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Air assistance and spray volumes on the coverage, droplet density, and spray deposition in melon plants

Larissa de Oliveira Fontes[1]*, Francisco Cláudio Lopes de Freitas[2], Mauri Martins Teixeira[2], Ítalo Nunes Silva[3], Robson Willian Nunes Lopes[1]

[1]Universidade Federal do Piauí, Bom Jesus-PI, Brazil
[2]Universidade Federal de Viçosa, Viçosa-MG, Brazil
[3]Universidade Federal do Semi-Árido, Mossoró-RN, Brazil
*Corresponding author, e-mail: larissa@ufpi.edu.br

Abstract

This study aimed to evaluate the influence of air assistance on the coverage, droplet density, and deposition of the mixture volume applied to melon plants. The experiment was conducted in a completely randomized design set up in a 4 x 4 x 2 factorial arrangement referring to four spray nozzles (AVI 110-02, TT 110-02, AVI 110-03, and TT 110-03), four mixture volumes (140, 200, 300, and 400 L ha^{-1}), and two application techniques (with and without air assistance), at a constant working pressure of 300 kPa. Deposition analysis was performed by using a bright blue dye, and the coverage pattern and droplet density were analyzed using water-sensitive paper tags attached to the adaxial and abaxial surfaces of the leaf blade of melon plants. Air assistance in the spray boom improved the deposition of the mixture sprayed on melon leaves only when using nozzle TT 110-02, whereas nozzles TT 110-03, AVI 110-02, and AVI 110-03 were not influenced by air assistance. Coverage and spray deposition on the adaxial leaf surface increased with the mixture volume applied for all nozzles. The technique using water-sensitive tags is not efficient to evaluate droplet density when working with high spray volumes.

Keywords: *Cucumis melo* L., droplet spectrum, spraying

Introduction

The melon crop (*Cucumis melon* L.) stands out as one of the main vegetables grown worldwide. In 2019, melon production in Brazil was estimated at 41 million tons (IBGE, 2020), with the Northeast region of the country accounting for more than 95% of the national production, mostly in the States of Ceará and Rio Grande do Norte (IBGE, 2020). This growing melon production is possible due to outstanding climatic conditions that include high temperatures (>28 °C), low rainfall rates (<600 mm/year), and abundant light availability, favoring higher fruit quality and yield (Souza Linhares et al., 2020).

However, the climatic conditions of this region, characterized by high temperatures and low relative air humidity, in addition to frequent winds, hinder the fast application of phytosanitary products, essential to control pests, diseases, and/or weeds through spraying (Ferreira, et al., 2013). As a result, this scenario requires the use of technologies that minimize the losses of such products by drift while facing problems such as efficacy reduction due to direct loss and the contamination of the environment and neighboring sensitive crops (Muziu et al., 2019; Moraes et al., 2019).

One alternative to minimize these problems consists of using air-assisted spray booms. However, studies using this technology have yielded controversial results (Sasaki et al., 2019; Kullmann et al., 2020). Air assistance can favor droplet deposition inside the plant. However, the good application of a product depends on factors such as choosing the right product, calibration and regulation of the sprayer, the skill of the operator, and the meteorological conditions at the moment of application (Sasaki et al., 2016).

In addition to the coverage percentage, the droplet density is also determined, among other factors, when it is necessary to determine spray deposition on

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leaves or other plant parts (Pereira et al., 2022). Another factor to be considered is the choice of spray nozzles responsible for determining the flow rate, the uniformity of distribution over the biological target, and the formation of droplet populations, which should show a compatible diameter with the finality of the application (Amler et al., 2021).

Negrisole (2018) stated that each nozzle has an individual deposition characteristic, which is specific for each use condition. According to Muziu et al. (2019), spray nozzles and working pressures should not be recommended based only on parameters of the population of droplets suspended in the air, but also by considering parameters that quantify the extent of spray deposits on the targets. Therefore, seeking improvement alternatives in air distribution and generation in manually-operated equipment could also be necessary, aiming at their use to improve the application of liquids through spraying (Ruas et al., 2013).

From this perspective, this study aimed to evaluate the influence of air assistance on the coverage, droplet density, and deposition of chemical mixtures in the leaf blade of melon, through applications with different spray nozzles and mixture volumes.

Material and Methods

The present study was conducted in a commercial yellow melon plantation, using the melon hybrid Goldex irrigated by dripping, with a spacing of 2.0 m between rows and 0.30 m between plants, in the municipality of Tibau-RN, located at the coordinates 04°50'06" S, 37°15'31'' W, and at an elevation of 5 m a.s.l. According to the Köppen classification, the climate is classified as a hot and dry steppe, with a rainy season during summer that can extend until autumn (Carmo Filho et al., 1987).

