

SPRAYING QUALITY OF CROP PROTECTION PRODUCTS USING TWO DROPLET SPECTRA IN THREE PERIODS OF THE DAY

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ABSTRACT: Spraying of crop protection products can be affected by weather conditions and spray nozzles, altering deposition patterns and coverage of the target surface. The objective of this research was to analyze the quality of sprayings performed in three periods of the day (9:00 am, 2:00 pm, and 6:00 pm), using two different droplet sizes (fine and coarse) in soybeans. Coverage and deposition were evaluated in the upper, middle, and lower portion of soybean canopy. Spraying the products at 2:00 pm increased leaf coverage in the medium portion but also increased losses to the soil. Spray nozzles with fine droplet sizes provided greater coverage and deposition in the medium and upper portion of the crop for the sprayings performed in the morning. If compared to coarse droplets, fine droplets increased leaf coverage and had no interference with the losses to the soil.

KEYWORDS: coverage, deposition, endo-drift, spraying time, application technology.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is one of the main crops grown worldwide, given its productive potential, chemical composition, and nutritional value. Its grains have high protein contents and a variety of applications in human and animal nutrition, as well as in industrialized products (Cunha & Espíndola, 2015). Unfortunately, during its cycle, these plants are subjected to the attack of pests and diseases, which may reduce productivity and quality. Chemical control is one of the most used techniques by farmers to control these damaging agents (Altoé et al., 2012). On the other hand, ineffective applications can generate losses to the farmer, ranging from the need for reapplications to a complete loss of the crop production potential. Therefore, it is extremely important to know the technology to be used for application of phytosanitary products (Zaidan et al., 2012).

Most of the crop protection techniques are ineffective in making drops penetrate into dense canopies, such as in soybeans at R3 and R5 stages (Cunha et al., 2014; Zhu et al., 2008). This condition decreases coverage levels and droplet deposition from the upper to the lower crop strata (Prado et al., 2015; Da Silva et al., 2014; Zaidan et al., 2012).

This irregular distribution of spraying droplets in crop canopy may hinder the control of damaging agents, especially those located at the lower stratum of plants, where deposition and cover are smaller. In addition, except in cases where the soil is the target of an application, the amount of drops striking it are also accounted as a form of drift (Payraudeau & Gregoire, 2012).

This way, weather and field conditions create specific local and temporal situations, which comprise a set of uncontrollable factors able to impair application efficiency. These conditions may be wind direction and speed, temperature, air relative humidity, and target features such as plant height and architecture, and position within the crop. Therefore, these factors must be taken into account while defining an application technique (Doruchowski et al, 2013).

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Given the above, this study aimed to evaluate the spray quality on soybean canopy, quantifying losses to the soil, in sprays performed in three periods of the day, and using two droplet spectra.

MATERIAL AND METHODS

The study aimed to characterize spray deposition and coverage in the upper, medium, and lower portions of soybean canopy, and quantify the losses of spray to the soil, during applications performed at different times of day and with two spray droplet spectra. The experiment was carried out in a randomized block design, with a 3 x 2 factorial arrangement scheme. One of the factors was three periods of application were 9:00-10:00 am, 2:00-3:00 pm, and 6:00-7:00 pm. The other factor was two spray droplet sizes fine (100 to 175 μm) and coarse (250 to 375 μm), according to the classification of ASAE S-572.1 (2009).

Each experimental unit measured 3.5 m x 20.0 m, with a 0.5 m border—47.5 m² of the useful area (2.5 m x 19 m). The soybean variety BMX Potência RR was sown on November 14, 2014, with a spacing of 0.45 m between rows and a density of 15 seeds per meter. The emergence of plants occurred on the fifth day after sowing, resulting in a final stand of 12 plants per meter and a population of 266,666 plants ha⁻¹. Sowing fertilization with formulated fertilizer (0-20-20) was applied at a dose of 165.29 kg ha⁻¹. At the time the treatments were applied, plants were at the R3 stage, with an average height of 0.95 m, determined by measuring ten plants per experimental unit.

