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Chemical thinning of 'BRS Kampai' peach trees

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Abstract – The objective of this work was to evaluate the effect of thinning with metamitron on the fruit yield and quality of 'BRS Kampai' peach (*Prunus persica*) trees. The experiment was carried out in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 and 2017 crop years. Treatments consisted of the application of 100, 200, 300, and 400 mg L^{-1} metamitron and of hand thinning 40 days after full bloom, besides control plants. Fruit abscission, effective fructification, number of fruits, and fruit yield per plant were evaluated. Regarding fruit quality, fresh fruit biomass, epidermis color, pulp firmness, soluble solids, total phenolic compounds, and antioxidant activity were assessed; fruits were also classified into diameter classes. For fruit abscission, the effect of the application of 100 mg L^{-1} metamitron is similar to that of hand thinning. Fruit yield and mean mass in all treatments with metamitron are similar to those obtained by hand thinning. The application of metamitron does not affect the fruit quality of peach trees. Chemical thinning with metamitron may be an alternative to hand thinning in peach trees used for the production of fruits for fresh consumption.

Index terms: *Prunus persica*, abscission, fruit quality, hand thinning, metamitron.

Raleio químico em pessegueiros 'BRS Kampai'

Resumo – O objetivo deste trabalho foi avaliar o efeito do raleio com metamitron sobre a produção e a qualidade dos frutos de pessegueiros 'BRS Kampai' (*Prunus persica*). O experimento foi realizado no Município de Eldorado do Sul, no Estado do Rio Grande do Sul, durante as safras de 2016 e 2017. Os tratamentos consistiram na aplicação de 100, 200, 300 e 400 mg L^{-1} de metamitron e no raleio manual aos 40 dias após a plena floração, além de plantas-testemunhas. Foram avaliados abscisão de frutos, frutificação efetiva, número de frutos e produção de frutos por planta. Em relação à qualidade dos frutos, avaliaram-se biomassa fresca, coloração da epiderme, firmeza de polpa, sólidos solúveis, compostos fenólicos totais e atividade antioxidante; os frutos também foram classificados em classes de calibre. Quanto à abscisão de frutos, o efeito da aplicação de 100 mg L^{-1} de metamitron é similar ao do raleio manual. A produção e a massa média dos frutos em todos os tratamentos com metamitron são similares às obtidas com o raleio manual. A aplicação de metamitron não influencia a qualidade dos frutos de pessegueiros. O raleio químico com metamitron pode ser uma alternativa ao raleio manual em pessegueiros usados para produção de frutos para consumo fresco.

Termos para indexação: *Prunus persica*, abscisão, qualidade dos frutos, raleio manual, metamitron.

Introduction

The high fructification of peach trees results in an excessive number of fruits, which are usually small and have a low commercial value (Giovanaz et al., 2016). To improve the quality of fruits for fresh consumption and increase their market value, as well as to mitigate production alternance, thinning is the practice commonly adopted (Costa et al., 2013; Greene & Costa, 2013). It is often carried out in peach-growing regions, mainly manually, between 40 and 50 days after full bloom (Meitei et al., 2013; Petri et al., 2016; Oliveira et al., 2017). However, it demands much workforce in a short period and, consequently, has a high cost (McArtney et al., 2012; Simões et al., 2013).

Therefore, to reach a new economically viable level of peach production, alternatives to hand thinning are necessary. Chemical thinning is one of them, since it is fast acting and allows the use of different products, leading to a decrease in required costs and time. However, the success of this practice depends on the environmental conditions of the region, the genetic characteristics of the grown cultivar, the used concentration of the product and the appropriate phenological moment for its application (Brunner, 2014; McArtney & Obermiller, 2014).

Some chemical substances have been studied for fruit thinning of apple (Petri et al., 2016; Gabardo et al., 2017; Goulart et al., 2017;) and peach (McArtney et al., 2012; Meitei et al., 2013; Giovanaz et al., 2014, 2016) trees, and metamitron has stood out among them. In apple trees, it has shown satisfactory results in fruit thinning by inhibiting photosynthesis (Petri et al., 2016; Gabardo et al., 2017; Goulart et al., 2017). In 'Contender' peach trees, however, the application of 100 to 400 mg L^{-1} metamitron did not show satisfactory results for chemical thinning (McArtney et al., 2012), whereas 100 mg L^{-1} metamitron applied to 'Maciel' peach trees close to full bloom acted similarly to manual thinning (Farias et al., 2019).

