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Are there differences on spray deposit distribution produced on citrus canopies by conventional and low-drift nozzles?

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Abstract

Air injection nozzles are often recommended to reduce drift, which is one of the major pollution sources caused by the application of plant protection products on fruit trees. However, it is important to know if the use of low-drift nozzles may affect the efficacy of treatments. This work is aimed at providing scientific evidence to asses if there are changes in the deposition pattern on citrus canopies when using conventional (cone) and low-drift (air injection) nozzles and discuss the consequences on efficacy of pesticides. Results showed that the air injection nozzles did not affect deposition in the conditions of the experiments, so they suggest that these nozzles can be regarded as a good alternative to the conventional ones.

Keywords: deposition, pesticide, airblast sprayer

1. Introduction

Sustainability of plant protection products necessarily involves reducing risks that their application may pose for human health and the environment. Although both pesticide users and manufacturing industries are continually acting for the improvement of the application of pesticide treatments, yet some of the products are lost to the environment as a result of runoff, washing, evaporation and drift. Drift is one of the major pollution sources caused by the application of plant protection products on fruit trees. The amount of drift produced during the application depends on the physicochemical characteristics of the spray, as its volatility, viscosity and the size of droplets produced, and atmospheric conditions during application (wind speed and direction, vertical movements of air, temperature and relative humidity). The adjustment of the equipment (number of open nozzles, position, tractor, speed, pressure, etc.) also influences, especially if air-assisted sprayers, as airblast sprayers, are used.

A large amount of methods to reduce drift can be found in the literature, from the use of windbreaks to the development of new machines or devices and their automatic control. Such methods include the use of low-drift nozzles, the electronic management of the air flow and direction, the electronic control of the opening of the nozzles, or the use of tunnels that recycle the product. The cheapest and more available method of reducing drift currently consists of the use of low-drift, air injection nozzles.

Most conventional air-assisted sprayers use disk and core nozzles that generate a cone of fine droplets which favor the uniformity of deposition of the product on the leaves. However, due to their low weight and reduced air resistance, excessively fine droplets have a tendency to drift (Fox, Reichard, Brazee, 1985). Furthermore, they evaporate faster. Air injection nozzles generate large droplets that are less prone to drift, but more to run off (Guler et al., 2006).

Because low-drift nozzles change the size and behavior of droplets, they may influence the efficacy of plant protection products to control a targeted pest. Although some studies in fruit orchards have dealt with this issue (Frießleben, 2004; Heinkel, Fried, Lange, 2000; McArtney & Obermiller, 2008), all of them have been conducted with apple trees, but none with citrus trees, which have a globular shape and a denser canopy. For this reason, the objective of this work is to provide scientific data to asses if the efficacy of pesticide treatments using low-drift nozzles may change. For this purpose, the deposition pattern generated by a treatment with these nozzles is compared to that produced by a similar one using conventional nozzles, always under Spanish citrus growing conditions.

2. Materials and methods

Experiments were conducted in a commercial 22-yr-old Navel orange (*Citrus sinensis* L.) orchard in El Puig (Valencia, Spain). Trees were planted at 6 x 4 m spacing, so density was 417 trees/ha. Trees averaged 2.7 m in height, with a crown projection of 3.6 x 3.8 m. Apparent canopy volume averaged 19.23 m^3, considering the canopy as an ellipsoid. Leaf area density (LAD) was 4.03 m^2/m^3.

A meteorological station monitored air temperature, wind speed and direction, and relative humidity during the experiments. Applications followed conventional atmospheric recommendations (air temperature between 5 and 35ºC, over 50% relative humidity) and standard good agricultural practices for the application of plant protection product in citrus cultivation. A conventional air-assisted sprayer (Fede Pulverizadores, mod. Futur 1500), at 1.65 km/h tractor speed, at 480 rpm at PTO (1440 rpm at engine), and maximal air flow (80000 m^3/h) was used.

Eight experiments were carried out from April to July 2010, at a rate of two every month, alternatively using conventional cone nozzles (Teejet D3 DC35) and air induction nozzles (Albuz TVI 80 03) in the same week, which led to 4 replicates per nozzle type. In all cases treatments were conducted at 10 bar pressure measured in the manifold. The sprayer was fitted with 26 nozzles, 13 on each side, but the two upper nozzles were closed to adjust the spray plume to the canopy. Sprayed volumes were 2930 and 3206 l/ha, respectively. Brilliant Sulfoflavine diluted at 1 g/L was used as a tracer.

The spray volume applied and the tracer concentration were verified in all tests by measuring the actual tractor speed and flow rate of each nozzle, and by determining the concentration of a liquid sample extracted from the tank. In each experiment the solution was sprayed to two adjacent tree rows along 30 m. Blotting paper collectors were used to sample deposition on the canopies that were directly sprayed. Deposition was measured in four trees, two at each side of the tractor path (Figure 1).

