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Comparative Analysis of Spray Nozzles on Drones: Volumetric Distribution at Different Heights

A paper from the Proceedings of the

16th International Conference on Precision Agriculture

21-24 July 2024

Manhattan, Kansas, United States

Abstract.

Farmers around the world often change drone nozzles without checking droplet parameters that decreases the quality and effectiveness of pest control. Climate change and agricultural pests are responsible for decreasing the quality and yield of Coffea arabica plants especially in mountainous regions. The objective of this study was to understand the droplet distribution of three different nozzles at three flight heights and how these parameters influence the volumetric diameter of 90% and 10% in Coffea arabica plants. The experimental tests were divided into volumetric distribution tests and field tests. The spray drone used during the experiment was a DJI Agras T10 with four nozzles. The standard nozzle on the drone was L110010 and two other nozzles, V110015 and L080010 were tested at three different flight heights: 2, 3, and 4 meters. During the volumetric distribution test, the volume (mL) at different heights and with different nozzles was collected using a low-cost table. The statistical design adopted for the field test was a randomized block design in a double factorial 3 x 3. Coffea arabica genotypes have three years old and each plant were divided into three parts: bottom, middle, and top. The water-sensitive paper was inserted in each part to evaluate the droplet volumetric diameters of 90% and 10%. Boxplots and bar charts were plotted to assess each treatment and variance analysis with Tukey's test was performed to evaluate the mean values of each treatment. In the volumetric distribution test, the nozzle L080010 presented the lowest spray width regardless of flight height, while for the L110010 and V110015 nozzles increasing the flight height from 2 to 4 meters increased the spray width by 19%. In the variance analysis, the L080010 nozzle showed the best variation coefficient values, and the droplets produced by this nozzle reached all parts of the coffee plants equally. Coffea arabica plants have a dense canopy with a high production of leaves, which causes an umbrella effect preventing droplets from reaching the bottom leaves when coarse droplets (V110015) are used. The small spray width (concentrating the droplets) of the L080010 nozzle and the downwash effect caused by the drone propeller increased the penetration of the droplets. However, choosing the correct nozzle and height depends on the specific target in the field.

Keywords.

Coffea Arabica, spray drone, volumetric diameter, spray drift, pesticide efficacy

Introduction

Agricultural pests significantly reduce plant health, and their impact is exacerbated by climate change, which facilitates the spread of unwanted insects, diseases, and weeds (Gullino et al., 2022). These pests can cause global production losses ranging from 10 to 28% (Gullino et al., 2022). Farmers are increasingly applying products to control pests in the field, but the efficiency and quality of these applications often yield suboptimal results (Gullino et al., 2022).

Agricultural production frequently adopts new technologies to enhance yield. Sensors, drones, and autonomous machines have become common tools for data collection, analysis, and field monitoring (Hafeez et al., 2023). Drones in particular have wide applications including field monitoring using multispectral, RGB, hyperspectral, or LiDAR sensors and the application of fertilizers and pesticides (Hafeez et al., 2023; Filho et al., 2019; Daponte et al., 2022). Recently, spray drones introduced into agriculture revolutionizing spray technologies.

Spray drones operate with ultra-low flow rates and highly concentrated products. Understanding drone configuration for different crops can enhance application quality and efficiency. However, improper application conditions can lead to significant droplet drift, failing to reach the target and negatively affecting the environment, pollinator populations, humans and water bodies (Wang et al., 2020; Souza et al., 2022; Grella et al., 2020).

Flight speed and height are frequently studied parameters in various crops, such as cotton, soybean, coffee, and fruit trees (Chen et al., 2021; Zhang et al., 2022; Vitória et al., 2023; Yan et al., 2023). Combining these parameters with the appropriate nozzle type can significantly improve spray quality and efficiency. Optimizing these parameters directly affects droplet deposition, uniformity, density and coverage in crops (Vitória et al., 2023). This optimization in all the cases need be test to assess the best configuration to increase the application quality on field conditions.

Despite that, different plants have varying canopy structures which directly influence the effectiveness of spray systems. Only adjusting flight speed and height does not necessarily improve application quality and the selection of optimal nozzle type can be crucial for optimization (Vitória et al., 2023; Anken et al., 2024). Nozzles determine the droplet spectrum and break up the spray. The choice of nozzle should be based on the target pest (insects, fungi or weeds) to ensure effective application.

Farmers often change nozzles without checking droplet distribution, reducing pest control quality and effectiveness. Understanding droplet distribution is essential to optimize application range and flight height, which are fundamental parameters affecting pest control and yield (Anken et al., 2024; Yallapa et al., 2023).

Spray drones are constantly evolving and their ease of use can sometimes overshadow their real importance and applications in agriculture. To address potential issues in the field studies need to be conduct to understand and compare the quality and efficiency of this equipment under various conditions. Therefore, the objective of this study was understand the droplet distribution of different nozzles at three flight heights and how these parameters influence into volumetric diameter of 90% and 10% in *Coffea arabica* plants.

