

## Effect of the application of prohexadione-calcium on the growth of ‘Packham’s Triumph’ and ‘Hosui’ pears (*Pyrus communis* L.)

Efeito da aplicação de prohexadione cálcico sobre o crescimento de pereiras ‘Packham’s Triumph’ e ‘Hosui’ (*Pyrus communis* L.)

Efecto de la aplicación de prohexadiona-calcio sobre el crecimiento de las peras "Packham’s Triumph" y "Hosui" (*Pyrus communis* L.)

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### Abstract

The necessity of controlling the vegetative growth of fruit trees is a growing concern for farmers since vigorous plants tend to have lower fruit yields. The use of chemicals that inhibit the vegetative growth of plants, such as prohexadione-calcium (PCa), an inhibitor of gibberellins which is currently used as a growth regulator for apple trees, is an agricultural practice aimed to help in reducing pruning time and cost. Pear trees grafted on vigorous rootstocks tend to present high rates of vegetative growth, hindering fruit production. Thus, this work aimed to evaluate the effect of the application of different doses of the plant growth regulator PCa on the vegetative growth, pruning time, radiation incidence, and productive and quality parameters of ‘Packham’s Triumph’ and ‘Hosui’ pears grafted on vigorous rootstocks. Two PCa applications were carried out, the first after the falling of petals (2009-10-10), and the second twenty-one days after the first (2009-11-02). The observed results showed a significant effect of PCa in reducing the vegetative growth of the pear trees and the pruning time in both cultivars. The effect on photosynthetic active radiation (PAR) was observed only in the ‘Packham’s Triumph’ variety, not being observed for the ‘Hosui’ pear trees. No statistical difference was observed relative to the quality parameters and yield of the fruits, in both cultivars, showing that PCa application has not caused any deleterious effect on fruit development.

**Keywords:** Plant growth regulator; Vegetative growth; Gibberellin inhibitor; Pruning.

### Resumo

A necessidade de controlar o crescimento vegetativo das árvores frutíferas é uma preocupação crescente para os agricultores, uma vez que plantas vigorosas tendem a ter menor produção de frutos. O uso de produtos químicos que inibem o crescimento vegetativo das plantas, como a prohexadiona-cálcio (PCa), um inibidor das giberelinas que atualmente é utilizado como regulador do crescimento de macieiras, é uma prática agrícola que visa auxiliar na redução do tempo e custo da poda. As pereiras enxertadas em porta-enxertos vigorosos tendem a apresentar altas taxas de crescimento vegetativo, dificultando a produção de frutos. Assim, este trabalho teve como objetivo avaliar o efeito da aplicação de diferentes doses do regulador de crescimento vegetal PCa sobre o crescimento vegetativo, tempo de poda, incidência de radiação e parâmetros produtivos e de qualidade de pêras 'Packham's Triumph' e 'Hosui' enxertadas em porta-enxertos vigorosos. Foram realizadas duas aplicações de PCa, a primeira após a queda das flores (2009-10-10) e a segunda 21 dias após a primeira (2009-11-02). Os resultados observados mostraram efeito significativo do PCa na redução do crescimento vegetativo das pereiras e do tempo de poda em ambas as cultivares. O efeito na radiação fotossinteticamente ativa (RFA) foi observado apenas na variedade ‘Packham’s Triumph’, não sendo observado para as pereiras ‘Hosui’. Não foi observada diferença estatística em relação aos parâmetros de qualidade e produtividade dos frutos, em ambas as cultivares, mostrando que a aplicação de PCa não causou nenhum efeito deletério no desenvolvimento dos frutos.

