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Development and technical validation of spray kit for coffee harvester

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Spraying a coffee plantation simultaneously with harvesting ensures that the coffee plants are protected from pests and diseases, which are intensified during this period. In addition to economical operation, the pulverizer adapted to all harvester models promotes greater uniformity in pulverized syrup dispensing since the spray tips are arranged evenly around the plant. Two experiments were carried out in the municipality of Capelinha and Varjão de Minas, MG, comparing the Pulverizer Kit with two volumes of syrup to the Arbus 2000 standard and Arbus 2000 Cerrado, respectively in experiment 2. The experiments were conducted using a randomized block design, with seven and ten replications, respectively, for plots of 20 plants to evaluate the deposition of the syrup in the upper, middle, and lower thirds of the plants. It was concluded that the Sprayer Kit adapted to the coffee harvester is a suitable option for spraying simultaneously to the harvest, using syrup volumes lower than those commonly used in coffee cultivation. The application with Arbus 2,000 had difficulty in reaching the upper third of the coffee tree, whereas this did not occur when the coffee was pulverized using the Spray Kit, regardless of the volume of syrup used.

Key words: coffee harvest, application technology, syrup volume.

INTRODUCTION

There are several challenges for the application of phyto- sanitary products during coffee cultivation, particularly

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in relation to uniform syrup deposition in tall plants, and the reduction of drift. The plant architecture and the large index of leaf area make it difficult to cover the leaves with the active ingredient (Silva et al., 2014a). Silva et al. (2014a) reported that the volume of the syrup must be adjusted in order to allow a satisfactory wetting of the leaves and minimizing loss of drops to the soil. Ramos et al. (2007) described the main difficulties to success in perennial cultures as plant size and number of leaves.

Sasaki et al. (2013) found that the main obstacles to the successful application of agrochemicals are due to coffee architecture (plant size and crown density), which forces research and the market to seek new technologies and/or adaptations of application techniques to solve the problem. In general, deposition is lower in the lower and inner parts of the crop canopy due to the umbrella effect provided by higher parts of the crown in some plant species (Silva et al., 2014b). Deposition is also impaired in the upper parts (upper third) of the crown, because the distance that the spray traverses is high, especially in sprayers with spray in the shape of an arc (Santinato et al., 2014b). Santinato et al. (2017a) studied various traditional ways of improving the efficiency of coffee sprays using syrup volumes, adjuvants and hydraulic tips and their results showed the extreme difficulty in achieving good results, especially in large-scale adult crops. They also found that the spray drift loss is very large, contaminating the environment.

After coffee harvesting, whether mechanical or manual, severe damage to the plants occurs, including trunk discarding, operational defoliation, breaking of branches, and falling of flower buds (Santinato et al., 2014a; Carvalho et al., 2016) since coffee harvesting process are often subjected to vibrations (Souza et al, 2018). Such damages serve as a gateway for pests and diseases that promote injury to the crop. Spraying is usually delayed due to the high demand for machinery during the harvest. When protective sprays are slow to occur, economic damage tends to be high because of the poor sanitation of the crop, which requires more combat spraying than usual in an attempt to maintain sound agriculture (Matiello et al., 2010).

An alternative to correct this deficiency in coffee plantations is to combine harvesting and spraying operations, reducing the effect of drift and the volume of syrup, and thereby contributing to the environment. The drift of phytosanitary products is one of the major problems of modern agriculture (Nuyttens et al., 2011). This wastes products and increases environmental contamination, constituting a point of failure of the operation, which must be corrected.

Another parameter of great importance in sprays is the size of the droplets-a decisive factor in deposition both inside and outside the target. This is one of the main factors related to the loss of phytosanitary products to the environment (Fritz et al., 2012). According to Viana et al. (2010), it would be possible to obtain a uniform distribution with a given diameter and number of drops, achieving success in an application, even with a smaller applied volume.

In the present work, a prototype spray was developed, adapted to the coffee harvester, and capable of simultaneously spraying the harvesting operation. The deposition of the syrup promoted by the prototype under two working pressures was evaluated in two experiments against the existing standard in the hydropneumatic sprayers, Arbus 2000 and Arbus 2000 Cerrado.

MATERIALS AND METHODS

The prototype was developed in Mundo Novo Aliança, located in the municipality of Capelinha, MG (Figure 1). The equipment was divided into two sectors, with completely individualized systems, each one located in opposite sides each on one side of the harvester. Each sector consisted of a support, with capacity for 1.000 kg (1), a tank of 200 L (2), an electric motor (3) that provides the necessary pressure for the spraying, and two stems equipped with spray nozzles (4), forming an angle of 90°. The vertical and horizontal rods are 3.2 and 1.6 m long and are provided with 8 and 2 nozzles, respectively. The nozzles were equidistant at 0.4 m. A 100-mesh filter and BD02 tip were used in each nozzle.

