Assessment of pesticide application quality with a manual sprayer in spinach

Evaluación de la calidad de aplicación de una pulverizadora de acción manual en espinaca

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ABSTRACT

Two experiments were conducted to evaluate the performance of three hollow cone nozzles (TeeJet® TX 800050 VK, TeeJet® TXA 8004 VK and TX-Royal Cóndor®) and one flat fan nozzle (TeeJet® XR 8004 VS) with two manual application techniques on a crop of spinach (*Spinacia oleracea* L.). In order to assess the quality of the application of pesticides, WSP (water sensitive paper) collectors and fluorescent tracer Tinopal® CBS-X were used. In one of the trials, percentage of tracer retained by the leaf surfaces was also determined. In this study, and based on the methodology of collectors, it was observed that the technique of applying two passes with the TX-Royal Condor® nozzle could be recommended for the application of pesticides with a hand-operated sprayer in the spinach crop. However, this was not corroborated by the fluorescent tracer technique.

Key words: collectors, nozzles, spraying techniques, Tinopal® CBS-X, water sensitive paper.

RESUMEN

En esta investigación se evaluaron tres boquillas de cono hueco (TeeJet® TX 800050 VK, TeeJet® TXA 8004 VK y TX-Royal Cóndor®) y una boquilla de abanico plano (TeeJet® XR 8004 VS), con dos técnicas de aplicación con el objetivo de mejorar la calidad de aplicación de plaguicidas que se realiza en los cultivos de espinaca (*Spinacia oleracea* L.). Se realizaron dos ensayos de campo y se emplearon dos técnicas de evaluación de las aplicaciones: El método de los colectores de papel hidrosensible y el método del trazador fluorescente con Tinopal® CBS-X, el cual se usó para determinar los depósitos de trazador sobre las hojas en uno de los ensayos. En este estudio, y con base en la metodología de colectores se observó que la técnica de aplicación de dos pases con la boquilla TX-Royal Cóndor® podría recomendarse para la aplicación de plaguicidas con una pulverizadora de accionamiento manual en el cultivo de la espinaca. Sin embargo, esto no fue corroborado con la técnica del trazador fluorescente.

Palabras clave: colectores, boquillas, técnicas de pulverización, Tinopal® CBS-X, papel hidrosensible.

Introduction

The need to make proper use of pesticides has led agriculture to the implementation of appropriate application techniques for crop and pest requirements (Foqué and Nyuttens, 2011). This has encouraged a number of studies on methods for evaluating the application of pesticides. Probably the most popular method is the water sensitive paper collectors (Hoffmann and Hewitt, 2005), since it is a technique that provides accurate information (Cunha *et al*., 2011), is easy to implement in the field and economical.

Nevertheless, the retention capacity of the droplets by the leaves is different from the retention capacity of water sensitive paper collectors (Holownicki *et al*., 2002). Therefore the method of fluorescent tracers is acquiring a great interest today because it is a practical and accurate method that allows quantitative and qualitative assesses of the amount of pesticide that was deposited on plants after spraying (Palladini *et al*., 2005).

Normally, the optimum characteristics of pesticide application are established using parameters such as: $D_{V0.1}$, $D_{V0.5}$, $D_{V0.9}$, which represent the distribution of the droplet diameters such that droplets with a diameter smaller than $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$ compose 10, 50 and 90% of the total liquid volume, respectively; droplet density per unit area and coverage percentage (Teixeira, 2010).

For example, when using artificial collectors such as: WSP or PVC sheets, a coverage of 20% is proposed as the minimum acceptable level (Magdalena, 2004), although it is believed that a 30% coverage ensures a satisfactory control (Holownicki *et al*., 2002), or in a specific case, with PVC sheets, that a 40% coverage would be considered good since 95% mortality of california red scale in state 1 was obtained with S. Ultra-Fine oil (Castillo, 2005). Lately, it has been stated that a coverage percentage between 20-50% can be considered as good. Below 20%, treatment is considered insufficient, above 50 to 80% in excess, and for over 80% as overdose (Mangado *et al*., 2013).

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Moreover, when natural collectors, such as leaves, are used to evaluate fluorescent tracer deposits, classes have been handled with qualitative visual ratings in relation to the amount of coverage, as pointed out Firveda *et al.* (2002).

The use of fluorescent tracers to quantify the deposits has been a common methodology in recent years to establish the quality of applications and models of biological effectiveness (Holownicki *et al.* 2002; Derksen *et al.*, 2007; Fritz, *et al.*, 2011).

