For ‘Maxi Gala’, the treatments presented this period equal to or greater than the control treatment in the 2014/2015 and 2016/2017 growing seasons (Tables 1 and 2).

According to Kozmá et al. [22], the duration of the flowering period is influenced by environmental conditions, being longer under low chilling accumulation during the winter. Petri and Leite [4] state that prolonged flowering periods may difficult some cultural practices such as thinning and disease control, due to the occurrence of different phenological stages within the same plant. The efficiency of bud break promoters can be evaluated by the duration of the flowering period, and the most efficient treatments are those with shorter flowering period and more uniform flowering, ripening and harvesting. The results of this work showed that Bluprins® acts in the advance and shortening of the flowering period of apple trees under mild winter conditions.

The axillary bud break was maximized by the bud break promoters at 30 and 60 DADB for ‘Maxi Gala’ and ‘Fuji Suprema’ apple trees in the four growing seasons (Tables 3 and 4). According to Petri [23], the rate of axillary bud break is the variable that better express the efficiency of bud break promoters, and can be used as indicative of cultivar adaptation to local environmental conditions. However, the efficiency of bud break promoters depends, in addition to the cultivar, on the vigor of the plant, time of application and concentration of the bud break promoter.

‘Maxi Gala’ cultivar showed lower axillary bud break compared to ‘Fuji Suprema’ cultivar. Hawerroth et al. [24] discussed the higher difficult in inducing bud break in ‘Maxi Gala’ apple trees, requiring more efficient bud brake promoters. For this cultivar, the treatment mineral oil + hydrogen cyanamide showed higher axillary bud break in relation to the other treatments at 30 and 60 DADB in the four growing seasons. The treatments Bluprins® 3% + $Ca(NO_3)_2$ 3% and Bluprins® 5% + $Ca(NO_3)_2$ 3% differed from the other treatments in the 2013/2014 growing season. In 2014/2015 and 2016/2017, there were no differences between Bluprins® treatments and the control treatment. In 2015/2016, the treatment Bluprins® 3% + $Ca(NO_3)_2$ 5% provided higher axillary bud break in relation to the control treatment and other Bluprins® treatments (Table 3). For ‘Fuji Suprema apple trees’, at 30 and 60 DADB, all treatments showed higher axillary bud break compared to the control treatment in the 2013/2014 growing season, without differences among them. Pasa et al. [7] verified that a nutritive solution containing calcium nitrate and mineral oil showed similar effects to hydrogen cyanamide on axillary bud break of this cultivar. In 2014/2015, except for the treatment Bluprins® 3% + $Ca(NO_3)_2$ 3%, all treatments presented higher axillary bud break compared to the control treatment. The treatment mineral oil + hydrogen cyanamide presented the highest axillary bud break, followed by Bluprins® 5% + $Ca(NO_3)_2$ 3%. In 2015/2016, the treatment Bluprins® 5% + $Ca(NO_3)_2$ 4% + NH_4 (NO_3) 4% was superior to the other Bluprins® treatments at 30 DADB. At 60 DADB, this treatment and the treatment Bluprins® 3% + $Ca(NO_3)_2$ 3% + NH_4 (NO_3) 3% were superior to the other Bluprins® treatments. However, both treatments were lower than the treatment mineral oil + hydrogen cyanamide at 30 and 60 DADB. In 2016/2017, the treatment Bluprins® 5% + $Ca(NO_3)_2$ 4% + NH_4 (NO_3) 4% was superior to the other Bluprins® treatments at 30 and 60 DADB, and did not differ from the treatment mineral oil + hydrogen cyanamide (Table 4). The low axillary bud break, similar to that verified in this work, has already been studied by Leite et al. [25], who conclude that temperate fruit trees cultivated in subtropical climate conditions, where the chilling requirement is not satisfied, present low bud break levels associated with high bud break and flowering heterogeneity along the branches.

Table 3 – Axillary bud break (%) of 'Maxi Gala' apple trees under the influence of compounds for bud break during four growing seasons. Caçador, SC, 2016.

