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Metamitron in the chemical thinning of 'PS 10711' peach trees

Metamitron no raleio químico de pessegueiros 'PS 10711'

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Highlights:
Chemical thinning in peach trees can be an alternative to hand thinning of the fruits.
The metamitron concentrations of 100 and 200 mg L^{-1} promote fruit abscission.
Chemical thinning with metamitron does not change fruit quality.

Abstract

Chemical thinning of fruits may be an alternative practice to hand thinning. Hand thinning must be performed in a short time during the fruiting stage, but lack of manpower and the onerous costs of the operation make it increasingly difficult to employ it at the right time and at the ideal intensity. The objective of this study was to examine the effect of different concentrations of metamitron as a chemical thinner on 'PS 10711' peach trees. The experiment was carried out during two harvests in an orchard in the municipality of Eldorado do Sul, in the Central Depression region of the state of Rio Grande do Sul, Brazil. Treatments consisted of the application of metamitron at the concentrations of 100, 200, 300 and 400 mg L^{-1}; hand thinning; and no thinning. The fruits were thinned chemically and by hand 40 days after the peach trees were in full bloom. Fruit abscission, fruit set, number of fruits, production per tree and fruit quality were evaluated. Metamitron has a thinning effect on the peaches of cultivar PS 10711. The metamitron concentrations of 100 and 200 mg L^{-1} result in less fruit abscission as compared with hand thinning. The thinning effect of metamitron alters production per tree, but does not interfere with fruit quality.
Key words: Fruit abscission. Fruit quality. Fruit set. Production. Stone fruits.

Resumo

O raleio químico de frutos pode ser uma prática alternativa ao raleio manual. O raleio manual necessita ser executado num curto período da frutificação, mas a falta de mão de obra e a onerosidade dos custos da operação cada vez mais dificultam o seu emprego no momento adequado e na intensidade ideal. O objetivo desse trabalho foi avaliar o efeito de diferentes concentrações do metamitron como raleante químico nos pessegueiros 'PS 10711'. O experimento foi realizado durante duas safras num pomar do

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município de Eldorado do Sul, região da Depressão Central do Rio Grande do Sul, Brasil. Os tratamentos consistiram na aplicação de metamitron nas concentrações de 100 mg L^{-1}, 200 mg L^{-1}, 300 mg L^{-1} e 400 mg L^{-1}, raleio manual e plantas sem raleio. O raleio químico e manual dos frutos foram realizados aos 40 dias após a plena floração dos pessegueiros. Avaliou-se a abscisão de frutos, frutificação efetiva, número de frutos, produção por planta e a qualidade dos frutos. O metamitron possui efeito raleante em pêssegos da cultivar PS 10711. As concentrações de 100 e 200 mg L^{-1} de metamitron promove abscisão de frutos inferior ao raleio manual. O efeito raleante do metamitron altera a produção por planta, mas não interfere na qualidade dos frutos.

Palavras-chave: Abscisão de frutos. Frutíferas de caroço. Frutificação efetiva. Produção. Qualidade dos frutos.

Introduction

Management practices performed in peach orchards notably pruning, irrigation, fertilization, phytosanitary treatments, as well as fruit thinning directly affect the yield and quality of fruits (Raseira, Nakasu, & Barbosa, 2014; Oliveira, Marodin, Almeida, Gonzatto, & Darde, 2017; Ferreira, Picolotto, Pereira, Schmitz, & Antunes, 2018). In fruit plants, thinning is aimed at reducing fruit load and providing an adequate size for sale, in addition to preventing alternating production (Petri, Couto, Gabardo, Francescatto, & Hawerroth, 2016). This practice is employed to provide balance between source and drain, thus minimizing the consumption of reserves and the synthesis of gibberellins (Costa, Blanke, & Widmer, 2013).

Peach trees produce abundant flowering and can fix a higher number of fruits than the tree supports (Giovanaz, Fachinello, Spagnol, Weber, & Carra, 2016). With vegetative growth, this leads to competition between fruits for water, nutrients and photoassimilates, requiring a thinning operation. Thinning is mostly performed manually, between 40 and 50 days after full bloom (Oliveira et al., 2017). However, it must be carried out in a short period and requires high labor demand, increasing production costs (Simões, Vuleta, & Belusic, 2013; Oliveira et al., 2017). For these reasons, this practice is usually performed out of season and at an inadequate intensity, ultimately affecting the production and quality of the fruit.

In view of the need to ensure the efficiency of thinning as well as reduce labor, new studies propose chemical thinning as an alternative to the hand thinning of fruits (Petri et al., 2016; Barreto et al., 2018b; Farias et al., 2019a; Farias, Barreto, Zandoná, Martins, & Mello-Farias, 2020). Chemical thinning consists of the application of chemicals during or shortly after bloom, which causes the abscission of flowers and/or fruits, thereby reducing or eliminating the need for hand thinning (Pavanello & Ayub, 2012).

