Is the use of growth regulators necessary to increase pecan size?

O uso de reguladores de crescimento é necessário para o aumento do tamanho de frutos de nogueira-pecã?

¿Es necesario el uso de reguladores de crecimiento para aumentar el tamaño del fruto de nuez?

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ABSTRACT
Barton is the most cultivated pecan cultivar in Brazil even though 42 cultivars have already been registered in the country. It bears small nuts, a fact that may represent a hindrance to demands of the Brazilian market and to new markets abroad. Nuts with a large caliber are valued by both internal and external markets. To increase fruit size in fruit trees, growth regulators have been used. Thus, this study aimed at evaluating the effects of plant growth regulators on the increase in pecan size. Two experiments were carried out with the cultivar in a commercial orchard in Santa Maria, Rio Grande do Sul (RS), Brazil, from the 2021 cycle to the 2023 one. Experiment 1 comprised the combination of two plant hormones and two doses of gibberellic acid (GA_3) and five doses of Benzylaminopurine (BAP), which was applied in different phenological stages. Experiment 2 consisted of five treatments conducted with a commercial product that has auxin, cytokinin and gibberellin, which were applied in different phenological stages. In general, GA_3, BAP and the commercial product need further studies of increase in 'Barton' pecan size.

Keywords: Phytohormones, Phytoregulators, Pecan Nuts.

RESUMO
Dentre os 42 cultivares de nogueira-pecã registrados no Brasil, Barton é o mais cultivado. Esse cultivar apresenta um tamanho reduzido de fruto, que com a abertura do mercado ao exterior, além da exigência do mercado interno, podem representar um entrave ao setor. Frutos com maior calibre são valorizados pelo mercado interno e externo. Como alternativa para aumento de frutos, uma pratica já utilizada em frutíferas é a utilização de reguladores de crescimento. Sendo assim, o objetivo do trabalho foi avaliar o efeito de reguladores de crescimento vegetal no aumento do tamanho de frutos em nogueira-pecã. Foram conduzidos dois experimentos em pomar comercial no município de Santa Maria, RS, entre os ciclos de 2021 e 2023, utilizando o cultivar. No experimento 1 foi utilizado a combinação de dois hormônios vegetais, com duas doses de ácido giberélico (GA_3) e cinco doses de Benzilaminopurina (BAP) aplicados em diferentes estádios fenológicos. O experimento 2 contou com a utilização de cinco tratamentos de um produto comercial contendo auxina, citocinina e giberelina, aplicado em diferentes estádios fenológicos. De modo geral, GA_3, BAP e o produto comercial carecem de estudos mais aprofundados para o aumento do tamanho dos frutos em nogueira-pecã do cultivar Barton.

Palavras-chave: Fitohormônios, Fitorreguladores, Nozes.

RESUMEN
Entre los 42 cultivares de nogal registrados en Brasil, el Barton es el más cultivado. Este cultivar tiene un tamaño de fruto reducido, lo que con la apertura del mercado en el exterior, además de las demandas del mercado interno, podría representar una barrera para el sector. Los frutos con mayor calibre son valorados por el mercado interno y externo. Como alternativa al aumento de frutos, una práctica ya utilizada en frutales es el uso de reguladores de crecimiento. Por lo tanto, el objetivo del trabajo fue evaluar el efecto de los reguladores de crecimiento vegetal en el aumento del tamaño de los frutos

en árboles de nogal. Se realizaron dos experimentos en una huerta comercial en el municipio de Santa Maria, RS, entre los ciclos 2021 y 2023, utilizando el cultivar Barton. En el experimento 1, se utilizó una combinación de dos hormonas vegetales, con dos dosis de ácido giberélico (GA_3) y cinco dosis de Bencilaminopurina (BAP) aplicadas en diferentes etapas fenológicas. El experimento 2 implicó el uso de cinco tratamientos de un producto comercial que contenía auxina, citoquinina y giberelina, aplicados en diferentes etapas fenológicas. En general, GA_3, BAP y el producto comercial requieren estudios adicionales para aumentar el tamaño del fruto en el cultivar Barton de pecan.

