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Quality of hydropneumatic and pneumatic sprays on conilon coffee plants

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Abstract:
Background: Brazil is one of the largest coffee producers and exporters in the world and has been facing difficulties due to the control of pests affecting the crop. The objective of this work was to compare the hydropneumatic and pneumatic sprayers, in order to determine their greater effectiveness and efficiency.
Materials and Methods: The experiment was carried out in a randomized block design with treatments distributed in a 2X3 factorial scheme, with two sprayers (one pneumatic and the other hydropneumatic) and three collection positions at the height of the plant canopy (lower, middle and upper), with four reps. Droplet deposition, coverage, volumetric median diameter and droplet density were quantified by the DropScope Wireless© meter.
Results: The coverage of the pneumatic sprayer presents values between 9.682% and 62.175%, for the lower and upper third, respectively. Drift was evaluated by the deposition of droplets on rods installed adjacent to the treatment, the pneumatic sprayer obtained greater drift, even so being mitigated by weather conditions, which were favorable for spraying. The hydropneumatic sprayer has greater uniformity and application coverage.
Key Word: Coffea canephora ; Efficiency; Pests and diseases; Application technology.

I. INTRODUCTION

The world production of coffee is currently in the range of 165 to 170 million bags, in some years surpassing 175 million bags, depending on the harvest and source. The distribution of coffee takes place in various regions of the world, it is observed that its cultivation is directed to tropical and subtropical regions, expressively in about 60 countries.

The beginning of the formation of the historical, economic and social identity of Espirito Santo had as its main structuring pillar the coffee culture from the mid-nineteenth century. This activity also integrated the State into the national economy and international trade, in addition to helping to build its sociocultural base[1].

For this reason, coffee is the great expression of the state's agricultural economy, generating, according to the Information and Analysis Management (GIA), of the State Secretariat for Agriculture, Supply, Aquaculture and Fisheries, 42.95% of the Gross Value of Agricultural Production in 2020. This value refers to the income generated in the sector, that is, that which actually remains on the property of the coffee growers. In that same year, the coffee complex (green, soluble, roasted and ground) occupied the second position in the ranking of agribusiness exports in Espírito Santo, only behind cellulose.

Currently, an imbalance in the system has been observed due to changes in the relationship between living beings and their natural enemies, and this can lead to the appearance of high populations of bacteria, fungi, insects and spontaneous plants. These organisms compete for water, light, space and nutrients with plants of economic interest or attack their plant parts in search of the food necessary for their survival. Thus, these organisms are called pests. Pests can occur systematically or sporadically in crops[2].

For the control of these pests it is usual to recommend chemical products aiming at the rapid reduction of their population. The inappropriate and excessive use of phytosanitary products can cause an environmental impact with the contamination of soil and water resources, increasing the danger of direct poisoning of rural producers exposed to the products, possibility of marketing fruits with residue levels above the tolerated and increased production cost[3].

An application of the phytosanitary product occurs when there is adequate coverage of the target surface, obtained by application equipment that provide uniform transversal and longitudinal distribution, similar droplet spectrum and appropriate size[4]. Therefore, the use of the correct equipment has a great influence on the distribution, uniformity and quality of spraying[5].

In this context, in addition to knowing the nature of the phytosanitary product, it is also necessary to use the best available technique or the best application equipment, in order to ensure the use of a smaller amount of active ingredient, reaching the target efficiently, reducing losses and environmental contamination[6,7].

Coffee producers lack technical information on which the best equipment should be used, therefore the work aimed at a comparative analysis between hydropneumatic and pneumatic sprayers, in order to highlight the best equipment to be used.

II. MATERIAL AND METHODS

Characterization of the experimental área

The experiment was carried out under field conditions, in July 2021, in a private plantation in the village of Juncado, municipality of Sooretama, north of the state of Espirito Santo, Brazil. The crop is located at an altitude of 66 m, at the coordinates 19º 05' 30" south latitude and 40º 06' 36" west longitude. The region has a warm humid tropical climate (Type Aw), with predominant northeast wind, dry winter, average annual temperature of 23°C and average annual rainfall of 1,112 mm per year.

The soils in the region are predominantly Dystrophic Yellow Argisols, with a medium sandy texture[8]. The experimental area was set up in a five-year-old Conilon coffee plantation (*Coffea canephora*), with localized drip irrigation and average productivity of 90 bags ha^{-1}. The crop has a spacing of 3.30 m between rows and 1.0 m between plants, which had an average height of 2.0 m.

