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# SEQUENTIAL APPLICATION OF BUD BREAK PROMOTERS IN APPLE (*Malus domestica*) CV. 'MAXI GALA' AND 'FUJI SUPREMA'

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## Abstract

Sequential application consists of reapplying the dormancy break treatment for greater uniformity of bud breaking and flowering. The objective of this study was to assess the effect of the reapplication of bud break promoters on the flowering and bud breaking of 'Maxi Gala' and 'Fuji Suprema' apple cultivars. The experiment was carried out in an experimental orchard located in the municipality of Caçador, SC, Brazil (26°50'S; 50°58'W, 960m altitude), during the seasons from 2016/2017 to 2019/2020. Treatments were applied in stages B and C, and those with reapplication were applied from 7 to 14 days after the first application. Phenology, axillary and terminal bud breaking, fruit set, production per plant and average fruit mass were evaluated. Phenology was advanced compared to the control treatment with the application of bud break promoters, regardless of application stage and sequential application. However, treatments applied in stage B promoted a greater advance compared to the applications in stage C. Regarding axillary and terminal bud breaking, all treatments were superior to the control treatment in the four years evaluated. In some seasons, the sequential application of bud break promoters increased axillary and terminal bud breaking compared to the standard treatment, with a single application. Fruit set was reduced in some treatments compared to the control in 2016/17. Some treatments with reapplication improved the yield of apple trees, and the MO 3.5% + HC 0.7% stage B + MO 3.5% 10DA treatment increased the average production per plant by 78.5% compared to the control treatment and by 130.9% compared to the single-application treatment. On average, the reapplication of bud break promoters increased the average fruit mass.

**Index Terms:** *Malus domestica*, dormancy breaking, phenology

# APLICAÇÃO SEQUENCIAL DE INDUTORES DE BROTAÇÃO NA MACIEIRA (Malus domestica) CV. 'MAXI GALA' E 'FUJI SUPREMA'

## Resumo

A aplicação sequencial consiste na reaplicação do tratamento de quebra de dormência para maior uniformização da brotação e da floração. O objetivo do trabalho foi verificar o efeito da reaplicação dos indutores de brotação na floração e brotação da macieira 'Maxi Gala' e 'Fuji Suprema'. O experimento foi desenvolvido em pomar experimental localizado no município de Caçador, SC (26°50'S; 50°58'W, 960m altitude), durante os ciclos de 2016/2017 a 2019/2020. Os tratamentos foram aplicados no estádio B e C e, os com reaplicação, de 7 a 14 dias após a primeira aplicação. Foram realizadas a avaliação da fenologia, brotação de gemas axilares e terminais, frutificação efetiva, produção por planta e massa média dos frutos. A fenologia foi adiantada em relação ao tratamento controle com a aplicação dos indutores de brotação independente do estádio de aplicação e a aplicação sequencial. Todavia, os tratamentos aplicados no estádio B propiciaram um maior adiantamento em relação às aplicações no estádio C. A brotação das gemas axilares e terminais, todos os tratamentos foram superiores ao tratamento controle nos quatro anos avaliados. Em alguns ciclos, a aplicação sequencial de indutores de brotação aumentou a brotação de gemas axilares e terminais em relação ao tratamento padrão, de uma única aplicação. A frutificação efetiva foi reduzida em alguns tratamentos em relação ao tratamento controle no ano de 2016/17. Alguns

tratamentos com reaplicação melhoraram a produtividade das macieiras, sendo que o tratamento MO 3,5% + HC 0,7% estádio B + OM 3,5% 10DA aumentou a produtividade média por planta em 78,5% em relação ao tratamento controle e a 130,9% em relação ao tratamento de aplicação única. Na média, a reaplicação de indutores de brotação aumentou a massa média dos frutos.

**Termos para Indexação:** *Malus domestica*, quebra de dormência, fenologia

## Introduction

In Brazil, apple cultivation is located in the southern region in areas where the chilling requirement of the main cultivars is not fully met (PETRI et al., 2008).

In this context, under milder winter conditions, several practices for artificially overcoming dormancy have been used to mitigate some of the problems arising from cold deficiency, promoting adequate bud breaking and flowering in the main temperate climate species, even in subtropical regions (BENMOUSSA et al., 2018). Under conditions of insufficiency in winter cold, temperate climate fruit crops show abnormalities in relation to bud breaking, with consequences during the vegetative cycle and leading to a reduction in both yield and quality of the fruits produced (PASA et al., 2018). Bud breaking and flowering are delayed compared to regions with colder winters, with the bud breaking date varying from year to year depending on the amount of cold that has occurred. Historically, winter cold has declined, which has been well documented in several locations (DARBYSHIRE et al., 2013; LUEDAQLING et al., 2009), leading to adjustments for the production of temperate climate fruits in several regions (LUEDAQLING; BORWN, 2011; DARBYSHIRE et al., 2013). Both the regularity and the amount of cold are indispensable for natural overcoming of dormancy. Among the practices with the best performance for bud break induction under these conditions is the use of chemicals, called bud break promoters. The grower has difficulty predicting the flowering date and even with mathematical models the results can be inconsistent (LUEDELING; BORWN, 2011). With the reduction of the bud breaking rate, the total leaf area decreases, thereby reducing the overall photosynthesis of the plant. This can lead to deficiency in plant nutrition, with the most diverse consequences, such as low fruit set and reduction of the cycle between flowering and maturation. The first reference to the action of chemicals in breaking dormancy dates back to 1918, when it was found that apple trees sprayed with linseed oil mixed with water during the dormancy period, for combating aphids, flowered first and for a shorter period than those not sprayed (PETRI et al., 1978). In Brazil, the first studies on bud break induction in apple date back to 1972 (PETRI et al., 1978). From the 80's onwards, mineral oil (MO), hydrogen cyanamide (HC), and the combination of both, became the most widely used products to promote the bud breaking of temperate-climate fruit crops (MOHAMED, 2008).

