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Scientific paper

Quality of pre-emergence herbicide application with adjuvant in sugarcane crop

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Abstract

Reduction of spraying rate can be an alternative to reduce costs in pesticide application. The aim of this study was to evaluate the distribution of fan and droplet size with different spraying rate and concentration of adjuvant on spraying liquid of herbicide to control *Ipomoea* spp. on sugarcane crop. The experiment was carried out at fully randomized plots, 3 x 4 + 1 factorial scheme. The factors were application volumes (80, 130 and 180 L ha^{-1}) pre-emergence application of herbicide sulfentrazone, and concentrations of adjuvant (0; 0.5; 1.5 and 4.5%). The variables were: Angle of the jet spray (degrees), flow of nozzles (L min^{-1}), coefficient of variation of fan distribution (CV), volume median diameter (VMD), coefficient of uniformity for static nozzles (SPAN), drift (percentage of volume in droplets smaller than 200 microns) and control of *Ipomoea* spp. (%), analyzed with statistical process control tool (CEP). The reduction of spraying volume did not change the control of *Ipomoea* spp. and have resulted in standardization of the droplet size when the concentration of adjuvant in spraying liquid was bigger than 1.5%.

Key words: spraying technology, *Ipomoea* spp., droplet size, straw.

Qualidade da aplicação de herbicida em pré-emergência com adjuvante em cana-de-açúcar

Resumo

A redução na taxa de aplicação pode ser uma alternativa para diminuir custos do tratamento fitossanitários. Objetivou-se avaliar a distribuição volumétrica e o espectro de gotas de pulverização com diferentes taxas de aplicação e concentrações de adjuvantes na calda herbicida para o controle de *Ipomoea* spp. em cultura de cana-de-açúcar. O delineamento experimental foi o inteiramente casualizado, em esquema fatorial 3 x 4 + 1, sendo os fatores: volumes de aplicação (80, 130 e 180 L ha^{-1}) do herbicida sulfentrazone (1,5 L ha^{-1}) aplicado em pré-emergência, e as concentrações do adjuvante de hidrocarbonetos alifáticos (0; 0,5; 1,5 e 4,5%), e uma testemunha sem aplicação. As variáveis avaliadas foram: ângulo do jato (graus), vazão da ponta de pulverização (L min^{-1}), coeficiente de variação da distribuição volumétrica (CV), diâmetro mediano volumétrico (DMV), coeficiente de uniformidade do jato aspergido (COEF), potencial de deriva (% volume em gotas menores que 200 μm) e controle de *Ipomoea* spp. (%); todas analisadas com auxílio da ferramenta controle estatístico de processo (CEP). A redução do volume de calda não alterou o controle da *Ipomoea* spp., mas resultou em padronização do espectro de gotas do jato aspergido quando a concentração do adjuvante foi maior que 1,5%.

Palavras-chave: tecnologia de aplicação, *Ipomoea* spp., tamanho da gota, palhada.

Calidad de la aplicación de herbicida en pre-emergencia con coadyuvante en caña de azúcar

Resumen

La reducción en la tasa de aplicación puede ser una alternativa para reducir los costes de tratamiento fitosanitario. Este estudio tuvo como objetivo evaluar la distribución volumétrica y el espectro de gotas de pulverización con diferentes tasas

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de aplicación y concentraciones de adyuvantes de pulverización de herbicidas para el control de *Ipomoea spp*. en la cultura de la caña de azúcar. El diseño experimental fue completamente al azar en un factorial 3 x 4 + 1, con los factores: volumen de aplicación (80, 130 y 180 L ha^{-1}) de sulfentrazona (1.5 L ha^{-1}) aplicadas en pre-emergencia y las concentraciones de adyuvante de hidrocarburos alifáticos (0, 0.5, 1.5 y 4.5%) y un control sin tratar. Las variables evaluadas fueron: el ángulo del chorro (grados), flujo de la boquilla de pulverización (L min^{-1}), coeficiente de variación del volumen de distribución (CV), volumen promedio del diámetro de la gota (VMD), coeficiente de uniformidad del chorro pulverizado (COEF) , potencial de dispersión (% de volumen en gotas más pequeñas de 200 mM) y el control *de Ipomoea spp*. (%), todos analizados con la herramienta Control Estadístico de Procesos (SPC). La reducción en volumen de pulverización no cambió el control de *Ipomoea spp*., Sin embargo, resultó en la normalización del chorro del espectro de gotas cuando la concentración del adyuvante era mayor que 1.5%.