Spray mixture consisted of water and dye tracers, Brilliant Blue FD&C (0.9% v v⁻¹) for deposition analysis, and Fluorescent LRM 100 (0.6% v v⁻¹) for coverage measurement.

Spraying was conducted using a tractor-mounted hydraulic field sprayer, with 3.5 m in length and seven nozzles spaced 0.5 m apart. Spray height was maintained at 0.5 m above the plant top, displacement speed at 1.8 m s⁻¹, and hydraulic operating pressure at 250 kPa, resulting in an application volume of 100 L ha⁻¹. For the fine droplet size, we used extended-range flat spray nozzles (model AXI 110015, Jacto[®]); as for the coarse droplets, we used air induction flat spray nozzles (model AVI 110015, Jacto[®]), according to the manufacturer's catalog.

In each application, temperature and relative humidity were measured using a thermo-hygrometer, brand ICEL, model HT-208; wind speed was determined using an anemometer, Minipa brand, model MDA-11; light intensity (lightness) was measured with a digital lux meter, Minipa brand, model MLM-1011 (Table 1).

TABLE 1. Temperature, relative air humidity, wind speed, and lightness during the three periods of daytime application.

Time (period)	Temperature (°C)	Relative humidity (%)	Wind speed (m s ⁻¹)	Lightness (lm m ⁻²)
9:00 - 10:00 am	29.9	68	0.27	944
2:00 - 3:00 pm	36.8	51	1.27	927
6:00 - 7:00 pm	33.9	53	0.34	89

Spray deposition and coverage were evaluated in crop leaves. For each experimental unit, fifteen leaves were taken for deposit analysis and other fifteen for coverage. These amounts were taken from each plant stratum (upper, middle, and lower), being obtained from three sampling points of each plot. The losses to the soil were evaluated by analyzing three glass plates with dimensions of 10 cm x 20 cm. These plates were placed on sheets of paper in the middle of the crop line, at the same sample sites for leaf collection.

After application, the leaves collected for deposit analysis were packed in 25 cm x 15 cm plastic bags. The leaves collected for the evaluation of coverage were conditioned in 30 cm x 20 cm paper bags. The glass plates for tracer deposition evaluation in between of the crop lines were packed in a rigid plastic container.

In the deposition evaluation, the leaves were washed with 25 mL of distilled water, shaken ten times while manually alternating between horizontal and vertical movements, and the glass plates were washed with 40 mL of water by shaking the container with the lid to remove the tracer. The liquid from washing the leaves and the glass plates were poured into rigid plastic containers with a capacity of 100 mL and the reading of absorbance was taken using a spectrophotometer, Fento brand; model 600 S (wavelength 630 μm).

After washing, the leaves were placed on a horizontal surface next to a scale graduated in millimeters and the upper part was photographed with a digital camera. The leaf area was measured using the software *ÁreaMed*[®] 1.1, calibrated with a scale in millimeters contained in the photo by delimitating the leaf edges and intern area. The standard curve of the mixture was made and the absorbance data converted to tracer mass per area (deposit).

The standard curve was made by consecutive and sequential dilution of the sample in 25 mL, then the absorbance of the samples was measured with a spectrophotometer (630 nm) and the angular coefficient of the regression curve was determined. The absorbance values were converted to mg L^{-1} , according to the standard curve coefficient.

Initial concentrations deposited on each leaf were obtained by equation 1. The product of this mathematical expression was multiplied by 1000 to obtain the volume in μL per plant and divided by the leaf area to obtain the results in $\mu\text{L cm}^2$.

$$C_i \cdot V_i = C_f \cdot V_f \quad (1)$$

where,

C_i - Initial concentration of spray, mg L^{-1} ;

V_i - Initial volume in mL which deposited in the different targets, mL;

C_f - Final concentration of the sample, mg L^{-1} ,

V_f - Final volume of water in mL used in the washing of each target, mL.