The objective of this study was to evaluate the quality of spray application of a knapsack sprayer of manual action in a crop of spinach, and for this two methods were used: the first one with water sensitive paper collectors and the second one with a fluorescent tracer.

Materials and Methods

Two experiments were conducted in 2011, at the Agricultural Center Marengo (CAM) located in Mosquera, Cundinamarca (Colombia). In an area of 790 m^2, eight experimental units were established, with a sowing density of 22 plants per m^2. Spinach (*Spinacia oleracea* L.) Hybrid 424 Grendell was planted.

The sprays were made with a knapsack sprayer of manual action of local manufacture, since this type of equipment is suitable for undersized and hilly areas, which use is notorious of Colombian small farmers (Matthews, 2008). The equipment used consists of a tank of 20 L, with a plunger pump and copper spray extension. The nozzles used are described in table 1.

High discharge nozzles were chosen to obtain a higher coverage and higher density of drops. Additionally, for the same discharge flat fan nozzle and a cone hollow are compared. Also, low discharge nozzles (both hollow cone), were selected in order to save time and water maintaining efficiency, also it was made possible to extend the range of application rates. Now, as the width of the bed was 90 cm and all the nozzles had the same spray angle (80°), then the operator held nozzle height between 50 and 55 cm over the plants of spinach.

In order to avoid unfavorable weather conditions, such as high temperature, low relative humidity and strong winds, applications were carried out in the morning between 8 a.m. and 10 a.m. for both field trials. Measurements of air temperature, relative humidity of the air and wind speed were not made.

Experiment 1

The first experiment was carried out from February to April 2011, and the experimental design was a randomized complete block with a factorial arrangement of 4 nozzles for 2 application techniques for 2 leaf surfaces (upper side and underside), with 5 repetitions. Application techniques consisted of a pass or run applying the pesticide on a bed, and the two passes consisted of a run outward and a return applying the pesticide on the same bed.

TABLE 1. Characteristics of the nozzles used.

Nozzles	Type	Discharge (L min^{-1})		Filter mesh size
		2 Bar	4 Bar	
Low discharge				
TeeJet® TXA 800050VK	Hollow cone	0.16*	0.22*	100*
TX-Royal Cóndor®	Hollow cone	n.d.	0.33°	100
High discharge				
TeeJet® TXA 8004VK	Hollow cone	1.29*	1.82*	50*
TeeJet® XR8004VS	Flat fan	1.29*	1.82*	50*

*: taken from Catalog 51-ES (Spraying Systems Co.®, 2011).
°: obtained in field trials with the equipment without movement.
n.d.: no data.

The crop was affected by downy mildew disease, which is caused by the fungus *Peronospora farinosa*, and its action threshold was the mere presence of the disease (Flórez and Segura, 2010). Therefore, the fungicide Metalaxyl-M 4% + Mancozeb 64% was selected, with a dose of 250 g of fungicide per 100 L of water.

To assess the quality of application two qualitative methods were used: WSP collectors and a fluorescent tracer Tinopal® CBS-X (with a dose of 10 g L^{-1}) was used, since this does not present a toxicological risk to humans (Bierman *et al.*, 1998) and is soluble in water (Derksen *et al.*, 2007), this technique allowed to use spinach leaves as collectors (Fig. 1).

To perform the image analysis of collectors, field samples (5 WSP collectors 3.5 cm x 2.6 cm by nozzle, technique and leaf surface, and 5 spinach leaves by nozzle, technique and leaf surface) were taken to a dark room, where photographs were taken with experimental setup: Two light sources and a (Samsung PL150) digital camera with a resolution of 600 dpi, attached to a tripod (Firveda *et al.*, 2002),. Then with the ImageJ 1.45S program, the area and diameter of each of the stains was determined. To determine the diameter of the drop (D_{Drop}) that generated the stain on the WSP collector, the equation of "DropletScan™" program was used, which was presented by Hoffmann and Hewitt (2005), and that is:

$$D_{Drop} = \frac{Diameter\ of\ stain}{1{,}6333 + (0{,}0009 \times diameter\ of\ stain)} \quad (1)$$

Subsequently the following data were determined: $D_{V0.5}$ (volume median diameter in µm) of drops and stains on leaves, density of drops and stains, and the coverage percentage for collectors and leaves.

