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SPRAY DEPOSITION AND CHEMICAL CONTROL OF THE COFFEE LEAF-MINER WITH DIFFERENT SPRAY NOZZLES AND AUXILIARY BOOM

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ABSTRACT: The coffee crop requires great spray ability to penetrate into the plant canopy during the application of pesticides. The aim of this study was to evaluate the spray deposition on leaves of coffee plants and the chemical control of the leaf miner provided by the application of different spray nozzles, with and without the use of an auxiliary boom. The deposition on the upper, middle and lower parts of the plants and the losses to the soil were evaluated using a tracer quantified by spectrophotometer. We also evaluated the chemical control of the leaf miner, counting the larvae, after the application of the insecticides cartap and fenpropathrin. The trial was carried out in a randomized block design, with four replications, in a factorial model (2×2+1): with and without the auxiliary boom, three spray nozzles (hollow cone – MAG 02, flat fan – AD 11002 and air induction hollow cone – TVI 8002) and a control. The use of the auxiliary boom increased the deposition in the lower part of the plants but decreased in the middle part, besides the increase in the runoff. The different nozzles do not provided differences in the deposition, showing the technical feasibility in the use of the hollow cone nozzles with coarse droplets and flat fan. All the chemical control decreased the leaf miner population, without differentiation.

KEY WORDS: *Coffea arabica L., Leucoptera coffeella,* spray, application technology.

INTRODUCTION

One of the major problems faced by farmer is the coffee plants susceptibility to various pests and diseases, which appear from the nursery to the crop in the field, raising costs and reducing production and the final product quality (CARVALHO et al., 2012).

The leaf miner, *Leucoptera coffella* (Guérin-Mèneville), is the main pest of the crop in Brazil, since it is favored by hot and dry seasons and by the management type applied in the coffee production. The appearance of necrotic spots on the leaves is a characteristic of the attack symptom, caused by the cell parenchyma destruction by the young insect, which inhabits the mesophyll, causing leaf fall (NAKANO et al., 2002).

In technified and high yield potential crops, the chemical control is the most used method to contain pests infestations and disease incidence, in the absence of more effective alternatives. The farmer is increasingly required of the proper and judicious use of pesticides; however, what you see in the field, mainly in coffee production, is the lack of information about application technology. The applications often are neither efficient nor effective because the best technique or equipment was not used (CUNHA et al., 2011; STEFANELO et al., 2014).

The correct disposal and distribution of the active ingredient in the aerial part of the plant depends on several factors such as: plant size and shape, planting density, droplet size produced by the spray nozzle, spray volume, spray displacement speed, wind speed, the equipment type used and fan air flow. However, in the coffee production, the plants leaf is a very relevant factor. The plantations in a coffee production area showed variations in canopy volume, requiring specific measures to suit the need and distribution of spray to the plant's need and size.

In this context, this crop shows great challenges for the technology application of the crop protection products. The plants have plant development, interspersing periods with great closing and leaf area, making the applications to control pests and plant pathogens to need great penetration

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capacity in the leaves mass for a good coverage, even in the application of products with systemic action characteristics, and defoliated periods, where there is easiness in the plants covering, but with higher risk of runoff.

CUNHA et al. (2011) studying ways to improve this penetration with sprayers already in use, without the need of large financial investments, in well-leafed crops, observed that the use of a device with an auxiliary boom with spray nozzles facing up attached to a conventional hydropneumatic sprayer, named “Gitirana Wing", increased, on average, 92% of the spray deposition, when compared to the treatment without “Wing”. However, they verified the need of additional studies due to the difficulty of regulation of it for different conditions of each crop.

In this idea, the correct selection of spray nozzles can increase the application quality because they can provide characteristics like droplet size and flow, promoting greater safety and effectiveness in the control of insects, pathogens or weeds (VIANA et al., 2010; CONSTANTIN et al., 2012). In coffee production, most of the applications are done with hollow cone spray nozzles, using fine droplets and high pressure. This has brought many drifting problems. Thus, it is necessary to expand the studies about the possibility of using medium or large droplets, generated by flat spray nozzles.

