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Lambda-cyhalothrin efficiency on fruit borer control and quali-quantitative spraying aspects in a pinecone crop

Eficiência de lambda-cialotrina no controle da broca-do-fruto e aspectos quali-quantitativos da pulverização na cultura da pinha

Jacqueline Lavinscky Costa Morais[1], Maria Aparecida Castellani[2*], Carlos Gilberto Raetano[3],
Juliana Alves de Macêdo[1], Moisés Silva Nery[4], Gabriela Luz Pereira Moreira[5]

[1]Universidade Estadual do Sudoeste da Bahia/UESB, Vitória da Conquista, BA, Brasil
[2]Universidade Estadual do Sudoeste da Bahia/UESB, Departamento de Fitotecnia e Zootecnia, Vitória da Conquista, BA, Brasil
[3]Universidade Estadual Paulista "Julio de Mesquita Filho"/UNESP, Departamento de Proteção Vegetal, Botucatu, SP, Brasil
[4]Universidade Estadual do Sudoeste da Bahia/UESB, Departamento de Tecnologia Rural e Animal/DTRA, Itapetinga, BA, Brasil
[5]Universidade Estadual do Sudoeste da Bahia/UESB, Laboratório de Melhoramento e Produção Vegetal, Vitória da Conquista, BA, Brasil
*Corresponding author: castellani@uesb.edu.br
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ABSTRACT

In Brazil, the state of Bahia is one of the largest pinecone (*Annona squamosa* L.) growers; nevertheless, fruit borer (*Cerconota anonella* L.) presence limits production. This research aimed to test the efficiency of lambda-cyhalothrin in controlling fruit borer using different spray volumes; additionally, this research tested qualitative and quantitative operational aspects. Trials were carried out in pinecone orchards in Caraíbas-BA, Brazil. Pesticide efficiency was tested by a randomized block experiment with six treatments and five replications. Treatments consisted of lambda-cyhalothrin application (1.5 g a.i. 100 L^{-1} water) with a surfactant (0.03% v v^{-1}) at spray volumes of 100, 200, 268, 382 and 488 L ha^{-1} and one control (without spray). Pest infestation was assessed by counting symptomatic fruits for further percentage calculation. Five treatments with five replications were developed to evaluate spraying performance. These treatments consisted of an aqueous solution with a Brilliant Blue tracer at 0.15% (p v^{-1}) and a surfactant at 0.03% (v v^{-1}), using the same spray volumes as the first experiment. Qualitative assessments were performed on water-sensitive paper cards and were quantified through tracer deposit levels on leaves. Spray volumes between 100 and 382 L ha^{-1} with lambda-cyhalothrin were efficient to control *Cerconota anonella* in the pinecone crop, providing good quality application.

Index terms: *Annona squamosa*; *Cerconota anonella*; tracer; spray application technology.

RESUMO

O Estado da Bahia é o maior produtor nacional de pinha (*Annona squamosa* L.), porém a ocorrência da broca-do-fruto, *Cerconota anonella* L., limita e compromete a produção. O trabalho teve por objetivos avaliar a eficiência do inseticida lambda-cialotrina no controle da broca-do-fruto com diferentes volumes de calda, bem como aspectos qualitativos e quantitativos da pulverização. Os estudos foram conduzidos em pomar comercial de pinha localizado em Caraíbas, BA. A eficiência do inseticida foi avaliada em experimento conduzido em blocos ao acaso com seis tratamentos e cinco repetições. Os tratamentos consistiram na pulverização do inseticida lambda-cialotrina (1,5 g de i.a.100 L^{-1} de água), com adição de espalhante adesivo a 0,03% v v^{-1} nos volumes de calda de 100, 200, 268, 382 e 488 L ha^{-1} e testemunha (sem pulverização). A infestação da praga foi avaliada por meio da contagem do número de frutos com sintomas de ataque para posterior cálculo da porcentagem de frutos brocados. Na avaliação da pulverização, o experimento constou de cinco tratamentos e cinco repetições. Os tratamentos consistiram de solução aquosa contendo o marcador Azul Brilhante a 0,15% (p v^{-1}) e espalhante adesivo a 0,03% (v v^{-1}) nos mesmos volumes de calda utilizados no primeiro experimento. As avaliações qualitativas foram em papel hidrossensível e a quantitativa pelos níveis dos depósitos do marcador nas folhas. O inseticida lambda-cialotrina, aplicado em volumes entre 100 e 382 L ha^{-1}, é eficiente para controle de *Cerconota anonella* em pinha, proporcionando boa qualidade das pulverizações.