Experiment 2

It was conducted from July to September 2011, and the experimental design was randomized complete block with a factorial arrangement of 4 nozzles for 2 application techniques (which were mentioned previously), for the 2 surfaces of the leaf with 6 replicates.

This crop was attacked by leafminer (*Liriomyza huidobrensis* Blanchard), with a percentage of infestation of 35%, which is below the threshold action, which is 50% of the leaves with eggs or galleries (Flórez and Segura, 2010). However, it was considered necessary to perform control so as not to compromise crop yield. Insecticide (14.1% thiamethoxam + 10.6% Lambda-cyhalothrin was used; with a dose of 100 cm^3 ha^{-1}.

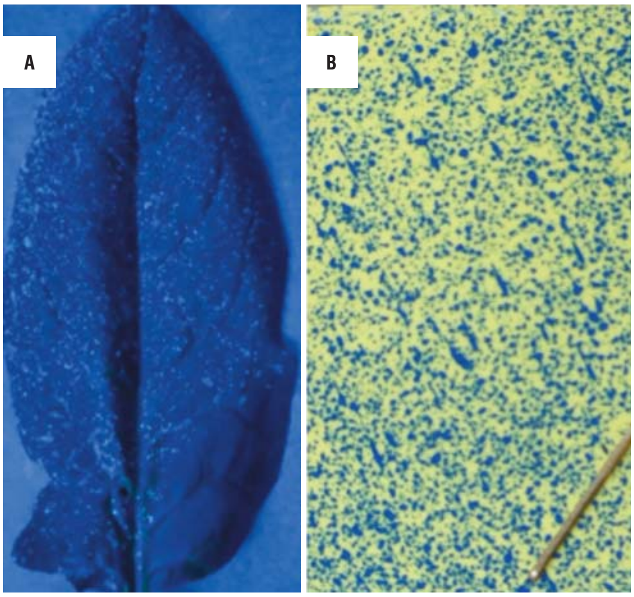

FIGURE 1. Collectors. A: Spinach leaf with tracer. B: WSP card.

To assess the quality of applications, WSP collectors and the qualitative method of fluorescent tracer were used as indicated in Expt. 1. In addition, tracer deposits on both sides of the leaf were evaluated with 3 replications. Tracer concentration was 10 g of Tinopal. CBS-X per liter of water. Sampling by the upper side leaf, was as follows: they were selected 3 of the 6 leaves that had been photographed by the upper side and they were four cuttings of 1 cm diameter to each one. Then, to remove the tracer deposited in the four cuttings of each leaf, one side of the cutting was washed for one minute, using a clamp and a Pasteur pipette with 10 mL of washing solution. The washing solution obtained was stored in jars lined with foil, and placed in polystyrene fridge boxes to 6°C, to be transported to the Laboratory of Biotechnology of the National University of Colombia, Bogotá. Regarding the samples on the underside, were selected 3 of the 6 leaves that had been photographed on the underside, and the process is repeated.

Three mL of each of the washing solutions were taken and decanted for 45 minutes in test tubes. The absorbance of each solution was then quantified with a spectrophotometer (SmartSpect™ Plus, Bio-Rad). The absorbance values of the replicates were averaged and corrected by the action of photodegradation. By using a calibration curve the tracer concentration in the solution was calculated, and employing the equation 2 (Fritz *et al*., 2011), deposits were calculated.

$$D_{Sample} = \frac{C_{washing\ sol.} \times V_{wash}}{A_{collector}} \quad (2)$$

Where

D_{sample}: Deposit in the sample (L cm^{-2})

$C_{washing\ sol}$: Concentration of the washing solution (ppm)

V_{wash}: 10 mL

$A_{collector}$: 3.1416 cm^2

Meanwhile, the percentage of tracer retained by the spinach leaf surfaces after sprayer was calculated as the difference (in percent) between the tracer doses (µg cm^{-2}) applied and the amount of tracer deposited in the leaves.

The results were analyzed by multi-factor ANOVA (GLM model), in order to study the differences between factor levels LSD method was used for a confidence level of 95%. A simple linear regression was also performed to relate the covering variables between artificial and natural collectors.

Results and discussion

For nozzles 3 and 4, the use of artificial collectors proved to be inconvenient. Since for both application techniques (one and two passes), all the upper leaf collectors got coverage level percentage above 60%, which did not allow to assess correctly the diameter and number of impacts, they had many overlapping stains. Authors like Fox *et al*. (2001), Fox *et al.* (2003) and Cunha *et al.* (2011) reported similar results. As for the classification of droplet sizes of nozzles, only collectors that were located on the underside of the leaves were considered. According to the methodology of "British Crop Protection Council (BCPC)", used by Nuyttens *et al.* (2007), to classify droplet sizes of the nozzles, assessment of the droplets size of the nozzles was made (Tab. 2).