Palabras clave: Fitohormonas, Fitorreguladores, Frutos Secos.

1 INTRODUCTION

Pecan (*Carya illinoinensis*) is native to North America but it has been grown in several continents, even in Soth America, where Brazil is the world's fourth largest producer (Martins *et al.*, 2023). Brazilian production is higher in the southern states and Rio Grande do Sul (RS) is the country's largest producer (Crosa *et al.*, 2020).

The Ministry of Agriculture, Livestock and Supply (MAPA) has registered 42 pecan cultivars in Brazil so far. 'Barton' is the most common cultivar in Brazilian orchards (Crosa *et al.*, 2020) mainly because it is resistant to scab (*Venturia effusa*), the main disease that affects pecan (Hamann *et al.*, 2018). Some studies conducted in Brazil (Hamann *et al.*, 2018) have shown that this cultivar bears nuts with medium dimensions. Recent and promising opening of the external market has led to the need to produce larger nuts and higher yields. Besides, brazilian industries also value nuts with a large caliber.

In this scenario, the use of growth regulators may enable larger nuts to be produced through cell division and elongation. Even though nut size is also influenced by genetic features and management, some growth regulators that contain cytokinin, gibberellin and/or auxin may contribute to increase it since they have been effective to several species, such as apple, grape, peach, passion fruit, pear, persimmon and plum (Zhang & Witing, 2013; Ainalidou *et al.*, 2015; Petri *et al.*, 2016). However, some studies of watermelon showed that the use of growth regulators did not exert any positive effects on the increase in nut dimensions (Gonçalves *et al.*, 2018).

Timing of application of growth regulators is also extremely important since it may be the difference between effectivity of a positive result and its absence. In some crops, phytoregulators act during blooming, end of blooming and fruit growth, which is when cell division and elongation take place (Petri *et al.*, 2016). In the case of pecan trees, these phases take place in the phenological stages of full booming (BBCH 55 and 65) and fast nut growth (BBCH 73), in agreement with the phenological scale proposed by De Marco et al. (2021). Considering these data and the fact that there is little information about pecan in the edaphoclimatic conditions found in the south of Brazil, further studies must be carried out to get to know this technological strategy better.

Therefore, this study aimed at evaluating the effects of plant growth regulators on the increase in pecan size.

2 MATERIAL AND METHODS

Two experiments were carried out in a commercial pecan orchard in Santa Maria, RS, Brazil (29°45’23”S and 53°39’55”W, 113 m above the sea level). In the Köppen classification, climate in the area is humid subtropical (Cfa) (Alvares *et al.*, 2013). Both experiments were conducted throughout two cycles, i. e., the 2021/2022 cycle - harvest in April 2022 and the 2022/2023 cycle - harvest in April 2023.

Pecan trees used in the experiment were grafted with the cultivar Barton on rootstocks derived from seedlings and conducted in a central leader system. Spacing was 8 x 8 m and trees were 20 years old at the beginning of the study. The orchard has subsurface drip irrigation while the nutritional management followed the manual of liming and fertilization issued for RS and Santa Catarina (SC), which are the southernmost states in Brazil.

Experiment 1: two plant hormones were applied throughout different phenological stages. The experiment had a randomly block design with a 2 x 5 factorial scheme and 10 treatments (Table 1). Two doses of gibberellic acid - Gibberellin GA_3 (0 and 10 mg plant^{-1}) were applied in BBCH 73 stage (fast nut growth) and five doses of Benzylaminopurine - Cytokinin BAP (0, 15, 30, 45 and 60 mg plant^{-1}) were applied in BBCH 55 stage (inflorescences were about 50% of the final standard of the cultivar) and re-applied in BBCH 65 stage (full blooming), in agreement with the phenological scale proposed by De Marco et al. (2021).

