Improvements in pesticide application in greenhouses

Sánchez-Hermosilla, J.; [1]Medina, R.; [2]Gázquez, J.C.

Departamento de Ingeniería Rural, Universidad de Almería, Ctra. Sacramento s/n, E-041+20, Almería, España, Tfno. 950 015107, jusanche@ual.es
[1]Fundación para la Investigación Agraria en la Provincia de Almería (FIAPA)
[2] Estación Experimental "Las Palmerillas"(CAJAMAR)

Summary

The spray distribution originated by a hydraulic spray-gun, a technique usually used in greenhouse crops, has been compared with a vertical boom sprayer installed in test equipment designed by the University of Almeria, so that it is possible to control and to register the value of the variables that define the application (pressure, flow rate and travel speed). The tests were made on tomato crop (*Lycopersicon esculentum*) in full crop canopy (LAI 3.25).
The spray-gun treatment was conducted in the normal working environment encountered by growers for this type of crop, whereas for the vertical boom the treatments were made with two types of nozzles (flat fan and hollow cone) and three volume rates (1000, 750 and 500 l/ha), at a pressure of 1500 kPa.
The treatments were characterized using water-sensitive paper as an artificial collector, measuring the coverage in the upper and lower surface of the leaves, at four depths and three heights in the canopy. The application volume was also evaluated on the ground and in an adjacent test-surface to the row of the test crop. Results indicate a better global behaviour of the vertical boom sprayer in comparison to the gun sprayer, as well as a better behaviour of the flat nozzle with respect to the hollow cone nozzle, in all the tests. As to the application volume, the covered surface is proportional to the volume rate, obtaining acceptable degrees of coverage with volumes of application of 500-750 l/ha, inferior to that normally used in tomato crops, although in most of the tests, the surface cover of the lower leaf surface was deficient.

Keywords: Spray, tomato crop, greenhouse, water-sensitive paper.

1 Introduction.

The Almeria province has undergone a powerful economic peak in the last 40 years, due above all, to the cultivation of vegetables inside greenhouses. The climate conditions of this area are very appropriate for this production system. It is estimated that some 30.000 ha of the surface are currently occupied by greenhouses, with the highest concentration in the western side of the province, although it is rapidly growing in the east. This figure implies the highest concentration in the world of protected crops, which shows the socio-economic importance it represents for this area.
As to the application techniques, it is important to bear in mind the scarce development of specific systems required for greenhouses. Most of the spraying equipment has been adapted from systems initially devised for working on other crops, mainly grown outdoors. The conventional application technique consists of the spraying of pesticides products by means of high pressure hydraulic spray guns, which are connected either on to fixed systems (pressure network distributed throughout the greenhouse or strategically situated sockets), or on to

hand trolleys which are placed in the central corridor of the greenhouse and on which the tank and the pump are transported (Aguera et al., 1998).

Generally, the technological deficit means that most of the treatments must be carried out manually, with poorly calibrated equipment and without a guarantee of the spraying quality, which results in relevant losses of pesticide (Planas, 2000). In recent years new application systems have been incorporated, such as air-assisted cannon. This is a technique which is rapidly becoming established, due fundamentally to the remarkable reduction in treatment costs it represents. However, recent studies (Garzon et al., 2000) have shown that these equipments are less efficient than the traditional spray guns when working on tutored crops, due to the scarce lengthways and transversal uniformity of the distribution within the crop lines, to a higher waste of the product used and to relevant losses in the soil.

Lee et al. (2000), evaluated the pipe-rail boom sprayers obtaining promising results in terms of the uniformity of application and the potential reduction in application volume using 45º spraying angles or using air to aid this process. Due to the mild winter temperatures, most farmers do not use radiating pipe heating systems so that the implementation of pipe-rail boom sprayers is practically non-existing in southeastern Spain.

The aim of the present study is to analyse and compare the distribution of pesticides using a hydraulic spray gun, under the usual working conditions of the area, and the distribution from using a vertical boom sprayer equipped with flat fan nozzle and hollow nozzle, distributing different unitary volumes.

2 Materials and methods.

2.1 Crop

The trials have been carried out in an curved, asymmetrical greenhouse situated in the experimental center “Las Palmerillas”, Cajamar, on a tomato crop cv Boludo grown on rock wool slabs at a plant density of 2 m^{-2}. The height of the plants at the time of the trials was 2 m. and leaf area index was 3.25.

2.2 Equipment for the treatment and trials carried out

The treatments have been carried out using a mobile equipment, developed in the University of Almería and fitted with a vertical boom sprayer which moves at around 30 cm from the crop.