The average data of field sprayer calibrations are also presented in table 2. The TX-Royal Cóndor and TXA 800050 VK nozzles had a medium and fine droplet size respectively in Expt. 1. But for Expt. 2, the droplet sizes were very fine and very fine, respectively. This behavior can be attributed to the efficient operation of the knapsack sprayer, since these devices have a quite variable application pressure (Kromann *et al.*, 2008). Also the operator affects the application, as this person regulate simultaneously: the speed, the height and position of the spray extension, and in accordance with Rodriguez *et al.* (1994) and Beltrán *et al.* (1994), factors such as training, fatigue, the operator's mood have significant influence on the quality of spray application. Also, it is worthy mention that droplets measured are those impacted on WSP collector, therefore, the observations correspond to a portion of the total droplets sprayed from the nozzle.

Moreover, to meet the GLM model hypothesis, it was necessary to perform logarithmic transformation of $D_{V0,5}$ parameter drops and stains density. It was required to transform the data by using the cube root of the variables: drops and stains, coverage percentage of leaves and collectors.

Experiment 1

Table 3 shows that factors: nozzle, application technique and leaf surface have significant influence on variables $D_{V0,5}$ of stains, density stains and the coverage percentage of leaves and collectors. The factor application technique does not affect the $D_{V0,5}$ of the drops (for this variable the factor leaf surface was not taken into account because only the collectors were considered on the underside).

In figure 2, it is observed that in upper side of leaves mean $D_{V0,5}$ stain sizes are significantly larger than the sizes of $D_{V0,5}$ on the underside of the leaves, for all nozzles. Meanwhile, Figure 3 shows that the coverage percentage of the upper side of leaf is significantly higher than the coverage percentage on the underside of leaves, similar results were reported for Derksen *et al.* (2001), Olivet (2009), Foqué and Nyuttens (2011). Moreover, it is observed that the higher application rate, the higher coverage is obtained, which is consistent with what was reported by Derksen *et al.* (2001) and Holownicki *et al.* (2002). According to Figure 3, notice that in upper side of leaves high discharge nozzles produce a medium coverage rate significantly higher than the low discharge nozzles do, and in turn the nozzle 2 has

TABLE 2. Results of the calibration of the backpack sprayer manually operated.

	Nozzle 1		Nozzle 2		Nozzle 3		Nozzle 4	
Nozzle	TXA800050VK		TX-Royal Cóndor		TXA8004VK		XR8004VS	
Application technique	1 pass	2 passes	1 pass	2 passes	1 pass	2 passes	1 pass	2 passes
Pressure (Bar)	3.8 - 4.1	3.8 - 4.1	3.8 - 4.1	3.8 - 4.1	2.0 - 2.4	2.0 - 2.4	2.0 - 2.4	2.0 - 2.4
Experiment 1								
Droplet size	**Fine**		**Medium**		**Medium**		**Coarse**	
Application rate (L ha^{-1})	105.9	187	131	272.7	523	951.1	530.4	963
Speed (km h^{-1})	1.709	1.818	1.709	1.782	1.69	1.8	1.71	1.806
Experiment 2								
Droplet size	Very fine		Fine		Medium		Coarse	
Application rate (L ha^{-1})	101.1	188.9	151.1	272.2	550.2	1,014.4	537.8	1,025.6
Speed (km h^{-1})	1.756	1.765	1.731	1.765	1.718	1.769	1.711	1.743

TABLE 3. Statistical significance of the main effects on the dependent variables of the experiment 1. The confidence level is 95%.

	$D_{V0,5\ Drops}$		Density of drops		Coverage of collectors		$D_{V0,5\ Stains}$		Density of stains		Coverage of leaves	
Factors	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Nozzle	5.28	<u>0.005</u>	3.99	<u>0.017</u>	28.50	<u>0.000</u>	59.69	<u>0.000</u>	10.39	<u>0.000</u>	41.53	<u>0.000</u>
Technique	3.13	0.087	8.52	<u>0.007</u>	22.69	<u>0.000</u>	5.35	<u>0.024</u>	6.62	<u>0.013</u>	12.16	<u>0.001</u>
Leaf surface	No data		No data		219.93	<u>0.000</u>	151.12	<u>0.000</u>	59.13	<u>0.000</u>	201.52	<u>0.000</u>
Repet.	1.27	0.268	0.26	0.614	0.23	0.633	0.05	0.826	0.43	0.515	0.21	0.647

a significantly greater percentage than the medium coverage of nozzle 1. Hollow cone and flat fan nozzles of high discharge do not differ in the size of the impacts and the coverage reached. All this, when crop leaves are used as collectors. Figure 4 shows that only the nozzle 3, for two passes, has a significantly higher coverage percentage than when a single pass is applied.