Material and methods

The experiment was develop in the city of Lavras, Minas Gerais, Brazil at Federal University of Lavras (UFLA). The drone used during the experiment was DJI Agas T10, Shenzhen DJI Sciences and Technologies®. The drone tank has the capacity of eight liters and a rated take-off weight 24.8 kilograms. The maximum flight speed is 10 m. s^{-1} and an operation hourly efficiency of 6 hectares or 15 acres.

The drone spray system use two diaphragm pump varying 2 – 4.5 kg/cm^2 of pump pressure and each pump control two nozzles. The maximum flow is 1.5 L. min^{-1} with a flowmeter error around 2% and a maximum effective spray width 3 – 5.5 meters with 4 nozzles and a distance of 1.5 – 3 meters to crops. The standard nozzle available in the drone is XR11001VS but other options can be use in the drone. The nozzles used in this study show in the table 1 and classified following the American Society of Agricultural and Biological Engineers (ASABE S572.1).

Table 1. Nozzle type and flow rate use in difference flight height.

Nozzle type	Color	Classification	VMD (µm)
110015	green	Very Coarse	404 - 502
110010	orange	Fine	106 – 235
080010	orange	Fine	106 - 235

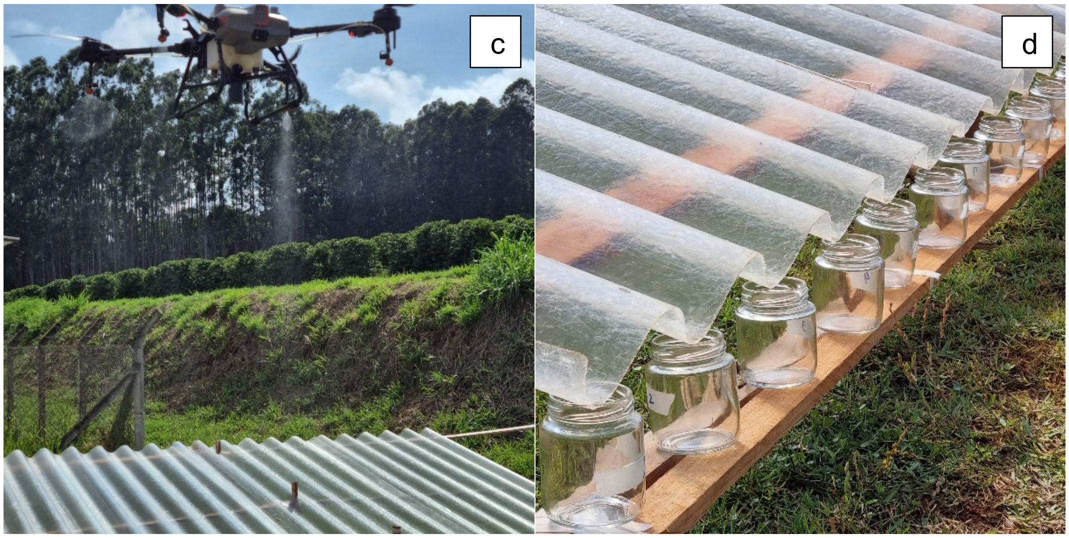
The height used to volumetric distribution and field analysis were 2, 3 e 4 meters with a flow 1.2 L. ha^{-1}. The nozzles and height were combine (table 2) and three repetitions was use for the volumetric distribution test. During the volumetric test distribution for each repetition the drone flight during three minutes. The test occur in field conditions start at 7:00 to 10:00 morning and 5:00 to 8:00 in the afternoon. The temperature, relative humidity and wind speed were measure using a thermos hygrometer model and an anemometer. The measure of the weather conditions occur during the flight and the values were register each one minute of flight.

Table 2. Flight heights, nozzle types and number of treatments using to volumetric distribution and in field evaluation.

Nozzle type	Heights	Treatment
V 110015	2	T1
V 110015	3	T2
V 110015	4	T3
L 110010	2	T4
L 110010	3	T5
L 110010	4	T6
L 080010	2	T7
L 080010	3	T8
L 080010	4	T9

The volumetric distribution table using during the test showed the dimensions of 5.30 x 4.05 meters of width and length (Figure 1A). The table was mount in different angles 15.06°, 10.88° and 6.58° with the first stake in a height of 0.95 meters, the second 0.60 meters and the third 0.20 meters from land and a distance amount the stakes of 1.30 meters (Figure 1B). The drone was insert in the middle of the table (Figure 1C) in all heights and using a graduated cylinder beaker (centimeters) the water was measure in 27 glass cups positioned 0.196 meters each (Figure 1D).

Figure 1. drone images and volumetric distribution table images used during the test.



The experimental field consisted *Coffee arabica* genotypes with 3 years and a row space of 3.0 meters. In this field, six rows of 50 meters each were define was the experimental area and the blocks were divide in two rows with a space 6 meters between the rows where the plots (coffee plants) were used to evaluation. The repetitions for each treatments were increase to field analysis. For each block, three plants were used to third row and two plants were used to fifth row. The statistical design adopted was randomized block design in double factorial 3 x 3 with five replications for each treatments. These five repetitions represented the five plants where the water-sensitive papers were insert. The five plants were distance 5 meters from each other and each plant was divide in three parts: bottom, middle and the top, where each part received one water-sensitive paper.

