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ORIGINAL ARTICLE

The effects of rates, nozzle tips and electrostatics on the quality of sprayed applications on soybean crop

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Abstract

There is an ongoing search for technologies that guarantee soybean productivity. Among them, the application of phytosanitary products stands out, since the sprayer is the most required implement during the agricultural production cycle and each error, in practice, represents a loss in the production process. With this in mind, the objective of this work was to evaluate the volume captured and the characteristics of the application in the different thirds of soybean plants with variations in hydraulic nozzles and spray volumes, as well as the use of electrification of the drops. To this end, a field experiment was conducted during the 2018/2019 summer harvest in an experimental area at the University of Rio Verde. The experimental design used was randomized blocks in a factorial scheme (3 × 4), with four repetitions, in which the first factor consisted of three variations of spray nozzles (simple fan, hollow cone and hollow cone with electrification of the drops). The second factor involved four application rates (50, 100, 150 and 200 l · ha^{-1}). The variables evaluated were the number of drops per cm^{-2}, percentage of coverage, volume median diameter (VMD) and the captured volume (μl · cm^{-2}). According to the results, for the upper thirds, an increase in the application rate increased the volume of captured syrup. However, for the lower third, the factors evaluated did not interfere in this characteristic. The hydraulic tips influenced the density of droplets in the three thirds and the coverage only in the lower one. The increasing rates of application, increases the density of drops and percentage of coverage in the different thirds of the plants. The evaluated factors had no effect on the syrup distribution on the median abaxial surface of the leaves.

Keywords: application technology, droplet electrification, spray nozzles, sprayed volume

Introduction

In view of the high worldwide demand for soybeans, agriculture needs technologies that guarantee yield gains, such as the application of phytosanitary products. Losses in sprayed applications can exceed 65% of the applied total, mainly due to drift, evaporation and runoff to the soil. Drift in applications is considered to be one of the biggest problems in agriculture, both economically, as well as the exposure of workers, and environmental contamination (Belo *et al.* 2012; Van Zyl *et al.* 2013).

Such problems can be mitigated by the type of spray tip used. This component produces droplets of various sizes, which is a fundamental factor in the deposition of the product on the target. Fine droplets can increase coverage in applications due to the larger contact area with the target, however, they are more susceptible to drag caused by drift and evaporation. On the other hand, thick drops are more likely not to fixate on the target, which results in runoff to the ground, a reduction of the number of drops cm^{-2} and as a result, lower contact of the product with the plant (Cunha *et al.* 2006; Czaczyk *et al.* 2012; Fritz *et al.* 2012).

The application rate or spray volume are other determining factors for the success of an application. An increase in volume applied can increase the uniformity and the application of the cover (Cunha *et al.* 2006). Currently, the goal is to reduce the application rate in an attempt to optimize the autonomy of the sprayer and reduce production costs. Reducing the spray volume requires optimization of the application technology to maintain the quality and efficiency of the applications, which makes the selection of the spray tips very important. According to Viana *et al.* (2010), it would be possible for an application to succeed with an even lower applied volume, using uniform distribution with a certain diameter and number of drops.

In the research being done to reduce the application rate without compromising the quality of the operation, there are tools that can be used, especially electrostatics. This technique consists of a system that charges the drops with a negative charge, the difference in electrical potential between the drop and the target causes it to be attracted to the plant (Law 2014). Accordingly, the electrification of the droplets can allow higher deposition of the sprayed targets at lower application rates, and reduce drift losses by up to 50%, compared to conventional methods (Zhou *et al.* 2012; Patel *et al.* 2017).