In figure 5 it is noted that the collectors of WSP placed on the upper side of leaves have a significantly greater coverage percentage than the collectors that were located on the underside of leaves, which coincides with that reported by Sumner *et al*. (2000), Magdalena (2004), and Holownicki *et al*. (2002). There is a strong agreement between the behavior of WSP collectors and the leaves, in connection with the coverage, if figures 3 and 5 are compared, and 4 and 6.

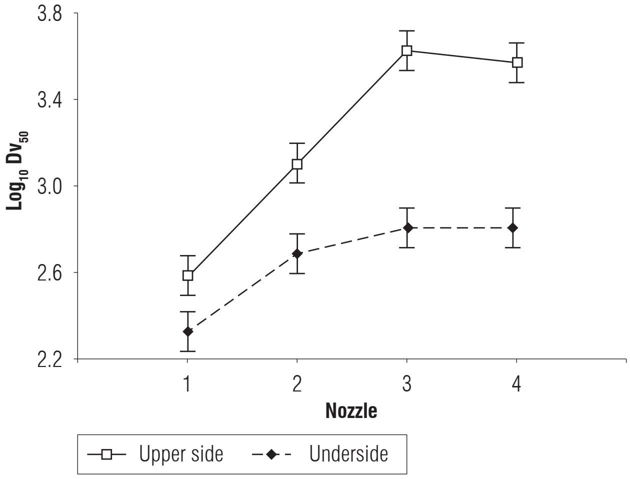

FIGURE 2. Interaction between the nozzle and leaf surface factors for $D_{V0,5}$ of stains on crop leaves in experiment 1.

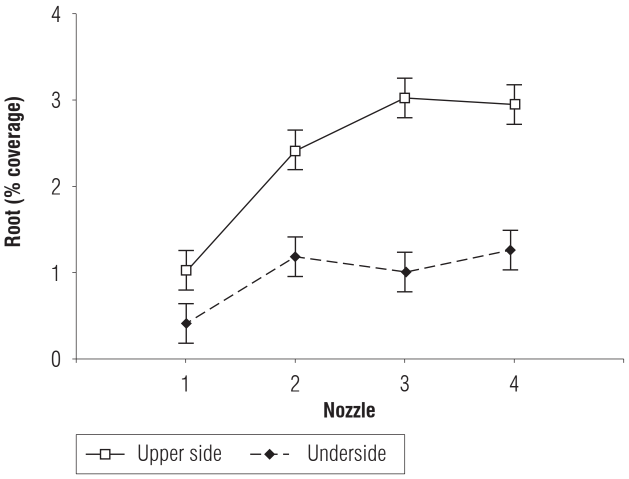

FIGURE 3. Interaction between the nozzle and leaf surface factors for the coverage percentage of leaves in experiment 1.

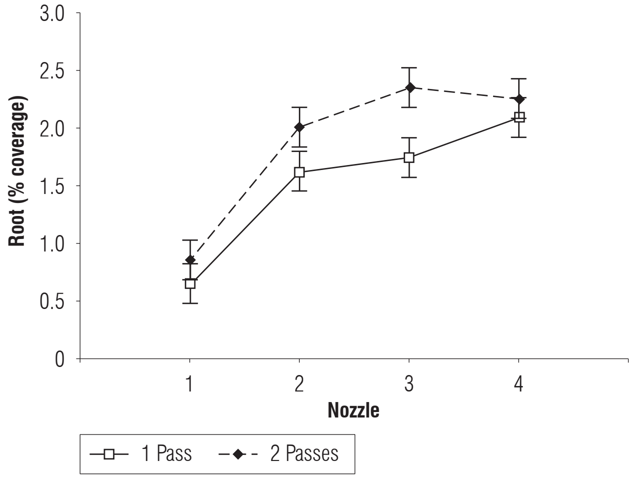

FIGURE 4. Interaction between the nozzle and application technique factors for the coverage percentage of leaves in experiment 1.

