Assessment of the influence of working pressure and application rate on pesticide spray application with a hand-held spray gun on greenhouse pepper crops

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ABSTRACT

Choosing the appropriate machinery for applying pesticides is crucial. Despite the availability of tech-nologically more advanced equipment, the hand-held spray gun is still widely used today for spraying greenhouse crops because of its ease of operation and its low economic cost. Growers believe that a high spray application rate and a high pressure are needed to achieve good pest and disease control. In this study, the effects of pressure and volume application rate for application of treatments using a hand-held spray gun to greenhouse pepper crops were evaluated. In the first case, three different pressures were assessed: a reference at 2000 kPa (P20) and two others at 1500 kPa (P15) and 1000 kPa (P10). To test the effects of application volume, three application volumes were used: one considered to be reference (V100), applied by an experienced grower, and two reductions thereof, i.e. 25% (V75) and 50% (V50). Each test was made at two different stages of crop development. The results showed that the use of high pressures did not improve either the deposition or the penetration into the crop canopy and the losses to the ground were not significantly different. On the other hand, a reduction by some 25% of the appli-cation rate routinely used by local farmers caused major reductions in deposition on the plant canopy, which might possibly compromise pest and disease control. The losses to the ground diminished with the application rate, although differences were not significant between V100 and V75.

1. Introduction

In Almería (S Spain), some 29,597 ha of greenhouses produce approximately 3,199,283 tonnes of different species of horticultural plants, primarily tomato and pepper (Cabrera et al., 2015). Although biological pest-control systems are on the rise, augmenting the use of beneficial insects to control pests and diseases, it is still necessary to use chemical control, whether alone or in combination with other integrated production systems.

For chemical pest control, a critical factor is the selection of the equipment to be used. For the application of pesticides in greenhouses, there are self-propelled autonomous machines (Balsari et al., 2012; Guzmán et al., 2008; González et al., 2009) as well as manually pulled trolleys equipped with vertical spray booms (Llop et al., 2015a; 2015b; Sánchez-Hermosilla et al., 2011, 2012; Nuyttens et al., 2004b), which provide good results for coverage, penetration, and uniformity. Despite the advantages of advanced machinery, the use of low-technology equipment remains widespread, including spray guns, in greenhouses in different parts of Europe, such as Belgium, Italy, and Spain (Goossens et al., 2004; Cerruto et al., 2009a; Céspedes-Lopez et al., 2009), primarily for their ease of use and low economic cost. However, such spray systems often prove deficient, being used normally at a high working pressure with excessive application volumes (Cerruto et al., 2009b), resulting ingreat losses to the soil (Sánchez-Hermosilla et al., 2011, 2012) while increasing exposure of the operator (Nuyttens et al., 2004a, 2009a; An et al., 2015; Tsakirakis et al., 2010). Therefore, it is important for this equipment to be properly calibrated and to be used correctly for a sustainable use of pesticides and thereby reduce risks to the environment and human health (Balsari, 1999, Fernández et al., 2012; Cerruto et al., 2008; Páez et al., 2010; García-García et al., 2016; Parrón et al., 2014).

In south-eastern Spain, the equipment most commonly used is the hand-held spray lance with a double flat fan nozzle, given that its use is somewhat more effective than those of a conical nozzle (Garzón et al., 2000). Derksen et al. (2001) observed that, on increasing the application rate, coverage improved on the upper side of the leaf but not on the underside, where the great majority of pests and diseases develop. In a study made in a tomato crop, Lee et al. (2000) identified a threshold to the application rate (2800 L ha^{-1}) beyond which deposition fails to increase. In previous studies evaluating the functioning of spray lances in a tomato crop, Sánchez-Hermosilla et al. (2013), reported that high pressures offered no advantage over lower pressures.

In the present work, the way in which working pressure and volume application rate influence deposition in the plant canopy were evaluated and also losses to the soil were assessed when a hand-held spray lance was used in a greenhouse pepper crop. The aim was to optimise application in order to make the use of this low-technology equipment as efficient as possible. For this, it was necessary to determine which working pressure performs best and whether is possible to reduce the application rate and achieve the same deposition in the canopy as with the application rate usually used by farmers.