Treatments	Axillary bud break (%)							
	2013/2014		2014/2015		2015/2016		2016/2017	
	30 DADB	60 DADB	30 DADB	60 DADB	30 DADB	60 DADB	30 DADB	60 DADB
1. Control	1.1 c	3.8 c	1.2 b	4.9 b	0.9 c	1.8 c	0.0 b	1.0 b
2. MO 3,5% + HC 0,35%	41.5 a	43.8 a	20.9 a	26.0 a	23.0 a	25.7 a	13.5 a	24.4 a
3. B 3% + $Ca(NO_3)_2$ 3%	22.0 b	23.7 b	2.5 b	9.5 b	2.2 c	4.6 c	0.9 b	2.0 b
4. B 5% + $Ca(NO_3)_2$ 3%	22.4 b	25.3 b	3.9 b	7.4 b	1.8 c	1.8 c	3.1 b	3.8 b
5. B 3% + $Ca(NO_3)_2$ 5%	9.2 c	12.5 c	3.8 b	10.0 b	8.5 b	9.8 b	5.7 b	7.7 b
6. B 5% + $Ca(NO_3)_2$ 5%	16.6 c	19.6 c	6.7 b	10.2 b	3.1 c	4.7 c	3.5 b	5.3 b
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	11.8 c	16.5 c	3.8 b	5.9 b	1.6 c	3.5 c	3.5 b	7.6 b
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	8.2 c	9.8 c	5.1 b	10.7 b	2.2 c	3.1 c	3.5 b	4.9 b
CV (%)	72.2	61.4	55.8	33.2	66.2	57.6	69.0	43.0

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®. DADB: Days after dormancy breaking; CV: coefficient of variation. Means followed by same letter do not differ by Scott-Knott test at 5% probability.

Table 4 – Axillary bud break (%) of 'Fuji Suprema' apple trees under the influence of compounds for bud break during four growing seasons. Caçador, SC, 2016.

Treatments	Axillary bud break (%)							
	2013/2014		2014/2015		2015/2016		2016/2017	
	30	60	30	60	30	60	30	60

	DADB	DADB	DADB	DADB	DADB	DADB	DADB	DADB
1. Control	3.3 b	12.6 b	0.0 d	5.2 d	0.0 d	4.4 c	15.2 c	22.6 c
2. MO 3,5% + HC 0,35%	53.1 a	60.2 a	48.0 a	51.9 a	50.1 a	50.1 a	65.5 a	81.0 a
3. B 3% + $Ca(NO_3)_2$ 3%	39.3 a	43.0 a	2.6 d	7.5 d	2.9 d	5.7 c	20.2 c	25.8 c
4. B 5% + $Ca(NO_3)_2$ 3%	52.7 a	59.4 a	22.3 b	30.3 b	5.1 c	7.3 c	32.3 b	48.4 b
5. B 3% + $Ca(NO_3)_2$ 5%	48.0 a	58.5 a	14.4 c	20.3 c	1.6 d	7.2 c	41.2 b	45.9 b
6. B 5% + $Ca(NO_3)_2$ 5%	56.1 a	62.3 a	11.3 c	14.2 c	0.6 d	4.6 c	33.4 b	37.2 b
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	72.4 a	73.8 a	13.7 c	20.0 c	7.9 c	11.0 b	25.2 c	29.2 c
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	55.6 a	71.3 a	11.4 c	14.9 c	18.8 b	19.9 b	67.3 a	70.9 a
CV (%)	27.8	27.9	47.2	31.0	49.0	35.4	25.5	21.5

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®. DADB: Days after dormancy breaking; CV: coefficient of variation. Means followed by same letter do not differ by Scott-Knott test at 5% probability.