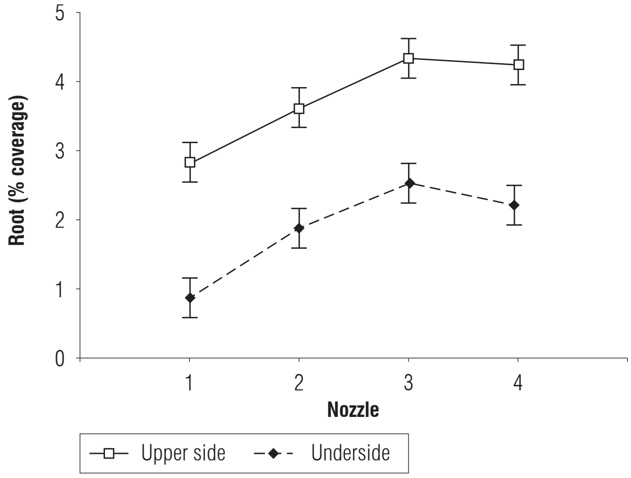

FIGURE 5. Interaction between the nozzle and application technique factors for the coverage percentage in WSP collectors in trial 1.

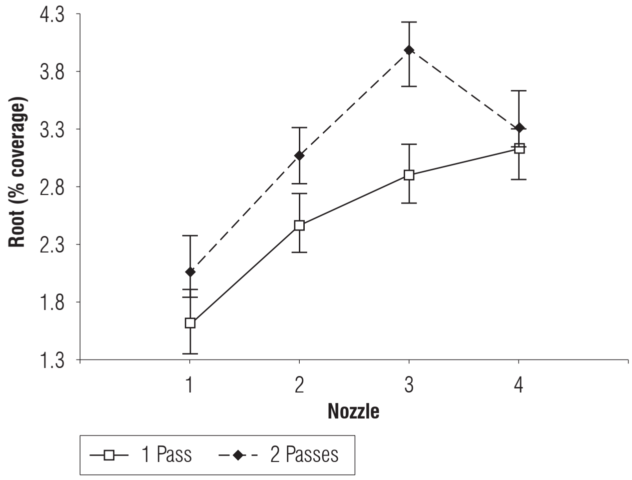

FIGURE 6. Interaction between the nozzle and leaf surface factors for the coverage percentage in WSP collectors in trial 1.

Besides, in figure 6, it is noted that the nozzles 2 and 3 differ significantly between application techniques, by implementing two passes the coverage percentage is greater than when only one pass is made, demonstrating that application volume rate is more important than nozzle type or the droplet size, in order to achieve a better target covering.

Moreover, in figures 3 and 5, it is observed that, on the underside of the leaves of spinach, higher coverage rates are achieved with medium and large droplet nozzles. This indicates that under field conditions and sparse foliage, medium and large droplet nozzles achieve a possible adequate minimum deposits on underside of leaves. Regarding of parameters used to evaluate the quality of the application, the coverage percentage proved to be the most reliable and consistent, coinciding with those reported by Salyani and Fox (1999) and Holownicki *et al.* (2002).

Experiment 2

In table 4 it is observed that factors nozzle, application techniques and leaf surface significantly influence $D_{V0,5}$ of stains, density of stains and coverage percentage on the leaves and collectors. Meanwhile, the nozzle factor significantly influences the $D_{V0,5}$ of drops.

Figure 7 shows that for two passes, the medium density of stains is significantly higher than when only one pass is applied. Thus, the increase in the application rate causes an increase in the number of stains per unit area, particularly nozzle 2 (273 L ha^{-1}), which is consistent with that reported by Rodríguez *et al.* (1994). With regard to figures 8 and 9, it is seen, again, as in experiment 1, the nozzles 2 and 3, for two passes, have a mean coverage percent greater than when applied one pass, giving preference to the use of larger volumes of application. Meanwhile, to the nozzles 1 and 4 there were no significant differences in coverage for this increase in volume, possibly due to the small size of the droplets in the nozzle 1 and conversely, in the case of the nozzle 4, the oversized drops could generate runoff losses, these results are similar to those reported by Koch and Weisser (1998) and Salyani *et al.* (2013). Thus, in cases where collectors presented coverages higher than 80%, runoff signals were observed on the leaves, where the drops were accumulating on the leaf, to the point of generating deposits scurrying by leaf veins toward the ground, and therefore it was never formed a film of liquid to wet the entire surface of the leaf.

