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Estimation of deposit and spray distribution in hydro sensible paper and morning glory plants

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Abstract

Herbicides application success depends, besides product correct choice, the observation of environmental conditions and application quality. The work aimed to quantify the effects of surfactant addition in spraying solution, in natural and artificial targets, associated to different nozzle boom angles in relation to application offset, by using distinct evaluation methods. Two experiments were conducted at NuPAM-FCA/UNESP, Botucatu County, São Paulo State, constituted by ten treatments, in factorial scheme 2 × 5, corresponding to two spraying solutions conditions (absence or presence of Aterbane BR™ (0.25% v/v) adjuvant) and five angles of spray nozzle in relation to offset application (-30°, -15°, 90°, +15° and +30°). In *Ipomea grandifolia* leaves, the distribution and drops deposition of a tracer solution were evaluated by using scores visual and spectrophotometer process. In hydro sensible papers, volumetric medium diameter (VMD), density (cm^2) and drops medium diameter, covered area (%) and application fees (L ha^{-1}) were evaluated through e-Sprinkle™ software. Aterbane BR™ (0.25% v/v) presence or absence, associated or no, to spray nozzles offset did not provide significant differences in *I. grandifolia* spray deposition. The use of artificial targets presented applicative technical limitations in relation to the use of natural ones as study matrix. Deposit and distribution variables esteem distinct behaviours, independent of target nature.

Key words: Target, tracer, deposition, application technology.

Introduction

Among distinct events that constitute the process of agricultural production, pesticides application is one of the most demanding process, since it serves not only to treatment of cultivated area, as well as caring for environment preservation. However, despite the recovery to rural producer by correct and careful use of pesticides, which is observed in field conditions, there is lack of information regarding application technology. Often, it is possible to produce the desired effect, however inefficiently, due to non-utilization of the most appropriate equipment or technique, which could result in the use of fewer or even less product waste due to bad application conditions [3].

In this regard, studies relating to deposition (spraying quantity retained in targets) and distribution (uniformity of spray deposits in targets) of droplets by spray nozzles in crops and weeds are of great importance in determining the efficiency of plant protection products application. For this, the choice of appropriate tips is crucial by interfering in coverage and flow distribution uniformity of application [8, 9, 19].

Cunha and Peres [5] mentioned that properties intrinsic to the drops are closely related to formulation components, highlighting the adjuvant amount in the composition of spraying suspension for each product. However, for operations in field conditions, such importance is given to the plant protection product to be applied and application technique, disregarding the need for uniformity and appropriate drops spectrum, in order to reach the target efficiently and with minimal losses.

In the majority of studies, spraying distribution and deposition variables in artificial and natural targets are measured through qualitative and quantitative methods, such as the use of visual scores, optical and chemical analysis measures. According to Boschini *et al.* [1], the evaluations of sprayer performance by retained amount and products distribution on target have always been constant concern of researchers, where the use of tracers compounds is frequently, added to spraying suspension.

In air applications and with turbo-sprayers, it is still a common practice to use water sensitive papers to assess the distribution and deposition of syrup sprayed. However, drops reflection and the difficulty of many surfaces wetting are obstacles to drops reflection, and consequently, the spraying effectiveness. Natural targets, even though being preferred in studies of spray deposition since faithfully constitute the characteristics of the studied target, also show complexity and natural variability that affect retention and spreading of the product applied.

The development of simple and reliable methods to evaluate the quality of pesticide applications is a challenge. Information based only on visual assessments, even by using hydro sensible paper, for example, would not be considered appropriate. With informatics development and available methodologies to assess the quality of pesticides application, it is possible to analyse samples in enough number, and in non-subjective matter, allowing more reliable conclusions, that become really easy to perform applications evaluations, which were not possible before.

