Original Article

SPRAY DEPOSITION ON COFFEE LEAVES FROM AIRBLAST SPRAYERS WITH AND WITHOUT ELECTROSTATIC CHARGE

DEPÓSITO DE CALDA APLICADA EM FOLHAS DE CAFEEIRO PROMOVIDA PELA PULVERIZAÇÃO HIDROPNEUMÁTICA COM E SEM CARGA ELETROSTÁTICA

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ABSTRACT: Studies on the quality of applications of plant protection products on coffee crops are lacking. Thus, we studied spray deposition on coffee leaves and losses to the soil from hydropneumatic spraying at different spray volumes and with and without an electrostatic charge. The experiment was set up using randomized blocks in a factorial design (4 x 2 + 1). Spray deposition on the upper, middle and lower parts of the canopy and losses to the soil were evaluated using Brilliant Blue tracer. Applications were made at 200, 300, 400 and 500 L ha^{-1} with a conventional airblast sprayer (axial fan type) and an airblast sprayer with directed air jets. Applications were also made with an electrostatic sprayer at 130 L ha^{-1}. Electrostatic spraying resulted in greater spray deposition on the lower part of the coffee canopy compared to non-electrostatic spraying. On the lower and middle parts of the plants, the sprayer equipped with directed air ducts performed better than the sprayer with nozzles arranged along the lateral arcs (axial). The spray volume of the airblast sprayers without electrostatic charge (200 to 500 L ha^{-1}) did not influence spray deposition on the plant leaves and losses to the soil, which were lower with the electrostatic sprayer.

KEYWORDS: *Coffea Arabica.* Electrostatic sprayer. Application technology.

INTRODUCTION

Coffee crop (*Coffea arabica* L.) presents several challenges to the application of plant protection products, principally canopy penetration and drift reduction. Plant architecture and large foliage area hinder spray coverage. The air currents from airblast sprayers can also increase the risk of spray drift that can reduce the effectiveness of the treatment and increase environmental contamination. Choosing the correct spray method and spray volume can improve spray deposition on the biological target.

Nevertheless, defining the correct spray volume is difficult given that low volumes can lead to inadequate coverage and high volumes can make applications more difficult, principally because of reduced operational capacity. According to Silva et al. (2008), there is insufficient information on appropriate spray distributions and spray volumes needed to effectively control pests and diseases in coffee crops. Cunha et al. (2005) observed that one of the causes of product loss is spray volume that is inappropriate for specific crop characteristics. The crop canopy is one of the most important of these characteristics (ROSELL POLO et al., 2009). According to Viana et al. (2010), uniform distribution within a specific diameter and using a specific number of droplets can lead to successful applications even at lower spray volumes. Other studies have achieved promising results using lower spray volumes on tree crops (BALAN et al., 2006; FERNANDES et al., 2010). Additionally, electrostatic spraying at lower volumes can improve leaf deposition and reduce drift losses (ZHAO et al., 2008; MASKI; DURAIRAJ, 2010). Some studies have demonstrated the advantages of electrostatic sprayers (MASKI; DURAIRAJ, 2010; DERKSEN et al., 2007; LARYEA; NO, 2005; XIONGKUI et al., 2011).

Sasaki et al. (2013) evaluated a pneumatic backpack sprayer and also showed that the electrostatic system was efficient for spraying coffee plants. Electrostatic spraying increased spray deposition by 37%. Zheng et al. (2002) claimed that electrostatic spraying can improve the distribution and deposition of droplets on plants, decrease environmental contamination, reduce spray volumes and process costs and improve treatment effectiveness compared to conventional sprayers.

Nevertheless, Hislop (1988) showed that some electrostatic equipment fails to produce consistent control results because of charges that are insufficient to improve deposition or droplet sizes that are unsuitable for use with electrostatic charges.

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Bayer et al. (2011) worked with rice plants and showed that electrostatic spraying produced lower drop penetration in the interior of the crop and lower droplet densities compared to other spraying systems. Magno Júnior et al. (2011) showed that electrostatic spraying did not increase deposition on citrus crops.

Therefore, the objective of the current study was to evaluate spray deposition on coffee plants and losses to the soil resulting from hydropneumatic spraying at different volumes and with or without an electrostatic charge.