Termos para indexação: *Annona squamosa*; *Cerconota anonella*; marcador: tecnologia de aplicação.

INTRODUCTION

Annona plants represent an important branch in the Brazilian fruit-growing sector by generating income and providing employment. The species *Annona squamosa* L. (pinecone, sweetsop or custard apple) and *Annona muricata* L. (graviola) stand out in Brazil due to commercial quotation being widely grown in Northeastern and Southwestern regions (Dias et al., 2003). Bahia state is the largest grower; however, phytosanitary problems, such as the fruit borer (*Cerconota anonella* L.) (Sepp. 1830) (Lepidoptera: Oecophroridae) may significantly impair production (Pereira et al., 2009).

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Pest incidence forces the adoption of control measures, such as fruit bagging (Pereira et al., 2009) and chemical control, during the fruiting period. Despite being the primarily used methods, there are no legally approved chemicals for pinecone according to the Brazilian Ministry of Agriculture, Livestock and Supply (MAPA). This is worrisome because illegal chemical use may affect the environment and also customers.

The Normative Ruling n° 01 on February 23, 2010 (Agência Nacional de Vigilância Sanitária - ANVISA, 2015) allows the use of chemicals, active ingredients and related matters that are registered for some crops on other crops with insufficient technical support; additionally, the ruling also regulates the upper limit of allowed residue, such as in the pinecone crop. For such use, target pest control must be tested using a minimum dose under an improved product distribution so that increased efficacy is reached without adverse effects to the environment (Alvarenga and Cunha, 2010).

Most often, the nature of the chemicals is of more importance than the technical application procedure. However, knowing the product that is to be applied is not enough to guarantee control success; the application techniques make it reach the target efficiently, thus minimizing losses, as recommended by application technology studies. Therefore, an adequate amount of active ingredient must be placed at the desired target, with maximum efficiency and in an economic manner, without affecting the environment (Cunha et al., 2003). The search for more efficient pest control and cost reduction in this operation through spraying promotes qualitative (Juliatti, Nascimento and Rezende, 2010) and quantitative (Balan, Saab and Silva, 2006) aspect studies to assist in the choice for an adequate operational system that enables a rational use of agrochemicals. Large spraying volumes are often used and are responsible for product losses and environmental contamination (Miranda et al., 2012). Thus, studies that aim to reduce those volumes would consequently reduce the operational costs and the required water amount, which is of great importance mainly in semiarid regions where water is a limiting factor.

This research aimed to assess the effect of lambda-cyhalothrin on fruit borer control and the qualitative and quantitative aspects of application under different spray volumes by using a Brilliant Blue tracer in the pinecone crop of a semiarid region in Bahia state, northeastern Brazil.

MATERIAL AND METHODS

Experimental location and period

Experiments were carried out at Umbuzeiro Farm, which is located at the geographical coordinates of 14°46' S and 41°16' W, at 440 m altitude, in the city of Caraíbas, southwestern Bahia state, Brazil. Trials were performed from December 2011 to April 2012. The local climate is classified as semiarid with typical vegetation. The average annual temperature is 23 °C and the mean rainfall is 690 mm per year with a rainy season from November to January. A pinecone orchard was selected that has been grown for four years with a spacing of 6.0 m between lines and 2.0 m between plants, within an area of 1.25 ha.

Experimental design and pesticide efficiency trial

A randomized block design was performed with six treatments and five replications, totalling 30 plots. Each plot consisted of seven plants; three central plants were considered to be useful for sampling and the other plants were used as a border strip. Blocks were 12 m apart from each other with one plant row used as the border. Treatments consisted of a lambda-cyhalothrin application (Karate Zeon® 50 CS) at a dose of 1.5 g a.i.100 L^{-1} water with the addition of Adesil® surfactant at 0.03% v v^{-1}. The hollow cone nozzles used were JA1, JA2, JA3, JA4 and JA5 (Jacto series) applying 100 L ha^{-1}, 200 L ha^{-1}, 268 L ha^{-1}, 382 L ha^{-1} and 488 L ha^{-1}, respectively; in addition, a control (without application) was included.

Initially, fruits from all sides within the middle third of the three central plants were randomly marked at each plot, totaling an average of 150 fruits per treatment. They were identified and observed throughout the experiment. Sprays were performed using a 4 x 2 FWD agricultural tractor model BF 65 (65 hp) equipped with an Arbus 400 air-blast sprayer, with a 1500 L tank capacity. For a 540 rpm FWD on the tractor, the engine rotation speed was fixed at 1700 rpm. Operational conditions were first gear at a speed at 6.1 km h^{-1} and a pressure of 1,000 kPa. Four fortnightly sprays were performed; the first was performed on February 9 and the last was performed on March 22, 2012. Sprays were made from 7 to 8 am on both sides of the plant.

