DROPLETS POPULATION SPECTROMETRY AND ITS EFFECT ON COSTAL HYDRAULIC SPRAYING DISPERSION

ESPECTROMETRIA DA POPULAÇÃO DE GOTAS E SEU EFEITO NA DISPERSÃO DA PULVERIZAÇÃO HIDRÁULICA COSTAL

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ABSTRACT: The droplets population and spectrum produced during a spraying influence the pesticides distribution efficiency. Through the droplets population and spectrum is possible to determine the quality of spraying and the implications on applicator and consumer safety, application efficiency and environmental impact. Droplet density (droplets cm^{-2}), percentage of coverage, coefficient of uniformity and relative amplitude were studied in this experiment. The experimental design was a factorial scheme 3 x 2: three spray volumes and two insecticides doses. During the tests all factors were analyzed on six parts of the plant canopy: on the top and external, top and internal, middle part and external, middle part and internal, bottom and external, and bottom and internal, using the completely randomized design with three replications. The objective of this study was to assess the characteristics of droplets population and spectrum produced during the hydraulic spraying. In general, for all factors assessed there was no significant difference between the parts of the plant canopy studied, having the greater values on the external parts of the plant canopy.

KEYWORDS: Droplets Population and Spectrum. Water Sensitive Papers. Spray Volume.

INTRODUCTION

Spraying technology lies on utilizing scientific knowledge to maximize a certain productive process. One approach to increase the spraying efficiency is to minimize the loss and contamination risk provoked by pesticides. Moreover, important aspects on each situation must be taken on consideration, likewise, climate, biologic, economic and operational factors (VIANA, 2010).

According to Teixeira et al. (2008), in locations where the predominant climate presents low humidity and high temperatures, coarse droplets should be applied in favor to reduce the evaporation and drift. When higher penetration on the target is expected, smaller droplets are recommended. Droplets with superior diameter are susceptible to runoff; smaller droplets are susceptible to evaporation and drift.

The adoption of correct techniques can effectively reduce the risk or problems during spraying phytosanitary products. The spray nozzle and adjuvant selection can be an important measure to produce droplets with larger diameter and less subjected to drift (COSTA et al., 2007; QUEIROZ et al., 2008).

The droplets formation are accountable to the spray nozzles and, each nozzle presents its proper characteristics regarding the droplets spectrum and deposition profile, specific to different targets (FERREIRA 2011).

On the hydraulic spraying, the droplets populations produced by a spray nozzle are not produced on a unique size. In this regard, the size used to classify the spraying (fine, medium or coarse) is in relation to the Volumetric Median Diameter (VMD).

According to Viana et al. (2010), the most important parameters to determine the droplets population are the Volume Median Diameter (VMD), the relative Amplitude (AR) and the percentage of droplets with less than 100 µm. On bulk, they define the spray drift potential, the homogeneity and droplets size produced by the spray nozzle (FERREIRA 2011).

There are two droplets size classifications; one is conducted by the British Crop Protection Council (BCPC) and the other by the American Agricultural Engineers Association (AAEA). The last one, as for being simpler and more practical, has being used by a wide range of nozzle producers to describe the different spray droplets sizes and facilitate the right selection by the user. Some pesticide manufacturers introduced the AAEA classification, as to recommend the droplets size class to be produced, on their labels. Being < 100 µm Very fine, between 100 and 175 µm Fine, 175 to

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250 µm Medium, 250 to 375 µm Coarse, 375 to 450 Very coarse and > 450 µm Extremely coarse (SILVA 2007).

To the droplet spectrum evaluation, water sensitive paper is used due to its handy aspect, the droplets stay preserved on the paper and can be analyzed with computer programs (BAESSO, 2009). Nevertheless, there are drawbacks due the impossibility to its use associated with high volume or low speed spraying. In addition, the selection of the period to spray can stain the water sensitive paper due the crop high relative humidity, usually early on the morning. Therefore, according to Romám (2009), high humidity should be avoided when utilizing water sensitive paper.

The study was undertaken to estimate the droplets population and spectrum produced by a manual sprayer culture of tomato. During the research, three different spraying volumes were tested, as well as two indoxacarbe pesticide doses.