2. Material and methods

2.1. Experimental design

The tests were conducted at the experimental farm of the Fundación UAL-ANECOOP of the University of Almería (36°52′N, 2°17′W), in a greenhouse of 1800 m^2 (45 × 40 m) bisected by a central east-to-west lane 2 m wide perpendicular to the crop rows which were 20 m long in the northern section and 18 m long in the southern section (Fig. 1). For spraying, a hand-held spray lance equipped with 2 or 4 twin flat fan nozzles (Novi Fan S.L., Almería, Spain) was connected through a hose 30 m long and 0.017 m in diameter to a wheelbarrow sprayer with a 100-L tank and a membrane pump (M-30, Imovilli Pompe s.r.l., Reggio Emilia, Italy). The crop was green pepper (*Capsicum annuum*, L. 'Palermo') in a twin-row system (two rows planted close together; see Fig. 2) 2 m apart with 0.4 m between plants (1.6 plants m^{-2}). The different trials were performed over a period of 2 years (two crop cycles). In the first year the effect of pressure and in the second year the influence of the application rate were investigated.

The assays were performed in the southern part of the greenhouse. For both studies, i.e. the influence of application pressure and volume, two tests were made: one in the early-growth stage (test 1) at 158 and 163 days after transplanting for pressure and application rate assessments, respectively, and another at full crop development (test 2) at 332 and 335 days after transplanting for pressure and volume application rate, respectively. Table 1 shows the characteristics of the crop during each of the trials. Leaf-area index (LAI) was measured from 6 plants taken at random in the greenhouse. The plants were completely stripped of their leaves and an electronic planimeter (WinDias, Delta-T Devices Ltd. Cambridge) was used to measure the surface area of each leaf blade. The test area was divided into 3 experimental plots (3 blocks), each made up of 6 crop rows (Fig. 1). Of these, in an alternating sequence, 3 rows were used for test 1 and the other 3 for test 2. This system reduced the risk of contamination between neighbouring applications. On each of the rows selected in each block, a random working condition was tested (one pressure for year 1 and one application rate for year 2). The sampling was conducted on a pair of plants assigned at random in each row of the test, dividing the plant canopy into 12 zones (Fig. 2), 3 heights (H1, H2, H3) and 4 depths (P1, P2, P3, P4). In each zone, a leaf was tagged with filter papers 0.03 × 0.08 m^2 (Filter-Lab Ref. 1238, Filtros Anoia, S.A., Barcelona, Spain), one on the upper side and the other on the underside of the blade. This methodology has been used previously in many studies for pesticide sprayer assessment (Nuyttens et al., 2004b; Sánchez-Hermosilla et al., 2011, 2012, 2013; Llop et al., 2015a). Coinciding with the 4 depths, 4 filter papers were also placed on the ground under the plants in order to quantify spray losses (Fig. 2). Thus, for each application, 84 samples were taken: (12 zones x 2 positions + 4 ground samples) x 3 replicates.

