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DETERMINATION THE DEGREE OF COVERAGE WHEN TREATING PEPPER WITH DIFFERENT TYPES OF NOZZLES

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Abstract

A variety of technical means are used to combat pest control. In this study, the operation of slit and diffuser sprays was observed in the coating of the lower and upper pepper leaves. When working with the slot spreader, the coverage of the entire leaf mass is significantly less. The sprayed working fluid does not have sufficient puncture force to penetrate the entire height of the plants. Leaf coverage averages 29% of the underside and 35% of the top. When using a diffuser sprayer, the air generated by the fan intensively stirs the leaf and forces the sprayed liquid with great force. This is a prerequisite for very good coverage of both the top of the leaves and the bottom. The coverage varies from 52 to 63% for the lower and upper leaves, respectively.

Key words: *diffuser and slit sprayer, pepper, spray deposit.*

INTRODUCTION

Pepper is appreciated for the very high nutritional, dietary and taste qualities it possesses. Vitamin C content ranks first among vegetables and even exceeds lemons 4-5 times.
Pepper is a valuable vegetable crop in the United States. The management of insects and diseases relies on chemical control capabilities (Derksen R. et al., 2007). Given the relatively low chemical capacity for pest management, it is crucial to make effective use of pesticides. It is imperative that the leaves be covered top and bottom with a spray. Several delivery systems have been evaluated, including air-induction nozzles and dual fans, air-assisted delivery with conventional hydraulic nozzles and pneumatic atomization nozzles producing electrically charged sprays. Travel speeds of 6.4 and 12.9 km/h were also evaluated. Faster travel speeds did not significantly affect spray retention in double row awnings. The electrostatic sprayer gave the largest differences in the deposition between the middle and the bottom of the canopy. Although there was no more than a 25 cm difference between the leaves taken from the mid and lower canopy specimens, the retention of spraying on the foliage at the locations of the lower canopy had significantly lower retention than the average canopy for almost all spray types. Despite the differences in atomization characteristics, the operation of the dual-fan nozzle and the air-induction nozzle treatment are similar. Air-assisted feeding did not favor the amount of spray retained on the greens, but resulted in a more desirable spray quality on the greens and resulted in more spray retained on whole fruits.
In this study (Rincón V. et al., 2017), the effects of pressure and volume dose of treatment application with a hand spray gun on greenhouse cultures were evaluated. In the first case, three different pressures were evaluated: a standard at 2000 kPa (P20) and two others at 1500 kPa (P15) and 1000 kPa (P10). Three volumes of application were used to test the effects of application volume: one considered as a reference (V100) applied by an experienced manufacturer and two reductions thereof, i.e. 25% (V75) and 50% (V50). The results showed that the use of high pressure does not improve either the deposition or entry into the shed, and the losses to the earth do not differ significantly. On the other hand, a reduction of about 25% of the application rate applied by local farmers has led to a significant reduction in plant canopy deposition, which could compromise the control of pests and diseases. Land losses decreased with the application rate, although the differences were not significant between V100 and V75.
Hand carts have recently been advertised to improve spray techniques in greenhouses in southeast Spain (Llop J. et al., 2016). This

study evaluated the deposition, coverage, and uniformity of spray distribution on the canopy. Leaf deposition is significantly greater when flat fan nozzles and air-assist nozzles are used for both large and small spray volumes. No differences were found between the reference system at high spray volume and the modified trolley at low spray volume. Flat-blower nozzles with air assist increase penetration into the shade. Air assist and flat fan nozzles allow volume reduction while maintaining or improving the distribution of spray quality. The operating parameters of hand-held sprayers must be taken into account in order to reduce the risk of the environment and to increase the efficiency of the spraying process.

In their study (Nuyttens et al., 2004), they work with frame spraying systems for tomato and pepper treatment. The effect of the distance between the sprayers and the distance to the treated objects on the quality of work was monitored. The optimum distance to the treated plants was found to be 0.3 m at spacing of 0.35 m.