The flight mode use during the application was automatic, the flight speed was 3.89 m s^{-1} and the flow rate was 15 L ha^{-1}. During the flight, the DJI D-Real Time Kinetic (RTK) was use to correct the drone position. The drone tank was filled with water and the task started in the first row continue the application until the last row. After the spray drone pass the papers were measure using the DropScope® System, SprayX Company, São Carlos, SP, Brazil. The parameters evaluate by DropScope system used to compare the nozzles in the different weights were volumetric diameter corresponding to 10% and 90% ($Dv_{0.1}$ and $Dv_{0.9}$).

Statistical analysis

The volumetric distribution data were compare using boxplot, histogram and bar graphs to understand the influence of the height in the spray distribution. The factorial design in randomized blocks used as the factor 1 (F1) the nozzles and factor 2 (F2) the height. The first analysis consist of descriptive analysis with median, variation coefficient (VC), minimum and maximum values of each treatment. After this, the Shapiro-wilk test was apply to evaluate to test the homogeneity and normality of residues. When needed the data were transformed using the Box-cox transformation and choose the best option. After the variance analysis the Tukey's test ($p<0.05$) were apply for the DropScope variables. All the statistical analysis occurred in the Software R using the package AgroR 1.3.4 (Shimizu, Marubayashi and Goncalves, 2023).

Results and discussion

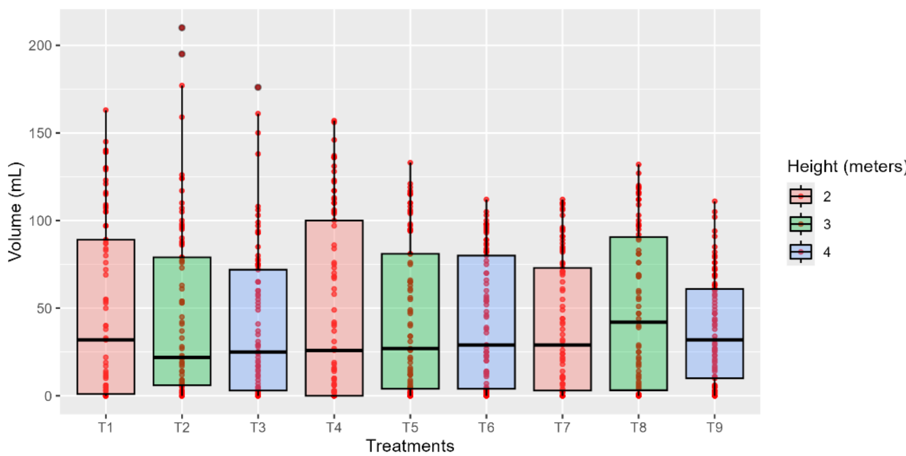
During the volumetric distribution test, the weather conditions (Table 3) showed low variation with exception of T1 that presented the lowest values of mean temperature 25.73 °C and the T3 that presented the highest values of mean temperature 30.48 °C. Despite that, the T6 showed the highest values of wind speed 1.574 m s^{-1} and the lowest values were observe in the T1 0.355 m s^{-1}. The relative humidity show the major values for T7 and the lowest values for T9 56.55% and 39.67%, respectively.

Table 3. Weather data collected during the volumetric distribution test.

Treatment	Wind Speed (m s^{-1})	Mean Temperature (°C)	Relative humidity (%)
T1	0.355	25.73	55.33
T2	0.599	30.01	55.55
T3	0.577	30.48	45.33
T4	0.463	30.04	49.22
T5	0.799	30.05	50.33
T6	1.574	29.40	45.11
T7	0.512	29.87	56.55
T8	0.506	29.79	51.45
T9	0.728	30.05	39.67