The mobile trials equipment consists of a platform activated by a electric motor on which the spray system elements are placed, as well as the sensors and control systems required to measure and regulate the variables intervening in the spraying (pressure, flow and travel speed).

Two different configurations of the boom sprayer were tested. One equipped with 3 flat fan nozzles (Teejet DG 9501 EVS) separated by 60 cm and another one with 4 hollow cone nozzles (Teejet TXA 8001 VK) separated by 40 cm. In both cases we worked with three application rates (500, 750 and 1000 l/ha) and a pressure of 1500 kPa.

On the other hand, a spray gun adjusted to the fixed spray installation within the greenhouse was also used. The spray gun was equipped with a high flow hollow cone nozzle. The application volume were 2000 l/ha at a pressure of 3800 kPa. These conditions are the ones normally used for applications in the area for this crop.

In both cases, the spraying was carried out only on one side of the crop line in order to have a greater capacity for analysing the results.

Table 1: Sprayer settings used for treatments.

Sprayers	*Nozzle type*	*Nº Nozzle*	*Pressure (kPa)*	*Travel speed (m/s)*	*Application rate (l/ha)*
Spray Boom	Flat fan	3	1500	0,87 0,58 0,43	500 750 1000
Spray Boom	Hollow cone	4	1500	1,09 0,73 0,55	500 750 1000
Spray gun	Hollow cone	1	3800	-----	2000

2.3 Layout of samples

The selected plants were divided into three heights placed at 75 cm, 125 cm, and 175 cm, from the ground and into 4 depths located at 30 cm, 80 cm, 100 cm and 150 cm, with regard to the treatment pipe (figure 1). At each height and depth in the canopy, two sampling zones can be differentiated: upper surface and lower leaf surface. According to this, samples were taken from each plant at 3 heights, 4 depths and 2 zones.

To evaluate the losses on the ground, samples were taken at ground level situated under the planes that define the four sampling depths, and below a fifth plane situated 160 cm from the boom sprayer.

The losses occur by crossing the vegetable mass corresponding to the crop line, they have been measured by placing a plane (loss plane) approximately 10 cm. from the last defined plane to characterise the spray. This plane was materialised in the crop lines, by placing two raffia chords in the greenhouse mesh and on the ground and it was divided into 3 heights coinciding with those defined for the crop.

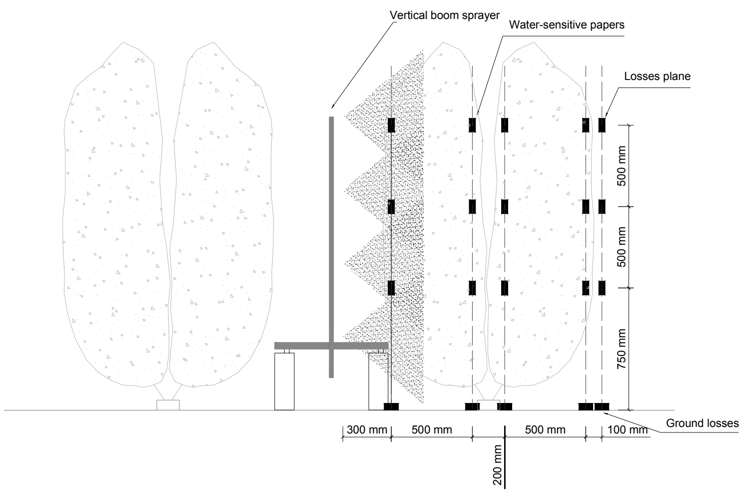

Figure 1. Location of artificial collectors.

2.4 Sample analysis

For the evaluation of the applications, 16 x 26 mm (Novartis) strips of water-sensitive papers were used. From each sample a 20 x 15 mm rectangle was digitalised with an hp 5400c (Hewlett-Packard Co) scanner, configured to obtain images in 8-bit TIFF format in the greys scale and 2400 ppp resolution. The

software employed to capture the images was HP Precisionscan Pro 3.13 (Hewlett-Packard Co.).
The images analysis software used was UTHSCSA Image Tool Version 3.00 developed by Texas University, Health Science Centre. The greatest problem posed by this analysis of surface covered methodology is the application of a binarisation threshold, which is more appropriate for each one of the images; for this reason an adaptive threshold selection model has been used which depends on the characteristics of the sample greys histogram (unpublished data).

3. Results.

3.1 Area covered in the canopy

The results corresponding to the total area covered (table 2) in each of the treatments show how the treatment pipe increases with the volume of application, in each of the nozzles used.
If both sprayer configurations are compared, it must be pointed out that the surface covered with the flat fan nozzle is between 69% and 87.5% larger than the area covered with the hollow cone nozzle sprayer for the same application rate, obtaining similar area covered with flat fan nozzle and with hollow cone nozzle, but distributing 750 l/ha and 1000 l/ha respectively.