Promoting bud breaking and flowering of fruit crops in already established orchards, by means of spraying with bud break promoters, is the practical way to mitigate the problems caused by insufficient cold. A new generation of products was developed in the 2000s, which contain inorganic nitrogen, amino acids, polysaccharides, glutamic acid and mineral nutrients. Erger®, Syncron®, Thidiazuron (TDZ), Siberio® and Bluprins®, in a mixture with calcium nitrate ($Ca(NO_3)_2$) or mineral oil, have an effect on inducing apple bud breaking, often showing results similar to those of the standard treatment with mineral oil plus hydrogen cyanamide. Most of the products are not allowed in organic or agroecological crops, as is the case with HC, already banned in some European countries. Application of MO alone may generate variable results, but with the sequential application of MO the problem can be corrected.

In some situations, there may be great variability in the response of plants to the application of the promoters, and there may be insufficient bud breaking, requiring new intervention. Sequential application consists of reapplying the treatment and can be performed on the whole plant or only on the upper part of the crown, standardizing bud breaking and flowering. With the new high-density planting systems, both in the plant formation and in the fruiting phases, it is important to obtain as much bud breaking as possible to avoid the lack of production branches as a result of poor bud breaking.

The objective of this study was to assess the effect of the reapplication of bud break promoters on the flowering and bud breaking of 'Maxi Gala' and 'Fuji Suprema' apple trees.

## Material and methods

The experiments were carried out in an experimental orchard located in the municipality of Caçador, SC, Brazil (26°50'S; 50°58'W, 960m altitude), during the seasons from 2016/2017 to 2019/2020. According to Köppen's classification, the climate in the growing region is classified as Cfb – temperate constantly humid, with mild summers. The average annual rainfall is 1653.2 mm and the average relative humidity is 77.9%. According to Petri et al.

(2010), the average chill accumulation during the autumn and winter period is 928 chill units, Modified North Carolina model (EBERT et al., 1986).

10-year-old plants of the cultivars 'Maxi Gala' and 'Fuji Suprema', grafted on the Marubakaido rootstock with M-9 interstock, were used. Planting density in the orchard used is 2,500 plants $ha^{-1}$, with spacing of 4 m between rows and 1 m between plants, with plants managed in the central leader training system. The pollination scheme adopted was based on the use of two producing cultivars, with 'Maxi Gala' being the pollinator of cv. 'Fuji Suprema' and vice versa. From the setting up of the experiments until the end of this study, the orchard was conducted according to the management practices recommended in the apple production system (SEZERINO, 2018).

The experimental design was in randomized blocks, with five replicates, with each unit composed of one plant. The treatments are presented in Tables 1 and 2. The bud break promoters were applied by spraying with a motorized knapsack sprayer, with an average volume of 1000 L $ha^{-1}$. Phenology of the C-C3 stages, beginning of bud breaking and beginning, full and final flowering, axillary bud breaking, terminal bud breaking, fruit set, production per plant, number of fruits per plant and average fruit mass were evaluated. Beginning of flowering was considered when the plants had 5% of flowers open, full flowering when more than 80% of flowers were open, and end of flowering when the last flowers were open.

**Table 1 –** Treatments and application stage for the apple cvs. 'Maxi Gala' and 'Fuji Suprema'.

| Treatments | Application | Reapplication |
|---|---|---|
| 1.Control | - | - |
| 2. MO 3.5% + HC 0.7% | Stage B | - |
| 3. (MO 3.5% + HC 0.7%) + (MO 3.5% + HC 0.7%) | Stage B | 7 DA |
| 4. (MO 3.5% + HC 0.7%) + (MO 3.5% + HC 0.7%) | Stage B | 14 DA |
| 5. (MO 3.5% + HC 0.7%) + MO 3.5% | Stage B | 7 DA |
| 6. (MO 3.5% + HC 0.7%) + MO 3.5% | Stage B | 14 DA |
| 7. (MO 3.5% + HC 0.7%) + HC 1.0% | Stage B | 7 DA |
| 8. (MO 3.5% + HC 0.7%) + HC 1.0% | Stage B | 14 DA |
| 9. (MO 3.5% + HC 0.7%) + HC 0.7% | Stage C | 5 DA |
| 10. (MO 3.5% + HC 0.7%) + (MO 3.5% + HC 0.7%) | Stage C | 10 DA |
| 11. (MO 3.5% + HC 0.7%) + MO 3.5% | Stage C | 10 DA |

MO = Mineral oil; HC = Hydrogen Cyanamide (Dormex®); DA = Days after.

**Table 2** – Treatments and application stage for the apple cvs. 'Maxi Gala' and 'Fuji Suprema' with different concentrations of mineral oil (MO). Caçador, SC.

| Treatments | Application | Reapplication |
|---|---|---|
| 1. Control | - | - |
| 2. Assist 4%+Dormex 0.7% | Stage B | 10 DA |

| | | |
|---|---|---|
| 3. Assist 4%+ Breaktrhoo 0.005% | Stage B | 10 DA |
| 4. Assist 3%+Assist 3% | Stage B | 10 DA |
| 5. Assist 4%+Assist 3% | Stage B | 10 DA |
| 6. Assist 5%+Assist 3% | Stage B | 10 DA |
| **7. Assist 4%+Assist 4%** | **Stage B** | **10 DA** |

Axillary bud breaking was obtained by counting sprouted and unsprouted buds in five previously selected twigs, located in the middle third of the plant. A lateral branch of each plant was selected to count sprouted and unsprouted terminal buds to estimate the terminal bud breaking percentage. Fruit set was obtained from the ratio between the number of fruits and the number of flower clusters counted during full flowering ([number of fruits/flower clusters x 100), and the counts were performed on the same lateral branch used to estimate the terminal bud breaking. Number of fruits per plant and production per plant were obtained by harvesting all fruits at maturity. Harvesting was carried out on two dates, according to the date of application of the bud break promoters.