**Palavras-chave:** Regulador de crescimento vegetal; Crescimento vegetativo; Inibidor de giberelina; Poda.

## Resumen

La necesidad de controlar el crecimiento vegetativo de los árboles frutales es una preocupación creciente para los agricultores, ya que las plantas vigorosas tienden a tener menor rendimiento de frutos. El uso de productos químicos que inhiben el crecimiento vegetativo de las plantas, como la prohexadiona-calcio (CaP), un inhibidor de las giberelinas que se utiliza actualmente como regulador del crecimiento de los manzanos, es una práctica agrícola destinada a ayudar a reducir el tiempo y el coste de la poda. Los perales injertados sobre portainjertos vigorosos tienden a presentar altas tasas de crecimiento vegetativo, lo que dificulta la producción de frutos. Así, este trabajo tuvo como objetivo evaluar el efecto de la aplicación de diferentes dosis del regulador del crecimiento vegetal CaP sobre el crecimiento vegetativo, tiempo de poda, incidencia de radiación y parámetros productivos y de calidad de peras 'Packham's Triumph' y 'Hosui' injertadas en vigorosos portainjertos. Se realizaron dos aplicaciones de CaP, la primera después de la caída de pétalos (2009-10-10), y la segunda veintiún días después de la primera (2009-11-02). Los resultados observados mostraron un efecto significativo del CaP en la reducción del crecimiento vegetativo de los perales y el tiempo de poda en ambos cultivares. El efecto sobre la radiación fotosintética activa (RFA) se observó solo en la variedad "Packham's Triumph", no observándose en los perales "Hosui". No se observó diferencia estadística relativa a los parámetros de calidad y rendimiento de los frutos, en ambos cultivares, lo que demuestra que la aplicación de CaP no ha provocado ningún efecto deletéreo en el desarrollo del fruto.

**Palabras-clave:** Regulador del crecimiento de las plantas; Crecimiento vegetativo; Inhibidor de giberelina; Poda.

## 1. Introduction

The cultivation of pears is an excellent alternative to diversify temperate fruit cultivation. Worldwide pear production in 2019 was 23.9 million tons. The main producing countries are China (17.1 million tons), Argentina (595,497 t), Italy (429,290 t), and South Africa (407,212 t). In 2019, the Brazilian pear production was 16,720 t, about 0.07% of world production; in the state of Rio Grande do Sul it was produced 9,362 t of pears in a cultivated area of 663 ha, with an average yield of 14.2 t·ha<sup>-1</sup>. The main pear cultivars cultivated are the European (*Pyrus communis* L.) and Asian (*Pyrus pyrifolia* Nak.) ones (Instituto Brasileiro de Geografia e Estatística [IBGE], 2019; Food and Agriculture Organization of the United Nations [FAO], 2019).

There is a technical and economic potential for the development of the management of pear tree cultivation in South Brazil. The already established structure for apple orchards may be used to increase the overall yield and profitability of pear orchards. For this to happen, the search for techniques that help increase the yield and quality of pears is paramount, especially taking into account that the Brazilian pear production in 2019 was 16,720 t on a cultivated area of 1,156 ha, with an average yield of 14.5 t·ha<sup>-1</sup>, below the world average, which, in 2019, was 17.3 t·ha<sup>-1</sup> (Faoro & Orth, 2010; FAO, 2019; Wrege et al., 2017).

The control of the vegetative growth in pear trees is particularly important to mitigate low productivity, variations in the production, time until new trees start producing fruits, and to enhance fruit quality. Controlling the excessive budding helps for better illumination of the tree and to enhance the production of photoassimilates, reducing the costs, simplifying the management, and increasing the efficiency of the phytosanitary treatments (Rademacher et al., 2004; Wrege et al., 2017).

The vegetative growth in pear trees is governed by dominance in the branches that grow vertically in the upper parts of the canopy (acrotonic), which generally causes a shading effect on the lower part and inside the canopy, inhibiting the formation of flower buds. The competition between the vegetative and reproductive parts of the tree by excessive vigor may cause low fruit yields. This happens especially when this competition is enhanced by vigorous rootstocks, such as *Pyrus calleryana* and *Pyrus betulaefolia*, which are widely used in pear orchards (Rademacher et al., 2004; El-Hamied & El-Amiry, 2015; Wrege et al., 2017).

Several strategies may be used to regulate the vegetative growth of pear trees in different phenological phases; among the plant growth regulators (PGR's) used there is the prohexadione-calcium (PCa). PCa is an inhibitor of the synthesis of gibberellins, which are phytohormones that are essential to promote the growth of vegetative buds. With the inhibition of the

vegetative growth, the reproductive buds are stimulated to grow more vigorously (Giannakoula et al., 2012; Carra et al., 2017a).