MATERIAL AND METHODS

The study was conducted in a commercial Tomato (*Lycopersicon esculentum* Mill) crop area, Santa Clara tomato cultivar, Coimbra City, Minas Geraes State, Brazil. (Latitude 20º51'24" S, Longitude 42º48'10" W and 720 meters height). The tests were performed using the manual backpack sprayer, Jacto brand, PJH model, 20L capacity.

To the volume/dose relation, the dose was considered as a quantitative factor, analyzing it through regression. Moreover, to the dose/volume and position/dose the means were compared using the Tukey test, 5% probability.

The droplets population was characterized by the droplets spectrum, coverage percentage and density. During the spraying, three different volumes were tested. The pesticide application, using the manual sprayer, was performed after previous volume determination by the TRV (Tree Row Volume) method. This method verifies the spray solution volume by the plant volume existing in the area; in other words, ascertain a pre-determined volume to the area vegetation volume. (Equation 1)

$$TRV = \frac{H\,L\,10000}{D} \quad (1)$$

Being:
TRV – Tomato canopy volume, $m^3 ha^{-1}$;
H – Tomato plant height, m;
L – Tomato plant length, m;
D – Lines distance, m.

The tomato plants used on this study presented the following average dimensions: 1,69 m height, 0,53 m length and distance between lines of 1,00 m.

Conforming to the Equation 1 the TRV was calculated, it corresponds to the tomato canopy in one hectare:

$$TRV = \frac{1{,}69\ 0{,}53\ 10000}{1{,}00} = 8{,}983{,}5\ m^3\ ha^{-1}$$

The solution volumes used on spraying were: VP_1 = 300 L ha^{-1}; VP_2 = 400 L ha^{-1}; VP_3 = 500 L ha^{-1}. Conforming with Equation 2, the volumetric indexes were calculated (IV): IV_1 = 33,4 ml m^{-3}; IV_2 = 44,5 ml m^{-3}; e IV_3 = 55,6 ml m^{-3}. Comparing the calculated volumetric indexes with the tabulated ones (Table 1), the volumes indexes (IV_1 = 33,4 ml m^{-3}; IV_2 = 44,5 ml m^{-3}) were considerate as very low spraying volume and the o IV_3 = 55,6 ml m^{-3}, considered as low spraying volume.

The AIXR 11002 spray nozzle, Teejet®, with a pressure regulating valve which provides for pulerização a pressure stability and thus adopted was a pressure corresponding to 2 bar. The spraying volumes were calculated by spraying 15 tomato plants, observing the volume to do so.

Using these values and knowing the vegetation volume in one hectare, the spraying volume was calculated, being: VP_1 = 300 L ha^{-1}; VP_2 = 400 L ha^{-1}; VP_3 = 500 L ha^{-1}. According with the spraying volume, the spraying speed was estimated, being VP_1 = 300 L ha^{-1}; VP_2 = 400 L ha^{-1}; VP_3 = 500 L ha^{-1} to 1,6 kmh^{-1}, 1,2 km h^{-1}, 0,96 km h^{-1} respectively.

The Volumetric Index was calculated using the TRV and spraying volumes values according to the Equation 2:

$$IV = \frac{VP}{TRV}\,1000 \quad (2)$$

Being:
IV – Volumetric Index, ml m^{-3};
VP – Spraying Volume, L ha^{-1};
TRV – Tomato canopy volume, m^3 ha^{-1}.

The recommended volumetric indexes, according to the spraying uniformity pattern, were compared according to the values at Table 1.

Table 1. Recommended volumetric indexes to different pulverization patterns

Spraying Patterns	Volumetric Index (mL m^{-3})
Very High	120
High	100
Medium	70
Low	50
Very Low	30
Ultra Low	10

Fonte: Virginia Cooperative Extension Service, 1989 Spray Guide.

Three spraying volumes and two pesticide doses were used 6 g p.c / 100 L spraying solution and 8 g p.c by 100 L spraying solution (100% (D1) and 50% (D2) recommended pesticide dose of indexacarbe, on the efficiency trials to control the South American Tomato Pinworm, composing a 3 x 2 factor, in a total of 6 treatments, being the treatments on a completely randomized design with 3 repetitions each, totaling 18 experimental unities.

The treatments were denominated as: $T_1 = VP_1D_1$; $T_2 = VP_1D_2$; $T_3 = VP_2D_1$; $T_4 = VP_2D_2$; $T_5 = VP_3D_1$; $T_6 = VP_3D_2$.