Some studies have shown the potential of chemical thinning in the peach crop (Taheri, Cline, Jayasankar, & Pauls, 2012; Giovanaz et al., 2016; Barreto et al., 2018a; Farias et al., 2020). In temperate fruit trees, chemical thinning has been performed with products with hormonal action or products which act on the electron transport chain between photosystems, such as metamitron (Petri et al., 2016; Goulart et al., 2017; Gabardo et al., 2017a; Farias et al., 2019a, 2020). This product has been used mainly for thinning apple trees in southern Brazil and has shown satisfactory results in reducing fruit load (Petri et al., 2016; Gabardo et al., 2017a).

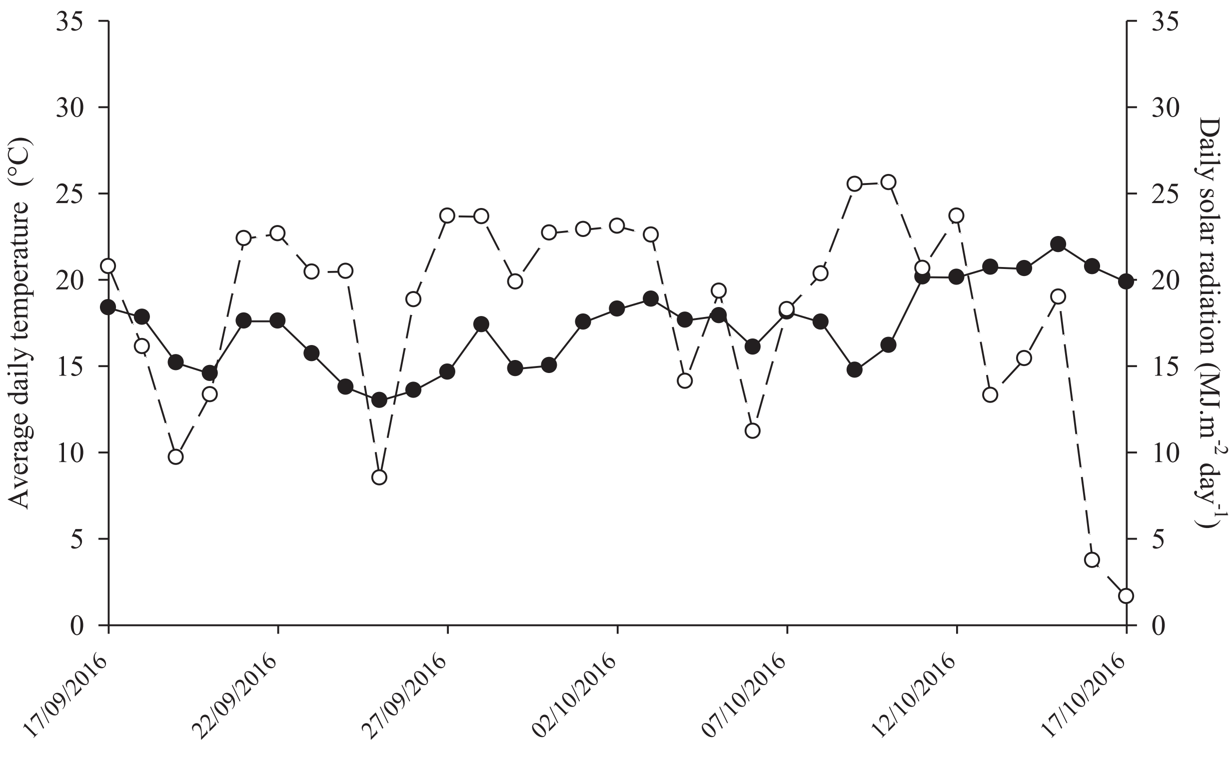
Metamitron acts on photosystem II by inhibiting electron transport from the chloroplast of plastoquinone QA to QB, reducing CO_2 fixation and the production of ATP and NADPH and consequently inhibiting photosynthesis (Basak, 2011; Stern, 2014). When applied to fruits, metamitron contributes to their physiological drop (Gabardo et al., 2017a), since photosynthetic inefficiency reduces the production of carbohydrates necessary for fruit fixation (Farias et al., 2019b, 2020). However, the success of chemical thinning depends on genetic traits of the cultivar, the concentration used and the appropriate phenological stage for application (Brunner, 2014; Mcartney & Obermiller, 2014).

Knowledge about chemical thinning in the peach crop is still incipient, warranting further research for the technology to be implemented, in effect, in Brazilian orchards. On this basis, this study was developed to examine the effect of different concentrations of metamitron as a chemical thinner on ‘PS 10711’ peach trees.

