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Plant growth regulators for reducing pre-harvest fruit abscission in rainfed avocados

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Abstract

Severe fruit drop events occurring after flowering and during early summer strongly limit rainfed avocado (*Persea americana* Mill.) production. This study aimed to evaluate the effect of late-spring and early-summer sprayings of plant growth regulators (PGRs) and monopotassium phosphite (PF), KH_2PO_3, on fruit abscission, yield and quality of non-irrigated 'Quintal' and 'Margarida' avocado trees. The following treatments were applied over two growing seasons: water; 25 mg L^{-1} of (2,4-dichlorophenoxy) acetic acid (2,4-D); and 45 mg L^{-1} of (E)-L-2-[2-(2-aminoethoxy)vinyl] glycine hydrochloride (AVG), separately applied as a single spraying in November; and three PF-sprayings, bi-weekly applied from mid-December to mid-January. The treatments did not affect fruit yield or quality of 'Quintal' avocados. Nevertheless, the PF sprayings significantly increased cumulative fruit yield of 'Margarida' trees (944 Kg $tree^{1}$, P = 0.0028). In both cultivars, the mean pre-harvest fruit drop in the studied biennium was not affected by the treatments, although AVG significantly reduced abscission of 'Quintal' avocados only in 2015 (3.88 fruits m^{-2}, P = 0.0121), under non-stressful environmental conditions during fruit growth. In this cultivar, a single spraying, either with AVG or 2,4-D, significantly reduced fruit size and modified fruit shape. In the 'Margarida' cultivar, those treatments did not affect fruit shape, but a single 2,4-D spraying significantly increased diameter and length, by 2.7% and 1.9%, respectively. Large variability of the responses to the treatments among cultivars confirms that fruit abscission is a complex process regulated by several factors and demanding a multidisciplinary approach to develop efficient methods for its chemical manipulation.

Keywords: fruit drop, fruit size and shape, *Persea americana* Mill, yield

Introduction

In spite of the reported effects of foliar applications of some plant growth regulators (PGRs) on reducing fruit abscission in 'Hass' avocados (Salazar-García et al., 2007; Duarte et al., 2018), little is known on their use in other avocado cultivars growing under different soil and climatic conditions. Among the PGRs previously evaluated for reducing fruit drop in avocados, the herbicide (2,4-dichlorophenoxy) acetic acid (2,4-D) is a synthetic auxin that blocks the effect of ethylene biosynthesis on fruit abscission (Peng et al., 2013), while the (E)-L-2-[2-(2-aminoethoxy)vinyl] glycine hydrochloride (AVG) is a naturally occurring non-protein L-amino acid that inhibits ethylene biosynthesis and delays fruit maturation in pome and stone fruit (Amarante et al., 2005; Petri et al., 2011). In a study conducted during two years in rainfed 'Hass' avocado orchards in Mexico, single applications of either 20 mg L^{-1} 2,4-D or 45 mg L^{-1} AVG, significantly reduced pre-harvest fruit drop and increased fruit size, without affecting fruit yield (Salazar-García et al., 2007).

Environmental conditions may influence the effectiveness of PGRs applications, mainly under extreme air temperatures, since extremely hot or cold events may inactivate the PGRs, and severe water stress conditions (Brogio et al., 2018). PGR's effect may also vary with the application dose, tree vigor and age, fruit load, phenological stage and architecture of the scion cultivar (Kozlowski & Pallardy, 1997; Rossouw et al., 2000).

Potassium phosphite (PP) is applied in several fruit species for crop protection against diseases caused by Oomycete fungi (Hardy et al., 2001; Silva et al., 2016). In avocados, PP is recommended for increasing fruit yield and size (Lovatt, 2013) and inducing plant defense responses against *Phytophthora cinnamomi*, the main soilborne plant pathogen affecting that crop (Silva et al.,

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2016). While PGRs may reduce fruit abscission, either by increasing the auxin/ethylene ratio, in the case of 2,4-D, or by inhibiting ethylene biosynthesis, as the AVG, the PP might enhance plant nutrition, with positive effects on avocado fruit growth and yield (Lovatt, 2013).

Brazil avocado production is mainly based on local selections of West Indian x Guatemalan hybrids, which are harvested at different times throughout the year and are highly appreciated by the local consumers. The 'Quintal' avocado cultivar has large-sized, pear-shaped fruits, harvested in the mid-season, from May to August, while the 'Margarida' avocado is a late-season cultivar, with a characteristic rounded fruit shape, harvested from September through December, during a period of high prices in the domestic market.