MATERIAL AND METHODS

The experiment was carried out in January 2014 on an eight-year-old coffee plantation (cultivar Catuai 144, spaced 3.8 x 0.65m) located in the municipality of Rio Paranaiba, MG, Brazil. The leaf area index (LAI) was 5.49 according to the methodology proposed by Favarin et al. (2002). The laboratory studies were conducted in the Federal University of Uberlândia.

Three types of trailer-mounted airblast sprayers were evaluated. The first (Sprayer A) was a *Jacto Arbus 2000 Super Export* model with a 2000 L tank, 36 nozzles mounted in two lateral arcs, a single air source driving all nozzles (conventional axial fan type sprayer), 150 L min^{-1} piston pump and an 850 mm axial fan with a capacity of 19 m^3 s^{-1}. The second (Sprayer B) was a *Montana Maozinha Twister 1500* model with 1500 L tank, 32 nozzles mounted on eight adjustable air spouts (directed air jet sprayer), 90 L min^{-1} membrane pump and a 900 mm fan with a capacity of 13.8 m^3 s^{-1}. This sprayer has four air spouts on each side. The first and fourth spouts have three nozzles each and the second and third spouts have five nozzles each. The third sprayer (Sprayer C) was an *Electrostatic Montana Maozinho* model that is similar to sprayer B except that the air spouts are replaced with four SPE electrostatic devices on each side and positioned at 0.35, 1.10, 1.85 and 2.60 m above the ground. The system electrically charges the spray droplets by producing a high voltage (5000 V) electric field at the base of the spray jet as it exits the hollow cone nozzle. The charge is the result of an electric field produced by induction rings connected to a high voltage generator.

The sprayers were pulled by a 5425N John Deere tractor (57.4 kW). Table 1 shows the nozzles used in each treatment. Pressure was adjusted to achieve the desired spray volume.

Table 1. Treatment description.

Treatment	Equipment	Spray volume (L ha^{-1})	Nozzle	Pressure (kPa)
1	Sprayer A (Axial fan)	500	MAG 02	410
2	Sprayer A (Axial fan)	400	MAG 02	290
3	Sprayer A (Axial fan)	300	MAG 01	840
4	Sprayer A (Axial fan))	200	MAG 01	400
5	Sprayer B (Directed air jet)	500	MAG 02	650
6	Sprayer B (Directed air jet)	400	MAG 02	500
7	Sprayer B (Directed air jet)	300	MAG 01	1000
8	Sprayer B (Directed air jet)	200	MAG 01	410
9	Sprayer C (Electrostatic)	130	SPE 03	700

The trial was conducted in randomized blocks. The experimental plots consisted of four rows of coffee, 15 m long; however, only the two central rows were considered.

Nine treatments were performed (2 x 4 + 1) consisting of two sprayer types (Sprayers A and B), four spray volumes (200, 300, 400 and 500 L ha^{-1}) and an additional sprayer (Sprayer C) with electrostatic equipment set at 130 L ha^{-1} (Table 1). Each treatment had four repetitions in which foliage deposition and losses to the soil were studied. The electrostatic sprayer was only tested at 130 L ha^{-1} because its biggest advantage over traditional equipment is a potential reduction in spray volume. Furthermore, according to the manufacturer, the electrostatic equipment does not perform well at high spray volumes given the difficulty of charging the droplets.

The MAG 1, MAG 2 and SPE 03 hollow cone nozzles used in this experiment are ceramic and angled at 80°. According to the manufacturers, the first two nozzles produce fine droplets and the third nozzle produces very fine droplets (at the pressure levels used in the experiment). The sprayers moved at a constant 2.2 m h^{-1} (7.8 km h^{-1}) with a constant PTO of 540 rpm throughout all treatments.

Brilliant Blue tracer (300 g ha^{-1}) was used in all treatments to determine leaf deposition on the upper, middle and lower parts of the canopy as well as spray run-off to the soil. Leaves were removed from plagiotropic branches that were internal and closer to the trunk of the coffee plant (0.20, 1.30 and 2.00 m above the soil). After removal, the leaves were placed in plastic bags and then stored in insulated containers. Ten leaves were collected for each repetition. The fungicide Azoxystrobin+Cyproconazole (750 mL ha^{-1}) and paraffinic mineral oil (0.5% v/v) were applied with the tracer.