PCa is widely employed in apple trees to control the vegetative growth of the plants, with positive results in pruning and no important deleterious effect on overall fruit quality and yield (Rademacher et al., 2004; Duyvelshoff and Cline, 2013; Amarante et al., 2020). Nowadays, PCa is being used in pear trees to hinder vegetative growth, especially of cultivars grafted on vigorous rootstocks (Carra et al., 2016; 2017b).

However, Rademacher et al. (2004) commented that, despite the excellent effect on apple trees, pear trees may require high PCa doses, which may cause a reduction in the return bloom. In this sense, suitable management involving both chemical reduction of vegetative growth associated with pruning may be required for the desired control effect to occur in pear trees without negative residual effects.

Thus, the objective of the present work was to evaluate the effect of the application of different doses of prohexadione-calcium (PCa) on the growth, pruning, and fruit yield and quality of 'Packham's Triumph' and 'Hosui' pear trees.

## 2. Material and Methods

The experiment was carried out in two commercial orchards, one composed of 'Packham's Triumph', and the other composed of 'Hosui' pear plants, both cultivars grafted on the *Pyrus calleryana* rootstock. The spacing between rows was 4.5 m and between plants was 2.0 m, with an average plant height of 3.5 m and plant density of 1,111 plants·ha<sup>-1</sup>. The orchards were established in 1992, on an east-west orientation, in the municipality of Monte Alegre dos Campos, at an altitude of 932 m and geographical coordinates of 28°35'25.12" S and 50°42'40.87" W. The orchard management was carried out following the usual practices of the company.

The treatments were divided into three groups. In 'Packham's Triumph' plants, the tested PCa doses were applied throughout the aerial part of the plant with a flow rate of 1,000 L·ha<sup>-1</sup>, and the following PCa doses were tested: T0 – control (no application), T1 – 330 mg·L<sup>-1</sup>; T2 – 250 mg·L<sup>-1</sup>; T3 – 165 mg·L<sup>-1</sup>.

In a second test with the 'Packham's Triumph' plants, the tested PCa doses were applied only on the plant canopy with a flow rate of 500 L·ha<sup>-1</sup>, and the following PCa doses were tested: T0 – control (no application), T1 – 330 mg·L<sup>-1</sup>.

In 'Hosui' plants, the tested PCa doses were applied throughout the aerial part of the plant with a flow rate of 1,000 L·ha<sup>-1</sup>, and the following PCa doses were tested: T0 – control (no application), T1 – 330 mg·L<sup>-1</sup>; T2 – 250 mg·L<sup>-1</sup>; T3 – 165 mg·L<sup>-1</sup>.

The PCa doses were applied twice; the first application was carried out when the plant branches reached a length between 5 and 13 cm after the fall of flowers (2009-10-10), and the second application was carried out 23 days after the first one (2009-11-02). All applications were performed using a backpack sprayer of pressurized carbon dioxide.

The following parameters were evaluated: length of selected branches (cm), the time necessary to carry out the orchard pruning (h), average branch length in pruning (cm), average photosynthetic active radiation (PAR) in the canopy after pruning (μmol·m<sup>-2</sup>·s<sup>-1</sup>), number of fruits per plant, fruit pulp firmness (lbf·cm<sup>-2</sup>), average fruit mass (g), and soluble solids content (°Brix).

To determine the branch length, random branches were selected and marked in each plant. The length of the branches was measured at the first PCa application, on 2009-10-10. The green pruning was carried out in 2009-12-18, in both experiments. The time spent carrying out the pruning was recorded using a digital chronometer. On this day, the measurement of the length of the marked branches and the mass of the removed branches also was carried out. The relative growth was calculated using the length data of the first and second measurements.