Experiment 1 was carried out in the municipality of Capelinha, MG, Brazil, in the cultivation of Cultivar Catuaí Vermelho IAC 144, 9 years of age, 2.8 m high, 1.5 m wide, and a hanging load of approximately 1,800 kg ha^{-1}. The crop was planted at a spacing of 4.0 m between rows and 0.5 m between plants (5,000 plants per ha) with a slope of 15%. The experimental design was a randomized block design with a split plot arrangement, considering the treatments T1, T2, and T3 as main, with 7 replications, totaling 21 plots. The treatments studied were Arbus 2000 with 500 kPa of pressure and syrup volume of 506 L ha^{-1} (T1) like the standard treatment; Spray kit with 100 kPa pressure and syringe volume of 308 L ha^{-1} (T2); Spray kit with 400 kPa pressure and syringe volume of 616 L ha^{-1} (T3). The third, upper, middle, and lower sites were the secondary treatments. The plots were equidistant at 20 m and each was composed of 20 plants.

The spray kit was installed on a K3, Jacto harvester with 7,220 h of use, operating at 1500 m h^{-1}, with 14 magnojet BD02 fan-type tips (110°). The Arbus 2000 was driven by a Massey Ferguson tractor, model MF 265, 4 × 2 TDA, with a nominal power of 47.8 kW (65 hp) operating at a speed of 5000 m h^{-1}, with the L3 gear at 2000 rpm in the engine. The Arbus was endowed with 20 J A^{-1} (black) Jacto (80°) brand cone tips.

It was installed in the municipality of Varjão de Minas, Minas Gerais State, Brazil, under cultivation at Catuaí Vermelho IAC 144, 11 years old, 2.5 m tall, 1.7 m wide, and spaced 3.8 × 0.5 m totaling 5,263 plants ha^{-1}, with a slope of 9%. The Spray Kit with 405 (T1) and 324 L ha^{-1} (T2) was compared to the Arbus 2000 Cerrado by spraying with a volume of 560 L ha^{-1} with 500 KPa of pressure (T3). In the two treatments that used the Kit, the pressure was set at 300 KPa, which in previous tests was the most adequate for the uniformity of the drops. In T1 and T2 the harvester/Kit was operated at 1600 and 2000 m h^{-1}, obtaining in this way the desired volumes of syrup. The treatments had 10 replications and were outlined in randomized blocks, in plots of 20 plants, equidistant at 20 m.

In this second experiment, the Sprayer Kit was installed in a K3,

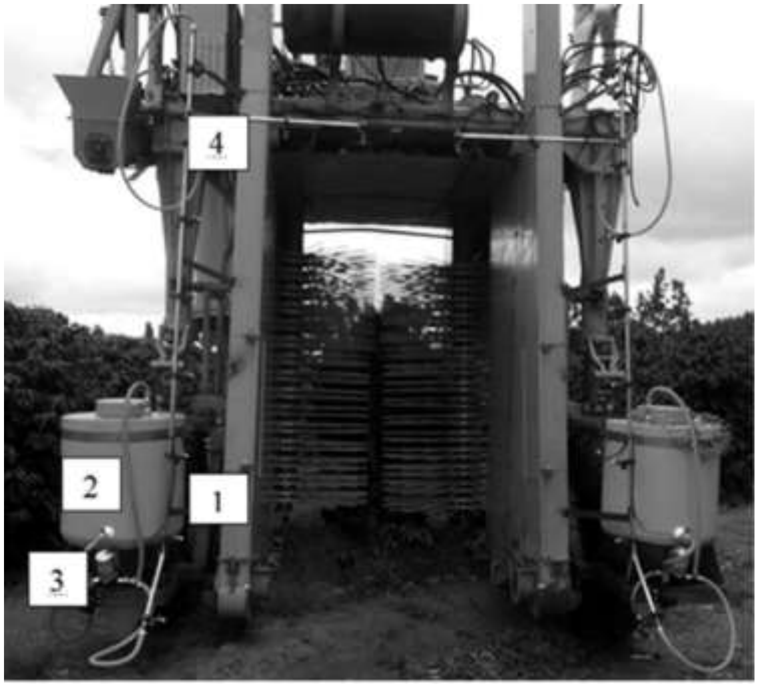

Figure 1. Sprayer kit for coffee harvester and its constituent parts. 1, Support, with capacity for 1.000 kg; 2, Tank of 200 L; 3, Electric motor; 4, Stems equipped with spray nozzles.