Two petri dishes (149.51 cm^2) were placed under the canopy (0.2 m from the stem) of each replicate to evaluate spray losses to the soil. In the laboratory, 100 mL of distilled water was added to each of the bags containing leaves and 40 mL was added to each petri dish. The resulting solutions were then removed and absorbance readings were made with a spectrophotometer (Biospectro SP-22) set at a wavelength of 630 nm. Leaf area was measured by digitalizing leaves and then analyzing them with the "Image Tool" program (University of Texas, Texas, USA). Absorbance data was transformed into concentration (mg L^{-1}) using a calibration curve. Tracer mass was then divided by the foliage or petri dish area from each repetition to obtain deposition in µg cm^{-2}.

Environmental conditions were measured during the applications. Temperature varied from 23.2 to 29.4°C, relative humidity from 62% to 80% and wind speed from 0.8 to 1.2 m h^{-1} (3.0 to 4.4 km h^{-1}).

Data assumptions were tested first. Homogeneity of variances and normality of residuals were tested by the Levene and Shapiro Wilk tests (SPSS statistical program, version 17.0), respectively. To meet the 0.01 level of significance, leaf deposition values from the lower part of the plants were transformed by the square root of x. The rest of the data was not transformed. The data were then submitted to analysis of variance. The averages were compared to each other by the Tukey test and compared to the additional treatment by the Dunnett test at the 0.05 significance level. Regression analysis was used to study the effect of spray volume; however, the resulting models were not significant

To determine the effect of the three sprayers on tracer distribution uniformity, the canopy deposit variances (upper, middle and lower parts) among the three sprayers were tested by an F test (5% probability). For sprayers A and B, the average variance from the four spray volumes from each equipment type was used.

RESULTS AND DISCUSSION

Table 2 shows the spray deposition on the upper part of the coffee canopy and demonstrates that there was no significant relationship or a non-dependent relationship between spray volume and sprayer type. There was also no significant interaction between these two factors and the additional treatment. In other words, there was no difference in spray deposition on the upper part of the canopy resulting from Sprayers A and B and the electrostatic sprayer. Note that the electrostatic sprayer used only 130 L ha^{-1}, while the conventional sprayers used 200 to 500 L ha^{-1}. Therefore, the electrostatic system produces the same foliar deposition with a lower spray volume and thus increases operational capacity and reduces application costs. Lower spray volumes allow greater treatment areas per tank and consequently reduce down time for refilling the tank.

Table 2. Tracer deposition (µg cm^{-2}) on the upper leaves of coffee plants resulting from different sprayer types and spray volumes.

	Spray volume (L ha^{-1})				Average
	200	300	400	500	
	Sprayer C - Electrostatic (130 L ha^{-1}): 0.477 µg cm^{-2}				
Sprayer A	0.423	0.422	0.458	0.555	0.465
Sprayer B	0.503	0.513	0.542	0.549	0.527
Average	0.463	0.468	0.500	0.552	
CV = 25.94%	$F_{spr} = 1.895^{ns}$; $F_{sv} = 0.828^{ns}$; $F_{int} = 0.255^{ns}$; $F_{int\ x\ test} = 0.073^{ns}$				

CV: coefficient of variation; F_{spr}, F_{sv}, F_{int}, $F_{int\ x\ test}$: F values calculated for sprayer factors, spray volume, interaction between factors and interaction between factors and the additional treatment, respectively; ns: not significant.

The upper part of the canopy is the farthest from the spray nozzles and is therefore most difficult to reach with the sprayer. Thus, none of three systems was superior in this regard. Not even electrostatic spraying, which creates attraction between the droplets and the target, increased foliar deposition given that the greater distance hinders the attraction between the droplets and the leaves. Increasing the height of the nozzles and thereby reducing the distance could improve deposition on the upper part of the canopy.

Ferreira et al. (2013) evaluated spray droplet coverage on coffee with and without an extension arm for tall plants and had difficulty reaching the upper part of the plants, corroborating the findings of the current study.

Table 3 shows average spray deposition on the middle part of the coffee canopy. Sprayer B, with directed air jets, performed better than sprayer A with the conventional arrangement of nozzles positioned along an arc. The use of directed air jets on airblast sprayers is increasing given the demand for greater deposition. This change is improving spray quality and reducing losses (DEVEAU, 2009). The ability to change the direction of the air current and the angle that spray enters the vegetation provides greater uniformity and control over droplet distribution.

Deposition from the electrostatic equipment was better than Sprayer A at all spray volumes and better than Sprayer B at 200 L ha^{-1}. At higher volumes (300 to 500 L ha^{-1}), Sprayer B produced similar deposition to that of the electrostatic equipment, thus demonstrating the potential spray volume reductions afforded by the electrostatic system. Spray volume did not produce significant differences in deposition. Consequently, a model was not fit to correlate deposition and volume.