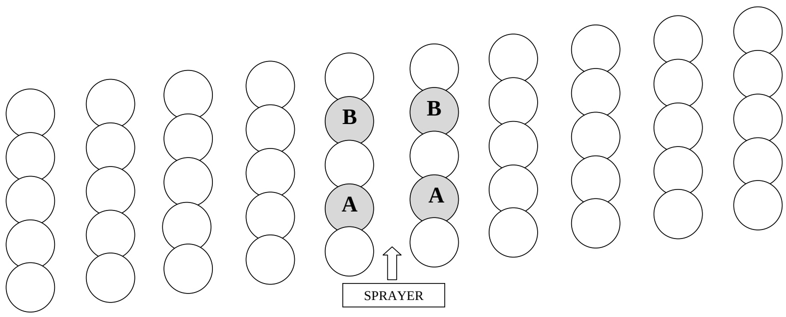


Figure 1: Sketch of the experiment. Test trees in grey.

Tree canopies were divided in thirty-six zones, taking into account different heights, depths and widths. These zones consisted of three heights (Low: 0-1m; Medium: 1-2 m; High: 2-3 m), two depths on each side of the canopy (outside: 0-1m; inside: 1-2 m) and three widths

(Right side: 0-1 m; Central: 1-2 m; Left side: 2-3 m). Eight collectors were randomly located on each zone.

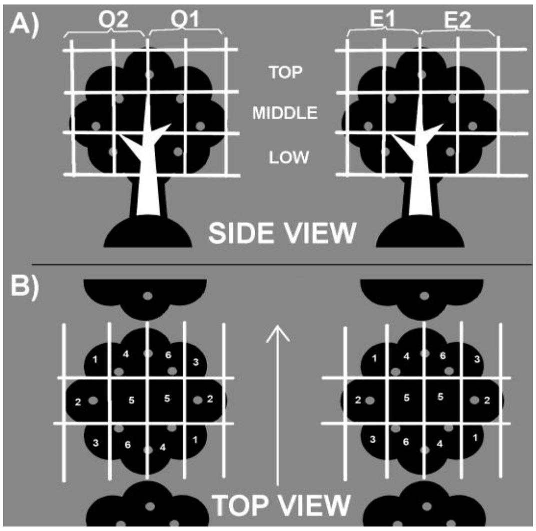


Figure 2: A) Side view of a standard tree. Distribution of collectors in height. B) Top view of a standard tree. Distribution of collectors at each height.

After collectors dried, they were individually put in plastic bags and stored in cool conditions. The collectors were washed with de-ionized water in laboratory and the resulting BSF concentration was quantified by fluorometry.

The amount of spray deposited per unit area (µl/cm^2) on each collector was determined from the measurement of fluorescence intensity, considering the actual concentration of the applied spray. From these data, the average deposition at each combination 'height x depth' was calculated. Outside and inside deposition was calculated by addition of the deposition measured on both sides of the tree.

The average amount of spray deposited on each zone of each tree was estimated considering all zones of equal size and with the same Leaf Area Density (LAD) (Equation 1).

$$Deposited\ volume\ (l) = \frac{V\ (m^3\ vegetation)*LAD\ (m^2/m^3)*D\ (\mu l/cm^2)}{\#\ Zones*100} \qquad \text{Equation 1}$$

where V, canopy volume (m^3), LAD, Leaf area density, m^2/m^3), D, spray deposited per unit area in a zone (µl/cm^2), and # Zones, number of zones (36).

The summation of all these values gave the total volume deposited on the tree and it was expressed as a percentage of the total volume applied to each tree, which was calculated by means of Equation 2.

$$Volume\ applied\ to\ each\ tree\ (l) = \frac{SAV\ (l/ha)*W\ (m)*d\ (m)}{10000} \qquad \text{Equation 2}$$

where SAV, spray application volume (l/ha), W, width of orchard path (m), and d, distance between adjacent trunks in a row (m).

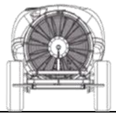
Furthermore, the volume deposited on each zone, was expressed as a percentage of the total volume deposited on the tree.

Data generated by both nozzles in the different parts of the canopy were compared using one way analysis of variance (ANOVA). The ANOVA assumption of normal distribution of residues was assessed by Shapiro-Wilk test (Shapiro and Wilk, 1965) and the assumption of homocedasticity by Levene´s test (Levene, 1960). Fisher's LSD test (Fisher, 1935) was used for mean comparisons. All tests were considered at the 95% confidence level and were carried out with Statgraphics® Plus version 5.1 software (STSC Inc., 1987).

3. Results and Discussion

No statistical differences were found between the nozzles on the percentage of the total volume deposited on the target canopies (p-value=0.9579)). 39.2±2.1% of applied volume was deposited in the canopy when using conventional nozzles, and 38.8±6.3% when using low-drift nozzles. Furthermore, no statistically significant differences were found in deposition in the canopies at each side of the sprayer, neither at each canopy depth (Table 1).