In the coverage evaluation, the percentage of leaves covered by the drops in the visual analysis was determined by visualizing the fluorescent tracer LRM 100 in a dark environment with an ultraviolet light projection (BL 15 BLB), with four 20 W lamps mounted in a lighting channel. This allowed a comparison of the leaves individually with a pre-established diagrammatic scale. To determine this scale, 50 leaves were collected and sprayed separately under the same conditions used in the experiment, from which 11 leaves were selected with levels of cover rising between the minimum and the maximum coverage obtained with the adopted spraying technique. The final scale presented grades between 0 and 100%, with intervals of 10%. The data were submitted to analysis of variance by using the F test and the means compared by the confidence interval (CI_{95%}).

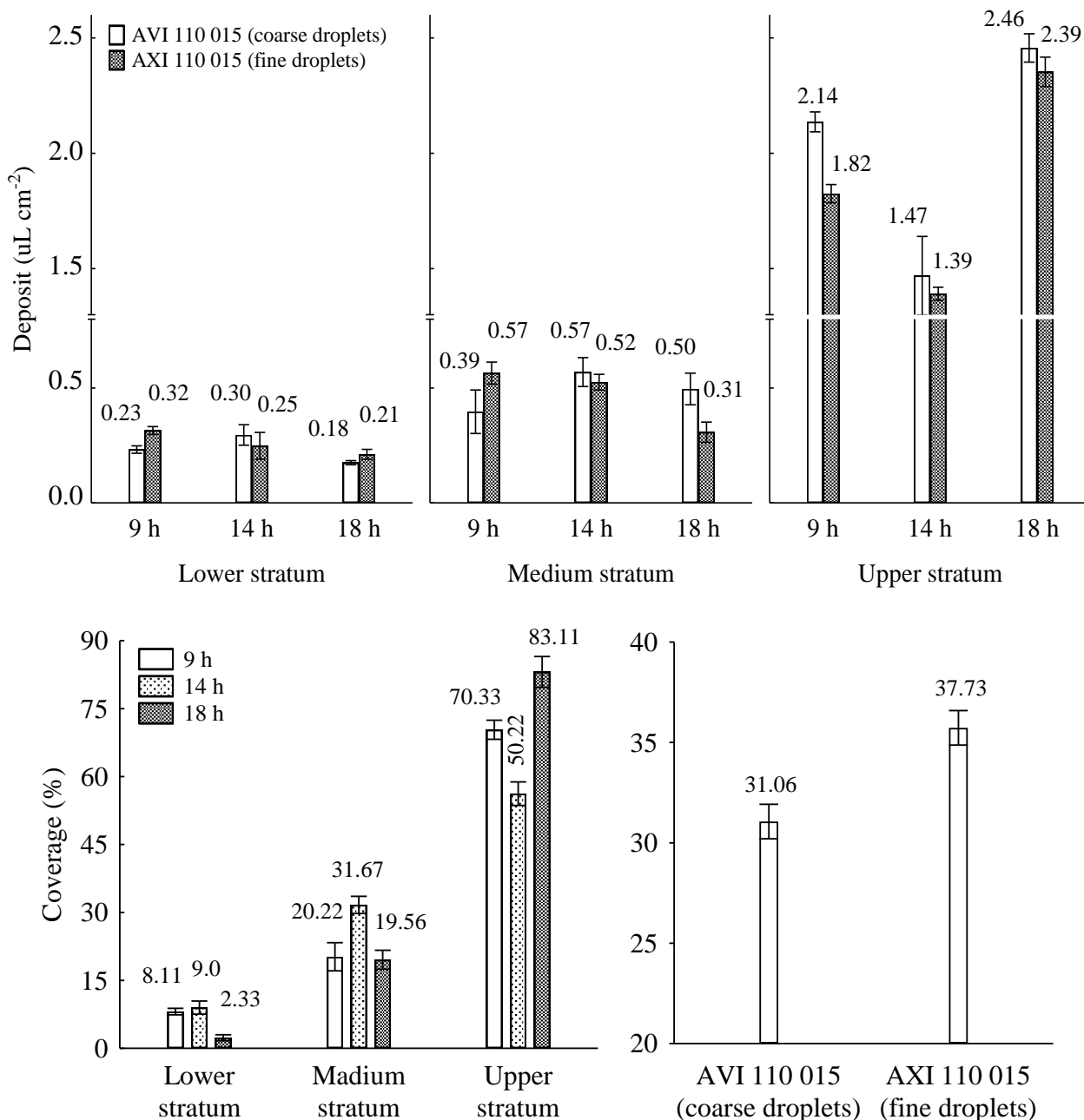
RESULTS AND DISCUSSION

An interaction among period of application, spray nozzle, and canopy stratum was observed for the variable deposition. As our main goal was to compare deposition at different times of application and droplet spectra, a statistical breakdown was performed for each canopy stratum. Yet for the variable coverage, there was an interaction between application time and canopy stratum. Daytime and nozzle model were analyzed separately to determine the loss of spray to the soil; however, there was no correlation between these factors.

The stratified analysis showed that deposition and coverage had a decreasing behavior from the upper to the lower stratum (Figure 1). This irregular deposition of spray throughout the crop canopy may reduce application efficiency, especially when the target is located at the lower portion of the crop.