Again, there is no difference between hollow cone and flat fan nozzles of the same discharge regarding droplet sizes, spot sizes and coverages in natural and artificial collectors as in experiment 1. It is surprising not find smaller sizes and higher densities of drops and stains for more coverage

TABLE 4. Statistical significance of the main effects on the dependent variables of the experiment 2. The confidence level is 95%.

Factors	$D_{V0,5\ Drops}$		Density of drops		Coverage of collectors		$D_{V0,5\ Stains}$		Density of stains		Coverage of leaves	
	F	P	F	P	F	P	F	P	F	P	F	P
Nozzle	11.77	0.000	1.09	0.365	27.99	0.000	115.73	0.000	3.91	0.012	42.77	0.000
Technique	2.55	0.12	0.01	0.921	7.87	0.006	12.09	0.001	5.38	0.023	18.31	0.000
Leaf surface	No data		No data		168.26	0.000	164.92	0.000	132.59	0.000	297.71	0.000
Repet.	0.28	0.6	0.59	0.448	0.33	0.567	2.81	0.098	0.75	0.388	0.76	0.386

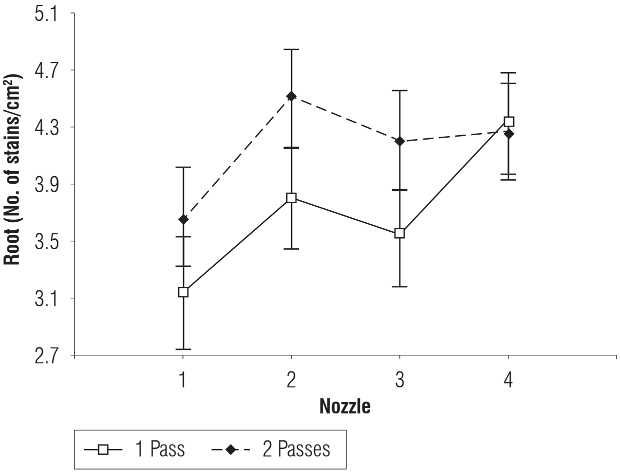

FIGURE 7. Interaction between the nozzle and application technique factors for spot density in experiment 2.

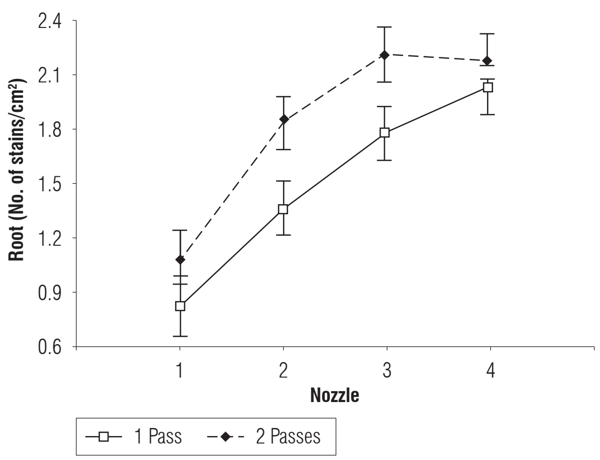

FIGURE 8. Interaction between nozzle and application technique factors for the coverage percentage of leaves in experiment 2.

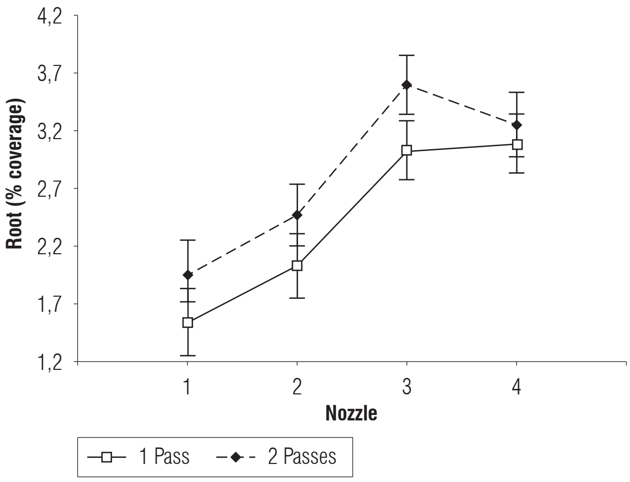

FIGURA 9. Interaction between the nozzle factors and application techniques for the coverage percentage in WSP collectors in experiment 2.