Experimental design and treatments

The experimental design was in randomized blocks, with treatments distributed in a 2x3 factorial scheme, with two sprayers (one pneumatic and the other hydropneumatic) and three collection positions at the height of the plant canopy (lower, middle and upper), with four replications . The sets of tractors and sprayers have different paths, and it is necessary to use the fifth row as useful, so eight representative plants were selected, four in each useful row. The hydropneumatic sprayer ran through 11 carriers and the pneumatic one ran through two, to apply the same volume of grout. The sprayings took place in different areas, at the same time, and a spacing of 33.0 meters was used so that there was no influence of one treatment on the other (Figure 1).

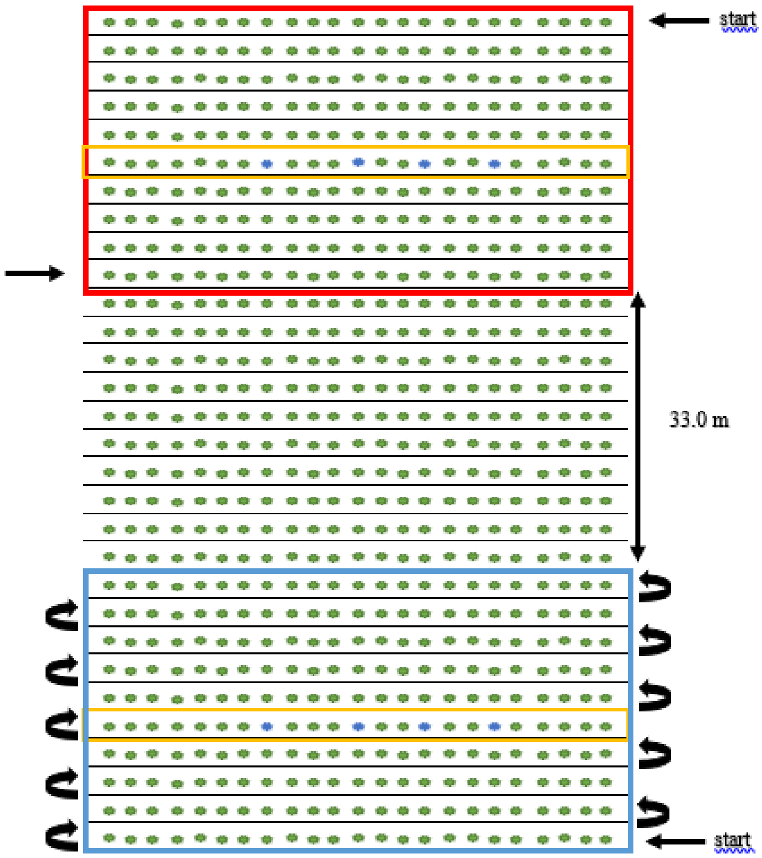

Figure 1. Experimental design scheme. Red area – delimits the application carried out by the pneumatic sprayer; Blue area – delimits the application carried out by the hydropneumatic sprayer; Yellow area – identifying the useful line; Blue dots – refers to repetitions.

Spectrum determination and droplet deposition

Water sensitive label with dimensions corresponding to 76 x 26 mm were installed on rods to facilitate handling and characterize the droplet spectrum. PVC was used for making the stems, with labels fixed at heights of 0.60 m, 1.20 m and 1.80 m, to correspond to the lower, middle and upper third of the plant, respectively (Figure 2), totaling three labels per experimental unit. The stalks were placed in the center of the plants representing the useful line, requiring eight stalks.