In several cases, the drops need to deposit on the abaxial surface of the leaves, e.g., for silverleaf whitefly (*Bemisia tabaci*) and Asian soybean rust (*Phakopsora pachyrhizi*), since the location of these agents in the plant hinders the correct deposition of the pesticides on the target (Baldin *et al.* 2017; Furlan *et al.* 2018). Law (2014), demonstrated that the electrostatic force greatly exceeds the gravitational force, suggesting that it is possible to induce the deposition of the drops on the abaxial surface of the leaves during spraying. However, the result of using this technology is still inconsistent, since there are studies in which there were noted improvements in applications performed using this tool (Bayer *et al.* 2011). By detailing the effects of the different spray tips, whether or not subjected to the droplet electrification process, it is possible to better control the phytosanitary agents that affect the soybean crop, as well as reduce the risks of pesticide losses in the environment by drift and other processes. In addition, it is necessary to determine if the use of the electrification technique of drops makes it possible to perform the applications with lower volumes. The aim of this work was to evaluate the volume of captured syrup and the characteristics of the application in the different thirds of soybean plants using variations in volumes and spray tips, as well as the use of electrification in the drops.

Materials and Methods

The work was conducted in a field belonging to the University of Rio Verde, located in the city of Rio Verde (Goiás) (17°47’04.87”S and 50°57’52.56”O, at 778 m asl). The experiment was conducted with soybean, sowed in the summer of 2018/2019.

The climate for the locality in which the experiment was carried out is of the Aw type, according to Köppen’s classification. It is identified as a tropical climate with a dry season, more intense rains in summer than in winter, and two well-defined seasons with regard to the occurrence of rain. The annual average precipitation is 1,500 mm and the annual average temperature is 23°C (climate data 2020).

The experimental design was a randomized complete block design with four replications in a factorial 3 × 4. The first factor was composed of three variations of spray tips: single range (AXI11002 – 275.79 kPa), hollow cone (TXA80015 – 489.52 kPa) and hollow cone (TXA80015 – 489.52 kPa) with drop electrification. The second, involved four application rates (spray volume): 50, 100, 150 and 200 $l \cdot ha^{-1}$. To perform the electrification process of the drops, the electrostatic equipment was adapted, using a charging system with indirect induction manufactured by the TSBJet® (TSBJet, Santa Maria, Brazil). The voltage varied from 3,000 to 7,000 volts. In the experiment the maximum voltage was supplied. It is worth mentioning that in order to obtain the application rate foreseen for each treatment, the working pressure of the spraying system was not changed, since adjustment was made by varying the speed of the application equipment. For this purpose, speeds of 18, 9, 6 and 4.5 $km \cdot h^{-1}$ were used to provide application rates of 50, 100, 150 and 200 $l \cdot ha^{-1}$, respectively.

The soybean cultivar used in the experiment was NS 7709 IPRO®, which belongs to the Nidera company portfolio. This cultivar is characterized by an early cycle (maturity group = 7.2), indeterminate growth habit and architecture favorable towards deposition of the liquid spray (Nidera 2020). In the sowing, seed density was adopted in order to obtain a final population of 380,000 plants $\cdot ha^{-1}$, using interline spacing of 0.5 m. The dimensions of the experimental units were 6 m long and 2.5 m wide (5 rows of sowed soybean). To make up the used area of the plot, 4 m of the three central lines of the experimental units were considered, totaling 6 m^2.

The experiment contained a central transition corridor 3 m wide in its entire length, since the applications were carried out via a mounted sprayer. In the application, an Agrale 5050 (TDA) tractor was used, coupled to a nozzle (Jacto Condor AM12/600), with the adaptation of an electrostatic system by indirect induction electrification. At the time of the applications, the soybean plants were in the R5 phenological stage, which is the moment when grain filling begins (Fehr and Caviness 1977). The treatments were applied in the morning, between 8 and 12 o'clock, and in the afternoon, between 4 and 7:30. During the application, the average weather conditions were: relative humidity – 69.3%, wind speed – 5.6 km · h^{-1} and air temperature – 28.4°C. The measurements of the climatological data were carried out with a portable thermo-hygro-anemometer device (Kestrel® 3000), positioned at a vertical distance of 0.5 m above the culture.

For spraying evaluation, two different methodologies were used. The first was aimed to quantify the volume of syrup captured in the different thirds of soybean plant (upper, middle and lower). It consisted of the application of syrup with water, adjuvant (Wide LIM, 50 ml · 100 l^{-1} of water) and tracer (bright blue edible dye FDC 1 in a concentration of 3 g · l^{-1} of water), performed at 0.5 m above the crop.

