

Short Research Article

Metamitron and different plant growth regulators combinations in the chemical thinning of 'Eva' apple trees

ABSTRACT

Aims: The objective of this study was to evaluate the effect of the application of Metamitron and the combinations of NAA + BA and Promalin + BA on the fruit thinning of the Eva cultivar apple tree in southern Brazil.

Study design: The experimental design used was a randomized complete block design, with four replications, with two plants per treatment in each block, following a one-step scheme with 10 treatments for the thinning factor.

Place and Duration of Study: The experiment was carried out in the agricultural year of 2013/2014 in a commercial orchard located in the municipality of Morro Redondo, RS, Brazil (Lat. 31° 40' 60" S and Long. 52° 34' 50" W).

Methodology: The experiment was carried out in a commercial orchard in the municipality of Morro Redondo, RS, Brazil. Spraying of Metamitron was carried out at doses of 300, 350 and 400 mg L⁻¹ and combinations of 5 mg L⁻¹ of NAA + BA at doses 50, 75 and 100 mg L⁻¹ and 0.5 ml L⁻¹ of Promalin® + BA at doses of 50, 75 and 100 mg L⁻¹. Only the doses of Promalin® were applied in full bloom, the other sprayings were carried out in fruiting with 5-8 mm in diameter. The variables analyzed were: number of fruits per trunk section area, number of fruits per plant, yield per plant, mean fruit mass, pulp firmness, fruit shape and diameter, fruit length, length/diameter ratio and soluble solids.

Results: A reduction in harvest load by Metamitron was only observed with the 300 mg L⁻¹ dose. The combination of NAA 5 mg L⁻¹ + BA 75 mg L⁻¹ showed the highest fruit reduction, with a low fruit density per cm⁻² and the highest average fruit mass. For the combinations of Promalin® + BA, as the increment of the dose of BA increased, there was a reduction of the number of fruits and consequently an increase in their size.

Conclusion: It was concluded that the Metamitron at the dose of 300 mg L⁻¹ was able to cause thinning when applied in the fruit formation phase (5-8 mm). And the combinations of NAA 5 mg L⁻¹ + BA 75 mg L⁻¹ and Promalin® 0.5 ml L⁻¹ + BA 100 mg L⁻¹ were able to reduce harvest load and increase the fruit size.

Keywords: *Malus domestica* (Borkh.) Borkh., Inhibitor of photosystem II, plant growth regulators.

1. INTRODUCTION

The apple tree crop usually presents an excessive load of flowers or fruits, more than the plant can support, causing a reduction in the quality of the fruits, due to competition for photoassimilates and nutrients. [1] Report that fruit species generally produce more flowers than necessary and that if all the flowers that appeared in flowering were to establish fruit development, the plant would not have the photosynthetic or structural integrity to mature

those fruits correctly. The same authors also state that fruit species have a self-regulating mechanism, capable of causing thinning of weak-structured, small-seeded and poorly-formed fruits, but that in general this mechanism is not sufficient to guarantee a commercial quality and size fruit.

Thus, fruit or flower thinning is necessary for commercial production of apples, improving fruit size and quality, leaving the plant with an ideal harvest load and increasing the flowering return [2].

According to [3], thinning substances can be divided according to their mode of action; caustic or hormonal. Among the substances with hormonal action Naphthalene Acetic Acid (NAA), Carbaryl, Ethephon and Benzyladenine (BA) can be mentioned. These substances were shown to be preferred for use in chemical thinning in relation to caustic substances due to their greater selectivity in the thinning, induction in the abscission of flowers and fruits with less growth capacity, besides not inducing morphological damages to the remaining fruits.

The most recent alternative in pomiculture has been the inhibitors of photosystem II such as the Metamitron, which is capable of causing thinning when applied on fruits of 10 to 12 mm in diameter [4,5,6,7]. Metamitron disrupts the photosynthesis process 7 to 10 days after application, reducing electron rates by up to 60% [8]. According to recent studies conducted by [5], [6] and [9], the Metamitron herbicide of the chemical triazinone group has a positive effect on the activity of apple fruit thinning due to its direct action in the inhibition of photosynthesis.

The objective of this study was to evaluate the effect of the application of Metamitron and the combinations of NAA + BA and Promalin + BA on the fruit thinning of the Eva cultivar apple tree in southern Brazil.

2. MATERIAL AND METHODS

The experiment was carried out in the agricultural year of 2013/2014 in a commercial orchard located in the municipality of Morro Redondo, RS, Brazil (Lat. 31° 40' 60" S and Long. 52° 34' 50" W). Seven-year-old "Eva" apple plants grafted on a Marubakaido rootstock were used and conducted in the central leader system with a density of 2,500 ha⁻¹ plants.

