POST-FLOWERING CHEMICAL THINNING OF 'FUJI SUPREMA' APPLE

Abstract

Under the climate variability conditions of southern Brazil, post-flowering thinning is a safer practice than thinning during flowering. This study aimed to evaluate the response of 'Fuji Suprema' apple to the application of post-flowering thinning agent combinations. The experiments were conducted during four cycles, evaluating the combination of Benzyladenine associated with Ethephon or Metamitron, and applicationsof each product alone and at different concentrations. The results showed that Metamitron in combination with Benzyladenine or Ethephon is efficient for 'Fuji Suprema' apple. The treatments proved to be effective in adjusting fruit set and improving fruit quality, being recommended for post-flowering thinning in cultivars with high fruit set.

Keywords:*Malus domestica* Borkh.; effective fruiting; fruit quality; production.

Introduction

Apple is one of the most important fruit crops of temperate climate in Brazil, with a planted area of approximately 33,000 ha and production above 1.0 million tons in years without climatic adversities (FAOSTAT, 2024). When the apple tree is grown under conditions where its chilling requirement is not satisfied, an irregular flowering that extends over a long periodoccurs, causing a heterogeneous effective fruiting (Sezerino, 2018). Under these conditions, post-flowering thinning is more efficient than thinning during flowering (Fernades, 2013). The efficiency of chemical thinning agents depends on some environmental factors such as temperature, humidity and the amount of light, which may be the reason for the variability in the results. Knowledge of the temperature and light incidence three to four days after the application of the thinning agents has made the thinning process more predictable and reliable (Byers; Coast; Vizzotto, 2003; Greene, 2016).

Reducing effective fruiting, particularly in years when climatic conditions favor excessive fruiting, is necessary to regulate production and increase fruit size and quality

(Salvador *et al.*, 2006). Thinning is an important technique, as it allows reducing the number of fruits per plant, significantly improving the quality of the remaining fruits (Bound, 2015), and can be done manually, chemically or mechanically (Ilie *et al.*, 2016; Lanar, 2024).

Chemical thinning can be adopted as a substitute for manual thinning to reduce labor costs, since this practice allows removing excess fruits, adjusting the production capacity of the plants and, consequently, avoiding the alternation of production, since the floral induction for the next year's production occurs concomitantly with the phase of intense cell division and initial growth of the fruits of the current crop season (Dennis, 2002; Greene, 2016; Petri *et al.*, 2013). In addition, the setting of four or more fruits per inflorescence makes manual thinning difficult (Costa; Dal Cin; Ramina, 2006).

The products used for chemical thinning of fruits can be applied before flowering, during flowering or in the post-flowering period (Petri *et al.*, 2016). Due to the climatic conditions of the southern region of Brazil, the effective fruiting from year to year is very variable. Under these conditions, the adoption of thinning during flowering becomes a practice of greater risk for the producer, since it is only possible to evaluate the need and intensity of thinning after fertilization of fruits (Petri *et al.*, 2016). Among the chemical thinning agents available for the apple crop, NAA (Naphthalene Acetic Acid), Benzyladenine (BA), Ethephon (Ethrel®) and, more recently, Metamitron, a product that inhibits photosynthetic activity (Basak, 2011), stand out.

The effect of BA on apple thinning is proportional to the time of application and concentration used (Greene *et al.*, 1990). BA is a compound of the cytokinin group that acts in cell division and, therefore, has been shown to be effective in increasing fruit diameter (McLaughlin; Greene, 1984; Greene *et al.*, 1992; Byers; Carbaugh, 1991; Wismer *et al.*, 1995). According to Greene (2005), BA can increase fruit diameterin the absence of thinning, by increasing cell division. BA has been considered a good thinning agent because it has a low toxicological profile and mimics the biological action of cytokinin, which is synthesized in plants (Yuan; Greene, 2000a; 200b). However, the combination of BA and Carbaryl is more effective than itssingle application, being considered one of the most effective combinations for chemical thinning of apple (Byers; Carbaugh, 1991). The objective of this study to evaluate the response of 'Fuji Suprema' apple to the application of post-flowering thinning agent combinations.

Methodology

Apple trees of the ‘Fuji Suprema’ cultivar, trained in the central leader system, according to the technical recommendations for the crop(Epagri, 2006), were used in the study. The study was carried out during four vegetative cycles in an orchard located in Caçador, SC, Brazil (latitude 26º46’S, longitude 51º W, altitude 960 m), with “Cfb” climate and soil classified as *Nitossolo Bruno distrófico* (Ultisol). The experimental design was randomized blocks, with five replicates, each consisting of one plant. Treatments consisted of post-flowering chemical thinning agents, arranged as follows: 1. Control (manual thinning); 2. Benzyladenine 400 ml/100 L + Ethephon 200 ml/100 L; 3. Benzyladenine 400 ml/100 L + Metamitron 100 g/100 L; 4. Benzyladenine 600 ml/100 L; 5. Ethephon 240 - 200 ml/100 L; Metamitron 150 ml/100 L; Metamitron 150 ml/100 L + Ethephon 200 ml/100 L. For the experiments, the commercial product Maxcel® with 2% BA was used as a source of BA; the commercial product Promalin® with 1.8% GA4+7 and 1.8% BAwas used as source of GA4+7+BA; and the commercial product Ethrel® with 24% Ethephon was used as a source of Ethephon. The products were applied using a motorized knapsack sprayer (20L) with a tip containing three D-S fan-type nozzles.

