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Fruit set and yield of 'Santa Maria' and 'Abate Fetel' pears are increased by early spring application of aminoethoxyvinilglycine (AVG)

A frutificação efetiva e produtividade de pereiras 'Santa Maria' e 'Abate Fetel' são incrementadas pela aplicação de aminoetoxivinilglicina (AVG) no início da primavera

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ABSTRACT

The objective of this study was to evaluate the effect of aminoethoxyvinilglycine (AVG), sprayed at different doses, on yield components and fruit quality of pear trees, during the growing seasons of 2015/2016 and 2016/2017, in São Joaquim, Santa Catarina state, Brazil. Treatments consisted of AVG sprayed one week after full bloom (WAFB)) at different doses on 'Santa Maria' (0 mg L^{-1}, 40 mg L^{-1}, 80 mg L^{-1}, and 120 mg L^{-1}) and 'Abate Fetel' (0 mg L^{-1}, 80 mg L^{-1}, and 100 mg L^{-1}) pear trees, arranged in a randomized block design. Yield components and fruit quality attributes were assessed. Fruit set, number of fruit per tree and yield are significantly improved and positively related to AVG dose for both cultivars, while fruit quality attributes and fruit size are not affected by treatments.

KEYWORDS: *Pyrus communis*, plant growth regulators, ethylene, fruit drop, fruit quality.

RESUMO

O objetivo desse trabalho foi de avaliar o efeito da aminoetoxivinilglicina (AVG), aplicado em diferentes doses, nos componentes de produtividade e qualidade de frutos de pereiras, durante as safras de 2015/2016 e 2016/2017, em São Joaquim, SC. Os tratamentos consistiram na aplicação de AVG uma semana após a plena floração (1 SAPF) em diferentes concentrações em pereiras 'Santa Maria' (0 mg L^{-1}, 40 mg L^{-1}, 80 mg L^{-1} e 120 mg L^{-1}) e 'Abate Fetel' (0 mg L^{-1}, 80 mg L^{-1}, e 100 mg L^{-1}). O delineamento experimental foi de casualização por blocos. Os componentes de produtividade e qualidade de frutos foram avaliados. A frutificação efetiva, número de frutos por planta e produtividade são significativamente aumentados e positivamente correlacionados com a dose de AVG para ambas as cultivares, enquanto os atributos de qualidade e tamanho de frutos não são afetados pelos tratamentos.

PALAVRAS-CHAVE: *Pyrus communis*, reguladores de crescimento, etileno, queda de frutos, qualidade de frutos.

The low fruit set is one of the most important factors responsible for the pear scenario in Brazil (HAWERROTH et al. 2011), where 90% of the domestic market is supplied by import (PASA et al. 2015). Plant growth regulators play an important role on fruit set of fruit trees (JACKSON 2003). Several studies have reported positive effects mainly of gibberellins (HAWERROTH et al. 2011, VERCAMMEN & GOMAND 2008), and thidiazuron (PETRI et al. 2001, BIANCHI et al. 2000) on pears when applied at full bloom. However, the higher fruit set induced by these substances is due to a higher rate of induced parthenocarpy (VERCAMMEN & GOMAND 2008, PETRI et al. 2001), which often leads to misshapen fruits (BIANCHI et al. 2000), which are not desirable. Besides, the application of gibberellins may reduce flower bud formation and return bloom (DECKERS & SCHOOFS 2002). Other plant growth regulators, mainly ethylene inhibitors, such as AVG, have shown promising results.

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Ethylene is involved in the senescence and abscission of flowers (GREENE 1980) and young fruits (WEBSTER 2002). Thus, the application of inhibitors of ethylene synthesis, such as AVG might be a potential tool to reduce fruit drop and increase fruit set of pears. AVG suppresses ethylene biosynthesis by inhibiting enzymatic activity responsible for the conversion of S-adenosyl methionine to 1-aminocyclopropane-1-carboxylic acid (YANG & HOFFMAN 1984). This substance has shown promising results when applied from one to two WAFB (DUSSI et al. 2002, SÁNCHEZ et al. 2011, EINHORN et al. 2013), with doses varying from 40 to 250 mg L^{-1}. The objective of this study was, therefore, to evaluate the effect of AVG, sprayed at different doses, on yield components and fruit quality of 'Santa Maria' and 'Abate Fetel' pears.