After each application, samples of one trifoliate leaf for each third were collected from five plants per experimental unit, which were randomly separated, identified and packed in plastic bags (30 cm × 15 cm). Each sample per experimental unit was composed of five trifoliate leaves for each third of the plant. Subsequently, the material was collected and sent to a laboratory. All samples were washed with 50 ml distilled water to remove the dye (tracer), after manual shaking for 30 s. The absorbance reading of the solution obtained after washing each sample was performed using a 630 ηm wavelength spectrophotometer. Using syrup collected directly from the spray equipment, a calibration curve with different concentrations (0, 0.2, 0.4, 0.6, 0.8 and 1.0 μl) was drawn up to determine a standard for comparing the analyzed samples.

The absorbance values as related to different concentrations of Shiny Blue dye, allowed for the establishment of a straight-line equation, in this case: $y = -0.0010 + 0.0453x$ ($r^2 = 99.46$), used to indicate the concentration of the dye (mg · l^{-1}) captured by the target during the application (Scudeler and Raetano 2006). By correlating the concentration of the dye in the sample washing solution with that obtained in the spray solution, it was possible to establish the volume captured by the target using the following equation:

$$Vi = (Cf \times Vf)/Ci,$$

where: Vi – volume captured by the target (ml); Cf – concentration of dye in the sample, detected by the spectrophotometer in absorbance and transformed to mg · l^{-1}; Vf – sample dilution volume (50 ml); Ci – dye concentration in the sample (3,000 mg · l^{-1}).

Using a laser measuring scanner device (Cl-202 Portable Laser Leaf Area Meter), the leaf area collected from each treatment was determined. Then, the volume deposited was divided by the leaf area, thus obtaining the amount of syrup in μl · cm^{-2} in each leaf layer, after the application of each treatment.

At the time of applications, the second methodology was carried out concurrently in order to assess the density of droplets cm^{-2}, coverage (%) and volume median diameter (μm). In this, four composite rods made of three basal supports containing moisture sensitive cards, pre-identified, were randomly placed in the used area of each plot. After 30 s of application, the cards were collected and packaged in absorbent paper, separated according to upper, middle (adaxial and abaxial) and bottom thirds, so that subsequently they could be digitized and the application characteristics evaluated by the 2.2 Drops program (Chaim *et al.* 2006).

For statistical analysis, data was tested for normality, using the Shapiro-Wilk test and for homogeneity of error variance, by Bartlett. The data of droplet density and percentage of coverage did not show normal distribution or homogeneity of variance, therefore, they were transformed into a root of $x + 0.5$. Analysis of variance was performed for the evaluated characteristics and when a significant effect was found, regression analysis was applied to the application rates and spray tips with the Tukey test at 5% probability.

Results and Discussion

Captured spray volume

According to the results of the analysis of variance (Table 1), for the three-thirds of the plant (upper, medium and lower), there was no significant interaction between spray tip and application rate, for the characteristic volume of spray solution captured.

In relation to the upper third of the plants, there was a significant difference only for variations in the application rate, represented by increasing linear behavior (Fig. 1A). The increase in the application rate from 50 to 200 l · ha^{-1} provided an increase of almost 95% in the volume of sprayed solution. Therefore, regardless of the spraying tip used, an increase in the application rate increased the volume of spray solution in that position of the plant. In a study by Farinha *et al.* (2009), with applications in the soybean culture, a similar result was observed, since there was a correspondence in the reduction of the deposition of the syrup in the upper third with the reduction of the applied volume.