Table 3. Tracer deposition (µg cm^{-2}) on the middle leaves of coffee plants resulting from different sprayer types and spray volumes.

	Spray volume (L ha^{-1})				Average
	200	300	400	500	
Sprayer C - Electrostatic (130 L ha^{-1}): 0.597 µg cm^{-2}					
Sprayer A	0.288^{+}	0.288^{+}	0.339^{+}	0.387^{+}	0.325 b
Sprayer B	0.369^{+}	0.438	0.434	0.434	0.419 a
Average	0.329	0.363	0.386	0.410	
CV = 25.19% MSD$_{test}$ = 0.202	MSD$_{spr}$ = 0.073	F_{spr} = 6.943*; F_{sv} = 0.964^{ns}; F_{int} = 0.365^{ns}; $F_{int\ x\ test}$ = 17.970*			

Averages followed by distinct letters in each column differ from each other (Tukey, 0.05). Averages followed by + differ from the additional treatment (Dunnett, 0.05). CV: Coefficient of Variation; MSD$_{test}$: minimum significant difference for the additional treatment; MSD$_{spr}$: minimum significant difference for a sprayer; F_{spr}, F_{sv}, F_{int}, $F_{int\ x\ test}$: F values calculated for sprayer factors, spray volume, interaction between factors and interaction between factors and the additional treatment; ^{ns}: not significant; *: significant at 0.05.

Table 4 shows the deposition on the lower part of the canopy. Again, Sprayer B, with directed air jets, performed better than Sprayer A. The electrostatic equipment produced better deposition than the two sprayers (A and B), regardless of spray volume. Lower leaves are closer to the point where the spray is emitted and to where the droplets are charged. This results in greater attraction between droplets and leaves, which reduces losses and increases deposition.

As in the present study, other authors have confirmed that in arboreal crops, good spray deposition is easier to achieve when the foliage has greater exposure to the spray nozzles (SCUDELER et al., 2004; RAMOS et al., 2007; FERNANDES et al., 2010; MIRANDA et al., 2012). The nozzles are closer to the lower part of the plant, which justifies the obtained results.

Once again, spray volume did not significantly affect spray deposition. Consequently, a model was not fit to correlate deposition and volume. This shows that lower volumes can be used and greater operational capacities achieved without affecting treatment quality. Applications greater than 500 L ha^{-1} are common in coffee crops; however, reducing these volumes is viable and yields significant gains in operational capacity.

There are few studies on coffee crop deposition; however, similar results can be gleaned from studies on citrus. Salyani and Farooq (2003), found no significant differences in leaf coverage with spray volumes from 250 to 3950 L ha^{-1}. In another study, Farooq and Salyani (2002) observed that spray deposition on orange trees was greater at a spray volume of 980 L ha^{-1} than at 250 L ha^{-1}. Nevertheless, they found little difference in spray coverage from 980 L ha^{-1} to 1945 L ha^{-1}.

Table 4. Tracer deposition (µg cm^{-2}) on the lower leaves of coffee plants resulting from different sprayer types and spray volumes.

	Spray volume (L ha^{-1})				Average
	200	300	400	500	
	Sprayer C - Electrostatic (130 L ha^{-1}): 0.984 µg cm^{-2}				
Sprayer A	0.303^{+}	0.356^{+}	0.380^{+}	0.481^{+}	0.380 b
Sprayer B	0.513^{+}	0.533^{+}	0.509^{+}	0.510^{+}	0.516 a
Average	0.408	0.444	0.444	0.496	
CV_T = 16.48% CV_{NT} = 37.92%	MSD_{Tpul} = 0.083	F_{spr} = 6.945*; F_{sv} = 0.530^{ns}; F_{int} = 0.537^{ns}; $F_{int\ x\ test}$ = 25.235*			

Averages followed by distinct letters in each column differ from each other (Tukey, 0.05). Averages followed by + differ from the additional treatment (Dunnett, 0.05). CV_T: coefficient of variation of transformed data; CV_{NT}: coefficient of variation of data not transformed; MSD_{Tspr}: minimum significant difference for a sprayer (transformed data); F_{spr}. F_{sv}. F_{int}. $F_{int\ x\ test}$: F values calculated for sprayer factors, spray volume, interaction between factors and interaction between factors and the additional treatment; ns: not significant; *: significant at 0.05. Analysis of variance conducted on data transformed by the square root of x.