Material and Methods

The experiment was conducted during the 2016 and 2017 harvests at the Experimental Agronomic Station (EEA) of the Federal University of Rio Grande do Sul (UFRGS) (30°06’33” S; 51°40’14” W), located in the municipality of Eldorado do Sul, state of Rio Grande do Sul (RS), Brazil. The work was carried out in an experimental orchard of ‘PS 10711’ peach trees grafted on ‘Capdeboscq’, at six years of age. The trees were trained in an open-pot system with 5.5-m spacing between planting rows and 2.5 m between trees. Figure 1 shows the average daily temperature and daily solar radiation at 30 days after the chemical thinning, in the two years of the experiment. The data were collected from the meteorological station of UFRGS, in the experimental station of Eldorado do Sul, RS, Brazil.

A



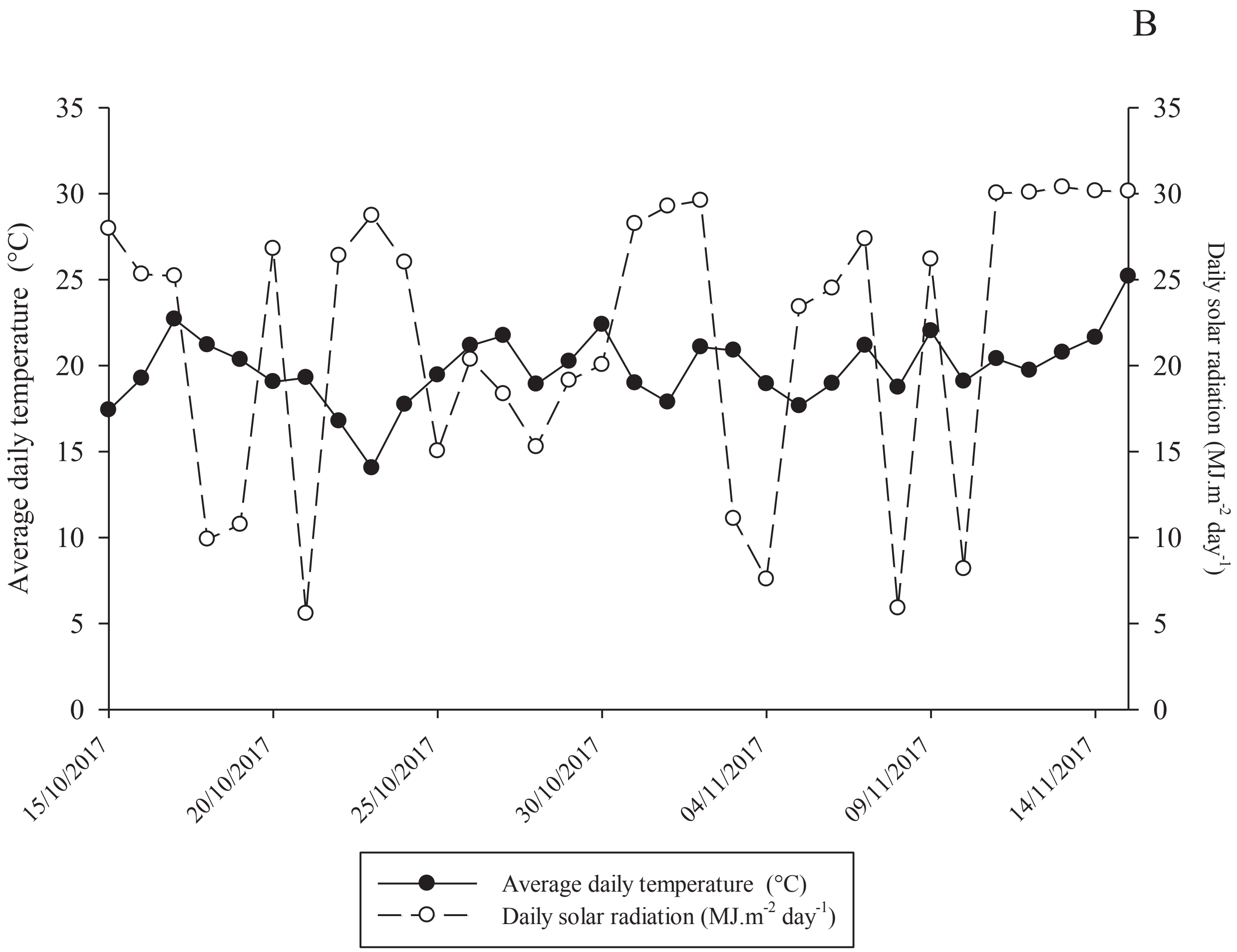


Figure 1. Average daily temperature and daily solar radiation 30 days after chemical thinning with different concentrations of metamitron in the years 2016 (A) and 2017 (B), in the municipality of Eldorado do Sul, RS, Brazil. Experimental Station at the Federal Universidade do Rio Grande do Sul, RS, Brazil.

The experiment was laid out in a randomized-block design with five replicates, with one tree per plot. High-fruiting trees were subjected to the treatments of chemical thinning with metamitron at the concentrations of 100, 200, 300 and 400 mg L^{-1} and hand thinning at 40 days after full flowering (DAFF). A control treatment was also used, in which the trees were not thinned. The diameter of the fruits at the time of chemical thinning and hand thinning ranged from 21 to 25 mm.