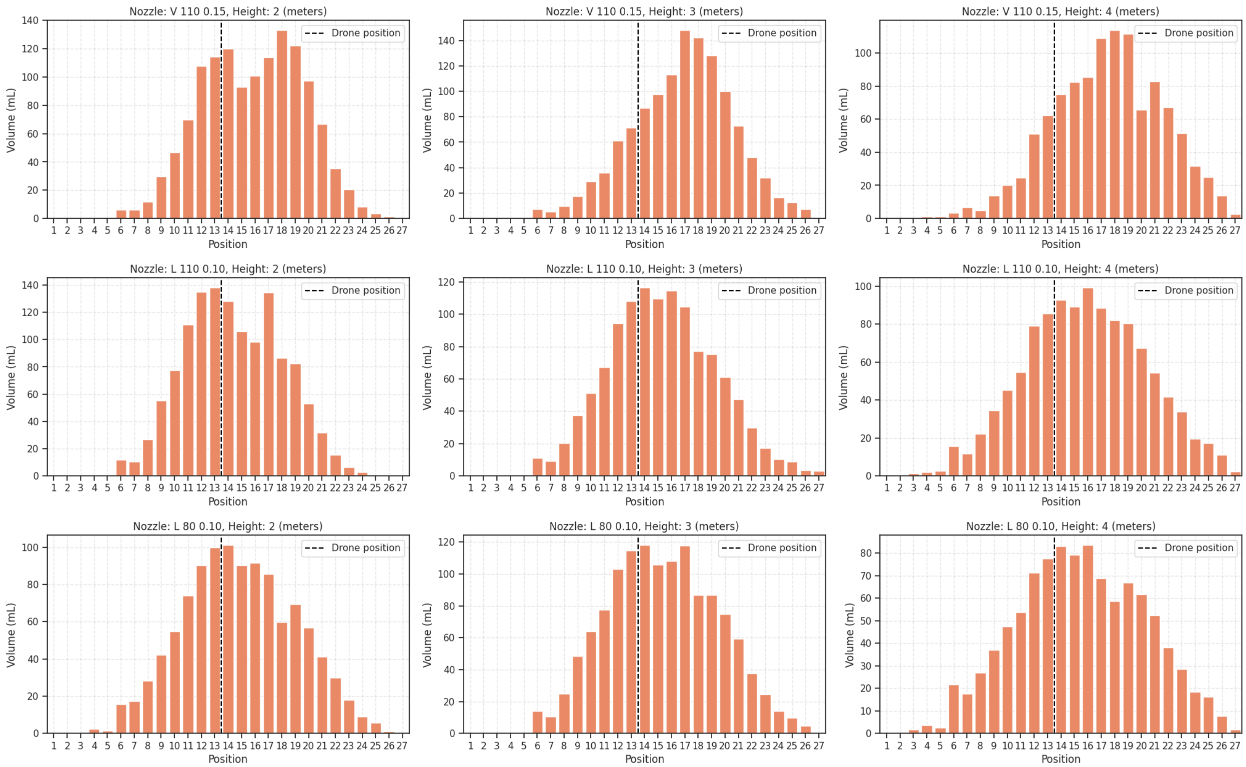
The spray drone is susceptible to droplet drift when the wind speed increase. Wind speed above 5 km h^{-1} affect negatively the droplet size below 200 μm influencing the drift from target (Liu et al. 2021; Bergeron, 2003). The influence of the wind and vortex contributed with the droplet drift and the water capture by the cups decreased mainly when this effect were combine with high flight height. These effect can be observed in the figure 2 where the height of 4 meters show the low values of volume (mL) and the 2 meters height the highest values were observed except to T7.

Figure 2. Volume (mL) range measure in the cups combining different heights and nozzles.



In the volumetric distribution test the different nozzles showed different behaviors. The low wind speed found during the test was able to change the direction of the application. The cups in the right position showed the major volume (mL) than the cups in the left of the volumetric distribution table. These difference in the position of the cups can be attributed the wind speed during the application and the downwash effect caused by the drone vortex. The wind effects increase in the high flight height what can be observe in the T3, T6 and T9 (Figure 2 C, F and I). When this effect increase the potential of droplet drift increase and the droplet size need be increase to avoid the droplet drift. The drone propellers contributed with downwash effect, this effect launch the droplet to down and when the airflow with the droplet arrive in the surface the flow have different direction. This different flow direction may carry the droplet to outside the table and this product will not be measure in the cups. These same effects was observe in others studies, the drone vortex effect when the drone is hovering is character as helical and when the droplet arrive next the surface there is turbulent mist with different droplet (Wen et al. 2019). The influence of downwash decrease the quality of uniformity distribution in one meters flight height and when change the flight height to 3 meters the uniformity distribution increase 10% (Yallapa et al. 2023). Similar results were observed in this work at 3 meters height all nozzles showed a good performance in the volumetric distribution.

Figure 3. Results obtained in volume (mL) in the volumetric distribution test.