Thus, the aim of this study was to evaluate the spray deposition in the coffee tree, the losses to soil and biological efficacy in the control of leaf miner, after hydropneumatic spray with different nozzles, with and without the use of an auxiliary boom.

MATERIAL AND METHODS

The experiment was carried out at the Glória Experimental Farm, in the Coffee Production Section, and at the Agricultural Mechanization Laboratory, belonging to the Federal University of Uberlândia, in Uberlândia-MG, Brazil. The geographic location is 18º58’52” South latitude and 48º12’24” West longitude, and altitude of 912 m.

We used a coffee plantation with the cultivar *Catuaí Vermelho* IAC 99, 12 years old, spaced in 3.5 x 0.70 m, in October 2013.The crop was in post-harvest phase, with high infestation of leaf miner with intense defoliated level (Figure 1).

We used a hydropneumatic sprayer (turbo atomizer), Jacto brand, Arbus 2000 model, tank with 2000 L capacity, 24 nozzles mounted on two curved arches on the sides, piston pump with a flow of 150 L min^{-1}, axial fan with diameter of 850 mm and air flow of 19 m^{3} s^{-1}, according to manufacturer's specifications with or without auxiliary boom. The spray was pulled and driven by a Massey Ferguson 265E tractor, 4 x 2 AFWD, with a power of 47.8 kW (65 hp).

FIGURE 1. Vegetative aspect of the crop.

FIGURE 2. Detail of the sprayer with the auxiliary boom.

We used three different spray nozzles: the first one was AD 11002, of flat spray, made of ceramic with an angle of 110°, the second was MAG 02, with hollow cone spray, made of ceramic with an angle of 80°, both manufactured by Magnojet Company. The third model was TVI 8002, also made of ceramic, but manufactured by Albuz Company, of hollow cone spray type with air induction. According to the manufacturers, the first two produce fine droplets and the third extremely coarse droplets, due to the air induction. The tractor working speed was maintained at 7.2 km h^{-1}, as well as the PTO rotation maintained in 540 rpm, with a tachometer. All the nozzles were tested with and without the use of auxiliary boom. The working pressures were adjusted to obtain the rate of application of 500 L ha^{-1} (Table 1).

TABLE 1. Description of the treatments.

Treatments		Nozzles number	Application rate	Pressure
Auxiliary boom	Nozzle		(L ha^{-1})	(kPa)
1 - Without	AD 11002	24	500	345 (50 lbf pol^{-2})
2 – With	AD 11002	24	500	345 (50 lbf pol^{-2})
3 - Without	MAG 02	24	500	690 (100 lbf pol^{-2})
4 – With	MAG 02	24	500	690 (100 lbf pol^{-2})
5 - Without	TVI 8002	20	500	517 (75 lbf pol^{-2})
6 – With	TVI 8002	20	500	517 (75 lbf pol^{-2})
7 - Control			---	---

The test was conducted in a randomized block design with four replications in a factorial 2 x 3 + 1: with or without auxiliary boom, three types of spray nozzles (Table 1) and a control without application. The experimental plots were consisted in four lines of coffee with 15 m of length (210 m²). As useful spot, only the two central lines with border of 3 m at each end were considered and we used 63 m².

The application treatments were carried out on 10/14/2013 after the mechanical harvesting of coffee made in July. This is a period in which it is common to carry out the pesticide treatments mainly for the control of leaf miner.

We studied the spray deposition in coffee foliage, losses to the soil and the biological efficacy in the control of leaf miner. The treatments one and three (without auxiliary boom) used nozzles arranged directly in the spray arches (Arbus 2000). The treatments two and four (with auxiliary boom) had 10 closed nozzles in the arches and other 10 nozzles added to the auxiliary boom, five spray nozzles on each side, facing up. In contrast, to maintain the same application rate, five nozzles were closed on each side of the arch, in an alternating way, beginning at the bottom. The treatment five used 20 nozzles inserted in the arch and the treatment six used only 14 in the arch, adding six other spray nozzles arranged in the auxiliary bar.