The experimental design used was a randomized complete block design, with four replications, with two plants per treatment in each block, following a one-step scheme with 10 treatments for the thinning factor.

• The treatments used were:

- T1 - Manual Thinning (30 days after full bloom);
- T2 - Metamitron 300 mg L⁻¹;
- T3 - Metamitron 350 mg L⁻¹;
- T4 - Metamitron 400 mg L⁻¹;
- T5 - NAA 5 mg L⁻¹ + BA 50 mg L⁻¹;
- T6- NAA 5 mg L⁻¹ + BA 75 mg L⁻¹;

- 64 • T7 - NAA 5 mg L⁻¹ + BA 100 mg L⁻¹;
- 65 • T8 - Promalin® 0.5 ml L⁻¹ + BA 50 mg L⁻¹;
- 66 • T9 - Promalin® 0.5 ml L⁻¹ + BA 75 mg L⁻¹;
- 67 • T10 - Promalin® 0.5 ml L⁻¹ + BA 100 mg L⁻¹.

68 The source of Metamitron was the herbicide Goltix® (70% active ingredient - ai), the
 69 commercial products Technical NAA (9.5% ai) and MaxCel® (2% ai) were used for
 70 naphthalene acetic acid (NAA) and 6-benzyladenine (BA), respectively. Promalin®, a
 71 phytohormone composed of gibberellins GA4 + 7 (1.8%) and cytokinin 6-benzyladenine
 72 (1.8%) (Valent Biosciences) was also used. In all treatments 0.2% Assist® mineral oil was
 73 added. The applications were performed by a sprinkler with costal spray, using a mean
 74 solution volume of corresponding to 1000 L ha⁻¹. Promalin® was applied in full bloom (PF),
 75 Metamitron, NAA and BA were applied when the larger fruits reached 5 to 8 mm in diameter.

76 The variables analyzed were: number of fruits per trunk section area (cm⁻²), trunk diameter
 77 at 20 cm from the ground, number of fruits per plant, production per plant (kg), mean fruit
 78 weight (g), pulp firmness (N), fruit shape through its diameter (mm), fruit length (mm), length
 79 and diameter ratio and soluble solids (°Brix).

80 The results were submitted to analysis of variance, and a comparison of means was made
 81 through the Tukey test, with a 5% probability of error.

82 83 84 **3. RESULTS AND DISCUSSION**

85 The fruits per plant variable stood out at a dose of Metamitron 400 mg L⁻¹ with a mean of
 86 105.5 fruits, not differing from NAA 5 mg L⁻¹ + BA 100 mg L⁻¹ with 92 fruits, which shows that
 87 these treatments were not effective in reducing the harvest load. However, it was observed
 88 that the dose of Metamitron 300 mg L⁻¹ with 34.75 fruits and Promalin® 0.5 ml L⁻¹ + BA 100
 89 mg L⁻¹ with 28 fruits were the treatments that presented the greatest reduction in harvest.
 90 When analyzing the treatments and comparing them with the manual thinning control, it was
 91 observed that of the Metamitron treatments, only Metamitron 300 mg L⁻¹ containing the
 92 lowest dosage of the product showed a reduction of fruits differing statistically from manual
 93 thinning (Table 1). [6] Obtained a reduction of effective fruiting and increase of average
 94 mass of fruits in the Gala Must cultivar with application of 350 mg L⁻¹ of Metamitron. [8]
 95 Report that the application of a photosystem II inhibitor, such as Metamitron, three weeks
 96 after flowering increases fruit sensitivity to abscission due to transient excess and stress of
 97 carbohydrates within the fruit caused by inhibition of electrons transport.

98 With the treatments sprayed with the NAA + BA mixture, the highest reduction occurred in
 99 NAA 5 mg L⁻¹ + BA 75 mg L⁻¹, whereas those treated with a 0.5 ml L⁻¹ Promalin® dose
 100 during flowering and different BA doses during fruiting presented a progressive reduction in
 101 the harvest load as the dose increased, with the combinations Promalin® 0.5 ml L⁻¹ + BA 75
 102 mg L⁻¹ and Promalin® 0.5 ml L⁻¹ + BA 100 mg L⁻¹ differing statistically from manual thinning
 103 (Table 1).

104 Manual thinning, Metamitron 400 mg L⁻¹ and NAA 5 mg L⁻¹ + BA 100 mg L⁻¹ were those that
 105 expressed the highest results in relation to the number of fruits by the cross-sectional area of
 106 the trunk, on the other hand, Metamitron 300 mg L⁻¹, NAA 5 mg L⁻¹ + BA 75 mg L⁻¹ and
 107 Promalin® 0.5 ml L⁻¹ + BA 100 mg L⁻¹ were the lowest results found in the same way as
 108 those with the highest reduction in the number of fruits per plant (Table 1). The reduction,

even when excessive, in the combination of Promalin® + BA was probably due to the excess cytokinin the plant received. [10] Obtained significant results of thinning with the application of NAA + BA in the Gala cultivar, however in the Golden Delicious cultivar the NAA + BA mixture reduced the number of fruits by the section of the trunk area, but did not differ from isolated doses of the plant growth regulators [11]. [12] Observed the effective action of the Promalin® + BA blend in the Fuji Suprema cultivar when applied on fruits with 20 mm diameter, but did not obtain effectiveness when applied in fruits of 5-8 mm, differing from the results found in this study.