However, drops formation in spray nozzle may be significantly changed by formulations and/or by adjuvant addition to sprayer suspension and frequently the studies do not express the importance of these variables. So, adjuvants act differently from each other, affecting wetting, adhesion, spreading, foaming and dispersion of sprayer suspension [4, 15]. Similarly, it highlights the fact that the addition of chemical components to sprayer suspension may cause interactions between applied products and negatively affect application results [17]. For Ryckaert *et al*. [20], the correct use of adjuvant may significantly increase applied products performance, and in some cases alter the permeability of plant surface, increasing pesticide penetration and its residual power. The present work aimed to quantify the effects of surfactants addition over deposition and distribution of sprayer suspension in natural and artificial targets associated with different nozzles in relation to application offset, by using different assessment methods.

Materials and Methods

The work was constituted by two experiments conducted at NuPAM-FCA/UNESP, Botucatu County, São Paulo State. Plots were represented by vases with 1.0 kg of soil, where deposit and distribution of agricultural spraying in natural and artificial targets were evaluated, using four and five repetitions, consisting of two *Ipomoea grandifolia* plants in four fully expanded leaves stage and of a hydro sensible paper positioned on the soil surface, not overlapped by the leaves, respectively.

The experimental design adopted was entirely randomized with ten treatments, in factorial scheme 2 × 5, two conditions of spraying suspension (Aterbane BR™ 0.25% v/v absence or presence) and five spray nozzles tip angles relative to application offset (-30°, -15°, 90°, +15° and +30°). Aterbane BR™ adjuvant is classified as spreader-sticker and constituted by a mixture of condensed phenol alcohol with ethylene oxide and organic sulphonates, with commercial concentration of 466 g L^{-1}. Positive and negative signs were adopted to indicate the opposite and favour direction of offset application, similarly to the studies carried out by Silva [23] and Tomazella *et al.* [25].

In all treatments, tracer solution formed by mixing colors bright blue FDC-1 (0.3% w/v) with Poliglow 830 YLSS (0.3% w/v) and Mancozeb fungicide (0.3% w/v) was used, with the objective of generating information about amount of tracing deposited, as well as the qualitative behaviour of drops distribution on the leaves.

In tracer solution application, a sprayer simulator armed with spray boom of four nozzles XR VS 110.02, spaced 50 cm and positioned at 50 cm high targets was used. Constant working pressure was 210 kPa in travel speed of 3.6 km h^{-1}, which provided spraying suspension volume application of 200 L ha^{-1}. At spray room, the temperature and relative humidity were monitored through digital thermo-hydro-anemometer, characterizing mediums of 26°C and 63%, respectively, as well as closed room environment where wind interference was not allowed during the sprayings.

After application, the aerial parts of five plants of each treatment were subjected to ultraviolet light in dark environment, where drops distribution on cotyledonary leaves and posterior pairs of defined leaves were assessed, using as criterion a visual scale of standardized notes for 0 to 5 values, where zero (0) represents coverage total absence, one (1) 25% coverage, two (2) 50% coverage, three (3) 75% coverage, four (4) 100% "light" coverage and five (5) 100% "heavy" coverage.

Tracer solution deposition in natural targets was assessed through the wash of two *I. grandifolia* plants with 50 mL of distilled water, in plastic bags, which were submitted to constant stirring for 20 seconds. Amount of recovered solution was measured by using a spectrophotometer, Cintra 40 model, similar to the methodology used by Maciel *et al.* [14]. After reading solution retrieved, leaves of target plants were subjected to area leaf determination by using a leaf area integrator, and then extrapolating solutions concentration for μl cm^{-2}.

Artificial targets (hydro sensible papers) have been collected and packed in closed container, to minimize the absorption of moisture from the air, and then scanned by using a scanner at 600 dpi resolution and analysed with the aid of e-Sprinkle™ software. In this phase, volumetric median diameter (VMD), droplets density per cm^2, droplet mean diameter, coverage area (%) and application rate (L ha^{-1}) parameters were assessed.

For the evaluation of *I. grandifolia* plants median distribution (natural target), confidence interval obtained by the following equation was used:

CI = (t × stdesv) / square root rn

where: CI = confidence interval; t = tabled t value at 5 % probability level; stdesv = standard deviation; square root rn = square root of repetition number.

Other obtained results were submitted to variance analysis by F test and the means were compared using Tukey test ($p<0.05$).