Pressure, droplet size classification, and arrangement of a series of nozzles with two flat jets on the number of droplet density on horizontal artificial manifolds were investigated using a fixed application rate (Ferguson J. et al., 2016). The relationship between coating and nozzle type was significant ($P < 0.001$), as was the relationship between coating and pressure ($P <0.001$). The arrangement of the nozzles has a significant impact on the asymmetric nozzle dual fan spray coating and it would be advisable to alternate these nozzles on a spray boom in order to increase the coverage, especially at higher application rates.

An alternative to improving chemical pest control is the use of electrostatic spray technology (Marques R. et al., 2019). For the application of insecticides, a boom sprayer with an induction electrostatic spray system with indirect electrification was used. There is a significant increase in the deposition by spraying, both in the upper and lower leaves of maize, using electrostatic spraying technology compared to the conventional spraying system. Electrostatic spraying also allowed the spraying rate to be reduced by approximately three times the rate used for conventional hydraulic spraying.

When treating vegetable crops with pesticides, the performance of classic barbells and frames (vertical barbells) was compared. (Sánchez J. et al., 2011) found that the use of a framework provides the same quality of work, but at lower volumes and with lower pesticide losses on the ground. This reduces soil and environmental pollution. The results of (Braekman P. et al., 2009) in the processing of ornamental crops are similar. Although the spray gun performed well in the easily accessible area for runner crops, its performance in the denser area of main crops was lower. With 240% more spraying of liquid (8500 l/ha) and chemicals, the deposits in this culture area do not differ significantly from those obtained with the vertical spraying system applying only 2500 l/ha. Spraying at 5000 l/ha, the vertical spray boom system achieves 82.9% greater overall spray deposition in the area of the main crop than the spray gun at an application rate of 8500 l/ha. In general, a standard vertical spray boom performs better than the reference equipment for strawberry spray (atomizer) and tomato (Twin sprayer) (Braekman P. et al., 2010). The type and settings of the nozzles significantly influence the delay of spraying and the penetration of crops. The use of vertical spray boom is a promising technique for the application of plant protection products in a safe and efficient manner for tomatoes and strawberries, and the selection and adjustment of nozzles must be carefully considered.

Pepper planting and cultivation has become an important red pillar industry in Xinjiang. With the continued growth of cultivated acreage in Xinjiang, diseases and pests are increasing year by year. The purpose of this study was to compare the drip deposition and control efficiency of Unmanned Aerial Vehicles (UAVs) and EAPs on a pepper treatment field. The drone has a poor degree of droplet coverage, droplet density and deposition uniformity, but shows the best deposition (1.01 $\mu g/cm^2$, which is 98% more than the EAP sprayer). The control efficiency of a UAV sprayer when treating pepper fields with *Phytophthora capsici* and aphids is slightly lower than that of the EAP sprayer. When a UAV sprayer is used to control diseases and pests of pepper, it can reduce the dosage of pesticides to provide a controlling effect. Further study of the high concentration of pesticide residues in pepper fruits and the environment sprayed with UAV is needed.

The purpose of the present study is to observe and compare top and bottom leaf coverage when treating pepper plants with slit and diffuser sprays.