Palabras clave: tecnología de aplicación, *Ipomoea* spp, tamaño de gota, paja.

Introduction

The Morning Glory (*Ipomoea* spp.) has consumed significant efforts and resources due to its potential damage on areas of cane without burning, resulting of its capacity to emerge even under great volume of straw. As the pulverization of herbicides in pre-emergence maintains itself as the principal strategy adopted by the producers to mitigate the damages of this group of plants, there are difficulties of control because of the physical barrage of the straw to the pulverization droplets.

The selection of the application technology of phytosanitary products which deposits the correct quantity of the active ingredient in the target, with energetic and economical efficiency, minimizing the impacts to the environment must be careful (MATUO, 1990; MATTHEWS, 2002). Items such as the pulverization tips and adjuvants, for direct influence to the distribution of the droplets and of the spray, impacting directly in the quality and security of the application (FERREIRA, 2010).

the evaluation of the droplets spectrum is important, because different targets demand thinner or wider droplets, in which interfere the model of the pulverization tip, the distance in relation to the target, the pulverization pressure, the inclination angle of the tip, the used spray in the pulverization, between other factors (CAMARA et al., 2008). Another aspect to consider is the Susceptibility of the drifting droplets, with losses in the way between the pulverization and the desired target (MATUO, 1990). Recently the rigor regarding the size of the susceptible droplets to drift has been increasing, being considered droplets smaller than 200 μm susceptible to this kind of loss (CUNHA et. al. 2004).

The parameters considered for the determination of the quality of distribution of the droplets are the volumetric median diameter (VMD), the coefficient of uniformity (COEF) and the percentage of the volume in droplets susceptible to drift. These characteristics define respectively the characteristic size, the homogeneity of the population of droplets and the potential of drift of a determined pulverization. As closer to zero the value of COEF, higher is the uniformity of the size of the pulverized droplets. The values of VMD and COEF must be analyzed as a whole for the characterization of the pulverization, being that the VMD singly is a value of reference and do not determine the dispersion of the data around a value (VIANA et. al., 2010).

The uniformity of the volumetric profile of the sprinkled spray solution is an indicative of the quality of distribution and deposition of the active ingredient on target. This uniformity is directly altered by the spacing between tips, work pressure, boom height in relation to the target and opening angle of the jet of spray nozzles. Usually is measured by the coefficient of variation of the overlap of deposition of a number of tips in a bar (FAO, 1998). The distribution uniformity recommended by the norm UNE-EN 12761:2 (2002) states that the coefficient of variation (CV%) of the overlap of jets be smaller than 7% when used in height, spacing and pressure recommended by the manufacturer and a limit of 9% in distinct configuration (VIANA et al., 2010).

Adjuvants have been used in Brazilian agriculture to assist in the effect of the active ingredients, especially in the case of adverse environmental conditions, with positive effects (QUEIROZ et al., 2008). The applications of pre-emergence herbicides in areas of sugar cane are predominant in times of adverse weather. Thus, it is indispensable the study on their employment and behavior for recommendations in these conditions. RODRIGUES et al. (2011) compared different application rates of glyphosate, regarding their efficiency in the control and to deposition of the spray on weeds, being the results are indicatives that there is the possibility of using it in lower application volumes without loss of quality.

With the objective of quickly detect changes in certain parameters and seek the reduction of variability in the system evaluated, the statistical process control (SPC) allows to measure and analyze the variation related to the quality by means of application of statistical techniques (TOLEDO et al. 2008). The control charts are among the most used tools in CEP in agricultural operations, being composed of a line that corresponds to the average of assessed values and other two lines (upper and lower) representing the control limits and the characteristic values of the process (BARROS and MILAN, 2010). The control limits are estimated by the average value plus or minus three times the standard deviation, being that, when all graph points are located between the control limits, it is considered that the process is under control or is stable. However, when the minimum of one point is located outside these limits, it is considered that the process is out of control or presents itself unstable regarding the CEP (SILVA et al., 2008).

Starting from the hypothesis that by employing adjuvants on weed control in growing areas of sugar cane, can be obtained changes in the quality of the application, with the possibility of reducing the volumes of application, the objective was to evaluate the volumetric distribution and the spectrum of spray droplets with different application rates and concentrations of adjuvants in the herbicide spray, for the control of *Ipomoea spp*. in crops of sugar cane.