Jacto harvester with 5,110 h of use, and 14 magnojet BD02 fan-type tips (110°). The Arbus 2000 Cerrado was driven by a 4 × 2 TDA (John Deere 5425N) tractor, with a nominal power of 55.2 kW (75 hp) operating at an average speed of 4000 m h^{-1} with the L3 gear at 1,400 rpm on the engine. The Arbus was endowed with 24 J A^{-1} (black) Jacto (80°) brand cone tips.

At the time of application, the relative air humidity was 84 and 70%, the winds were 3.0 and 4.4 km h^{-1}, and the temperature 22 and 24°C, therefore, ideal for spraying.

In both experiments, the quality of application parameter measured was the deposition of syrup. For the analysis of the deposition of the syrup on the leaves, aqueous tracer solution, constituted by the food colorant Azul Brilhante, at the dilution of 3,000 mg L^{-1} was sprayed.

At each sampling point (thirds of the plant), ten leaves were collected. Thereafter, they were packed in plastic bags, washed in 100 mL of deionized water, and shaken for 30 s. Subsequently, the absorbance was determined by spectrophotometric laboratory analysis. A wavelength of 630 nm was used in the spectrophotometer readings (Silva et al., 2014b).

The calibration of the spectrophotometer was performed by constructing a standard curve, which consisted in determining the absorbance of solutions having known concentrations of the dye. In order to obtain these solutions, dilutions of the syrup used in the spray containing 3,000 mg L^{-1} of dye were carried out. The regression equation of the standard curve was used to convert the absorbance to dye concentration. From the concentration of the dye in the washing solution, the volume of water used to wash the leaves (100 mL), and concentration of the solution applied (3,000 mg L^{-1}), it was possible to determine the deposit of the solution by Equation 1 proposed by Limberger (2006):

$$D = \frac{10^6 x[\text{solution}]}{\text{Ax[spray syringe]}} \qquad (1)$$

Where, D = syrup deposition (μl); V = volume of water used to wash the leaves (L); [solution] = concentration of the dye in the wash solution (mg L^{-1}); A = leaf area of the segment (cm^2); [syrup] = concentration of the dye in the spray syringe (mg L^{-1}).

After being washed, the leaves had the determined leaf area (cm^2) using ruler. For this measurement, the leaf length and width were multiplied by 0.66, as indicated by Matiello et al. (2010). Then, according to the methodology proposed by Palladini (2000) and cited by Souza et al. (2007), the deposition of the dye per unit area (μL cm^{-2}) was determined, relating the deposition with the obtained leaf area. The deposition was analyzed separately considering subdivided plots, where the plots were the treatments and the subplots were the thirds of the plants (lower, medium, and higher), totaling 63 and 90 experimental units, respectively. The data were submitted to analysis of variance by the F test and when appropriate, the Tukey test was performed, both at 5% significance.

RESULTS AND DISCUSSION

In experiment 1, the application using Arbus 2000 obtained the lowest values of syrup deposition for the average of thirds (Table 1). The deposition of this treatment was lower than the treatments that used 308

Table 1. Deposition of the pulverized syrup in the thirds of the coffee tree, according to the equipment used in experiment 1, Capelinha, MG.

Treatments	Deposition of syrup (µl cm^{-2})			
	Botton	**Medium**	**Higher**	**Average of thirds**
Arbus 2.000 (506 L ha^{-1})	0.218 ^{bA}	0.153 ^{cA}	0.058 ^{cB}	0.143 ^{b}
Spray kit (308 L ha^{-1})	0.406 ^{aA}	0.337 ^{bA}	0.262 ^{aA}	0.335 ^{a}
Spray kit (616 L ha^{-1})	0.375 ^{abAB}	0.501 ^{aA}	0.323 ^{aB}	0.399 ^{a}
CV (%)		32.83		25.33

*Means followed by the same lowercase letters, in the columns, and upper case, in the lines, do not differ by Tukey test, at 5% probability.

Table 2. Deposition of the pulverized syrup in the thirds of the coffee tree, according to the equipment used in experiment 2, Varjão de Minas, MG.