Manual thinning was performed when the fruits were 8 to 12 mm in diameter, and chemical thinning was performed when the fruits were 15 to 20 mm in diameter, adopting as a criterion the maintenance of two fruits ontwigs and one fruit on spur.In each plant, two branches were marked for the evaluations of effective fruiting, fruit drop and number of fruits per inflorescence. Effective fruiting was evaluated by the ratio between the number of fruits and the number of flower clusters observed during full flowering, multiplied by 100 to obtain the fruiting percentage ([number of fruits/flower clusters] x 100). Total fruit production per plant was determined by weighing the fruits at harvest in kg plant^{-1}, and the average fruit mass was calculated by dividing the total mass by the total number of fruits harvested, with the fruits being classified by size. The data collected were analyzed using ANOVA, with the means of significant variables ($p<0.05$) compared by the Scott-Knott test at a significance level of 5%.

Results and Discussion

The control treatment showed the highest average values of production per plant (28.7 kg plant^{-1}), similar to the treatments with BA + Metamitron (25.2 kg), Ethephon(25.3 kg) and Metamitron alone (26.6 kg). The combined use of Metamitron + Ethephonled to the lowest average production (17.5 kg), indicating a greater drop or reduction in the number of fruits (Table 1). There were significant differences between treatments and between years (2017 and 2018), but not in all years. This may be related to climatic variations or response of the plants. The variation in responses between years demonstrates the importance of considering climatic conditions and the management of post-flowering thinning agents. High concentrations of Metamitron can cause excessive thinning, and it should be considered that high temperatures (29 to 31°C) during the application or up to 4 days after intensify the thinning action (Greene, 2014).

Table 1 – Effect of chemical thinning agents on production per plant (kg plant^{-1}) of 'Fuji Suprema' apple trees. Caçador, SC, Brazil, 2024.

Treatments	2017	2018	2019	2020	Mean
1. Control (manual thinning)– Fruits 8-12 mm	53.5 a	25.2 a	18.3 ns	15.3 ns	28.7a
2. Benzyladenine 400 ml/100 L + Ethephon200 ml/100 L– Fruits 15-20 mm	39.8 a	24.9 a	14.0	15.7	23.6
3. Benzyladenine400 ml/100 L + Metamitron 100 g/100 L– Fruits 15-20 mm	44.0 a	22.6 a	23.5	10.7	25.2a
4. Benzyladenine600 ml/100 L– Fruits 15-20 mm	46.1 a	15.2 b	19.8	14.2	23.8b
5. Ethephon240 - 200 ml/100 L– Fruits 15-20 mm	44.3 a	20.2 a	20.1	16.5	25.3a
6. Metamitron150 ml/100 L– Fruits 15-20 mm	51.5 a	20.5 a	19.6	14.7	26.6a
7. Metamitron150 ml/100 L + Ethephon200 ml/100 L– Fruits 15-20 mm	28.6 b	9.8 b	16.8	14.7	17.5b

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

The treatments with Benzyladenine alone and combinedwith Ethephon maintained the highest number of fruits per inflorescence after thinning (4.6 and 4.2 fruits, respectively). This indicates lower efficiency of chemical thinning in reducing the number of fruits per inflorescence (Table 2). Regarding fruit drop, the treatments Metamitron alone and combined with Ethephon induced a higher percentage of drop of fruits larger than 15 mm (18.1% and 24.9%, respectively). This may include the reduced production observed in treatments that combine these products.

Table 2 – Effect of chemical thinning agents on the number of fruits per inflorescence and percentage of fruit drop of 'Fuji Suprema' apple trees. Caçador, SC, Brazil, 2024.

Treatments	Before thinning	After thinning	Drop of fruits larger than15mm (%)

1. Control (manual thinning) – Fruits 8-12 mm	4.2 b	3.5 b	8.7 b
2. Benzyladenine 400 ml/100 L + Ethephon 200 ml/100 L– Fruits 15-20 mm	4.7 a	4.6 a	8.5 b
3. Benzyladenine 400 ml/100 L + Metamitron 100 g/100 L– Fruits 15-20 mm	4.2 b	3.6 b	19.4 a
4. Benzyladenine 600 ml/100 L– Fruits 15-20 mm	5.1 a	4.2 a	5.9 b
5. Ethephon 240 - 200 ml/100 L– Fruits 15-20 mm	4.9 a	4.3 a	10.2 b
6. Metamitron 150 ml/100 L– Fruits 15-20 mm	4.1 b	3.9 b	18.1 a
7. Metamitron 150 ml/100 L + Ethephon 200 ml/100 L– Fruits 15-20 mm	3.9 b	3.5 b	24.9 a

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

Treatments with Metamitron alone and combined with Ethephon showed fruits with higher average weights (112.0 and 117.5 g, respectively), indicating that the reduction in the number of fruits favors individual growth. The control treatment had a lower average weight compared to these treatments, probably due to the greater competition between fruits for the assimilation of resources (Table 3). Manual thinning maintains the highest average production per plant, but with fruits of lower weight.