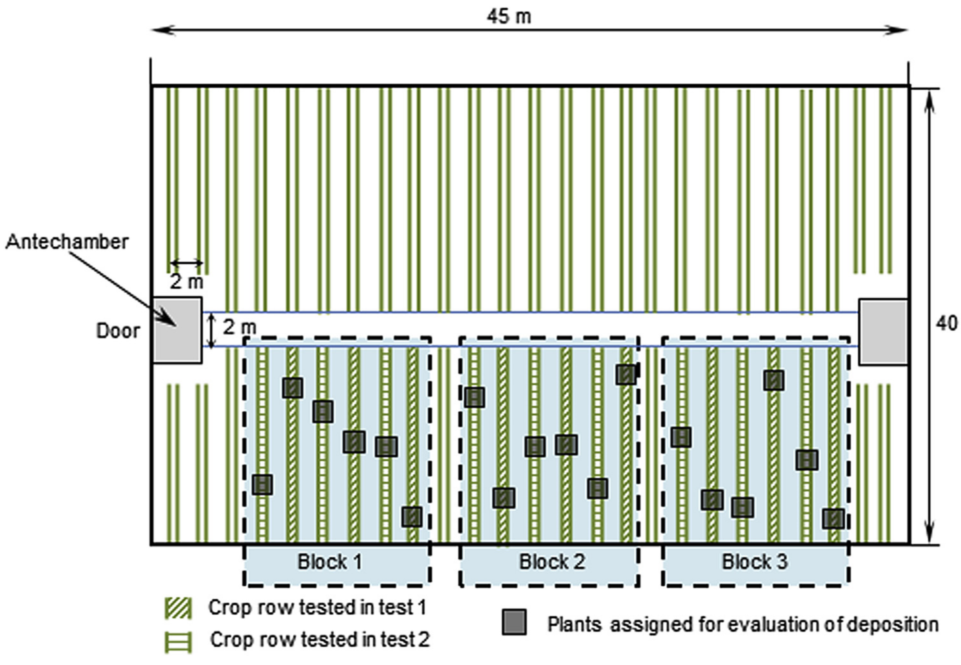

Fig. 1. Ground plan of the greenhouse indicating the sampling blocks of the experimental plants.

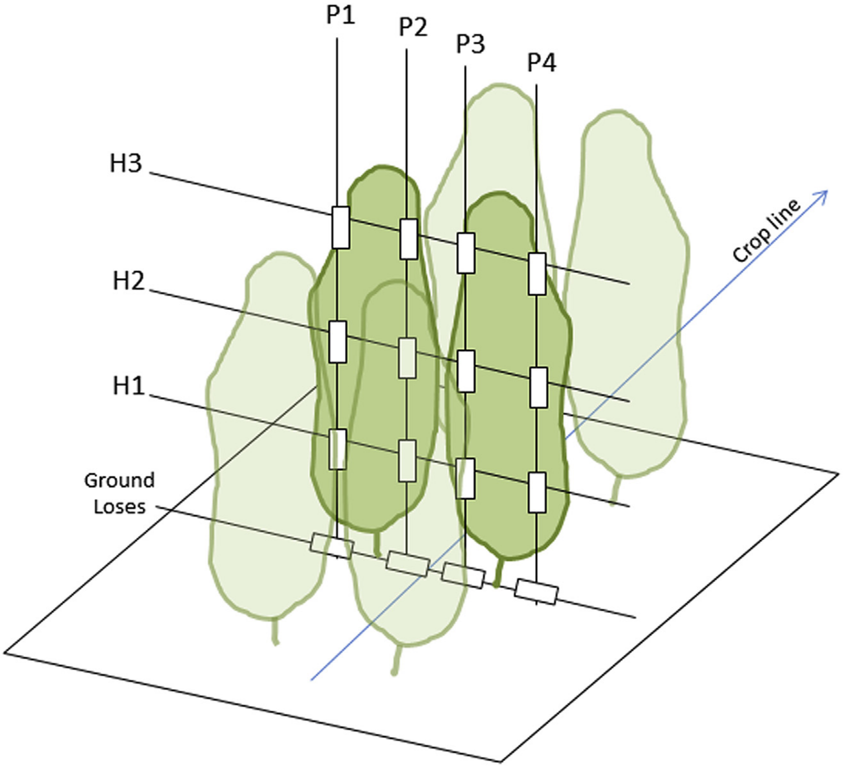

Fig. 2. Placement of samples at each sampling point (twin plants) within the crop row.

Table 1
Crop characteristics.

Evaluation	Test	LAI	Crop height (m)	Crop depth (m)
Pressure	1	2.73	1.45	0.84
	2	4.39	1.93	0.95
Application rate	1	2.73	1.46	0.86
	2	4.46	1.96	0.95

The pressure evaluation was made based on 3 applications: one reference at 2000 kPa (P20), which is the pressure routinely used by local farmers; one at 1000 kPa (P10); and one at 1500 kPa (P15). An effort was made to maintain a constant application rate by varying the travelling speed. Table 2 shows the conditions of the assays conducted. For the evaluation of the application rates, 3 spray tests were made: one reference at the standard rate applied by an experienced local farmer (V100); one reducing the rate by 25% (V75); and one reducing the rate by 50% (V50) (Table 2). When the spray was applied with a spray gun, the operational variables slightly fluctuated for the imprecise regulation of this machinery, and therefore the real reductions in the application rate evaluated were 17.1% and 38.8% in test 1, and 22.1% and 48.9% in test 2.

