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SPRAY DRIFT AND CATERPILLAR AND STINK BUG CONTROL FROM AERIAL APPLICATIONS WITH ELECTROSTATIC CHARGE AND ATOMIZER ON SOYBEAN CROP

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ABSTRACT: The use of aerial application with electrostatic charge is an alternative to improve the quality of insecticide applications in soybean crop. The objective of this study was to evaluate the drift and chemical control of the caterpillar and stink bug complex promoted by aerial applications of insecticide in the soybean crop, using electrostatic spray system and rotary atomizers. The insecticide Thiamethoxam + Lambda cyhalothrin was applied with a Cessna 188 Ag Truck agricultural aircraft in two treatments: SPE® electrostatic system, with 54 SPE-5 nozzles and 10 L ha^{-1} application rate, and Travicar model® 05165 rotary atomizer, with 55° angle blades and application rate of 20 L ha^{-1}. Drift was evaluated through quantification of active ingredient, by means of liquid chromatography, on nylon strings set 20, 40, 80, 160 and 320 m downwind from the applied area. Control efficiency was measured by counting caterpillars and stink bugs found five days after application. The droplet spectrum was also evaluated through water sensitive papers placed in the target area. It was verified that the hydraulic nozzles, associated with the electrostatic system, generated lower drift, but there was no difference in pest control efficiency, in relation to the rotary atomizers.

KEYWORDS: agricultural aviation, application technology, exodrift, *Glycine max*.

INTRODUCTION

The soybean crop (*Glycine max* L. Merrill) is subject to the attack of different species of insects. Among them the complexes of caterpillars and stink bugs are outstanding. When they reach high populations capable of causing significant losses in crop yield, they need to be controlled (Bueno et al., 2015). In this process, in addition to choosing the right product it is essential to use the correct application technology.

The coverage provided by the application of insecticides on the soybean canopy in general is less uniform mainly in the inferior part, resulting in inefficient control even with systemic products (Cunha et al., 2016). Thus, for the success of the application, it is necessary to master the proper form of application in order to ensure that the product reaches the target efficiently, minimizing losses and reducing environmental contamination. Often part of the applied product is lost mainly due to the poor quality of the application, whether terrestrial or aerial this being one of the biggest problems of modern agriculture to be overcome (Tsai et al., 2005; Nuyttens et al., 2011).

The use of aerial application insecticides in soybean crops has grown a lot, but little scientific information exists regarding their effectiveness which raises doubts as to its technical viability, especially regarding the control effectiveness and drift potential (Cunha et al., 2014).

An alternative to improve the deposition of spray on the leaves is spraying with electrostatic assistance (Zhao et al., 2008; Maski & Durairaj, 2010). In that equipment, generated droplets receive electric charge, that is, the loading of the spray occurs with positive or negative charges. The drop electrically charged tends to be attracted to its target with smaller deviations of its trajectory and losses of spray (Pascuzzi & Cerruto, 2015).

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Some research has demonstrated the advantages of electrostatic spraying (Maski & Durairaj, 2010; Derksen et al., 2007; Laryea & No, 2005; Xiongkui et al., 2011). However, according to Hislop (1988) some electrostatic equipment does not provide consistent control results because the developed designs do not generate droplets with sufficient charge level to improve deposition, or the droplet size produced is not suitable for use with electrostatic charge. Bayer et al. (2011) working with aerial application in rice crop verified lower penetration of droplets inside the crop and lower droplet densities with electrostatic equipment compared to other spray systems.

The objective of this study was to evaluate the drift and chemical control of the caterpillar and stink bug complex promoted by aerial applications of insecticide in the soybean crop, using electrostatic spray system and rotary atomizers.