The auxiliary boom, called “Gitirana wing” designed to be attached to any hydropneumatic spray, working together with this to improve the spray deposition mainly in the lower inner part of plants. The spray system has a metal structure folded in wing-shape and an inner pipe with outlets for ten spray nozzles connection facing up, placed on each side of the spray, close to the ground under the coffee. The structure is attached through a central base with articulated body, which provides a spacing adjustment between the planting lines and working height. In the wings are inserted a distributor bar, fixed with the assistance of fixative bearing, and on it coupled the nozzles. To use the “Wing” together with the spray, we installed a splitter on the hoses that comes from the command.

For the evaluation of spray deposition, we used the Brilliant Blue tracer internationally catalogued by the Food, Drug & Cosmetics as FD&C Blue n.1, at a concentration of 600 mg L^{-1} giving a dose of 300 g ha^{-1} to all treatments to be detected by absorbance spectrophotometry. We measured the deposition in leaves of the upper, middle and lower canopy and the spray runoff to the ground. We removed the leaves from plagiotropic branches that were more internal and near to the coffee tree trunk in two lines per plot, in approximate heights of 0.2, 1.3 and 2.0 m above the ground, being placed in plastic bags inside thermal boxes. In each repetition, we collected 10 leaves. With the tracer application, cartap hydrochloride (1.0 kg b.w. ha^{-1}) and fenpropathrin (0.4 L b.w. ha^{-1}) insecticides were also applied, beside the adhesive spreader dodecylbenzenesulfonic acid (0.5 v/v). This is a usual combination of products used in the test region for the control of leaf miner after performing mechanical harvesting.

For the evaluation of spray losses into the soil, petri dishes were placed with 153.94 cm^2 each under the canopy of the coffee plants within the crown projection area, 0.2 m from the stem, two dishes by repetition.

In the laboratory, we added 100 mL of distilled water to the samples, for bags containing the leaves, and 40 mL into the petri dishes, and after the removal of the resulting washing liquid, we performed the absorbance reading of the solution containing the tracer in a spectrophotometer (Biospectro SP-22), regulated at a wavelength of 630 nm. The leaves areas were measured through the "Image Tool” (University of Texas, Texas, USA) image analysis program, after being scanned. The absorbance data were converted into concentration (mg L^{-1}) through the calibration curve, subsequently proceeding the mass division of the tracer by the leaf area of each repetition or the glass plate area to obtain the deposition amount in µg cm^{-2}.

The biological efficacy was evaluate on 11/01/2013 (18 days after the application), sampling 10 viable mines per plot, collected in the mid-upper region of the plant, where it was observed the number of live caterpillars of leaf miner. The viable mines were those that did not show symptoms of predation, parasitism or abandonment of the caterpillar, in function to the pupa stage, during metamorphosis.

During the applications, the conditions of temperature, relative humidity and wind speed were monitored. The temperature varied from 30.5 to 34.1°C, the relative humidity from 39.5% to 47.2% and the wind speed from 1.0 to 3.6 m s^{-1}. Although, those are not the ideal conditions for spraying, these are the conditions in which usually takes place the control of pests, particularly the leaf miner, in this time of year in the “Cerrado Mineiro” region, between the months of September and October. Thus, we tried to approximate the normal conditions performed by local farmers.

Initially, the data assumptions were tested. The Levene and Shapiro Wilk test were applied to verify the homogeneity of variances and the normality of residues, respectively, using the SPSS statistical software (version 17.0). All the presuppositions with significance at 0.01 that met the data were not changed. Later, the data were submitted to analysis of variance and the averages were compared with each other by the Tukey test and with additional treatment by Dunnett test at 0.05 of significance.

The efficacy of each treatment was determined by the ABBOTT (1925) formula:

$$E\% = \frac{T - I}{T} \times 100$$

where,

T - number of caterpillars in the control treatment;

I - number of caterpillars in insecticide treatments, and

E% - efficiency percentage.

RESULTS AND DISCUSSION

Analyzing the deposition on coffee leaves and losses near to the ground, resulting from the application with three spray nozzles and with or without the use of the auxiliary boom, we noted that there was no significant interaction between the factors (Table 2). For the middle and lower positions and the runoff, the use of the boom promoted significant differences. The nozzles distinguished in relation to the runoff.