Full bloom in the peach trees occurred on the 12th of August in the year 2016 and on the 5th of September in the year 2017. In hand thinning, depending on the vigor of the branches, an average of 10 to 15 cm of spacing was kept between the fruits. To proceed with the application of the products, the solutions were prepared in the field, at the time of application. The commercial product Goltix® was used as a source of metamitron, containing 70% of active ingredient, and 0.05% of Silwet L-77® non-ionic adhesive spreader was added to all treatments. The different concentrations were applied by spraying using a Jacto backpack sprayer (40-psi working pressure). At the time of application, the limit for the applied volume was the point of runoff, totaling an average of 1000 L ha^{-1} of spray mix. The climatic conditions at the time of application were temperature close to 15 °C and relative humidity of

75% in 2016, and approximately 17 °C and 69%, respectively, in 2017. All applications were carried out in the morning, and no precipitation occurred in the six hours after application of the product. The other cultivation treatments (e.g. fertilization, winter and summer pruning, phytosanitary treatments and weed control) were applied according to the norms of Integrated Peach Production (Fachinello, Tibola, Picolotto, Rossi, & Rufato, 2005).

The evaluated parameters consisted of fruit abscission, fruit set, production and post-harvest quality. Fruit abscission was evaluated (%) by selecting five mixed branches of approximately 25 cm in length, at random, in each tree, encompassing the vegetative canopy. The percentage of fruit abscission was determined by counting the number of fruits before the chemical thinner was applied and at the time of harvest. Fruit set (%) was evaluated in the five branches marked per tree by counting the number of flowers in full bloom and the number of fruits at the time of harvest. Production was determined as the number of fruits per tree (fruits/tree) and by weighing the fruits at harvest (kg/tree).

The harvest was carried out in the commercial calendar on November 2, 2016 (82 DAFF) and November 9, 2017 (65 DAFF), with only one sweep. After harvesting, a sample of 50 fruits per replicate was evaluated to determine average fruit weight, by weighing the fruits on a digital scale, with results expressed in grams (g); and fruit diameter, which was divided into four categories: > 70 mm, 70 to 60 mm, 60 to 50 mm and < 50 mm. According to Raseira et al. (2014) these classes correspond to very large, large, medium and small fruits, respectively.

For the physico-chemical and bioactive-compound analyses, samples of 20 fruits were collected per replicate. The color of the peach skin was evaluated using a Minolta CR-300® colorimeter with a D65 illuminant; readings were taken in the equatorial region of the fruits by measuring the parameters of "L" (lightness), "a*", "b*" and hue (represented by the hue angle, °Hue). Pulp firmness was measured using a handheld bench-top penetrometer (TR TURONI, model 53205, Italy) with an 8-mm diameter plunger, at two opposite points in the equatorial region of the unpeeled fruits, with results expressed in Newtons. Lastly, soluble solids were determined using an Atago® digital refractometer, with results expressed in ºBrix.

The following analyses were carried out to determine bioactive compounds in the peach pulp: total phenolic compounds, determined by the method based on reaction with the Folin-Ciocalteu reagent, according to the method adapted from Singleton and Rossi (1965), with results expressed in mg of gallic acid equivalent in 100 g of sample; antioxidant activity, determined by the DPPH radical method adapted from Brand-Williams, Cuvelier and Berset (1995), with results expressed in mg trolox equivalent 100 g^{-1} fresh weight.

Data were subjected to analysis of variance, by the F test ($p \leq 0.05$). When the F test was significant for the metamitron concentrations, polynomial regression was performed. Additionally, when statistical significance was confirmed, the treatments were compared using orthogonal contrasts ($p \leq 0.05$). The orthogonal contrasts were arranged as follows: C1 - control vs. thinning methods (hand thinning and metamitron at the concentrations of 100, 200, 300 and 400 mg L^{-1}); C2 - hand thinning vs. metamitron concentrations. The contrasts were considered significant when $p \leq 0.05$ for the F test. Statistical analysis was performed using Sisvar software (Ferreira, 2014).

Results and Discussion

The increasing concentrations of metamitron in the trees provided a decrease in fruit set in the peach trees in 2016 (Table 1). In the same year, there was a reduction in fruit set at the metamitron concentration of 400 mg L^{-1}, whereas higher means were observed in the trees which were not treated with the chemical thinner. Fruit set is determined as the ratio of number of fruits formed to number of flowers open at bloom (Tomaz, Lima, Gonçalves, Rufato, & Rufato, 2010). Thus, a high fruit set implies a higher fixation of fruits than the ideal support capacity of the trees, requiring the removal of part of the fruits to allow the peaches to reach commercial size and prevent alternating production.