The experimental design used was completely randomized and set up in a 4x4x2 factorial arrangement referring to four spray nozzles (AVI 110-02, AVI 110-03, TT 110-02, and TT 110-03), four mixture volumes (140 L ha^{-1}, 200 L ha^{-1}, 300 L ha^{-1}, and 400 L ha^{-1}), and two application methods (with and without air assistance), with four replications.

A Falcon Vortex® sprayer with a 600-L tank was used in the experiment. The device was equipped with a 14-m long spray boom with nozzles spaced 0.50 m and above the target by 0.50 m. The mixture volumes were obtained based on variations in the tractor's speed: for nozzles AVI 110-02 and TT 110-02, the tractor operated at 6.7, 4.7, 3.1, and 2.3 km h^{-1}; for nozzles AVI 110-03 and TT 110-03, the speeds were 10, 7.0, 4.7, and 3.5 km h^{-1}, thus obtaining the application volumes of 140, 200, 300, and 400 L ha^{-1}, respectively, at a constant pressure of 300 kPa.

The meteorological conditions were monitored during the application using a digital anemometer (Sonambra - Lutron LM-8000®). The temperature, relative air humidity, and wind speed means at the moment of application were 31.3 °C, 60.5%, and 3.6 m s^{-1} respectively.

The quantitative evaluation of spray deposits under different operational conditions was performed using a bright blue food dye (Palladini et al., 2005) in an aqueous solution (3,000 mg L^{-1}). Four experimental plots consisting of three rows 30-m long were used, whereas the useful plot corresponded to the central row of each plot. Five central plants were selected to be sampled in each experimental unit. Then, after spraying was performed in each plot, five leaves were collected from the upper part of each plant chosen in the central region of the melon planting row. These leaves were then individually packed in plastic bags and stored in an expanded polystyrene cooler box.

Subsequently, the leaf samples were sent to the laboratory. Then, each plastic bag received 50 mL of distilled water and was stirred for 30 seconds, aiming to remove the dye from the target leaves. The solutions obtained after washing the leaves (water and dye) were analyzed in a Coleman® spectrophotometer (D 33), at the wavelength of 630 nm, according to Palladini et al. (2005).

The concentration of the spray deposits (mg L^{-1}) was determined based on the linearity calibration curve obtained by relating the absorbance read in the spectrophotometer and the concentrations of bright blue dye removed from the leaves and obtained through dilutions of the solution applied in the field (**Figure 1**).

After washing, the leaf area of the leaves was measured with a LICOR Leaf Area Meter, MODEL 3100. Then, the volume retained by the target was determined

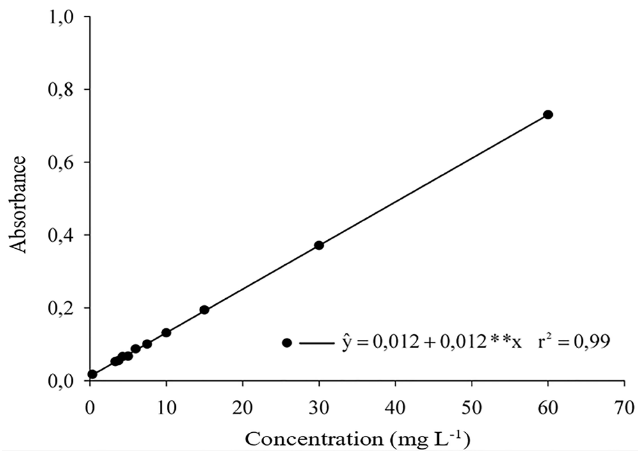

Figure 1. Linearity curve obtained by absorbance after diluting the mixture applied to melon.

based on the concentration of the mixture's dye applied in the field and the dilution volume of the samples. With these results, the next step consisted of dividing the total volume retained in the target by the leaf area from which the leaf was removed, thus obtaining the amount in µL cm^{-2} per leaf.

Four experimental plots formed by three rows 30 m long were used for the coverage and droplet density analyses in the different operational conditions, with the useful plot consisting of the central row of each plot. In each experimental unit, 10 water-sensitive paper labels were attached to the adaxial surface of the leaf blade of melon leaves, in the central part of the plant row, and five to the abaxial surface, totaling 45 tags per experimental unit. Immediately after application, the tags were collected, packed in paper bags, and taken to the laboratory the be digitized using a camera for later analysis of the coverage (quantification of the leaf area covered by the droplets) and population density (expressed as droplets per cm^2) using the software "Image Tool®" (Image Tool, v. 2.0). The data were subjected to analysis of variance and, in cases of significance, the qualitative data were compared by Tukey's test at 5% of probability, whereas the quantitative data were subjected to regression analysis. The choice of the models took into account the explanation of the phenomenon, the significance of the mean square of the regression, and the estimates of the parameters. The data referring to droplet density on the abaxial surface were transformed into $(x+0.5)^{0.5}$ (Banzatto; Kronka, 2006), aiming to meet the assumptions of the analysis of variance.