The study was performed in São Joaquim, in the state of Santa Catarina, Brazil (28º17'39''S, 49º55'56''W, at 1,350 m of altitude), during the growing seasons of 2015/2016 and 2016/2017. The climate of the region is mesothermal humid (Cfb) according to Köppen-Geiger classification, i.e, temperate climate constantly humid, without dry season, and cool summer. Average accumulation of temperatures below 7.2 ºC is 900 hours. The soil of the experimental field is a Cambissolo Húmico (Inceptisol), according to the Brazilian soil classification system (SANTOS et al. 2013).

Plant material consisted of 'Santa Maria' (5 years-old) and 'Abate Fetel' (10 years-old) pear trees grafted on quince rootstock 'BA29', trained in a central leader system. The cultivars 'Rocha' and 'Packham's Triumph' were used as pollen source. Trees were spaced at 4 m between rows and 1m within the row, totaling 2,500 trees per hectare.

Treatments consisted of different doses of AVG sprayed 1 WAFB to the cultivars Santa Maria (0 mg L^{-1}, AVG 40 mg L^{-1}, AVG 80 mg L^{-1}, and AVG 120 mg L^{-1}) and Abate Fetel (0 mg L^{-1}, AVG 80 mg L^{-1}, and AVG 100 mg L^{-1}). The source of AVG was Retain® (15 % a.i.). All solutions were supplemented with 0.05% (v:v) of nonionic silicone surfactant (Break-Thru®). Trees were sprayed to runoff with a motorized hand-gun backpack sprayer (Stihl SR 450) with a flow rate of 2.64 L min^{-1}. Spraying volume was approximately 1000 L ha^{-1}. The application water pH was ~6.95. Trees were sprayed during the morning, with temperature ranging from 20 to 25 °C, relative humidity of 85 to 95% and wind speed not exceeding 7 km h^{-1}. Climatic conditions following application of AVG in both seasons are shown in Figure 1.

Trees were arranged in a randomized complete block design with four replicates of three trees each. Only the central trees were used for evaluation, leaving one at each end as border. At full bloom all flower clusters per tree were counted and after the

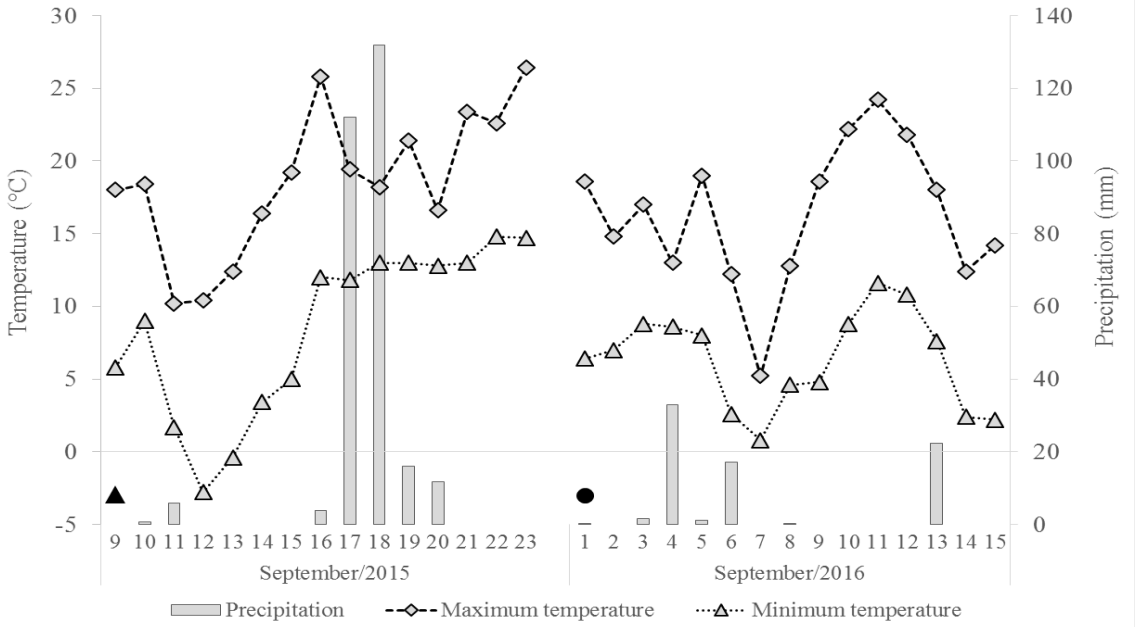

Figure 1. Climatic conditions following the application of AVG in 2015 and 2016. Triangle and circle in the "x" axis denotes the time of application in 'Santa Maria' and 'Abate Fetel', respectively.