Table 1
Fruit set and fruit abscission in 'PS 10711' peach trees subjected to chemical thinning with different concentrations of metamitron or hand thinning, in the municipality of Eldorado do Sul, RS, in the years 2016 and 2017

Metamitron concentration ($mg\ L^{-1}$)	Fruit set (%)		Fruit abscission (%)	
	2016	2017	2016	2017
0	39.01	21.66	48.99	29.74
100	17.10	15.41	75.67	39.86
200	27.10	17.11	63.68	38.82
300	11.56	12.77	83.76	53.50
400	8.92	19.35	87.98	34.99
CV (%)	26.02	33.61	14.27	23.87
Linear	*(1)	ns	*(2)	ns
Quadratic	ns	ns	ns	ns
Hand thinning	13.16	12.31	82.65	43.25
Contrast				
C1	*	ns	*	ns
C2	*	ns	*	ns

(1) $y = 33.882 - 0.0657x$; $R^2 = 0.7063$. (2) $y = 54.802 + 0.0861x$; $R^2 = 0.7365$. * significant at 5% probability. ns = not significant. CV (%) = coefficient of variation. C1 - control vs. thinning methods (by hand and using metamitron at the concentrations of 100, 200, 300 and 400 $mg\ L^{-1}$); C2 - hand thinning vs. metamitron concentrations, significant at $p \leq 0.05$.

The results of fruit set in 2016 corroborate the fruit abscission data of the same year, in which the increasing metamitron concentrations resulted in a greater intensity of fruit drop (Table 1). This effect is due to the action of metamitron on photosystem II, whereby it inhibits electron transport in the chloroplast, ultimately inhibiting photosynthesis (Basak, 2011; Stern, 2014). Because of the photosynthetic inefficiency of the tree, there may be a reduction in the production of carbohydrates necessary for fruit fixation. During the development stage, fruits are the main drains of the final products of photosynthesis, and an interruption or reduction of the photosynthetic rate may cause the fruits to fall due to competition (Gabardo et al., 2017b).

However, in 2017, fruit set and abscission were not influenced by the chemical thinning of the peach trees (Table 1). According to Brunner (2014), metamitron has shown variable results as a chemical thinner of apple trees, with different effects observed according to the cultivar, concentration, and time of application. The variable efficiency of thinning products for fruits over the years makes it difficult to accurately define suitable concentrations. According to Petri et al. (2016), both environmental and plant-related factors are involved in a complex interaction in the final response to the application of chemical thinners.

The metamitron concentration of 300 $mg\ L^{-1}$ provided fruit set values close to those obtained with hand thinning, in both studied harvests (Table 1). For fruit abscission, the metamitron concentrations of 300 and 400 $mg\ L^{-1}$ resulted in values similar to those achieved with hand thinning in 2016; however, in the second year, similar values were observed at concentrations of 100 and 200 mg L^{-1}. These differences in the effect of concentrations between the years were possibly due to the fruit load and climatic conditions. With a higher fruit load on the trees in 2016, the higher concentrations of metamitron resulted in similar values to hand thinning, whereas with the lower fruit load on the trees seen in 2017, the lower metamitron concentrations provided values similar to those obtained with hand thinning. With regard to climatic conditions, as shown in Figure 1, the lowest concentrations had an effect in 2017, possibly due to the lower light intensity, as demonstrated by solar radiation in the 30 days after the application of the chemical thinner. This was also confirmed in the first 10 days after application in 2016, when the sum of solar radiation was approximately 173 MJ m^{-2}, with only two days with radiation above 20 MJ m^{-2}. In 2017, however, the sum of solar radiation in the 10 days after application was approximately 213 MJ m^{-2}, with seven days of radiation above 25 MJ m^{-2}. According to McArtney and Obermiller (2014), metamitron changes the photosynthetic apparatus for 7 to 10 days after its application, reducing electron transport rates by up to 60%. Farias et al. (2020) reported that the intensity and oscillation of solar radiation influences the rate of abscission in peach fruits. Thus, as seen in the apple tree (Petri, Hawerroth, Berenhauser, & Couto, 2013), the results obtained with the use of chemical thinner in the peach tree depend on the interaction between genotype and climatic conditions.

With respect to the contrasts, the first (C1) revealed that lack of thinning altered peach fruit set and abscission in 2016 (Table 1). The second contrast (C2) showed that hand thinning in 2016 altered fruit set and abscission in relation to the trees thinned with different concentrations of metamitron. However, in 2017, the tested contrasts indicated no differences for fruit set and abscission.

It is important to stress that chemical thinning can be used as a complementary technique to hand thinning. The application of chemical thinning is also aimed at reducing the fruit load to facilitate the manual labor of thinning and consequently reduce the demand for labor. In this way, the metamitron concentration that ensures the maintenance of a fruit load consistent with the fruit set and abscission obtained by the hand thinning method is desirable for producers, as it renders the practice strategically safer and easily adopted. For this parameter, in the two years of evaluation, metamitron concentrations of 100 to 200 mg L^{-1} resulted in a fruit drop below the values obtained by hand thinning.