To determinate the droplets density (impacts) and the plants coverage, the tomato canopy was divided on 3 parts (superior, central and inferior) and on each part two different depths were accounted (external – P1 and internal – P2). On each one of the positions water sensitive paper tags were fixed.

To estimate the produced droplets size, water sensitive paper tags, 38 x 26 mm dimension, were used, they were clipped straight on the leaves. On each depth, three tags were distributed and clipped. After each spraying process, using the manual backpack sprayer, the tags were taken from the plants and packed inside paper bags, separated according with its position on the plant, to further laboratory analysis.

On the lab, the images were photographed using a digital camera, Sony DSC-W35 model, 7.2 megapixels. Each treatment tag group, properly identified and digitalized, were processes using the image analysis computer app "Image Tool", 3.0 version, according and used as well by (RUAS, 2007).

The droplets sizes were fixed by the spreading factor, proper to the water sensitive paper and adapted by Chaim *et al.* (1999) using the equation (3):

$$F(D) - 0{,}71057 + 0{,}0001010399\,D + 0{,}2021831\ln(D) \quad (3)$$

Being:
F – Spreading factor
D- Size class limit size, µm.

After processing the tag images, parameters were determined referring to the droplet population and spectrum: Droplet density, which is the number of droplets sprayed by surface area (Droplets cm^{-2}); Coverage, that is the percentage of sprayed area covered by droplets (%); Homogeneity Coefficient (CH), that represents the homogeneity of the droplets on the tag; Relative amplitude (AR) that provides the droplets size variability in relation to the diameter of the volumetric median, estimated using the following equation (4):

$$AR = \frac{Dv0{,}9 - Dv0{,}1}{Dv0{,}5} \quad (4)$$

Being:
AR- Relative Amplitude, dimensionless;
$D_{v0,9}$ – Droplet diameter in witch 90% of the sprayed volume is composed by droplets smaller than this value, when ordained in crescent size order (going from smaller to bigger).
$D_{v0,1}$ – Droplet diameter in witch 10% of the sprayed volume is composed by droplets smaller than this value, when ordained according with the droplet size
Dv0,5 – Droplet diameter in witch 50% of the sprayed liquid volume is composed by droplets smaller than this value, when ordained in crescent size order.

The data obtained by all the analyzed variables was submitted to variance and regression analysis. Models were chosen based on the regression coefficients significance using the Tukey test, adopting the 5% probability level to the determination coefficient (R^2 = S.Q. Regression/ S.Q. Treatments) and to the biologic phenomenon. Statistical analysis was performed using the computer program SAEG 9.1 (SAEG, 2007).

To measure wind speed, the thermo-anemometer INSTRUTHERM TAFR-180 model was used and to temperature and relative humidity measurement the "METEORO INSTRUMENTOS – M-II" psychometer was used.

RESULTS AND DISCUSSION

Wind speed during the trials was between 2,5 km h^{-1} 8,9 km h^{-1}, temperature between 27º C e 27,2 º C and relative humidity between 63 % e 67%.

The Table 2 presents the variance analysis resume to the analyzed variables in accordance to: applied pesticide dose, spray solution volume and the leaves position on the tomato plant crown.

Table 2. Variables variance analysis: Droplets density, Dg (droplets cm^{-2}), Coverage ((% C), Homogeneity Coefficient (CH), Relative Amplitude (AR), according with spraying pesticide dose (D), spray solution volume (VP) and leaves position on the tomato plant (P)

FV	GL	Mean Squares			
		Dg	% C	CH	AR
Vp	2	1442,68 **	153,89 *	191,77*	0,051 ^{ns}
D	1	1,05 ^{ns}	2,58 ^{ns}	19,31^{ns}	0,33 *
D x V	2	221,46 *	1027,92 **	617,24 **	0,21 ^{ns}
Residue (a)	12	107,19	97,71	56,54	0,22
P	5	5607,25 **	3608,53 **	917,43**	0,23 **
P x D	5	41,78 ^{ns}	129,83 *	75,51 *	0,02 *
P x V	10	476,03 **	160,42 *	74,85 *	0,03 *
P x V x D	10	158,04 *	255,22 *	123,56 **	0,01^{ns}
Residue (b)	60	104,03	119,43	41,07	0,02
CV (%) Parcel		26,76	47,15	59,83	51,67
CV (%) Sub-parcel		26,4	52,13	50,99	14,02

^{ns} Not significant at 5% probability, ** Significant at 1% de probability; and * significant at 5% de probability.