For ‘Maxi Gala’ apple trees, the treatment mineral oil + hydrogen cyanamide showed higher terminal bud break than the other treatments at 30 and 60 DADB in the 2013/2014 and 2015/2016 growing seasons. This treatment and the treatment Bluprins® 3% + $Ca(NO_3)_2$ 3% achieved higher terminal bud break than the other treatments at 30 DADB in 2014/2015 and at 60 DADB in 2016/2017. The Bluprins® treatments were superior to the control at 30 DADB in 2013/2014, 2014/2015 and 2015/2016. In 2016/2017, all the Bluprins® treatments were superior to the control at 30 and 60 DADB, and at 30 DADB, they did not differ from the treatment mineral oil + hydrogen cyanamide (Table 5). Marchi et al. [26] found that even terminal buds, which require low stimulus to break the dormancy, [27] only showed a high bud break by the application of mineral oil + hydrogen cyanamide. However, Pasa et al. [7] did not find differences between plants treated with hydrogen cyanamide, nutrient solution containing calcium nitrate and control (untreated) plants, considering terminal bud break. For 'Fuji Suprema' apple trees, all the treatments showed higher terminal bud break compared to the control at 30 DAQD in 2013/2014. At 60 DADB, the treatments Bluprins® 3% + $Ca(NO_3)_2$ 3% and Bluprins® 3% + $Ca(NO_3)_2$ 5% provided lower terminal bud break than the other Bluprins® treatments and the treatment mineral oil + hydrogen cyanamide. The treatment mineral oil + hydrogen cyanamide was superior to the other treatments in 2014/2015 at 30 DADB, whereas the treatment Bluprins® 3% + $Ca(NO_3)_2$ 3% was superior to the control treatment and the other Bluprins® treatments. At 60 DADB, the treatments mineral oil + hydrogen cyanamide, Bluprins® 3% + $Ca(NO_3)_2$ 3% and Bluprins® 5% + $Ca(NO_3)_2$ 3% were superior to the other treatments. In 2015/2016, at 60 DAQD, the treatments Bluprins® 3% + $Ca(NO_3)_2$ 5%, Bluprins® 5% + $Ca(NO_3)_2$ 3% and Bluprins® 5% + $Ca(NO_3)_2$ 4% + $NH_4(NO_3)$ 4% did not differ from the control, while the other treatments were superior to the control, not differing from the treatment mineral oil + hydrogen cyanamide. In 2016/2017, only the treatment Bluprins® 5% + $Ca(NO_3)_2$ 3% did not differ from the control treatment. The other treatments presented higher terminal bud break and did not differ from each other at 30 and 60 DADB (Table 6). For both 'Maxi Gala' and 'Fuji Suprema' apple trees, the high terminal bud break confirms the good efficiency of Bluprins® associated with calcium nitrate regardless of its concentration.

Table 5 – Terminal bud break (%) of 'Maxi Gala' apple trees under the influence of compounds for bud break during four growing seasons. Caçador, SC, 2016.

Treatments	Terminal bud break (%)							
	2013/2014		2014/2015		2015/2016		2016/2017	
	30 DADB	60 DADB	30 DADB	60 DADB	30 DADB	60 DADB	30 DADB	60 DADB
1. Control	15.9 c	60.3 b	12.6 c	52.9 ^{ns}	8.2 c	35.6 b	26.7 b	45.7 c
2. MO 3,5% + HC 0,35%	96.1 a	96.4 a	71.8 a	77.1	80.6 a	90.8 a	77.2 a	90.6 a
3. B 3% + $Ca(NO_3)_2$ 3%	57.8 b	57.5 b	43.9 b	68.1	27.9 b	49.2 b	55.4 a	66.8 b
4. B 5% + $Ca(NO_3)_2$ 3%	46.8 b	68.4 b	36.0 b	59.2	37.6 b	61.2 b	53.4 a	70.1 b
5. B 3% + $Ca(NO_3)_2$ 5%	42.2 b	60.3 b	32.0 b	72.1	38.4 b	60.8 b	59.5 a	83.5 a
6. B 5% + $Ca(NO_3)_2$ 5%	68.3 b	78.5 b	45.9 b	63.2	34.5 b	65.1 b	57.7 a	69.6 b
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	62.9 b	71.9 b	51.3 b	73.3	33.4 b	44.0 b	63.1 a	72.8 b
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	51.0 b	64.8 b	37.3 b	71.7	29.6 b	56.7 b	65.4 a	74.2 b
CV (%)	24.8	17.9	29.8	18.3	26.1	21.9	24.2	15.6

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®. DADB: Days after dormancy breaking; CV: coefficient of variation. Means followed by same letter do not differ by Scott-Knott test at 5% probability. ns: not significant.

Table 6 – Terminal bud break (%) of 'Fuji Suprema' apple trees under the influence of compounds for bud break during four growing seasons. Caçador, SC, 2016.