Pest infestation was checked by counting the number of infested fruits among those previously marked throughout six evaluations before each spray (first five evaluations) and before the last evaluation 15 days after the fourth application, which coincided with the pre-harvest period. Evaluations were carried with the aid of a 10x magnifying lens, recording borer attack evidence on the fruit for further calculation of the attack percentage. Infested fruits were immediately removed from the plant and then crushed to prevent reinfestation, similar to local grower methods. Such procedures were performed up to the fruit harvest.

Experimental design and spraying quali-quantitative trial

A randomized block design with five treatments and five replications, totalling 25 plots, was performed. Each plot had seven plants; three central plants were considered to be useful for sampling. Treatments consisted of a tracer solution application with a Brilliant Blue tracer FD&C nº 1 at 0.15% (p v^{-1}) with an Adesil® surfactant at 0.03% (v v^{-1}), using the same volumes and nozzles as described in the previous trial.

The spray was performed on February 7, 2012. Time, temperature, relative humidity and wind speed data were registered during an operation that was performed from 08:45 to 10:32 am.

Water-sensitive 26 x 76 mm paper cards were used for qualitative evaluation. Two branches located in the middle third of the treated plants were chosen for the placement of two water-sensitive paper cards. One card was placed at the branch tip (BTC) and another was placed in the center (BCC), totalling 12 cards per plot. After spraying, cards were carefully removed and placed into appropriately identified paper bags, which were kept in a thermally isolated recipient (polystyrene) and taken to the Laboratory of Entomology of the Animal and Plant Science Department in the Universidade Estadual do Sudoeste da Bahia – UESB (State University of Southwestern Bahia), Campus in Vitória da Conquista - BA, Brazil. These cards were then scanned at 600 dpi and then a droplet spectrum analysis was carried out using Gotas 1.0 software (Chaim, Camargo and Pessoa, 2006). This procedure determined the following variables: droplet number and diameter (µm), droplet uniformity, spray volume (L ha^{-1}), droplet density, volume median diameter (VMD), numerical median diameter (NMD) and spray coverage (%).

The quantitative spray evaluation was made together with water-sensitive paper card removal. Specifically, leaves within the middle third of the plants were sampled from the branch center (BCL) and branch tip (BTL) with the aid of surgical gloves and tweezers. Then, samples were set individually into plastic bags that were kept in a thermally isolated recipient under refrigeration (8 ± 3 °C) in the Laboratory of Entomology of the UESB.

In the laboratory, abaxial and adaxial leaf surfaces were simultaneously washed with 20 mL of distilled water and the washing solution was collected and deposited into properly identified plastic pots. Sample reading was accomplished with a Femto brand spectrophotometer to measure the absorbance at 630 nm. Leaf area was gauged by a LI-3.100 leaf area meter (LI-COR, Lincoln, NE, USA). The deposited solution was determined by the Brilliant Blue strain concentrations (mg L^{-1}) at different dilutions. From these data, a linear standard curve was built by crossing absorbance readings from the spectrophotometer with the concentrations (Figure 1). Because the spray solution concentration was equal at all applied volumes, the same equation was used for all treatments. Therefore, solution deposit values were obtained from the initial volume and leaf area of each sample.

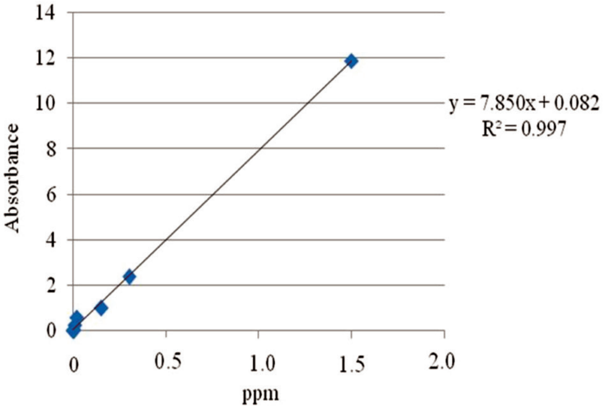

Figure 1: Reading the absorbance curve to infer the concentration of the samples.

