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Effect of phytoregulators on vegetative characteristics of 'packham's triumph' pear trees

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Abstract

This study aimed at evaluating the use of phytoregulators in vegetative characteristics of 'Packham's Triumph' pear trees in both 2014/2015 and 2015/2016 cycles. The orchard, was implemented in 2011. The following phytoregulators and doses were used: Ethephon and 6-Benzyladenine at 100, 200, 300 and 400 ml L^{-1}. The experiment had a randomized block design with five replicates. Each experimental unit was composed of a plant. Variables under evaluation were leaf area, annual branch length, annual branch diameter, number of buds on the annual branch, internode length, fertility index and trunk cross section areas of the crown cultivar and of the rootstock. Only the following variables exhibited significance: leaf area, annual branch length and number of buds in plants treated with Ethephon in the 2015/2016 cycle. Leaf area was smaller when high concentrations of Ethephon were applied while the least efficient doses for annual branch length and number of buds were 162.66 ml L^{-1} and 107.30 ml L^{-1}, respectively.

Keywords: *Pyrus communis*; plant hormones; plant vigor.
Abbreviations: ANOVA_ analysis of variance; P-Ca_ prohexadione calcium; CC_ chlomerquat chloride; PBZ_ paclobutrazol; LA_ leaf area; BL_ annual branch length; NB_ number of buds of the annual branch; EL_ entrenode length; FI_ fertility index; BD_ annual branch diameter; TCAC_ trunk cross section area of the crown cultivar; TCAR_ trunk cross section area of the rootstock.

Introduction

Due to its pleasant taste and nutritional value, the pear (Pyrus spp.) is one of the most popular fruits in the world (Simirgiotis et al., 2016). Despite the fact that consumption is high and domestic production does not support such demand, pear cultivation is not considered very expressive in Brazil, representing only 0.5% of the total temperate fruits produced in the country (Fachinello et al., 2011).
Pears have led Brazilian imports of fresh fruit (Pasa et al., 2011; Pasa et al., 2012). Among temperate fruits, pear is the third most consumed in Brazil (Rufato et al., 2011).
Comparison between Brazilian pear production and its consumption shows that the culture has great expansion potential, mainly in the south of Brazil, where there are favorable weather and soil conditions, and that it is a consistent alternative which may diversify temperate fruit farming in the region (Machado et al., 2013).
Development of pear trees and other fruit trees is influenced by phenomena of competition for photoassimilates among the vegetative part, fruiting organs and the rest of the plant. Branches, sprouts and leaves are strong drains of photoassimilates, a fact that harms the whole reproductive unit, such as flower bud and fruit development. Excess of vegetative growth and little flower differentiation may characterize a plant that is quite unproductive (Rufato et al., 2012).
The use of short plants, which start production precociously, is one of the requirements to obtain regular production of quality fruits, besides decreasing workforce costs, mainly the ones related to pruning and thinning activities. Practices to control vegetative growth, such as the use of growth regulators and/or rootstocks that decrease the vigor of the crown cultivar, are fundamental to modern pear tree orchards (Pasa et al., 2012).
Phytoregulators have been considered one of the best contributions to fruit farming in the 20th century (Brighenti et al., 2012). These compounds have a particularity regarding the fact that, in some cases, the same active ingredient may lead to different answers, depending on its concentrations and application period (Dussi, 2011). Plant hormones have usually been grouped in the following categories: auxin, gibberellin, cytokinin, abscisic acid and ethylene (Southwick, 2007).
In general, it can be considered that plant hormones function as an important intrinsic regulator, responsive to external conditions, in the coordination of the expression of genes responsible for the process of differentiating meristems (Francescatto, 2014). Among the endogenous

substances that have been investigated so far, plant hormones are the only ones that have a consistent close relationship with the induction of flowering (Bangerth, 2006).
Therefore, this study aimed to evaluate the effects of using different doses of the phytoregulators Ethephon and 6-Benzyladenine on the vegetative characteristics of 'Packham's Triumph' pears, thereby seeking to evaluate the influence of these phytoregulators on plant vigor.