TABLE 2. Summary of the data variance analysis in relation to the tracer deposition on the upper, middle and lower leaves of coffee tree and on the soil, as a result of the application with three spray nozzles, with and without the use of the auxiliary boom.

Variation source	F value calculated by position			
	Upper	Middle	Lower	Soil
Nozzle	0.929^{ns}	2.330^{ns}	0.182^{ns}	46.700**
Auxiliary boom	0.161^{ns}	23.153**	5.685*	14.038**
Nozzle x boom	0.328^{ns}	1.784^{ns}	0.179^{ns}	0.753^{ns}
CV (%)	23.75	17.60	19.31	25.84

CV: coefficient of variation. * Significant at 0.05; ** significant at 0.01; ^{ns} not significant at 0.05.

Table 3 shows the tracer deposition (μg cm^{-2}) in the upper, middle and lower parts of the coffee trees and the losses to the soil, as a result of the application with three spray nozzles. Because the interaction between nozzles and the auxiliary boom was not significant, we considered the average between treatments with and without boom. The nozzle with air induction (TVI 8002) generated greater runoff compared to the nozzles with fine droplets (AD 11002 and MAG 02). The use of lower application rate could perhaps lead to reduction of loss by runoff, as seen in this study that the rates were equal.

In this study, the drift was not evaluated, which prevents that a complete study of the mass balance is done, the similarity of SALYANI et al. (2007). However, taking into consideration that the deposition in the target was similar for the three used nozzles and the runoff was greater for the TVI nozzle, possibly the loss for drift must have been greater with the use of MAG and AD nozzles, which produces smaller droplets, since the amount of spray applied per area was the same in all treatments.

WENNEKER & ZANDE (2008) state that the droplets with air induction, due to its size, showed a more rapid vertical trim tending to accumulate in the soil. SILVA et al. (2014) observed a greater runoff with the use of nozzles with air induction (TVI) compared to ATR nozzles of the hollow cone type. In the ATR nozzles, with smaller droplets (VMD), these authors verified greater deposition on the leaves, probably due to the increase penetration and fixing on the coffee tree.

TABLE 3. Spray deposition on upper, middle and bottom coffee leaves and losses to the soil, resulting from the application with three types of spray nozzles*.

Nozzles spray	Tracer deposition (µg cm^{-2})			
	Position in the plant			
	Upper	Middle	Lower	Soil
AD 11002	0.755 a	0.810 a	0.947 a	0.211 a
MAG 02	0.671 a	0.702 a	0.905 a	0.185 a
TVI 8002	0.787 a	0.681 a	0.897 a	0.531 b
SMD	0.228	0.167	0.230	0.104

* Averages followed by the same letter in columns do not differ from each other by Tukey test, 0.05 probability of error. SMD significant minor difference. * Average between the treatments with and without auxiliary boom.

This result shows the viability of the use of cone spray nozzles with coarse droplets and flat spray nozzles. Traditionally, the farmers use hollow cone spray nozzles and high pressures, above 700 kPa, during the spraying with hydropneumatic sprayers in coffee trees, with the aim of generating fine droplets and thus higher deposition and spray penetration. However, this type of treatment has a high risk of drift. Thus, we note that is possible to use coarse droplets and flat fan spray nozzles, gaining environmental safety and longer lifespan of the equipment, due to the reduction of work pressure, while it has remained the deposition level. However, we highlight that in this study only the deposition was evaluated, without considering the coverage. For contact products, the percentage of leaf area covered by the plant can be as important as the deposition.

The auxiliary boom provided greater deposition in the lower leaves, a region also known as the bottom plant (Table 4). This result is in agreement with the observations of CUNHA et al. (2011), who also reported about the device contribution in improvements in deposition of products on the bottom of the plant without increasing the runoff to the ground. The increase in the distribution of droplets in the lower region can contribute with the higher efficiency of the plants in the control of pests initial outbreaks that inhabit this region, which are housed under the plants. This is the case of pupae and leaf miner adults, rust, drill, mites, diseases that attack the flowerings, among others (GITIRANA NETO, 2012).