There were no differences in spray losses to the soil between sprayers A and B (Table 5) and no differences in spray volumes. All treatments without electrostatic charges produced greater losses than the electrostatic treatments. In general, electrostatic spraying allows greater deposition, mainly on the abaxial side of the leaves, which reduces runoff to the soil. In general, it is expected that up to a point, increases in spray volume will increase the spray retained by the leaves. After this point, the leaf surfaces will not be able to retain additional liquid and undesirable runoff will occur.

Table 5. Tracer deposition (ηg cm^{-2}) on petri dishes at ground level from different sprayer types and spray volumes.

	Spray volume (L ha^{-1})				Average
	200	300	400	500	
	Sprayer C - Electrostatic (130 L ha^{-1}): 4.044 ηg cm^{-2}				
Sprayer A	10.413^{+}	10.500^{+}	11.316^{+}	11.736^{+}	10.991
Sprayer B	11.633^{+}	12.185^{+}	12.168^{+}	12.830^{+}	12.204
Average	11.023	11.343	11.742	12.283	
CV = 24.88% MSD_{test} = 5.412		F_{spr} = 1.643^{ns}; F_{sv} = 0.330^{ns}; F_{int} = 0.034^{ns}; $F_{int\ x\ test}$ = 28.408*			

Averages followed by + differ from the additional treatment (Dunnett, 0.05). CV: coefficient of variation; MSD_{test}: minimum significant difference for the additional treatment; F_{spr}. F_{sv}. $F_{int.}$ $F_{int\ x\ test:}$ F values calculated for sprayer factors, spray volume, interaction between factors and interaction between factors and the additional treatment; ns: not significant; *: significant at 0.05.

Table 6 compares the variances in the tracer mass retained on the foliage throughout the entire plant. There were no differences between sprayers A and B. This demonstrates that these sprayers did not influence variations in deposition throughout the plant. Relative to the conventional sprayers (A and B), the electrostatic sprayer produced less uniform distribution across the entire plant because of the greater tracer concentration on the lower foliage. This data shows that charged droplets increase deposition on the lower foliage. In cases where it is desirable to increase distribution on the lower parts of the plant, without causing great variability throughout the entire plant, it may be necessary to find alternatives such as positioning the spray nozzles closer to the upper part of the plant.

Table 6. Variances in the tracer mass retained throughout the coffee foliage after applications with different sprayer types.

Sprayer	Variance - σ^2	F Test
Sprayer A	0.014386	1.120644^{ns}
Sprayer B	0.012837	
Sprayer A	0.014386	9.027619*
Sprayer C – Electrostatic	0.129873	
Sprayer B	0.012837	10.116750*
Sprayer C - Electrostatic	0.129873	

^{ns} No significant difference between variances (F test, 5% probability). * Variances differ by the F test at 5% probability.

CONCLUSIONS

Electrostatic spraying produced greater spray deposition on the lower part of the coffee canopy than did non-electrostatic spraying. In this region and in the middle part of the foliage, the sprayer with directed air jets performed better than the sprayer with nozzles positioned in lateral arcs. Deposition on the upper part of the plants was similar among the sprayer types and lower than deposition on the middle and lower parts.

Spray volume in the airblast sprayers without electric charge (200 to 500 L ha^{-1}) did not influence spray deposition on the plants and losses to the soil.

The electrostatic sprayer reduced losses to the soil.

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RESUMO: Estudos relacionados à qualidade da aplicação de produtos fitossanitários no cafeeiro são ainda escassos. Dessa forma, o objetivo deste trabalho foi estudar a deposição de calda pulverizada em folhas de cafeeiro e a perda para o solo promovidas pela pulverização hidropneumática, em diferentes volumes de calda, com e sem carga eletrostática. O experimento foi conduzido em delineamento em blocos casualizados, em esquema fatorial 2 x 4 + 1. Foram avaliadas a deposição de calda nos terços superior, médio e inferior e as perdas para o solo promovidas pela pulverização do traçador Azul Brilhante, empregando um pulverizador hidropneumático convencional e um com dutos de ar direcionado, com volumes de calda de 200, 300, 400 e 500 L ha-1, e um pulverizador eletrostático, com volume de calda de 130 L ha^{-1}. A pulverização eletrostática proporcionou maior deposição de calda no terço inferior do cafeeiro em comparação à pulverização não eletrostática. Nesta região e na parte média das plantas, o pulverizador dotado de dutos de ar direcionado teve melhor desempenho do que o equipamento com bicos dispostos ao longo dos arcos laterais (Axial). O volume de calda empregado nos pulverizadores hidropneumáticos sem carga eletrostática (200 a 500 L ha^{-1}) não influenciou a deposição de calda nas plantas e as perdas para o solo, que foram menores quando se empregou o pulverizador eletrostático.