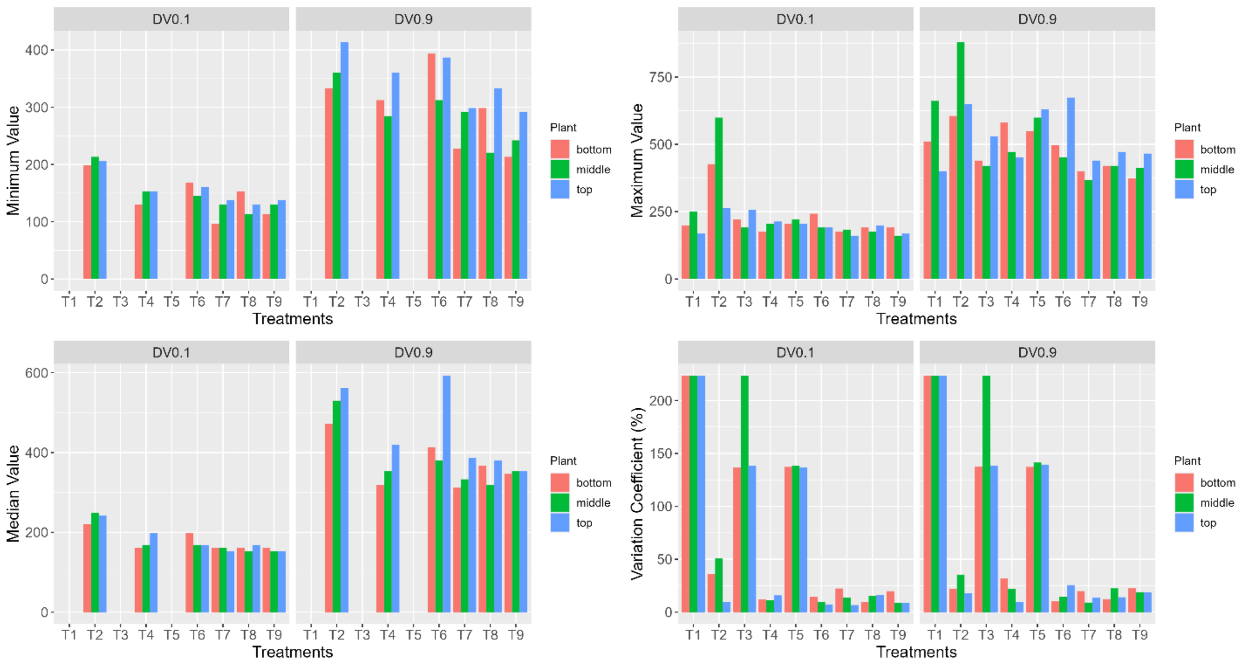


The 2 meters flight height and using the nozzle 0.15 ga min^{-1} (0.57 L min^{-1}) low values were found in the cups position 14, 15 and 16. The attack angle of each nozzle influence in the quality of the application. The nozzle 110° 0.15 when close the coffee plants not have a good performance because the position of each nozzle limit the application. In a low flight height as 2 meters, there is a gap between the distance the nozzle that not receive the correct application. This gap occur because each nozzle is distance 1.5 meters and in the low flight height not have overlap between the nozzles. Specially in the coffee plants that have a triangular canopy low flight height below 2 meters may be contribute with this effect and the product will be apply in the side of each plant not arriving in the center. The crop protection of coffee plants the bottom and top parts of the plant need be coverage to increase the efficiency and quality of the application (Souza et al. 2022). The results reported by Zheng et al. (2018) simulate the airflow dynamics caused by drone propellers show that the when increase the height the uniformity, coverage and spray penetration decrease the quality. On the other hand, Souza et al. (2022) analysis different flight heights in coffee plants observed that the 2.5 and 3 meters flight height contributed with a good distribution of droplet and a high coverage in the top and bottom parts of the plant. The low overlap in low flight height was also reported to Yallappa et al. (2023) the flights in 1 meters decrease the quality of uniformity distribution and in the middle of the volumetric distribution table the values observed were low, similar the observed in this work in the low flight height.

Despite the flight height above 4 meters contribute with droplet drift at ideal weather conditions the use of droplet with VMD fine can improve the spray width. The 110° and 0.80° 0.10 nozzles (figure X) at 2 meters the spray width was 3.72 and 4.31 meters, at 3 meters the spray width was 4.12 meters and when the flight height was change to 4 meters the spray width change to 4.90 meters. Nozzles with fine droplet (VMD 106 – 205 µm) had the capacity of increase the spray width different observed for coarse droplet (green nozzle) that showed difference in the spray width only for 2 meters height. The fine droplet are easily carry by the wind and the drone vortex, this effect directly impact in the penetration in the plants as well in the droplet drift. For cultures as coffee, a big spray width not affects directly because in a big spray width the droplet are susceptible to drift and the droplet penetration decrease.

After the volumetric distribution test the treatments were apply in the coffee plants. The descriptive analysis was performance and the result for each variable showed in the figure 4. The treatments T1, T3 and T5 for both parameters ($Dv_{0.9}$ and $Dv_{0.1}$) the minimum values were zero, consequently the median and CV (%) were affected. The median values in this treatments were zero and in the CV (%) the zero values influence in the calculate obtained high CV (%).

Figure 4. Descriptive analysis for variables diametric volume ($Dv_{0.9}$ and $Dv_{0.1}$) for each part (bottom, middle and top) of coffee plants.



Despite these treatments not showed a good result in CV (%) and median the maximum values to $Dv_{0.1}$ showed similar results with exception of T2. The $Dv_{0.9}$ the maximum values were observe in T2 for middle and bottom whereas the highest values for top were observe in the treatment T6. Amount the nozzles the conic (T7, T8 and T9) independent of flight height showed similar results with low values of CV (%).The $Dv_{0.9}$ and $Dv_{0.1}$ represents the droplet diameter at which 90% and 10% of the volume of spray liquid consists of droplets smaller than or equal this value. These results revealed that fine droplet have high capacity in penetrate in the coffee canopy especially when conic nozzle were use. The low angle (80°) when compare with high angle (110°) exhibited that the droplet are concentrate in a small area (spray width) and the potential to arrive in all coffee parts (top to bottom) increase with the same quality and droplet diameter.