Production per tree fitted a decreasing linear regression in response to the metamitron concentrations in the 2016 and 2017 harvests (Table 2). A similar result was found in apple trees, where metamitron applied at different concentrations reduced production per tree proportionally to the increase in concentration (Brunner, 2014). Decreased peach production may occur in chemically thinned tree due to the intense reduction in number of fruits (Moyano, Flores, Seta, Leone, & Severin, 2010; El-Boray, Shalan, & Khouri, 2012). In this regard, in the year 2016, the increasing metamitron concentrations induced a reduction in number of fruits per tree, which reached the lowest value at the concentration of 400 mg L^{-1} (Table 2). This result corroborates those observed in apple trees, where increasing metamitron concentrations reduced the number of fruits per inflorescence and the number of fruits per tree (Gabardo et al., 2017a).

In the first year of evaluation (2016), no significant differences were found for average fruit weight in relation to the metamitron concentrations (Table 2). In the second year, average fruit weight fitted a quadratic regression, which showed that the highest weight would be obtained at the metamitron concentration of approximately 160 mg L^{-1}. The photosynthetic reduction caused by the higher concentrations of metamitron possibly influenced this result, as it interfered with the production of photoassimilates, reflecting in a decreased fruit weight. According to Basak (2011) and Stern

(2014), metamitron interrupts CO_2 fixation and the production of ATP and NADPH, which are essential elements for the production of carbohydrates, sugars and other compounds that need metabolic energy to be produced. The availability of sugars in plants increases in the early stages of fruit development, thereby maintaining a high demand for photoassimilates, since they may require large amounts of energy in the period of cell division (Mehouachi et al., 2009). Gabardo et al. (2017b) reported that, in 'Maxi-Gala' apple trees treated with metamitron, fruit growth rate decreased with the increase in the applied concentration, which was observed until the 14th day after application of the product.

Table 2
Production per tree, number of fruits and average fruit weight of 'PS 10711' peach trees subjected to chemical thinning with different concentrations of metamitron or hand thinning, in the municipality of Eldorado do Sul, RS, in the years 2016 and 2017

Metamitron concentration ($mg\ L^{-1}$)	Production per tree (kg)		Number of fruits		Average fruit weight (g)	
	2016	2017	2016	2017	2016	2017
0	59.74	41.97	803	396	74.17	105.96
100	60.38	31.84	774	284	78.09	112.11
200	43.26	42.23	457	367	94.56	115.12
300	44.60	32.41	617	290	72.31	111.78
400	41.27	29.47	439	340	93.95	79.65
CV (%)	16.60	9.34	11.47	10.93	14.23	9.53
Linear	*(1)	*(2)	*(3)	ns	ns	ns
Quadratic	ns	ns	ns	ns	ns	*(4)
Hand thinning	66.08	33.12	675	299	97.87	110.77
Contrast						
C1	*	*	*	*	*	*
C2	ns	*	*	*	ns	*

(1) $y = 60.394 - 0.0527x$; $R^2 = 0.7867$. (2) $y = 40.47 - 0.0244x$; $R^2 = 0.4076$. (3) $y = 795.00 - 0.885x$; $R^2 = 0.6722$. (4) $y = 103.67 + 0.1839x - 0.0006x^2$; $R^2 = 0.9156$. * significant at 5% probability. ns = not significant. CV (%) = coefficient of variation. C1 - control vs. thinning methods (by hand and using metamitron at the concentrations of 100, 200, 300 and 400 $mg\ L^{-1}$); C2 - hand thinning vs. metamitron concentrations, significant at $p \leq 0.05$.

The analysis of contrast 1 revealed that, in the trees that were not thinned to produce peaches, the number and weight of fruits differed from those seen in the thinned trees, in both harvests (Table 2). The second contrast (C2) showed that hand thinning led to different production per tree (2017), number of fruits (2016 and 2017) and fruit weight (2017) as compared with chemical thinning with metamitron.

In terms of fruit quality, there were no significant differences for skin color, pulp firmness or soluble solids between the metamitron concentrations or for the contrasts tested in the two harvests (Table 3). The fact that chemical thinning in peach trees does not alter the quality characteristics of the fruit and maintains them similar to those achieved with hand thinning reinforces the effectiveness of metamitron as an alternative product in that it does not compromise fruit quality traits such as appearance, flavor and color of the peaches for sale.

Table 3
Skin color, pulp firmness and soluble solids of 'PS 10711' peach fruits subjected to chemical thinning with different concentrations of metamitron or hand thinning, in the municipality of Eldorado do Sul, RS, in the years 2016 and 2017

Metamitron concentration (mg L^{-1})	Skin color		Pulp firmness		Soluble solids	
	2016	2017	2016	2017	2016	2017
0	88.10	85.62	21.70	33.61	9.94	10.96
100	80.63	74.09	20.29	30.57	10.3	12.94
200	81.44	74.72	22.69	29.57	10.36	11.82
300	79.30	77.73	19.69	31.57	10.26	12.24
400	83.01	72.63	22.95	31.69	10.4	12.00
CV (%)	7.70	9.93	10.79	7.4	4.75	7.29
Linear	ns	ns	ns	ns	ns	ns
Quadratic	ns	ns	ns	ns	ns	ns
Hand thinning	86.21	70.78	25.84	28.04	9.92	11.40
Contrast						
C1	ns	ns	ns	ns	ns	ns
C2	ns	ns	ns	ns	ns	ns

ns = not significant. CV (%) = coefficient of variation. C1 - control vs. thinning methods (by hand and using metamitron at the concentrations of 100, 200, 300 and 400 mg L^{-1}); C2 - hand thinning vs. metamitron concentrations, significant at $p \leq 0.05$.