It is observed that, to the analyzed variables: droplets density, percentage coverage and homogeneity coefficient there was significant interaction between the evaluated factors (positions, volumes and doses). In the other hand, to the relative amplitude factor, there was no significant difference between the evaluated factors.

With the obtained results, even not occurring significant interaction to analyzed factors, the following interactions were studied: volume/doses, dose/volumes and positions/doses (Table 3 and 4).

Table 3. Regression analyses of Droplets Density, Dg (droplets cm^{-2}), Coverage (% C), Homogeneity Coefficient (CH) and Relative amplitude (AR), considering a 50% recommended pesticide dose.

Dose(%)	Position	Variable	Adjusted Equation	R^2
50	Sup. Ex.	Dg	$\hat{y} = 48{,}3476$	-
		% C	$\hat{y} = 30{,}8733$	-
		CH	$\hat{y} = -247{,}654 + 1{,}3544\ v - 0{,}00168153\ v^2$ *	0,7069
		AR	$\hat{y} = 1{,}1015$	-
	Sup. Int.	Dg	$\hat{y} = 19{,}6575$	-
		% C	$\hat{y} = 3{,}7631$	-
		CH	$\hat{y} = 4{,}0420$	-
		AR	$\hat{y} = 0{,}7896$	-
	Cent. Ex.	Dg	$\hat{y} = -198{,}939 + 1{,}37254\ v - 0{,}00171567\ v^2$ *	0,7869
		% C	$\hat{y} = 29{,}5529$	-
		CH	$\hat{y} = 26{,}0332$	-
		AR	$\hat{y} = 1{,}0562$	-

	Cent. Int.	Dg	$\hat{y}$ = -242,264 + 1,43754 v - 0,00181775 v^2 *	0,5204
		% C	$\hat{y}$ = 14,6366	-
		CH	$\hat{y}$ = 9,4592	-
		AR	$\hat{y}$ = 0,8626	-
	Inf. Ex.	Dg	$\hat{y}$ = 45,9027	-
		% C	$\hat{y}$ = 40,4057	-
		CH	$\hat{y}$ = 17,1174	-
		AR	$\hat{y}$ = 4,48279 - 0,0163461 v + 0,0001855 v^2 *	0,5286
	Inf. In.	Dg	$\hat{y}$ = 23,7257	
		% C	$\hat{y}$ = 7,4669	
		CH	$\hat{y}$ = 7,0425	
		AR	$\hat{y}$ = 0,9202	

** Significant at 1% probability; and * Significant at 5% F test probability

Table 4. Regression analyses of Droplets Density, Dg (droplets cm^{-2}), Coverage (% C), Homogeneity Coefficient (CH) and Relative amplitude (AR), considering a 100% recommended pesticide dose

Dose (%)	Position	Variable	Adjusted Equation	R^2
100	Sup. Ex.	Dg	$\hat{y}$ = 45,3298	-
		% C	$\hat{y}$ = 36,2200	-
		CH	$\hat{y}$ = 16,7736	-
		AR	$\hat{y}$ = 0,9860	-
	Sup. Int.	Dg	$\hat{y}$ = -248,888 + 1,37001 v - 0,00168127 v^2 *	0,5503
		% C	$\hat{y}$ = 4,0179	-
		CH	$\hat{y}$ = 5,9306	-
		AR	$\hat{y}$ = 0,7750	-
	Med. Ex.	Dg	$\hat{y}$ = -482,777 + 2,94705 v - 0,00377756 v^2 **	0,8640
		% C	$\hat{y}$ = 33,4715	-
		CH	$\hat{y}$ = 17,6477	-
		AR	$\hat{y}$ = 0,8893	-
	Med. Int.	Dg	$\hat{y}$ = 26,7375	-
		% C	$\hat{y}$ = -194,138 + 1,06481 v - 0,00131688 v^2 *	0,5456
		CH	$\hat{y}$ = 80,1895 - 0,393615 v + 0,0005050 v^2 *	0,5717
		AR	$\hat{y}$ = 0,7133	-
	Inf. Ex.	Dg	$\hat{y}$ = 50,4949	-
		% C	$\hat{y}$ = - 578,834 + 3,23735 v - 0,00411267 v^2 **	0,7881
		CH	$\hat{y}$ = 229,678 - 1,26106 v + 0,0175840 v^2 **	0,9566
		AR	$\hat{y}$ = 0,9702	-
	Inf. In.	Dg	$\hat{y}$ = 24,8206	-
		% C	$\hat{y}$ = 8,1726	-
		CH	$\hat{y}$ = 44,4790 - 0,237037 v + 0,000345697 v^2 **	0,8177
		AR	$\hat{y}$ = - 2,31211 + 0,142150 v - 0,0000156769 v^2 *	0,5332

