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Reducing spray drift by adapting the spraying equipment to the canopy shape in olive orchards with isolated trees

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Summary

The lack of specificity of the spraying equipment commonly used in olive orchards is a remarkable problem, for not allowing farmers to apply adjusted pesticide doses to their trees, making necessary to spray very high liquid volumes that increase the environmental pollution risk. In this context, three prototypes were specially developed to increase the application efficiency in olive orchards with isolated trees, which represent 98% of the olive harvested area in Spain. A study was conducted to assess the drift produced by one of these prototypes in comparison with a commercial airblast sprayer like the ones commonly used in the current practices.

A total of 10 trees belonging to two different fields inside an olive commercial farm in Córdoba, Southern Spain, were selected. The selected fields presented the traditional and intensive cultivation systems. A commercial airblast sprayer and a prototype airblast sprayer with six small-sized axial fans, placed in both sides of the equipment, were tested. In order to set the application volume, the tree crown volume was manually measured, using a specific spray volume of 0.12 L m^{-3}. This configuration resulted in applied volumes of 1150 and 580 L ha^{-1} in the traditional and intensive system, respectively. The air flow rate was set in 12.5 and 11.0 m^3 s^{-1} in the aforementioned systems, and it was equal for both sprayers. Food dye E-102 (Tartrazine) was used to assess deposition on filter paper pieces, in the canopy, and Petri dishes on the ground, to evaluate drift. A total of 16 sampling positions were set in the canopy, and 16 and 12 were set on the ground in the traditional and intensive systems. Water sensitive paper (WSP) was used to assess the percentage coverage and the impacts per square centimeter.

The results show that the prototype significantly reduced the spray drift in both systems: 52.7% and 57.0% in the traditional and intensive orchard, respectively. Nevertheless, the ground deposit distribution among the different sampling positions was similar in both cases. The deposition values collected in the canopy, along with the percentage coverage and the impact number did not vary significantly, though they were slightly higher in the

prototype. These results are promising for indicating a potential for reducing the drift risk associated to the operation.
Keywords: olive, pesticide application, sprayer testing, drift reduction, spray quality

Introduction

Olive is a very important crop in Spain, the main World producer, with 2.6 Mha and a mean annual production of about 6 Mt. This crop is mostly grown in very traditional cultivation systems, with very low plantation densities, what makes trees to be very large in size. This fact makes difficult its mechanization, and especially the pesticide application, as the target to be covered is very irregular in shape, and trees may differ markedly from one to the next (Miranda-Fuentes et al., 2015a). In this situation, pesticide losses are very important as the commonly-used conventional airblast sprayer do not have the possibility to adapt the application to the tree shape and volume.

Over the last years, many authors have designed improvements to be implemented to conventional sprayers in order to adjust the spray dose or the airflow rate according to the signal of different sensors which characterize the canopy volume and shape (Doruchowski et al., 2014; Escolà et al., 2013; Gil et al., 2013; Giles et al., 1989; Landers, 2010; Pai et al., 2009). Nevertheless, these improvements have not the possibility to reduce the flight time of the sprayed droplets. In this sense, further improvements should be made in these sprayers to increase the application efficiency in isolated olive tree orchards. This study tests a sprayer prototype specifically designed for olive to check its application quality and efficiency against a commercial airblast sprayer.

Materials and methods

A description of the materials and methods of the trials is presented.

Farm and field selection, canopy and weather conditions characterization.

The trials were performed in two olive fields belonging to a commercial olive farm (coordinates: 37°42′53″ N; 4°48′32″ W). The two fields had different olive cultivation systems (Fig. 1). On the one hand, the intensive one had 7 m in row spacing with a plantation density of 204 trees per ha. On the other hand, the traditional one had a quincunx scheme, with row spacing of 10 m and tree spacing of 12 m (107 trees $\cdot$ ha^{-1}).

The canopy characterization was done according to the mean vector method (Miranda-Fuentes et al., 2015a), which consists of calculating the average value from 8 measurements of the distance from the centre of the tree to 8 external points of the canopy, chosen in 8 pre-established directions separated 45º among them (Fig. 2). This parameter showed to have a good correlation with the LiDAR volume of different kinds of olive trees.

The weather conditions were measured to ensure that every treatment was done with similar conditions, especially concerning wind speed and direction. A meteorological station (CR800, Campbell Scientific Inc., Logan, UT, USA) with a 2D sonic anemometer (WindSonic 232, Campbell Scientific Inc.) and two temperature and relative humidity probes (CS215, Campbell Scientific Inc.) was used, recording air speed and direction, temperature and relative humidity data each 10 s (0.1 Hz registration frequency).