MATERIAL AND METHODS

The experiment was carried out in a commercial area of grain production, located in the municipality of Monte Alegre de Minas (Minas Gerais, Brazil) whose approximate latitude and longitude are 18°52’ South and 48°52’ West. The area belongs to the Paraná River Basin with average altitude between 850 and 900 m. The land has slightly undulating relief. The climate of the region was classified as Aw by the Köeppen System. It presents cold and dry winter and hot and rainy summer (between the months of October and March). The total annual precipitation is from 1,400 to 1,500 mm. The average annual temperature is between 20 and 24 °C ranging from 18 °C, to the coldest month to 25 °C, for the warmer month. The characteristic vegetation of the area is the savanna. The soil was classified as sandy clay loam oxisol.

The sowing of soybean cultivar P98Y30 RR Pioneer was done with an early cycle with row spacing of 0.5 m and 10 plants per linear meter. The experiment had two treatments and four replications where were evaluated after application of insecticide with different aerial application technologies: drift, spectrum of drops and control of caterpillars and stink bugs. In the first treatment an electrostatic system was used with 54 SPE-5 hollow cone nozzles with induction ring (SPE®) backward, application rate of 10 L ha^{-1}, pressure of 400 kPa, 3 m of flight height and range of 16 m. In the second treatment were used eight rotary atomizers screen (model 05165, Travicar®) with D12 restrictor and 55 ° angle blades, application rate of 20 L ha^{-1}, pressure of 380 kPa, 3 m flight height and range of 16 m. The rate of application in the first treatment was the one recommended by the manufacturer of the electrostatic equipment and in the second it was the most usual in the region of the test.

The applications were made with the soybean in stage R6 (Development of the grain) within the normal management of the farm as to the moment of insecticide application. The leaf area index was 1.95 characterized by measuring the leaf area on four sample points of 1 m^2.

The aircraft used in all applications, model Cessna 188 Ag Truck was equipped with beaconing system by DGPS and flowmeter, and operated at a speed of 177 km h^{-1} (110 miles h^{-1}). The length of the experimental plots was 250 m and the width of 320 m. For each plot, the airplane made 20 passes of 16 m of track to ensure adequate overlap with lateral wind direction to the travelling direction (wind across).

The treatments were composed of the insecticide Engeo Pleno (thiamethoxam - 141 g L^{-1} + lambda cyhalothrin - 106 g L^{-1}) at the dose of 200 mL ha^{-1} and Aureo (Vegetable oil - soybean oil methyl ester - 720 g L^{-1}) at the concentration of 200 mL 100 L^{-1}.

For the evaluation of the drift, collectors were installed prior to the applications which consisted of PVC structures supporting nylon yarns 2 mm in diameter and 2 m in vertical length. The collectors were positioned at 20, 40, 80, 160 and 320 m of the applied area from the limit of each experimental plot in the direction of the wind displacement, in four replications. They were installed so that each yarn was positioned immediately above the canopy of the soybean crop.

The drift evaluations were made by quantifying the active ingredient thiamethoxam by means of high performance liquid chromatography. For this, immediately after the applications were made, the nylon yarns were carefully collected to avoid cross-contamination between packed samples in plastic bags, under light, and sent for analysis to the Laboratory of Pesticide Residues belonging to Embrapa Environment located in the city of Jaguariúna-SP.

The samples were then chopped into approximately 0.5 cm pieces using pliers. We weighed 5 g of sample into a 125 mL Erlenmeyer. After that 10 mL of methanol was added and stirred for 48 h on a shaker table at 65 rpm at room temperature. Them we pipetted 1 mL aliquot and filtered directly into a filter unit (PVDF-Hydrophilic, 0.22 μm). Chromatographic separations were performed using a high performance liquid chromatography system (Shimadzu, Japan), consisting of a pumping system (LC 10 AT pv), automatic injector (SIL 120 A), column oven (CTO 10 A) and UV-VIS detection (SPD 10 AV pv) at a wavelength of 254 nm. It was used a column C18 5μ (250 x 4.6 mm), 0.6 mL min^{-1} flow, elution in gradient mode, mobile phase acetonitrile: water starting with 10% of acetonitrile increasing linearly up to 40% for 20 minutes holding for a further minute, totaling 30 minutes of running. The injection volume was 20 μL. The retention time attributed to thiamethoxam was 20.4 minutes. Quantification assays were performed using an analytical curve with six different concentrations (0.0025 to 0.2500 μg mL^{-1}).