The results obtained were subjected to analysis of variance, whose significant variables ($p<0.05$) had their means compared by the Scott-Knott test at 5% probability of error. Analysis procedures were performed using SISVAR software, version 5.6 (FERREIRA, 2010). Percentage data were transformed by the formula sine arc $[(x+1)/100]^{1/2}$ before being subjected to ANOVA.

## Results and discussion

The phenology was advanced compared to the control treatment with the application of bud break promoters, regardless of the application stage and sequential application. Regarding the application stage, the treatments applied at stage B promoted a greater advance compared to the applications at stage C in the 'Maxi Gala' cultivar (Figure 1). As for the sequential application, it had a small effect compared to the single application, the same occurring with the reapplication of only mineral oil (MO) or hydrogen cyanamide (HC). The greatest effect on the advance of flowering was caused by the application stage, which confirms the results of Petri et al. (2012). George et al. (2002) state that bud break promoters can be used to modulate the bud breaking and flowering period. There is also an influence of the year on the advance of phenological stages, which is related to the intensity of the cold. The highest advances of full flowering in cv. 'Maxi Gala' were 19, 33, 34 and 27 days, for the years 2016, 2017, 2018 and 2019, respectively (Figure 1). For the applications in stage B, there was also advance in the phenological stages compared to applications in stage C, but less than that observed in untreated plants. The greatest advances of full flowering for the cultivar 'Fuji Suprema' were 18, 26, 24 and 21 days compared to the treatment without bud break promoters (Figure 2). For the applications in stage B, there was also advance in the phenological stages compared to applications in stage C, but lower than those observed in relation to the untreated plants. Hawerroth et al. (2010) also observed early flowering with applications of MO plus HC. According to Pasa et al. (2018), advance of flowering with bud break promoters is greater in early applications after completion of endo-dormancy. Bud break promoters shorten the period between full flowering and the end of flowering.

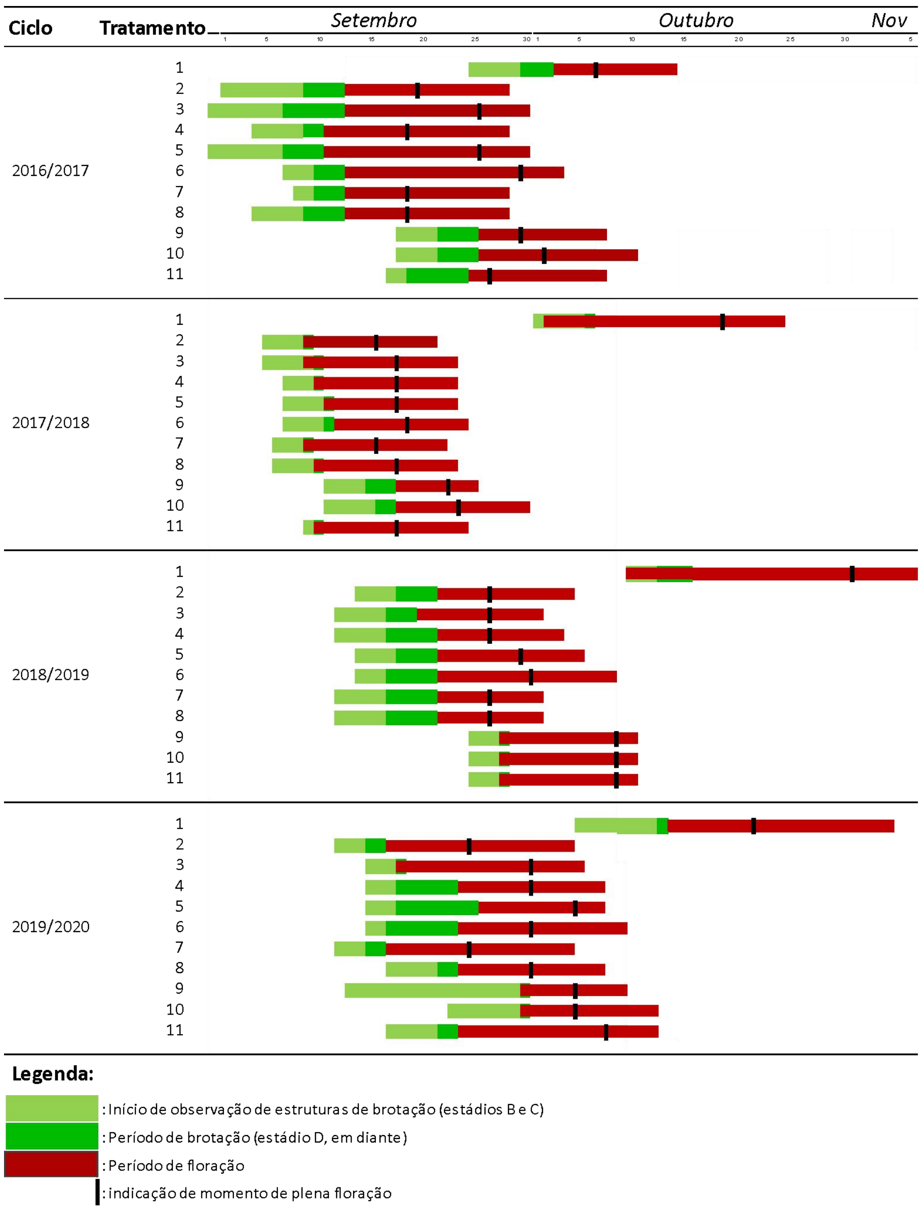


**Figure 1** – Evolution of the phenological stages of 'Maxi Gala' apple with different treatments of bud break promoters, in four seasons. Caçador, SC.