Results and Discussion

In the 2014/2015 cycle, the following variables were not significant in the cases of both products: leaf area, annual branch length, number of buds, internode length, fertility index, annual branch diameter and trunk cross section areas of the crown cultivar and of the rootstock (Table 1).
Leaf area decreased linearly in the 2015/2016 cycle when Ethephon doses were applied (Figure 1A). Since leaf area is one of the main parameters in the evaluation of vegetative growth, it has been often used in agricultural and phisiological studies (Gonçalves et al., 2002). Means found by this experiment ranged from 18.36 cm^2 in the control treatment to 13.71 cm^2 when the highest dose of Ethephon was applied (400 ml L^{-1}).
Regarding the effect of Ethephon on leaf expansion, Colli and Purgatto (2008) stated that, in potato, tobacco, sunflower and grass plants, leaf area may be inhibited by ethylene application, mainly due to apparent decrease in cell division rate. In agreement with the behavior of this variable, the higher the Ethephon dose, the lower the leaf size of 'Packham's Triumph' pear trees.
In many situations, leaf area is related to the technical management plants are submitted to in orchards, such as type of rootstock (either vigorous or dwarfish), antihailstone screen and spacing among plants.
Franscescatto (2009) evaluated the leaf area of 'Pachkam's Triumph' grafted on rootstocks with different vigor for two years in a row (2008 and 2009) and concluded that, depending on the production cycle, '*Pyrus calleryana'* was the rootstock that better responded to this variable; it led to the highest specific leaf area (85.44 cm^2 g^{-1}) in 2008, but to the lowest one (60.82 cm^2 g^{-1}) in 2009, when all rootstocks were evaluated. The leaf area reported by this author may result from the vigor induced by the rootstock '*Pyrus calleryana'* on plants.
According to Amarante et al. (2007), 'Royal Gala' apple trees which were covered with antihailstone screen exhibited leaf area means of 32 cm^2, 33.21 cm^2 and 37.50 cm^2 in the control treatment, plants under white screen and plants under black screen, respectively, a fact that may have resulted from plant adaptation to the screens.
Regarding another topic related to management, Hennerich et al. (2015) found that leaf area estimated by vertical projection in 'Hosui' pear trees showed values which were 50% higher than the ones of the cultivar 'Rocha'. They also stated that, regardless of the cultivar, leaf area was about 75% when spacing was 0.4 m, i. e., higher than values found when spacing was 1.0 m. It shows that the highest density had the best use of space and sunlight interception.
Control of vegetative growth in Brazilian conditions is important because pear orchards are mostly formed by the rootstock Pyrus sp., which usually induces excessive vigor. Besides, since climate variables, such as mean and maximum summer temperatures, together with the length of the growth season, worsen the situation, appropriate balance between vegetative and reproductive development is needed for good production of pear trees (Pasa, 2014).
Annual branch length decreased in a quadratic form during dormancy in 2015/2016, when the most efficient dose (vigor control) was 162.66 ml L^{-1} Ethephon (Figure 1B). In this experiment in the 2015/2016 cycle, plants were starting their so-called fourth leaf, i. e., the end of their fourth year in the orchard; thus, the variable was expected to have descending linear behavior because Ethephon application would increase the stimulus to produce auxines in lateral buds and, consequently, decrease branch length. As a result, increase in the number of flower buds would be favored and vegetative vigor would be controlled.
Einhorn et al. (2014) found that a single Ethephon application (150 ppm when the branch had grown 5 cm) and two applications (150 ppm when the branch was 5 cm long and 300 ppm 57 days after full bloom) did not affect vegetative growth, but influenced return bloom and productivity of 'D'Anjou' pears positively, by comparison with treatments with prohexadione calcium (P-Ca).
Considering growth regulators of vegetative growth, P-Ca has been the favorite one in several fruit cultures because of its efficiency in controlling plant vegetative vigor without affecting return bloom (Costa et al., 2006). Costa et al. (2004) reported that the application of this product led to significant decrease in final branch length of 'Abbé Fetel' and 'Beurré Hardy' pear trees on rootstock 'Marmeleiro C' and 'William' pear trees on 'Kirchensaller'.
In Spain, where the most economically important pear tree cultivars are 'Blanquilla' and 'Conference', Asín ans Vilradell (2006) tested the following growth regulators to control their vegetative vigor: chlomerquat chloride (CC), paclobutrazol (PBZ) and P-Ca. Final branch sizes in the cases of CC, PBZ and P-Ca were 34, 39.9 and 41.4 cm, respectively. The authors also concluded that P-Ca decreased the index of branch growth quickly, while PBZ led to the highest decrease in the length of the aerial part and index of branch growth. Besides, they stated that the ideal situation would be product combination, depending on the orchard vigor and the evolution of branch growth.
Regarding the number of buds on the annual branch, decrease happened in a quadradic form; 107.30 ml L^{-1} Ethephon was the least efficient dose (Figure 1C). This behavior is similar to the variable annual branch length since there was also decrease in the number of buds, despite the control of vegetative vigor, and there was sligth increase when 200 ml L^{-1} Ethephon was used. It was expected that the shorter the length, the larger the number of buds, as the result of induction of the development of new fructification structures.
Development of a large number of buds per branch could lead to the formation of flower buds, thus favoring fruit fixation and decreasing vegetative growth and plant vigor considerably. According to Fachinello et al. (2008), the more intense sap circulation is, the higher the vegetative growth and branch vigor, whereas more flower buds are formed when there is decrease in sap circulation.
Pasa et al. (2011) found differences between numbers of buds of 'Packham's Triumph' pear trees grafted on quince trees and on Pyrus calleryana. Among quince trees, 'D'Angers' was the one that exhibited the largest number of buds (117.5) while Pyrus calleryana had 65 buds per branch. 'D'Angers' and Pyrus calleryana exhibited 117 and 74.33 buds in 2010 and 2009, respectively. Values found by this