The first measurement of the photosynthetic active radiation (PAR; light in the wavelengths of 400-750 nm) was carried out on 2009-10-25, the second one was performed in 2009-12-16, during the green pruning. To measure the PAR, it was used a digital ceptometer (AccuPAR LP-80, Decagon Devices Inc., USA). The measurement was carried out above the tree canopy and inside the canopy, 1.5 and 2.5 m above the ground level, on a sunny day, between 10:00 and 13:00 h to avoid variations in PAR measurement due to the solar position.

The pears of the ‘Hosui’ cultivar were harvested on 2010-01-14; the ones from the ‘Packham’s Triumph’ were harvested on 2010-01-22. The number of fruits per plant was determined during the harvesting.

Average fruit mass was measured using a digital scale with a capacity of 1 kg and a resolution of 0.01 g. The soluble solids content was measured using an Incoterm analogic refractometer, with a measuring range of 0-30 °Brix and a resolution of 0.25 °Brix; the results were expressed as °Brix. Fruit pulp firmness was measured using a digital penetrometer with an 8 mm tip. Two readings were carried out in diametrically opposite sites, in the equatorial portion of the fruit after the removal of the peel by a shallow cut of two discs of 1 cm of diameter. The results were expressed as Newtons (N).

The experimental design was randomized blocks. Each treatment was composed of four repetitions, each repetition was composed of four plants. The results underwent analysis of variance (ANOVA) and the means were compared by Duncan’s multiple range test at 5% probability ( $\alpha = 0.05$ ), using the SPSS 16.0 software (IBM, USA).

### 3. Results and Discussion

#### 3.1 Experiment with ‘Packham’s Triumph’ pears

The obtained results relative to growth, pruning, and PAR parameters of ‘Packham’s Triumph’ pear trees treated with different PCa doses, applied throughout the aerial part of the trees, are presented in Table 1.

**Table 1.** Growth parameters, pruning, and PAR for ‘Packham’s Triumph’ pears treated with increasing doses of PCa in the 2009/2010 harvest.

PCa dose (mg·L <sup>-1</sup> )	Branch length (cm)	Relative growth (%)	Mass of pruned branches (kg·plant <sup>-1</sup> )	Length of pruned branches (cm)	Pruning time (h·ha <sup>-1</sup> )	PAR on 2009-11-25 (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )	PAR on 2009-12-16 (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )
zero	28.2 a	267 a	2.11 a	74.4 a	190 a	148 b	108 a
165	15.8 ab	160 b	1.37 b	56.1 b	130 b	160 b	121 a
250	11.1 ab	110 c	1.25 b	51.8 bc	111 b	191 ab	123 a
330	8.6 b	88 d	0.95 b	47.6 c	102 b	265 a	136 a
CV <sup>1</sup> (%)	7.11	20.68	25.37	15.87	22.90	18.47	11.25

Means in column followed by the same letter do not present statistical difference by Duncan’s multiple range test at 5% probability ( $\alpha = 0.05$ ). <sup>1</sup> – Coefficient of variation. Source: Authors.

According to Table 1, the length growth of the marked branches treated with different doses of PCa in the ‘Packham’s Triumph’ pear trees was reduced at the dose of 330 mg·L<sup>-1</sup> when compared to the control; the other treatments (165 and 250 mg·L<sup>-1</sup>) have not differed statistically from the control. Considering the relative growth, each PCa dose had a better performance than the control; higher doses yielded lower relative growths. Carra et al. (2017a), who evaluated the application of PCa in ‘Smith’ pear trees at the doses of zero, 100, 200, 300, and 400 mg·L<sup>-1</sup>, reported a linear inverse trend between the PCa dose and the length of the plant branches. Pasa and Einhorn (2017) also reported a reduction of average branch length for ‘Starkrimson’ pear trees, from 55.1 cm in the control to 38.9 cm in trees treated with 250 mg·L<sup>-1</sup> PCa.