** Significant at 1% probability; and * Significant at 5% F test probability

According to the regression analysis results, it is observed that to mostly analyzed variables, independently of the dose and position on the plant, the model that provided better adjustment was the linear. To the regression analysis, in which the linear model was followed, the R² (determination coefficient) represents the variation percentage on y (dependent variable) that is being explicated by the regression equation. Since the adjusted equation to most of the analyzed variables was linear, the R² is not presented. Being considerate as a linear model when R² is very low (lower than 0,5) and adjusted as an quadratic equation when R² is superior to 0,5. Following the regression analysis results, it is observed that independently of the applied volume (300, 400, 500 L ha^{-1}), there is not significant difference. The explanation to the obtained results is that the sprayed volumes were a lot lower than the recommended by the manufacturer (Tables 5, 6, 7).

Table 5. Droplets Density, Dg (droplets cm^{-2}), Coverage (% C), Homogeneity Coefficient (CH), Relative Amplitude (AR), with 300 L ha^{-1} spraying volume on the plants parts and with 50% and 100% of the recommended dose

Position	Dg		% C	
	50%	100%	50%	100%
Higher External	45,27 ab A	54,41 ab A	21,67 ab A	26,92 ab A
Higher Internal	14,3087 c A	10,80 c A	2,96 b A	5,11 b A
Central External	58,41 a A	61,35 a A	27,48 ab A	40,08 a A
Central Internal	25,39 bc A	32,52 bc B	13,37 b A	6,78 b A
Lower External	56,27 a B	73,03 a A	45,75 a A	22,23 ab B
Lower Internal	29,55 bc A	29,74 c A	10,81 b A	5,38 b A
Position	**CH**		**AR**	
	50%	100%	50%	100%
Higher External	7,63 ab A	8,29 a A	1,00 abc A	0,86 ab A
Higher Internal	3,51 b A	4,25 a A	0,80 c A	0,62 abc A
Central External	22,45 a A	19,52 a A	1,13 ab A	0,81 abc A
Central Internal	6,97 b A	7,56 a A	0,88 bc A	0,57 bc A
Lower External	17,16 ab A	9,61 a A	1,25 a A	0,89 a A
Lower Internal	9,17 ab A	4,48 a A	0,97 abc A	0,54 c B

* Means followed by the same uppercase letter on the line and lowercase letter in the column do not differ by the Tukey test at 5% probability.

Table 6. Droplets Density, Dg (droplets cm-2), Coverage (% C), Homogeneity Coefficient (CH), Relative Amplitude (AR), with 400 L ha-1 spraying volume on the plants parts and with 50% and 100% of the recommended dose

Position	Dg		% C	
	50%	100%	50%	100%
Higher External	54,53 ab A	42,16 b A	28,58 ab A	45,67 ab A
Higher Internal	20,35 c A	30,11 b A	3,81 b A	1,29 d A
Central External	75,57 a A	91,63 a A	21,36 ab A	33,12 abc B
Central Internal	41,91 bc A	25,16 b B	13,56 ab A	21,08 bcd A
Lower External	48,48 b A	46,26 b A	30,67 a B	58,08 a A
Lower Internal	22,35 c A	24,99 b A	6,47 ab A	12,50 cd A
Position	**CH**		**AR**	
	50%	100%	50%	100%
Higher External	25,46 a A	19,16 a A	1,07 a A	0,96 a A
Higher Internal	3,59 b A	5,98 ab A	0,74 b A	0,89 a A
Central External	29,90 a A	13,02 ab A	1,06 a A	1,02 a A
Central Internal	14,60 ab A	3,55 b A	0,87 ab A	0,82 a A
Lower External	23,91 a A	6,60 ab B	0,91 ab A	1,00 a A
Lower Internal	6,04 b A	4,97 ab A	0,89 ab A	0,86 a A

* Means followed by the same uppercase letter on the line and lowercase letter in the column do not differ by the Tukey test at 5% probability.