Table 2. Mean area covered in the canopy

Sprayers	*Nozzle type*	*Pressure (kPa)*	*Application rate (l/ha)*	*Area covered (%)*		
				Total	*Upper Surface*	*Lower surface*
Spray boom	*Flat fan*	1500	500	23.32[ab]	22.44[ab]	0.88[ab]
			750	39.32[bc]	34.07[bc]	5.25[ab]
			1000	56.67[c]	43.81[c]	12.86[c]
Spray boom	*Hollow cone*	1500	500	13.80[a]	13.71[a]	0.09[a]
			750	20.97[ab]	17.80[ab]	3.17[ab]
			1000	32.85[abc]	24.81[ab]	8.04[bc]
Spray-gun	*Cone*	3800	2000	33.70[abc]	28.50[abc]	5.20[ab]

Averages in the same column with the same letter do not differ significantly.
(P=0.05; Fisher LSD test)

If the application rates are compared for each type of nozzle, statistically significant differences are observed only between extreme values (figure 2).

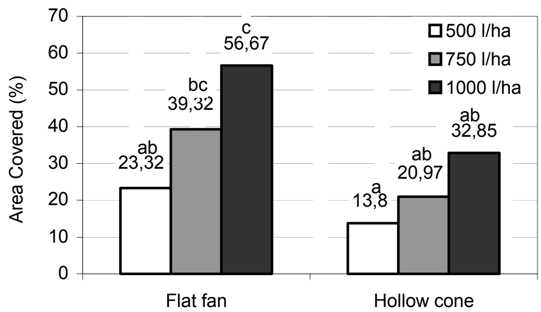

Figure 2. Area covered with different nozzle type and flow rate
(Averages with the same letter do not differ significantly (P=0.05; Fisher LSD test)

With regard to the spray-gun the results obtained have been poor bearing in mind that 2000 l/ha have been distributed and the total surface covered presents similar values to those obtained with the vertical boom sprayer equipped with a flat fan and a hollow cone nozzle respectively for 750 l/ha and 1000 l/ha applications.
The distinction between upper surface and lower surface is necessary because the pests, which at present cause the greatest economic damage, are usually located on the lower leaf surface.
Analysing the surface covered on the upper and the lower leaf surfaces for the vertical boom sprayer it is possible to observe the same tendency in every case as for the global results: the greater the volume applied, the larger the surface covered in both areas. It is necessary to highlight the important differences that occur between the surface covered between both measure areas. For both types of nozzle the surface covered on the upper surface has proved to be five times greater that of the lower leaf surface.
Comparing nozzles for the same application volume, in every case, flat nozzles present a covered surface, for the upper and lower leaf surfaces, at least 1.5 times larger than that covered by cone nozzles.
In the case of the spray-gun the analysis of the surface covered, the upper and lower leaf surface, confirms the results discussed previously for the total surface. Applying 2000 l/ha the surface covered in both areas is similar to that covered with lower volumes using the boom sprayer.

3.3 Losses

Two types of losses have been considered. Those occurring on the ground, either because of the pesticide falling directly on it, or by run-off and those that occur through crossing the vegetable mass (plane losses).
In order to quantify the ground losses, the covered surface has been measured in the water-sensitive paper placed on the ground (table 3). It was observed that when the vertical boom sprayer is used, the ground losses increase with the volume applied and these are greater when flat fan nozzles are used, for the same application volume. On average, for all the trials carried out with the boom sprayer ground losses have been approximately 50% higher with flat fan nozzles than with the hollow cone ones.

Table 3. Losses in the ground and the adjacent plane

Sprayer	*Nozzle type*	*Pressure (kPa)*	*Application rate (l/ha)*	*Losses (%)*	
				ground	*Leave canopy*
Spray boom	Flat fan	1500	500	36.47^{ab}	0.00^{a}
			750	51.87^{ab}	6.47^{b}
			1000	69.21^{b}	6.80^{b}
Spray boom	Hollow cone	1500	500	31.51^{a}	0.00^{a}
			750	30.84^{a}	0.22^{a}
			1000	41.79^{ab}	1.40^{ab}
Spray gun	Cone	3800	2000	38.60^{ab}	0.80^{a}

Averages in the same column with the same letter do not differ significantly.
(P=0.05; Fisher LSD test)

This tendency is not observed in the treatment carried out with spray-gun, since ground losses are relatively low in relation to the volume applied.