Treatments	Deposition of syrup (µl cm-2)			
	Botton	**Medium**	**Heigher**	**Average of thirds**
Arbus 2.000 Cerrado (560 L ha^{-1})	210.6 ^{aA}	213.1 ^{aA}	129.1 ^{cB}	184.26 ^{b}
Spray kit (405 L ha^{-1})	181.3 ^{abA}	224.1 ^{aA}	237.6 ^{aA}	214.13 ^{a}
Spray kit (324 L ha^{-1})	148.35 ^{bA}	215.3 ^{aA}	161.6 ^{bA}	171.75 ^{b}
CV (%)		39.22		18.19

*Means followed by the same lowercase letters, in the columns, and upper case, in the lines, do not differ by Tukey test, at 5% probability.

and 616 L ha^{-1} (lower volume and superior to the conventional system, respectively), demonstrating that the cause of this low deposition was not the volume of syrup but the structure of the equipment.

The arbus structure of Arbus 2,000 hinders the deposition of syrup when compared to the vertical structure of the Sprayer Kit (Sasaki et al. 2013). In the average of the thirds, there was no difference between treatments T2 and T3 for the deposition of syrup. This gives the viability of using the syrup volume of 308 L ha^{-1}, lower than the other evaluations. This result corroborates that of Ferreira et al. (2013), which enabled the reduction of the volume of syrup applied by modifying the arc structure of the sprayer.

It was observed that in the largest volume of the syrup (T3), the deposition was 48.66% higher in the middle third of the plants. This is commonly observed in sprays that use higher volume of syrup (Santinato et al., 2014b). In spite of this, the higher volume of syrup did not increase the deposition in the lower and upper thirds of the plants.

It was also observed that the Sprayer Kit, in the lowest volume tested, obtained the best distribution of the syrup, with no difference in the deposition for the evaluated thirds. Otherwise, the other treatments had lower deposition in the upper third. This was due to the difficulty presented by Arbus 2000 by the distance between the tips and the target, in reaching the upper third, a fact pointed out by Scudeler et al. (2004). In the case of the Spray Kit with a volume of 616 L ha^{-1}, this fact does not condemn the spraying, since the deposition, however uneven, was adequate. What happened was justified by the predominance of the syrup in the middle third that was elevated.

In experiment 2 (Table 2), there was a higher deposition of syrup in the lower third, in the treatment that used Arbus 2000 Cerrado. This was probably due to the higher volume of syrup used and also the high speed of the equipment turbine that allows greater mobility of the coffee leaves, overcoming the difficulty imposed by the “umbrella” effect. In the background was the Spray Kit in the largest syrup volume followed by the lowest syrup volume.

In the middle third, there was no difference between treatments. This fact shows that in this third, regardless of the volume of the syrup used (324, 405 and 560 L ha^{-1}), the deposit was satisfactory.

In the upper third, the largest syrup deposition was obtained using the Sprayer kit with the largest volume of syrup used, followed by the same equipment with the lowest syrup volume and both higher than the Arbus 2000 Cerrado, with the lowest value. Again, the inferior quality of the upper third was obtained using the arbor sprayer, even if it was of the Cerrado model, equipped with branches with tips positioned at a height higher than conventional Arbus (Table 2).

Comparing the uniformity of spray distribution, large differences were observed in the Arbus 2000 Cerrado treatment, with much higher deposition in the lower and middle thirds, compared to the upper third. In the Sprayer Kit operating with the lowest volume of syrup, a uniform syrup was deposited. This was due to the high deposition in the middle third, which was superior to the lower and upper thirds, which did not differ from itself. In the treatment that used the Sprayer Kit with the largest sample volume tested, satisfactory uniformity occurred across the entire plant. This is due to the arrangement of the nozzles and the volume of syrup used (Table 2).

In general, the Spray Kit with 324 L ha^{-1} obtained a similar deposition to that of the Arbus Cerrado, with 560 L ha^{-1}, and both had lower deposition than the 405 L ha^{-1} Sprayer Kit.

In general, comparing the two areas studied, the results were positive for the Spray Kit. However, in each type of crop, adjustments must be made in relation to the volume of syrup, pressure and hydraulic tips used to obtain the best possible results. Santinato et al. (2016) did a study in crops of several vegetative volumes and verified that in each of them a specific volume of syrup is required.

Conclusions

The Sprayer Kit adapted to the coffee harvester is suitable for simultaneous spraying with a low volume of the syrup and with the deposition and distribution of the regular syrup. This work examined the deficiency in uniformity of syrup distribution of arc sprayers.

The technique studied here presented practical and economic benefits, for doing two operations at the same time, for improving the efficiency of the pulverization and environmental ones by using smaller volume of syrup and reducing the drift of the products for the environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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