Materials and Methods

The study was conducted in September 2010 at the premises of the Department of Plant Protection of UNESP, Jaboticabal - SP, in three steps: 1) analysis of the droplet spectrum, 2) determination of profiles of volumetric distribution and 3) the application of treatments in sown pots with *Ipomoea spp*. (Morning Glory) with straw of sugar cane. It was used spray nozzles of the Teejet brand, model TTI 110 015, which provide a pre-orifice in which occurs entrance and sprays air-filled droplets, providing drops very coarse to extremely coarse, both with low susceptibility to drift, being suitable for application of pre-emergence herbicides.

We adopted the completely randomized design, with 12 treatments in factorial arrangement 3 x 4 + 1 control, being the first factor spray volumes of 80, 130 and 180 L ha^{-1} of the herbicide Boral® (sulfentrazone), at a dosage of 1.5 L ha^{-1}, and the second the concentrations of the adjuvant Agridex (mineral oil from the group of aliphatic hydrocarbons) of 0, 0.5, 1.5 and 4.5% v/v with three replications on laboratorial phases. The variables analyzed on laboratorial phases were the angle of the jet (degrees), flow in each spray tip (L min^{-1}), coefficient of variation of the volumetric distribution, volume median diameter (VMD), coefficient of uniformity of the sprayed jet (COEF) and potential of drift, characterized by the percentage of volume in droplets smaller than 200 um (CUNHA et al., 2004).

The analysis of the population of droplets was performed at the Laboratory of Particle Analysis of UNESP, Campus of Jaboticabal – SP with equipment Mastersizer S® (Malvern Instruments Ltd.), through the diffraction of the laser light, using the spray solution prepared with the concentrations of adjuvant and herbicide for each one of the treatments. The laser beam was positioned at 350 mm below the spray tip to analyze in two dimensions through the horizontal plane. Each tip was installed in a radial conveyor, which allowed the jet sprayed to pass transversely across the light beam within half a second. It was used three examples of spray nozzles selected at random from a lot of ten, in a completely randomized design, in factorial scheme 3 x 4 with the factors previously described, and three samples for each tip in each of the treatments.

The pressure (300 kPa) was constant in all stages of the work, provided by a pressurized sprayer by compressed air, being for the variations of the application taxes of stages of fields it varied the speed of application, being for the phases laboratorial only varying the concentrations of adjuvant and herbicides proportionally to the volume of solution to be applied. In this last step was determined the volume median diameter (VMD), the coefficient of uniformity (COEF) and the potential of drift.

The evaluation of volumetric distribution was performed on the deposition table composed of a corrugated metal sheet, forming 67 channels in V, 25 mm apart from each other. At the bottom of the table of deposition were placed test tubes of 100 ml for the collection of the spray solution, being one tube for each channel. The spray tip was positioned at the center of the table, so that the jet was released vertically, with a 400 mm of height, according to recommendations of FAO (1998). The volumetric distribution profile was evaluated for the three tips previously mentioned, in the working pressure of 300 kPa, where the opening angle of the jet was measured by an analogical goniometer.

Initially, in each test, was conducted the collection of spray for 30s to evaluate the flow of the solution in each treatment. With basis on the volumes collected in the replications of each treatment were determined the volumetric distribution profiles of each sample of tip, with further simulation of the average standard of volumetric distribution along the spray boom. The analysis of the volumetric distribution of the spray nozzles was performed by the calculation of coefficient of variation of overlapping of the jets.

In the greenhouse, were sowed 30 seeds of *Ipomoea spp.* with 60% of germination in pots of edged area of 0.04 m² covered with the equivalent 12 t ha^{-1} of straw of sugar cane. After sowing, was carried out the application on the straw of the pre-emergence treatments, being the relative humidity between 28 and 30% and the temperature between 32.2 and 34.1 °C.

For the pulverization was used an equipment specifically developed for testing, pressurized by CO_2, with the spray boom at a height of 400 m of the vases, maintaining a constant pressure of 300 kPa as well as the flow at the spray tip. The only thing that varies is the speeds of dimensioned application by the applicator in 10.0, 6.1 and 4.4 km h^{-1}, for the volumes of application respectively of 80, 130 and 180 L ha^{-1}.

The data of droplet spectrum and the volumetric distribution profiles were submitted to the variance analysis (ANOVA - P <0.01 or P <0.05) and their average subjected to Tukey test at 5% probability. Data were also analyzed by means of statistical process control (SPC), using control charts as a tool in order to identify causes of variability not related to the application process, considered critical. The control charts used to check in conjunction if the process and its variation are under control when the data are individual observations.