The lack of information on chemical control of fruit abscission in other avocado cultivars different from 'Hass' motivated this research, with the objective to evaluate the effect of foliar sprayings of 2,4-D, AVG and PP on fruit abscission, yield and quality of 'Quintal' and 'Margarida' avocados trees under rainfed conditions.

Material and Methods

The trial was conducted at Fazenda Santa Cecilia and Fazenda Santa Elisa farms, located in the municipalities of Bernardino de Campos (23°5'50.6"S; 49°30'42.7"W, 551 m altitude) and Timburi (23°14'05.3"S 49°34'42.4"W, 780 m altitude), respectively, both in Southwestern São Paulo State, Brazil. The local climate is Cwa, according to Köppen's classification, subtropical, rainy in summer and dry in winter, with 1,500 mm mean annual rainfall. The 'Quintal' and 'Margarida' orchards were planted in 1999 and 2003 respectively, on a clayey, distrophic Ferralsol or red Latosol, according to the Brazilian soil classification system (Santos et al., 2013), in a 10 x 10 m spacing (100 trees ha^{-1}). Cumulative fertilization rates applied to the soil during the experimental period were (kg $tree^{-1}$): N = 3.2; P_2O_5 = 0.7; K_2O = 4.2; Zn = 0.6; B = 0.20 in the 'Quintal' cultivar, and N = 2.1; P_2O_5 = 1.1; K_2O = 2.6; Zn = 0.6; B = 0.20 in the 'Margarida' cultivar, as defined by annual soil and leaf analysis and fruit yield data. The orchard was managed following the standard cultural traits recommended for avocado trees (Silva et al., 2017).

Regional meteorological data were obtained from the nearest automatic station in Ourinhos/SP, situated 55-65 km from the experimental sites (Inmet, 2016). Regional climatic water balance was calculated according to Rolim et al. (1998) (Figure 1).

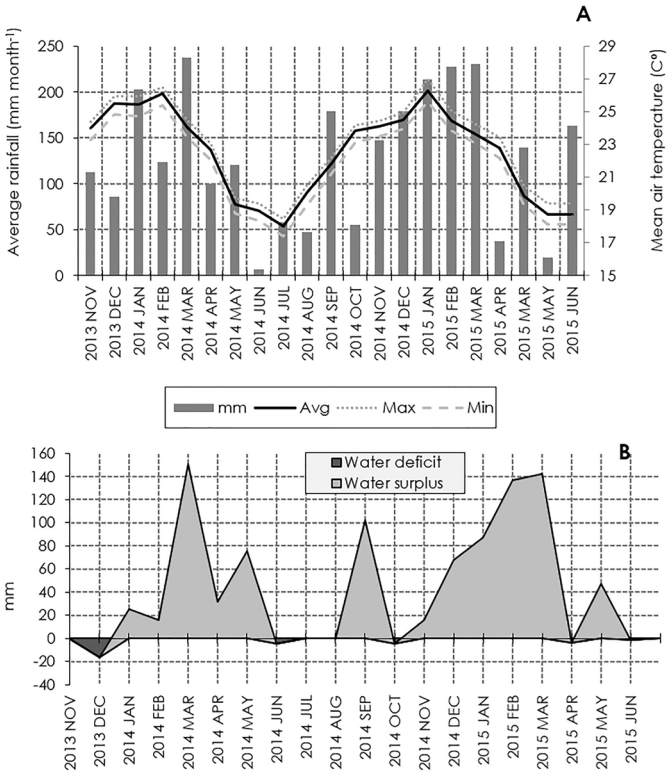

Figure 1. (A): Monthly mean rainfall (mm) and maximum (Max), minimum (Min) and average (Avg) air temperature (°C). (B): Climatic water balance from November 2013 through June 2015. National Institute of Meteorology, Ourinhos, SP, Brazil, 2016.