Relative to the mass of pruned branches, a trend of reduction could be seen with the increase in PCa dose applied, from 2.11 kg·plant<sup>-1</sup> in the control to 0.95 kg·plant<sup>-1</sup> at the PCa dose of 330 mg·L<sup>-1</sup>, a difference of about 55%. Statistically, no PCa dose differed among themselves, but all of them differed from the control. As commented by Rademacher et al. (2004), pear trees need higher PCa doses when compared to apple trees to control vigorous growth. Ferreira (2009) and Tukamoto

(2008), working with the application of PCa in apples, also observed a reduction of the pruned branch mass in the range of 53% with the application of increasing doses of PCa. Carra et al. (2017b) reported a similar behavior for 'Shinseiki' pear trees treated with PCa, in which the mass of pruned branches reduced from 1.74 kg·plant<sup>-1</sup> to 0.43 kg·plant<sup>-1</sup> in the trees treated with 600 mg·L<sup>-1</sup> PCa.

The length of pruned branched was influenced by the PCA dose. While the pruned branches in the control presented an average length of 74.4 cm, the trees treated with 330 mg·L<sup>-1</sup> PCa had pruned branches with an average length of 47.6 cm, a reduction of 36%. Although all PCa doses differed from the control, the dose of 250 mg·L<sup>-1</sup> has not differed from the doses of 125 and 330 mg·L<sup>-1</sup>, a behavior like the one seen for the mass of pruned branches. Carra et al. (2017b) reported for 'Shinseiki' pear trees treated with PCa a reduction of the length of pruned branches from 1.22 m in the control to 0.41 m in the trees treated with 600 mg·L<sup>-1</sup> PCa (a reduction in pruned branch length of about 60% with a PCa dose about twice the one used in the present study).

The application of PCa also influenced the pruning time. While the average pruning time for the control treatment was 190 h, the PCa-treated orchards had a pruning tie in the range of 102-130 h·ha<sup>-1</sup>, a reduction of about 30-40%; no statistical difference was observed between the PCa doses. Rademacher et al. (2004) reported an average reduction of 30% of pruning time for apple orchards treated with two applications of PCa 125 mg·L<sup>-1</sup>; however, the authors reported that the effect on pear trees was smaller than in apple trees. Privé et al. (2004) and Ferreira (2009) also reported a decrease in the pruning time of apple trees with the application of PCa. According to the literature, pear trees need higher PCa doses to control the vegetative growth when compared to the literature. Thus, higher PCa doses may be linked to smaller pruning times, at least until a point in which the PCa dose becomes high enough to cause toxicity or becomes inefficient (Rademacher et al. 2004, Carra et al. 2017b).

The measurement of PAR in 2009-11-25, 23 days after the first PCa application, showed that the highest dose (330 mg·L<sup>-1</sup>) differed from the control (265 against 148 μmol·m<sup>-2</sup>·s<sup>-1</sup>, respectively), presenting an increase of 79%; the PAR above the canopy was 1,452 μmol·m<sup>-2</sup>·s<sup>-1</sup>, suggesting that even with the effect of PCa, most of PAR is absorbed in the higher and external parts of the canopy. However, higher levels of PAR available help in the synthesis of photoassimilates and foster the growth of reproductive buds (Singh et al., 2012). Relative to the other two PCa doses, they have not differed from the control, suggesting that lower doses may not have a pronounced effect in hindering the vegetative growth inside the canopy.

In the PAR measurement of 2009-12-16, no treatment differed statistically from the control; the PAR values ranged between 108 and 136 μmol·m<sup>-2</sup>·s<sup>-1</sup>, whereas the PAR above the canopy was 1,880 μmol·m<sup>-2</sup>·s<sup>-1</sup>. These results suggest that the vegetative growth of the external part of the canopy, even with the application of PCa, was vigorous enough to block the incident PAR in approximately 20 days.

The results of yield and quality parameters of 'Packham's Triumph' pears treated with different doses of PCa applied throughout the aerial part of the trees are presented in Table 2.

**Table 2.** Effect of the application of different PCa doses on the yield and quality parameters of 'Packham's Triumph' pears in the 2009/2010 harvest.