last natural fruit drop period occurred (~40 DAFB) the number of fruit per tree was recorded to calculate fruit set. Fruit set was obtained from the following equation: number of fruit per tree/number of flower cluster per tree, and expressed as number of fruit per flower cluster. After evaluating fruit set, thinning was performed in the cultivar Abate Fetel, leaving two fruit per flower cluster and the number of thinned fruits was counted. Trees were harvested at commercial maturity, i.e, with flesh firmness ranging from 60 to 70 Newton (N) and total soluble solids (TSS) from 11 to 13 °Brix, in 01/15/2016 'Santa Maria' and 02/23/2017 'Abate Fetel'. The total number of fruit per tree was counted and weighed (kg). From these data, the following parameters were calculated: yield per tree (kg), estimated yield (ton ha^{-1}), and average fruit weight (g). At harvest, samples of 15 fruit per replicate (tree) were taken for fruit quality analysis (flesh firmness and soluble solids). Fruit firmness (N) was measured with an automatic penetrometer (Fruit Texture Analyzer, Güss Manufacturing, Strand, South Africa), using an 8 mm diameter probe. Sections of skin, 2 cm in diameter, were removed at the widest point of the fruit on opposite sides prior to the determination of fruit firmness. After fruit firmness measurements, a composite sample per replicate was juiced, and 0.5 mL of juice was placed onto a digital refractometer, model PR-32 (Atago Co., Tokyo, Japan) to determine TSS, expressed as ºBrix. The number of viable seeds per fruit was assessed by cutting the fruit in two halves and manually removing and counting the seeds of each fruit individually.

Statistical analyses were performed using the R software (R CORE TEAM 2014), with the ExpDes package (FERREIRA et al. 2013). Data was analyzed for statistical significance by means of F test. Polynomial regression and Tukey's test were performed to compare treatments when analysis of variance showed significant differences among means.

Fruit set, number of fruit per tree, yield per tree, and estimated yield were significantly increased by AVG in both cultivars. This increase was linear and positively related with AVG dose in 'Santa Maria' pears. On the other hand, considering the cultivar Abate Fetel, fruit set, number of fruit per tree, yield per tree, and estimated yield were greater with AVG 100 mg L^{-1}, which did not differ of AVG 80 mg L^{-1}. The number of fruit thinned was greater with AVG 100 mg L^{-1} (Table 1).

Table 1. The effect of AVG sprayed 1 week after full bloom at different doses on yield components pear trees, in the growing seasons of 2015/2016 ('Santa Maria') and 2016/2017 ('Abate Fetel'). São Joaquim, SC.

AVG dose (mg L^{-1})	Fruit set (NFFC)	Number of fruit thinned	Number of fruit per tree	Yield per tree (kg)	Estimated yield (t ha^{-1})
	----------'Santa Maria'----------				
0	0.69	-	3.33	0.61	1.53
40	1.00	-	6.00	1.10	2.75
80	1.52	-	13.33	2.13	5.33
100	2.18	-	17.00	2.70	6.75
p					
Linear effect	0.016	-	<0.001	<0.001	<0.001
Quadratic effect	0.617	-	0.645	0.732	0.735
Cubic effect	0.973	-	0.121	0.079	0.080
	----------'Abate Fetel'----------				
0	0.17 b*	2.67 b	13.67 b	2.17 b	5.42 b
80	0.80 ab	16.00 b	35.67 a	5.00 ab	12.50 ab
100	1.44 a	44.50 a	50.50 a	6.92 a	17.31 a
p	0.015	0.006	0.010	0.017	0.017

*Different letters within column indicate significant differences according to Tukey's test ($p<0.05$).
NFFC = number of fruit per flower cluster. Regression equations for 'Santa Maria': $y = 0.0124x + 0.6036$, $r^2 = 0.976$ (Fruit set); $y = 0.1208x + 2.6667$, $r^2 = 0.969$ (Number of fruit per tree); $y = 0.0183x + 0.5403$ $r^2 = 0.981$ (Yield per tree); $y = 0.0456x + 1.3508$, $r^2 = 0.981$ (Estimated yield).