During all the applications, the working flow and pressure were recorded using a data-acquisition system (DataChart 1250, Monarch Instrument, Amherst, NH, USA) equipped with a pressure sensor (ARAG s.r.l., Reggio Emilia, Italy) and a flow sensor (ORION Visual Flow, ARAG s.r.l., Reggio Emilia, Italy). Also the environmental conditions data were collected (Digital Thermo-hygrometer 2410WC, RSPro, Corby, Northants, UK), Table 3 shows the maximum and minimum temperature and relative humidity values for each test.

2.2. Spray-deposit measurements

Tartrazine (Roha Europe, S.L.U., Torrent, Spain), used as a tracer to quantify the deposition, was applied at a concentration of some

Table 2
Spray application parameters for the tests.

Evaluation	Applications		Nº Nozzle	Spray pressure (kPa)	Flow (L min^{-1})	Travel speed (m s^{-1})	Application rate (L ha^{-1})
Pressure	Test 1	P10	2	1041	2.29	0.33	1156.57
		P15	2	1532	2.60	0.40	1083.33
		P20	2	2057	3.27	0.44	1238.64
	Test 2	P10	4	980	4.63	0.50	1543.33
		P15	4	1510	5.50	0.60	1527.78
		P20	4	2010	6.43	0.69	1553.14
Application rate	Test 1	V100	2	1532	2.66	0.41	1081.30
		V75	2	1523	2.69	0.50	896.67
		V50	2	1523	2.7	0.68	661.76
	Test 2	V100	4	1570	5.30	0.58	1522.99
		V75	4	1540	5.2	0.73	1187.21
		V50	4	1510	5.04	1.08	777.78

Table 3
Environmental conditions during the tests.

Evaluation	Test 1				Test 2			
	T_{max} (°C)	T_{min} (°C)	$R.H._{max}$ (%)	$R.H._{min}$ (%)	T_{max} (°C)	T_{min} (°C)	$R.H._{max}$ (%)	$R.H._{min}$ (%)
Pressure	15.1	11.5	66	62	39.2	36.9	55	52
Application rate	22.3	21.4	59	56	36.4	34.2	58	56

10 g L^{-1} (measured leaving the nozzles for each spray application). Each crop row was sprayed on both sides of the configuration established for each evaluation. After each application, the samples were collected and placed in self-sealing plastic bags of 120 × 180 × 0.05 mm. In the laboratory, distilled water (25 mL) was added to each of the bags to begin the washing of the samples. Each bag was shaken for 1 min and left to soak for 1 h. Afterwards, the solution in the bag was removed and the concentration of colorant was measured using a double-beam UV–visible spectrophotometer (Helios Zeta, Thermospectronic, Cambridge, UK) at a wavelength of 425.5 nm, using as a baseline a solution from having washed unsprayed strips of filter paper.

To make the test comparable in all the trials the concentration was normalized to 10 g L^{-1}. In the trials to evaluate the effect of pressure on spray deposition, the results were also normalized to a volume of 1100 L ha^{-1} for Test 1 and 1500 L ha^{-1} for Test 2 (Table 4). In the trials to determine the effect of the volume application rate, the results were not normalized in respect to a volume because if the normalization is applied the effect of the application rate cannot be assessed, the lower application rate could prove over-estimated and the higher application rate underestimated.

All the data were statistically analysed using the software SPSS v22.0 (SPSS Inc, an IBM Company, Chicago, IL, USA). The data did not fit a normal distribution and therefore the Kruskal-Wallis test was used with a significance level of 95% ($P < 0.05$) to establish significant differences.

The uniformity in the distribution of the deposition on the plant canopy was measured with the coefficient of variation (CV), which was calculated by dividing the standard deviation by the mean deposition values for the crop. Also, for each application the recovery rate was calculated by Eq. (1):

$$R = \frac{2 \times D \times LAI}{V} \times 10^4 \qquad \text{(Eq. 1)}$$

where R is the recovery rate (in %), D the average deposited tracer solution per unit of collector area (in μL cm^{-2}), LAI the Leaf Area Index (dimensionless), and V the application rate (in L ha^{-1}).