Table 1. Leaf area (LA, cm^2), annual branch length (BL, cm), number of buds of the annual branch (NB), entrenode length (EL, cm), fertility index (FI), annual branch diameter (BD, mm), trunk cross section area of the crown cultivar (TCAC, cm^2) and trunk cross section area of the rootstock (TCAR, cm^2) of 'Packham's Triumph' pear trees after the application of Ethephon and 6-Benzyladenine doses in the 2014/2015 cycle, Ipê, Rio Grande do Sul state, Brazil.

Cycle 2014/2015									
		LA	BL	NB	EL	FI	BD	TCAC	TCAR
Etefon	T1 (control)	15.58 ns	26.13 ns	12.77 ns	2.08 ns	0.59 ns	6.59 ns	10.00 ns	10.52 ns
	T2	15.31	18.16	10.88	1.66	0.60	6.34	9.07	9.52
	T3	14.69	26.69	12.61	1.96	0.59	6.41	8.87	9.80
	T4	15.38	34.10	14.66	2.21	0.48	6.42	10.36	10.66
	T5	12.90	28.93	12.99	2.20	0.46	5.95	10.15	9.14
	Mean	14.70	26.81	12.78	2.02	0.54	6.34	9.69	9.93
	C.V.(%)	10.21	57.67	30.82	25.05	36.11	12.9	20.13	20.07
6-Benzyladenine	T1 (control)	15.58 ns	26.13 ns	12.77 ns	2.08 ns	0.59 ns	6.59 ns	10.0 ns	10.5 ns
	T6	15.73	26.14	11.83	2.12	0.48	7.45	10.69	11.24
	T7	15.19	25.75	9.38	1.23	0.83	5.93	10.70	11.75
	T8	16.86	11.68	16.11	2.31	0.43	7.27	11.22	11.37
	T9	14.85	37.50	12.88	2.03	0.50	6.06	12.75	12.93
	Mean	15.66	27.51	12.59	1.92	0.57	6.66	11.07	11.56
	C.V.(%)	9.77	46.55	23.36	23.28	23.50	9.18	13.45	16.80
Cycle 2015/2016									
Etefon	T1 (control)	-	-	-	1.99 ns	0.51 ns	5.25 ns	11.82 ns	13.15 ns
	T2	-	-	-	2.25	0.47	4.39	11.33	12.38
	T3	-	-	-	1.47	0.69	4.3	10.41	10.85
	T4	-	-	-	2.18	0.43	4.51	13.12	13.77
	T5	-	-	-	2.14	0.52	4.25	11.29	12.01
	Mean	-	-	-	2.01	0.52	4.54	11.59	12.48
	C.V.(%)	-	-	-	18.99	15.85	15.58	26.08	16.71
6-Benzyladenine	T1 (control)	18.36 ns	15.63 ns	7.55 ns	1.99 ns	0.51 ns	5.14 ns	11.82 ns	13.15 ns
	T6	18.01	9.91	6.27	1.48	0.78	4.50	11.88	12.58
	T7	20.38	14.38	6.44	2.01	0.51	4.56	12.46	13.70
	T8	14.50	14.70	6.72	2.18	0.49	4.58	11.92	12.50
	T9	15.22	16.36	5.75	1.75	0.56	5.75	12.98	16.58
	Mean	17.27	14.19	6.55	1.88	0.57	4.90	12.21	13.70
	C.V.(%)	17.56	38.49	26.85	24.68	34.99	23.97	12.00	15.35