Results and Discussion

Results showed that there was no significant differences in sprayed suspension deposition for *I. grandifolia* species, in adjuvant presence or absence, as well as to the different positions of spray nozzles angle, in relation to application direction (Table 1). These results corroborate with those reported by Scudeler *et al.* [21] for spraying suspension deposition of adaxial and abaxial surfaces of soybean plants (IAC-8 genotype), in a controlled environment, where influence of nozzle type and its inclination angle in relation to application direction were not characterized. However, the data obtained in the present study disagree with Silva [23], Tomazela *et al.* [25] and Rodrigues *et al.* [18], who used *Brachiaria plantaginea*, *Cyperus rotundus* and *Commelina benghalensis* natural targets and observed significant increases in spraying suspension deposit, mainly for 15° and 30° angles, in offset direction.

Friesen and Wall [10] and Shaw *et al.* [22] also found that the inclination of spray nozzles with traditional angle from 90° to 45°, in application offset direction, promoted control gains of fluazifop-p-butil over *Avena fatua*, *Triticum aestivum* and *Hordeum vulgare* in rice crop, as well as, acifluorfen for *Xanthium estrumarium* weed specie. These additions of deposition may be justified by

Table 1. Mean deposition (μL cm^{-2}) of tracer solution over *I. grandifolia* plants, using or no adjuvant, associated to variation in spray nozzle angle, in relation to application offset direction favor (+) or opposite (-).

Treatments	Nozzle angle in relation to spray boom offset					Mean
	+30º	+15º	90º	-15º	-30º	
Without Surfactant	1.4247	1.1609	1.2953	1.2413	1.2557	1.2756 a
With Surfactant	1.2145	1.5352	1.3505	1.3004	1.2614	1.3324 a
Mean	1.3197 a	1.1609 a	1.2954 a	1.2413 a	1.2557 a	-
Variance Analysis		Spray Suspension	Angle	Spray Suspension x Angle		
F		0.2422 ^{ns}	0.9404 ^{ns}	0.5346 ^{ns}		
D.M.S.(5%)		0.1588	0.3562	0.5037		
C.V. (%)		-	-	-		18. 84

Obs: - Means followed by the same small letter in lines and columns did not differ by Tukey test ($p<0.05$). - ^{ns} = No significant.

leaves of referred targets that showed perpendicular disposition, and better provision of drops capture, unlike *I. grandifolia*, that at application, leaves were well positioned in horizontal plane.

In relation to Aterbane BR™ (Table 1), the results corroborate with those described by Carbonari *et al.* [2] and Iost and Raetano [11] with *Cynodon dactylon* and *Euphorbia heterophylla* species, respectively, where the use of the same adjuvant did not favour the deposition of spraying suspension in quantitative terms, but in some situations, an improvement only in spraying distribution uniformity over the plants was observed. Probably, obtained results should be linked to different plant architectures analysed and their interaction with the suspension sprayed, since theoretically, leaves oriented in horizontal position are more efficient at catching drops than the ones vertically positioned. Maciel *et al.* [13] evaluating the quality of spraying tracer solution in bean plants and *Brachiaria plantaginea*, found that Aterbane BR™ use reduced significantly the deposition over the crop and had increase in weed.

For spraying distribution in leaves of *I. grandifolia* specie (Fig. 1), it was possible to observe through the visual scale of adopted notes (0 to 5), that the presence of adjuvant (S) significantly increased the drops mean distribution on adaxial surface of the three pairs of seedlings leaves in relation to positive inclination angles (favour to the application offset direction) of spray nozzles. However, for nozzles angles with negative inclination, that is, against application offset, the adjuvant presence in spray solution significantly reduced the drops distribution in the three pairs of leaves, when compared with the adjuvant absence in 90° angle position. In Aterbane BR™ absence, all angles have provided significantly similar distribution of sprayed drops, when compared to the standard angle of 90°. No deposition on abaxial part of leaves from studied species was found in any treatments. Cunha and Carvalho [7] reported that adjuvant selection should be done quite carefully, and it is not advisable to generalize the results to all products, since there is difference between marketed products.