Table 1 - Number of fruits per plant, fruits per trunk cross-sectional area and yield per plant, in different treatments on Eva cultivar.

Treatments	Nº. of Fruits per plant	Fruit cm ⁻² TCSA	Yield per plant (Kg plant ⁻¹)
T1 - Manual Thinning	86.25 ab	8.01 ab	9.25 a
T2 - Metamitron 300 mg L ⁻¹	34.75 cd	2.98 e	3.91 b
T3 - Metamitron 350 mg L ⁻¹	83.25 ab	7.52 a-c	8.55 a
T4 - Metamitron 400 mg L ⁻¹	105.5 a	9.45 a	9.87 a
T5 - NAA 5 mg L ⁻¹ + BA 50 mg L ⁻¹	58.5 bc	5.84 b-d	5.28 b
T6 - NAA 5 mg L ⁻¹ + BA 75 mg L ⁻¹	32.5 cd	2.81 e	3.6 b
T7 - NAA 5 mg L ⁻¹ + BA 100 mg L ⁻¹	92 a	8.42 ab	9.36 a
T8 - Promalin® 0.5 ml L ⁻¹ + BA 50 mg L ⁻¹	60 bc	5.0 c-e	5.64 b
T9 - Promalin® 0.5 ml L ⁻¹ + BA 75 mg L ⁻¹	41 cd	3.96 de	4.35 b
T10 -Promalin® 0.5 ml L ⁻¹ + BA 100 mg L ⁻¹	28 d	2.63 e	3.04 b
Mean	62.17	5.60	6.28
Coefficient of variance (%)	18.64	19.10	17.61

Means followed by the same letter do not differ from each other, by the Tukey test, at 5% probability. (p< 0.05). TCSA – trunk cross-sectional area.

When analyzing the average mass of fruits, a direct relation can be established with fruits per cm² of cross-sectional area of the trunk, where the three treatments that expressed the lowest fruit density per plant were those that presented the highest average fruit mass (Metamitron 300 mg L⁻¹ with 113.16 grams, NAA 5 mg L⁻¹ + BA 75 mg L⁻¹ with 111.94 grams and Promalin® 0.5 ml L⁻¹ + BA 100 mg L⁻¹ with 109.89 grams) and consequently the same ones that obtained the smallest yields in kilos per plant (Table 2). According to [12], the application of Metamitron or Metamitron + BA was efficient in fruit thinning in the Fuji Suprema, MaxiGala and Fred Hough apple cultivars, proving their potential to compose the chemical thinning program of apple trees in substitution of Carbaryl in the Brazilian climatic conditions. In addition, the possibility of using Metamitron in the thinning of fruits with larger diameter was observed, according to work conducted by [13] in which they verified the efficiency of Metamitron in fruit thinning from 5 mm to 20 mm in diameter in the Fred Hough apple cultivar.

In Table 2, when analyzing the treatments that had metamitron in their formulation, it is observed that as the product dosage is increased, the average mass of fruits decreases, different from what happened with the treatments with BA (combined with NAA as well combined with Promalin®, the increase in BA dosage resulted in a progressive increase in mean fruit mass. The combination of different BA + NAA 5 mg L⁻¹ doses showed effective

138 results in increasing fruit mass and a reduction in yield per plant in Kozara cultivar [14].
139 However, using the BA + NAA mixture,[15] obtained dwarf fruits.

140 Soluble solids were not significantly affected by the treatments used, presenting an average
141 of 12.51° Brix, different from the pulp firmness that presented statistical difference between
142 the treatments, with NAA 5 mg L⁻¹ + BA 50 mg L⁻¹ with 81.37 N being the best result found
143 and Promalin® 0.5 ml L⁻¹ + BA 50 mg L⁻¹ with 69.94 N the lowest result (Table 2).

Table 2 - Average mass of fruits, total soluble solids and pulp firmness, in different treatments in the Eva cultivar.

