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# Deposition of spray droplets by four spray nozzles and two working pressures

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## Abstract

The deposition of spray droplets on the target can be influenced by the type spray nozzle used, as well as the employed working pressure. Thus, with the commercial availability of new spray nozzles, performance studies with the new models become necessary. This study was carried out to evaluate ground deposition of spray droplets by four models of spray nozzles, at two working pressures. The experiment was conducted in Dourados/MS, in September 2020, with strip design and 4x2 factorial scheme, with five repetitions. Four spray nozzles were used (single flat fan, ST-IA 02 model; angle flat fan MUG 02; hollow cone MGA 02; and double flat fan ST-IA/D 02), working at 30 and 50 psi pressures. The distance between each nozzle was 50 cm, 60 cm above the ground. Water-sensitive paper was used and, immediately after application, the paper was scanned using the DropScan® tool. Subsequently, the number of droplets, coverage, amplitude, dispersion, Volume Median Diameter (VMD), Number Median Diameter (NMD), DV09, and DV01 were evaluated. The hollow cone spray nozzle provided a higher number of droplets and greater coverage compared to the other nozzles for the studied weather conditions.

**Keywords:** Application technology; spray nozzle; water-sensitive paper.

## Introduction

Considering the crucial role of the application of agricultural pesticides, understanding their effectiveness is essential for the proper management of crops. During pesticides application, there are particular concerns regarding the efficiency of spraying; among them, the percentage of coverage, which is the disposition of spray droplets over the crop. Therefore, the efficiency of pesticide application can be defined simply by the volume of pesticide reaching the intended target divided by the total amount applied (MASSOLA et al, 2018; MORAES et al, 2019).

Another important factor for the efficiency of application is the adjustment of spraying equipment, speed of movement, spacing between nozzles, and, mainly, the choice of spray nozzles. In these systems, nozzles are responsible for fragmenting the liquid into droplets and forming the spray pattern, determining the volume at a specific operational pressure. Thus, selecting the nozzle that produces the largest droplet size while providing adequate coverage at the intended application rate and pressure can minimize losses and reduce production costs (CHECHETTO et al, 2014).

To achieve the greatest coverage, the correct selection of droplets sprayed through nozzles is necessary. The nozzles are formed by a set of components installed at the end of the hydraulic system through which the solution is fragmented (CUNHA, 2004). Among the constituent parts of the nozzle, the spray tip is the most important since it is directly responsible for the formation and distribution of droplets (BAUER, RAETANO, 2004; VIANA et al, 2010) and one of the determining components of the flow rate.

The simple flat jet is usually used in boom sprayers, and it is essential to consider the spacing between each nozzle to ensure a crossing spray and provide perfect coverage. The flat jet is used in various situations since it evenly distributes the spray, making it ideal for application across the entire strip (AZEVEDO, FREIRE, 2006).

The droplet size is also one of the most important factors that affect drift and it is essential to consider proper coverage to increase the chances of the product coming into contact with the target (DRESHER, 2015). The Volume Median Diameter (VMD) is the diameter of the droplets that divides the mass of sprayed droplets into two equal parts, with the sum of the volume of larger droplets equal to the sum of the volume of smaller droplets (CHECHETTO et al, 2014). According to ASABE (2018), the classification of droplets according to diameter for ground applications is: extremely fine (<60 $\mu$m); very fine (61–105 $\mu$m); fine (106–235 $\mu$m); medium (236–340 $\mu$m); coarse (341–403 $\mu$m); very coarse (404–502$\mu$m). Target coverage is influenced by the number of droplets, but fine droplets do not always provide more droplets nor better coverage. Weather conditions may be the factor that determines the choice of droplet size (VIEGAS NETO et al, 2021).

It is known that reducing the droplet size increases the efficiency of the application since a higher number of droplets increases the probability of the droplets hitting the target, which is measured by the Number Median Diameter (NMD) and the cumulative volumetric diameters of 10%, 50%, and 90% (DV 0.1, DV 0.5, and DV 0.9, respectively). However, fine and very fine droplets may be more easily influenced by weather conditions (SASAKI et al, 2016).