MATERIALS AND METHODS

The experiments are carried out on a production field of correct geometric shape with dimensions 60 x 30 m. The planting scheme is 0.60 x 0.15 m. A drip irrigation system is installed. Rows in the middle of the width field, spaced 5 apart, were selected to eliminate the effect of the type of spreader on the results obtained.
Biometric characterization of pepper plants is performed by observing the following indicators: stem height, shrub height and maximum shrub width. For this purpose, measurements of 100 randomly selected plants are made and the obtained results are statistically processed by determining the average value, variance and coefficient of variation (Mitkov A., Minkov D., 1985).
In this work, experiments are performed with 2 sprayers. The first is a traditional flat jet sprayer with a spread angle of up to 110º - № 3 (https://www.lechler.com/de-en/products/). It is mounted on a simple back sprayer. The second is a diffuser sprayer. It is mounted on a back-motor sprayer. The following indicators are: coverage of the top and bottom of the leaves when working with the two plant height spreaders. The plants are divided into 3 layers in height: upper, middle and lower. On 10 randomly selected shrubs, in each layer, the bottom and top sheets of water log paper are attached.
The tanks of both sprayers are filled with water. They are put into operation and each row is processed separately. Then, with a planimeter, the area covered with drops is recorded for each sheet of water log paper. The recorded area relative to the total area of the water log paper gives the coverage of the leaves. The obtained results are processed with the help of Statistica v.7 software package by testing the hypothesis for equality of mean values between different variants.

RESULTS AND DISCUSSIONS

Biometric characteristics of pepper plants
The results obtained are reflected in Table 1.

Table 1. Biometric indicators

Descriptive Statistics			
Indicators	**Average value**	**Dispersion**	**Coefficient of variation**
Stem height, cm	22.90	2.23	9.74
Overall height, cm	65.50	7.28	11.11
Width of shrub, cm	34.60	4.50	13.01

The data shows that the average height of the plants is 65.5 cm, with a variation of this value of ± 7.28 cm. In this situation, the most developed plants are about 75 cm tall. The stem, on the other hand, has an average height of 22.90 cm and a variation of this value of ± 2.23 cm. It follows that the stem of the various plants has a length of 20.50 to 25.00 cm. From the foregoing it follows that when treating pepper plants, a leaf mass of approximately 55 cm height is treated. The three observed layers are: upper - at height from 56 to 74 cm, middle - respectively from height from 38 to 56 cm and lower - at height from 20 to 38 cm.
Cover the top of the leaves
The data from the experience and the primary statistical processing are shown in Table 2.
There is a clear difference in coverage when working with the two dispensers.
During the experiments, the fluid sprayed with the diffuser spray along with the air stream penetrated very well throughout the entire height of the bush. The spray coating ranged from 44% in the lower layer to 69% in the upper layer. There was no difference in coverage between the upper and middle layers. No statistically significant difference, but comparatively less coverage of the top of the leaves in the bottom layer.

Table 2. Cover of top of leaves, %

	Valid N	Mean	Minimum	Maximum	Standart Deviation	Coefficient of Variation
flat jet upper top	10	35.50000	30.00000	45.00000	5.016639	14.13138
flat jet middle top	10	6.80000	0.00000	12.00000	4.541170	66.78191
flat jet lower top	10	1.80000	0.00000	6.00000	1.988858	110.4921
diffuse upper top	10	62.80000	52.00000	69.00000	6.014797	9.577702
diffuse middle top	10	60.60000	52.00000	68.00000	4.402020	7.264059
diffuse lower top	10	53.60000	44.00000	64.00000	7.834397	14.61641

When working with the slit spreader, a much lower degree of coverage of the leaf mass is observed. The sprayed working fluid does not have sufficient puncture force to penetrate the entire height of the plants. It is observed satisfactorily covered in the upper layer, at a height above 56 cm. The middle and lower layers lack a drip on the top of the leaves. In order to have a good treatment of the foliage with this type of sprayer, it is necessary to use another type of spreading device - frame or droplets, which allow for complete treatment of the plant.

The data from the attempts to cover the top of the leaves made a comparison of the mean values (Table 3).

There is a proven difference ($p < 0.001$) between the work of the two spreaders. This is well illustrated in Figure 1.