The variance analysis (Table 4) performance in each treatment show that significance (^{ns}) only for the interaction in all parts of the plant. The high CV (%) observed in the middle part revealed that in this region can be found high variation of droplet diameter. This high variation of droplet diameter occur due to the transition of medium and fine droplet to middle part of the plant, whereas in the top and bottom the pattern of the droplet diameter are more homogeneous. At the top, the droplets are uniform as described by the manufacturer. However, when it move towards the bottom due to increased distance a higher proportion of droplets reaching the target can be classified as fine with less variation observed in droplet diameter.

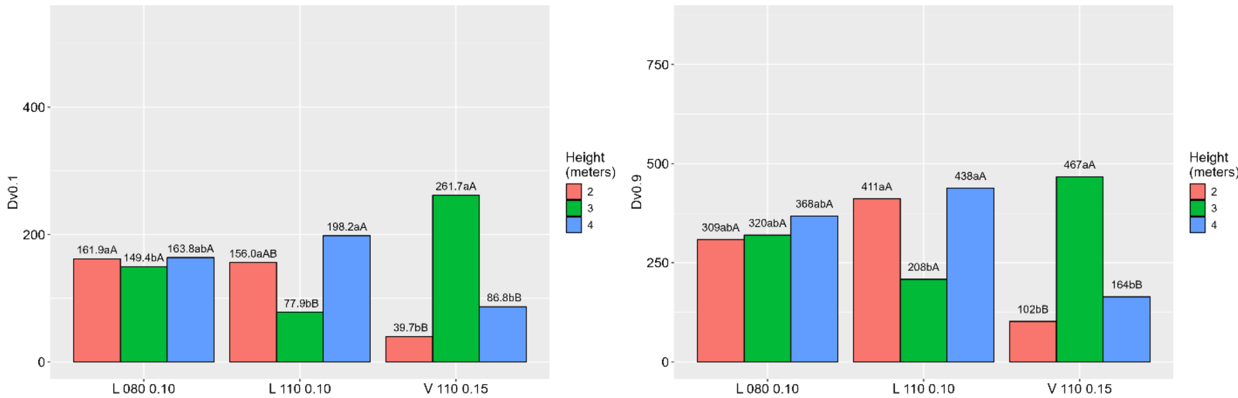
Table 4. Variance Analysis for diametric volume (Dv) 90 and 10% in the bottom part of the coffee plant.

	SV	DF	$Dv_{0.1}$		$Dv_{0.9}$	
			F-values	Pr>F	F-values	Pr>F
Bottom	Nozzle (N)	2	2.184	0.128^{ns}	0.632	0.538^{ns}
	Height (H)	2	0.644	0.532^{ns}	1.516	0.233^{ns}
	Block	1	4.808	0.035^{ns}	1.834	0.184^{ns}
	H X N	4	5.737	0.0012^{*}	8.006	0.00011^{*}
Middle	Nozzle (N)	2	0.176	0.839^{ns}	0.823	0.447^{ns}
	Height (H)	2	2.981	0.0637^{ns}	1.605	0.215^{ns}
	Block	1	0.386	0.538^{ns}	4.522	0.041^{ns}
	H X N	4	8.847	0.000479^{*}	6.746	0.0004^{*}
Top	Nozzle (N)	2	1.298	0.285^{ns}	3.034	0.062^{ns}
	Height (H)	2	1.199	0.313^{ns}	1.620	0.212^{ns}
	Block	1	3.786	0.059^{ns}	7.118	0.015^{ns}
	H X N	4	8.830	0.000049^{*}	8.242	0.000085*
	VC bottom (%)		49.04		48.61	
	VC middle (%)		57.03		53.88	
	VC top (%)		43.63		43.51	
	Mean bottom		143.92		309.61	
	Mean middle		142.79		303.08	
	Mean top		140.84		343.39	

In all parts of the plant the interaction was significate ($p<0.05$). The mean result for this test showed in the figure 5 with the Tukey's test ($p<0.05$). The mean values following the same lowercase letter not differ and compare the nozzle type in the same flight height and the values following the same uppercase letter not differ and compare the flight height in each nozzle. The conic and flatten nozzle (080 and 110 0.10) not differ in the bottom part at 2 meters height, but in the V 110 0.15 the values for this parameters were low. This value indicated that the droplet diameter were very small increased the drift potential and decreased the coverage area. The low values in this treatment occur because the minimum values observed were zero influencing in the mean values, as well observed in T3 and T5. In another hand, this nozzle not show a good quality different of observed for conic and flatten nozzle. These nozzles produce fine droplet and due this fact, the target in the bottom part can be reach. This effect also observed in citrus trees in the bottom layer the VC (%) present the high values with low droplet density (Tang et al. 2018). In papaya, the use of hollow cone increased the coverage, density, uniformity and volumetric median diameter of droplet in the lower layer when compare with XR110015. The authors revealed that the XR110015 nozzle show good result for upper layer, similar to observed for this work (RIBEIRO et al. 2023).