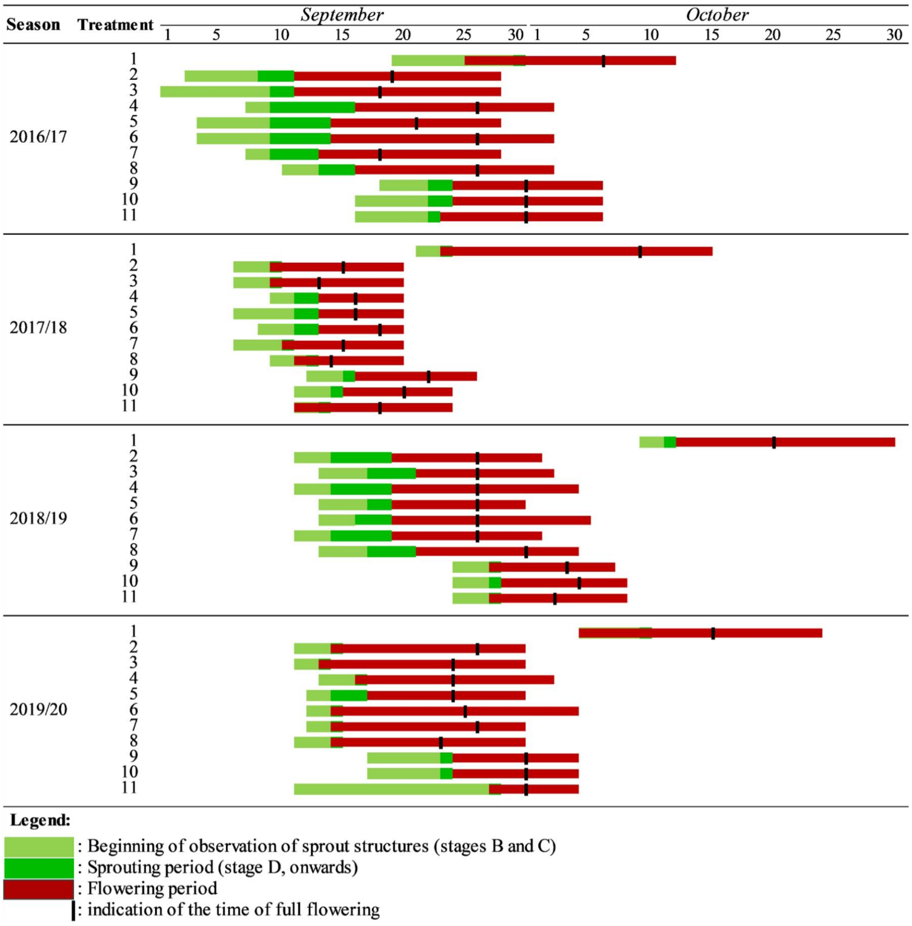


**Figure 2 –** Evolution of the phenological stages of 'Fuji Suprema' apple tree with different treatments of bud break promoters, in four seasons. Caçador, SC.

Regarding axillary bud breaking, all treatments were significantly superior to the control treatment in the four years for the cultivars 'Maxi Gala' and 'Fuji Suprema' (Tables 3 and 4). Among the treatments, MO 3.5% + HC 0.7% stage B + 7DA, MO 3.5% + HC 0.7% + stage B + HC 1.0% 14DA and MO 3.5% + HC 0.7% stage C + HC 0.7% 5DA stood out for being significantly superior to the others at 30 days after application in the four years. These same treatments, at 60 days, were superior in three years, which demonstrates that sequential application increases axillary bud breaking percentage. The transition between the different phases of dormancy involves genetic, physiological, biochemical, and anatomical aspects, changes that lead to differentiated effects at the stage of application of treatments (COOKE et al., 2012). Sequential applications of MO alone showed similar results compared to the treatment with single application of MO+HC, which may be an option for agroecological plantations (Table 7). Bud breaking percentages also varied with the years, which can be attributed to the cold that occurred, with the lowest bud breaking percentages in 2019/2020, the year with the lowest cold intensity in the period in which the experiment was conducted, which confirms the results reported by Pasa et al. (2018), who observed an increase in axillary bud breaking only in the year with lower cold intensity. Axillary bud breaking is important for the formation of fruiting structures for the following year and to avoid failures in the formation of the plant, affecting canopy volume.