PALAVRAS-CHAVE: *Coffea Arabica*. Pulverizador eletrostático. Tecnologia de aplicação.

REFERENCES

BALAN, M. G.; ABI SAAB, O. J. G.; SILVA, C. G. Depósito e perdas de calda em sistemas de pulverização com turboatomizador em videira. **Engenharia Agrícola,** Jaboticabal, v. 26, n. 2, p. 470-477, 2006.

BAYER, T.; COSTA, I. F. D.; LENZ, G.; ZEMOLIN, C.; MARQUES, L. N.; STEFANELO, M. S. Equipamentos de pulverização aérea e taxas de aplicação de fungicida na cultura do arroz irrigado. **Revista Brasileira Engenharia Agrícola Ambiental**, Campina Grande, PB, v. 15, n. 2, p. 192-198, 2011.

CUNHA, J. P. A. R; TEIXEIRA, M. M.; VIEIRA, R. F.; FERNANDES, H. C. Deposição e deriva de calda fungicida aplicada em feijoeiro, em função de bico de pulverização e de volume de calda. **Revista Brasileira de Engenharia Agrícola**, Campina Grande, PB, v. 9, n. 1, p.133-138, 2005. http://dx.doi.org/10.1590/S1415-43662005000100021

DERKSEN, R. C.; VITANZA, S.; WELTY, C.; MILLER, S.; BENNETT, M.; ZHU, H. Field evaluation of application variables and plant density for bell pepper pest management. **Transactions of the ASAE**, St. Joseph, v. 50, n. 6, p.1945-1953, 2007. http://dx.doi.org/10.13031/2013.24090

DEVEAU, J. **Six elements of effective spraying in orchards and vineyards.** Ontário: Ministry of Agriculture, Food and Rural Affairs, 2009. 12 p. (Factsheeh Order, 09-39).

FAROOQ, M.; SALYANI, M. **Spray penetration into the citrus tree canopy from two air-carrier sprayers**. St. Joseph; Asabe, 2002. 12p. (paper 02-1038).

FAVARIN, J. L.; DOURADO-NETO, D.; GARCÍA Y GARCÍA, A.; VILLA NOVA, N. A.; FAVARIN, M. G. G. V. Equações para a estimativa do índice de área foliar do cafeeiro. **Pesquisa Agropecuária Brasileira**, Brasília, v. 37, n. 6, p. 769-773, 2002. http://dx.doi.org/10.1590/S0100-204X2002000600005

FERNANDES, A. P.; FERREIRA, M. C.; OLIVEIRA, C. A. L. Eficiência de diferentes ramais de pulverização e volumes de calda no controle de *Brevipalpus phoenicis* na cultura do café. **Revista Brasileira de Entomologia**, São Paulo, v. 54, n. 1, p. 130-135, 2010. http://dx.doi.org/10.1590/S0085-56262010000100018

FERREIRA, M. C.; LEITE, G. J.; LASMAR, O. Cobertura e depósito de calda fitossanitária em plantas de café pulverizadas com equipamento original e adaptado para plantas altas. **Bioscience Journal,** Uberlândia, v. 29, Supplement 1, p. 1539- 1548, 2013.

HISLOP, F. C. Electrostatic ground-rig spraying: an overview. **Weed Technology**, Lawrence, v. 2, p. 94-104, 1988.

LARYEA, G. N.; NO, S. Y. Effect of fan speed and electrostatic charge on deposition of orchard canopy sprays. **Atomization and Sprays**, Redding, v. 15, p. 133-144, 2005.

MAGNO JÚNIOR, R. G.; TEIXEIRA, M. M.; VIEIRA, L. B.; FERREIRA, L. R.; ALVARENGA, C. B. Desenvolvimento de um dispositivo eletrônico para atração de gotas da aplicação eletrostática em plantas cítricas. **Bioscience Journal**, Uberlândia, v. 27, n. 5, p. 798-804, 2011.