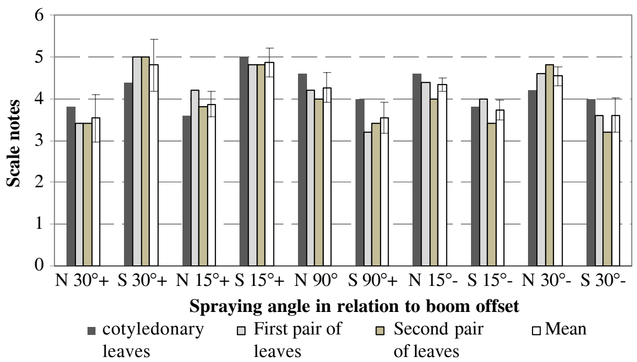

Figure 1. Distribution of spray droplets over *I. grandifolia* seedlings, by using tracer solutions plus (S) or no of adjuvant (N), and different spraying nozzles angles, in relation to the offset direction toward (+) or against (-) application, according to visual notes scale from 0 to 5. Note: 0 = 0% coverage; 1 = 25 % coverage; 2 = 50% coverage; 3 = 75% coverage; 4 = 100% light coverage and 5 = 100% heavy coverage.

The improvement in drops distribution on *I. grandifolia* seedlings observed in the adjuvant presence for angles with positive inclination perhaps may be explained by increased adhesion of the drops on the leaves surface, as well as by the "extra" force applied to them as a result of spraying movement towards the application offset. Adjuvant presence in spraying suspension provided small drops and evident draining, characterized in visual analysis by accumulation of tracing solution especially in definitive leaves (non cotyledonary). Cunha and Alves [4] reported that adjuvant effects on physic-chemical properties of aqueous solutions proved to be dependent on the chemical composition and formulation, and the behaviour of these features was not similar, even for adjuvant with the same indication of use.

For the parameters related to drops distribution of spraying in hydro sensible paper (Table 2), which were analysed and quantified through computational resources, the methodology found significant differences for some variables studied, which diverged from the responses obtained in natural targets. In this sense, VMD estimates responses and application rate resembled to deposition results in natural target, showing no significant differences for deposition condition on Aterbane BR™ adjuvant presence or absence. Oliveira *et al.* [16], who studied the characteristics of drops formation through particle meter, by the method of laser diffraction, also found that adjuvant addition did not alter distribution pattern and uniformity of drops formed.

By another side, to the following variables: density, mean diameter and coverage area of deposited drops in hydro sensible papers, the results proved to be significantly different in relation to the use or non-use of adjuvant and spray nozzle angle. Suguisawa *et al.* [24], who used hydro sensible cards for analysis of glyphosate application quality through the construction of geo referenced maps, observed high variability of results for coverage area and drops density. According to the authors, the explanation for this behaviour may be related to an increase in environment temperature and decrease in air relative humidity during the day.

Artificial target estimated the superiority of quality application for nozzles angles towards boom offset (+) in relation to the reverse position (-), generating undue conclusions induction, such as the increase in application rate and drops DMV, due to the greater inertia force applied to the same, during the offset movement, a fact that was not noted for natural target (*I. grandifolia*) (Table 2). Density and droplets mean diameter allow the same reasoning, and higher values were estimated in Aterbane BR™ adjuvant presence and absence in spraying suspension, respectively, which in spite of showing a reverse logic relation, do not match the distribution results, determined by visual notes scale for natural targets.

In relation to angles disposition, significant differences in estimates of density, mean diameter and coverage area of sprayed

Table 2. Parameters of sprayed drops distribution over hydro sensible paper, plus adjuvant or not, associated with the variation in spray nozzle angle, relative to the direction of offset application toward (+) or (-) opposite.