Results and discussion

There was significance for the triple interaction between the spray nozzles (AVI 110-02, TT 110-02, AVI 110-03, and TT 110-03), the mixture volumes applied (140, 200, 300, and 400 L ha^{-1}), and the application techniques (with and without air assistance) for all variables studied, e.g., spray deposition, coverage percentage on the adaxial and abaxial surfaces, and droplet density on the adaxial and abaxial surfaces.

Spray deposition increased as the volume applied increased for all spray nozzles evaluated, regardless of the use or not of air induction (**Figure 2**). These findings corroborate Sousa Christovam et al. (2018), who stated that higher volumes provide larger spray deposits at the same application speed, even though excessive volumes can cause runoff, especially under the effect of air assistance, which can tilt the leaves. There was a positive effect of air induction only for nozzle TT 110-02 at the application volumes of 200, 300, and 400 L ha^{-1} (**Table 1**).

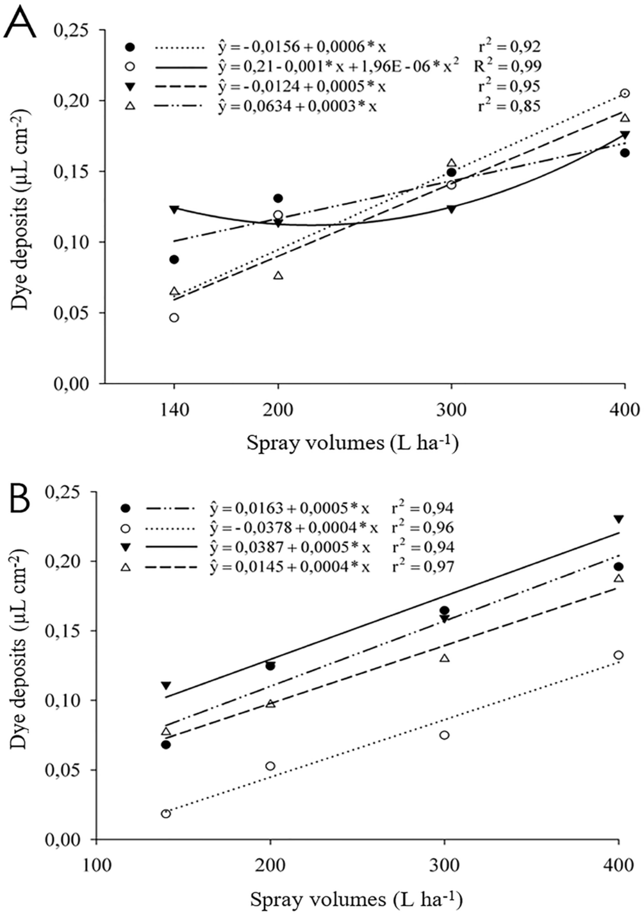

Figure 2. Dye deposits on the upper leaves of melon plants as a function of the spray volumes and spray nozzles AVI 110-02 (●), TT 110-02 (○), AVI 110-03 (▼), and e TT 110-03 (△) with (A) or without (B) air assistance

Table 1. Mean dye deposition values on the upper leaves of melon plants (µL cm^{-2}) as a function of application volumes and spray nozzles within each application technique level (with or without air assistance)

Mixture volume applied	Spray nozzles	Application techniques	
		With air	Without air
140 L ha^{-1}	AVI 110-02	0.09 Aab*	0.07 Ab
	TT 110-02	0.05 Ac	0.02 Ac
	AVI 110-03	0.12 Aa	0.11 Aa
	TT 110-03	0.06 Abc	0.08 Aab
200 L ha^{-1}	AVI 110-02	0.13 Aa	0.12 Aa
	TT 110-02	0.12 Aab	0.05 Bb
	AVI 110-03	0.11 Aab	0.13 Aa
	TT 110-03	0.08 Ab	0.10 Aa
300 L ha^{-1}	AVI 110-02	0.15 Aa	0.16 Aa
	TT 110-02	0.14 Aa	0.07 Bb
	AVI 110-03	0.12 Ba	0.16 Aa
	TT 110-03	0.15 Aa	0.13 Aa
400 L ha^{-1}	AVI 110-02	0.16 Ba	0.20 Aab
	TT 110-02	0.21 Aa	0.13 Bc
	AVI 110-03	0.18 Ba	0.23 Aa
	TT 110-03	0.19 Aa	0.19 Ab
CV (%)		18.83	

*Means followed by the same uppercase letters in the rows compare spray nozzles between application techniques, and means followed by the same lowercase letters in the columns, for each volume, compare spray nozzles within each application technique by Tukey's test at 5% of significance.