Table 1 - Description of treatments

Treatment	GA_3	BAP
	------ mg plant^{-1} ------	
GA_3 0 + BAP 0		0
GA_3 0 + BAP 15		15
GA_3 0 + BAP 30	0	30
GA_3 0 + BAP 45		45
GA_3 0 + BAP 60		60
GA_3 10 + BAP 0		0
GA_3 10 + BAP 15		15
GA_3 10 + BAP 30	10	30
GA_3 10 + BAP 45		45
GA_3 10 + BAP 60		60

where: GA_3 = gibberellic acid; BAP = benzylaminopurine.
Source: Author.

Experiment 2: the experiment had a randomly block design which used five treatments of a commercial product containing 0.005% indole-3-butyric acid (auxin), 0.009% kinetin (Cytokinin) and 0.005% gibberellic acid GA_3 (Gibberellin) at doses of 0, 5, 10, 15 and 30 mL plant^{-1}; spray volume was 5 L planta^{-1}. Treatments were applied in BBCH 55 stage (inflorescences were about 50% of the final standard length of the cultivar) and re-applied in BBCH 65 (full blooming) and BBCH 73 (fast nut growth) stages, in agreement with the phenological scale proposed by De Marco et al. (2021).

Timing of application was based on other fruit and non-fruit crops. In pecan trees, it is when cell division (BBCH 55 and BBCH 65) and cell elongation (BBCH 73) take place. Experiments with other crops have shown that it is when growth regulators act in plants.

Both experiments used three trees per treatment and every tree was considered an experimental unit. Every dose of treatments was diluted in five liters of water and applied at the end of the day (Table 2) by a back atomizer.

Table 2 - Schedule, temperature and air relative humidity at the moment of product application in the cycles of the experiment. Data provided by the Meteorological Station A803 in Santa Maria, RS, Brazil

Application schedule	SIA	MTIA (°C)	RH
10/28/2022	17 to 20	27.3	62
11/09/2022	17 to 20	23.7	61
12/21/2022	18 to 21	28.4	60
10/20/2023	17 to 20	23.6	64
11/01/2023	17 to 20	22	73
12/22/2023	18 to 21	22	84

where: SIA = schedule of the interval of application; MTIA = mean temperature in the interval of application; RH = relative humidity.
Source: INMET (2024).

To determine kernel dimensions and yield, ten nuts per tree were randomly selected, totaling 30 replicates. Nut length, nut width, kernel length, kernel width and kernel height were measured by a digital pachymeter while fresh nut mass and fresh kernel mass were weighed by a two-decimal precision scale. Kernel yield resulted from its percentage in relation to total nut mass.

Effective fructification (EF) was also evaluated when eight feminine inflorescences (racemes) per tree were randomly selected. The number of flowers in the full blooming stage and the number of nuts at harvest were counted. The following formula was used for calculating EF:

$$\text{EF (\%)} = \frac{(\text{No. of nuts x No. of flowers})\ x\ 100}{\text{No. of flowers}} \qquad (1)$$

where:

EF = effective fructification expressed as percentage. No. of nuts at harvest. No. of flowers in the full blooming stage.

To meet assumptions of the analysis of variance, tests of normality and homogeneity of variances proposed by Shapiro-Wilk and Bartlett, respectively, were applied. Afterwards, data on evaluations were subject to the analysis of variance. In Experiment 1, when there was significant interaction, data were subject to the analysis of regression and to the Tukey's test of factor BAP in every level of factor GA_3. Regarding parameters with no significant interaction, simple effects were split. In Experiment 2, means of treatments were subject to the analysis of regression and compared by the Tukey's test at 5% probability with the use of the Assistat® statistical program.

3 RESULTS AND DISCUSSION

The use of growth regulators in fruit farming may be an important management tool in the search for fruit with high quality, shape and size. Even though these factors are influenced by genetic characteristics, environmental conditions, management practices and crop handling in the orchard, they may also be influenced and potentialized by effects of growth regulators (Fauate *et al.*, 2007; Fiovaranço *et al.*, 2010; Petri *et al.*, 2016).