In November 2013 and 2014, approximately one month before the second fruit drop in summer 'Margarida' and 'Quintal' avocado trees were sprayed with the following treatments: water; 25 mg L^{-1} of 2,4-D (Atanor S.C.A., Rio Tercero, Córdoba, Argentina), as a salt, and 45 mg L^{-1} of AVG (Valent Bioscience Corporation, Libertyville, IL, USA). Another treatment consisted of three sprayings with 4 mL L^{-1} potassium phosphite (30% P_2O_5 and 20% K_2O), applied every two weeks from mid-December to mid-January, in years 2013/2014 and 2014/2015. AVG and 2,4-D applications occurred with mean fruit length of 40 mm for 'Margarida' and 45 mm for 'Quintal' avocado, while potassium phosphite was applied with mean fruit length between 66-90 and 63-110 mm for 'Margarida' and 'Quintal' cultivars, respectively. An organosilicone surfactant was added to all the treatments (0.01% Silwett L-77®) to enhance coverage, and the pH of the water was adjusted to 5.0. An airblast sprayer (Arbus 2000, Jacto, Pompéia, SP, Brazil) dragged by a tractor (MF-275, Massey Ferguson, Duluth , GA, EUA) travelling at an average speed of 3.5 km h^{-1} was used for all sprayings, with an application rate of 23 L $tree^{-1}$ (2300 L ha^{-1}). Environmental conditions during sprayings were: air temperature of 23-26°C, wind speed of 1-7 km h^{-1} and air relative humidity of 60-80%.

Fruit abscission was evaluated from early fruit set until harvest on both varieties during the 2013-2014 and 2014-2015 fruiting seasons, by bi-weekly counting the number of fruitlets dropped into four wooden boxes (0.6 m^2 total surface area) previously distributed in the quadrants under the canopy of each tree (Silva et al., 2017), and expressed as the total fruit drop per unit of canopy surface area. Fruit yield was annually computed in 2014 and 2015 in the harvest date for each cultivar, by counting and weighing all the fruit picked from each measured tree. Individual fruit mass, diameter and length were measured with a digital scale (AD 1000, Marte, Santa Rita do Sapucaí, MG, Brazil) and a caliper (C11, Elbo, Castel Maggiore,Bologna, Italy) in samples of 200 fruits randomly collected from each treatment. The ratio between individual fruit length and diameter (L:D ratio) was utilized for defining fruit shape. According to the individual weight, the fruit was classified into three different marketable size classes for each cultivar: < 700 g; 700 to 900 g; > 900 g for 'Quintal', and < 600 g; 600 to 900 g; > 900 g for 'Margarida' (Ceagesp, 2015).

The experiment was set up on a randomized complete block design, with four treatments and four replicates of two plants per plot, totalizing 32 measured trees per cultivar. Data were subjected to analyses of variance using the SAS statistical software, version 9.0 (SAS Institute Inc., Cary, NC, USA). Treatments were compared by the Tukey's test. All statistical analyses were performed at 5% probability. Data that did not meet the assumptions of the analysis of variance were either transformed by the Box-Cox method, or subjected to nonparametric tests (Friedman's test).

Results and Discussion

In the 2014-2015 period, fruit yield responses to the applied treatments varied largely between cultivars (Table 1). The treatments did not affect cumulative fruit number and yield per tree of the 'Quintal' cultivar, while spraying 'Margarida' avocado trees with potassium phosphite significantly increased the cumulative fruit yield in the analyzed biennium (Table 1). Similar positive yield responses to foliar applications of potassium phosphite are well documented in several plant species and were previously reported in California in 'Nules Clementine' mandarin and 'Hass' avocado trees (Lovatt, 2013). Although some authors propose a nutritional effect of potassium phosphite, it has been found to be a poor source of nutritional phosphorus, as its conversion into orthophosphate by soil microorganisms is too slow to be agriculturally sustainable (Mohan et al., 2017).

Table 1. Fruit yield of rainfed 'Quintal' and 'Margarida' avocado trees in the 2014-2015 biennium, in response to sprayings with 2,4-dichlorophenoxy-acetic acid (2,4-D), aminoethoxyvinyl glycine hydrochloride (AVG) and potassium phosphite (PP) for reducing pre-harvest fruit abscission[(1)].

	Fruits per tree					
	'Quintal'			'Margarida'		
Treatment	2014	2015 *	Cumulative**	2014 **	2015 *	Cumulative
Water (control)	303 a	387 a	690 a	263 b	715 a	978 a
2,4-D (25 mg L^{-1})	353 a	464 a	817 a	392 ab	508 a	900 a
AVG (45 mg L^{-1})	364 a	259 a	623 a	453 ab	561 a	944 a
PP (4 mL L^{-1})	374 a	349 a	718 a	606 a	522 a	1128 a
CV (%)	29.43	22.79	4.69	7.25	16.21	26.44
P-value	0.5289	0.0747	0.3257	0.0058	0.3181	0.3980
	Fruit yield (kg $tree^{-1}$)					
	'Quintal'			'Margarida'		
Treatment	2014 **	2015	Cumulative	2014 **	2015 *	Cumulative
Water (control)	319.05 a	345.44 a	664.49 a	199.66 b	560.01 a	759.68 b
2,4-D (25 mg L^{-1})	362.91 a	351.63 a	714.54 a	324.69 ab	422.43 a	747.12 b
AVG (45 mg L^{-1})	312.13 a	201.50 a	513.63 a	306.04 ab	441.82 a	741.98 b
PP (4 mL L^{-1})	353.14 a	316.25 a	669.39 a	502.56 a	441.55 a	944.11 a
CV (%)	4.56	51.34	50.92	7.50	22.70	19.56
P-value	0.7099	0.1275***	0.1057	0.0028	0.4133	0.0468