When comparing the spray nozzles at each volume applied (Tabela 1), nozzle TT 110-02 at the mixture volume of 140 L ha^{-1} obtained a lower deposition mean in relation to the other nozzles, in the applications with or without air assistance. At the volume of 200 L ha^{-1}, the largest deposits were observed in nozzles AVI 110-02, TT 110-02, and AVI 110-03 with air assistance. On the other hand, without air assistance, the largest deposits occurred with nozzles AVI 110-02, TT 110-03, and AVI 110-03. There was no difference between spray nozzles when working with air assistance at the volumes of 300 and 400 L ha^{-1}. When air assistance was not used at these same volumes, the nozzle TT 110-02 obtained lower mean values compared to the others. The nozzles with air induction (AVI 110-02 and AVI 110-03) showed the largest droplet spectrum, which, according to Vallent & Tinnet (2013) occurs because of the Venturi effect, which makes the droplets thicker, with air bubbles inside, and being more adequate for application with a spray boom, without air assistance, than deflector nozzles (TT 110-02 and TT 110-03). These observations occurred because of the climatic conditions at the moment of application, with high temperatures, low air humidity, and the occurrence of winds. When air assistance was employed, the deposition showed lower variation between the evaluated nozzles (Table 1). Ruas, Balan & Abi Saab (2011) studied a spraying technique in coffee and concluded that air assistance generated by a backpack turbo-atomizer resulted in better coverage of the inner and middle-positioned leaves in coffee plants, improving the deposition and coverage levels in these positions.

The coverage provided by the nozzles on the adaxial surface of melon leaves, regardless of the application techniques with (**Figure 3**A) and without air assistance (Figure 3B) in the spray boom, increased with the volume applied. The increase in coverage can be achieved by increasing the mixture volume applied, even when using spray nozzles that generate larger droplets (Silva et al., 2014), e.g., air-induced nozzles (AVI 110-02 and AVI 110-03). In this study, the variation in the mixture's volume was performed by varying the nominal flow rate of the spray nozzles and the tractor's speed. According to Volpe et al. (2012) and Contiero et al. (2018), small variations in the mixture's volume can be achieved by changing the height of the spray boom and the working pressure, or even by changing the spacing between nozzles. However, in order to obtain greater variations, it is necessary to replace the spray nozzle with others of higher or lower flow rates, depending on the variation aimed.

For spraying with products that require low coverage rates, e.g., the application of herbicides with translocation via symplast (systemic) during post-emergence and herbicides during pre-emergence, the coverage obtained at the smaller mixture volumes (140 and 200 L ha^{-1}) was satisfactory for all nozzles evaluated. However, products that work through contact and require more coverage, since there is no redistribution in the plant, demand larger volumes, especially under the environmental conditions of the region where the study was conducted, with high temperatures and abundant winds. In the region, the use of nozzles that produce small or medium droplets can lead to drift.

Another option to improve the coverage of the target by using larger droplets is the addition of surfactant adjuvants to the mixture, thus improving the adherence and spacing of droplets on the target by reducing the superficial tension of the solution and the angle of contact with the surface, consequently increasing coverage (Prado et al., 2015; Cunha et al. 2020). When comparing