*Table 1: Percentage of deposited volume on each side of the sprayer (mean±SE) by each nozzle**

Nozzle	**Left side/inner canopy**	**Left side/outer canopy**		**Right side/outer canopy**	**Right side/inner canopy**
Conventional	6.2±0.8 a	13.8±0.9 a		13.9±0.7 a	5.3±0.5 a
Low-drift	6.7±1.2 a	14.9±2.8 a		11.9±1.6 a	5.3±1.0 a
*Means within a column followed by a different letter are significantly different (LSD test, P < 0.05)					

Moreover, no statistically significant differences in spray distribution on the canopy were found after applications with both nozzles (Figure 3).

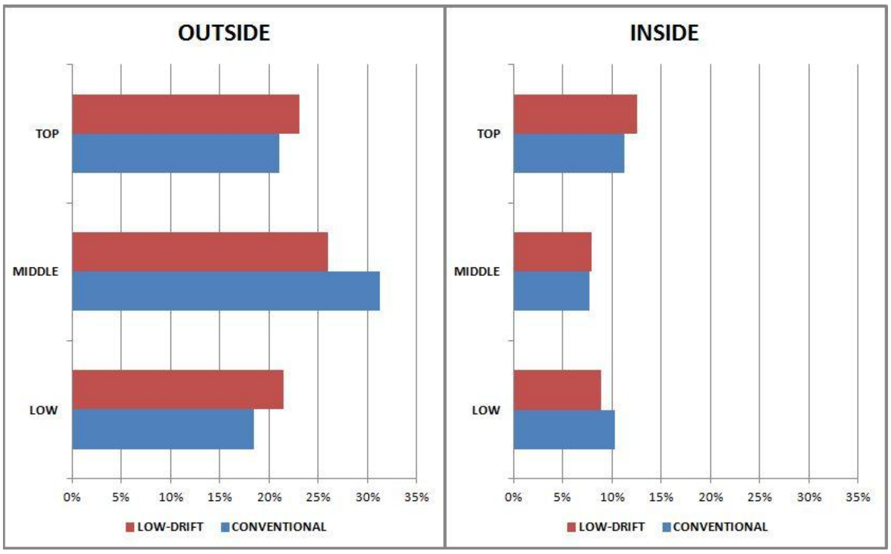


Figure 3: Distribution of the spray on the canopy of a citrus tree with low-drift and conventional nozzles.

Around 71% of the total deposit was located in the outer zones of the canopy and around 29% in the inner zones with both types of nozzles. Regarding height distribution, the top of the canopy received approximately 34% of the total deposit, the medium zone 36% and the bottom part 30%. These results showed large differences of deposition between the outer and the inner part of the canopy, due to the high foliar density and globular shape of citrus, but not between the nozzles.

4. Conclusions

Results suggest that the air injection nozzles did not affect the deposition on the target canopies, so they can be regarded as a good alternative to conventional nozzles. The large differences of deposition between the outer and the inner part of the canopy highlight the importance of improving the design of current airblast sprayers, and the accurate set up of these machines before and during the applications.

5. Acknowledgements

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6. References

Fisher, R.A. (1935) *The Design of Experiments*. Edinburgh and London: Oliver and Boyd.

Fox, R.D., Reichard, D.L., & Brazee, R.L. (1985) A model study of the effect of wind on air sprayer jets. *Transactions of the American Society of Agricultural Engineers*, 28, 83-88.

Frießleben, R. (2004) Balancing drift management with biological performance and efficacy. *Proceedings of the International Conference on Pesticide Application for Drift Management*, October 27-29, 2004, Waikoloa, Hawaii, 72-79.

Guler, H., Zhu, H., Ozkan, H.E., Derksen, R.C., Yu Y., & Krause C.R. (2006) Spray characteristics and wind tunnel evaluation of drift reduction potential with air induction and conventional flat fan nozzle. *American Society of Agricultural and Biological Engineers, Annual International Meeting*, Paper No. 06111. (Abstr.)

Heinkel, R., Fried, A., & Lange, E. (2000) The effect of air injector nozzles on crop penetration and biological performance of fruit sprayers. *Aspects of Applied Biology*, 57, 301-307.

Levene, H. (1960) Robust Tests for Equality of Variances, in: Olkin, I., Ghurye, S.G., Hoeffding, W., Madow, W.G., & Mann, H.B. (Eds.), *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*. Stanford University Press, Palo Alto, CA, 278-292, 278-292.

McArtney, S.J., & Obermiller, J.D. (2008) Comparative performance of air-induction and conventional nozzles on an axial fan sprayer in medium density apple orchards. *HortTechnology*, 18, 365-371.

Shapiro, S.S., & Wilk, M.B. (1965) An analysis of variance test for normality (complete samples). *Biometrika* 52, 591-611.