Assuming Thiamethoxam mass per collector area, we estimated the relative drift index in relation to the amount of active ingredient applied per area (28.2 g ha^{-1}).

$$D = \frac{\beta_{dep} \times 10000 m^2 ha^{-1}}{\beta_V}$$

On what,

D - Relative drift index (adm);

β_{dep} - Deposited drift (μg cm^{-2}),

β_V - dose (g ha^{-1}).

The evaluation of the effectiveness of treatments in the control of the caterpillar complex (*Anticarsia gemmatalis* and *pseudoplusia includens*) and stink bugs (*Euschistus heros*, *Nezara viridula* and *Scaptocoris castanea*) was performed in two periods: before application and five days after application. In order to do so, ten sampling points were randomly selected in each experimental plot and the counting of individuals was performed with the aid of a beat cloth (1.0 x 0.5 m). From the mean of collected data the efficacy control was calculated by the Abbott (1925) formula. The obtained values were then classified according to the criteria of low efficacy (less than 80%), good efficacy (from 80 to 90%) and high efficacy (greater than 90%).

A droplet spectrum study was also conducted to characterize the treatments done in the field by evaluating the droplets deposited on water-sensitive papers (76 x 26 mm), similar to the one used by Latheef et al. (2009). Before spraying, ten water sensitive papers were placed in each plot, all suspended on a metal rod, five immediately above the plants and five in the median position, held horizontally, facing upwards.

Subsequently, it was made the quantification and characterization of the impacts on each paper. For this, the papers were scanned (spatial resolution of 600 dpi non-interpolated with 24-bit color) and analyzed using the e-Sprinkle® software (v.2005) specific for this purpose. We determined the volumetric median diameter (VMD, μm), the relative span (RS, dimensionless) and the percentage of droplet volume with a diameter of less than 150 μm (% droplets <150 μm, %).

During the applications the environmental conditions of temperature, relative air humidity and wind speed were monitored through a climatological automatic data acquisition station positioned near to the test area. The temperature ranges from 26.7 to 29.1 °C, the relative air humidity from 65 to 71% and the wind speed from 6.7 to 9.8 km h^{-1}.

The obtained data were compared by the statistical method “Confidence Interval for Differences between the Means” with a confidence level of 90% (IC90%), as described by Velini (1995).

RESULTS AND DISCUSSION

The analysis of the confidence intervals of the droplet spectrum evaluations (Table 1) did not allow finding differences for RS in the median position of the soybean canopy, possibly due to foliage interference in droplet deposition. The rotary atomizer produced smaller droplets, both in the upper and medium positions, compared to the nozzles used in the electrostatic system. However, their droplets presented greater uniformity of size (lower RS) in the upper position.

TABLE 1. Volumetric median diameter (VMD), relative span (RS) and percentage of droplet volume with a diameter of less than 150 μm (% droplets <150 μm) from thiamethoxam aerial applications using electrostatic assisted spray nozzle and rotary atomizer in the upper and middle positions of the soybean canopy crop.

Treatment	VMD (μm)	RS	% droplets < 150 μm (%)
	Upper position		
Electrostatic	192.25 [182.38-202.11][1]	0.75 [0.68-0.81]	16.55 [11.10-22.00]
Atomizer	173.20 [170.39-176.01]	0.45 [0.33-0.56]	28.88 [23.14-34.61]
	Medium position		
Electrostatic	206.75 [201.45-212.04]	0.70 [0.51-0.89]	13.67 [9.11-18.24]
Atomizer	175.01 [174.17-175.83]	0.50 [0.36-0.63]	25.08 [20.84-29.32]

[1] The values in parentheses indicate the confidence interval (90%)

The blades angle (55°) of the atomizer was chosen because it is the most commonly used in the region for insecticide applications. In this sense, it is emphasized that there are other angulations that allow different droplet sizes.