When applied to fruit trees, metamitron contributes to fruit fall. According to several authors (Barber, 2001; Formaggio et al., 2001; Basak, 2011; Stern, 2014), the substance acts on photosystem II as an inhibitor of electron transfer from plastoquinone QA to QB in the chloroplast. This blockage leads to the formation of chlorophyll in a higher energetic state (triplet chlorophyll), which may react with molecular oxygen, yield singlet oxygen, and cause lipid peroxidation and damage to protein and pigments, besides the photoinhibition of the photosynthetic apparatus. This photoinhibition decreases the production of adenosine triphosphate and nicotinamide adenine dinucleotide phosphate, as well as CO_2 fixation, limiting the production of carbohydrates and the synthesis of sucrose and starch by the plant (Hugie et al., 2008).

Despite these researches, there is still little knowledge of chemical thinning in peach tree crops in the South of Brazil and specifically of the use and effectiveness of metamitron as a thinning agent.

The objective of this work was to evaluate the effect of thinning with metamitron on the fruit yield and quality of 'BRS Kampai' peach trees.

Materials and Methods

The experiment was carried out at a peach orchard at the experimental station of Universidade Federal do Rio Grande do Sul (30°06'33"S, 51°40'14"W, at 46 m altitude), in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 and 2017 crop years. The soil of the region is classified as an Argilossolo Vermelho distrófico típico (Santos et al., 2013), i.e., a Rhodic Ultisol. According to Köppen's classification, the climate is Cfa, humid temperate, with a hot summer.

The evaluated cultivar was BRS Kampai [*Prunus persica* (L.) Batsch]. It is characterized by a low-acidity white pulp and by a precocious maturation, being harvested starting in the first fortnight of November in the state of Rio Grande do Sul; in the subtropical region of Brazil, including the states of São Paulo, Minas Gerais, and Espírito Santo, low chill allows for its normal germination and flowering (Raseira et al., 2014).

At the experimental orchard, six-year-old 'BRS Kampai' peach trees had been grafted onto 'Capdeboscq' rootstocks. Plants were trained to the open-vase system, using four to six primary branches or scaffolds, on which the productive branches are located; primary branches are emitted from nearby trunk points about 30 to 50 cm from the ground. Spacing between rows and plants was 5.5 and 2.5 m, respectively.

The experimental design was a randomized complete block, with five replicates, each plant being considering an experimental unit of one plant. The treatments consisted of: plants with high fructification

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subjected to chemical thinning with 100, 200, 300, and 400 mg L^{-1} metamitron and to hand thinning 40 days after full bloom (DAFB), which occurred on 7/16/2016 and 7/26/2017; and control plants, without thinning. Goltix (Adama Agan Ltd., Ashdod, Israel), with 70% active ingredient, was the source of metamitron, and 0.05% Silwet L-77 (Momentive Performance Materials USA, INC, Friendly, WV, USA), a nonionic surfactant, was added to all treatments. Solutions were prepared on the field right before they were applied with the Jacto PJH backpack pulverizer (Jacto, Pompéia, SP, Brazil) at a working pressure of 40 psi. Hand thinning was performed to leave from 10 to 15 cm between fruits on peach tree branches, depending on plant vigor. It should be noted that no hand thinning was carried out during the chemical thinning treatments.

Fruit abscission (%) was obtained by randomly choosing five branches in every peach tree, marking them, and counting the number of fruits, both before the treatments and at harvest time. Effective fructification (%) was determined on those five branches per plant by counting the number of flowers at full bloom and the number of fruits at harvest time. The number of fruits per plant was obtained by counting fruits at harvest time and was used to determine fruit yield per plant (kg per plant).

Fruits were harvested on 11/11/2016, at 118 DAFB, and on 11/9/2017, at 106 DAFB, only once each year. After harvest, a 50-fruit sample per replicate was taken to the Fruit Laboratory of Universidade Federal de Pelotas, located in the municipality of Pelotas, also in the state of Rio Grande do Sul, to evaluate: mean fresh fruit biomass, determined by weighing fruit on a digital scale, with results expressed in grams; and fruit diameter, classified into four categories (>70 mm, from 70 to 60 mm, from 60 to 50 mm, and <50 mm).