**Table 3 –** Axillary bud breaking (%) at 30 and 60 days after the dormancy break of 'Maxi Gala' apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| Treatment | Axillary bud breaking (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
| | 30 days after dormancy breaking | | | | 60 days after dormancy breaking | | | |
| 1. | 4.9 c | 0.0 c | 1.6 c | 0.0 c | 8.6 c | 0.4 c | 4.0 b | 1.1 d |
| 2. | 50.9 b | 37.3 b | 35.9 b | 21.5 b | 54.3 b | 38.7 b | 42.6 a | 23.8 c |
| 3. | 74.0 a | 45.7 b | 47.3 a | 28.4 b | 78.3 a | 49.5 b | 54.0 a | 32.5 c |
| 4. | 63.5 a | 44.6 b | 40.5 a | 22.6 b | 67.1 b | 46.1 b | 47.8 a | 29.5 c |
| 5. | 74.4 a | 59.2 a | 47.5 a | 32.6 a | 75.5 a | 61.0 a | 52.4 a | 38.1 b |
| 6. | 57.5 b | 63.6 a | 55.3 a | 22.5 b | 58.6 b | 65.0 a | 63.4 a | 24.4 c |
| 7. | 63.6 a | 30.7 b | 47.9 a | 36.9 a | 68.1 b | 34.9 b | 55.5 a | 38.5 b |
| 8. | 68.7 a | 58.0 a | 51.0 a | 36.9 a | 73.5 a | 60.5 a | 60.8 a | 40.9 b |
| 9. | 60.1 a | 65.5 a | 42.8 a | 47.6 a | 75.3 a | 66.0 a | 63.2 a | 57.2 a |
| 10. | 46.1 b | 60.7 a | 20.5 b | 24.2 b | 61.1 b | 62.0 a | 54.5 a | 33.6 b |
| 11. | 45.3 b | 38.5 b | 30.0 b | 19.3 b | 58.9 b | 42.9 b | 56.3 a | 27.9 c |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level.

**Table 4 –** Bud break of axillary buds (%) at 30 and 60 days after the dormancy breaking of 'Fuji Suprema' apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| Treatment | Bud break of axillary buds (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
| | 30 days after the dormancy breaking | | | | 60 days after the dormancy breaking | | | |
| 1. | 1.9 c | 0.0 d | 0.0 c | 1.4 c | 17.2 c | 15.3 b | 7.7 c | 7.2 c |
| 2. | 47.8 b | 47.3 b | 55.4 a | 52.1 b | 58.0 b | 41.5 a | 57.2 b | 58.6 b |
| 3. | 73.0 a | 73.7 a | 49.0 a | 70.4 a | 77.0 a | 75.6 a | 51.6 b | 82.8 a |
| 4. | 73.6 a | 58.8 a | 44.2 a | 62.1 a | 78.1 a | 67.2 a | 50.0 b | 65.8 b |
| 5. | 78.2 a | 61.8 a | 38.7 a | 65.0 a | 79.8 a | 69.2 a | 46.5 b | 74.2 a |
| 6. | 67.6 a | 49.9 b | 52.5 a | 42.8 b | 73.5 a | 63.2 a | 59.2 b | 47.9 b |
| 7. | 80.2 a | 62.1 a | 59.6 a | 55.0 b | 83.1 a | 63.9 a | 63.2 b | 74.5 a |
| 8. | 74.1 a | 55.2 b | 48.4 a | 48.6 b | 75.3 a | 62.2 a | 56.1 b | 57.6 b |
| 9. | 48.2 b | 24.1 c | 11.9 b | 68.5 a | 81.7 a | 49.7 a | 60.9 b | 77.8 a |
| 10. | 60.2 b | 35.1 c | 11.4 b | 72.4 a | 80.4 a | 58.2 a | 78.6 a | 89.5 a |
| 11. | 45.3 b | 48.4 b | 20.8 b | 60.3 a | 75.8 a | 68.9 a | 77.0 a | 77.3 a |
| CV (%) | 12.1 | 15.9 | 20.5 | 19.9 | 10.3 | 23.5 | 16.0 | 20.8 |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level.

Axillary bud breaking at 60 days after application in the control treatment ranged from 0.4% to 8.6% in the cv. 'Maxi Gala' and from 7.2% to 17.2% in 'Fuji Suprema', according to the year, and in treatments with bud break promoters from 23.8% to 78.3% and 41.5% to 89.5%, respectively, which are in agreement with De Martin et al. (2017).

Regarding the bud break of terminal buds, located at the end of the twigs, in the cultivars ‘Maxi Gala’ and ‘Fuji Suprema’, all treatments differed from the control at 30 and 60 days after full flowering, except for cv. ‘Fuji Suprema’ in 2019/2020 (Tables 5 and 6). As for the standard treatment, with a single application, for ‘Maxi Gala’ it was significantly inferior to the treatments with sequential application in the years 2018/19 and 2019/20 and, in the year 2017/18, only to the MO 3.5% + HC 0.7% stage C + HC 0.7% 5DA treatment, which was significantly superior to the others in 2019/20. As for the sequential application of mineral oil only, the results were inferior to those obtained in the treatment with MO + HC, but at higher doses this treatment was superior to the control (Table 7).

**Table 5 –** Bud break of terminal buds (%) at 30 and 60 days after the dormancy breaking of ‘Maxi Gala’ apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| **Treatment** | **Bud break of terminal buds (%)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **2016/17** | **2017/18** | **2018/19** | **2019/20** | **2016/17** | **2017/18** | **2018/19** | **2019/20** |
| | **30 days after dormancy breaking** | | | | **60 days after dormancy breaking** | | | |
| 1. | 24.5 d | 3.5 b | 15.8 b | 11.5 c | 73.7 c | 31.3 c | 32.2 c | 44.0 d |
| 2. | 96.7 a | 83.2 a | 55.5 a | 70.5 b | 97.2 a | 90.9 b | 63.6 b | 73.2 c |
| 3. | 100.0 a | 76.2 a | 86.9 a | 83.5 b | 100.0 a | 93.3 b | 88.9 a | 87.7 b |
| 4. | 98.0 a | 89.3 a | 73.4 a | 79.4 b | 100.0 a | 91.9 b | 78.1 a | 90.6 b |
| 5. | 100.0 a | 84.2 a | 73.4 a | 87.8 b | 100.0 a | 92.8 b | 75.1 a | 89.8 b |
| 6. | 100.0 a | 75.8 a | 62.2 a | 87.1 b | 100.0 a | 86.8 b | 67.3 b | 88.4 b |
| 7. | 99.4 a | 72.8 a | 80.4 a | 88.4 b | 99.4 a | 87.6 b | 90.4 a | 95.6 b |
| 8. | 100.0 a | 84.0 a | 72.9 a | 72.9 b | 100.0 a | 86.2 b | 79.2 a | 88.1 b |
| 9. | 92.1 b | 95.9 a | 91.5 a | 100.0 a | 99.6 a | 98.2 a | 92.9 a | 100.0 a |
| 10. | 84.6 b | 89.5 a | 76.5 a | 78.8 b | 99.4 a | 97.7 a | 82.5 a | 85.6 b |
| 11. | 73.7 c | 74.8 a | 66.0 a | 75.8 b | 91.7 b | 83.2 b | 85.7 a | 79.2 b |
| CV (%) | 10.4 | 17.0 | 21.0 | 14.7 | 6.5 | 12.8 | 19.9 | 14.2 |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level.