Data analysis

Data were tested to determine the normality of their distribution and variance homogeneity, and transformation by $\sqrt{x} + 0.5$ was required for those related to infestation percentage. Each treatment control efficiency rate was calculated using the formula proposed by Abbott (1925). Data from both experiments underwent regression analysis, except for means between branch positions (BTC and BCC), which were compared by a t-test at 5%. Statistical analysis was performed using SAEG software (Statistical and Genetic Analysis Systems) version 9.1. The relationship between the volume sprayed and the volume retrieved for the respective treatments was assessed by Pearson's correlation.

RESULTS AND DISCUSSION

Lambda-cyhalothrin efficiency

Borer infestation was not found in the first evaluation, which was performed during the fruiting period; thus, statistical analysis was exempted. At this time, fruit had a mean diameter and length of 2.0 cm and 2.1 cm, respectively. Pereira et al. (2009) observed that pinecone crop protection against the pest must start when the fruit reaches 2.5 to 3.0 cm in length in the fruit enclosure. Moths prefer to lay eggs on the fruit surface and, after hatching, caterpillars move to fruit fractures (Oliveira, Souza and Silva, 2004).

In other evaluations, the relationship between spray volume and percentage of infested fruit had a quadratic effect, indicating decline of infestation rate with spray volume increase. The maximum spray amounts reached volumes of 272.43, 272.03, 276.49, 285.19 and 288.80 L ha^{-1} in the second, third, fourth, fifth and sixth evaluations, respectively; the lowest average number of infested fruit was recorded at the sixth evaluation. Thereafter, infestations increased according to the rise of spray volume per hectare, however, infestations remained under the control levels (Figure 2).