Treatments	**Terminal bud break (%)**							
	2013/2014		**2014/2015**		**2015/2016**		**2016/2017**	
	30 DADB	**60 DADB**	**30 DADB**	**60 DADB**	**30 DADB**	**60 DADB**	**30 DADB**	**60 DADB**
1. Control	46.7 c	80.2 b	24.3 c	80.3 b	30.9^{ns}	83.6 b	69.2 b	82.6 b
2. MO 3,5% + HC 0,35%	89.7 a	94.0 a	86.3 a	96.2 a	73.3	99.4 a	95.0 a	97.7 a
3. B 3% + $Ca(NO_3)_2$ 3%	68.5 b	86.2 b	59.2 b	87.5 a	52.5	98.3 a	78.5 b	91.3 b
4. B 5% + $Ca(NO_3)_2$ 3%	88.9 a	100 a	44.1 c	88.2 a	53.1	97.0 a	95.1 a	97.8 a
5. B 3% + $Ca(NO_3)_2$ 5%	74.5 b	87.9 b	44.9 c	77.8 b	48.4	93.6 b	95.3 a	95.8 a
6. B 5% + $Ca(NO_3)_2$ 5%	95.2 a	97.8 a	29.2 c	82.7 b	46.1	92.3 b	91.0 a	97.5 a
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	96.3 a	99.6 a	37.8 c	70.0 b	63.2	95.6 a	92.6 a	98.2 a
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	90.7 a	99.4 a	36.0 c	81.2 b	59.9	80.3 b	96.2 a	99.3 a
CV (%)	16.0	7.1	28.1	14.1	21.9	12.2	13.1	10.7

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®. DADB: Days after dormancy breaking; CV: coefficient of variation. Means followed by same letter do not differ by Scott-Knott test at 5% probability. ns: not significant.

For 'Maxi Gala' apple trees, the treatments Bluprins® 3% + $Ca(NO_3)_2$ 3% and Bluprins® 3% + $Ca(NO_3)_2$ 3% + $NH_4(NO_3)$ 3% were superior to the other treatments in the 2015/2016 growing season. In 2013/2014, 2014/2015 and 2016/2017, the treatments showed no differences. For 'Fuji Suprema' apple trees, the treatments Bluprins® 5% + $Ca(NO_3)_2$ 3% and Bluprins® 3% + $Ca(NO_3)_2$ 3% + $NH_4(NO_3)$ 3% did not differ from the control treatment and were significantly superior to the other treatments in 2013/2014. In 2014/2015 and 2015/2016, the treatments showed no differences. In 2016/2017, the control treatment showed a higher fruit set in relation to the others. Erez [12] and Petri and Leite [4] discussed the possibility of reduction in the fruit set when bud break promoters are applied, due to non-synchronization of the pollination between cultivars under conditions of insufficient cold accumulation during the winter period, or due to climate conditions that affect the pollination activity and the pollen viability. The high fruit set values obtained in some treatments indicates that there were no problems related to pollination and that the concentration of the flowering period for the treatments with bud break promoters did not reduce the fruit set, even though the flowering period was more concentrated in the treatments with bud break promoters in comparison to the control treatment. El-Agamy et al. [28] verified a negative effect of the treatments with hydrogen cyanamide on the fruit set for 'Anna' cultivar. According to Erez [12], in some situations, the use of bud break promoters may result in a drastic reduction of the fruit set due to the nutritional competition established between vegetative and reproductive sinks. For both cultivars, the fruit set was equal to or higher than the treatment mineral oil + cyanamide hydrogen.

Considering the fruit production per tree, the treatments Bluprins® 5% + $Ca(NO_3)_2$ 3%, Bluprins® 3% + $Ca(NO_3)_2$ 3%+ $NH_4(NO_3)$ 3% and Bluprins® 5% + $Ca(NO_3)_2$ 4%+ $NH_4(NO_3)$ 4% resulted in higher values compared to the other treatments for 'Maxi Gala' apple trees in the 2013/2014 growing season. Apple trees treated with Bluprins® 3% + $Ca(NO_3)_2$ 3%+ NH_4 (NO_3) 3% produced 19.9 kg $tree^{-1}$ and the control treatment, 9.0 kg $tree^{-1}$, an increase of 121.1%. There were no significant differences between treatments in the 2014/2015 growing season (Table 7). The harvest was not evaluated in 2015/2016. For 'Fuji Suprema' apple trees in 2013/2014, the treatments Bluprins® 3% + $Ca(NO_3)_2$ 3% and Bluprins® 3% + $Ca(NO_3)_2$ 3%+ $NH_4(NO_3)$ 3% resulted in lower fruit production per tree than the other treatments and did not differ from the control treatment in the 2013/2014 growing season. In the 2014/2015 growing season, except for the treatment Bluprins® 3% + $Ca(NO_3)_2$ 3%+ $NH_4(NO_3)$ 3%, the treatments resulted in lower production of fruit per tree compared to the control treatment. In 2015/2016, the harvest was not evaluated and in 2016/2017, the treatments did not differ from each other (Table 8). The average fruit weight did not show significant differences between treatments in the 2013/2014 and 2015/2016 growing seasons for 'Maxi gala', and in 2013/2014, 2014/2015 and 2015/2016, for 'Fuji Suprema' cultivar. In the 2014/2015 growing season, for 'Maxi Gala' apple trees, the treatments Bluprins® 5% + $Ca(NO_3)_2$ 3%, Bluprins® 3% + $Ca(NO_3)_2$ 3%+ $NH_4(NO_3)$ 3% and Bluprins® 5% + $Ca(NO_3)_2$ 4%+ $NH_4(NO_3)$ 4%, did not differ from the control treatment and resulted in lower values than the other treatments (Tables 7 and 8).