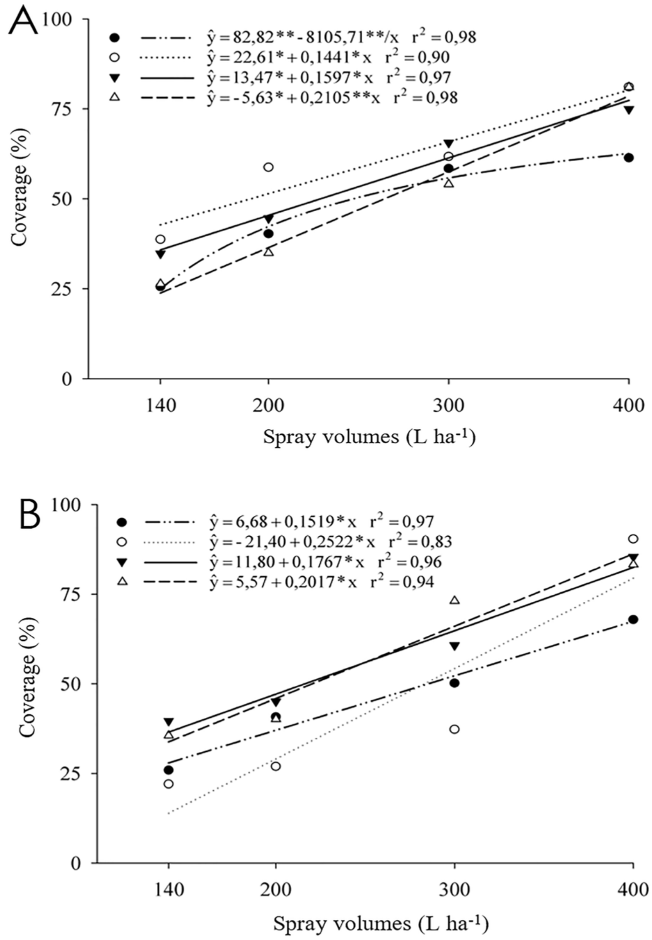

Figure 3. Coverage percentage on the adaxial surfaces of melon leaves as a function of application volumes for spray nozzles AVI 110-02 (●), TT 110-02 (○), AVI 110-03 (▼), and TT 110-03 (Δ) with (A) or without (B) air assistance.

the effect of air assistance in each spray nozzle and the mixture volume on the coverage of the adaxial surface of melon leaves (**Table 2**), there was positive effect of this technique when using nozzle TT 110-02 at the volumes of 140, 200, and 300 L ha^{-1}.

These observations could result from the association of the smaller droplet spectrum produced by this nozzle in relation to air-induced nozzles (AVI 110-02 and AVI 110-03), associated with the faster travel speed of the tractor in relation to the nozzles with higher nominal flow rate (TT 110-03 and AVI 110-03), especially at lower mixture volumes.

In the unfolding of the spray nozzles at each mixture volume applied, it was observed that, when working with air assistance, despite the small variation between the nozzles evaluated, nozzle TT 110-02 stood out with a good coverage at all volumes studied (Table 2), performing better than the others, especially when applying 200 L ha^{-1}. However, without air assistance, this nozzle showed the lowest coverage indices for the mixture volumes of 140, 200, and 300 L ha^{-1}. The nozzles with higher nominal flow rates (AVI 110-03 and TT 110-03) stood out when the smallest mixture volume was applied (140 L ha^{-1}) without air assistance, which may have occurred due to the faster travel speed, which reduces the oscillation of the boom in uneven terrains, in addition to wind-related effects associated with travel speed.

Baesso et al. (2014) verified positive effects after increasing the mixture volume and air assistance in the spray boom on the coverage of labels positioned on lower leaves of common bean plants, both with JA-4 empty conical jet nozzles and AXI-110-04 flat jet nozzles.

Similar to the adaxial surface, the factors referring to spray nozzles, spray volumes applied, and application techniques interacted for the coverage of the abaxial surface of melon leaves. However, the indices achieved by all evaluated nozzles, regardless of air assistance, were very low, with values always below 5% and without a behavioral trend, not allowing the adjustment of any response function for this variable. (**Table 3**) shows that, despite the significant differences in the applications with or without air assistance between nozzles within each mixture volume, the levels achieved were not satisfactory.

The low coverage on the abaxial surface shows the high difficulty in making the drops reach this side of the leaves, mainly due to the flat position and the size of the leaves, about 15 cm long. Thus, in order to reach targets that are lodged on the abaxial surface of melon leaves, it is necessary to use products that have translaminar translocation.

There was no adjustment of any response function for droplet density on the adaxial surface for the nozzles evaluated as a function of the spray volumes applied in the presence of air induction (**Figure 4**A). This may have occurred due to the spreading of the drops on the water-sensitive paper by the air jet, causing overlap and giving the impression of having fewer drops of larger diameters, especially in larger volumes, a fact that can be seen in

Table 2. Percentage of coverage on the adaxial surface of melon leaves as a function of application volumes and spray nozzles within each application technique level (with or without air assistance)

Mixture volume applied	Spray nozzle	Application techniques	
		With air	Without air
140 L ha^{-1}	AVI 110-02	25.6 Aa	25.9 Ab
	TT 110-02	38.7 Aa	22.0 Bb
	AVI 110-03	34.8 Aa	39.7 Aa
	TT 110-03	26.3 Aa	35.6 Aab
200 L ha^{-1}	AVI 110-02	40.3 Ab	40.8 Aab
	TT 110-02	58.8 Aa	26.9 Bb
	AVI 110-03	44.6 Aab	45.1 Aa
	TT 110-03	34.9 Ab	40.1 Aab
300 L ha^{-1}	AVI 110-02	58.4 Aa	50.2 Abc
	TT 110-02	61.7 Aa	37.3 Bc
	AVI 110-03	65.6 Aa	60.8 Aab
	TT 110-03	54.0 Ba	73.1 Aa
400 L ha^{-1}	AVI 110-02	61.4 Ab	67.9 Ab
	TT 110-02	81.1 Aa	90.4 Aa
	AVI 110-03	74.9 Aab	85.4 Aa
	TT 110-03	81.1 Aa	83.3 Aa
CV (%)	24,81		