A 20-fruit sample per replicate was collected for physicochemical and bioactive compound analyses. The color of peach epidermis, expressed as Hue angle, was analyzed at the equatorial region of the fruits using the CR-300 chroma meter (Konica Minolta Business Solutions do Brasil Ltda., São Paulo, SP, Brazil) with a D65 light source. Pulp firmness was measured on two opposite sides of the equatorial region of the fruits with no skin, using the 53205 digital fruit firmness tester (T.R. Turoni srl, Forlì, Italy), with an 8-mm tip, and results were expressed as Newtons. Soluble solid contents were obtained by the PAL-1 digital refractometer (Atago Brasil Ltda., Ribeirão Preto, SP, Brazil), and results were expressed as ºBrix.

To determine the bioactive compounds of peach pulp, two analyses were carried out. Total phenolic compounds were determined based on their reaction with the Folin-Ciocalteu reagent, as adapted from Singleton & Rossi (1965); results were expressed as milligrams of gallic acid equivalent per 100 g sample. Antioxidant activity was obtained by the 2,2-diphenyl-1-picrylhydrazyl free radical method, adapted from Brand-Williams et al. (1995); results were expressed as mg of Trolox equivalent per 100 g fresh weight.

Data were evaluated for normality by the Shapiro-Wilk test and for homoscedasticity by Hartley's test, being subjected to the analysis of variance, at 5% probability, afterwards. When statistical significance was found for metamitron concentrations, polynomial regression was used. In addition, when there was statistical significance, treatments were compared by the following orthogonal contrasts, at 5% probability: C1, control vs. chemical thinning process (hand thinning vs. 100, 200, 300, and 400 mg L^{-1} metamitron); and C2, hand thinning vs. metamitron concentrations. Contrasts were considered significant when $p \leq 0.05$ in the F-test. The Sisvar software, version 5.6, was used for the statistical analysis (Ferreira, 2014).

Results and Discussion

The application of metamitron had a thinning effect on fruits in the 2016 and 2017 crop seasons, i.e., fruit abscission occurred when the concentration of 100 mg L^{-1} metamitron or higher was applied (Table 1), resulting in an ascending linear regression. These results corroborate those reported by Brunner (2014), Greene (2014), and Gabardo et al. (2017), who found that the increase in the concentrations of metamitron for apple tree thinning caused a greater fruit fall.

As previously mentioned, metamitron acts on photosystem II by inhibiting electron transport (Basak, 2011; Stern, 2014). This reduces fruit quantity, possibly due to the direct action of the substance on photosynthetic inefficiency, which reduces the production of carbohydrates required for fruit fixation (Farias et al., 2019).

The effective fructification of peach trees in both experimental years was not affected by the different metamitron concentrations (Table 1). In C1,

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control plants altered fruit abscission and effective fructification in both crop seasons; however, in C2, hand thinning showed the same behavior as chemical thinning with metamitron for fruit abscission and effective fructification, but only in 2017.

Fruit yield and number per plant responded to metamitron concentrations following a descending linear regression in the 2016 and 2017 crop seasons (Table 2). Therefore, the increase in metamitron concentrations led to a decrease in fruit yield and number per plant. These results are similar to those of Farias et al. (2019), who found that high metamitron concentrations increased the average mass of 'Maciel' peach fruits, reducing the number of fruits per plant. Furthermore, concentrations of metamitron higher than 200 mg L^{-1} were phytotoxic to 'Contender' peach leaves, reducing their chlorophyll content (McArtney & Obermiller, 2012).

Fruit yield per plant decreased as metamitron concentrations increased in both crop seasons, probably because of the strong thinning effect of the substance and the consequent small fruit load. Similar results were reported by Moyano et al. (2011) and El-Boray et al. (2013), who verified low peach yields in chemically-thinned plants due to a decrease in the number of fruits. In C1, control plants influenced peach yield and affected the number of fruits in both crop seasons. However, in C2, hand thinning had the same behavior as chemical thinning with the different metamitron concentrations for fruit yield per plant in 2016 and 2017 and for number of fruits in 2017.

No significant differences were observed for mean fresh fruit biomass in relation to metamitron concentrations in the first crop season (Table 2). However, in the second one, this trait resulted in a quadratic convex regression: the lowest and highest mean mass were found with 150 and 400 mg L^{-1} metamitron, respectively. According to Brunner (2014), high metamitron concentrations cause an increase in mean apple mass. In C1, control plants affected mean fruit mass in 2016, whereas, in C2, hand thinning and thinning with metamitron behaved similarly in both studied crop seasons.