A process under control shows only random variation, within the limits established, now a process considered out of control demonstrates variation due to special causes, not inherent in the process (COSTA et al., 2005).

Results and Discussion

On Table 1 are presented the data of synthesis of analysis of variance, in which the tests of averages were not significant for the variables: jet spraying angle, uniformity coefficient of the jet sprayed (COEF) and potential drift, corroborating with BAUER and RAETANO (2004), because there was uniformity in the treatments for the angle of the jet.

As for the coefficient of variation (CV), the results corroborate with FERNANDES et al. (2007) who found CV values between 6.67 and 8.07%, respectively, for the pressures of 200 and 300 kPa, being acceptable even lower than 10%, although for the spray volume of 80 L ha^{-1} had been of 10.10% and the one without adjuvant be of 12.45%.

The volume median diameter, with the addition of adjuvant showed inversely proportional to the concentration of adjuvant. As for the potential drift, no significant difference was observed.

However, CUNHA et al. (2004) reported that the addition of adjuvant to the spray solution, at a pressure of 200 kPa, decreased the percentage of droplets smaller than 100 μm, reducing the risk of drift. As for the SPAN there was no significant difference between treatments, finding similarity in the results obtained.

In all the application volumes tested and for all concentrations of adjuvant evaluated, the treatments did not differ statistically between themselves, being that all presented control statistically superior to the control. Therefore, we observe that for the control of Ipomoea spp. it is possible to reduce the application volume for up to 80 L ha^{-1} and the addition of adjuvant to the spray solution does not influence in this variable.

For the variable flow of the tip (Table 2) there was an interaction between the application volume and concentration of adjuvant, being that for the spray volume of 180 L ha^{-1} at a dose of 4.5% of adjuvant there was higher flow in relation to the lower concentrations. That is, the use of adjuvant in applications of higher volume increase the flow capacity of the system and of the spray tips under the same conditions of pressure, which did not occur for the lower application rates.

Table 3 shows the unfolding of the interaction for the variable CV between the factors application volume and concentration of adjuvants, was observed that in the presence of adjuvant there was greater uniformity of distribution. The lowest variation was observed for the higher application rate and higher concentration of adjuvant, 180 L ha^{-1} at the concentration of 4.5% of adjuvant, reaching a CV equal to 3.41%. As the analyzes were in stationary sprayer, to the variations of CV as to the volume of application are due to the differences in concentration of the adjuvant in the spray solution, since it was kept the pressure and the spray tip in all conditions. Similar results were obtained by other authors in simulations of overlapping of jet, suggesting the use of spacing according to the individual distribution profile of the sprayed solution by the tips on the deposition Table, by overlaying the jets, with coefficients of variation of distribution profile set of tips near of 6% for all situations evaluated (FERREIRA et al., 2011).

Table 1. Synthesis of the analysis of variance for the angle of the jet spray (degrees), flow from the tip (L min^{-1}), coefficient of variation (CV), volume median diameter (VMD), uniformity coefficient of the jet sprayed (COEF) potential drift (percentage of droplets smaller than 200 µm that present risk of drift) and control of the *Ipomoea spp.* using three application volumes in four concentrations of adjuvant.

Factors	Angle	Flow	CV	VMD	COEF	% < 200 µm	Control
			Volume (V)				
80 L ha^{-1}	122.12	0.589	10.10	627.92	1.46	7.38	99.75
130 L ha^{-1}	120.89	0.583	9.55	610.10	1.38	7.11	99.50
180 L ha^{-1}	121.08	0.580	6.74	654.02	1.47	7.09	99.50
			Adjuvant (A)				
0.0 %	120.00	0.571	12.45	638.91	1.47	6.76	99.50
0.5 %	120.67	0.578	9.45	623.50	1.40	7.45	99.67
1.5 %	121.33	0.590	6.60	630.41	1.43	7.36	99.50
4.5 %	122.33	0.596	6.70	629.90	1.44	7.20	99.67
			Test F				
Control x Factorial		-	-	-	-	-	51000.89**
V	1.09ns	0.82ns	25.67**	55.87**	2.48ns	0.45ns	0.46ns
A	1.29ns	3.92*	45.59**	3.43*	0.46ns	1.20ns	0.15ns
VxA	2.70ns	1.59*	3.04*	17.98**	0.95ns	1.93ns	0.62ns
Average	121.36	291.86	8.80	630.68	1.44	7.20	91.92
CV (%)	2.17	2.92	14.01	1.62	8.18	11.64	0.92

***: significative (P< 0.01); *: significative (P< 0.05); ns: non-significative; CV: coefficient of variation.*

Table 2. Unfolding of the interaction between the factors: application volume and concentration of adjuvant for the variable flow of the tip (L min^{-1}).