In relation to the middle third of the plants, there was behavior similar to that described for the upper one, since the spray tips also did not interfere in the volume of syrup captured in that position of the plant (Table 1). This may have occurred due to the difficulty

Table 1. Summary of the analysis of variance for the characteristic volume of syrup captured (μl · cm^{-2}) on the adaxial surface of leaves of the upper, middle and lower strata of soybeans after application of a tracer with variations in rates and spray tips

FV	GL	Medium square		
		upper	medium	lower
Block	3	0.067281	0.004311	0.000472
Tip (*T*)	2	0.052046 ns	0.001890 ns	0.002803 ns
Rate (*R*)	3	0.315120*	0.020996*	0.008219 ns
T × *R*	6	0.008382 ns	0.002094 ns	0.006484 ns
Error	33	0.021983	0.003532	0.005692
CV (%)		29.0	22.9	31.7

*significant at 1% probability by the *F* test; ns – not significant

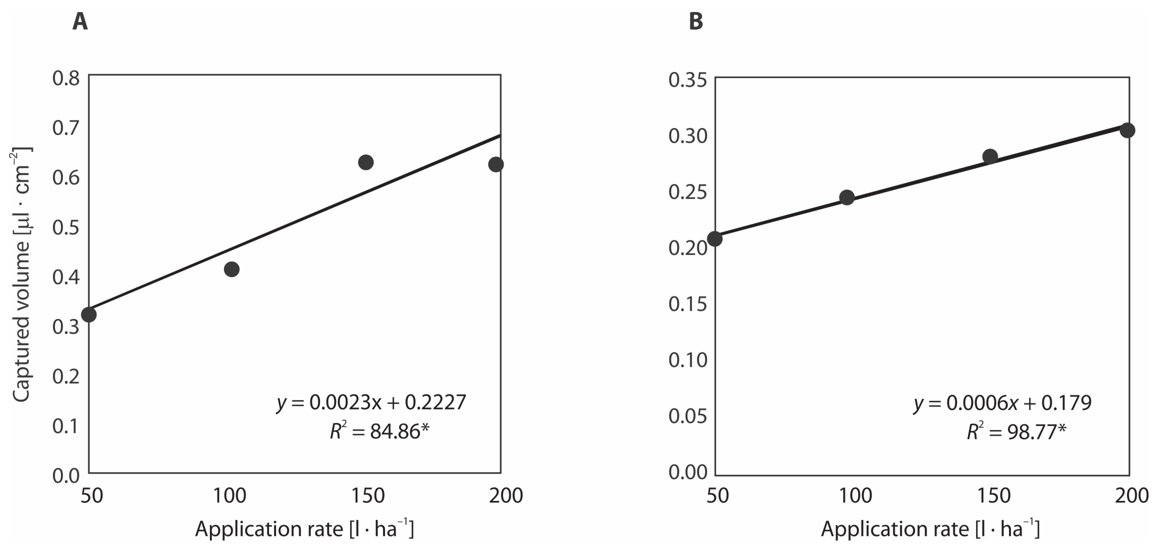

Fig. 1. Graphical representation of the regression for the characteristic volume of captured syrup as a function of the variation of the application rate in the upper (A) and medium (B) thirds in soybean plants; *significant adjust at 1% probability

of penetration, even of the thinnest drops, in the layer formed by the upper leaves. In an experiment carried out by Omoto *et al*. (2017), when evaluating the volume of syrup captured in the middle and lower thirds of soybean plants in the R5 reproductive stage, a significant difference in this characteristic after application with different spray tips was not observed. For the median third of the plants, regardless of the type of tip used, an increase in the application rate from 100 to 200 l · ha^{-1}, resulted in an increase of approximately 30% in the volume of captured syrup, represented by an increasing linear behavior (Fig. 1B).

According to Negrisoli *et al*. (2019), a spray volume of 250 l · ha^{-1} promoted better penetration of drops in the canopy of soybean plants, and, compared to lower volumes, it increased deposition in the middle third of the plant. Therefore, it is worth noting that despite the various benefits of reducing the application rate, this decision, when not carried of appropriately, can affect the quality of the application due to the lower deposition of the syrup on the leaves of the plant.

In the lower third there was no effect of spray tip variations, nor of increasing application rates for the evaluated characteristic. In this case, the use of electrostatics, was also not enough to optimize the range of the drops at the bottom of the plant. This can once again be attributed to the greater difficulty of penetrating the drops at the stage of development with the highest leaf area index (Souza *et al*. 2019).