Table 1. Fruit abscission and set of 'BRS Kampai' peach (*Prunus persica*) trees subjected to chemical thinning with metamitron and to hand thinning in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 and 2017 crop seasons.

Metamitron concentration (mg L^{-1})	Fruit abscission (%)		Fruit set (%)	
	2016	2017	2016	2017
0	34.87	32.61	42.20	28.05
100	62.36	72.96	35.37	19.40
200	59.30	71.33	34.89	23.31
300	69.06	71.06	25.62	23.46
400	65.96	73.65	28.33	19.86
CV (%)	16.68	10.91	27.52	26.28
Linear	*(1)	*(2)	ns	ns
Quadratic	ns	ns	ns	ns
Hand thinning(3)	81.29	74.86	14.46	18.46
Contrasts(4)				
C1	*	*	*	*
C2	*	ns	*	ns

(1)$y = 49.914 + 0.052x$; $R^2 = 0.7671$. (2)$y = 54.286 + 0.0602x$; $R^2 = 0.5118$. (3)Performed 40 days after full bloom. (4)C1, control vs. chemical thinning process (hand thinning vs. metamitron concentrations); and C2, hand thinning vs. metamitron concentrations. *Significant at 5% probability. nsNonsignificant.

Table 2. Yield per plant, number of fruits per plant, and mean fresh fruit biomass of 'BRS Kampai' peach (*Prunus persica*) trees subjected to chemical thinning with metamitron and to hand thinning in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 and 2017 crop seasons.

Metamitron concentration (mg L^{-1})	Yield per plant (kg)		Number of fruits per plant		Mean fresh fruit biomass (g)	
	2016	2017	2016	2017	2016	2017
0	65.27	42.37	696.40	438.20	93.76	96.73
100	55.26	38.86	512.20	416.60	107.98	93.36
200	45.48	35.55	427.00	374.80	106.56	95.10
300	48.57	39.40	476.00	404.20	102.05	97.40
400	39.94	36.35	386.80	332.40	103.32	109.42
CV (%)	10.02	15.51	11.67	9.32	9.45	8.29
Linear	*(1)	*(2)	*(3)	*(4)	ns	ns
Quadratic	ns	ns	ns	ns	ns	*(5)
Hand thinning(6)	44.97	35.70	410.00	362.00	109.70	103.96
Contrasts(7)						
C1	*	*	*	*	*	ns
C2	ns	ns	*	ns	ns	ns

(1)$y = 62.372 - 0.0573x$; $R^2 = 0.8644$. (2)$y = 42.02286 - 0.0134x$; $R^2 = 0.8459$. (3)$y = 632.6 - 0.656x$; $R^2 = 0.7672$. (4)$y = 437.6 - 0,224x$; $R^2 = 0.7426$. (5)$y = 96.993 - 0.0601x + 0.0002x^2$; $R^2 = 0.9703$. (6)Performed 40 days after full bloom. (7)C1, control vs. chemical thinning process (hand thinning vs. metamitron concentrations); and C2, hand thinning vs. metamitron concentrations. *Significant at 5% probability. nsNonsignificant.

Regarding fruit quality, metamitron did not interfere in fruit color (Table 3). Therefore, no significant differences were found among metamitron concentrations or in the tested contrasts in both crop seasons. This result is interesting since the color of fruit epidermis, especially red, is the main quality parameter influencing consumer acceptance (Li et al., 2002).

Pulp firmness did not differ significantly among metamitron concentrations in 2016. However, a quadratic regression was observed in 2017, when the highest pulp firmness of 27 N was obtained with 173 mg L^{-1} metamitron (Table 3). Therefore, each crop season behaved differently regarding this variable. Fruit size reflects, in addition to environmental conditions for cultivation, the number or load of fruits on the plant, which directly influence it and also plant nutrition, especially in relation to nitrogen fertilization. The results of the present study agree with those of Raseira et al. (2014), who reported an average pulp firmness from 22 to 35 N for the same cultivar. In C1, the pulp firmness of fruits from plants that had not been thinned was altered in 2017. In C2, in both evaluated crop seasons, hand-thinning affected the pulp firmness of peaches.

