POPULATION AND SPECTRUM OF DROPLETS PRODUCED DURING ELECTROSTATIC SPRAYING AND HYDRAULIC SPRAYING USING AIR ASSISTANCE

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ABSTRACT

The droplet population produced during spraying influences the efficiency of pesticide application. It is possible to define a minimum number of droplets per unit area depending on the treatment and product to be applied. This study aimed to evaluate the characteristics of the populations and the spectra of droplets produced during electrostatic and air-assisted spraying. Factors including types of nozzles, spray volume, type of spray and its influence on the percentage coverage and density of droplet population. The experiment was arranged in a 2 x 2 x 2 factorial [two types of nozzles (Jacto JA-4, hollow cone and Jacto AXI-110-04, flat fan nozzle tip), two spray volumes (200 L ha^{-1} and 400 L ha^{-1}) and two sprayer types (air-assistance in the spraying sleeve boom and electrostatic spraying)] in a randomized block design with four replications. The electrostatic sprayer increased droplet density per cm^2 of leaf.

Keywords: Nozzle tip, water-sensitive card and spray volume.

RESUMO

POPULAÇÃO E ESPECTRO DAS GOTAS PRODUZIDAS DURANTE PULVERIZAÇÃO ELETROSTÁTICA E PULVERIZAÇÃO HIDRÁULICA COM ASSISTÊNCIA DE AR NA BARRA.

A população de gotas produzidas durante a pulverização influencia a eficiência da aplicação de um fitossanitário. De acordo com o tratamento e o produto a ser aplicado, é possível definir um número mínimo de gotas por unidade de superfície. Este trabalho teve por objetivo avaliar as características das populações e o espectro das gotas produzidas durante a pulverização com assistência de ar e eletrostática. Foram estudados os fatores tipo de ponta, volume de calda aplicado, tipo de pulverizador e sua influência sobre porcentagem de cobertura e densidade da população de gotas. Foi conduzido um experimento em esquema fatorial 2 x 2 x 2:, sendo dois tipos de ponta (jato cônico vazio, modelo JA-4, marca Jacto e jato leque, modelo AXI-110-04, marca Jacto), dois volumes de calda (200 e 400 L ha^{-1}) e dois tipos de pulverizador (com assistência de ar na barra e pulverização eletrostática). Foi usado o delineamento de blocos ao acaso, com quatro repetições. A pulverização eletrostática aumentou a densidade de gotas por cm^2 de folha.

Palavras-chave: Pontas, papel hidrossensível e volume de calda.

Recebido para publicação em 06/05/2013. Aprovado em 22/07/2014.

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INTRODUCTION

For many years the common bean (*Phaseolus vulgaris* L.) was regarded as a subsistence crop mainly grown by small farmers; however, in recent years beans have been grown in farms using advanced technology.White mold is one of the most severe bean diseases worldwide, especially when cultivated in areas of mild temperatures and high soil and air moisture. In crop lands where white mold occurred previously, the disease can be successfully managed by integrated management of pests and diseases. This strategy aims to obtain quality products with great reduction in pesticides. Fungicides are available for chemical control and are among the management measures that should be undertaken to reduce the effects in the field or even prevent the entry of white mold in the area. In general, primary infections caused by the fungus initiate in presence of free water and exogenous energy sources; usually senescing petals of flowers lying on the ground or retained on the plants. Thus, effective control of this fungus requires an efficient coverage of flowers, especially those located in the lower parts of the bean plant.

To ensure the biological effectiveness of fungicides, it is necessary to define an appropriate droplet size spectrum adapted to the meteorological conditions at the time of application. In locations of low humidity and high temperatures, large droplets must be used to reduce the risk of evaporation and drift; however, small droplets are desirable when applying fungicides because they provide better penetration into the canopy and better coverage. Small diameter droplets are susceptible to drift and evaporation, and large diameter droplets can often run off the target surface before the pesticide can act; in either case, failure occurs during a pesticide application.

The evaluation of spray deposition is the most representative method to understand the various aspects related to pesticide spraying (DERKSEN *et al*., 2012). An appropriate droplet size is one of the factors that provides the most effective control of pests, diseases or weeds with the smallest amount of pesticide applied and environmental contamination. A spray nozzle produces different droplet sizes. Thus, a classification method used to describe the general droplet-size spectrum (fine, medium or coarse) produced by a nozzle is the volume median diameter (VMD), which takes into account the droplet diameter that divides the volume corresponding to the droplets of a sample into two equal parts.