This demonstrates with applications carried out on plants during initial developmental stages, i.e., during low leaf development of the crop, there is a greater chance of the drops depositing in the lower third, since this is a target difficult to access in sprayed applications. A second experiment carried out by Negrisoli *et al*. (2019), in which the spraying was carried out at the V9 vegetative stage, significant differences were found regarding the spray deposition (μl · cm^{-2} leaf) at the bottom of the crop canopy for the different spray volumes evaluated.

However, there are reports that the relationship between the type of spray tip and the volume applied, influenced the spray deposition in the lower third. In a study by Boschini *et al.* (2008), evaluating syrup spray deposition as a function of the applied volume and the type of hydraulic nozzle, the best combination was to use a hollow conical jet tip, with spray volumes of 200 or 300 l · ha^{-1}.

Application characteristics

According to results obtained by the analysis of variance, for all characteristics evaluated in the upper third, there was no significant interaction between spray tip and application rate (Table 2). However, regardless of rates, the tips significantly influenced the three characteristics. Analyzing the increasing application rates, except for volume median diameter (VMD), there was also an effect on the other characteristics.

For droplet density in the upper third (Table 3), referring to the spray tips, it was observed that, comparing the hollow cone tip with the fan, there was no difference, demonstrating that, for this plant location, both tips provided similar results. However, when using the electrostatic resource associated with a hollow cone tip, there was an increase in the number of drops cm^{-2}, when compared to the fan.

Sasaki *et al.* (2013), in work carried out with applications using electrostatics in coffee culture, found an increase of 37% in the deposition of the applied syrup. The various spray tips, influenced the percentage of coverage. The hollow cone tip with the use of electrostatics was better than without electrostatics. However, it gave a result similar to the fan type. Therefore, because the upper third is a more exposed target, the use of the fan tip becomes more viable due to the greater ease of work related to climatic conditions.

The volume median diameter of the droplets was influenced only by variations in spray tips. The VMD of the drops produced by the fan tip was higher than

Table 2. Summary of the analysis of variance for density droplets cm^{-2}, coverage (%) and volume median diameter (VMD), on the adaxial leaf surface in different strata of soybean plants after applications with varying rates and spraying tips

Source	*DF*	Mean square								
		upper			medium			lower		
		DD	COV	VMD	DD	COV	VMD	DD	COV	VMD
Block	3	385.24	5.37	541.28	208.07	1.23	579.09	132.24	0.62	274.80
Tip (*T*)	2	2253.89**	18.65**	2045.89**	705.89**	4.96 ns	22256.44*	379.00*	1.71**	7.48*
Rate (*R*)	3	12657.85*	462.12*	448.97 ns	5963.90*	108.14*	1055.10 ns	518.18*	11.49*	1312.61 ns
T x *R*	6	310.72 ns	4.63 ns	1190.34 ns	158.28 ns	0.26 ns	424.07 ns	87.16 ns	0.61 ns	1590.21 ns
Error	33	490.00	4.98	1730.72	264.04	3.41	1243.08	55.75	0.42	847.70
CV (%)		20.2	18.5	17.0	24.8	32.3	15.7	23.9	26.7	14.5

**, *, ns – significant at 5% and 1% probability and not significant, respectively, by the F test; DD, COV, VMD – droplet density, coverage and volume median diameter, respectively

Table 3. Average values for the characteristics of droplet density, coverage and volume median diameter on a leaf's adaxial surface of upper, middle and lower strata of soybean plants, with variations after application rates and spray tips

Spray tips	Density of droplets [cm^{-2}]		
	upper	medium	lower
Single fan	97.12 b	59.81 b	27.56 b
Hollow cone	110.93 ab	72.82 a	36.81 a
Hollow cone with electrification	120.75 a	64.25 ab	29.56 b
	Coverage [%]		
Single fan	12.04 ab	5.77 a	2.19 b
Hollow cone	10.99 b	6.24 a	2.82 a
Hollow cone with electrification	13.15 a	5.13 a	2.34 ab
	Volume median diameter [µm]		
Single fan	288.94 a	266.47 a	224.97 a
Hollow cone	223.06 b	214.52 b	192.75 b
Hollow cone with electrification	220.59 b	194.14 b	183.85 b

Averages followed by the same letter, in a column, do not differ by Tukey's test at 5% probability those obtained by the hollow cone tip, with or without electrostatics. This probably occurred due to the higher pressure used for the hollow cone jet tip. Related to this fact, in a study with applications using varying tips and application rates in coffee crops, there was an effect on leaf coverage only as a function of the spray tips regarding the deposition of drops in the different thirds of the plants (Silva *et al*. 2014a).