(except Fig. 6, two passes) on artificial and natural collectors as claimed by the theory of the turbulence action in the hollow cone nozzles.

On the other hand, it was determined that exists a linear relationship between the coverage percentage on the leaves and the coverage percentage on the artificial collectors, and for that an analysis of simple linear regression was used, which confirmed that between these two parameters there was a significant linear relationship (P=0.000), the degree of data adjustment R^2 was 0.679 in experiment 1, and 0.693 in experiment 2. This relationship is consistent with Salyani andWhitney (1988), and indicates that the estimation made by a coverage method can be obtained with the other.

However, the coverage percentages on the leaves were lower compared with the coverage percentages on the collectors, which can be explained by the phenomenon of retention of the drops which is a very complex process, where the peculiarities of a surface affect behavior retention of the drops and the formation of deposit (Bertola, 2008).

Trough quantitative fluorescent tracer technique, in table 5) the percentage of tracer retained by the leaves after spraying is presented, and it is clear the lower deposition obtained in the underside of leaves compared with the upper side of the leaves in accordance with that obtained in natural and artificial collectors.

Now, if the upper and underside retention percentages are added for each nozzle and technique, table 5 shows that the application of a second pass does not achieve a gain in the percentage of tracer retained by the leaves.

This behavior is probably due to, in the case of high discharge nozzles, part of the volume applied in the double pass is lost by runoff, which may indicate that the retention capacity of leaves of spinach is limited (Koch and Weisser, 1998; Panneton *et al*., 2000).

Also, it was found that low discharge nozzles with fine or medium droplets reached same percentage of deposits or something more compared to high discharge nozzles; this is in disagreement with the analysis derived from the collectors. The exact explanation for this behavior is unknown, but it is certainly related with the real retention

TABLE 5. Average volume tracer deposited spinach leaves.

Nozzle	Technique	Leaf surfaces	Application rate (L ha^{-1})	Tracer dose applied (μg cm^{-2})	Deposit recovered (μg cm^{-2})		Tracer retained (%)	
							surfaces	add
1	1 pass	Upper side	101.1	10.11	4.5	(46.4)	45,0	68,3
		Underside			2.4	(2.0)	23,3	
	2 passes	Upper side	188.88	18.888	6.9	(3.3)	36,8	53,6
		Underside			3.2	(37.6)	16,8	
2	1 pass	Upper side	151.11	15.111	8.3	(22.3)	54,8	79,3
		Underside			3.7	(57.6)	24,5	
	2 passes	Upper side	272.22	27.222	13.1	(28.7)	48,3	67,8
		Underside			5.3	(7.3)	19,5	
3	1 pass	Upper side	550.22	55.022	32.5	(17.2)	59,1	64,5
		Underside			3	(9.2)	5,4	
	2 passes	Upper side	1,014.44	101.444	39.6	(37.1)	39,1	56,9
		Underside			18	(27.1)	17,8	
4	1 pass	Upper side	537.78	53.778	25.4	(34.4)	47,3	75,7
		Underside			15.3	(25.9)	28,4	
	2 passes	Upper side	1,025.56	102.556	28.5	(30.6)	27,8	42,3
		Underside			14.9	(33.5)	14,5	

Value in parenthesis is the coefficient of variation of deposit recovered.

capacity of droplets of different sizes. Although the use of fluorescent tracer to assess the amount of deposited product was quite wasteful methodology, it seems to be the most accurate technique for establishing the actual formation of the deposit which should determine the effectiveness of the pesticide in controlling pests.

Conclusions

The increase in application volume, as a result of the application of the second pass, generated a significant increase in the coverage percentage achieved by the hollow cone nozzles TX-Royal Condor and TeeJet TXA8004VK. Therefore, due to the smaller amount of water needed to prepare the mixture (273 L ha^{-1} of application volume) for the technique with two passes of the TX-Royal Condor nozzle, it could be suggested as having the best characteristics for the application with a hand-operated back sprayer, compared to the application volume (951 L ha^{-1}) that the equipment would use with theTeeJet TXA8004VK nozzle. The above according to the results obtained with the artificial and natural collectors. However, this possibility is not verified with the information obtained with the quantitative methodology of the fluorescent tracer. Although it is not known the exact causes of this situation, it may be advisable to prefer the results achieved with this type of technique when establishing real recommendations on the best nozzle combination, manual spraying equipment and application technique.

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