Table 7 – Fruit production per plant (FPP, kg) and average fruit weight (AFW, g) of 'Maxi Gala' apple trees under the influence of compounds for bud break during tree growing seasons. Caçador, SC, 2016.

Treatments	2013/2014		2014/2015		2016/2017	
	FPP (kg)	AFW (g)	FPP (kg)	AFW (g)	FPP (kg)	AFW (g)
1. Control	9.0 b	145.1 ns	8.0 ns	120.9 b	4.7 b	132.8 ns
2. MO 3,5%+HC 0,35%	3.9 b	137.4	13.1	138.0 a	8.4 a	139.7
3. B 3% + $Ca(NO_3)_2$ 3%	9.4 b	165.3	10.1	133.0 a	5.0 b	154.3
4. B 5% + $Ca(NO_3)_2$ 3%	13.9 a	141.3	13.6	118.6 b	4.9 b	148.3
5. B 3% + $Ca(NO_3)_2$ 5%	16.1 a	142.6	11.0	130.3 a	3.7 b	149.4
6. B 5% + $Ca(NO_3)_2$ 5%	9.6 b	149.6	14.6	130.1 a	6.8 b	151.8
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	19.9 a	140.6	15.2	121.4 b	10.5 a	150.1
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	16.6 a	140.0	12.8	119.2 b	6.0 b	140.9
CV (%)	33.2	11.2	39.8	8.1	52.1	12.4

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®; CV: coefficient of variation. Means followed by same letter do not differ by Scott-Knott test at 5% probability. ns: not significant.

Table 8 – Fruit production per plant (FPP, kg) and average fruit weight (AFW, g) of 'Maxi Gala' apple trees under the influence of compounds for bud break during tree growing seasons. Caçador, SC, 2016.

Treatments	2013/2014		2014/2015		2016/2017*	
	FPP (kg)	AFW (g)	FPP (kg)	AFW (g)	FPP (kg)	AFW (g)
1. Control	25.9 b	123.6 ns	35.1 a	129.2 ns	19.6 ns	101.7 ns
2. MO 3,5%+HC 0,35%	35.6 a	113.9	19.7 b	120.5	11.8	118.2
3. B 3% + $Ca(NO_3)_2$ 3%	23.4 b	116.7	15.4 b	138.0	14.6	102.2

4. B 5% + $Ca(NO_3)_2$ 3%	34.5 a	120.3	23.0 b	124.8	15.4	111.1
5. B 3% + $Ca(NO_3)_2$ 5%	40.6 a	118.7	17.8 b	126.6	14.4	104.6
6. B 5% + $Ca(NO_3)_2$ 5%	42.7 a	113.6	19.6 b	125.5	17.9	102.5
7. B 3%+$Ca(NO_3)_2$ 3%+$NH_4(NO_3)$ 3%	14.2 b	125.9	37.3 a	122.7	11.8	114.8
8. B 5%+$Ca(NO_3)_2$ 4%+$NH_4(NO_3)$ 4%	38.0 a	111.3	13.3 b	122.1	15.2	112.0
CV (%)	31.9	118.0	22.7	126.2	33.1	12.2

MO: Mineral oil; HC: Hydrogen cyanamide; B: Bluprins®; CV: coefficient of variation. Means followed by same letter do not differ by Scott-Knott test at 5% probability. ns: not significant.

4.1 CONCLUSION

Bluprins® in combination with calcium nitrate and ammonium nitrate proved effective in inducing bud break of ‘Maxi Gala’ e ‘Fuji Suprema’ apple tree cultivars under mild winter conditions. Bluprins® in combination with calcium nitrate and ammonium nitrate anticipates the bud break and flowering period and reduces the flowering period for ‘Maxi Gala’ and ‘Fuji Suprema’ apple tree cultivars. Bluprins® does not compromise the fruit set and fruit production of ‘Maxi Gala’ and ‘Fuji Suprema’ apple tree cultivars.

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