PCa dose (mg·L <sup>-1</sup> )	Fruits per plant	Average fruit mass (g)	Pulp firmness (N)	Soluble solids (°Brix)
zero	271 a	196 a	74.7 a	11.6 a
165	309 a	205 a	73.4 a	12.1 a
250	309 a	206 a	73.4 a	11.8 a
330	261 a	210 a	71.2 a	12.0 a
CV <sup>1</sup> (%)	33.27	12.15	1.94	2.11

Means in column followed by the same letter do not present statistical difference by Duncan's multiple range test at 5% probability ( $\alpha = 0.05$ ). <sup>1</sup> – Coefficient of variation. Source: Authors.

According to Table 2, the fruit yield and the quality parameters were not influenced by the application of PCa, regardless of the dose. Carra et al. (2016), studying the effect of the application of increasing doses of PCa on ‘Le Conte’ pears, reported that PCa did not influence fruit yield, soluble solids content, titratable acidity, and average fruit mass, even at doses high as 400 mg·L<sup>-1</sup>. Carra et al. (2017a) reported the same behavior for ‘Smith’ pear trees, in which fruit quality and yield were not influenced by the use of PCa, even with reapplication of the doses. However, Carra et al. (2017b) observed that ‘Shinseiki’ pear trees were influenced by the application of PCa, in which the fruit yield decreased in the trees treated with 600 mg·L<sup>-1</sup> PCa, whereas the dose of 300 mg·L<sup>-1</sup> has not differed from the control; the quality parameters of the pears were not influenced by the PCa dose. Very high PCa doses may have negative effects on the yield of the trees due to excessive inhibition of the vegetative growth, reducing the synthesis rate of photoassimilates, or due to negative effects on the growth of the reproductive buds, hindering their development.

### 3.2 Experiment with ‘Packham’s Triumph’ pears with PCa application only in the tree canopy

The obtained results relative to growth, pruning, and PAR parameters of ‘Packham’s Triumph’ pear trees treated with different PCa doses, applied only on the tree canopies, are presented in Table 3.

**Table 3.** Growth parameters, pruning, and PAR for ‘Packham’s Triumph’ pears with only the tree canopy treated with increasing doses of PCa in the 2009/2010 harvest.

PCa dose (mg·L <sup>-1</sup> )	Branch length (cm)	Relative growth (%)	Mass of pruned branches (kg)	Length of pruned branches (cm)	Pruning time (h·ha <sup>-1</sup> )	PAR on 2009-11-25 (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )	PAR on 2009-12-16 (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )
zero	34.3 a	316 a	1.71 a	72.8 a	157 a	141 b	221 a
250	11.7 b	159 b	0.83 a	50.4 b	107 ab	169 b	241 a
330	8.6 b	120 c	0.95 a	47.5 b	102 b	265 a	136 a
CV <sup>1</sup> (%)	9.94	18.47	47.25	12.10	20.57	17.75	19.80

Means in column followed by the same letter do not present statistical difference by Duncan’s multiple range test at 5% probability ( $\alpha = 0.05$ ). <sup>1</sup> – Coefficient of variation. Source: Authors.

According to Table 3, the branch length of the trees treated with the application PCa only on the canopy, regardless of the dose, were smaller than the control (34.3 cm against 8.6-11.7 cm), a trend that was similar in the previous experiment, in which the doses of 250 and 330 mg·L<sup>-1</sup> have not differed statistically between themselves. However, in this experiment, the dose of 250 mg·L<sup>-1</sup> PCa differed from the control; this was not observed in the previous experiment. The relative growth also presented a decreasing trend with the increase of PCa doses, reducing from 315.5% in the control to 120.4% at the dose of 330 mg·L<sup>-1</sup>; the doses also differed between themselves, showing that this reduction is dependent on the dose, regardless of the application mode.

However, the mass of pruned branches was not influenced by the application of PCa. This behavior is distinct from one of the previous experiments, in which the application of PCa caused a significant reduction of the mass of pruned branches relative to the control; on the other hand, there was no difference between the doses.

Relative to the length of pruned branches, both doses have differed from the control, but have not differed between themselves. The same trend was observed in the previous experiment, in which the doses of 250 and 330 mg·L<sup>-1</sup> performed similarly, but the PCa dose of 250 mg·L<sup>-1</sup> was also statistically similar to the dose of 165 mg·L<sup>-1</sup>.