In 2016, phenol concentration and antioxidant activity in the fruits fitted a quadratic equation (Table 4). The total phenol concentration in the fruits decreased with the use of metamitron when higher concentrations (300 and 400 mg L^{-1}) were applied, in 2016. The exact causes of the decreasing phenolic compounds with the use of metamitron are not elucidated in this experiment. However, these results are in line with Barreto, Farias, Martins, Malgarim and Mello-Farias (2018a), who observed that peach fruits harvested from trees of cultivar Maciel thinned with metamitron at 200, 300 and 400 mg L^{-1} had lower concentrations of these compounds.

Table 4
Phenols concentration and antioxidant activity of 'PS 10711' peach fruits subjected to chemical thinning with different concentrations of metamitron or hand thinning, in the municipality of Eldorado do Sul, RS, in the years 2016 and 2017

Metamitron concentration (mg L^{-1})	Total phenols		Antioxidant activity	
	2016	2017	2016	2017
0	93.02	70.64	226.27	242.19
100	119.94	69.74	131.08	227.50
200	111.33	68.85	136.00	165.48
300	89.27	67.95	130.63	181.93
400	79.42	67.05	190.95	188.99
CV (%)	10.98	24.39	19.41	31.77

continue

continuation

Linear	ns	ns	ns	ns
Quadratic	*(1)	ns	*(2)	ns
Hand thinning	118.87	90.92	252.37	251.28
Contrast				
C1	ns	ns	ns	ns
C2	*	ns	ns	ns

(1) $y = 97.743 + 0.1907x - 0.0006x^2$; $R^2 = 0.7933$. (2) $y = 220.17 - 0.9303x + 0.0021x^2$; $R^2 = 0.9189$. * significant at 5% probability. ns = not significant. CV (%) = coefficient of variation. C1 - control vs. thinning methods (by hand and using metamitron at the concentrations of 100, 200, 300 and 400 mg L^{-1}); C2 - hand thinning vs. metamitron concentrations, significant at $p \leq 0.05$.

Regardless of the dose, metamitron reduced antioxidant activity in the peaches in 2016 (Table 4). It is suggested that this reduction may be due to the use of metamitron in association with the dose (Barreto et al., 2018a; Farias et al., 2019a) and/or time of application (Farias et al., 2017). In both harvests, the unthinned trees obtained similar antioxidant activity values when compared with the trees subjected to the hand thinning of fruits. For total phenols, contrast 1 was not significant in either year (Table 4). In contrast 2, hand thinning changed the total phenol concentration in relation to the thinning performed with metamitron in 2016.

However, in 2017, there were no differences between the metamitron doses in relation to phenolic compounds and antioxidant activity in the fruits (Table 4). Thus, it was not possible to establish a direct relationship between thinning methods for bioactive compounds, considering that different responses occurred depending on the harvest. This was also observed by Farias et al. (2017), Barreto, Farias, Martins, Malgarim and Mello-Farias (2018b) and Farias et al. (2019a), who described that concentration of these compounds varied according to the chemical thinning method and between harvests, in peach trees.

In peaches, it is reported that the bioactive compound contents may be associated with factors other than thinning, such as cultivar, rootstock (Santos, Abreu, Freire, & Correa, 2013; Barreto et al., 2017), environmental conditions and harvests (Forcada, Gogorcena, & Moreno, 2013). In addition to the difference in bioactive compounds in the fruits between harvests, the peach cultivar may also be associated. Differences between metamitron doses and harvests have been reported for cultivars BRS Kampai (Farias et al., 2019a), Maciel (Barreto et al., 2018a) and Sensação (Farias et al., 2017).

All treatments resulted in a higher frequency of fruits in the diameter classes of 50 to 60 mm and 60 to 70 mm, in the 2016 and 2017 harvests (Figure 2). In 2016, fruits with a diameter > 70 mm were not found in any of the treatments. The highest frequency of fruits in the diameter class of < 50 mm was found in the control trees in the 2016 harvest and at the metamitron concentration of 400 mg L^{-1} in the 2017 harvest. These findings are directly linked to fruit weight, since, in addition to promoting smaller diameters, these treatments also led to decreased weight per fruit (Table 2).