**Table 6 –** Bud break of terminal buds (%) at 30 and 60 days after the dormancy breaking of ‘Fuji Suprema’ apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| **Treatment** | **2016/17** | **2017/18** | **2018/19** | **2019/20** | **2016/17** | **2017/18** | **2018/19** | **2019/20** |
|---|---|---|---|---|---|---|---|---|
| | **30 days after the dormancy breaking** | | | | **60 days after the dormancy breaking** | | | |
| 1. | 30.6 d | 8.0 c | 7.3 b | 26.7 b | 74.3 b | 61.7 c | 57.9 b | 89.7 $^{ns}$ |
| 2. | 96.9 a | 86.6 a | 84.4 a | 91.9 a | 98.7 a | 84.2 b | 91.3 a | 96.3 |
| 3. | 95.7 a | 93.2 a | 94.3 a | 95.6 a | 100.0 a | 97.0 a | 94.9 a | 96.8 |
| 4. | 90.9 a | 92.2 a | 95.6 a | 94.5 a | 98.4 a | 96.9 a | 92.7 a | 97.5 |
| 5. | 96.4 a | 91.7 a | 90.6 a | 94.8 a | 99.1 a | 95.5 a | 90.6 a | 96.4 |
| 6. | 82.5 b | 85.0 a | 86.1 a | 93.1 a | 97.3 a | 88.7 b | 88.0 a | 95.0 |
| 7. | 96.0 a | 93.8 a | 95.1 a | 92.8 a | 98.8 a | 100.0 a | 95.0 a | 100.0 |
| 8. | 94.5 a | 87.4 a | 89.3 a | 87.1 a | 99.6 a | 95.5 a | 95.0 a | 94.4 |
| 9. | 79.1 b | 73.2 b | 89.4 a | 91.8 a | 95.5 a | 84.9 b | 89.4 a | 94.6 |
| 10. | 80.3 b | 71.0 b | 71.0 a | 94.1 a | 100.0 a | 80.7 b | 93.8 a | 96.7 |
| 11. | 67.0 c | 75.5 b | 86.4 a | 87.3 a | 95.7 a | 82.0 b | 92.3 a | 92.1 |
| CV (%) | 13.6 | 14.1 | 16.4 | 14.7 | 7.3 | 14.4 | 13.6 | 17.4 |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level. ns = not significant ($p>0.05$).

**Table 7** – Axillary bud breaking (%) of the apple cv. 'Maxi Gala' at 30 days after application of treatments. Caçador, SC.

| Treatments | Axillary bud breaking (%) | | | | |
|---|---|---|---|---|---|
| | **2015** | **2016** | **2017** | **2018** | **2019** |
| 1. Control | 0.0 c | 43.9 b | 1.6 c | 0.2 c | 1.4 c |
| 2. Assist 4%+Dormex 0.7% | 5.8 b | 80.0 a | 20.8 a | 31.5 a | 31.9 a |
| 3. Assist 4%+ Breaktrhoo 0.005% | 0.8 c | 44.7 b | 0.0 c | 1 0.3 b | 9.2 b |
| 4. Assist 3%+Assist 3% 10DA | 8.1 b | 63.3 a | 12.1 b | 32.1 a | 10.0 b |
| 5. Assist 4%+Assist 3% 10DA | 6.9 b | 60.4 a | 0.3 c | 35.9 a | 11.2 b |
| 6. Assist 5%+Assist 3% 10 DA | 16.7 a | 65.8 a | 6.3 c | 46.2 a | 14.3 a |
| **7. Assist 4%+Assist 4%** | **9.0 b** | **70.6 a** | **10.0 b** | **37.4a** | **19.1 a** |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level.

For being floriferous, terminal buds usually sprout more than axillary buds, due to lower chill requirements and apical dominance (UBER et al., 2019). According to Francescatto (2014), the lack of axillary bud breaking favors terminal bud breaking and compromises the formation of reproductive organs, favoring excessive vegetative development.

Axillary and terminal buds show better bud break with sequential applications, with a significant increase mainly in the bud break of axillary buds, which are responsible for the formation of fruiting structures for the following year.

Fruit set was reduced in 'Maxi Gala', which did not occur with 'Fuji Suprema', in some treatments compared to the control treatment in 2016/17, but the same did not occur in the other years (data not shown). There was no reduction in fruit set in treatments with sequential application compared to the single application or between the reapplication dates and the applications involving reapplication with MO plus HC. Reduction in fruit set is due to the concentration of flowering with the use of bud break promoters, which can increase the risk of poor pollination, especially if the environmental conditions are unfavorable for the work of bees (HERNANDEZ; CRAIG, 2011).