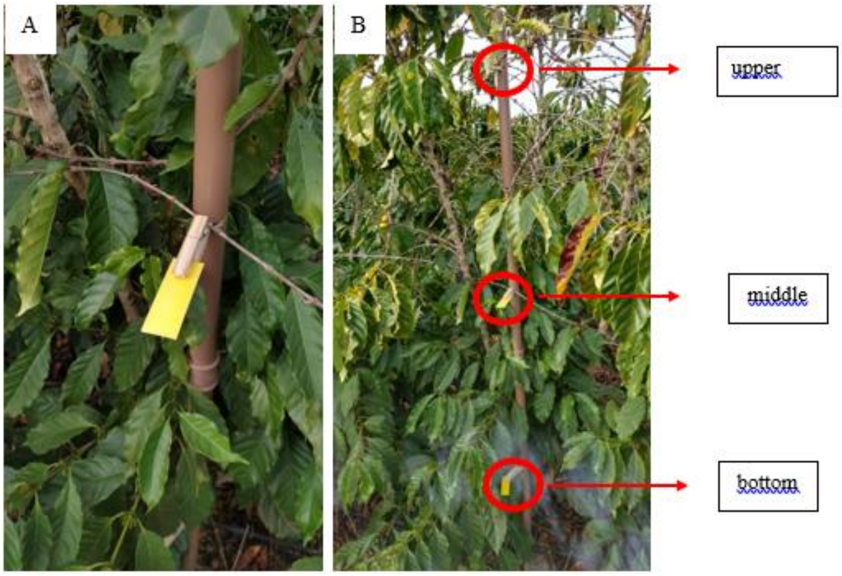

Figure 3. Detachment of the set of rods with the water-soluble label. A – Water-soluble label and the way it was attached to the stem; B – Spacing between labels arranged on the rod.

The quantification and characterization of the impacts on each water-sensitive paper label was performed after the applications in each treatment and drying of the labels. The DropScope Wireless© meter was used, a water-soluble paper reader composed of programs, a web area for viewing and sharing analysis, and a wireless digital microscope with a digital image sensor with more than 2500 dpi (Figure 3). The following parameters were evaluated: mean volume diameter (VMD, µm), drop density (drops cm⁻ ²), coverage rate (%) and deposition (µL cm⁻ ²).

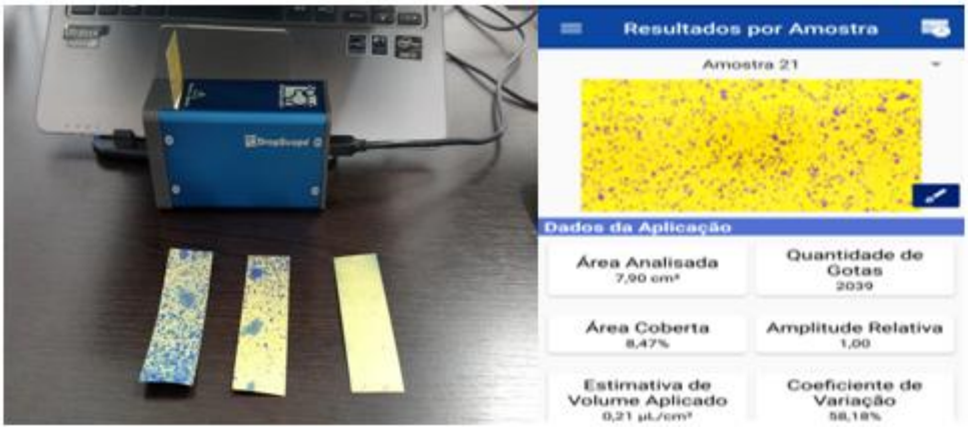

Figure 3. DropScope device processing tags and a report generated by a tag.

Drift Assessment

The drift evaluation consisted of the distribution of 34 collector rods, in a region of influence of winds on the drift, spaced every 3.0 m, with 17 collectors for evaluating each sprayer. The rods were positioned in a northeasterly direction, in an area adjacent to the spray. For better understanding, they were separated into area “A” where the spraying took place and area “B” where the collecting rods were placed (Figure 4). Each rod was made of PVC, 3.0 m high, with a water-soluble label at the end fixed by a double-sided adhesive tape and duly designed to facilitate the allocation in the area adjacent to the spraying