Air-assisted sprayers have been used to increase droplet penetration into the crop and reduce spray drift (YASIN, 2012). Hydraulic tractor sprayers with air assistance have one or two fans, usually of axial flow, positioned near the central section of the spray bar that distribute a high volume of air in an inflated duct mounted above the spray bar (MATTHEWS, 2000). Sprayers with air-assistance in the spraying sleeve boom are reported to decrease losses due to drift, especially when working with small droplets (GARCIA-RAMOS *et al*., 2012).Electrostatic spraying has also been used to improve the quality of pesticide application, allowing for reduced doses needed to obtain high levels of disease control. When studying the effect of electrostatic charge of spray droplets on the variability of spray deposition and the efficacy of glyphosate on weed control in soybeans, Souza (2002) found that charging of spray droplets produced a more uniform deposition on *Commelina benghalensis*, which allowed for reducing the doses of glyphosate necessary to achieve high levels of control of this species.

This study aimed to evaluate the coverage and density of droplets deposited on bean leaves at the bottom of the canopy using a hydraulic sprayer with air assistance in the spraying sleeve boom and an electrostatic sprayer, two sets of spray nozzles and two spray volumes.

MATERIAL AND METHODS

The experiment was conducted in a field cultivated with the common bean cv. Carioca Pérola, under pivot irrigation, in the developmental stage R6 (the opening of the first flowers defines the R6 stage (flowering)), extending until fall of the corolla of the first fertilized flower, exposing the first pod in early development. The field belongs to the Agro-Reservas Farm of Brazil, located in the municipality of Unai, Minas Gerais. The experiment was performed using a Jacto Falcon Vortex, with a 600 L tank, and an axial fan for air assistance in the spray boom (coupled to a Valtra BM 100 tractor with 73.5 kW (100 hp) engine) with a Spra-Coupe 3640 electrostatic sprayer.

Droplet density and coverage were characterized according to the droplet spectrum, droplet density and percent coverage. Forward speed of the tractor-sprayer was timed over a distance of 50 m and adjusted to maintain the solution application rate at 200 L ha^{-1} and 400 L ha^{-1}. The hydraulic spray nozzles used in the experiment were: Jacto JA-4, hollow cone with working pressure of 600 kPa, and Jacto AXI-110-04, flat fan nozzle tip, with working pressure of 300 kPa.

The experiment was arranged in a 2 x 2 x 2 factorial: nozzle type, spray volume and spray type, in a randomized block design with four replications. The area of the experimental unit was 15 m^2 (5 x 3 m). Air velocity was obtained using an angular fan with shaft speed of 2100 rpm (219.91 rad s^{-1}).

The relative humidity and air temperature were monitored using a psychrometer. Manometers were calibrated based on the principle of comparison using a class-A standard pressure gauge to obtain the ratio between the pressure indicated and actual pressure. The fan shaft speed was using a Tako TD 303 digital tachometer.

Droplet size was estimated using water-sensitive paper. The water-sensitive papers were taped to the lower part of the plant canopy. Five papers were distributed per plant, one at each cardinal point and one in the center. Three plants were analyzed from each plot. After the sprayings, the water sensitive papers were removed and stored.

Each set of papers from the same treatment was identified and photographed using a Nikon Coolpix 5.1 Megapixel Digital Camera. Photographs were processed using the image analysis software Image Tool 3.0. The size of the droplets collected on the water sensitive papers was corrected by Equation 1 as shown below.

$$F = 0{,}74057 + 0{,}0001010399\ D + 0{,}2024884\ \ln(D) \quad (1)$$

Where,

F = spread factor, and
D = limit diameter of each size class (μm).

Data were subjected to analysis of variance and means were compared by the Tukey test at 5% probability using the software SAEG 2.0.

RESULTS AND DISCUSSION

In the lower canopy of plants, there was a significant effect of the sprayer type and spray volume, as well as the interaction between these two factors (Table 1).

Table 1. Summary of the analysis of variance of the target coverage on water-sensitive papers taped to the lower canopy leaves of bean plants, for the variables: hydraulic nozzle types, spray volumes and sprayer types.