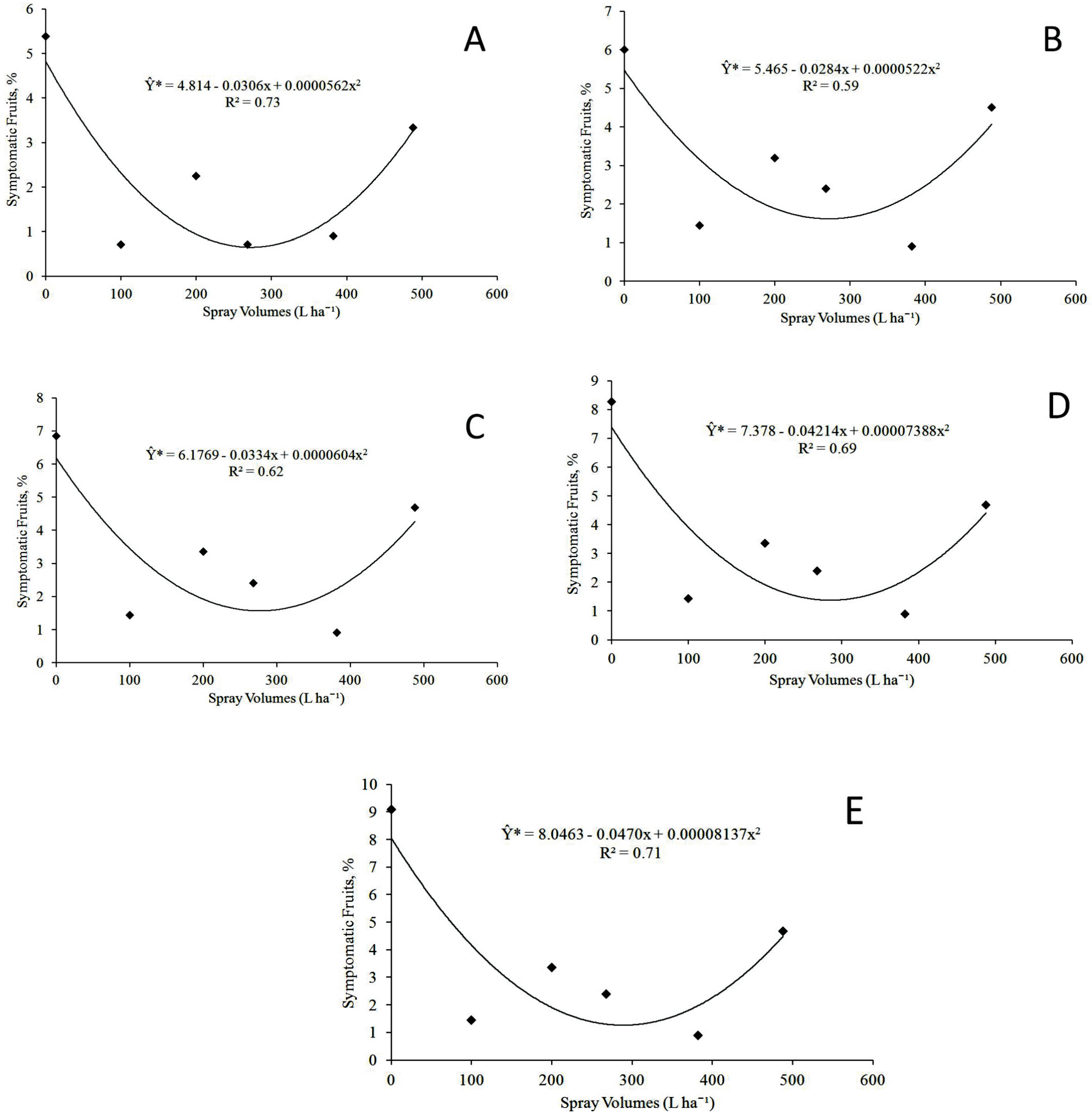

Figure 2: Estimates of pinecone fruit bored by *Cerconota anonella* based on fortnightly assessments (2nd - A, 3rd - B, 4th - C, 5th - D and 6th - E) as a function of different spray volumes.
*Significant at 5% probability by regression variance analysis.

In general, the applied insecticide promoted a pest population decrease for all spray mixture volumes, with lower infestation rates for 200, 268 and 382 L ha^{-1}. Pyrethroid insecticides kill insects on contact and through digestion; it is registered for use in many crops against Diptera larvae, aphids, coleopterans and Lepidoptera larvae (Sistema de Agrotóxicos Fitossanitários - AGROFIT, 2015). It is known that *C. anonella* females lay eggs on fruit surfaces and flowers during high infestation (Silva et al., 2006). Newly hatched caterpillars shelter within natural fruit fractures covered by silk thread; then, they scrape the peel, and after 3 to 4 days, they enter the fruit (Bittencourt, Mattos Sobrinho and Pereira, 2007). In this way, when scraping the fruit, they come in contact with the pesticide and become intoxicated by contact or ingestion. This chemical is registered to control citrus fruit borer that also grow inside fruits (AGROFIT, 2015).

Concerning efficiency, the product did not show significant results to control the borer only for the highest volume (488 L ha^{-1}) in all evaluations. This fact might have occurred because of spray spillage. Moreover, in this treatment, insect population rates decreased in a range from 44.83% to 73.89%, which is below the recommended level (80%) to classify the chemical as efficient (Table 1). In addition, it was not effective at a volume of 200 L ha^{-1} during the third and fourth evaluations. However, the other application volumes had efficiency rates superior to 80%, reaching 99.46% (382 L ha^{-1}) at preharvest. This result matches the result observed by Farias et al. (2006) in green stinkbug (*Piezodorus guildinii*) control on soybean fields. Similarly, Brustolin, Bianco and Neves (2011), testing lambda-cyhalothrin with thiamethoxam on corn crops against *Dichelops melacanthus* achieved more than 80% efficacy.

In addition to the efficiency, insecticide selectivity to natural enemies has been investigated by various authors and is an important tool in chemical selection for Integrated Pest Management (IPM) programs. Beserra and Parra (2005) observed that lambda-cyhalothrin reduced *Trichogramma pretiosum* parasitism by 27.3%. In addition, Fonseca et al. (2007) stated that the same product on cotton crops might drastically reduce many predator populations by great contact action. However, Farias et al. (2006) considered the product to be selective to predators in soybean crops.

Spray quality

Digital imaging results of the water-sensitive paper cards denoted decreases in number and density of droplets with application volumes greater than 100 L ha^{-1} and in droplet diameters from 194 L ha^{-1} (Figures 3A, B and C). Concerning target positions within plants, BTC received a greater number of drops in all treatments except for 268 L ha^{-1} (Table 2). Generally, smaller droplet diameters were not expected in greater volumes; the greater the spray volume, the larger the droplet size because the lower volume of spray promotes smaller droplet sizes that are susceptible to loss by drift and evaporation. Thus, the research data differs from published studies that have presented smaller droplets for lower spray volumes and larger sizes for greater ones (Cunha et al., 2003; Freitas et al., 2005).

It was observed that weather conditions were not favorable especially for greater volumes (Table 3) and might have benefited droplet evaporation; therefore, a reduced number of drops was found on the water-sensitive paper cards of those treatments. Freitas et al. (2005), studying the volume distribution of flat spray nozzles (TeeJet 11002) at varied operational conditions, noted that smaller drops are more susceptible to loss. However, with increasing diameter, the percentage of drops subjected to the action of temperature, air humidity and wind decreases once these factors change the droplet number on the target area (Cunha et al., 2003).