In Table 4, less deposition on the leaves of the middle region of the plant, when using the auxiliary bar, is shown. This probably occurred because of an uneven distribution of spray over spraying profile. With the use of the boom, a higher number of nozzles concentrated under and the number of nozzles in the spraying arch decreased. The difference in the nozzles number may have affected the deposition in the middle region.

TABLE 4. Spray deposition on upper, middle and bottom coffee leaves and losses to the soil, resulting from the use or not of the auxiliary boom.

Auxiliary boom	Tracer deposition (µg cm^{-2})			
	Position			
	Upper	Middle	Lower	Soil
Without	0.752 a	0.857 a	0.830 b	0.248 b
With	0.723 a	0.604 b	1.002 a	0.370 a
SMD	0.152	0.112	0.154	0.069

* Averages followed by the same letter in columns do not differ from each other by Tukey test, 0.05 probability of error. SMD significant minor difference.

The use of boom increased the loss of tracer to the soil. We believe that in plants with small number of leaves, according to this plantation, may contribute to excessive deposition, increasing runoff to the ground. Possibly the benefits with the use of the device may be associated to leaf growth of the crop, canopy shape and biological target. The greater deposition on the bottom of the plants may be beneficial when the biological target is located at this location. This reinforces the need of technical monitoring during the applications for the maximum use of the device.

In Table 5, there is the average number of caterpillars found after the application with three types of spray nozzles. We observed that the caterpillars number was not influenced by the auxiliary boom use, neither by the type of the used nozzle, but by the use of insecticides (hydrochloride cartap and fenpropathrin), in comparison to the control. In the treatments where insecticides were added, the caterpillars' number was lower than that observed in the control, indicating the exerted control by the products.

TABLE 5. Average number of caterpillars found after insecticide application with three types of spray nozzles, with and without the use of auxiliary boom.

Auxiliary boom	Caterpillars number			
	Nozzles spray			Average
	AD 11002	MAG 02	TVI 8002	
	Control = 8.75			
Without	3.25+	1.00+	4.25+	2.83 a
With	2.25+	2.00+	1.50+	1.92 a
Average	2.75 A	1.50 A	2.87 A	
C.V = 48.50%		$F_{nozzle} = 1.821^{ns}$		
$SMD_{nozzle} = 2.034$		$F_{wing} = 1.985^{ns}$		
$SMD_{wing} = 1.366$		$F_{inter} = 2.773^{ns}$		
$SMD_{cont} = 3.189$		$F_{cont} = 54.865^{**}$		

Averages followed by the same lower case in columns and capital letters in line do not differ from each other by Tukey test at 5% probability of error. Averages followed by + differ from the control by the Dunnett test. ^{ns}: not significant; ** significant at 0.01. CV: coefficient of variation. SMD significant minor difference for nozzle, wing and control, respectively.

Evaluating the relative effectiveness of treatments (Table 6), we note that they showed levels ranging between 60% and 89% in the control of the leaf miner. In practice, the relation between efficacy, cost and benefit is the more recommended solution. Thus, the results showed no need to use the device, auxiliary boom, in coffee trees with little foliage.

TABLE 6. Control effectiveness of the leaf miner with three types of spray nozzles, with and without the use of the auxiliary boom.

Treatment	Control effectiveness (%)
1 – AD 11002 nozzle	69
2 – AD 11002 nozzle + boom	74
3 – MAG 02 nozzle	89
4 – MAG 02 nozzle + boom	77
5 – TVI 8002 nozzle	60
6 – TVI 8002 nozzle + boom	83

CONCLUSIONS

The AD 11002, MAG 02 and TVI 8002 nozzles, with or without the use of auxiliary boom, showed similar performance as the spray deposition on the canopy of the coffee leaves and mortality of the leaf miner, but the TVI 8002 nozzles showed higher deposition in the soil.

The use of the auxiliary boom increased the spray deposition in the bottom and decreased in the middle region of the coffee tree. Its use did not show benefits for coffee in the post-harvest phase, possibly because of the defoliation presented by the crop.

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