The general limit weather conditions for spraying are winds from 3 to 10 km h$^{-1}$, relative humidity above 55%, and temperature up to 30°C (ANDEF, 2004; ANTUNIASSI, BAIO, 2004). Therefore, this study was conducted to evaluate the deposition on the ground of sprayed droplets from four different models of spray nozzle at two different working pressures.

## Material and methods

The experiment was conducted at the University Center of Grande Dourados – UNIGRAN (22°12’36.2” S, 54°49’45.5” W), on September 3$^{rd}$, 2020, in the municipality of Dourados – MS. The soil in the region is classified as Dystrophic Red Latosol. The climate is classified as humid subtropical with high rainfall in the summer and dry winters, framed under the Cfa, Cwa, and Aw climate, according to the Köppen classification (PEEL, FINLAYSON, MCMAHON, 2007). The weather conditions were measured using a thermo-hygrometer, and the day was recorded as sunny, with winds from 2.5 to 5.4 km/h$^{-1}$, a 32.4 °C temperature, and a 32.2% relative humidity.

The experiment was carried out using a strip plot design with five repetitions and a 4 × 2 factorial scheme, where four spray nozzles were used (single flat fan, ST-IA 02 model; angle flat fan, MUG 02 model; hollow cone spray, MGA 02 model; and double flat fan, ST-IA/D 02 model), working at 30 and 50 psi pressures. The distance between each nozzle on the boom was 50 centimeters, 60 centimeters above the ground. The tractor used for the application was a 2003 New Holland TL 65, at a constant speed of 6.7 km h$^{-1}$ during application. The application volume varied according to the pressure and nozzle used.

Water-sensitive papers were placed on a flat surface on the ground, parallel to the sprayer boom. After application, the papers were collected and stored to avoid interference from moisture and subsequently analyzed using the DropScan® tool, which generated reports for evaluation of the application technology factors.

The Volume Median Diameter (VMD), Number Median Diameter (NMD), the diameter of the volume applied at 10% and 90% (DV01 and DV09), the number of droplets (cm$^{-2}$), coverage (%), amplitude, and dispersion were evaluated.

**Table 1** - Technical characteristics of the spray nozzles.

| Spray nozzle | Nozzle type | Brand | Application volume (L ha$^{-1}$) | |
|---|---|---|---|---|
| | | | Working pressure | |
| | | | 30 psi | 50 psi |
| MUG-02 | Angle Flat Fan | Magno Jet | 130 | 160 |
| MGA 02 | Hollow Cone | Magno Jet | 140 | 165 |
| ST-IA/D 02 | Double Flat Fan | Magno Jet | 130 | 160 |
| ST-IA 02 | Single Flat Fan | Magno Jet | 130 | 160 |

The data were subjected to analysis of variance and the means were compared by the Tukey' test at 5% probability.

## Results and discussion

Table 2 presents mean VMD, NMD, DV01 and DV09 with the four nozzles and the two working pressures. There was no interaction between pressure and nozzles, but there was an influence of the isolated factors. The coefficients of variation for the evaluations were 38.46% for VMD; 6.02% for DV01; 31.39% for DV09; and 4.59% for NMD.

The application performed with 30 psi and 50 psi pressures provided a mean Volume Median Diameter of 1,066.70 $\mu$m and of 623.30 $\mu$m VMD, respectively. The working pressure regulated in the spraying has a direct effect on the flow rate of the nozzle, as the higher the pressure, the greater the flow rate within the range stipulated by the manufacturer. However, increasing the pressure reduces the diameter of the droplet and increases the fraction of the droplet spectrum susceptible to drift. Fine droplets have a higher risk of drift, but can provide better coverage (MACIEL et al, 2017). The volume of application varied according to the pressure and nozzle used in this study.