[(1)]Means followed by equal letters do not differ by Tukey's test, at 5% probability. Original data were transformed to follow a normal distribution: (*) $\hat{y} = y^{0.5}$ and (**) $\hat{y} = \log_{10} y$. (***) P-value by Friedman's test.

'Quintal' avocado trees consistently showed higher pre-harvest fruit drop rates as compared to the 'Margarida' cultivar along the 2014-2015 biennium (Table 2), a well-known characteristic of the former cultivar in Brazil that reduces its productive potential. The applied treatments did not modify the mean monthly fruit drop rate for the 2014-2015 biennium, in any of the evaluated cultivars. Nonetheless, in 2015, spraying 'Quintal avocado trees with 45 mg L^{-1} AVG significantly reduced the pre-harvest fruit drop rates in this cultivar (Table 1), coinciding with the results reported by Salazar-García et al. (2007) in non-irrigated 'Hass' avocados in Nayarit, Mexico. This

effect is attributed to an enzymatic inhibition of ethylene biosynthesis modulated by AVG, which competitively inhibits the pyridoxyl phosphate-dependent enzyme ACC Synthase, a key enzyme in the ethylene biosynthesis pathway, thus reducing fruit abscission and maturation events initiated by this plant hormone (Petri et al., 2011). Contrastingly, fruit yield of mature 'Margarida' avocado trees was not influenced by any of the applied treatments in the 2014-2015 period (Table 1).

Differences on tree responses to the applied treatments may be also a result of the large variations in the environmental conditions recorded in the experimental sites during the studied biennium (Figure 1). In November 2013, shortly after the first treatment application, the occurrence of a period with high air temperatures and severe drought conditions at the experimental site (Figure 1A) induced a negative water balance (Figure 1B), and no effect of AVG on fruit drop was observed (Table 2). Nevertheless, in November 2014, during the second treatment application and under high rainfall and moderate air temperature conditions (Figure 1A), the AVG application significantly reduced fruit abscission of 'Quintal' avocado trees (Table 2).

Table 2. Fruit drop rate in non-irrigated 'Quintal' and 'Margarida' avocados in the 2014-2015 biennium, in response to sprayings with 2,4-dichlorophenoxy-acetic acid (2,4-D), aminoethoxyvinyl glycine hydrochloride (AVG) and potassium phosphite (PP) for reducing pre-harvest fruit abscission[(1)].

Cultivar	Treatment	Fruit drop per unit crown projection area (fruits m^{-2})		
		2014	2015	Mean 2014-2015
'Quintal'	Water (control)	5.08 a	8.54 a	6.04 a
	2.4-D (25 mg L^{-1})	5.22 a	8.38 ab	6.10 a
	AVG (45 mg L^{-1})	5.32 a	3.88 b	4.92 a
	PP (4 mL L^{-1})	5.53 a	8.50 a	6.35 a
	CV (%)	54.02	39.39	21.91
	P-value	0.4030	0.0121*	0.4257
'Margarida'	Water (control)	0.67 a	1.90 a	1.18 a
	2.4-D (25 mg L^{-1})	1.04 a	1.69 a	1.31 a
	AVG (45 mg L^{-1})	0.97 a	1.35 a	1.13 a
	PP (4 mL L^{-1})	1.01 a	1.47 a	1.20 a
	CV (%)	53.83	48.21	24.80
	P-value	0.3985	0.5149*	0.5134

[(1)]Means followed by equal letters do not differ by Tukey's test at 5% probability. Original data were transformed to follow a normal distribution ($\hat{y} = y^{0.01}$).*P-value by Friedman's test.