Table 3 – Effect of chemical thinning agents on the average fruit weight (g fruit^{-1}) of 'Fuji Suprema' apple trees. Caçador, SC, Brazil, 2024.

Treatments	**2017**	**2018**	**2019**	**2020**	**Mean**
1. Control (manual thinning) – Fruits 8-12 mm	125.2 b	96.3 a	122.8 ^{ns}	113.8 ^{ns}	115.0 a
2. Benzyladenine 400 ml/100 L + Ethephon 200 ml/100 L– Fruits 15-20 mm	127.6 b	88.0 b	111.6	104.7	108.0 b
3. Benzyladenine 400 ml/100 L + Metamitron 100 g/100 L– Fruits 15-20 mm	146.2 a	82.1 b	125.6	94.1	112.0 a
4. Benzyladenine 600 ml/100 L– Fruits 15-20 mm	120.6 b	85.8 b	112.1	92.1	102.6 b
5. Ethephon 240 - 200 ml/100 L– Fruits 15-20 mm	125.2 b	82.4 b	110.5	102.8	105.2 b
6. Metamitron 150 ml/100 L– Fruits 15-20 mm	138.2 a	83.1 b	122.6	104.0	112.0 a
7. Metamitron 150 ml/100 L + Ethephon 200 ml/100 L– Fruits 15-20 mm	145.9 a	91.1 a	131.2	102.0	117.5 a

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

The control treatment showed higher effective fruiting (108.7%) over the years. Benzyladenine combined with Metamitron and Metamitron alone led to the lowest levels of effective fruiting (67.2% and 102.9%, respectively), which may be a consequence of the higher percentage of fruit drop induced by these treatments (Table 4). Significant differences in effective fruiting were observed only in the first year of evaluation, when the treatment Benzyladenine + Ethephon did not differ from the control. This demonstrates that the efficiency of chemical thinning agents depends on factors such as application stage, climatic conditions and formulation.

Table 4 – Effect of chemical thinning agents on the effective fruiting (%) of 'Fuji Suprema' apple trees. Caçador, SC, Brazil, 2024.

Treatments	2017	2018	2019	Mean
1. Control (manual thinning) – Fruits 8-12 mm	109.0 a	142.2 ns	75.0 ns	108.7 ns
2. Benzyladenine 400 ml/100 L + Ethephon 200 ml/100 L– Fruits 15-20 mm	119.9 a	112.8	71.5	101.4
3. Benzyladenine 400 ml/100 L + Metamitron 100 g/100 L– Fruits 15-20 mm	59.5 b	135.8	73.9	89.7
4. Benzyladenine 600 ml/100 L– Fruits 15-20 mm	58.3 b	80.0	63.3	67.2
5. Ethephon 240 - 200 ml/100 L– Fruits 15-20 mm	76.0 b	235.5	80.6	130.7
6. Metamitron 150 ml/100 L– Fruits 15-20 mm	66.6 b	181.8	60.3	102.9
7. Metamitron 150 ml/100 L + Ethephon 200 ml/100 L– Fruits 15-20 mm	25.9 b	207.5	52.5	95.3

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

The results show that manual thinning maintains a higher number of fruits and, consequently, higher production per plant, but with lower average fruit weight. In turn, chemical treatments, Metamitron (alone and combined), reduce the number of fruits and increase their average weight. Similar results were reported by Greene (2014), who indicated that high concentrations of Metamitron (>300 mg/L) and high temperature conditions (29–31 °C) intensify the thinning effect, so care should be taken in the application to avoid excessive fruit drop. These results reinforce that chemical thinning is a viable alternative to manual thinning, especially when optimizing fruit size and quality. Proper management, adjusted to climatic conditions, is essential to maximize the benefits of these technologies.

The incidence of russeting did not show significant differences, indicating that Benzyladenine, Ethephon and Metamitron do not cause russetingwhen applied to fruits with 15 mm diameter. The results showed that Metamitron or Metamitron plus Ethephon or BA can be effective for fruit drop when applied to fruits of 15 mm or more in the cv. 'Fuji Suprema', so they can be used as a chemical thinning supplement in the whole plant or in the upper part of the crown. The results confirm those reported by Brunner (2014), who obtained maximum reduction of effective fruiting in the cv. 'Fuji' when applyingMetamitron to fruits up to 12 mm in diameter.

Final considerations

Treatments with chemical thinning agents were effective in fruit drop, number of fruits and average fruit weight. Benzyladenine (Maxcel®) and Ethephon (Ethrel®) alone or in combination maintained production at competitive levels, with moderate effects on fruit reduction.

Metamitron (Goltix®), alone or in combination with Ethephon (Ethrel®), promoted greater fruit drop, favoring fruits of higher weight and quality, which is relevant for markets that prioritize large fruits (>70 mm).

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