ns: non-significant

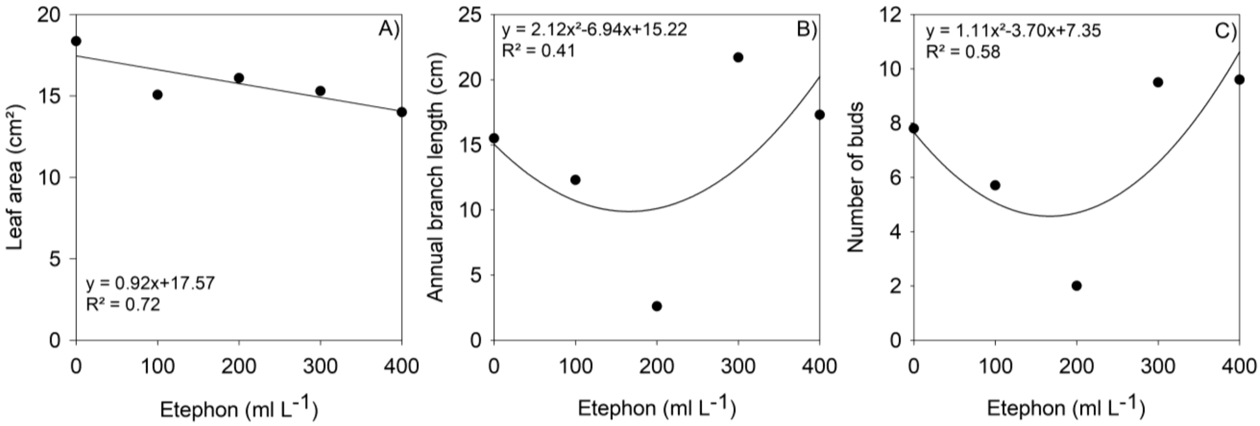

Fig 1. Leaf area (A), Annual branch length (B) and Number of buds (C) of 'Packham's Triumph' pear trees after the application of Ethephon doses in the 2015/2016 cycle, Ipê, Rio Grande do Sul state, Brazil.

experiment were 7.55, 5.22, 1.83, 9.22 and 9.28 for the control when 100, 200, 300 and 400 ml L^{-1} Ethephon doses were applied, respectively (Figure 1C).

Even though resulting values were not the expected ones, the literature reports that the development of reproductive buds is more harmed in vigorous plants, since growth spots compete for carbohydrates with developing buds, causing their abortion and preventing them from being differentiated as flower buds (Pasa et al., 2011). Besides, ethylene is a hormone that may either be involved in the induction process of floral meristem or be lethal in male gametogenesis, a common fact in grasses treated with this hormone (Colli and Purgatto, 2008). Variables entrenode length, fertility index, annual branch diameter and trunk cross section areas of the crown cultivar and of the rootstock did not show any significance when they were evaluated in plants treated with Ethephon in 2015/2016 (Table 1). In the same years and vegetative cycle, variables leaf area, annual branch length, number of buds on the annual branch, entrenode length, fertility index, annual branch diameter and trunk cross section areas of the crown cultivar and of the rootstock were not significant when they were sprayed with 6-Benzyladenine (Table 1).