Table 3. Comparison of average values for top leaf coverage

	Mean 1	Mean 2	t-value	Df	p
flat jet upper top vs. flat jet middle top	35.50000	6.80000	13.4123	18	0.000000
flat jet upper top vs. flat jet lower top	35.50000	1.80000	19.7478	18	0.000000
flat jet upper top vs. diffuse upper top	35.50000	62.80000	-11.0224	18	0.000000
flat jet upper top vs. diffuse middle top	35.50000	60.60000	-11.8926	18	0.000000
flat jet upper top vs. diffuse lower top	35.50000	53.60000	-6.1526	18	0.000008
flat jet middle top vs. flat jet lower top	6.800000	1.80000	3.1893	18	0.005080
flat jet middle top vs. diffuse upper top	6.800000	62.80000	-23.4971	18	0.000000
flat jet middle top vs. diffuse middle top	6.800000	60.60000	-26.9000	18	0.000000
flat jet middle top vs. diffuse lower top	6.800000	53.60000	-16.3433	18	0.000000
flat jet lower top vs. diffuse upper top	1.800000	62.80000	-30.4493	18	0.000000
flat jet lower top vs. diffuse middle top	1.800000	60.60000	-38.4936	18	0.000000
flat jet lower top vs. diffuse lower top	1.800000	53.60000	-20.2657	18	0.000000
diffuse upper top vs. diffuse middle top	62.80000	60.60000	0.933381	18	0.362976
diffuse upper top vs. diffuse lower top	62.80000	53.60000	2.945519	18	0.008650
diffuse middle top vs. diffuse lower top	60.60000	53.60000	2.463269	18	0.024074

Cover the bottom of the leaves

A large dispersion of the experimental data is observed with the flat jet spreader - coefficient of variation over 75%. This is largely due to the height at which the data is recorded from the bush. Due to its small breakthrough force, the working fluid penetrates 10-15 cm into the upper layer of the plant (Table 4).

A large dispersion of the experimental data is observed with the slit spreader - the coefficient of variation varies from 36 to 161% in the individual layers of the plant. It does not create a powerful jet to stir the leaf mass of the plants and due to its small breakthrough force, it penetrates to 10-15 cm depth in the upper layer. For this reason, the middle and lower layers lack coverage on the underside of the leaves. When using a diffuser sprayer, the air generated by the fan intensively stirs the leaf and forces the sprayed liquid with great force. This is a prerequisite for very good coverage of the lower part of the leaves as well.

The data on the coverage of the lower part of the leaf made a comparison of the mean values. The results show that there is a proven statistical difference in the quality of operation of the two broadcasters (Table 5).

The better coverage of the underside of the leaves using a diffuser is very good in Figure 2.