The pruning time was influenced by the canopy application of PCa, similarly to the previous experiment. The dose of 330 mg·L<sup>-1</sup> differed from the control (102 and 158 h, respectively). The main difference was regarding the PCa dose of 250 mg·L<sup>-1</sup>; this dose has not differed from the control, neither from the dose of 330 mg·L<sup>-1</sup> when applied in the tree canopy only.

When applied throughout the aerial part of the tree, its effect was statistically different from the control. A greater exposure area may have allowed for higher absorption of PCa, enhancing its effect relative to application on tree canopy only.

The PAR measurements on 2009-11-25 were higher only in the trees treated with 330 mg·L<sup>-1</sup> PCa (265 μmol·m<sup>-2</sup>·s<sup>-1</sup>); the dose of 250 mg·L<sup>-1</sup> has not differed from the control (169 and 141 μmol·m<sup>-2</sup>·s<sup>-1</sup>, respectively). This trend is similar to the one of the previous experiments, in which the dose of 250 mg·L<sup>-1</sup> PCa has not differed from the control, neither from the dose of 330 mg·L<sup>-1</sup>. In the second measurement (2009-12-16), no treatment has differed, showing that the vegetative growth is vigorous enough to block the light inside the canopy in 20 days, regardless of the application mode or dose.

The results of yield and quality parameters of ‘Packham’s Triumph’ pears treated with different doses of PCa applied only on the tree canopies are presented in Table 4.

**Table 4.** Effect of the application of different PCa doses on the yield and quality parameters of ‘Packham’s Triumph’ pears in the 2009/2010 harvest, with the PCa application being carried out only on the tree canopy.

PCa dose (mg·L <sup>-1</sup> )	Fruits per plant	Average fruit mass (g)	Pulp firmness (N)	Soluble solids (°Brix)
zero	423 a	210 a	74.7 a	11.8 a
250	349 a	185 a	73.4 a	12.1 a
330	261 a	175 a	71.2 a	12.0 a
CV <sup>1</sup> (%)	12.24	30.11	1.88	2.54

Means in column followed by the same letter do not present statistical difference by Duncan’s multiple range test at 5% probability ( $\alpha = 0.05$ ). <sup>1</sup> – Coefficient of variation. Source: Authors.

As observed in the previous experiment, the application of the PCa only on the tree canopies, regardless of the dose, has did not affect the fruit yield, and the quality parameters of the pears. This shows that the action of PCa is independent of the application form, having the same effect on plant growth and no influence on the fruit parameters regardless of the method of application, i.e., if directed only to the canopy or if sprayed throughout the entire aerial part of the tree.

### 3.3 Experiment with ‘Hosui’ pears

The obtained results relative to growth, pruning, and PAR parameters of ‘Hosui’ pear trees treated with different PCa doses, applied throughout the aerial part of the trees, are presented in Table 5.

**Table 5.** Growth parameters, pruning, and PAR for ‘Hosui’ pear trees treated with increasing doses of PCa in the 2009/2010 harvest.

PCa dose (mg·L <sup>-1</sup> )	Branch length (cm)	Relative growth (%)	Mass of pruned branches (kg)	Pruning time (h·ha <sup>-1</sup> )	PAR on 2009-11-25 (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )	PAR on 2009-12-16 (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )
zero	80.4 a	120 a	3.90 a	231 a	219 a	230 a
250	55.4 b	37 b	2.15 b	162 b	362 a	229 a
330	48.5 b	21 b	1.80 b	157 b	335 a	243 a
CV <sup>1</sup> (%)	15.07	10.40	5.28	7.79	13.65	15.28

Means in column followed by the same letter do not present statistical difference by Duncan’s multiple range test at 5% probability ( $\alpha = 0.05$ ). <sup>1</sup> – Coefficient of variation. Source: Authors.