Regarding the application rates, there was a similar behavior for the characteristics of droplet density (Fig. 2A) and coverage (Fig. 2B), since the increase in the application rate from 50 to 200 l · ha^{-1} increased both characteristics by 94 and 301%, respectively. These behaviors are shown as a straight upward line. However, it is noteworthy that an exaggerated increase in the application rate can cause losses of the spray solution due to runoff to the soil.

According to the results of the analysis of variance, independence between the evaluated factors was observed for the middle third, given that there was no interaction between the spray tips and application rates for the evaluated characteristics (Table 2). Except for coverage percentage, variation in spray tips influenced all the features. However, the percentage of coverage was influenced by increasing application rates, as well as droplet density.

Regarding the density of droplets (Table 3), the two factors evaluated influenced this characteristic, highlighting the behavior of the hollow cone tip, which was superior to the fan tip, however, providing a similar result when the electrostatic resource was used.

Therefore, although the fan tip is the most used regionally, if the middle third of the soybean plants is in the reproductive stage of development, its use is not always justified. The creation of thicker droplets, which with this type of tip are larger than those produced by the hollow cone tip, can hinder their penetration in the middle third. Accordingly, it would be more feasible to choose the hollow cone tip in applications of 200 l · ha^{-1}, given that this volume afforded an 136% increase in drop density compared to the lowest rate used (50 l · ha^{-1}). This behavior is represented by an ascending linear line (Fig. 2C).

According to Durão and Boller (2017), in a study carried out with applications to control Asian rust in soybean crops using varying spray tips, it was reported that greater disease control in the middle and lower canopy of the crop was obtained using tips that produced drops of up to 250 μm due to greater ease of penetration than drops of a greater spectrum.

Even though the hollow cone tip types provided a greater number of drops cm^{-2} than the fan types, this difference was not enough to improve the percentage of leaf coverage in the middle third, even when using the electrostatic resource. This behavior also demonstrates the difficulty of the finer drops in crossing the leaf layer formed by the upper canopy of the culture. The only influence was from increasing application rates, in which the increase from 50 to 200 l · ha^{-1} increased this characteristic by 294%. It is represented by an increasing linear line (Fig. 2D). Thus, it is emphasized that the decision to reduce the application rate may impair the coverage in that position of the plant, regardless of the tip used.

Silva *et al*. (2014b), evaluating the spray deposition applied in soybean plants, found that the tips that produced drops between 100 and 200 μm, showed better coverage in the different thirds of the crop. Therefore, in order to increase the chances of obtaining satisfactory coverage in the middle third of soybean plants, in addition to the application rate, attention should be paid to the spray tip, opting for those that generate finer drops, given the difficulty of penetration.

With the results of the analysis of variance for the lower third of the plants (Table 2), there is factor independency. No significant interaction between the spray tips and application rates was found for any of the evaluated characteristics. The spray tip variations influenced the three evaluated characteristics. Except for the VMD, the application rates influenced the other parameters.

Regarding the characteristics of droplet density and percentage coverage in the lower third (Table 3), one can observe results different than those described for the upper thirds since the use of electrostatics in the applications does not differ from the simple fan tip type for both characteristics, highlighting the performance of the hollow cone type tip, which in turn was superior to the fan.