Concerning soluble solids contents, there was no significant difference among metamitron concentrations in both crop seasons (Table 3). The obtained results are in alignment with those described by Raseira et al. (2010), who found mean values ranging from 9 to 13° Brix. In C1, control plants and thinned plants showed the same behavior regarding soluble solid contents in 2016 and 2017. However, in C2, the soluble solid contents of hand-thinned plants was altered in both crop seasons. It should be highlighted that no direct relationship could be established between both thinning methods, since physiological responses differed depending on the crop. The cause of this behavior was not clearly determined, but it is known that the content of soluble solids may be associated with other management factors, such as the position of fruits in the plant, light penetration through the crown, and interaction between irrigation and exposure to sunlight (Picolotto et al., 2009; Alcobendas et al., 2013). Soluble solid contents are also related to plant nutrition, mainly regarding nitrogen and potassium fertilization, and the application of potassium (via soil or leaf) near fruit harvesting generally increases fruit color and sweetness (Jawandha et al., 2017; Solhjoo et al., 2017). The yield and quality of peach fruits were affected by texture, water content, organic matter, exchangeable potassium and magnesium (Oldoni et al., 2019). In another study, the application of potassium to 'Flordastar' peach

Table 3. Epidermis color, pulp firmness, and soluble solid contents of 'BRS Kampai' peach (*Prunus persica*) fruits from trees subjected to chemical thinning with metamitron and to hand thinning in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 and 2017 crop seasons.

Metamitron concentration (mg L^{-1})	Epidermis color (°Hue)		Pulp firmness (N)		Soluble solids (°Brix)	
	2016	2017	2016	2017	2016	2017
0	85.63	80.93	26.44	25.60	9.86	11.64
100	83.73	85.29	24.62	32.65	10.04	10.60
200	88.85	85.82	24.48	28.61	9.92	10.42
300	87.47	88.31	26.73	28.48	10.24	13.50
400	86.56	80.61	26.78	27.44	10.38	12.74
CV (%)	3.03	13.97	7.85	6.69	4.33	6.17
Linear	ns	ns	ns	ns	ns	ns
Quadratic	ns	ns	ns	*(1)	ns	ns
Hand thinning(2)	87.38	84.69	22.20	25.04	9.06	12.92
Contrasts(3)						
C1	ns	ns	ns	*	ns	ns
C2	ns	ns	*	*	*	*

(1)$y = 26.9011 + 0.0346x - 0.0001x^2$; $R^2 = 0.4029$. (2)Performed 40 days after full bloom. (3)C1, control vs. chemical thinning process (hand thinning vs. metamitron concentrations); and C2, hand thinning vs. metamitron concentrations. *Significant at 5% probability. nsNonsignificant.

increased total soluble solid contents, but did not affect total acidity; consequently, the soluble solids/titratable acidity ratio followed the same response as that of total soluble solids (Dbara et al., 2016).

Total phenolic contents and antioxidant activity did differ significantly in the pulp of peaches from trees subjected to chemical thinning in 2016 (Table 4). In 2017, total phenolic content and antioxidant activity showed a descending linear response to metamitron concentrations, i.e., the more the metamitron concentrations increased, the more the bioactive compounds in the peach pulp decreased. Both in C1 and C2, the thinning methods did not affect total phenolic contents of the peach pulp. In C1, control plants affected antioxidant activity in 2016, and, in C2, hand-thinned plants altered the antioxidant activity of peaches in both crop years.

In general, the factors evaluated for peach quality were inconsistent among fruit-thinning treatments. Moreover, fruit quality characteristics were better correlated with conditions related to the environment and crops than with treatments using chemical thinning.

All treatments resulted in a high frequency of fruits in the diameter classes between 50 and 60 mm and from 60 to 70 mm, in both the 2016 and 2017 crop seasons (Figure 1). The highest frequency of fruits in the diameter class of <50 mm was found for the control plants, being 7.20 and 8.60% in 2016 and 2017,

Table 4. Total phenolic contents and antioxidant activity of the pulp of 'BRS Kampai' peach (*Prunus persica*) fruits from trees subjected to chemical thinning with metamitron and to hand thinning in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 and 2017 crop seasons.