Treatments	Average Mass of fruits (g)	SS (°Brix)	PF (N)
T1 - Manual Thinning	107.04 ab	12.55 ns	71.27 b
T2 - Metamitron 300 mg L ⁻¹	113.16 a	11.53	76.31 ab
T3 - Metamitron 350 mg L ⁻¹	97.63 ab	13	75.57 ab
T4 - Metamitron 400 mg L ⁻¹	93.82 ab	12.76	70.41 b
T5 - NAA 5 mg L ⁻¹ + BA 50 mg L ⁻¹	88.02 b	12.7	81.37 a
T6 - NAA 5 mg L ⁻¹ + BA 75 mg L ⁻¹	111.94 a	12.93	77.78 ab
T7 - NAA 5 mg L ⁻¹ + BA 100 mg L ⁻¹	102.73 ab	12.33	70.19 b
T8 - Promalin® 0.5 ml L ⁻¹ + BA 50 mg L ⁻¹	94.35 ab	12.1	69.94 b
T9 - Promalin® 0.5 ml L ⁻¹ + BA 75 mg L ⁻¹	106.77 ab	12.16	73.62 ab
T10 - Promalin® 0.5 ml L ⁻¹ + BA 100 mg L ⁻¹	109.89 a	12.26	74.09 ab
Mean	102.93	12.51	74.05
Coefficient of variance (%)	8.24	8.91	5.53

144 Means followed by the same letter do not differ from each other, by the Tukey test, at 5%
145 probability. (p< 0.05). ns – not significant. SS – Soluble Solids. PF – Pulp Firmness in N –
146 Newton.

147 The high pulp resistance in the NAA 5 mg L⁻¹ + BA 50 mg L⁻¹ is probably due to a paralysis
148 of cell expansion, since this was the treatment that obtained the lowest mean mass and the
149 lowest fruit diameter among the analyzed treatments (Table 2 and 3). [14] Obtained good
150 results in relation to fruit size and quality when NAA + BA was applied in Senabija, Pasinka
151 and Kozara cultivars in Montenegro in Europe. The combination of NAA and BA increased
152 the size of 'Summerred' fruits, as reported by [16]. BA is considered a good thinning agent
153 because the substance has a low toxicological profile [17].

154 The fruit shape is evaluated by the diameter, length and the relation between them, and
155 consumers generally take this into account, always looking for symmetrical fruits, that is,
156 those that do not appear flat, that do not have deformations in some sides and are not too
157 long. Table 3 presents the variables that evaluate the fruit shape. It is observed that in all
158 treatments, the length was larger than the diameter, with the L/D ratio being always higher
159 than 1.0. Thus it can be inferred that during the year of the experiment, the fruits of the Eva
160 cultivar tended to be more elongated than round, denoting a possible problem of pollination
161 and seed formation and also by varietal characteristics.[12] reported that the use of BA
162 increases the size of the fruit by the thinning effect, besides promoting increase in fruit size
163 because it is a compound of the cytokinins group, acting in the increase of cell division.
164 Because of this increase in cell division, according to [18], BA can increase fruit size even in
165 the absence of thinning.

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Table 3 - Evaluation of the fruit shape through diameter, length and length/diameter ratio, in different treatments in the Eva cultivar.

Treatments	Diameter (mm)	Length (mm)	L/D
T1 - Manual Thinning	60.5 a	61.75 ab	1.02 ab
T2 - Metamitron 300 mg L ⁻¹	61.37 a	65.5 a	1.06 ab
T3 - Metamitron 350 mg L ⁻¹	59 ab	61.25 ab	1.03 ab
T4 - Metamitron 400 mg L ⁻¹	58.62 ab	59.5 b	1.01 b
T5 - NAA 5 mg L ⁻¹ + BA 50 mg L ⁻¹	56.37 b	60.25 ab	1.06 ab
T6 - NAA 5 mg L ⁻¹ + BA 75 mg L ⁻¹	59 ab	63.5 ab	1.07 ab
T7 - NAA 5 mg L ⁻¹ + BA 100 mg L ⁻¹	58.87 ab	63.5 ab	1.07ab
T8 - Promalin® 0.5 ml L ⁻¹ + BA 50 mg L ⁻¹	57.12 b	61.5 ab	1.07 ab
T9 - Promalin® 0.5 ml L ⁻¹ + BA 75 mg L ⁻¹	59.37 ab	63.5 ab	1.06 ab
T10 - Promalin® 0.5 ml L ⁻¹ + BA 100 mg L ⁻¹	59.37 ab	65.5 a	1.1 a
Mean	58.96	62.57	1.06
Coefficient of variance (%)	2.33	3.57	3.46

Means followed by the same letter do not differ from each other, by the Tukey test, at 5% probability.

4. CONCLUSIONS

The use of a Metamitron dose of 300 mg L⁻¹ was able to cause thinning when applied during the fruit formation stage (5-8 mm).

The combinations of NAA 5 mg L⁻¹ + BA 75 mg L⁻¹ and Promalin® 0.5 ml L⁻¹ + BA 100 mg L⁻¹ were able to reduce harvest load and increase fruit size.

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