The fact that hollow cone nozzles cause fewer losses than flat fan nozzles, and as previously seen, less coverage in the canopy indicates that for the same application volume, a greater amount of liquid circulates inside the canopy when flat fan nozzles are used. Thus, analysing the results obtained for the ground losses in the different sampling planes (figure 3) we can see how the average values for the different volumes tested are higher for the flat fan nozzles than for the hollow cone ones.
Likewise, in figure 3 it is observed that the spray gun treatment generates ground losses close to 95% of the area covered in the first sampling plane that means approximately 100% higher compared with the other applications. This fact can indicate that a major part of the drops generated is unable to penetrate the canopy.
When analysing the samples in the loss plane the stained area increases in every case with the volume application, for the vertical boom sprayer. The results obtained (table 3) show an average value for all the trials carried out with flat fan nozzles of 4.4% and 0.5% for the hollow cone ones. These results highlight once more the greater penetrating power of flat fan nozzles.

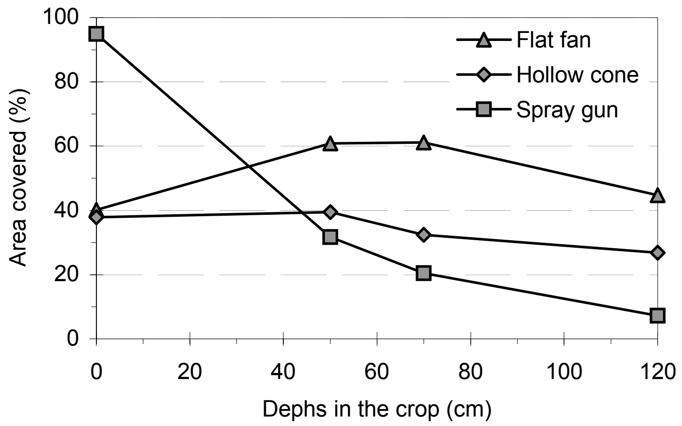

Figure 3. Ground losses

For the spray gun, the losses are relatively low in relation to the application volume. The results obtained are similar to those obtained with the pipe fitted with flat nozzles applying 500 l/ha or with cone nozzles applying 1000 l/ha. This may be due to the fact that the drops remain suspended in the atmosphere or evaporate because of their small size, caused by the high pressure and by the high temperatures inside the greenhouse.

4. Conclusions

The trials carried out have allowed us to establish that the use of spray guns at high pressure and volume in greenhouses are poor distributors of pesticides. With regard to the surface covered, similar results have been obtained using a vertical boom sprayer equipped with flat fan nozzles working under a pressure 2.5 times lower and distributing a volume of 750 l/ha. This represents a saving of 2.6 times in the application volume, apart from a saving in energy when using lower pressures.

With regard to the vertical boom sprayer, the trials carried out show that flat fan nozzles behave better in terms of covered surface and penetration, than hollow cone nozzles, for the same unitary application volume. The use of flat fan nozzles allows us to obtain similar results to the hollow cone ones using lower volumes. If we consider that 30% of area covered is appropriate for a good degree of control (Holwnicki et al. 2002) applications fewer than 750 l/ha could be suitable if flat fan nozzles are used.

The reason for the difference observed when using a spray-gun and vertical boom sprayer may be due to the use of very high pressures which produce such a minute drop size that they lack the capacity to penetrate the canopy and yield lower global percentages of area covered applying a larger quantity of volume.

Acknowledgements

This work was funded by the "Foundation for the agricultural research in Almería, FIAPA" and CAJAMAR/Almería University. We are grateful to the research centre "Las Palmerillas, CAJAMAR" for their help in these experiments.

References

Agüera, I.; Justicia, L.; Garzón, E.; Barranco, P.; Cabello, T., 1998. Caracterización de los equipos de control de plagas y enfermedades en invernaderos del sureste de España. *Phytoma España* 104: 14-22.

Garzón, E.; Lopez, L.; Sánchez-Hermosilla, J.; Barranco, P.; Agüera, I.; Cabello, T., 2000. Eficacia técnica de la aplicación de fitosanitarios con cañón atomizador. Vida Rural 112: 44-48.

Holownicki, R., Doruchowski, G., Świechowski, W. and Jaekenand, P. 2002. Methods of evaluation of spray deposit and coverage on artificial targets. *Electronic Journal of Polish Agricultural Universities, Agricultural Engineering.* 5:1.

Lee, W., Miller, P.C. and Power J.D. 2000. The application of pesticide sprays to tomato crops. Aspects of Applied Biology, 57: 383-390.

Planas S., 2000. Tratamientos químicos en invernadero. *Vida Rural* 102:54-56.