Metamitron concentration (mg L^{-1})	Total phenols(1)		Antioxidant activity(2)	
	2016	2017	2016	2017
0	75.43	46.05	238.54	188.98
100	99.66	49.39	275.97	199.82
200	62.97	38.96	136.10	165.92
300	62.26	36.43	466.36	138.92
400	67.25	38.29	243.00	154.26
CV (%)	17.32	17.23	10.2	9.51
Linear	ns	*(3)	ns	*(4)
Quadratic	ns	ns	ns	ns
Hand thinning(5)	80.09	45.68	480.88	240.18
Contrasts(6)				
C1	ns	ns	*	ns
C2	ns	ns	*	*

(1)mg Gallic acid equivalent per 100 g^{-1} fresh weight. (2)mg equivalent Trolox per 100 g^{-1} fresh weight. (3)$y = -47.518 + 0.0285x$; $R^2 = 0.6495$. (4)$y = 195.65 - 0.1303x$; $R^2 = 0.6853$. (5)Performed 40 days after full bloom. (6)C1, control vs. chemical thinning process (hand thinning vs. metamitron concentrations); and C2, hand thinning vs. metamitron concentrations. *Significant at 5% probability. nsNonsignificant.

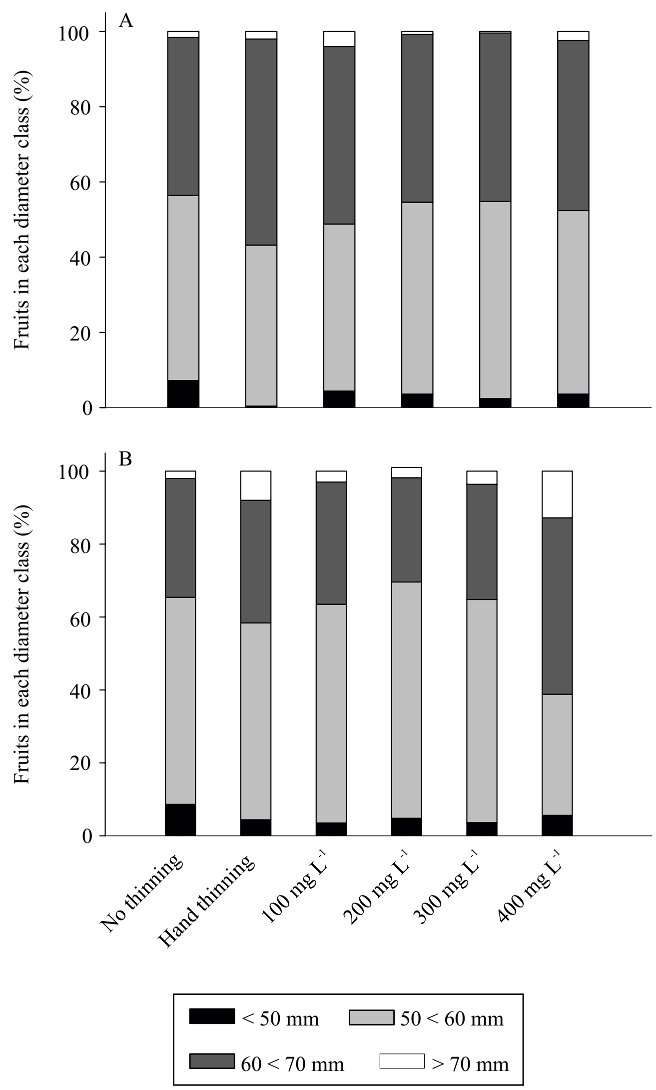

Figure 1. Diameter classes of 'BRS Kampai' peach (*Prunus persica*) fruits from trees subjected to no thinning, to hand thinning, and to chemical thinning with different metamitron concentrations (100, 200, 300, and 400 mg L^{-1}) in the municipality of Eldorado do Sul, in the state of Rio Grande do Sul, Brazil, in the 2016 (A) and 2017 (B) crop seasons.

respectively. In 2017, the frequency of fruits whose diameters ranged between 60 and 70 mm decreased, in comparison with the previous crop. In this crop, plants thinned with 400 mg L^{-1} metamitron had a high distribution of fruits with diameters above 70 mm, corresponding to 12.8% of the fruit, while plants with no thinning represented only 2% of this class.

Conclusions

1. The application of metamitron has a thinning effect on 'BRS Kampai' peach (*Prunus persica*) trees.
2. Regarding fruit abscission, the concentration of 100 mg L^{-1} metamitron has a similar effect to that of hand thinning.
3. Chemical thinning with 100 mg L^{-1} metamitron results in a similar fruit yield and mean mass to those achieved by hand thinning.
4. Fruit quality, especially epidermis color, is not affected by chemical thinning with metamitron.

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