This may have occurred due to the greater difficulty of the drops to penetrate the lower third. Since the drops generated by the fan type tips were larger than the other tip variations, they were probably retained in the leaf mass of the upper third, or drained into the soil, thereby not reaching the lower third. The same may have happened with the hollow cone tip with the use of electrostatics. Even though drops of similar size were produced by the hollow cone jet tip, the electrification of the drops may have increased the difficulty of penetration due to the interaction with the leaves of the upper third.

From a study by Cunha *et al*. (2016) on applications of various types of spray tips, it was concluded that the hollow cone jet tip generated smaller and more uniform drops. This resulted in greater deposition of the syrup on the lower leaves of soybean plants than the same type of tip with air induction, which resulted in larger drops and thus, less coverage of the lower third. This behavior suggests that for late applications, the use of electrostatics can reduce the spray distribution in the lower third of soybean plants, since the number of droplets cm^{-2} and the coverage percentage, were similar to the fan type tip.

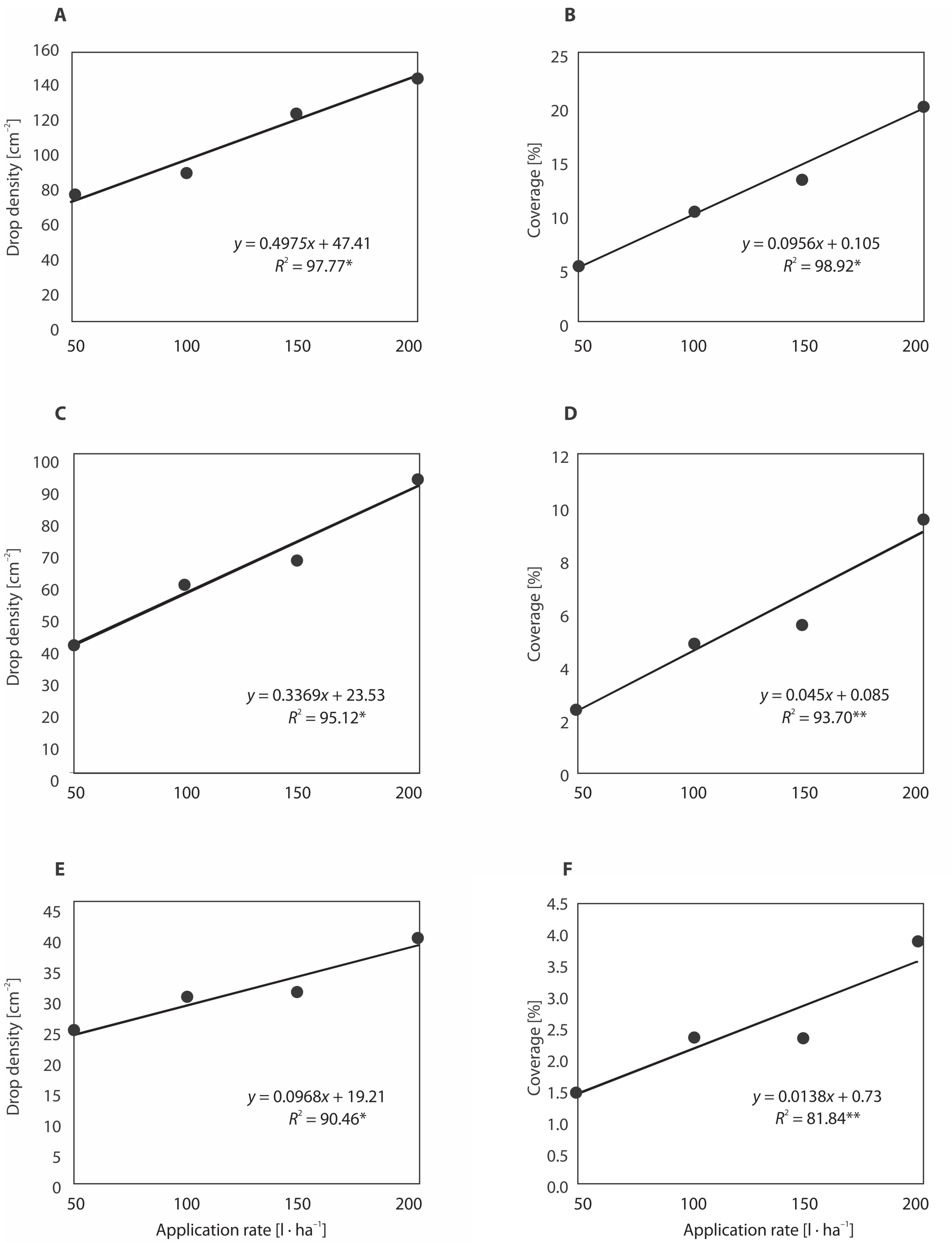

Fig. 2. Graphical representation of the regression for the characteristics of drop density and percentage of coverage in different strata of soybean plants as a function of the variation in application rate; A and B – density of droplets and coverage in the upper third; C and D – drop density and coverage in the middle third; E and F – drop density and coverage in the lower third; **, *significant adjust at 5% and 1% probability

In relation to application rates, there was a similar result for both drop densities (Fig. 2E). and for coverage percentage (Fig. 2F). An increase in application rate from 50 to 200 $\mathrm{l \cdot ha^{-1}}$ increased both characteristics by 69 and 159%, respectively. Thus, these characteristics are widened by increasing the application rate.

Tavares *et al.* (2017) carried out an experiment with applications for the control of fall armyworm

Table 4. Summary of analysis of variance for droplet density cm^{-2}, coverage (%) and volume median diameter (μm), on the abaxial surface of leaves of the middle third of soybean plants, after application with variations in rates and spray tips

Source	*DF*	Mean square		
		droplet density	coverage	volume median diameter
Block	3	2.18	0.01	17131.67
Tip (*T*)	2	0.27 ns	0.00 ns	12.60 ns
Rate (*R*)	3	1.74 ns	0.00 ns	2913.37 ns
T x *R*	6	0.32 ns	0.00 ns	1232.35 ns
Error	33	1.06	0.00	4707.75
CV (%)		141.6	150.9	120.5

ns – not significant by the *F* test