*Means followed by the same uppercase letters in the rows compare spray nozzles between application techniques, and means followed by the same lowercase letters in the columns, for each volume, compare spray nozzles within each application technique by Tukey's test at 5% of significance.

Table 3. Percentage of coverage on the abaxial surface of melon leaves as a function of application volumes and spray nozzles within each application technique level (with or without air assistance)

Mixture volume applied	Spray nozzle	Application techniques	
		With air	Without air
140 L ha^{-1}	AVI 110-02	0.03Aa*	0.01Ab
	TT 110-02	2.26Aa	0.03Ab
	AVI 110-03	0.09Aa	0.03Ab
	TT 110-03	0.79Ba	4.21Aa
200 L ha^{-1}	AVI 110-02	0.10Ab	0.08Aa
	TT 110-02	0.49Ab	0.28Aa
	AVI 110-03	0.15Ab	0.04Aa
	TT 110-03	3.98Aa	0.21Ba
300 L ha^{-1}	AVI 110-02	0.06Aa	0.06Ab
	TT 110-02	0.31Ba	4.15Aa
	AVI 110-03	0.11Aa	0.08Ab
	TT 110-03	1.89Aa	0.19Ab
400 L ha^{-1}	AVI 110-02	0.11Aa	0.07Aa
	TT 110-02	0.70Aa	0.06Aa
	AVI 110-03	0.18Aa	0.10Aa
	TT 110-03	1.39Aa	0.45Aa
CV (%)	313.11		

*Means followed by the same uppercase letters in the rows compare spray nozzles between application techniques, and means followed by the same lowercase letters in the columns, for each volume, compare spray nozzles within each application technique by Tukey's test at 5% of significance.

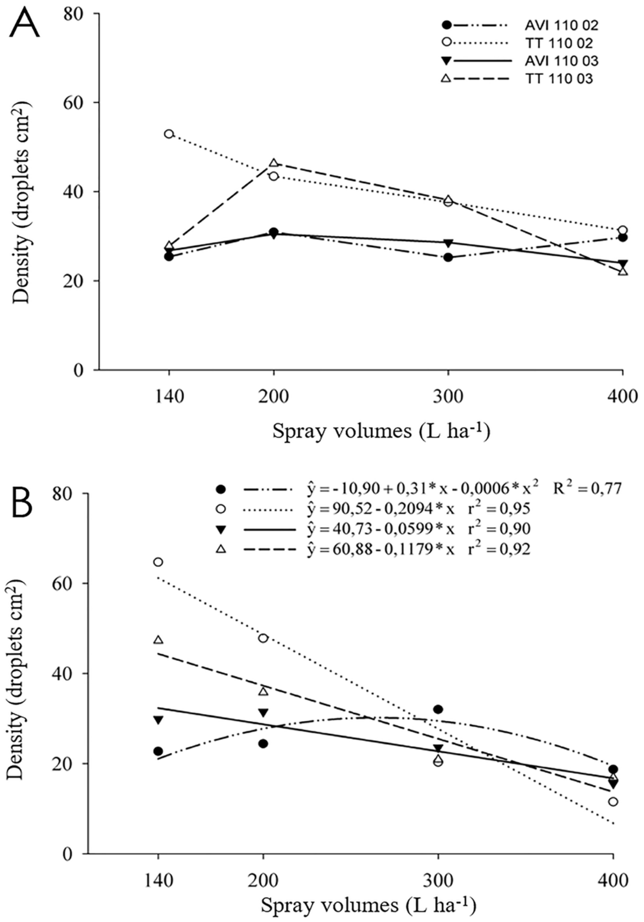

Figure 4. Droplet density of the adaxial surface of melon leaves as a function of the volumes applied for spray nozzles AVI 110-02 (●), TT 110-02 (○), AVI 110-03 (▼), and TT 110-03 (△) with (A) or without (B) air assistance.

the application without air assistance.