SOURCE	DF	MEAN SQUARE
Sprayer	1	123.95**
Volume	1	475.86**
Nozzle	1	1.065ns
Sprayer x Volume	1	44.604**
Sprayer x Nozzle	1	0.9870ns
Volume x Nozzle	1	0.396ns
Sprayer x Volume X Nozzle	1	1.209ns
Residual	21	1.90
CV (%)		15.58

ns Non significant at 5% probability; ** Significant at 1% probability and * Significant at 5% probability by the F-test.

Both the air assistance-sleeve boom sprayer and electrostatic sprayer provided significant difference between the volumes 200 L ha^{-1} and 400 L ha^{-1}. Therefore, coverage of the papers placed on the lower leaves of bean plants increased with the spray volume. However, in the two volumes tested, the target coverage was statistically higher with the electrostatic sprayer than with the air assistance-sleeve boom sprayer (Table 2).

Increased target coverage in the lower bean canopy can mean better control of diseases, especially fungal infections that begin in this part of the plant, as in the case of the bean white mold. The best results obtained by the Spra-Coupe sprayer are likely related to the droplet size produced, since small droplets provide better target coverage (in appropriate weather conditions); they also have high penetration capacity into the plant canopy and are less susceptible to runoff losses from the leaves. Conversely, the wind moves small droplets more than large droplets causing drift, which can increase evaporation during application.

For droplet density in the lower canopy of the bean plants, similar to target coverage, there was a significant effect for the sprayer type and spray volume, as well as significant interaction between these two factors (Table 3).

Both the increased volume of application and the sprayer type increased the droplet density. The largest number of droplets was provided by the electrostatic sprayer with the spray volume of 400 L ha^{-1}, presenting an average of 126.41 droplets per cm^2 leaf (Table 4).

Table 2. Mean values of target coverage (%) for the combination of spray volume x sprayer type in lower canopy leaves of bean plants

Volume (L ha^{-1})	Sprayer	
	Vortex	**SPRA-COUPE**
200	1.85^{Aa}	8.15^{Ab}
400	11.93^{Ba}	13.50^{Bb}

* Means followed by the same capital letters in the columns and lower-case letters in the rows are not significantly different by the Tukey's test at 5% probability.

Table 3. Summary of the analysis of variance of the droplet density on water-sensitive papers taped to the lower canopy leaves of bean plants, for the variables types of hydraulic nozzles, spray volumes and sprayer types

SOURCE	DF	MEAN SQUARE
Sprayer	1	42313.59**
Volume	1	9839.59**
Nozzle	1	206.90^{ns}
Sprayer x Volume	1	667.67**
Sprayer x Nozzle	1	303.13^{ns}
Volume x Nozzle	1	429.17^{ns}
Sprayer x Volume X Nozzle	1	451.72^{ns}
Residual	21	29.63
CV (%)		8.01

^{ns} Non significant at 5% probability; ** Significant at 1% probability and * Significant at 5% probability by the F-test.

Table 4. Mean values of droplet density for the combination spray volume x sprayer type in lower canopy leaves of bean plants

Volume (L ha^{-1})	Sprayer	
	Vortex	**SPRA-COUPE**
200	18.62^{Aa}	82.21^{Ab}
400	44.55^{Ba}	126.41^{Bb}

* Means followed by the same capital letters in the columns and lower-case letters in the rows are not significantly different by the Tukey's test at 5% probability.

The increase in spray volume increased the droplet density on the leaves collected from the middle third of the bean plants. The larger number of droplets can provide better pest control, however, with the increase in volume of application, the risk of soil contamination increases and the operational capacity of the tractor-sprayer decreases.

On the other hand, several authors have studied the fact that electrostatic spraying increases droplet density, mainly when working with small droplets, which in order to be applied efficiently, electric forces can be introduced in sufficient magnitude to control their movements, including the movement against gravity.

Larger droplet density is generally associated with smaller-diameter droplets which could be a problem if application is performed in locations of low humidity and high temperatures, due to the risk of evaporation and drift. In summary, it can be stated that small-diameter droplets are susceptible to drift and evaporation while large-diameter droplets are susceptible to run off.

CONCLUSIONS

- In general, electrostatic spraying improved droplet density and target coverage of the middle and lower parts of bean plants;Droplet density on the leaves and the target coverage increased significantly in the lower parts of bean plants when the spray volume increased from 200 to 400 L h^{-1}.

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