Experiment 1:

The analysis of variance showed that, in 2022, there was only significant interaction ($p \leq 0.05$) in 2022 between two variables – nut length and nut mass –, but regression equations could not be adjusted. In 2023, there was significant interaction not only between nut length and nut mass, but also among kernel length, kernel width, kernel mass and kernel yield. However, estimates of regression equations had low coefficients of determination (r2 < 0.50), which prevented precise interpretations. Thus, means were compared by the Tukey's multiple comparison test (Table 3). There was no significant difference in nut length, nut mass and kernel yield when doses of BAP were applied. However, nut length and nut mass were higher in nuts born by trees treated with BAP – 0 and BAP – 30 (Table 3).

Table 3 - Effects of GA_3 and BAP application on pecan mean length (mm), mean mass (g) and kernel yield (%) in the 2021/2022 cycle

GA_3	BAP									
	0*		15		30		45		60	
	Nut length (mm)									
0*	43.9	aA**	42.6	aA	43.7	aA	42.8	aA	42.9	aA
10	42.1	bAB	42.5	aAB	42.1	bAB	43.3	aA	42.7	aAB
CV (%)	4.42									

GA_3	Nut mass (g)									
0	8.9	aA	8.3	aA	8.8	aA	8.6	aA	8.7	aA
10	8.3	bAB	8.6	aA	8.3	bAB	8.4	aA	8.5	aA
CV (%)	9.98									
	Kernel yield (%)									
0	52.2	aA	55.3	aA	55.6	aAB	55.1	aAB	56.1	aA
10	52.4	aA	54.9	aA	56.0	aA	55.4	aA	55.9	aA
CV (%)	4,60									

where: *mg plant^{-1}; GA_3 = gibberellic acid; BAP = benzylaminopurine; **Means followed by a certain uppercase letter on a line and a lowercase letter on a column do not differ statistically by the Tukey's test at 5% error probability; CV = coefficient of variation.
Source: Author.

Gibberellin and cytokinin are hormones that act on cell division and elongation, which may increase fruit length and size (Fiovaranço et al.; Pasa et al 2017). Some authors have stated that the use of gibberellic acid (GA^3 ou GA^{4+7}) together with cytokinins (BA/BAP) may increase fruit size through cell elongation and division, resulting in longer fruit (Bezerra *et al.*, 2021). Besides, this combination does not need to be carried out in a single application. For instance, a regulator may be applied throughout full blooming while another is applied when petals fall (Macedo *et al.*, 2015). Combining hormones that belong to the groups of gibberellins and cytokinins in fruit farming leads to different responses and functionalities; it depends on the crop, doses and timing of application (Giovanaz *et al.*, 2014).

Doses of GA3 and BAP did not influence EF of pecan trees in any cycle under evaluation (Table 4).

Table 4 – Effects of GA_3 and BAP application on effective fructification of pecan trees in both 2021/2022 and 2022/2023 cycles

Treatment*	EF (%) in 2022	EF (%) in 2023
GA_3 - 0	42.3 ^{ns}	66.6 ^{ns}
GA_3 - 10	43.9	67.5
BAP - 0	42.4 ^{ns}	69.6 ^{ns}
BAP - 15	43.5	64.8
BAP - 30	42.7	70.1

BAP - 45	43.2	64.7
BAP - 60	43.6	63.2
CV (%)	6.2	7.8

where: *mg plant^{-1}. GA_3 = gibberellic acid; BAP = benzylaminopurine; EF = effective fructification; ^{ns} = non-significant at 5% error probability by the Tukey's test; CV = coefficient of variation.
Source: Author.

EF may be influenced by several factors, such as meteorological, nutritional and management conditions (Fagundes *et al.*, 2017; Fronza *et al.*, 2018). However, the use of growth regulators has become a potential tool to increase EF, mainly in fruit trees (Vieira *et al.*, 2016; Fagundes *et al.*, 2017; Petri *et al.*, 2017; Ayub *et al.*, 2019). Souza et al. (2006) studied persimmon trees and observed that, when gibberellic acid was applied to 'Fuyu' trees in full blooming, EF increased and that its increase depended on the concentrations of gibberellic acid applied to the trees.