Table 1: Efficiency (%) of lambda-cyhalothrin on *Cerconota anonella* control in pinecone plants in response to different spray volumes and evaluation times.

Spray volumes (L ha^{-1})	Evaluations					
	1st	2nd	3rd	4th	5th	6th
100	-	100.00	92.05	94.52	96.28	96.88
200	-	83.99	71.83	75.52	83.40	86.08
268	-	100.00	83.98	87.59	91.58	92.94
382	-	98.50	98.78	99.05	99.36	99.46
488	-	62.12	44.83	54.08	68.86	73.89

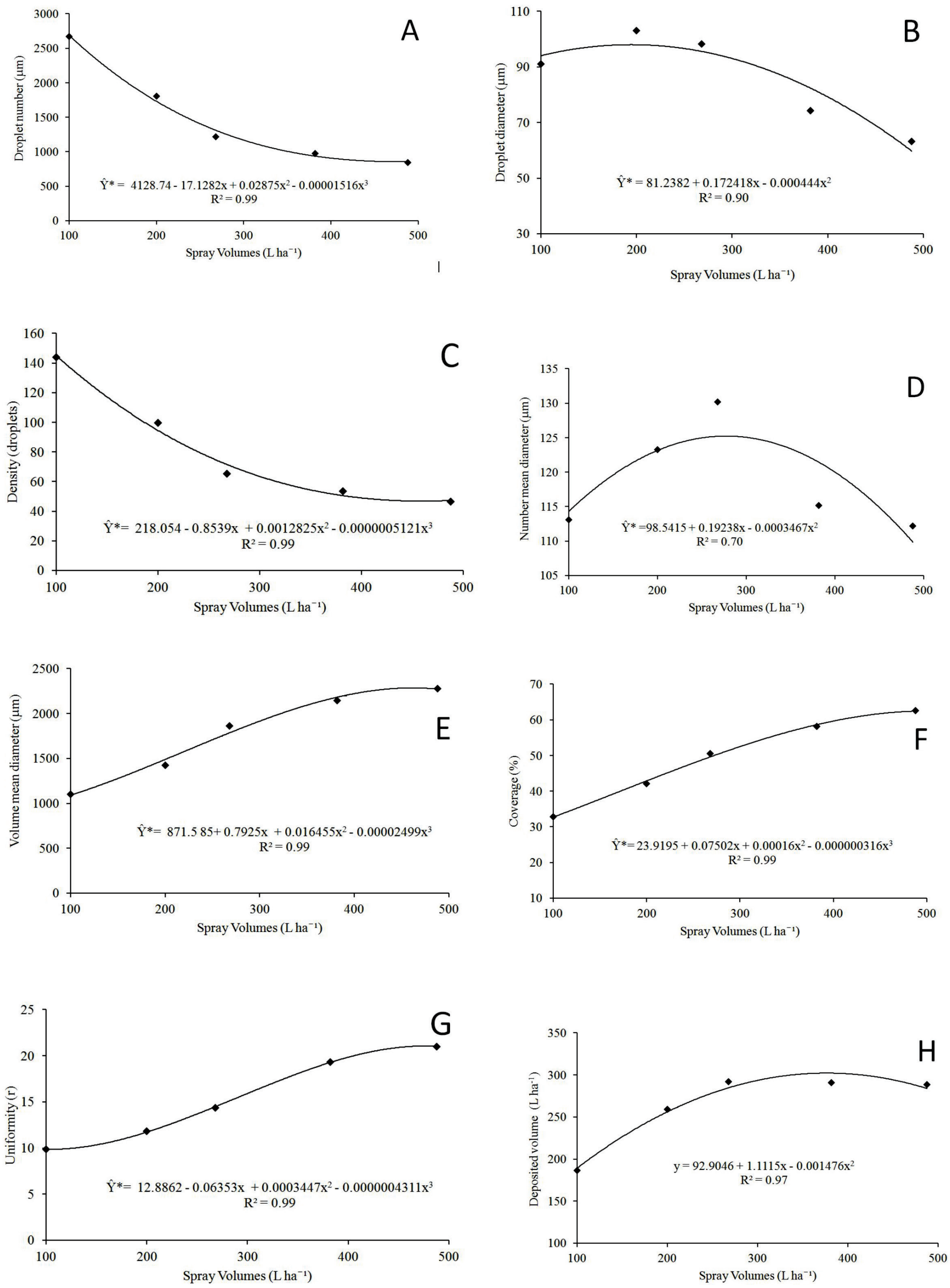

Figure 3: Droplet number (µm) (A), diameter (µm) (B), density (drops) (C), numerical median diameter (µm) (D), volumetric median diameter (µm) (E), coverage (%) (F), uniformity (r) (G) and volume (L ha^{-1}) (H) for different volumes of spray solution (L ha^{-1}).