If the sprayed product has difficulty reaching the lower part of plant canopy, the control of diseases may be impaired, favoring an early leaf senescence, what may decrease productivity

(Fiallos & Forcelini, 2011). Furthermore, a higher deposition on the upper part of plants can cause phytotoxicity symptoms because of a larger amount of product retained in this region.



Vertical bars: confidence interval (CI 95%). Coefficient of variation: 12.25% (deposition) and 13.38% (coverage)

FIGURE 1. Deposition and coverage in the upper and lower portions of soybean canopy (R3 stage) sprayed with AXI and AVI nozzles at three times of the day: 9:00 am, 2:00 pm, and 6:00 pm.

In spray applications at 9:00 am, fine droplets reduced deposition on the top of plants but increased in the lower and middle portions if compared to those of AVI nozzle. Target coverage was higher in applications with fine droplets than were those with coarse ones for all periods of applications and canopy portions.

Cunha et al. (2014) and Carvalho (2012) reported that fine droplets might improve coverage and penetration of spraying droplets into crop canopies with high leaf area indices. The size of the droplets produced by a spray nozzle should be chosen by considering target location. Smaller

droplets may improve control when the damaging agent is located in the lower part of plants. In addition to improving deposition in the lower portion of crops, fine droplets increased, on average, 21% coverage when compared to coarse droplets.

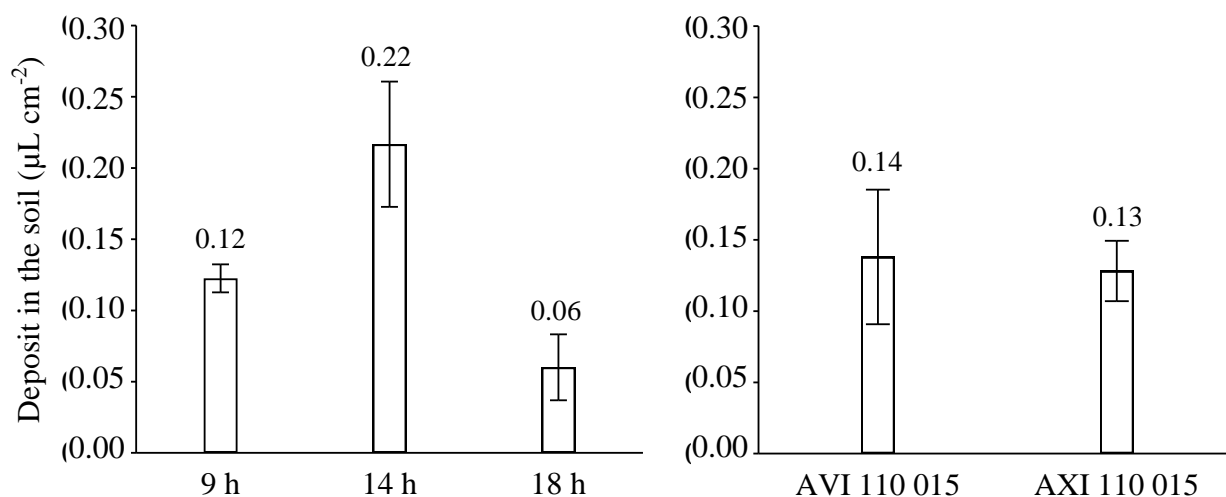
Spraying performed at 6:00 pm promoted the highest deposition for both droplet spectra in the upper stratum, while the application at 2:00 pm resulted in the lowest deposition level. At 6:00 pm, spraying provided a lower deposition in the medium stratum when comparing coarse to fine droplets; yet in the lower portion of plants, deposition was lower with coarse droplets.