Gibberellins are essential to EF because they induce the development of proteolytic enzymes which may release tryptophan, the precursor of indoleacetic acid (IAA). This acid regulates almost all processes in plants, such as fruit setting and development (Wang *et al.*, 2009). However, different responses have been given to exogenous applications of gibberellins (Souza *et al.*, 2006). Pereira et al. (2014) studied EF in cherimoya (*Annona cherimola* Mill.) and noticed that the highest doses of GA_3 led to increase in its percentages. On the other hand, Mota Filho et al. (2012) also applied gibberellic acid to cherimoya and concluded that the doses they applied did not give efficient responses regarding increase in EF. The same happened in the study reported by this paper, i. e., results of both experiments showed that exogenous application of GA_3 did not influence pecan EF.

Another plant hormone that may influence EF is cytokinin since it helps nutrient translocation to plant organs under treatment. It provides stimuli to make them compete with vegetative organs, thus, decreasing competition for carbohydrates between buds and fruit; consequently, fruit increase and setting are promoted (Botelho *et al.*, 2005; Carra *et al.*, 2017; Carra *et al.*, 2021). Carra et al. (2021) concluded that other doses of cytokinins must be investigated since they did not get the expected response, i. e., EF did not increase in 'Rocha' pear trees. This conclusion is corroborated by the study reported by this paper.

However, Luz et al. (2017) studied ‘Rocha’ pear trees and concluded that doses of 20 mg L^{-1} thidiazuron (cytokinins) increased EF and productivity.

It should be highlighted that pecan trees exhibit alternate bearing, which means that a year with a large crop (on) is followed by a year with a small crop (off). Data issued by the University of Georgia show that ‘Barton’, the cultivar used by this study, has an alternate bearing index equal to 0.81 (it ranges from 0 to 1); the closer to 1, the higher the alternate bearing. It helps to explain the difference in EF in both years: in 2022, EF was below 44% and the year was characterized as an ‘off year’ while, in 2023, EF was above 63% and it was characterized as an ‘on year’. However, the use of growth regulators (cytokinin and gibberellin) did not influence EF in any year.

Table 5 shows data on nut diameter (mm), nut width (mm), nut height (mm) and nut mass (g) collected in 2022. There was no significant interaction among experimental factors. There was decrease in nut diameter, kernel width and kernel height when 10 mg plant-1 GA3 was applied. However, doses of BAP under investigation did not affect the variables; they did show any significant difference.

Table 5 – Effects of GA_3 and BAP application on nut diameter (mm), kernel length (mm), kernel width (mm), kernel height (mm) and kernel mass (g) in the 2021/2022 cycle

Treatment*	ND	KL	KW	KH	KM
		mm			g
GA_3 - 0	23.1 a**	34.4 ns	17.4 a	8.7 a	4.7 ns
GA_3 - 10	22.6 b	34.3	17.1 b	8.5 b	4.6
BAP - 0	23.9 ns	34.6 ns	17.1 ns	34.6 ns	4.7 ns
BAP - 15	22.6	34.3	17.1	34.3	4.7
BAP - 30	23.0	34.2	17.5	34.2	4.7
BAP - 45	22.8	34.0	17.3	34.0	4.6
BAP - 60	22.8	34.6	17.2	34.6	4.7
CV (%)	4.7	5.24	5.3	7.41	12.6

where: ND = nut diameter; KL = kernel length; KW = kernel width; KH = kernel height; KM = kernel mass; * mg $plant^{-1}$; GA_3 = gibberellic acid; BAP = benzylaminopurine; **Means followed by a certain letter on a column do not differ statistically at 5% error probability by the Tukey’s test; ns = non-significant; CV = coefficient of variation.
Source: Author.