Materials and Methods

Plant materials and location of the experiment

Evaluations started at the end of production cycles and the beginning of dormancy in 2014/2015 and 2015/2016, in a commercial orchard located at 28°48'20''S, 51°16'32''W and 744 m. Pear trees that belong to the cultivar 'Packham's Triumph', grafted on BA-29 quince rootstock, and filter FT were used. The orchard, which was implemented in 2011, has 4,081 plants ha^{-1} conducted in a free system. Spacing between rows is 3.5 m and between plants is 0.7 m.

Experimental design and treatments

The experiment comprised nine treatments in randomized blocks with five repetitions of 1 plant: plants with no application (T1), plants treated with Ethephon at 100 (T2), 200 (T3), 300 (T4) and 400 (T5) ml L-1 active ingredient and plants treated with 6-Benzyladenine at 100 (T6), 200 (T7), 300 (T8) and 400 (T9) ml L-1 active ingredient.

All treatments were sprayed once per week for five weeks. The first dose was applied 30 days after full bloom. Aspersion was carried out by a gasoline-powered backpack sprayer whose syrup mean volume was 1,000 L ha^{-1}. Mineral oil (Silwet®) at 0.1% was added to all treatments.

Analysis

Fifteen leaves per plant were collected in March 2014 and 2015 to produce random samples from all areas of the crown. Collection focused on leaves that did not exhibit any damage caused by plagues and diseases. They were then stored in paper bags. Petioles were removed by cutting the base of the leaf blade. Length (cm) and width (cm) of every leaf were measured. Length was defined as the distance between the insertion of the petiole in the leaf blade and its opposite end, while width was the largest separation between points measured perpendicular to the length axis. Afterwards, the product of length times width was calculated in order to determine leaf area (cm^2).

In order to evaluate vegetative vigor of plants, annual branch lengths were measured in six branches per plant by a measuring tape (cm), where the number of buds of annual branches were counted. To obtain the internode length (cm), the direct relation between annual branch length and number of buds of the annual branch was calculated. The number of buds and the annual branch length were also related so that the fertility index could be calculated.

Besides, annual branch diameters were evaluated by a digital caliper ruler (mm) at the spot which was 1.5 cm away from the insertion between the secondary branch and the main trunk.

The trunk cross section area of the crown cultivar was evaluated by measuring the trunk diameter 5 cm above the grafting point, while the one of the rootstock was measured 5 cm below the grafting point by a digital caliper ruler. The formula "trunk cross section area = 3.14.(trunk diameter^2)$^{\wedge 2}$" was used for calculating the area (cm^2).

Statistical analysis

The experiment had a randomized block design with five replicates; every experimental unit was composed of a plant. Resulting data were analyzed by the analysis of variance (ANOVA) and by polynomial regression, when they were significant.

Conclusions

Higher doses of Ethephon caused smaller was the leaf area. Thus, Ethephon caused a decrease in the leaf area of 'Packham's Triumph' pear trees.

The application of Ethephon influenced the growth of pear branches. According to the regression equation found, the most efficient dose to control the growth of the branches is 162.66 ml of L-1 Ethephon.

Little improvement is observed in the number of buds on branches when Ethephon is applied to this cultivar.

The application of 6-Benzyladenine had no influence on the characteristics evaluated. Therefore, its application is not able to change the vigor of pear plants of the cultivar 'Packham's Triumph'.

Finally, it can be concluded that the application of Ethephon can be used as a tool to control the vigor of 'Packham's Triumph' pear trees, however further studies are needed evaluating application epochs, other doses, mixing with other active ingredients, application techniques, cultivars, etc..

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