In relation to the production per plant in 'Maxi Gala', the treatments MO 3.5% + HC 0.7% stage B + MO 3.5% 7DA, MO 3.5% + HC 0.7% stage B + MO 3.5% 14DA and MO 3.5% + HC 0.7% stage B + MO 3.5% 10DA were significantly superior to the control treatment and the single-application treatment, in the 2016/17, 2018/19 and 2019/20 seasons, in the average of the four years (Table 8). There was no significant difference regarding reapplication at 7 or 14 days after the first application. As for the reapplication with MO alone, higher yields were obtained with the treatments MO 3.5% + HC 0.7% stage B + MO 3.5% 7DA, MO 3.5% + HC 0.7%, stage B + MO 3.5% 14DA and MO 3.5% + HC 0.7% stage B + MO 3.5% 10DA, compared to the treatments with MO plus HC or HC only. These results may be related to the flowering concentration in the treatments that involve reapplication with HC. The best treatment, MO 3.5% + HC 0.7% stage B + MO 3.5% 10DA, increased the average production per plant by 78.5% compared to the control treatment and by 130.9% compared to the single-application treatment. This same trend was observed in the number of fruits per plant (Table 8).

**Table 8 –** Production per plant (kg and number of fruits) of 'Maxi Gala' apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| Treatment | Production per plant (kg) | | | | Mean | Number of fruits | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | | 2016/17 | 2017/18 | 2018/19 | 2019/20 |
| 1. | 10.0 b | 6.0 b | 6.3 b | 6.0 b | 7.1 b | 79.6 b | 60.2 b | 59.2 a | 57.8 ns |
| 2. | 4.8 c | 7.0 b | 5.2 b | 4.9 b | 5.5 b | 37.0 c | 78.4 a | 46.6 b | 46.2 |
| 3. | 8.8 b | 11.5 a | 2.9 b | 8.2 a | 7.8 b | 67.2 b | 105.4 a | 22.2 b | 59.6 |
| 4. | 3.5 c | 12.4 a | 3.1 b | 8.0 a | 6.8 b | 26.0 c | 124.4 a | 28.4 b | 64.6 |
| 5. | 17.3 a | 5.4 b | 11.9 a | 7.3 a | 10.5 a | 134.8 a | 51.0 b | 95.2 a | 58.0 |
| 6. | 21.0 a | 3.0 b | 8.9 a | 9.1 a | 10.5 a | 189.4 a | 33.8 b | 67.8 a | 84.6 |
| 7. | 2.0 c | 9.3 a | 2.0 b | 5.9 b | 4.8 b | 16.0 c | 92.2 a | 16.6 b | 49.6 |
| 8. | 9.4 b | 10.2 a | 4.7 b | 4.9 b | 7.3 b | 77.2 b | 93.8 a | 34.8 b | 39.6 |
| 9. | 18.5 a | 3.8 b | 5.0 b | 3.7 b | 7.7 b | 180.2 a | 36.8 b | 40.6 b | 32.6 |
| 10. | 15.7 a | 5.0 b | 3.5 b | 4.4 b | 7.1 b | 134.8 a | 43.4 b | 26.2 b | 32.6 |
| 11. | 23.0 a | 10.6 a | 8.1 a | 9.1 a | 12.7 a | 212.4 a | 97.4 a | 64.8 a | 70.2 |
| CV (%) | 36.8 | 44.6 | 47.3 | 48.1 | 26.7 | 21.6 | 22.4 | 24.4 | 25.3 |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level. ns = not significant ($p>0.05$).

For the production per plant in the cv. 'Fuji Suprema' only in the 2017/18 season most of the treatments were superior to the control treatment, but the sequential applications did not differ from the single application. In the 2016/17 season, the treatments MO 3.5% + HC 0.7% stage C + MO 3.5% + HC 0.7% 10DA and MO 3.5% + HC 0.7% stage C + MO 3.5% 10DA were superior to the single-application treatment. As for the number of fruits per plant, it showed a similar behavior to the production per plant in kilograms (Table 9).

**Table 9** – Production per plant (kg and number of fruits) of 'Fuji Suprema' apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| Treatment | Production per plant kg | | | Number of fruits | | |
|---|---|---|---|---|---|---|
| | 2016/17 | 2017/18 | 2019/20 | 2016/17 | 2017/18 | 2019/20 |
| 1. | 33.3 a | 5.8 b | 9.5 ns | 313.6 a | 57.8 ns | 101.6 ns |
| 2. | 21.0 b | 11.1 a | 6.4 | 149.4 b | 102.8 | 60.0 |
| 3. | 26.6 b | 9.3 a | 7.3 | 219.6 b | 79.8 | 72.4 |
| 4. | 27.3 b | 10.0 a | 8.5 | 187.8 b | 87.4 | 98.4 |
| 5. | 29.2 b | 10.3 a | 7.7 | 219.6 b | 102.0 | 77.6 |
| 6. | 44.0 a | 11.7 a | 8.4 | 391.8 a | 116.4 | 92.4 |
| 7. | 15.7 b | 9.2 a | 5.9 | 112.2 b | 90.6 | 57.8 |
| 8. | 34.7 b | 13.0 a | 8.7 | 229.0 b | 115.4 | 87.4 |
| 9. | 29.2 b | 5.4 b | 9.8 | 265.8 a | 61.0 | 97.8 |
| 10. | 41.7 a | 6.2 b | 6.7 | 371.2 a | 69.6 | 67.6 |
| 11. | 38.2 a | 8.9 a | 9.3 | 323.8 a | 96.2 | 100.6 |

| CV (%) | 30.2 | 40.0 | 44.3 | 18.4 | 24.2 | 23.9 |
|---|---|---|---|---|---|---|

Means followed by the same letter in the columns do not differ by the Scott-Knott test at 5% probability level. ns = not significant (p>0.05). ns = not significant (p>0.05).