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When the study was repeated in the 2022/2023 cycle, there was significant interaction between the doses of BAP and GA_3 in nut length, nut mass, kernel length, kernel width, kernel mass and kernel yield (Table 6). In general, the use of 10 mg plant^{-1} GA_3 did not increase the variables under study. In fact, there was decrease in nut length (BAP - 0, 30 and 60 mg plant^{-1}), nut mass (BAP – 0, 15 and 30 mg planta^{-1}) and kernel length (BAP - 0 and 30 mg planta^{-1}). The analysis of effects caused by doses of cytokinin (BAP) on the increase in fruit size showed that trees that were not subject to BAP (BAP – 0) did not differ from the other doses under investigation. Negative effects could even be observed on some variables when BAP was used.

Table 6 - Effects of GA_3 and BAP application on nut length (mm), nut mass (mm), kernel length (mm), kernel width (mm), kernel mass (g) and kernel yield (%) in the 2022/2023 cycle

GA_3	BAP									
	0		15		30		45		60	
	Nut length (mm)									
0*	42.2	aA**	40.4	aB	41.0	aB	41.2	aAB	41.2	aAB
10	40.9	bAB	40.4	aBC	39.6	bC	41.8	aA	40.4	bBC
CV (%)	3.72									
	Nut mass (g)									
0	6.8	aA	6.8	aA	6.5	aA	6.6	aA	7.1	aA
10	6.4	bAB	6.3	bC	6.1	bC	7.0	aA	6.9	aAB
CV (%)	11.6									
	Kernel length (mm)									
0	33.4	aA	32.6	aA	32.8	aA	32.7	aA	32.5	aA
10	32.5	bAB	32.1	aB	31.7	bB	33.3	aA	32.5	aAB
CV (%)	4.11									
	Kernel width (mm)									
0	16.5	aA	16.9	aA	16.4	aA	16.5	aA	16.8	aA
10	16.4	aAB	16.1	aB	16.2	aAB	16.8	aA	16.4	aAB
CV (%)	5.16									
	Kernel mass (g)									
0	3.6	aAB	3.8	aA	3.4	aB	3.5	aAB	3.9	aA
10	3.4	aAB	3.3	aC	3.2	aC	3.8	aA	3.7	aAB
CV (%)	15.34									
	Kernel yield (%)									
0	52.8	aAB	55.4	aA	52.6	aAB	53.4	aAB	54.4	aA

10	52.7	aA	53.9	aA	52.8	aA	53.9	aA	54.5	aA
CV (%)					4,96					

where: *mg plant^{-1}; GA_3 = gibberellic acid; BAP = benzylaminopurine; **Means followed by a certain uppercase letter on a line and a lowercase letter on a column do not differ statistically at 5% error probability by the Tukey's test; CV = coefficient of variation.
Source: Author.

Some studies that used cytokinins associated with gibberellins showed increase in quality and size of grapes and mangos (Pérez *et al.*, 2015; Barraza *et al.*, 2017; Bezerra *et al.*, 2021). However, the study reported by this paper did not show any significant differences in its results. It corroborates results found by Fioravanço et al. (2010), who did not observe any influence of the mixture of gibberellin and cytokinin on 'Starking Delicious' and 'Royal Gala' apples.

Regarding nut diameter and kernel height, there was no significant interaction between doses of BAP and GA_3 under evaluation (Table 7). Nut diameter was smaller when 10 mg plant^{-1} GA_3 was used. However, there was no difference in kernel height when GA_3 was used. Doses of BAP were not efficient in increasing nut diameter and kernel height.

Table 7 - Effects of GA_3 and BAP application on nut diameter (mm) and kernel height (mm) in the 2022/2023 cycle

Treatment*	Nut diameter (mm)	Kernel height (mm)
GA_3 - 0	21.6 a**	7.9 ns
GA_3 - 10	21.3 b	7.8
BAP - 0	21.6 ns	7.7 ns
BAP - 15	21.5	7.9
BAP - 30	21.2	7.7
BAP - 45	21.5	8.0
BAP - 60	21.5	8.1
CV (%)	4.68	7.26

where: *mg plant^{-1}; GA_3 = gibberellic acid; BAP = benzylaminopurine; **Means followed by a certain letter on a column do not differ statistically at 5% error probability by the Tukey's test; ^{ns} = non-significant; CV = coefficient of variation.
Source: Author.