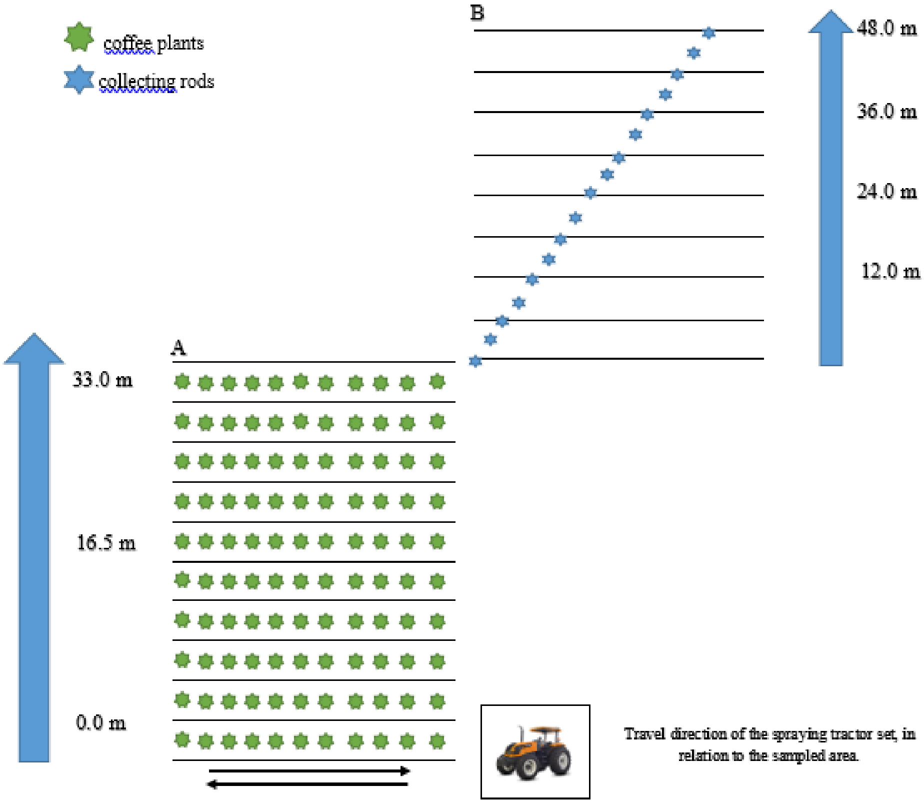

Figure 5. A - Scheme indicating the path of the sprayer in the coffee plantation. B - Arrangement of the collecting rods in the adjacent region.

Characterization of tractors and sprayers

Two sprayers were used in the treatments, a hydropneumatic tractored sprayer from COMIL brand, model TURBO PTC and a tank with a capacity of 700L, with a branch with double nozzles consisting of 6 tips on each side, totaling 12 tips, from the MagnoJet brand, model MAG-CH (full cone) of blue color, recommended by the manufacturer to work under pressure range from 340 to 1040 kPa. With the aid of a manometer, the working pressure was established, 340 kPa, resulting in a flow of 1.0 L min^{-1}, totaling a volume of 600 L ha^{-1}. The sprayer was pulled and driven by an AGRALE brand tractor, model 4100, with a working speed of 1.5 km h^{-1}.

The second sprayer, a pneumatic tractor transported in the tractor's hydraulic lifting system, JACTO brand, "cannon" model with a capacity of 600L, with a unidirectional nozzle branch with six tips and an air flow director, being regulated to apply 600 L ha^{-1}. The sprayer was transported and driven by a VALTRA brand tractor, model BF75, with a working speed of 2.8 km h^{-1}.

Monitoring of weather conditions

During the experiment, the environmental conditions were monitored by means of a portable digital anemometer model AD-250©, indicating wind gusts between 0.0 ms^{-1} to 1.5 ms^{-1} and a digital thermo hygrometer Herbicat model. SH-122©, indicating a relative humidity of 65% and a temperature of 24.8°C. Taking into account the descriptive methodology in the ISO Standard 22866 106 (International Organization for Standardization – ISO, 205). This standard recommends that during applications the temperature must be between 5 and 35ºC, for the wind speed, the standard allows a maximum of 10% of the measurements to be below 1.0 ms^{-1} and the wind direction within a limit of 90° ± 30° to spray line.

Statistical analysis

In the statistical analyses, the assumptions of the DMV, drop density, coverage and drop deposition data were tested. To verify the homogeneity and normality of the residues, the Levene and Shapiro Wilk tests were applied, respectively. Data transformation was performed when necessary and later the analysis of variance, applying the Tukey test. All tests were performed using the Rbio software, considering a 5% significance level.

III. RESULT

Table 1 presents the results of droplet deposition and coverage as a function of sprayer and canopy height of the coffee plant.

Table no 1. Effect of spray type and canopy height of coffee plants on coverage and droplet deposition.