3. Results and discussion

3.1. Pressure assessment

Table 5 presents the mean normalized deposition data on the crop, as well as losses to the soil. It can be seen that P15 application gave 11% and 19% higher deposition on the crop than P20 (the reference application) in the first and second stage respectively, but without significant differences. The application at the lowest pressure (P10) gave results without significant differences, being somewhat lower than in the P15 application but better than with the reference rate, in both trials. These results may be related to the droplet size resulting at the different pressures and the initial momentum received by the droplets leaving the nozzle. For example, increased pressure reduces the droplet size (Etheridge et al., 1999; Nuyttens et al., 2009b). Also, small droplets lose their initial momentum sooner than do the large ones (Spillman, 1984; Nuyttens et al., 2009b) and fall vertically due to gravity. There-fore, for P20, the droplets making up the population were smaller in size and consequently the initial propulsion was lost quickly and were was more likely to fail to reach the plant canopy. This was confirmed on analysing the deposition in the inner zone (depths P2 and P3, Fig. 2) of the canopy, which proved to be between 3.63% and 16% lower than for P20, with respect to P10 and P15 in the two trials, although without significant differences (Table 6).

On the other hand, the small droplets that did not reach the vegetation began to descend slowly when they lost their initial momentum, so that many were slow in descending, increasing the probability that they would evaporate before reaching the ground. The time needed for water droplet evaporation is a function of temperature and relative humidity. This may be calculated by the equation proposed by Amsden (1962), where the lifespan is calculated based on a quotient between droplet diameter and the temperature difference between the wet bulb and dry bulb.

As the temperature and relative humidity showed little variation during the tests, the droplet size was the only factor that determined the lifespan of droplets. Even though the droplet size was not measured, it is known that using the same nozzle at a higher pressure provides a smaller droplet population, and therefore, it is conceivable that in P20 the droplet-evaporation rate was higher. This circumstance was confirmed by analysing the data for losses to the ground (Table 5), in which it was found that for P20 the losses were between 0.6% and 20% lower than for the other pres-sures in the two trials, although differences were not significant.

With respect to the uniformity of the applications, measured with the CV (Table 5), the best results were found with the less developed crop (test 1) for all the pressures used, with values of between 64% and 70%, whereas for the fully developed crop (test 2) the values proved high, between 120% and 151%. This was due to the difference in deposition between the outer side of the plant canopy (depths P1 and P4, Fig. 2) and the interior (depths P2 and P3, Fig. 2), which accentuated with the growth of the crop due to the training system customarily used in greenhouse peppers. This was an espalier system in which the stems and lateral branches are not clipped and the plant canopies are supported vertically by

Table 4
Normalization factors in the tests for pressure assessment.

	Test 1			Test 2		
	P10	P15	P20	P10	P15	P20
Application rate (L ha^{-1})	1156.57	1083.33	1238.64	1543.33	1527.78	1553.14
Rate correction factor	0.95	1.02	0.89	0.97	0.98	0.97

Application rates normalized to 1100 L ha^{-1} for Test 1 and 1500 L ha^{-1} for Test 2.

Table 5
Normalized deposition on the canopy (mean ± SD), coefficient of variation of deposition on the canopy and losses to the ground (mean ± SD).

Application	Test 1			Test 2		
	Canopy (μL cm^{-2})	CV (%)	Ground (μL cm^{-2})	Canopy (μL cm^{-2})	CV (%)	Ground (μL cm^{-2})
P10	1.18 ± 0.83a	70.16	1.99 ± 0.76a	1.13 ± 1.72a	151.96	3.44 ± 2.36a
P15	1.19 ± 0.82a	68.90	2.17 ± 0.41a	1.19 ± 1.51a	126.73	3.61 ± 1.78a
P20	1.07 ± 0.69a	64.24	1.72 ± 0.64a	1.00 ± 1.47a	147.19	3.42 ± 2.64a

Means in the same column with the same letter do not differ significantly ($P < 0.05$).

Table 6
Normalized deposition (in μL cm^{-2}) in the outer and inner zones of the canopy (mean ± SD).

Application	Test 1		Test 2	
	Outer	Inner	Outer	Inner
P10	1.81 ± 0.69a	0.55 ± 0.30a	2.02 ± 2.08a	0.25 ± 0.34a
P15	1.79 ± 0.64a	0.60 ± 0.49a	2.15 ± 1.65a	0.24 ± 0.29a
P20	1.61 ± 0.47a	0.53 ± 0.37a	1.79 ± 1.76a	0.21 ± 0.21a

Means in the same column with the same letter don't differ significantly ($P < 0.05$).

Table 8
Normalized deposition (in μL cm^{-2}) in the upper side and underside of the leaves (mean ± SD).