Contrasting effects of the applied treatments on fruit size and shape were observed in both avocado cultivars (Table 3). While a single 2,4-D pre-harvest spraying increased mean individual fruit mass and length in the 'Margarida' cultivar, both the 2,4-D and AVG treatments significantly reduced mean fruit length, diameter and L:D ratio of 'Quintal' avocados in the studied period (Table 3). These undesirable effects on 'Quintal' avocado fruit shape depreciate fruit appearance and hampers its acceptance by the final consumers. Furthermore, in 'Quintal' avocados, the AVG and 2,4-D treatments significantly increased the percentage of small-fruit size class (<700 g) and reduced the percentage of large-size fruit class in 2014. Contrastingly, the treatments did not affect fruit shape, as represented by the L:D ratio, of 'Margarida' avocados (Table 3). These effects on fruit shape contrast with those reported by Salazar-Garcia et al. (2007) in rainfed 'Hass' avocado trees in Nayarit, Mexico, where single applications of 45 mg L^{-1} AVG or 20 mg L^{-1} 2,4-D increased the percentage of large-fruit size class.

Fruit size reduction in response to pre-harvest AVG sprayings, as observed in 'Quintal' avocados, has been previously reported in deciduous species, such as apples (Petri et al., 2011) and peaches (Amarante et al., 2005), but not yet in avocados. Since AVG is also able to inhibit other enzymes that utilize pyridoxal phosphate as co-factor (Taiz & Zeiger, 2013), its effects might impair other plant metabolic processes related to fruit growth, thus affecting final fruit shape (Amarante et al., 2005).

The results obtained in this study confirm that fruit abscission is a complex process regulated by tree genetics, resource availability and the environmental conditions (Haberman & Smith, 2019; Sawicki et al., 2015).

Table 3. Least-square means for fruit length (L), diameter (D), length: diameter (L:D) ratio and yield percentage per commercial fruit size class in the 2014-2015 period for rainfed 'Quintal' and 'Margarida' avocado trees, in response to different foliar sprayings for reducing pre-harvest fruit abscission[(1)].

		Fruit length (L)	Fruit diameter (D)	L:D ratio	Fruit size class (%)		
Cultivar	Treatment	---------- mm ----------			< 700g	700 – 900g	> 900g
'Quintal'	Water	223.52 a	105.25 a	2.11 a	15.00 b	52.50	32.50 a
	2.4-D	213.50 b	101.97 b	2.09 a	29.00 b	56.00	15.00 b
	AVG	193.60 c	97.58 c	2.02 b	46.00 a	43.50	10.50 b
	PF	223.13 a	105.37 a	2.11 a	16.50 b	54.50	29.00 a
	CV (%)	8.18	4.51	6.15	24.80	16.57	23.09
	P-value	<0.0001*	<0.0001	<0.0001*	0.0003	0.2327	0.0169*
		L	D	L:D ratio	Fruit size class (%)		
	Treatment	---------- mm ----------			< 600g	600 – 1000g	> 1000g
'Margarida'	Water	119.73 b	105.94 b	1.13	7.30	92.70	0.00
	2.4-D	122.97 a	107.93 a	1.14	1.00	99.00	0.00
	AVG	119.55 b	105.50 b	1.13	9.40	89.60	1.00
	PF	120.11 ab	105.68 b	1.14	3.10	94.80	2.10
	CV (%)	4.64	3.29	4.67	33.89	15.10	16.65
	P-value	0.0094	0.0005	0.8081	0.2497	0.2071	0.2867*

[(1)]Means followed by equal letters do not differ by Tukey's test at 5% probability. (*) P-value by Friedman's test

Conclusions

In rainfed 'Quintal' avocado cultivar, the chemical control of pre-harvest fruit abscission by a single AVG is possible only under non-stressful environmental conditions, but it causes fruit deformation and size reduction.

Potassium phosphite sprayings were not effective for reducing pre-harvest fruit drop in rainfed avocados, but increased cumulative fruit number per tree in the 'Margarida' cultivar.

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References

Amarante, C.V.T., Drehmer, A.M.F., Souza, F., Francescatto, P.A. 2005. Pulverização pré-colheita com ácido geberélico (GA_3) e aminoetoxivinilglicina (AVG) retarda a maturação e reduz as perdas de frutos na cultura do pessegueiro. *Revista Brasileira de Fruticultura* 27:1-5.

Brogio, B.A., Silva, S.R., Cantuarias-Avilés, T., Angolini, S.F., Baptista, E.G., Ribeiro, R.V. 2018. Influence of gibberellin inhibitors applied during flowering of non-irrigated 'Hass' avocado trees. *Pesquisa Agropecuária Brasileira* 54:918-923.