The $Dv_{0.9}$ result for different flight height in L080010 nozzle not differed ($p<0.05$).The similar results observed for bottom layer for (T1, T3 and T5) were observe for middle and top layer in both parameters. The zero minimum values (Figure 4) increase the VC (%) (Figure 4) and presented low mean values at 2 and 4 meters height (Figure 5B). Thus, the nozzle L110010 in 3 meters (Figure 5) and V110015 in 2 and 4 meters (Figure 5) not showed good means values for both parameters in the bottom, middle and top layers. The low and high flight height using the nozzle L110015 (coarse droplet) revealed that the droplet not arrive in the target, but when combine with correct height (3 meters) satisfactory result can be obtained using this nozzle. Nevertheless, the use of this nozzle restricted to products that not require a high coverage during the application and the big droplet produce by this nozzle decrease the potential of drift.

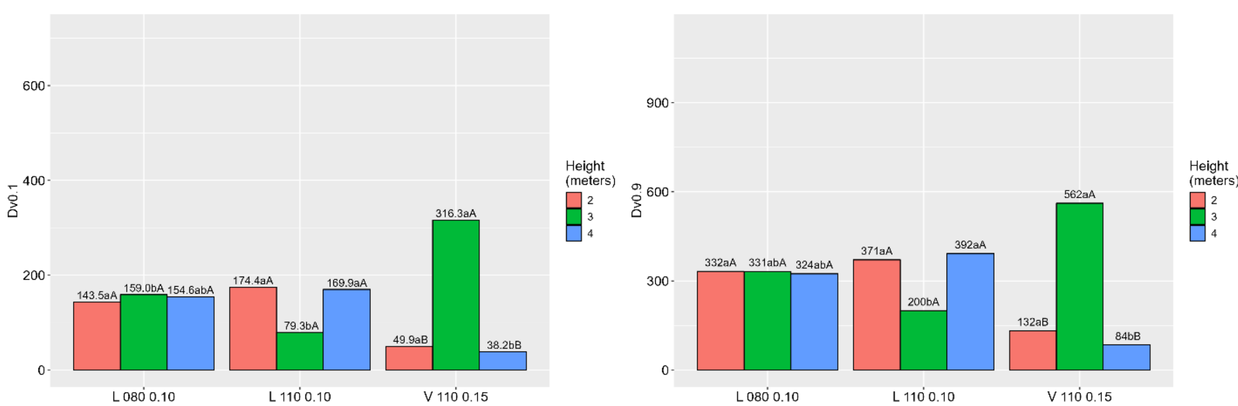
Figure 5. Mean values of volumetric diameter 90% ($Dv_{0.9}$) and 10% ($Dv_{0.1}$) and result for Tukey test bottom part of coffee plants



The L110010 and L080010 at 4 meters height presented similar mean values not differing statistically. The pulverized volume presented 90% of the droplets below 438 and 398 µm, respectively. In 4 meters height the droplet are susceptible to drift if the wind speed increase the application, but the fine droplet produce by the nozzles can arrive in the target easily.

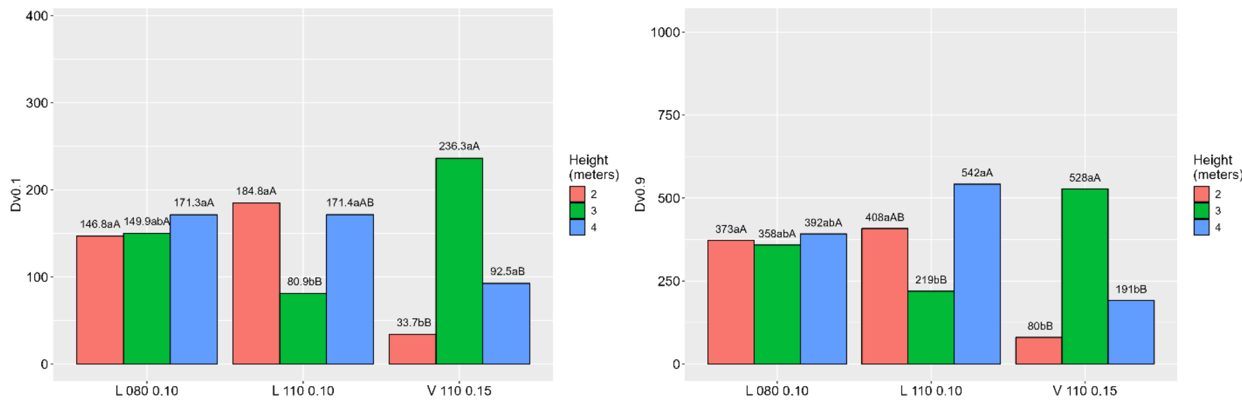
The middle layer (Figure 6) the nozzle L080010 not differed ($p<0.05$) amount the height at both parameters. The nozzle L110010 at 2 and 4 meters for $Dv_{0.1}$ the results were similar not differing ($p<0.05$) and the three meters height the mean values were lower for both parameters ($Dv_{0.1}$ and $Dv_{0.9}$). The lower values in this treatment and the nozzle V110015 at 2 and 4 meters height present the same trouble found in the bottom and top, the DropScope system detected less droplet in the water sensitive papers and the values were low. The nozzle V110015 only 3 meters height show the high mean values (316 and 562 µm) for diametric droplet volume in both $Dv_{0.1}$ and $Dv_{0.9}$. When compare the same height the V110015 produce droplet with high diameter volumetric than the other nozzles.