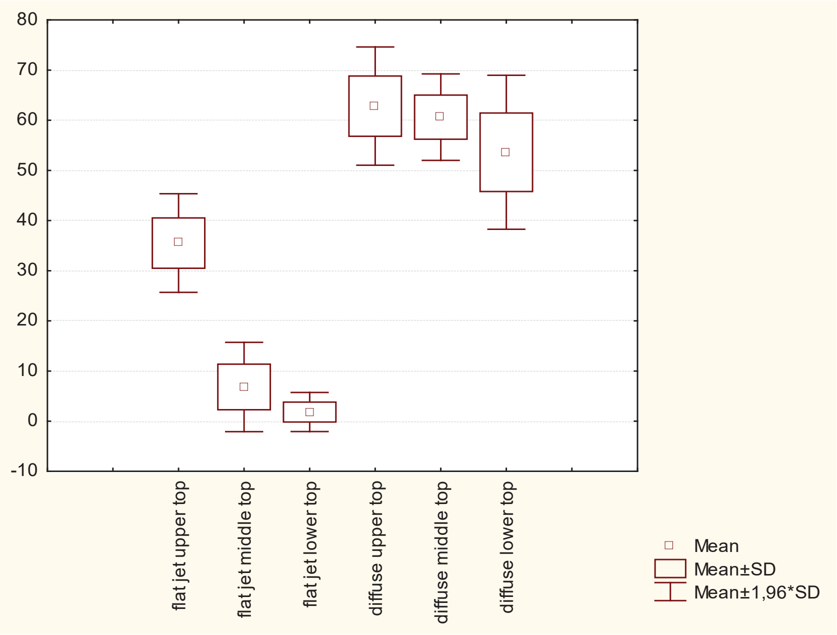

Figure 1. Cover of top of leaves, %

Table 4. Cover of bottom of leaves, %

	Valid N	Mean	Minimum	Maximum	Standart Deviation	Coefficient of Variation
flat jet upper bottom	10	18.00000	6.00000	27.00000	6.548961	36.38312
flat jet middle bottom	10	0.70000	0.00000	2.00000	0.823273	117.6104
flat jet lower bottom	10	0.30000	0.00000	1.00000	0.483046	161.0153
diffuse upper bottom	10	61.00000	55.00000	67.00000	3.399346	5.572698
diffuse middle bottom	10	57.30000	52.00000	61.00000	3.128720	5.460244
diffuse lower bottom	10	46.40000	39.00000	57.00000	5.796551	12.49257

Table 5. Comparison of the mean values of leaf coverage from below

	Mean 1	Mean 2	t-value	df	p
flat jet upper bottom vs. flat jet middle bottom	18.00000	0.70000	8.2884	18	0.000000
flat jet upper bottom vs. flat jet lower bottom	18.00000	0.30000	8.5236	18	0.000000
flat jet upper bottom vs. diffuse upper bottom	18.00000	61.00000	-18.4286	18	0.000000
flat jet upper bottom vs. diffuse middle bottom	18.00000	57.30000	-17.1230	18	0.000000
flat jet upper bottom vs. diffuse lower bottom	18.00000	46.40000	-10.2688	18	0.000000
flat jet middle bottom vs. flat jet lower bottom	0.700000	0.30000	1.3252	18	0.201688
flat jet middle bottom vs. diffuse upper bottom	0.700000	61.00000	-54.5186	18	0.000000
flat jet middle bottom vs. diffuse middle bottom	0.700000	57.30000	-55.3238	18	0.000000
flat jet middle bottom vs. diffuse lower bottom	0.700000	46.40000	-24.6837	18	0.000000
flat jet lower bottom vs. diffuse upper bottom	0.300000	61.00000	-55.9052	18	0.000000
flat jet lower bottom vs. diffuse middle bottom	0.300000	57.30000	-56.9368	18	0.000000
flat jet lower bottom vs. diffuse lower bottom	0.300000	46.40000	-25.0627	18	0.000000
diffuse upper bottom vs. diffuse middle bottom	61.00000	57.30000	2.532557	18	0.020846
diffuse upper bottom vs. diffuse lower bottom	61.00000	46.40000	6.870641	18	0.000002
diffuse middle bottom vs. diffuse lower bottom	57.30000	46.40000	5.232837	18	0.000056