For the average fruit mass, only in the 2019/20 season, the treatments MO 3.5% + HC 0.7% stage B + MO 3.5% + HC 0.7% 7DA, MO 3.5% + HC 0.7% stage B + MO 3.5% + HC 0.7% 14DA and MO 3.5% + HC 0.7% stage B + MO 3.5% 14DA, MO 3.5% + HC 0.7% stage B + HC 1.0% 14DA, MO 3.5% + HC 0.7% stage C + MO 3.5% + HC 0.7% 10DA and MO 3.5% + HC 0.7% stage C + MO 3.5% 10DA were significantly superior to the control treatment and the single-application treatment, which was reflected in the average of the four years, when only the MO 3.5% + HC 0.7% stage C + HC 0.7% 5DA treatment did not differ from the control and single-application treatments, and all the others had a higher average fruit mass, which can be attributed to the advance of flowering and greater foliage of the plants (Table 10). In the cv. 'Fuji Suprema', for the average fruit mass in the 2016/17 and 2017/18 seasons there were treatments with sequential application that were significantly superior to the control treatment, but only in the 2017/18 season the single-application treatment was inferior to some treatments with sequential application (Table 11). The increase in average fruit mass may be related to the advance and uniformity of flowering and to better foliage of the plants, since there was an increase in bud breaking percentage, which contributes to a larger leaf area.

**Table 10 –** Average fruit mass (g) of 'Maxi Gala' apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| Treatment | Average fruit mass (g) | | | | |
|---|---|---|---|---|---|
| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | Mean |
| 1. | 128.2 a | 100.8 a | 106.1$^{ns}$ | 106.0 b | 87.0 b |
| 2. | 130.7 a | 89.4 b | 110.8 | 101.4 b | 87.9 b |
| 3. | 133.3 a | 108.5 a | 132.1 | 138.4 a | 103.5 a |
| 4. | 133.9 a | 100.9 a | 112.4 | 120.8 a | 94.5 a |
| 5. | 129.4 a | 102.6 a | 131.9 | 125.8 a | 98.5 a |
| 6. | 112.9 b | 89.7 b | 140.9 | 113.3 b | 93.2 a |
| 7. | 128.8 a | 100.4 a | 123.0 | 117.3 b | 94.7 a |
| 8. | 122.5 a | 108.7 a | 136.9 | 122.7 a | 97.9 a |
| 9. | 103.4 b | 99.1 a | 122.1 | 114.8 b | 86.5 b |
| 10. | 116.3 b | 115.4 a | 133.6 | 133.7 a | 97.5 a |
| 11. | 109.0 b | 106.2 a | 126.6 | 129.3 a | 93.6 a |
| CV (%) | 6.8 | 9.1 | 19.3 | 9.5 | 7.8 |

Means followed by the same letter in the columns do not differ from each other by the Scott-Knott test at 5% probability level. ns = not significant (p>0.05).

**Table 11 –** Fruit set (%) and average fruit mass (g) of 'Fuji Suprema' apple trees, treated with different bud break promoters, in four seasons. Caçador, SC.

| Treatment | Fruit set (%) | | | | Average fruit mass (g) | | |
|---|---|---|---|---|---|---|---|
| | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2016/17 | 2017/18 | 2019/20 |
| 1. | 331.2 a | 62.9 $^{ns}$ | 251.4 a | 76.0 ns | 107.2 b | 91.3 b | 90.2 $^{ns}$ |
| 2. | 46.6 c | 33.8 | 15.9 b | 44.5 | 140.0 a | 100.7 b | 107.7 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3. | 22.6 c | 59.6 | 32.6 b | 68.2 | 127.8 b | 116.7 a | 98.7 |
| 4. | 26.5 c | 46.5 | 33.5 b | 74.9 | 146.2 a | 114.5 a | 88.6 |
| 5. | 74.9 b | 88.7 | 43.7 b | 25.7 | 133.0 a | 102.4 b | 99.1 |
| 6. | 89.9 b | 60.0 | 41.3 b | 109.5 | 114.3 b | 100.9 b | 93.5 |
| 7. | 22.4 c | 42.4 | 7.5 b | 35.0 | 140.4 a | 103.7 b | 104.1 |
| 8. | 76.5 b | 113.0 | 53.2 b | 68.9 | 153.6 a | 113.5 a | 103.3 |
| 9. | 80.2 b | 37.6 | 21.4 b | 76.1 | 112.3 b | 89.3 b | 101.0 |
| 10. | 155.4 b | 60.4 | 44.1 b | 50.8 | 114.3 b | 92.6 b | 97.2 |
| 11. | 152.5 b | 67.9 | 30.9 b | 45.7 | 123.3 b | 88.9 b | 92.7 |
| CV (%) | 52.0 | 69.4 | 51.2 | 70.1 | 12.0 | 12.7 | 10.8 |

Means followed by the same letter in the columns do not differ by the Scott-Knott test at 5% probability level. ns = not significant (p>0.05). ns = not significant (p>0.05).

## Conclusion

Application of bud break promoters in stage B advances the phenological stages of apple compared to the application of bud break promoters in stage C, regardless of the reapplication and the time interval of reapplication. Sequential application of bud break promoters can increase axillary and terminal bud breaking percentage in apple, depending on the season, and does not reduce fruit set compared to single application. Reapplication of mineral oil in breaking the dormancy of apple can increase the yield of the plants. Sequential application of bud break promoters can increase the average mass of apple fruits, depending on the year. **Sequential application of mineral oil alone proved to be efficient in inducing apple bud breaking and flowering compared to the standard treatment with mineral oil plus hydrogen cyanamide, being an alternative for agroecological production systems.**

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