The potential risk of drift represented by the percentage of droplet volume with a diameter less than 150 μm was higher when the rotary atomizer was used, as a consequence of lower VMD. It should be noted that in the water sensitive paper it is difficult to mark lower diameter droplets, especially below 50 μm. In this sense, we must evaluate the results with due caution without extrapolating the data. However, it can be seen that the found values for the rotary atomizer are within the same drop category (ASABE S572.1) of those found by Carvalho et al. (2016), who evaluated the droplet size of the rotary atomizer Travicar in a wind tunnel with measurement system based on laser diffraction.

In Figure 1 are represented the drift curves elaborated from the collected data in the field. From the regression analysis, it can be observed that the power model showed good adjustment to the data. These models allow knowing the covered distances by the droplets after their generation, being very useful for the study of the environmental impact on applications and for the determination of the safety strips (Bueno et al., 2016).

For drift up to 320 m distance from the sprayed area it was noticed that there was difference between the treatments mainly in the smaller distances. The rotary atomizer application promoted the greatest drift. At 20 m the relative drift index promoted by this treatment was 0.181 followed by the application with electrostatic system (0.110) which generated reduction of 39% drift.

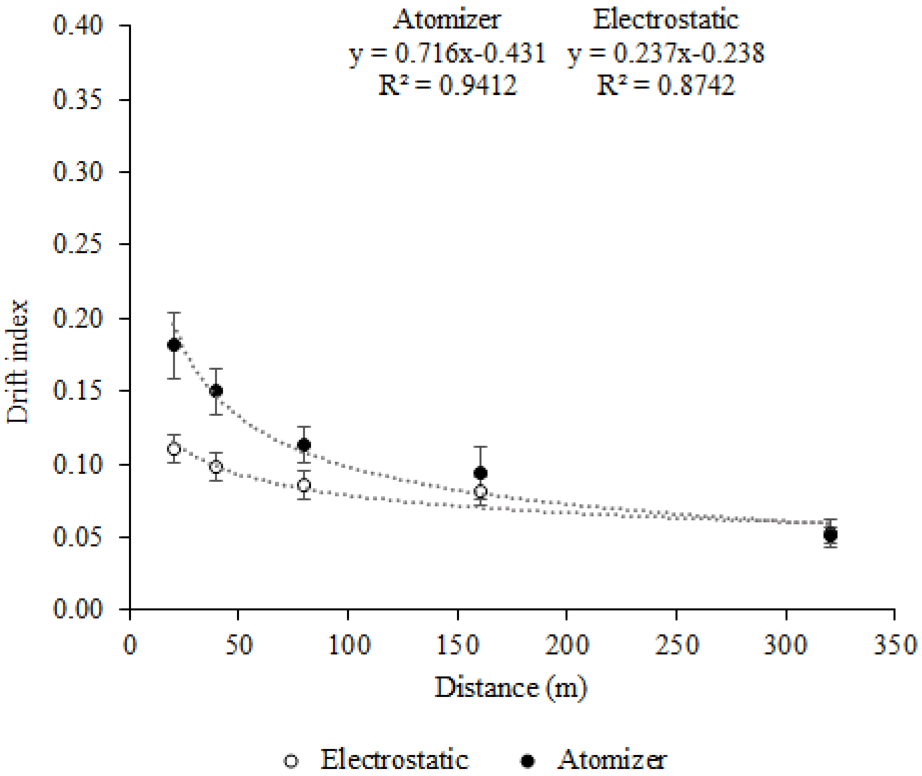

FIGURE 1. Drift curves for aerial applications of thiamethoxam in soybean using electrostatic system (10 L ha^{-1}) and rotary atomizer (20 L ha^{-1}). Vertical bars represent the confidence interval (90%).

It is verified that the hydraulic nozzles used in the electrostatic system compared to the atomizers on regulation used in this test did not generate greater risk of drift. The drops after being generated by the hydraulic energy of the tips are subjected to an electric field positioned around them, carrying them electrically, so that they are attracted by the plants (Schroder & Loeck, 2006).