Spray	thirds of plants			
		Bottom	Middle	Upper
Deposition (µL cm²)	Pneumatic	0.551 C	3,340 BC	8,672 aA
	Hydropneumatic	0.913 B	0.312 bB	3,400 ba
CV = 37.68%	$W = 0.640^{ns}$	$F_L = 1.85^{ns}$	$DW = 1.57^{ns}$	
$F_{thirds} = 0.00000$*	$F_{sprayer} = 0.00002$*	$F_{interaction} = 0.0004$*		
Roof (%)	Pneumatic	9,682 B	27.5 aB	62,175 aA
	Hydropneumatic	7,367	9,085b	15,525b
CV = 49.82%	$W = 0.161^{ns}$	$F_L = 0.99^{ns}$	$DW = 1.63^{ns}$	
$F_{third} = 0.00018$*	$F_{sprayer} = 0.00014$*	$F_{interaction} = 0.0034$*		

Means followed by distinct letters, lowercase in the columns and uppercase in the lines, differ from each other by the Tukey test, at 0.05 of significance; CV - Coefficient of variation; W, FL, DW and F - Shapiro-Wilk test statistics for normality of residuals, Levene for homogeneity of variances, Durbin-Watson for independence of residuals and F test; nsNormally distributed residuals, homogeneous variances, independent residuals and acceptance of hypothesis H0, all at 0.05 significance; * Non-normally distributed residuals, non-homogeneous variances, non-independent residuals and rejection of the H0 hypothesis, all at 0.05 significance.

Droplet density in the middle third of the plant was influenced by the form of droplet spraying (Table 2).

Table 2. Effect of spray type and canopy height of coffee plants on droplet density and VMD.

	Drop density (drops cm²)	VMD (µm)
Pneumatic sprayer	220.1333^{ns}	519.4908^{ns}
Hydropneumatic sprayer	826.3292^{ns}	344.7083^{ns}
Upper	188.0875^{ns}	569.1000^{ns}
Middle	155.4437^{ns}	403.5625^{ns}
Botton	1226.1625^{ns}	323.6363^{ns}

Comparing the treatments under similar weather conditions, although the volumetric quantity is reduced, it is noted that the spraying carried out with the pneumatic sprayer presents greater susceptibility to drift (Figure 6).

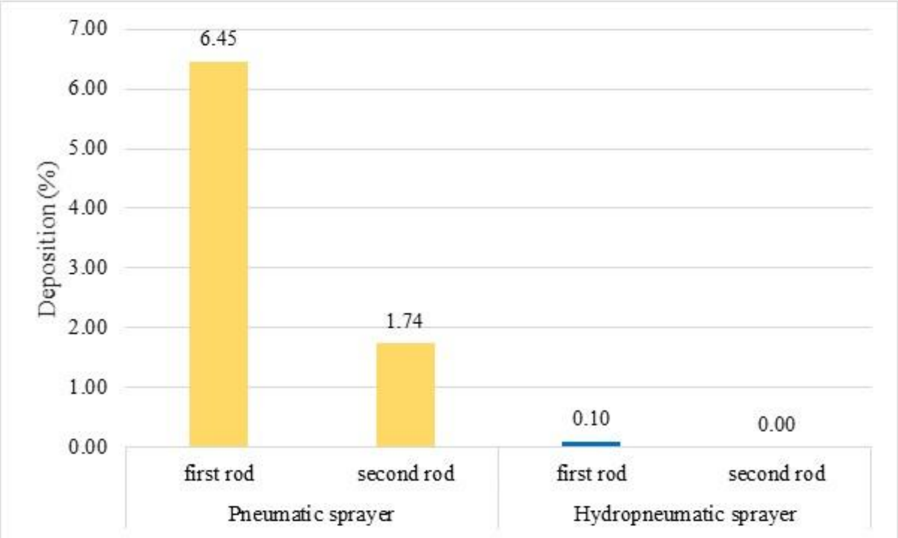

Figure 6. Evaluation of drift in different treatments

IV. DISCUSSION

The deposition values of the middle and upper thirds were higher for the pneumatic sprayer, with the lower third showing no significant difference between the sprayers. The highest value found was 8,672 µL cm⁻ ² and the lowest was 0.312 µL cm⁻ ², for the upper and middle third respectively (Table 1). The correct spray distributions in the aerial part of the plant are conditioned by several factors, such as plant height and architecture, planting density, droplet diameter produced by the spray tip, spray volume, speed of displacement of the plant. sprayer, wind speed, type of equipment used and its characteristics[9].