Experiment 2:

There was no significant difference ($p > 0.05$) among doses of treatments that used the commercial product in any cycle under study; thus, regression equations could not be adjusted. Therefore, results are shown as means of the Tukey's test (Table 8). Doses of treatments that used the commercial product based on gibberellic acid and cytokinins did not affect the variables analyzed by this study in any cycle (2022 and 2023). Even when doses were increased, results were not significant in any year.

Table 8 - Effects of exogenous application of a commercial growth regulator on effective fructification, dimensions of pecan nuts and kernel yield in both 2021/2022 and 2022/2023 cycles

Treat. *	EF	NL	ND	NM	KL	KW	KH	KM	KY
	%	---- mm ----		g	------- mm --------			g	%
2022									
0	43.4 ns	44.9 ns	23.2 ns	8.7 ns	35.5 ns	18.0 ns	8.2 ns	4.7 ns	54.5 ns
5	46.0	44.9	23.0	8.3	35.5	18.1	8.3	4.4	54.5
10	43.1	45.1	22.7	8.0	34.5	17.4	8.1	4.2	54.2
15	42.1	44.5	23.1	8.6	35.4	18.0	8.3	4.5	53.3
30	41.4	44.7	22.5	8.1	35.3	17.7	8.1	4.5	55.1
CV (%)	8.4	4.8	4.6	12.2	5.3	5.9	7.3	15.6	8.4
2023									
0	68.3 ns	42.3 ns	21.7 ns	6.8 ns	33.5 ns	16.5 ns	7.8 ns	3.6 ns	53.2 ns
5	63.7	40.6	21.2	6.3	32.4	16.4	7.9	3.3	53.2
10	69.6	39.4	20.8	6.2	31.8	16.1	7.5	3.4	54.2
15	73.7	39.7	21.1	6.3	32.0	16.2	7.7	3.4	54.5
30	65.4	40.5	21.4	6.4	32.3	16.2	7.1	3.4	52.7
CV (%)	6.9	3.9	4.3	11.3	4.2	5.1	6.7	15.2	5.6

where: Treat. = treatment; EF = effective fructification; NL = nut length; ND = nut diameter; NM = nut mass; KL = kernel length; KW = kernel width; KH = kernel height; KM = kernel mass; KY = kernel yield; * mL plant^{-1}; ns = non-significant at 5% error probability by the Tukey's test; CV = coefficient of variation.
Source: Author.

Castro et al. (1998) observed the effects of Stimulate® (containing auxin, gibberellin and cytokinin) in 'Pêra' orange trees and found increase in fruit production. Gonçalves et al. (2018) concluded that the factor doses of Stimulate® did not exhibit any significant effect on passion fruit plants. Even though the study reported by this paper used doses recommended by the literature for other crops, there were no significant results of increase in nut size. It reinforces the need for further studies since the literature does not show any result that is different from the ones found by this study.

In general, neither the application of GA_3 and BAP in different phenological stages (Experiment 1) nor the application of the commercial product containing a mixture of gibberellin, cytokinin and auxin (Experiment 2) showed any significant result of increase in pecan size. The lack of any significant effect, which had already been observed by some studies, may be related to the fruit species and to differences found in cultivars that belong to a certain species. However, it may also be related to the timing of application, environmental conditions during application and in the following days and dosage of hormones. In this scenario, it should be pointed out that studies of effects of plant growth regulators on pecan trees are scarce. Therefore, new and complementary studies of different doses and timing of application should be carried out to enable better understanding of this issue.

5 CONCLUSION

Results of this study enable to conclude that the application – either isolated or associated – of plant growth regulators GA_3 and benzylaminopurine did not affect the sizes of nuts born by ‘Barton’ pecan trees. In addition, the use of a commercial product containing auxin, gibberellin and cytokinin does not lead to increase in sizes of nuts born by ‘Barton’ pecan trees.

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