Table 7. Droplets Density, Dg (droplets cm^{-2}), Coverage (% C), Homogeneity Coefficient (CH), Relative Amplitude (AR), with 400 L ha^{-1} spraying volume on the plants parts and with 50% and 100% of the recommended dose.

Position	Dg		% C	
	50%	100%	50%	100%
Higher External	45,26 ab A	39,41 ab A	42,37 ab A	36,07 a A
Higher Internal	24,31 bc A	15,80 b A	24,31 bc A	5,65 b A
Central External	58,41 a A	46,36 a A	39,82 ab A	27,21 ab A
Central Internal	22,06 bc A	22,52 ab A	16,97 bc A	9,04 b A
Lower External	32,94 bc A	32,19 ab A	46,79 a A	11,67 ab B
Lower Internal	19,55 c A	19,73 b A	5,13 c A	6,63 b A
Position	**CH**		**AR**	
	50%	100%	50%	100%
Higher External	9,66 b B	22,87 b A	1,22 a A	1,13 a A
Higher Internal	5,02 b A	7,56 b A	0,82 b A	0,8167b A
Central External	25,74 a A	20,39 b A	0,97 ab A	0,8405 ab A
Central Internal	6,81 b A	9,64 b A	0,83 b A	0,7391 b A
Lower External	10,29 b B	38,75 a A	0,95 ab A	1,0152 ab A
Lower Internal	5,92 b A	12,38 b A	0,89 b A	0,8762 ab A

* Means followed by the same uppercase letter on the line and lowercase letter in the column do not differ by the Tukey test at 5% probability.

It was observed that when using 50% and 100% recommend dose, there is no significant difference when the spraying volume of 300 L $ha^{-1}$was applied to most of the analyzed positions.

As to the droplets density variable, significant difference only occurred on the central internal and inferior internal positions. To the coverage variable, there was significant difference on the inferior external position. To the homogeneity coefficient variable, there was no significant difference of the dose on all the six analyzed parts and to the relative amplitude, there significant difference only on the inferior internal part. With the obtained results, it was verified that independently of the used dose, the variables: droplets density, coverage, homogeneity coefficient and relative amplitude, the correspondent values does not differ statistically.

On the six plant positions, it was noticed that there was significant difference when applying 300 L ha^{-1} to all the analyzed variables.

To the variables droplets density, coverage and relative amplitude, for the two used pesticide doses of 50% and 100%, it is noticeable that to all the external positions, superior, inferior and central,

It was observed that when using 50% and 100% recommend dose, there is no significant difference when the spraying volume of 400 L ha^{-1} was applied to most of the analyzed positions.

all the values were higher, not differing statistically. This result can be explained by the fact that the droplets can reach the external parts of the plant easier than the internal ones. The hydraulic sprayer simply launch the droplets towards the target, not being able to transport them to the canopy interior. This demonstrate that this kind of sprayer should not be used on this crop.

As to the homogeneity coefficient variable, considering 50% recommended dose, all the superior positions, superior, inferior and central, differ statistically, presenting higher values. In the other hand, the 100% dose did not showed significant difference. Referring to the used spray nozzle (even fan nozzle), the ideal homogeneity coefficient would be between 2,0 and 8,0 (TEIXEIRA, 2008), but to most of the positions the CH values are above the ideal. The obtained values can be explained, because, when a hydraulic sprayer is used a high variation of the droplets size can be expected, consequently the values of the Volumetric Median Diameter (VMD) and number median diameter (NMD) are very different and the homogeneity coefficient stay above the ideal.

To the droplets density variable, there was significant difference only on the central internal position. To the coverage variable, there was significant difference on the central external and inferior external positions. To the homogeneity coefficient variable, there was significant difference on the inferior external position and to the relative amplitude variable, there was no significant difference of the doses on all the six analyzed positions. With the obtained results, it is noticeable the independently of the applied dose, the variables: droplets density, coverage, homogeneity coefficient and relative amplitude the values were statistically equal to the 400L ha^{-1} spraying volume.