It should be noted that the size of droplets generated by the atomizers is a function of the angulation of their blades and, therefore, it is possible to increase it by modifying this angle. The 55° angle of the blades was chosen because of their wide field use. Other features such as the arrangement of nozzles and atomizers along the plane boom may also interfere with drift results in addition to the droplet spectrum.

The evaluation of the water sensitive papers, although with previously limitations helps to understand the found results, since the rotary atomizers presented lower VMD and a higher percentage of composed volume with droplets smaller than 150 µm. Thus, the greatest drift potential measured on the sensitive paper was confirmed in the quantification of the active ingredient outside the target area.

Comparative drift assessments between atomizers and nozzles, including electrostatics, are not very common in the literature. Esehaghbeygi et al. (2010) evaluated an electrostatic sprayer in comparison to a ground centrifugal sprayer and concluded that electrostatic charging in fine droplets increased herbicide deposition on weeds and reduced drift.

The highest drift indexes were obtained at the collection point closest to the crop, decreasing as it moved away from the treated area (Figure 1). Drift curves with this profile have already been found by other authors, such as Hoffmann & Kirk (2005) and Antuniassi et al. (2014).

At 40 and 80 m distances, the behavior was similar: atomizers promoted at 40 m, greater drift (0.150) followed by electrostatic system (0.099) with reduction of 34%. The electrostatic forces can be used to direct and control the trajectory of the droplets, especially the fine ones (Maski & Durairaj, 2010; Laryea & No, 2002).

From 160 m there was a tendency for treatments to decrease the difference between them. Therefore, this region of the drift curve was detailed (Figure 2). At distances of 160 and 320 m, there was no difference between treatments.

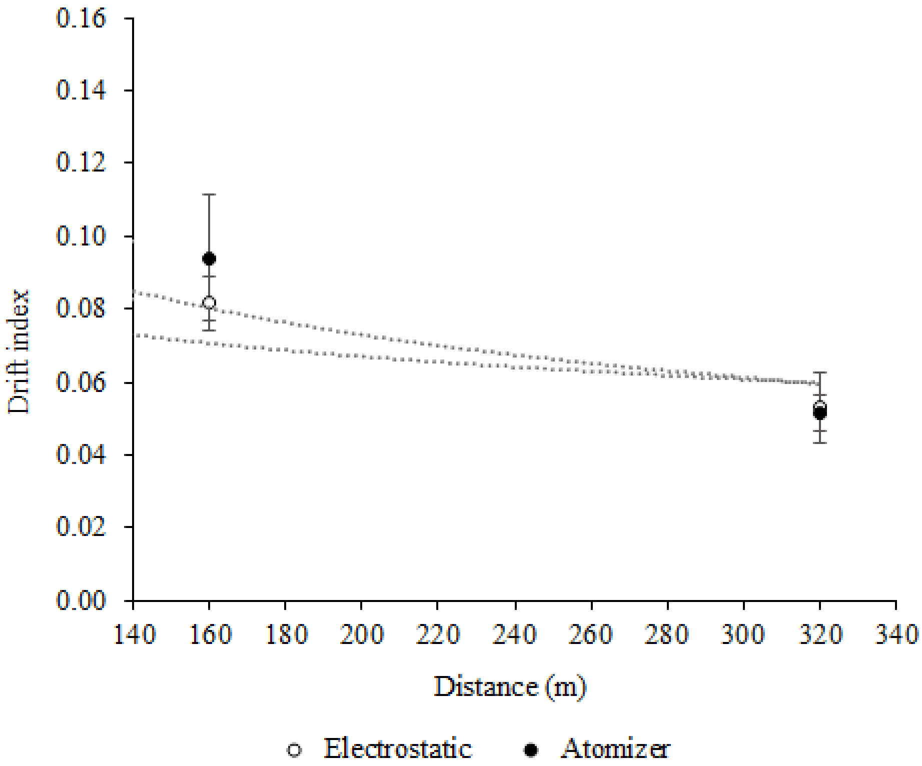

FIGURE 2. Detail of part on drift curves for aerial applications of thiamethoxam in soybean using electrostatic system (10 L ha^{-1}) and rotary atomizer (20 L ha^{-1}). Vertical bars represent the confidence interval (90%).