Droplets VMD	Nozzle angle relative to boom offset					Mean
	+30º	+15º	90º	-15º	-30º	
Without Surfactant	222.23	212.32	192.17	190.48	185.26	201.23 A
With Surfactant	223.73	199.16	202.31	185.26	195.70	200.49 A
Média	222.98 a	205.74 ab	197.24 b	190.48 b	187.87 b	
Density (Nº/cm^2)	+30º	+15º	90º	-15º	-30º	Mean
Without Surfactant	85.66 B	104.86 B	121.68 B	122.83 B	125.13 A	112.03 B
With Surfactant	106.91 A	143.51 A	145.61 A	145.61 A	123.60 A	133.05 A
Mean	96.28 c	124.18 b	133.64 a	134.22 a	124.36 b	
Mean Diameter	+30º	+15º	90º	-15º	-30º	Mean
Without Surfactant	142.59 A	132.45 A	125.50 A	125.35 A	119.66 B	129.11 A
With Surfactant	128.07 B	118.39 B	125.79 A	116.64 B	126.32 A	123.04 B
Mean	135.33 a	125.42 b	125.65 b	121.00 b	123.00 b	
Covered Area (%)	+30º	+15º	90º	-15º	-30º	Mean
Without Surfactant	36.71 A	38.02 B	39.04 A	38.49 A	35.11 B	37.47 B
With Surfactant	36.60 A	40.13 A	37.59 A	39.79 A	39.93 A	38.81 A
Mean	36.66 b	39.08 a	38.32 ab	39.14 a	37.52 ab	
Application rate (L ha^{-1})	+30º	+15º	90º	-15º	-30º	Mean
Without Surfactant	211.10	206.31	180.40	171.06	174.34	188.64 A
With Surfactant	188.34	238.67	202.75	172.78	188.52	198.21 A
Mean	199.72 ab	222.49 a	191.58 ab	181.43 b	171.91 b	
Variance Analyzes		Spray Suspension	Angle	Spray Suspension x Angle		
VMD (paper)	F	0.0266 ^{ns}	7.8349 *	1.0052 ^{ns}		
	D.M.S. (5%)	9.15	20.44	28.91		
	C.V. (%)	-	-	-		7.98
Density (Nº cm^{-2})	F	171.7419 *	74.3051 *	16.1618 *		
	D.M.S. (5%)	3.24	7.25	10.24		
	C.V. (%)	-	-	-		4.63
Drops Mean Diameter	F	22.5675 *	14.8925 *	10.5524 *		
Diameter	D.M.S. (5%)	2.58	5.77	8.16		
	C.V. (%)	-	-	-		3.58
Covered Area (%)	F	10.894 *	5.489 *	6.910 *		
	D.M.S. (5%)	0.82	1.83	2.59		
	C.V. (%)	-	-	-		3.75
Application Rate	F	1.1147 ^{ns}	3.6345 *	1.1001 ^{ns}		
(L ha^{-1})	D.M.S. (5%)	18.34	40.96	57.93		
	C.V. (%)	-	-	-		16.78

Obs: - Means followed by the same capital letter in the columns and small letter in lines, do not differ from each other by Tukey Test ($p<0.05$). - ^{ns} = No significant. * = Significant.

droplets on artificial targets were also observed. These results are in agreement with those reported by Iost and Raetano [11], who evaluated the effect of spray droplets size to adjuvant with characteristics anti-drift (Antideriva™, Uno™, Pronto™, Li-3 700™ and Supersil™), and noticed only little influence on VMD and the potential of drift loss, to doses recommended by manufacturers. Cunha *et al.* [6] also verified that the effect of adjuvant in droplets spectrum was dependent on used product spray nozzle, and that adjuvant addition to spray suspension did not alter the drift potential risk. Second to Lan *et al.* [12], adjuvant affects application performance, but these effects may be positive or negative, regarding the deposition of product on target.

Conclusions

Presence or absence of Aterbane BR™ (0.25% v/v) adjuvant in spraying solution, associated or not to spray nozzle angles disposition, did not provide significant differences in spraying suspension deposition on *I. grandifolia* plants.

Hydro sensible paper and specific software which were used to estimate the deposit and/or distribution of agricultural pesticide spraying suspension, despite being a practical and economically viable method, still feature application technical limitations in relation to methods that were used natural targets as matrix of study.

There is no necessarily direct relationship between deposit and distribution variables estimated by distinct behaviours, regardless of target nature.

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