A decreasing linear behavior was observed for nozzles TT 110-02, AVI 110-02, and TT 110-03 as the mixture volume applied increased, whereas nozzle AVI 110-03, which produces larger drops, showed a quadratic behavior, with an increase in density and a subsequent reduction with the increase in the mixture volume applied. Nascimento et al. (2013) stated that the application of high mixture volumes makes it impossible to determine droplet density since several water-sensitive labels are completely taken over by a single stain, which can be explained by the combination of several drops. Thus, in view of the results found in this study, corroborating the aforementioned authors, it appears that water-sensitive paper is more suitable for verifying target coverage and inadequate for evaluating the population of droplets. Khah et al. (2022) recommend a density of 30 to 40 drops cm^{-2} for systemic insecticides. Furthermore, according to Wang et al. (2019), the ideal application of contact fungicides should range from 50 to 70 droplets cm^{-2}.

However, in this study, we can see that, when using higher application volumes, the combination of two or more droplets makes this value questionable when using the water-sensitive paper technique. (**Table 4**) shows that, as the spray volume increased, the number of droplets decreased due to their joining, especially when air assistance was not used.

There was no adjustment of any response function for droplet density on the abaxial surface as a function of the applied volume for all spray nozzles evaluated when using air assistance on the spray boom (**Figure 5**A). An increasing trend was observed in the droplet population

Table 4. Droplet density per cm^2 on the adaxial surface of melon leaves as a function of application volumes and spray nozzles within each application technique level (with or without air assistance)

Mixture volume applied	Spray nozzles	Application techniques	
		With air	Without air
140 L ha^{-1}	AVI 110-02	25.4 Ab*	22.7 Ac
	TT 110-02	52.9 Ba	64.8 Aa
	AVI 110-03	26.8 Ab	29.9 Ac
	TT 110-03	27.8 Bb	47.2 Ab
200 L ha^{-1}	AVI 110-02	30.9 Ab	24.4 Ab
	TT 110-02	43.4 Aab	47.8 Aa
	AVI 110-03	30.5 Ab	31.5 Aab
	TT 110-03	46.3 Aa	35.8 Aab
300 L ha^{-1}	AVI 110-02	25.2 Aa	32.0 Aa
	TT 110-02	37.6 Aa	20.3 Ba
	AVI 110-03	28.6 Aa	23.6 Aa
	TT 110-03	38.1 Aa	20.9 Ba
400 L ha^{-1}	AVI 110-02	29.7 Aa	18.7 Aa
	TT 110-02	31.3 Aa	11.5 Ba
	AVI 110-03	24.0 Aa	15.6 Aa
	TT 110-03	21.9 Aa	16.9 Aa
CV (%)		41.50	

*Means followed by the same uppercase letters in the rows compare spray nozzles between application techniques, and means followed by the same lowercase letters in the columns, for each volume, compare spray nozzles within each application technique by Tukey's test at 5% of significance.

with the increase in the mixture volume applied to the deflector nozzles, whereas those with air induction remained stable, with a very small droplet population. When spraying was carried out without air assistance (Figure 5B), the droplet population remained stable, with unsatisfactory rates because the melon leaves are notably flat and large, making it difficult for the droplets, even the finest ones, to penetrate plant parts and reach the abaxial face.

When evaluating the use of air assistance in the spray boom on droplet density on the abaxial leaf surfaces of melon plants, there was a positive effect of nozzles TT 110-02 at the mixture volumes of 140, 200, and 400 L ha^{-1} and TT 110-03 at the volumes of 200, 300, and 400 L ha^{-1} (**Table 5**).

There was no effect of air assistance on the air-induced nozzles due to the larger droplet sizes generated