CEAGESP. Centro de Qualidade em Horticultura. São Paulo, SP, Brasil. Abacate: Normas de Classificação. 2015. http://www.ceagesp.gov.br/wp-content/uploads/2015/07/abacate.pdf <Acessed in 20 Mar.2017>.

Duarte, J.L.P., Pires, M.C., Peixoto, J.R., Yamanishi, O.K. 2018. Evaluation of the application of ethylene inhibitors to prevent preharvest fall in 'Hass' avocado plants. *Acta Horticulturae* 1206:35-42.

Haberman, A., Smith, H.M. 2019. Positioning for better management of avocado fruit drop. Talking Avocados 30(2 y):3. http://hdl.handle.net/102.100.100/195688?index=1<Accessed in 10 Mar. 2020>.

Hardy, G.E.S.J., Barret, S., Shearer, B.L. 2001. The future of phosphite as a fungicide to control the soilborne plant pathogen *Phytophthora cinnamomi* in natural ecosystems. *Australasian Plant Pathology* 30:133–139.

INMET, Instituto Nacional de Meteorologia. 2016. =estacoes/estacoesAutomaticas <Accessed in 1 Mar. 2016>.

Kozlowski, T.T., Pallardy, S.G. 1997. Cultural Practices and Vegetative Growth. p. 352-393. In Kozlowski, T.T., Pallardy, S.G. (eds.) *Growth Control in Woody Plants*. Academic Press, London, UK.

Lovatt, C.J. 2013. Properly timing foliar-applied fertilizers increases efficacy: A review and update on timing foliae nutrient applications to citrus and avocado. *HortTechnology* 23:535-54.

Mohan, V., Achary, M., Ram, B., Manna, M., Datta, D., Bhatt, A., Reddy, M.K., Agrawal, P.K. 2017. Phosphite: a novel P fertilizer for weed management and pathogen control. *Plant Biotechnology Journal* 15:1493–1508.

Peng, G., Wu, J., Lu, W., Li, J. 2013. A polygalacturonase gene clustered into clade E involved in lychee fruitlet abscission. *Scientia Horticulturae* 150:244-250.

Petri, J.L., Hawerroth, F.J., Leite, G.B., Couto. M. 2011. Concentração e época de aplicação de aminoetoxivinilglicine (AVG) na maturação de macieiras 'Fuji' suprema. *Revista Brasileira de Fruticultura* 33:335-344.

Rolim, G.S., Sentelhas, P.C., Barbieri, V. 1998. Planilhas no ambiente Excel™ para os cálculos de balanços hídricos: normal, seqüencial, de cultura e de produtividade real e potencial. *Revista Brasileira de Agrometeorologia* 6:133-137.

Rossouw, T., Robertse, P.J., Kremer-Köhne, S., Köhne, J.S. 2000. Effect of gibberellic acid treatments on flowering of avocado. *South African Avocado Growers' Association Yearbook* 23:43-45.

Salazar-García, S., Cossio-Vargas, L.E., González-Durán, I.J.L. 2007. Uso de biorreguladores vegetales para mejorar la productividad del aguacate 'Hass' en Nayarit. INIFAP, CIRPAC, Campo Experimental Santiago Ixcuintla. *Folleto Científico* 1:35.

Santos, H.G., Jacomine, P.K.T., Anjos, L.H.C., Oliveira, V.A., Lumbreras, J.F., Coelho, M.R., Almeida, J.A., Cunha, T.J.F., Oliveira, J.B. 2013. *Sistema brasileiro de classificação de solos.* Embrapa, Brasília, Brazil. 353p.

Sawicki, M., Aït Barka, E., Clément, C., Vaillant-Gaveau, N., Jacquard, C. 2015. Cross-talk between environmental stresses and plant metabolism during reproductive organ abscission. *Journal of Experimental Botany 66:707-1719.*

Silva, S.R. da., Cantuarias-Avilés, T., Bremer Neto, H., Mourão Filho, F.A.A., Medina, R.B. 2016. Management of root rot in avocado trees. *Revista Brasileira de Fruticultura* 38:1-5.

Silva, S.R. da., Cantuarias-Avilés, T., Chiavelli, B., Martins, M.A., Oliveira, M.S. 2017. Phenological models for implementing management practices in rain-fed avocado orchards, *Pesquisa Agropecuária Tropical* 47:321-327.

Taiz, L., Zeiger, E. 2013. Fisiologia Vegetal. Artmed, Porto Alegre, Brazil.

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