Application	Test 1		Test 2	
	Upper side	Underside	Upper side	Underside
P10	2.10 ± 1.67a	0.26 ± 0.22a	2.08 ± 3.27a	0.19 ± 0.28a
P15	2.06 ± 1.58a	0.33 ± 0.33a	2.10 ± 2.85a	0.28 ± 0.35a
P20	1.88 ± 1.33a	0.26 ± 0.22a	1.75 ± 2.70a	0.25 ± 0.39a

Means in the same column with the same letter do not differ significantly ($P < 0.05$).

horizontal twine tied to posts distributed along the plant row. This system limits growth in canopy width, resulting in a concentration of leaves in the outer zone of the canopy, which increases as the crop grows, hampering the penetration of the droplets into the inner zones. This was confirmed on analysing the deposition data for the inner and outer parts of the plant canopy (Table 6). As shown in Table 6, the deposition in the exterior was greater than in the interior, and the differences between the two were greater for the fully developed crop. While in test 1 the deposition on the outer part was some 3-fold greater than that for the inner part at all the pressures tested, for test 2 the deposition on the exterior was 8- and 8.9-fold greater.

The data corresponding to the recovery rates (Table 7) show that the lowest values were registered for the highest pressure (P20) in both trials, indicating that the total losses (soil plus evaporation and deposition in the adjacent row) for this application were greater than in the other cases. This confirms that for P20, the droplet population was smaller in size and resulted in greater evaporation, since the losses to the ground were slightly inferior to those found at the other pressures in the two trials.

With respect to the deposition on the leaf blade, Table 8 shows how in both trials deposition was greater on the upper side than on the underside of the leaf. On the upper side the deposition in both tests proved similar for P10 and P15, values were between 10% and 20% higher than found with the reference pressure (P20), although without significant differences. On the underside, the P15 application registered the best results, with deposition being 27% and 20% greater than found with the reference application (P20) in test 1 and 2, respectively. These findings agree with those of Foqué and Nuyttens (2011) studying ornamental plants on which high-pressure results proved no better in terms of penetration or deposition on the underside of the leaf.

In general, the results indicate that the use of high pressure in the hand-held spray lance improved neither deposition on nor penetration into the plant canopy, nor did it increase deposition on the underside of the leaves. On the other hand, the total losses were greater for the highest pressure, although the losses to the ground were slightly greater for the lower pressures. Therefore, for pesticide application with a hand-held spray lance, the recommended pressure is between 1000 kPa and 1500 kPa.

Table 7
Recovery rates (%).

Application	Test 1	Test 2
P10	58.7	66.6
P15	59.5	70.1
P20	53.3	58.7

3.2. *Volume application-rate assessment*

Given the results for the pressure trials, in the study on the influence of the application rate, all the applications were made at 1500 kPa (Table 2).

The deposition results for the crop and the losses to the ground are listed in Table 9. For the reference application (V100) the deposition results in both trials were similar to those found in the pressure test with the P15 application. A lower application rate resulted in a marked reduction in deposition on the plant canopy. For a reduction of 25% (P75), the deposition diminished between 36% and 39% in the assays made, and for a reduction of 50% (P50), the deposition decreased 66% and 69%. In all cases, there were significant differences with respect to V100. Also, a lower application rate was found to result in less uniformity (measured with the CV) of the distribution of the deposition on the canopy. This agrees with those results found by Lee et al. (2000), who found greater deposition on the crop while increasing application rate up to a maximum rate of 2800 L ha^{-1}.

With respect the ground, losses were found to diminish with the application rate, although differences were not significant between V100 and V75 in the two trials. These results were expected and are consistent with the reduction in deposition on the canopy when the application rate was reduced.

The data corresponding to the recovery rate (Table 10) show that the highest values were registered for the reference application (V100) in both tests. The recovery rate decreases according to the application-rate reduction, although the ground losses show the same trend, a reduction in the applied volume causes proportionally larger losses.

Table 11 shows the results for deposition in the inner part and outer part of the crop foliage. The deposition on the outside was greater than for the inside, as occurred in the pressure tests, the differences between the outer and inner parts being greater in the fully developed crop (test 2) due to the training system of the pepper. In both tests, the reductions in rate gave rise to less deposition with respect to the V100 both on the outside as well as

Table 9
Normalized deposition on the canopy (mean ± SD), coefficient of variation of deposition on the canopy and losses to the ground (mean ± SD).