*Significant at 5% probability by regression variance analysis.

Table 2: Droplet number, diameter, and density according to water-sensitive paper card position on the plant: branch center card (BCC) and branch tip card (BTC).

Spray volume (L ha^{-1})	Droplet number		Droplet diameter		Density (droplets)	
	BCC	BTC	BCC	BTC	BCC	BTC
100	2329.2 b	2913.2 a	87.5 b	95 a	138.2 a	150.4 a
200	1505.3 b	2104.7 a	101.9 b	103.9 a	82.7 b	116.1 a
268	1281.9 a	1106.0 b	108.6 a	90.9 a	68.7 a	58.9 b
382	864.1 b	1175.2 a	71.0 a	81.1 a	45.4 b	64.1 a
488	760.2 b	983.2 a	54.4 a	72.1 a	54.0 a	45.5 b
V. C. (%)	18.12	29.54	27.93	18.47	32.80	33.23

Means followed by same lower case letter in the line do not differ from each other by a t-test with 5% probability.

Table 3: Weather conditions at spraying time using a Brilliant Blue marker on February 2, 2012.

Treatment (L ha^{-1})	Hour	Temperature (°C)	RH (%)	Wind speed (km h^{-1})
100	8:45	38.0	45	0.3
200	8:57	31.8	44	0.3
268	9:09	33.5	44	0.3
382	10:20	37.8	42	0.3
488	10:32	38.5	40	0.3

In relation to the density, the results partly support those presented by Scudeler, Raetano and Araújo (2004), who studied ethephon spray in coffee trees. These authors obtained droplet mean densities from 30 to 60 drops per cm^2 at the upper plant part and from 217.5 to 229.9 at the bottom one, using Arbus 400 equipment and JA2 nozzles (corresponding to 200 L ha^{-1}). However, the coffee tree architecture is different from the pinecone. The greater amount of smaller droplets observed on the upper plant and larger droplets at the bottom is associated with the deposition model of droplets onto the target and their size. Smaller droplets are deposited by impact at the top and larger ones by sedimentation at the bottom. In addition, droplets that were not deposited on the tops influence deposition on the bottoms. The spray sample position effect on droplet density was not clear; for two studied volumes (200 and 382 L ha^{-1}), the densities were higher in the outer part of the plant, while in the other two (268 and 488 L ha^{-1}), the reverse was observed. This effect may have been influenced by other factors, such as leaf density, plant architecture and leaf position at drop capture time.

NMD and VMD values had different behaviors in response to spray mixture volumes, presenting quadratic and cubic models, respectively. NMD values underwent increases with spray volume rises, attaining a peak at 277.44 L ha^{-1}, from which they decreased (Figure 3D). In contrast, VMD values remained constant and reached a peak point at the highest volume (488 L ha^{-1}) (Figure 3E). Regarding the parts of the plants, external areas had significantly higher VMD values at 200 and 382 L ha^{-1}. NMD values also varied by plant part; higher values were observed in external areas at 268 L ha^{-1} (Table 4). Overall, VMD and NMD values observed here were far above those found in literature. According to Cunha et al. (2003), VMD values superior to 500 µm result in spillage problems that are observed for droplets greater than 800 µm. However, in this study, an air blast sprayer was used; thus, the droplet impact area was overestimated and non-spherical droplets were generated. This fact significantly influenced VMD and NMD, which had values much higher than those set by the manufacturer (VMD ranged from 131 µm to 154 µm for hollow cone nozzles type JA1 and JA5, respectively, and at 1,000 kPa, as recommended by Jacto).

A cubic model was set for the relationship between spray coverage and spray volume, indicating a certain trend of increasing spray coverage with spray volume increases (Figure 3F). The sampling location had no effect on coverage percentage, and significant differences were only observed in a volume of 200 L ha^{-1} (Table 5). According to Santos (2015), spray overlap in perennial crops such as citrus, coffee and apple rarely reaches 20%. Current coverage values were higher than those obtained by Ramos et al. (2007) in citrus leaves using an Arbus 2000 sprayer at variable volumes from 50 to 200 L ha^{-1}. This study produced spray coverage data that are in agreement with those reported by Rodrigues et al. (2010), who also observed that lower volumes do not necessarily promote improved coverage. The sprayings were relatively heterogeneous with uniform increments as a function of the increase in the sprayed volume (Figure 3G). Nevertheless, there were no significant differences for the different parts of the plants, except at 200 L h^{-1}, which showed greater uniformity within the central portion (Table 5).