For the ‘Hosui’ pear trees, the average branch length was reduced with the application of PCa relative to the control; however, there was no difference between the doses; the same trend was observed for the relative growth and the mass of pruned branches. This behavior is distinct from the one observed for ‘Packham’s Triumph’ pear trees, in which the PCa dose of 250 mg·L<sup>-1</sup> has not differed from the control and the dose of 330 mg·L<sup>-1</sup>. Carra et al. (2017b) reported the same behavior for

'Shinseiki' pear trees treated with PCa at the doses of 300 and 600 mg·L<sup>-1</sup> in both summer and winter pruning. However, Carra et al. (2017a) reported a different trend for 'Smith' pear trees treated with the PCa doses of 100, 200, 300, and 400 mg·L<sup>-1</sup>, in which the PCa dose influenced the average branch length.

Similar behavior was also observed for the pruning time, which was reduced with the application of PCa, but without difference between the doses; with an average reduction relative to the control in the range of 45% (from 231 h·ha<sup>-1</sup> in the control to 157-162 h·ha<sup>-1</sup> in the PCa-treated trees). This behavior is distinct from the one of 'Packham's Triumph' pear trees, in which the PCa dose of 250 mg·L<sup>-1</sup> has not differed from the control.

The PAR measurements in both days for the 'Hosui' pear trees have not presented a statistical difference, regardless of the PCa dose. This behavior is similar to the one of 'Packham's Triumph' for the second measurement but was distinct from the first measurement, in which the PCa dose of 330 mg·L<sup>-1</sup> differed from the control. This may indicate that the sensibility of the pear trees to PCa may differ with the cultivar, as can be seen when comparing the works of Carra et al. (2016, 2017a, 2017b), who studied 'Le Conte', 'Smith', and 'Shinseiki' pear trees, and Pasa and Einhorn (2017), who worked with 'Starkrimson' pear trees.

The results of yield and quality parameters of 'Hosui' pears treated with different doses of PCa applied throughout the aerial part of the trees are presented in Table 6.

**Table 6.** Effect of the application of different PCa doses on the yield and quality parameters of 'Hosui' pears in the 2009/2010 harvest.

PCa dose (mg·L <sup>-1</sup> )	Fruits per plant	Average fruit mass (g)	Pulp firmness (N)	Soluble solids (°Brix)
zero	135 a	156 a	53.4 a	11.6 a
250	199 a	150 a	51.2 a	11.6 a
330	163 a	167 a	55.6 a	11.9 a
CV <sup>1</sup> (%)	27.31	8.79	1.88	1.40

Means in column followed by the same letter do not present statistical difference by Duncan's multiple range test at 5% probability ( $\alpha = 0.05$ ). <sup>1</sup> – Coefficient of variation. Source: Authors.

According to Table 6, the fruit yield and the quality parameters were not influenced by the application of PCa, regardless of the dose. This behavior is the same observed in the previous experiments with the 'Packham's Triumph' pears, suggesting that both cultivars respond similarly to the application of PCa. Other authors reported similar trends for 'Le Conte', 'Starkrimson', and 'Smith' pear trees, whose fruit yield and quality were not affected by the application of PCa in the range of 100-400 mg·L<sup>-1</sup> (Carra et al., 2016, 2017a; Pasa and Einhorn, 2017). The only exception was the 'Shinseiki' pear trees, whose fruit quality parameters were not influenced by the application of PCa, but the fruit yield was reduced when the trees were treated with PCa 600 mg·L<sup>-1</sup> (Carra et al., 2017b).

#### 4. Conclusion

The application of PCa at the concentration of 330 mg·L<sup>-1</sup> reduced the overall vegetative growth of the trees from both cultivars and reduced significantly the time of green pruning. The application of PCa at 330 mg·L<sup>-1</sup> also reduced the average mass and length of the pruned branches. The incidence of PAR was inside the tree canopies increased during the action of PCa, however, with the normal plant growth, it eventually reached similar values independently of the dose applied. Relative to the 'Packham's Triumph' cultivar, the application of PCa may be carried out on the entire areal part of the tree or only on its canopy, without effect on the PCa efficiency. Relative to the fruit parameters, there were no statistical differences between any of the treatments and any of the pear cultivars, showing that PCa has did not affect the fruit yield, neither on fruit quality.

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