Volume (V)	Concentration of Adjuvants			
	0.0%	**0.5%**	**1.5%**	**4.5%**
80 L ha^{-1}	291.66 Aa	290.00 Aa	290.00 Aa	293.33 Aa
130 L ha^{-1}	295.00 Aa	286.67 Aa	299.00 Aa	296.67 Aa
180 L ha^{-1}	280.00 Ba	280.00 Ba	296.67 ABa	303.33 Aa

Means followed by the same lowercase letter in columns and capital letters in rows do not differ, by the Tukey test at 5% of probability.

Table 3. Unfolding of the interaction between the factors: application volume and concentration of adjuvant for the variable Coefficient of Variation (%).

Volume (V)	Concentration of Adjuvants			
	0.0%	**0.5%**	**1.5%**	**4.5%**
80 L ha^{-1}	12.84 Aa	9.66 Bab	9.28 Ba	8.63 Ba
130 L ha^{-1}	13.05 Aa	10.84 Aa	6.28 Bb	8.02 Ba
180 L ha^{-1}	11.47 Aa	7.86 Bb	4.23 Cb	3.41 Cb

Means followed by the same lowercase letter in columns and capital letters in rows do not differ, by the Tukey test at 5% of probability.

This value is acceptable, standing below the limit value of 10% of variation in profile, thus maintaining margin of safety for users, commonly recommended by manufacturers (FERNANDES et al., 2007).

For the variable VMD was no interaction between application volume and concentration of adjuvants, being the highest average observed for volume of application of 180 L h^{-1} until the concentration of 1.5% of adjuvant (Table 4). With the reduction in spray volume, the increase in adjuvant concentration remained the standard of the droplet size, being in this case for the application of herbicide, there is a preference for larger droplets due to the risk of drift, but with the use of adjuvant to the spray solution we can employ smaller droplets minimizing this effect.

In Figure 1 are the statistical control charts for the variables of droplet spectrum and distribution profiles studied, where it is noted on the chart of VMD (Figure 1A) that for all application volumes there are points outside the control limits established, characterizing this variable as unstable, that is

VMD obtained in all repetitions for spray volumes tested, did not present stable behavior, having large variability between samples (SILVA et al., 2008). For COEF (Figure 1B) shows that with the increase of spray volume, it promoted increase in the variability detected by the largest value of COEF between the control limits, well as for the larger volumes of solution, the presence of unstable points (BARROS and MILAN, 2010). It is noteworthy that for the application of 80 L ha^{-1}, the variable presented itself in statistical control, which is, there was stability in the coefficient, despite of that it maintained relatively low rates when compared to the application volumes 130 and 180 L ha^{-1}.

Table 4. Interaction between application volume and concentration of adjuvant for variable Volumetric Median Diameter (VMD - μm)

Volume (V)	Concentration de Adjuvants			
	0.0 %	0.5 %	1.5 %	4.5 %
80 L ha^{-1}	651.35 Ab	625.47 Ab	618.25 Bb	616.60 Ba
130 L ha^{-1}	581.42 Bc	594.99 Ac	627.06 Aab	636.18 Aa
180 L ha^{-1}	683.95 Aa	650.03 Aa	645.92 Ba	636.18 Ba

Means followed by the same lowercase letter in columns and capital letters in rows do not differ, by the Tukey test at 5% of probability.