The amount of spray recovered varied among treatments, increasing with the applied volume and reaching a peak at 376.52 L ha^{-1}. At volumes higher than this peak, there was a slight decrease in recovered amounts (Figure 3H), thus resulting in a positive correlation between sprayed and recovered spray volumes (r = 0.8). A maximum amount of spray (100%) on the target was observed at 100, 200 and 268 L ha^{-1}; however, reduced amounts were observed at 382 and 488 L ha^{-1} (Table 5). Thus, higher spray losses were observed for higher sprayed volumes, which may be the result of evaporation and spillage occurrence.

Regression analysis did not reveal any significant models for deposition value changes regarding application volumes. Generally, the higher the spray amounts, the higher the deposits (Rodrigues et al., 2010); this was not confirmed in this study. The presence of the Adesil® surfactant at 0.03% (w^{-1}) may have aided in spray runoff from the adaxial leaf surface and may have consequently reduced spray deposit levels. Deposits were significantly larger in outer portions of the plant only at 268 L h^{-1}, with higher values in the middle part at 382 and 488 L ha^{-1} (Table 6).

Table 4: Volume median diameter (VMD) and number median diameter (NMD) according to water-sensitive paper card position on the plant: branch center card (BCC) and branch tip card (BTC).

Spray volume (L ha-1)	VMD (µm)		NMD (µm)	
	BCC	BTC	BCC	BTC
100	1105.0 a	1099.6 a	114.6 a	111.5 a
200	1615.8 a	1237.0 b	112.6 a	123.8 a
268	1599.7 a	1943.4 a	128.8 b	131.4 a
382	2230.1 a	2063.2 b	118.5 a	111.6 b
488	2212.5 a	2348.3 a	118.5 a	105.8 b
V.C. (%)	16.37	34.39	8.13	6.04

Means followed by same lower case letter in the line do not differ from each other by a t-test with 5% probability.

Table 5: Spray coverage and uniformity of spray deposit volume according to water-sensitive paper card position on the plant: branch center card (BCC) and branch tip card (BTC).

Spray volume (L ha^{-1})	Coverage (%)		Uniformity (r)		Deposited volume (L ha^{-1})	
	BCC	BTC	BCC	BTC	BCC	BTC
100	32.1 a	36.2 a	9.8 a	9.7 a	192.0 a	180.6 b
200	44.7 a	39.2 b	13.2 a	10.3 b	285.8 a	231.8 b
268	48.3 a	53.0 a	13.9 a	14.6 a	294.1 a	271.6 a
382	52.6 a	56.6 a	19.1 a	19.3 a	291.8 a	289.4 a
488	59.8 a	65.9 a	19.1 a	22.7 a	275.0 b	301.6 a
V.C. (%)	21.32	27.27	27.93	35.69	20.40	25.88

Means followed by same lower case letter in the line do not differ from each other by a t-test with 5% probability.

Table 6: Spray deposit (μL cm-²) according to the different spray volumes and leaf positions within the branch. Branch center leaves (BCL) and branch tip leaves (BTL).

Spray volumes (L ha^{-1})	Spray deposit (μL cm^{-2})	
	BCL	BTL
100	5.50 a	5.10 a
200	6.95 a	4.14 a
268	3.85 b	5.02 a
382	5.18 a	3.94 b
488	4.48 a	3.16 b
V.C. (%)	21.43	20.68

Means followed by same lower case letter in the line do not differ from each other by a t-test with 5% probability.

Therefore, the current research results showed that smaller amounts of spray solutions (up to 382 L ha^{-1}) promote a greater density of droplets and consequently result in larger coverage. Droplets deposited per unit of area onto the surface of the fruit have crucial importance in spray effectiveness. Smaller volumes ensure the success of reaching the target in an efficient way, minimizing losses and costs, improving sprayer operational capacity when compared to larger ones. Currently, farmers spray volumes within the range of approximately 500 to 700 L ha^{-1}; reduced amounts contribute to water savings, shorter supply times and less product losses by drift, thus lowering pest control costs and potential environmental impacts. However, it is necessary to obtain information regarding the product's selectivity under various operational conditions to make appropriate decisions concerning its use on pinecone crops.

CONCLUSION

Sprayings of lambda-cyhalothrin at a dose of 1.5 g a.i. 100 L^{-1} of water and volumes between 100 and 382 L ha^{-1} are efficient to control *Cerconota anonella* in pinecones and provide good quality applications.

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