MASKI, D.; DURAIRAJ, D. Effects of charging voltage, application speed, target height, and orientation upon charged spray deposition on leaf abaxial and adaxial surfaces. **Crop Protection**, London, v. 29, n. 2, p. 134–141, 2010. http://dx.doi.org/10.1016/j.cropro.2009.10.006

MIRANDA, G. R. B.; RAETANO, C. G.; SILVA, V. C.; CUNHA, M. D. Q.; CARVALHO, R. H.; PINHEIRO, J. M.; GONÇALVES, M. P.; REINATO, C. H. R.; PAIVA, L. C.; ARAÚJO, D. Avaliação dos depósitos da pulverização em frutos de cafeeiro utilizando dois equipamentos associados a diferentes volumes de calda. **Revista Agrogeoambiental**, Pouso Alegre, v. 4, n. 1, p. 15-20, abr. 2012.

RAMOS, H. H.; YANAI, K.; CORRÊA, I. M.; BASSANEZI, R. B.; GARCIA, L. C. Características da pulverização em citros em função do volume de calda aplicado com turbopulverizador. **Engenharia Agrícola**, Jaboticabal, v. 27, n. especial, p. 56- 65, 2007.

ROSELL POLO, J. R.; SANZ, R.; LLORENS, J.; ARNO, J.; ESCOLA, A.; RIBES-DASI, M.; MASIP, J.; CAMP, F.; GRACIA, F.; SOLANELLES, F.; PALLEJA, T.; VAL, L.; PLANAS, S.; GIL, E.; PALACÍN, J. A tractor mounted scanning LIDAR for the non-destructive measurement of vegetative volume and surface area of tree-row plantations: a comparison with conventional and destructive measurements. **Biosystem Engineering**, Silsoe, v. 102, n. 2, p. 128-134, 2009. http://dx.doi.org/10.1016/j.biosystemseng.2008.10.009

SALYANI, M.; FAROOQ, M. Sprayer air energy demand for satisfactory spray coverage in citrus applications. **Proceedings of the Florida State Horticultural Society**, Lake Alfred, v. 116, p. 298-304, 2003.

SASAKI, R. S.; TEIXEIRA, M. M.; FERNANDES, H. C.; MONTEIRO, P. M. B. Deposição e uniformidade de distribuição da calda de aplicação em plantas de café utilizando a pulverização eletrostática. **Ciência Rural**, Santa Maria, v. 43, n. 9, p. 1605-1609, 2003. http://dx.doi.org/10.1590/S0103-84782013000900011

SCUDELER, F.; RAETANO, C. G.; ARAÚJO, D.; BAUER, F. C. Cobertura da pulverização e maturação de frutos do cafeeiro com ethephon em diferentes condições operacionais. **Bragantia,** Campinas, v. 63, n. 1, p. 129-139, 2004. http://dx.doi.org/10.1590/S0006-87052004000100013

SILVA, A. R.; LEITE, M. T.; FERREIRA, M. C. Estimativa da área foliar e capacidade de retenção de calda fitossanitária em cafeeiro. **Bioscience Journal**, Uberlândia, v. 24, n. 3, p. 66-73, 2008.

XIONGKUI, H.; AIJUN, Z.; YAJIA, L.; JIANLI, S. Precision orchard sprayer based on automatically infrared target detecting and electrostatic spraying techniques. **International Journal of Agricultural and Biological Engineering**, Beijing, v. 4, n. 1, p. 35-40, 2011.

VIANA, R. G.; FERREIRA, L. R.; FERREIRA, M. C.; TEIXEIRA, M. M.; ROSELL, J. R.; TUFFI SANTOS, L. D.; MACHADO, A. F. L. Distribuição volumétrica e espectro de gotas de pontas de pulverização de baixa deriva. **Planta Daninha**, Viçosa, v. 28, n. 2, p. 439-446, 2010.

ZHAO, S.; CASTLE, G. S. P.; ADAMIAK, K. Factors affecting deposition in electrostatic pesticide spraying. **Journal of Electrostatics**, Amsterdam, v. 66, n. 11, p. 594–601, 2008. http://dx.doi.org/10.1016/j.elstat.2008.06.009

ZHENG, J.; ZHOU, H.; XU, Y. **Advances in pesticide electrostatic spraying in China**. St. Joseph: ASAE, 2002. (Paper nº 021034).