Figure 6. Mean values of volumetric diameter 90% ($Dv_{0.9}$) and 10% ($Dv_{0.1}$) and result for Tukey test middle part of coffee plants



The top layer (Figure 7) the $Dv_{0.1}$ and $Dv_{0.9}$ mean values (Figure 5) for L080010 not differed significantly ($p<0.05$). The same parameters for L110010 not differed between the flight height of 2 and 4 meters with the means for $Dv_{0.1}$ 184 and 171 µm and the mean values for $Dv_{0.9}$ 408 and 542 µm. The L110015 presented and 3 meters height presented the high mean values (236 µm and 528 µm) for $Dv_{0.1}$ and $Dv_{0.9}$. In low flight height, the L110010 presented the high volumetric diameter when the flight height increase to 3 meters the V110015 showed the best result in volumetric diameter.

Figure 7. Mean values of volumetric diameter 90% ($Dv_{0.9}$) and 10% ($Dv_{0.1}$) and result for Tukey test top part of the coffee plants



The effect observed at different layers also had reported in papaya where the XR110015 nozzle presented high values on overage, density, and deposition of drops in the middle and upper layer and the MGA015 (conic) high values in the lower layer (Ribeiro et al. 2023). The low flight height (1.2 meters) in citrus trees presented statistical difference between the upper and lower layers but the middle and the lower not statistical difference were observe. The structure of the canopy influence directly in the droplet density in the citrus trees and the author concluded that in canopy inverted triangle trees the droplet density increase 48% (Tang et al. 2018). The same effect observed in the above studies was report in sugarcane the author describe that the droplet above 300 µm had difficult in penetrate in the canopy and drops lower than 50 µm easily can be drift (Zhang et al. 2020). The canopy of each plant had different effects during the application, the coffee Arabica showed high number of leaves what can difficult the penetration. This effect knew as "umbrella" was observed for Ribeiro et al. (2018), Tang et al. (2018) and Li et al. (2023). In this study, the coffee Arabica genotypes had 3 years old but in general, coffees with high age present high height and number of leaves. However, the influence of the age and morphology structure of coffee arabica have not yet been study.

Despite the efficiency of each nozzle in each layer (bottom, top and middle), the quality and effectiveness of pulverization must be maintained across the entire plant. Select the nozzle based on the target in the field to achieve the required coverage. Fine droplets produced by the L110010 and L080010 nozzles can ensure optimal coverage. The conic nozzle's narrow spray width increases droplet penetration and reduces product drift during application. If a wider spray width needed, the L110010 nozzle is suitable. For applications that do not require high coverage and penetration, the V110015 nozzle is a better choice, as it further minimizes droplet drift. The nozzle type and angle was have study by Yu et al. (2020) and the author concluded that XR and TP nozzles most common in agriculture have a high drift potential. The authors presented that the same nozzles when change the angle 10° to 20° can decrease the drift potential. The study and combination of different flight parameters and flight angles can help the mountain coffee farmers in increase the quality during the application. In high speed the drone change the flight and nozzle angle what can decrease the quality and increase the droplet drift.

However, the sprayer drones have a wide application for farmers and the agriculture sector. The automatic flight can decrease the contact with toxic products, decrease the water use and increase the application quality (Ribeiro et al. 2018; Gertis and Karampekos, 2022). In the present study the result show that the potential diseases, insect and weeds can be control choose the best option according to target in the field. The study still avoided to evaluate the performance of the different nozzles and flight height in the volumetric diameter in bottom, middle and top of *Coffee Arabica* plants.

Conclusion

The present study show that the L080010 nozzle in all flight height show a good performance.

This nozzle show a low VC (%) and volumetric diameter around 150 µm that represent a good coverage and penetration in the canopy of the coffee Arabica plants. The fan flat nozzle L110010 had a good performance in high flight height and presented a large spray width different to observed for V110015. The last nozzle show good performance in 3 meters height the mean volumetric diameter was the biggest and the top of the plants were observe the best results. Still the high VC (%) values were found in this nozzle that revealed the high variability in produce droplet with different volumetric diameters.

The volumetric distribution test the flight height of 2 meters show small spray width and high volumes collect in the cups, whereas at 4 meters height present less volume collect in the cups and an increase in the spray width of 19% was observed. The low volume occur due the downwash effect during the flight the airflow generate by drone propellers launch the small droplet to outside the table and this values not are collect.

Acknowledgments

The authors acknowledge the Minas Gerais State Research Support Foundation (FAPEMIG), the Coordination of Superior Level Staff Improvement (CAPES), and the Brazilian National Council for Scientific and Technological Development (CNPq) for their financial support during the development of this research and the support of the students involved.

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