Analyzing the Table 6, considering the six plant positions, it is verified that there is significant difference, when the 400L ha^{-1} spraying volume was used to all the analyzed variables.

To the variables: droplets density, coverage percentage and homogeneity coefficient, considering the two pesticide doses, 50% and 100%, it is observed that on the external positions, superior, inferior and central, most of the variables presented higher values, not differing statistically. This result can be explained by the fact that the droplets can reach the external parts of the plant easier than the internal ones, when a hydraulic sprayer is being used.

As to the relative amplitude variable, using 50% of the recommended dose, only the superior internal position differed statistically, presenting the lower value from all. In the other hand, using 100% recommended dose, there was no significant difference, being observable close values of relative amplitude.

The explanation to this result is that, when using hydraulic spraying, a high variation of droplets diameter, produced by the nozzle, should be expected. Thus, a single spraying can result on droplets with potential to drift (diameter smaller than 150 µm) or drain within the target (diameter higher than 800 µm). To lower relative amplitudes, it is verified a softer inclination line, presenting more uniform droplets spectrums and allowing a broader monitoring of the spraying quality (TEIXEIRA, 2008).

It was observed, analyzing table 7, that when using 50% and 100% recommend dose, there is no significant difference when the spraying volume of 500 L ha^{-1} was applied to most of the analyzed positions.

To the droplets density variable, there was no significant difference of the doses on all six analyzed parts. To the coverage, there was only significant difference on the inferior external position. To the homogeneity coefficient, there was significant difference of the doses on the superior external and inferior external parts and to the relative amplitude, there was not significant difference of the doses on all the six analyzed positions. With the obtained results, it is noticeable that independently of the applied dose, the variables: Droplet density, Coverage, homogeneity Coefficient and relative amplitude, the values were statistically equal to the 500 L ha^{-1} spraying volume.

Analyzing table 7, on the six plants positions, it is verified that there is significant difference, when using 500 L ha^{-1} spraying volume, to all analyzed variables.

To the variables: droplets density, coverage percentage and homogeneity coefficient, considering the two pesticide doses, 50% and 100%, it is observed that on the external positions, superior, inferior and central, most of the variables presented higher values, not differing statistically. This result can be explained by the fact that the droplets can reach the external parts of the plant easier than the internal ones when a hydraulic sprayer is being used.

CONCLUSIONS

For volumes of 300, 400 and 500 L h $^{-1}$, the parameters studied as droplet density, % coverage and Span were not significant at the 5 % probability by Tukey's test due to the high coefficient of variation. But it is observed to technically analyze the data, to an increase in each factor studied, providing a better quality of application of insecticide indoxacarb.

The insecticide indoxacarb promotes physical change in solution due to the great change of the spectrum.

For all evaluated factors (density drops coverage , Uniformity coefficient and amplitude relative), no difference using two different doses of indoxacarb insecticide , but when using different spray volumes to external position divided into upper , middle and lower were larger.

RESUMO: A população e o espectro de gotas produzidas durante a pulverização influencia a eficiência da distribuição do defensivo agrícola. Por meio da população e do espectro de gotas é possível avaliar a qualidade da pulverização e as implicações na segurança do aplicador e do consumidor, na eficácia do tratamento e no impacto ambiental da pulverização. Foram estudadas, durante os ensaios, a densidade de gotas (gotas cm^{-2}), a porcentagem de cobertura, o coeficiente de homogeneidade e a amplitude relativa. Foi montado um esquema fatorial 3 x 2 três volumes de pulverização e duas doses do inseticida. Durante os ensaios todos os fatores foram analisados considerando-se as amostras coletadas em seis posições na planta superior externo, superior interno, mediano externo, inferior externo e inferior interno, utilizando-se o delineamento inteiramente casualizado, com três repetições. Objetivou-se com esse trabalho avaliar as características das populações e o espectro de gotas produzidas durante a pulverização hidráulica. De maneira geral, para todos os fatores avaliados não houve diferença significativa entre os volumes e as doses utilizadas, entretanto houve diferença significativa entre as posições das plantas, sendo os maiores valores obtidos nas posições externas do dossel da planta.

PALAVRAS-CHAVE: População e Espectro de Gotas. Papel Hidrossensível. e Volume de Calda.

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