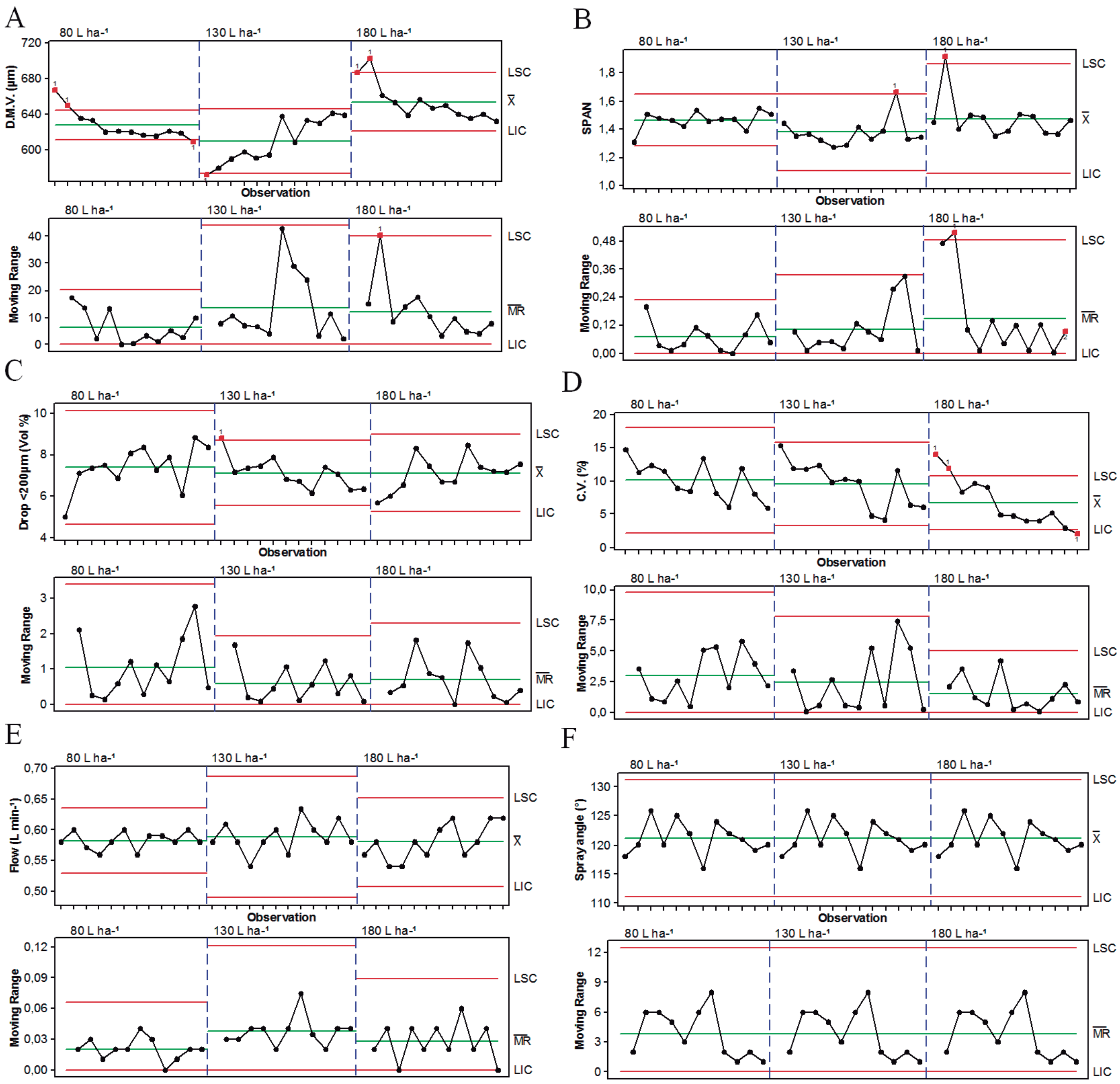

Figure 1. Control charts for the variables of droplet spectrum and the profiles of volumetric distribution: VMD, COEF, Drift, CV, Flow and Jet Angle; in different application volumes.

Analyzing the control chart for the contents of potential drift (Figure 1C), is observed great variability in all application volumes, being presented just one point outside the control limits, which according TOLEDO et al. (2008) may be considered as an outlier, which represent the process as a whole in statistical control, and maintaining the indexes of this type of droplet relatively low. To the coefficient of variation of the volumetric distribution (CV, Figure 1D), it is observed that the middle lines were below 10%, pattern considered critical for the operation, coming to extrapolate these values in some cases. For application in 180 L ha^{-1} the limits were more close to each other but with the presence of several points out of control, characterizing the application in this case as unstable.

For the flow patterns (Figure 1E) and angle of jet spraying (Figure 1F) it was observed that in all application volumes, they maintained the standards within acceptable levels with stable distribution in statistical control, which is within a standard. Just for the flow in application volume of 130 L ha^{-1} we observed higher amplitude compared to the other volumes, which was characterized as a greater variability in the process.

Conclusion

The reduction in spray volume did not change the control of *Ipomoea spp*., but resulted in standardization of droplet spectrum of the jet sprayed when the concentration of the adjuvant was higher than 1.5%.

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