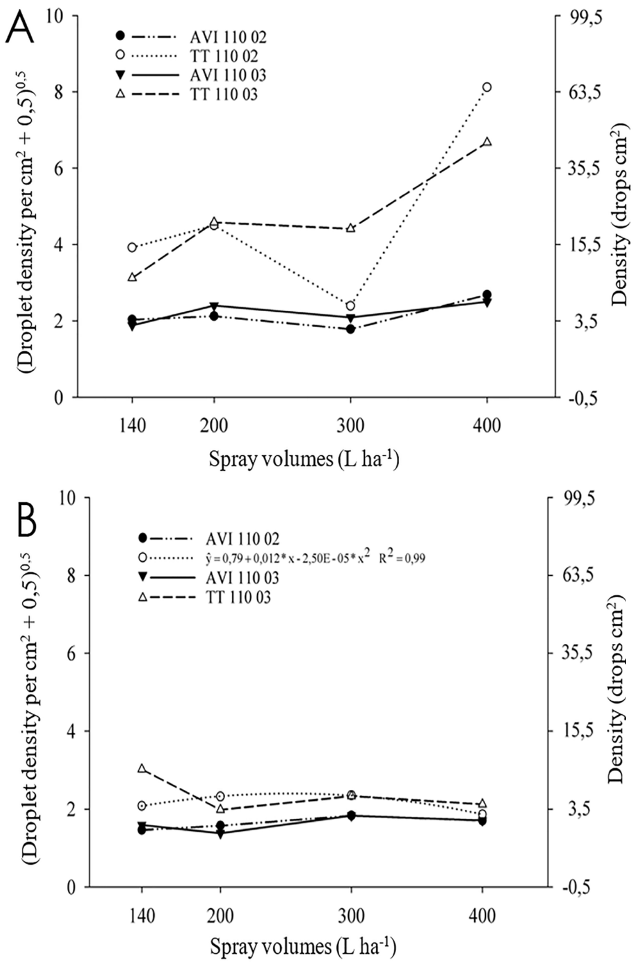

Figure 5. Droplet density on the abaxial surface of melon leaves (data transformed into square root of x + 0.5) as a function of volumes applied for spray nozzles AVI 110-02 (●), TT 110-02(○), AVI 110-03 (▼), and TT 110-03 (Δ) with (A) or without (B) air assistance.

by these nozzles, which make them less prone to drift, also reducing the possibility of the droplets reaching the abaxial surface of the leaves.

(Figure 5B) shows that there was no difference between spray nozzles in the different volumes applied when the mixture was applied without air assistance (Table 5). However, with air assistance, nozzles TT 110-02 and TT 110-03 stood out in relation to those with air induction at the volumes of 200, 300, and 400 L ha^{-1}.

The results show that air assistance is an important tool to improve product deposition, target coverage, droplet density, and reduce drift losses in the application of phytosanitary products. However, this will depend on factors such as the droplet spectrum produced, environmental conditions at the time of application, operational conditions (travel speed, boom height, and working pressure), as well as factors related to the crop (height and architecture of the plants, layout and leaf density in the canopy).

Conclusions

1. Air assistance in the spray boom improved spry deposition on melon leaves only when using nozzle TT 110-02;

2. Spray coverage and deposition increased on the adaxial surface of melon leaves with the increase in the mixture volume applied for all spray nozzles;

3. Air assistance improved droplet coverage and density on the abaxial surface of melon leaves only for nozzle TT 110-03 at 200 L ha^{-1};

Table 5. Droplet density on the abaxial surface of melon leaves (droplets cm^{-2}) as a function of application volumes and spray nozzles within each application technique level (with or without air assistance)

Mixture volume applied	Spray nozzles	Application techniques	
		With air	Without air
140 L ha^{-1}	AVI 110-02	2.03[1] (3.85) Aa*	1.46 (1.69) Aa
	TT 110-02	3.15 (17.97) Aa	2.08 (4.35) Ba
	AVI 110-03	1.88 (3.41) Aa	1.59 (2.05) Aa
	TT 110-03	3.12 (9.97) Aa	3.02 (12.82) Aa
200 L ha^{-1}	AVI 110-02	2.12 (4.20) Ab	1.57 (1.99) Aa
	TT 110-02	4.50 (26.38) Aa	2.32 (5.28) Ba
	AVI 110-03	2.40 (5.53) Ab	1.38 (1.46) Aa
	TT 110-03	4.58 (26.41) Aa	1.98 (3.56) Ba
300 L ha^{-1}	AVI 110-02	1.78 (2.69) Ab	1.83 (2.94) Aa
	TT 110-02	2.39 (6.28) Aab	2.35 (6.02) Aa
	AVI 110-03	2.09 (4.15) Ab	1.83 (3.02) Aa
	TT 110-03	4.41 (22.97) Aa	2.33 (5.57) Ba
400 L ha^{-1}	AVI 110-02	2.68 (8.06) Ab	1.70 (2.77) Aa
	TT 110-02	8.12 (66.57) Aa	1.86 (3.05) Ba
	AVI 110-03	2.50 (6.54) Ab	1.71 (2.72) Aa
	TT 110-03	6.67 (50.57) Aa	2.12 (4.32) Ba
CV (%)		47.02	

*Means followed by the same uppercase letters in the rows compared spray nozzles between application techniques, and means followed by the same lowercase letters in the columns, for each mixture volume, compare spray nozzles within each application technique by Tukey's test at 5% of significance. [1] Results transformed into $(x+0.5)^{0.5}$. Original means in parentheses.

4. The air-induced nozzles AVI 110-02 and AVI 110-03 showed unsatisfactory indices of spray deposition, coverage, and droplet density on the abaxial leaf surface of melon leaves regardless of air assistance;

5. The water-sensitive paper technique is not efficient for evaluating droplet density when working with high application volumes.

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