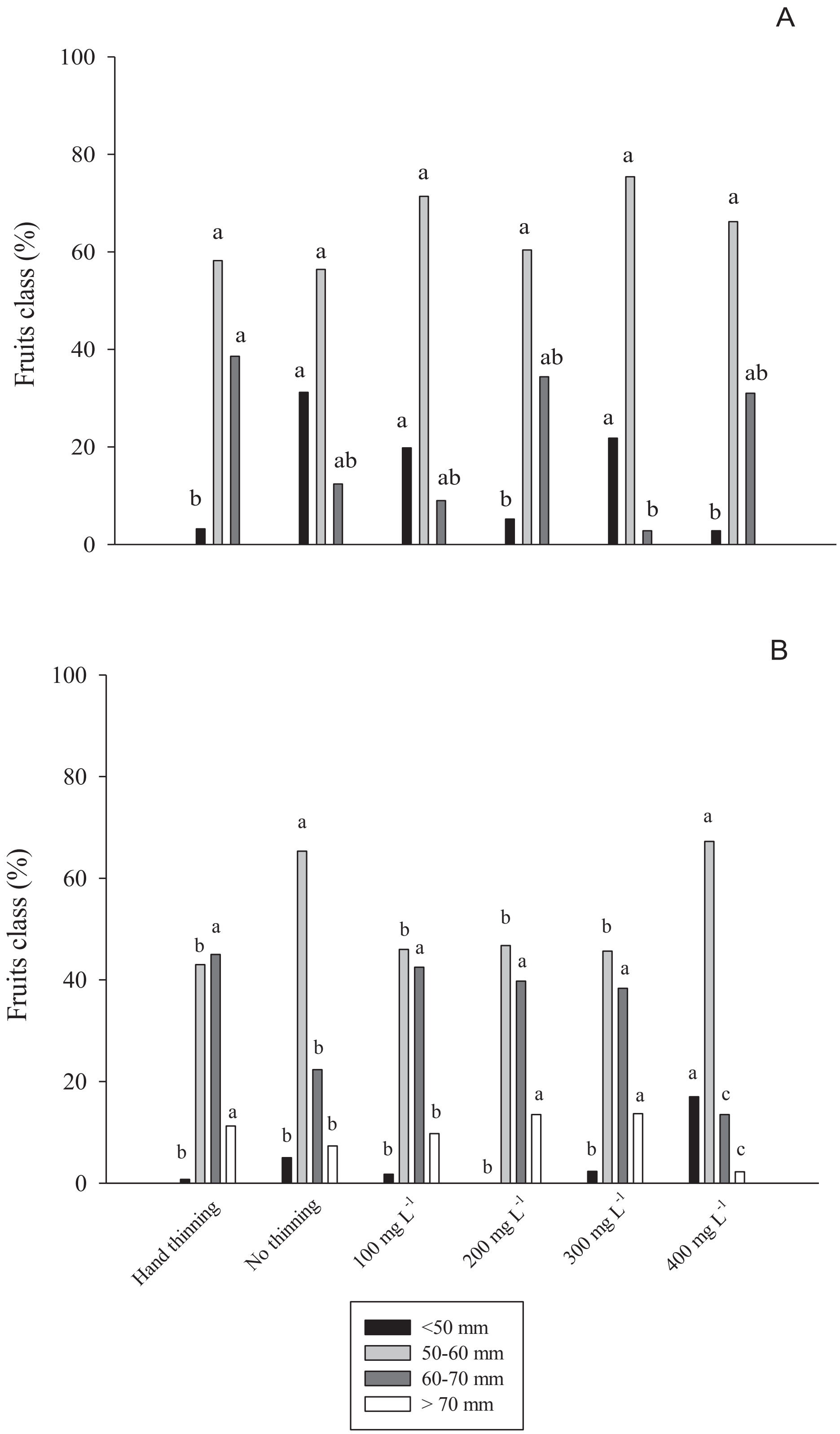


Figure 2. Percentage of fruits in the diameter classes of < 50 mm, 60 to 50 mm, 70 to 60 mm and > 70 mm in 'PS 10711' peach trees subjected to chemical thinning with different concentrations of metamitron or hand thinning, in the municipality of Eldorado do Sul, RS, in the years 2016 (A) and 2017 (B).

In the 2017 harvest, fruits with a diameter greater than 70 mm were observed more frequently in the trees thinned with 200 and 300 mg L^{-1} of metamitron, corresponding to 13.5% and 13.7% of the fruits, respectively (Figure 2). These same concentrations of metamitron used in the chemical thinning of peach trees promoted similar values for fruits > 70 mm in the hand-thinning method (11.3%).

Conclusion

Metamitron has a thinning effect on the peaches of cultivar PS 10711.

The metamitron concentration that promotes a thinning effect similar to that achieved with hand thinning on peach trees depends on light intensity and air temperature. When associated with higher solar radiation and temperature, lower concentrations of metamitron promote similar fruit abscission to hand thinning.

The thinning effect of metamitron changes production per tree but does not influence post-harvest quality.

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