Similar results were previously reported by SÁNCHEZ et al. (2011), which observed greater fruit set and yield of 'Abate Fetel' and 'Packham's Triumph' pears in response to AVG 250 mg L^{-1} sprayed 2 WAFB. EINHORN et al. (2013) also found increased fruit set, number of fruit per tree and yield of 'd'Anjou' and 'Comice' treated with 40 and 80 mg L^{-1} of AVG at 2 WAFB, as well as DUSSI et al. (2002) in 'Packham's Triumph'. The reduction in ethylene synthesis is probably the main explanation for these results since this plant hormone is involved in the senescence and abscission of flowers and young fruit (GREENE 1980).

Fruit weight was not affected by treatments in both cultivars (Table 2). On the other hand, EINHORN et al. (2013) and DUSSI et al. (2002) found reduction of fruit size in AVG treated 'D'Anjou' and 'Packham's Triumph' trees, respectively, which was attributed to the higher crop load of AVG treated trees. Reduction in fruit weight is usually associated with higher crop load in pears (ROBINSON 2011). However, the greater crop load of AVG treated trees did not influence fruit weight in our study, probably because the regular crop load, considering no AVG treatment, was under the maximum crop load capacity of the trees

Flesh firmness and total soluble solids did not differ among treatments in both cultivars (Table 2). Despite inhibiting ethylene biosynthesis (YANG & HOFFMAN 1984), which is involved in fruit ripening, seems that early applications of AVG do not influence fruit quality attributes, as we have found in the present study. This effect is highly desirable, since the main goal is to increase fruit set and yield, but without affecting fruit quality.

Differences in number of seeds per fruit were found only in 'Abate Fetel', where the greatest number of seeds per fruit was found with AVG 100 mg L^{-1} (Table 2). Ethylene is closely related to flower development and reproduction. The application of exogenous ethylene at anthesis increases ovule senescence and promotes fruit abscission (SANZOL & HERRERO 2001). On the contrary, as might be expected, the application of ethylene inhibitors, such as AVG, effectively retained fruit and increased the number of seeds per fruit in pear, probably as a consequence of prolonged effective pollination period (EPP) due to longer life span of the ovules (CRISOSTO et al. 1986). The greater number of seeds of AVG treated fruit was observed only in 'Abate Fetel', suggesting this is cultivar-dependent. Since this cultivar starts to bloom 1 to 2 weeks earlier than 'Santa Maria', and consequently there is lower pollen availability to fertilize the first flowers, a possible explanation is that AVG prolonged the EPP, then increasing the chance of pollination of those flowers that otherwise would abort.

In conclusion, fruit set, number of fruit per tree and yield are significantly improved by AVG sprayed one week after full bloom with doses ranging from

Table 2. The effect of AVG sprayed 1 week after full bloom at different doses on fruit weight, flesh firmness, soluble solids and number of seeds per fruit of pear trees, in the growing seasons of 2015/2016 ('Santa Maria') and 2016/2017 ('Abate Fetel'). São Joaquim, SC.

AVG dose (mg L^{-1})	Fruit weight (g)	Flesh firmness (N)	Soluble solids (°Brix)	Number of seeds per fruit
		----------'Santa Maria'----------		
0	183.57	62.23	10.03	1.30
40	186.11	66.46	10.37	1.11
80	163.94	65.22	11.90	1.22
100	165.06	62.11	10.00	1.21
p	0.474	0.397	0.062	0.987
		----------'Abate Fetel'----------		
0	156.82^{ns}	65.60^{ns}	12.40^{ns}	1.56 b*
80	140.56	64.04	12.33	1.77 b
100	136.34	64.30	12.23	2.50 a
p	0.103	0.511	0.948	<0.001

*Different letters within column indicate significant differences according to Tukey's test ($p<0.05$).
^{ns}: not significant.

40 to 100 mg L^{-1} for 'Santa Maria', while for 'Abate Fetel' the most responsive dose is 100 mg L^{-1}. Fruit quality attributes and fruit size are not affected by treatments. Collectively, our results show that AVG is a promising substance to increase fruit set and yield of pear orchards grown in Southern Brazil.

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