The deposition of drops in the lower third presents a statistical difference when compared to the forms of spraying, this behavior is related to the way in which the drops are sprayed. Evaluating the hydropneumatic sprayer or as commonly called "air curtain", we observed that the deposition of the likes actually form a "curtain" aspect, depositing the drops more evenly on the heights of the coffee tree. Studies with different volumes of syrup applied with the hydropneumatic sprayer corroborate the results found in this work[10]. [11]State that spraying with a cannon-type sprayer presents uneven deposition, which corroborates the results of this work. The hydropneumatic sprayer showed a more homogeneous deposition in the three thirds of the plant, compared to the pneumatic[12].

The coverage of the pneumatic sprayer presents values between 9.682% and 62.175%, for the lower and upper third, respectively. As with deposition, coverage presents its highest values in the upper third, being 642.25% higher than the lower third. Pneumatic application is always carried out above the canopy of the plants, which promotes greater coverage in the upper and middle thirds[13].

The volumetric median diameter was classified according to the ASABE S-572.1 standard established by the American Society of Agricultural and Biological Engineers[14]. The upper third and the pneumatic sprayer had extremely coarse drops; the middle third and the hydropneumatic sprayer presented coarse drops; and the lower third showed medium drops.

The volumetric median diameter only indicates the quality of the spray and, therefore, should not be used in isolation[15]. Therefore, when performing a correlation between DMV and droplet density, we notice that the smaller the diameter of the volumetric median, the greater the density. The syrup densities on the leaves of the coffee tree were higher with finer drops, obtaining an estimate of 826,3292 and 1226,1625 drops cm² in the hydropneumatic sprayer and in the lower third, respectively. Comparing the droplet density between spray applications, it is observed that the density of the hydropneumatic sprayer was 375.37% higher than that of the pneumatic sprayer. Therefore, the finer drops have greater area coverage and possibly less run-off and loss.

Droplet density in the middle third of the plant was influenced by the form of droplet spraying (Table 2). Although these results were not significant, there is a tendency for approximation in the values of depositions in the middle and upper third, however, when compared to the lower third, they obtained results that were 88 and 85% lower, respectively. Efficient applications require uniform distribution and adequate droplet density, with appropriate size on the target surface[9]. The same authors emphasize that inefficient applications, although they can produce effective control, are due to not using the best technique available or the best application equipment, responsible for determining the use of a smaller amount of active ingredient and obtaining the same results. For [16], it is likely that a uniform distribution of droplet density in a given diameter allows for successful application, even with the use of low volumes of syrup in tree crops, which increases the importance of knowing the best combination between droplet density and diameter, volume and concentration of active ingredient in the spray liquid for the main pests whose control is carried out via spraying, mainly in pneumatic and hydropneumatic spraying. Droplet density and diameter are the main technical parameters to establish the quality of an application[17].

Droplet deposition occurred on the first two rods of the pneumatic spray treatment, and drift was mitigated by favorable weather conditions for spraying. Comparing the treatments under similar weather conditions, although the volumetric quantity is reduced, it is noted that the spraying carried out with the pneumatic sprayer presents greater susceptibility to drift (Figure 10). [13]State that the deposition of droplets formed by a pneumatic sprayer occurs through a sedimentation process and follows a ballistic movement where larger diameter droplets, with greater weight and inertia, do not follow the air stream over long distances, depositing on closer targets. On the other hand, smaller drops, with less weight and inertia, will continue to be moved through the air stream, thus being deposited on more distant surfaces[18].

Therefore, the pneumatic sprayer is more susceptible to drift due to its spray shape and the discrepant difference in droplet formation. [19]State that, in order to achieve a more uniform deposition, it is necessary to superimpose the application ranges, using ranges that cover values between 25 and 45% of the maximum machine range, which corroborates this study.

The hydropneumatic sprayer did not show drift, being favored by the coarse drops and the homogeneity of application, as shown in the study, the size of the droplets is undoubtedly a decisive factor in their deposition, both inside and outside the target[20, 21, 22].

V. CONCLUSION

The hydropneumatic sprayer on coffee crops has good spray quality, resulting in consistent coverage, uniform deposition and high density. Hydropneumatic spraying proved to be more uniform compared to pneumatic spraying. The use of coarse drops in the hydropneumatic sprayer is a viable alternative for application efficiency, as it allows for a reduction in drift.

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