Nascimento et al. (2013) tested several nozzles and two periods for the control of Asian soybean rust and found higher values of coverage and deposition in the upper portion of plants, but these variations did not affect crop productivity.

The spraying at 2:00 pm also reduced coverage in the upper stratum and improved it in the middle portion. Yet the spraying performed at 6:00 pm provided the lowest coverage in the lower portion.

There was no relationship between the meteorological conditions (temperature, relative humidity, lightness, and wind speed) and deposition at any daytime; however, a reduction of both deposition and coverage was observed in the lower and middle portions for the 6:00-pm application. This reduction might have been caused by changes in soybean leaf inclination throughout the day (Boller et al., 2011; Favera, 2012). According to Boller et al. (2011), leaf position tends to be horizontal in the first hours of the day, with the tips facing downwards. As the day progresses, it switches to a vertical position with the ends facing upwards, returning to the start position at the end of the afternoon. As such, such changes may benefit or even hinder penetration of drops into crop canopy at certain periods of the day.

In our study, these changes in leaf inclination raised the amount of droplets penetrated into the canopy at 2:00 pm, compared to the other schedules. Therefore, the smaller depositions on the upper stratum at this time were not only caused by increased losses but also by a facilitated penetration of droplets through the canopy, and consequently increasing the losses to the soil.



Vertical bars: confidence interval (CI 95%). Coefficient of variation: 31.38%.

FIGURE 2. Droplet losses to the soil in the soybean crop (R3 stage) sprayed with AXI and AVI nozzles, at three times throughout the day: 9:00 am, 2:00 pm, and 6:00 pm

Some studies have recommended applications of crop protection products in the morning or late afternoon to avoid higher temperatures and lower relative humidity and, consequently, evaporation and drift losses (Santos et al., 2013; Matuo, 1990).

Although the daytime when spraying is performed has changed deposition and coverage on soybeans in all plant strata, recommendations based on this variable should not be made to maximize application efficiency, since meteorological conditions vary widely from one day to another, and other environmental variables can interfere as well.

Sprays during warmer periods of the day are advisable since crop leaves are widely spread, facilitating penetration of droplets throughout the canopy. Even though these conditions are risky due to losses by evaporation and drift, they may benefit penetration of droplets into the crop canopy when associated with low-loss technologies, thus facilitating the control of damaging agents.

CONCLUSIONS

The time of the day to spray can be used as a technical strategy to increase the control efficiency of damaging agents in soybeans. The application of phytosanitary products at 2:00 pm increases coverage on leaves in the medium part of plants but also increases the losses to the soil.

Sprays in the morning using fine-droplet nozzles provided improved coverage and deposition in the medium and upper plant canopy parts. If compared to coarse droplets, besides increasing leaf coverage, fine droplets did not interfere with losses to the soil.

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