(*Spodoptera frugiperda*) in corn crops and concluded that, up to a certain limit, lower application rates do not harm the deposition of the syrup, and do not compromise the effectiveness of insecticides. However, it is worth mentioning that this behavior was possibly due to the fact that the leaf architecture of the corn plant favored the penetration and distribution of the drops, providing satisfactory product coverage for pest control. Therefore, the target and its location in the plant are essential factors in deciding which application rate to use, since an exaggerated increase, as well as a wrong reduction, can cause losses.

Related to the distribution of the syrup applied to the abaxial face of the leaves of the middle third of soybean plants, according to the analysis of variance, there was no interaction between the factors (Table 4).

Variations of spray tips and increasing application rates also did not influence, independently, any of the evaluated characteristics. Since this leaf region is an extremely difficult target to reach, the increase in the application rate, the use of fine drops, as well as their electrification, are not able to promote an efficient distribution of the spray in this location in soybean plants in the reproductive stage of development.

Considering the results of the present study, it is evident that the hollow cone tip provides better parameters related to the application technology than the fan type. In addition, the electrification process of droplets contributes to greater droplet densities being deposited on the biological target. Finally, the use of higher application volumes provides improvements in the syrup deposition in the different thirds of the soybean plants. In this sense, these results indicate the benefit of using the electrification process of drops in agricultural sprayings, a fact that may help in the management of pests and diseases in soybean crops. In addition, this work emphasizes the importance of using adequate application volumes to ensure that there are no flaws in the control of the biological target by performing this practice inappropriately.

Conclusions

Applications with fan, or hollow cone tips with or without electrification of the drops, provided a similar volume of syrup captured in the different thirds of soybean plants in the R5 phenological stage of development.

Related to the lower third, the hollow cone tip provided a greater number of drops per cm^{-2} and greater coverage than the fan tip. For the upper third, applications with the use of electrostatics increased the density of droplets when compared to the fan tip, however they did not differ in relation to the coverage.

An increase in the application volume rate increased coverage in the different thirds of soybean plants, as well as the volume captured in the upper and middle thirds.

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