It has been found that it is possible to reduce drift by the spraying system used, and thus tests with different arrangements of the spraying elements on the boom, new droplet atomizers, different blade angles and adjuvants are required in order to further minimize drift loss.

Regarding the chemical control efficiency (Figure 3) it was observed that there was no difference between the two treatments, both in relation to the caterpillar complex and the stink bug. This demonstrates that there is technical feasibility in using the treatment that provided the lowest levels of drift. The mean number of individuals, considering the two treatments, five days after the applications was 0.3 m^{-2} caterpillar and 0.2 m^{-2} stink bugs. Before applications, the area had 3.3 m^{-2} caterpillars and 3.7 m^{-2} stink bugs thus, the mean efficiency control was 90.9% and 94.6%, respectively, and insecticidal treatments high efficiency (> 90%).

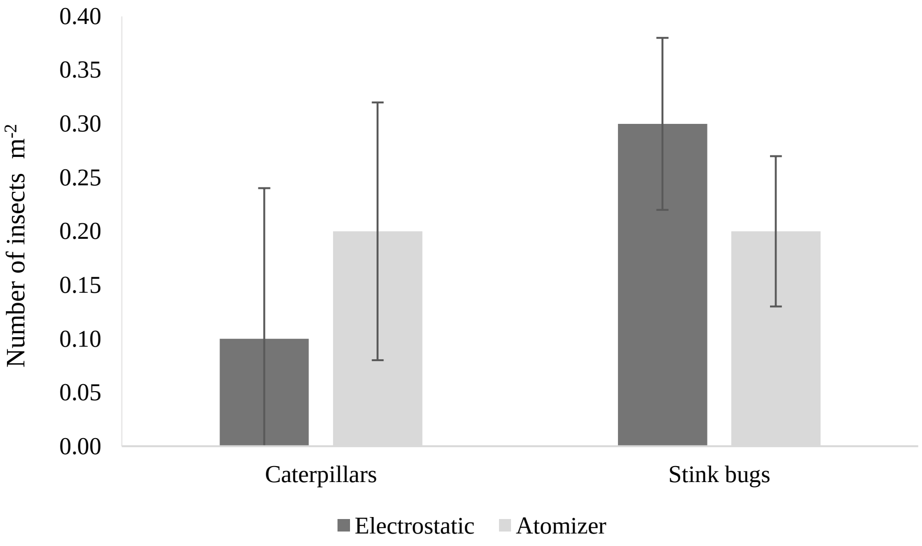

FIGURE 3. Number of caterpillars and stink bugs, five days after aerial applications of thiamethoxam in soybean, using electrostatic system (10 L ha^{-1}) and rotary atomizer (20 L ha^{-1}). Vertical bars represent the confidence interval (90%).

The results in this study are in agreement with those presented by Latheef et al. (2009) when comparing the aerial electrostatic spraying system with the conventional aerial spraying system with CP nozzles on the control of *Bemisia tabaci* in cotton in Arizona State, USA. In general, the authors found similar control results highlighting the advantage of working with lower rates of application in the electrostatic system. The authors concluded that there is potential for improved electrostatic application, but there is need for further studies to increase the charge-mass ratio in the drop loading system.

CONCLUSIONS

The hydraulic nozzles associated with the electrostatic system generated lower levels of drift and presented control efficiency of stink bug complex and caterpillars on soybean in relation to the rotary atomizers with blade angles at 55° under tested conditions.

It is possible to reduce the drift of aerial application by appropriate selection of the droplet spray system. In this sense, it is necessary to expand the studies of drift reduction techniques.

The drift at greater distances (from 160 m) tends to be little influenced by the droplet spectrum generated and the electric charge.

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