Application	Test 1			Test 2		
	Canopy (μL cm^{-2})	CV (%)	Ground (μL cm^{-2})	Canopy (μL cm^{-2})	CV (%)	Ground (μL cm^{-2})
V100	1.18 ± 1.41c	69.80	3.31 ± 0.91b	1.04 ± 0.79c	125.37	3.70 ± 1.83b
V75	0.71 ± 0.93b	74.66	2.37 ± 0.40b	0.66 ± 0.85b	127.10	2.80 ± 1.33b
V50	0.39 ± 0.55a	81.41	0.95 ± 0.74a	0.33 ± 0.64a	194.75	1.04 ± 0.75a

Means in the same column with the same letter do not differ significantly ($P < 0.05$).

Table 10
Recovery rates (%).

Application	Test 1	Test 2
V100	59.6	60.9
V75	43.2	49.6
V50	32.2	37.8

Table 11
Normalized deposition (in μL cm^{-2}) in the outer and inner zones of the canopy (mean ± SD).

Application	Test 1		Test 2	
	Outer	Inner	Outer	Inner
V100	1.77 ± 1.68c	0.59 ± 0.71c	1.78 ± 0.26c	0.31 ± 0.29b
V75	1.07 ± 1.15b	0.35 ± 0.41b	1.13 ± 0.98b	0.20 ± 0.23b
V50	0.53 ± 0.60a	0.25 ± 0.46a	0.61 ± 0.82a	0.05 ± 0.08a

Means in the same column with the same letter don't differ significantly ($P < 0.05$).

inside the canopy, although no significant differences were found between V100 and V75 in the inner part on the test 2.

The deposition values of the upper side and underside of the leaf are shown in Table 12, reflecting a trend similar to that of the other parameters analysed above. As the application rate was reduced the deposition diminished both on the upper side as well as the lower side of the leaf. These results are in accordance with those previ-ously found in a tomato crop (Sánchez-Hermosilla et al., 2011) where a reduction in application rate sharply reduces both depo-sition on the underside of the leaves as well as penetration into the canopy.

Therefore, a reduction of 25% of the application rate with respect to the rates routinely used by local farmer resulted in pronounced reductions in average deposition on the crop, in inner parts and in the underside of the leaves, which could give rise to a poor control of pests and diseases.

In conclusion, the results of this study show that there were no significant differences between the three pressures evaluated. The use of high pressures with the hand-held spray lance (the main technique used by growers) did not improve the deposition onto or the penetration into the plant canopy, nor was deposition on the underside of the leaves improved. Furthermore, for the highest pressure, lower recovery rates resulted, despite slightly lower losses to the ground than for the rest of the pressures. This result was due mainly to the droplet size, as the droplet population was smaller in size and resulted in greater evaporation. The droplets were larger at lower pressures and thus reached the soil more easily because of the initial momentum.

Table 12
Normalized deposition (in μL cm^{-2}) in the upper side and underside of the leaves (mean ± SD).

Application	Test 1		Test 2	
	Upper side	Underside	Upper side	Underside
V100	2.02 ± 1.57b	0.34 ± 0.37c	1.88 ± 1.49c	0.21 ± 0.16c
V75	1.30 ± 1.02b	0.12 ± 0.11b	1.20 ± 1.69b	0.13 ± 0.20b
V50	0.73 ± 0.63a	0.05 ± 0.04a	0.54 ± 1.14a	0.12 ± 0.36a

Means in the same column with the same letter do not differ significantly ($P < 0.05$).

With regard to the application rate, it was found that reductions of at least 25% with respect to the rate habitually used by local farmers resulted in substantial reductions in deposition on the canopy (inner parts and underside of the leaves). This fact could imply problems of pest and disease control. The recovery rate decreased according to the application-rate reduction, although the ground losses showed the same trend, a reduction in the applied volume caused proportionally larger losses.

In general, the results indicate that for the application of pesticides with the hand-held spray lance in greenhouse pepper crops, the use of high pressures (>2000 kPa) is not justified, since pressures of 1000 kPa–1500 kPa provide similar results with better recovery rates. Nor is it justified to reduce the application rate normally used by local farmers, since this could result in poor control of pests and diseases.

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