There was a difference between the spraying nozzles used, in which the ST-IA/D 02 nozzle provided greater VMD when compared to ST-IA 02 nozzle (Table 2). Following the ASABE S572.1 classification (ASABE, 2018), the droplets generated by the ST-IA 02 nozzle were extremely coarse, and the droplets generated by the MUG 02, MGA 02, and ST-IA/D 02 nozzles were ultra-coarse. Extremely coarse and ultra-coarse droplets are ideal for applications where drift reduction is necessary (ALVES et al, 2017).

**Table 2** – Volume Median Diameter (VMD; $\mu$m), Number Median Diameter (NMD; $\mu$m), with the diameter of volume applied at 10% and 90% (DV01 and DV09; $\mu$m), obtained on the water-sensitive paper. Dourados–MS, 2020

| Treatment | VMD | DV01 | DV09 | NMD |
|---|---|---|---|---|
| 30 psi | 1066.70 A | 470.45 | 1425.05 | 222.65 |
| 50 psi | 623.30 B | 318.80 | 1055.20 | 219.55 |
| ST-IA 02 | 530.70 B | 301.20 | 945.20 | 229.70 AB |
| MUG 02 | 870.30 AB | 452.40 | 1325.08 | 172.40 B |
| MGA | 874.50 AB | 291.60 | 1234.05 | 245.50 A |
| ST-IA/D 02 | 1104.50 A | 533.30 | 1455.00 | 236.80 A |
| CV (%) | 38.46 | 6.02 | 31.39 | 4.59 |

* Equal letters in the same column do not differ from each other by the Tukey test at 5%

There was no difference in DV01 and DV09. Regarding the definition of the two terms, Schabatoski (2019) comments that the DV01 represents the diameter in which 10% of the volume was sprayed with droplets smaller than or equal to that diameter, and the DV09 represents the diameter in which 90% of the droplets were sprayed with droplets smaller than or equal to that diameter, as can be seen by the percentage of target coverage area.

For the Number Median Diameter, there was no difference when working pressure was changed, whereas, when the application was performed with the MUG 02 nozzle, a lower NMD was observed than the ST-IA/D 02 and MGA 02 nozzles.

Table 3 presents the data on the number, coverage, amplitude, and dispersion of droplets.

Matthews (2002) states that the number of droplets plays an important role in application purposes since the higher or lower number of droplets is related to the pesticide manufacturers' recommendations. According to the author, for instance, systemic fungicides require around 30 to 50 droplets $cm^{-2}$. However, for contact fungicides, the number of droplets $cm^{-2}$ should be greater than 70 droplets $cm^{-2}$.

Regarding number of droplet evaluations, we observed that the MGA 02 nozzle had a higher number of droplets than the other nozzles, resulting in greater coverage. The MGA 02 nozzle differed from the others regarding shape of the spray (cone), whereas the others are flat sprays. The analysis of number of droplets can be difficult due to droplet overlapping, which can lead to underestimated values (VIEGAS NETO et al., 2021). However, in this study, the values were consistent, with the MGA 02 nozzle providing the highest number of droplets.

## Conclusion

The MGA 02 hollow cone spray nozzle provided a higher number of droplets and greater coverage compared to the other nozzles for the weather conditions of the study.

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**Table 3** – Analysis of number , coverage, amplitude, and dispersion of droplet with 30 psi and 50 psi working pressures obtained in the water-sensitive paper. Dourados–MS, 2020

| Treatment | Number of droplets ($cm^{-2}$) | Coverage (%) | Amplitude | Dispersion |
|---|---|---|---|---|
| 30 psi | 49.20 | 26.55 | 1.022 | 4.674 |
| 50 psi | 52.25 | 18.40 | 1.069 | 3.164 |
| ST-IA 02 | 48.40 B | 18.90 B | 1.169 | 2.356 |
| MUG 02 | 19.60 C | 10.40 B | 0.985 | 5.386 |
| MGA | 108.30 A | 40.20 A | 1.010 | 3.217 |
| ST-IA/D 02 | 26.60 BC | 20.40 B | 1.019 | 4.717 |
| CV (%) | 19.58 | 28.34 | 13.50 | 29.54 |

* Equal letters in the same column do not differ from each other by the Tukey test at 5%

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