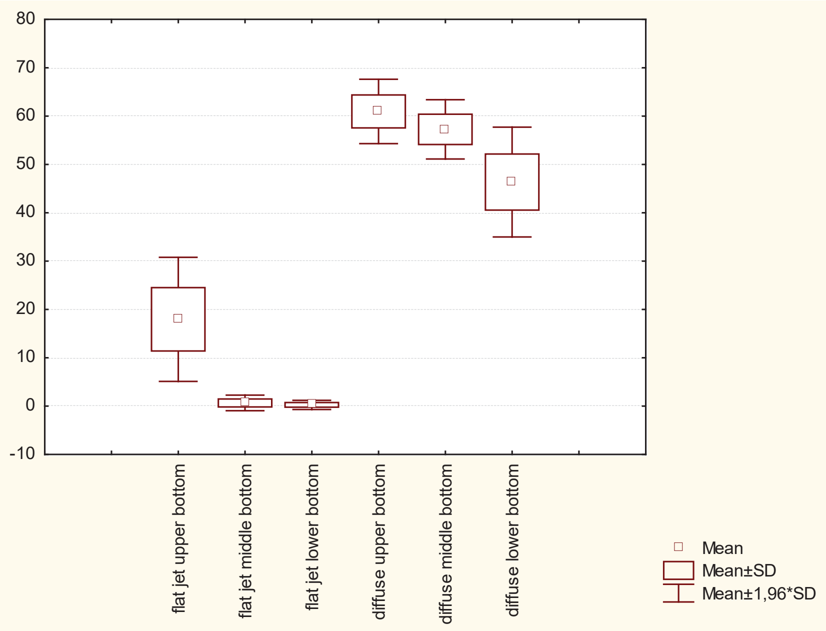

Figure 2. Cover of bottom of leaves, %

CONCLUSIONS

The following conclusions can be drawn from the experiments performed, the processing of their results and the analyzes:

With the help of the air flow, the working fluid sprayed by the diffuser spray penetrates the entire height of the treated pepper plant. However, the coating applied both from the bottom and the top decreases from top to bottom.

With the flat-blower sprayer, there is good coverage only in the upper layer on the top of the leaves.

A statistically proven better coating is obtained when working with a diffuser sprayer.

REFERENCES

Braekman P., D. Foque, M.van Labeke, J. Pieters, D. Nuyttens (2009). Influence of Spray Application Technique on Spray Deposition in Greenhouse Ivy Pot Plants Grown on Hanging Shelves, Horticulture Science, 44 (7), pp.1921-1927.

Braekman P., D. Foque, W. Messens, M. van Labeke, J. Pieters, D. Nuyttens (2010). Effect of spray application technique on spray deposition in greenhouse strawberries and tomatoes, Pest Management Science, Vol.66/2, p. 203-212.

Derksen R., S. Vitanza, C. Welty, S. Miller, M. Bennett, H. Zhu (2007). Field Evaluation of Application Variables and Plant Density for Peeper Pest Management, Transactions of the ASABE, 50(6), pp. 1945-1953.

Ferguson J., A. Hewitt, C.O'Donne (2016). Pressure, droplet size classification, and nozzle arrangement effects on coverage and droplet number density using air-inclusion dual fan nozzles for pesticide applications, Crop Protection, 89, pp. 231-238.

Llop J., E. Gil, M. Gallart, F. Contador, M. Ercilla (2016). Spray distribution evaluation of different settings of a hand held trolley sprayer used in greenhouse tomato crops, Pest Management Science, 72 (3), pp. 505-516.

Marques R., J. da Cunha, G. Alves, T. Alves, S. Silva, C. Zandonadi (2019). Control of *Dalbulus maidis* in maize crop with electrostatic spraying, Bioscience Journal, 35 (6), pp. 1780-1788.

Mitkov A., D. Minkov (1985). Mathematical Methods of Engineering Research, VTU, Ruse (Митков А., Д.Минков, 1985, Математични методи на инженерните изследвания, ВТУ, Русе).

Nuyttens D., S. Windey, B. Sonck (2004). Optimisation of a Vertical Spray Boom for Greenhouse Spray Applications, Biosystems Engineering, 89(4), pp. 417-423.

Rincón V., J. Hermosilla, F. Páez, J.P. Alonso, Á. Callejón (2017). Assessment of the influence of working pressure and application rate on pesticide spray application with a hand-held spray gun on greenhouse pepper crops, Crop Protection, 96, pp. 7-13.

Sánchez Hermosilla J., V. Rincón, F. Páez, F. Agüera, F. Carvajal (2011). Field evaluation of a self propelled sprayer and effects of the application rate on spray deposition and losses to the ground in greenhouse tomato crops, Pest Management Science, Vol. 67/8, p. 942-947.

Xiao Q., Du R., Yang L., Han X., Zhao S., Zhang G., Fu W., Wang G., Lan Y. (2020). Comparison of Droplet Deposition Control Efficacy on *Phytophthora capsica* and Aphids in the Processing Pepper Field of the Unmanned Aerial Vehicle and Knapsack Sprayer, *Agronomy*, 10(2):215.

https://www.lechler.com/de-en/products/