Fig. 1. Experimental fields used in the field trial: a. Intensive and b. Traditional plantation systems.

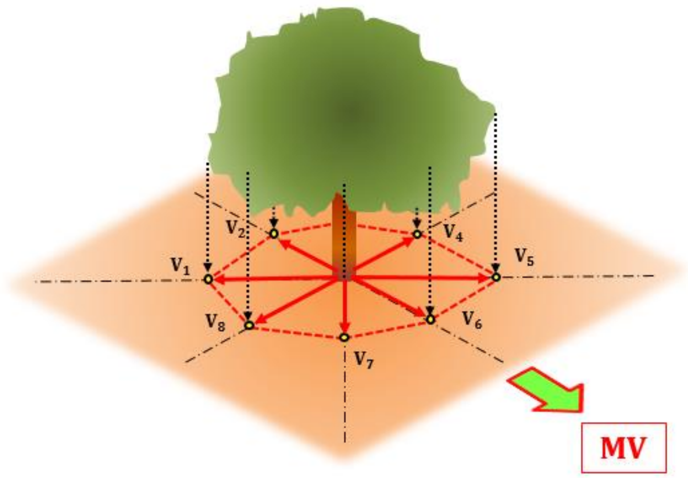

Fig. 2. Mean vector method for canopy characterization. Measurements.

Application equipment and working parameters

The sprayers used in this trial were a conventional airblast sprayer (Eolojet 2200 L, Osuna-Sevillano S.L., Jauja, Spain), like those typically used in olive orchards (Fig. 3a) and a prototype of air-assisted sprayer specially developed for olive (Fib. 3b). This prototype had 6 small-size hydraulically-driven axial fans with perimeter hollow cone nozzles that can be approached towards the canopy by being mounted on two mobile structures moved by analogical ultrasonic sensors (UC6000-30GM-IUR2-V15, Pepperl+Fuchs, Mannheim, Germany). This prototype was fully described in previous works (Miranda-Fuentes et al., 2017).

Fig. 3. a. Conventional airblast sprayer. b. Air-assisted sprayer prototype.

The working parameters were optimized for the conventional airblast sprayer, according to the optimization trials previously undertaken. The operation parameters can be found in Table 1.

Table 1. Operation parameters for the field trials.

	Cultivation system			
	Intensive		Traditional	
Parameter	**Prototype**	**Conventional**	**Prototype**	**Conventional**
Nozzle colour	Yellow	Green	Red	Blue
Number of open nozzles	36 (2 x 18)	14 (2 x 7)	36 (2 x 18)	14 (2 x 7)
Pressure (bar)	11	13	7	14
Liquid flow rate ($L \cdot min^{-1}$)	38.52	39.06	58.32	55.86
Spray volume ($L \cdot ha^{-1}$)	585.1	583.0	1170.3	1151.8
Forward speed ($km \cdot h^{-1}$)	3.95	4.02	2.99	2.91
Air volumetric flow rate ($m^3 \cdot s^{-1}$)	10.8	10.9	12.3	12.3

The low speed values are related to the high volumes to be applied and the low nozzle number of the conventional sprayer. As it can be seen, the volumes needed to be almost doubled in the traditional orchard because of their high crown size, as the volume per tree was calculated by multiplying the crown volume by the specific spray volume of 0.12 $L \cdot m^{-3}$, which showed to be optimal for isolated olive trees (Miranda-Fuentes et al., 2016).

Experimental design and sampling system.

Five consecutive trees per cultivation system (10 in total) were sprayed from both sides to assess the deposition and coverage generated by each one of both sprayers. A total of 16 sampling positions were set in the canopy, organized in 4 sectors, 3 heights and 2 depths in the intermedium height (Fig. 4). Each sampling position contained a squared 10 x 10 cm filter paper collector and two water sensitive paper (WSP) pieces (76 x 26 mm, Syngenta Crop Protection

AG, Basel, Switzerland). The food dye E-102, Tartrazine, was used as tracer and added at 8 g · L^{-1} concentration to the sprayer tank.

The spray drift comparative assessment was undertaken by placing 6 sampling areas per single field, two per side of the row. These areas were placed inside the field, at two row distance (Fig. 5a).

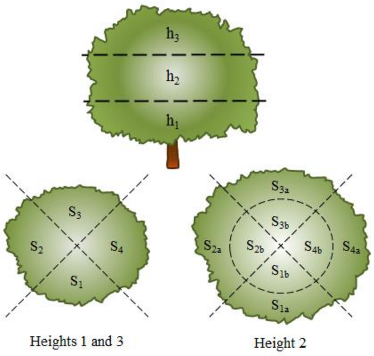

Fig. 4. Sampling positions in the tree crown.

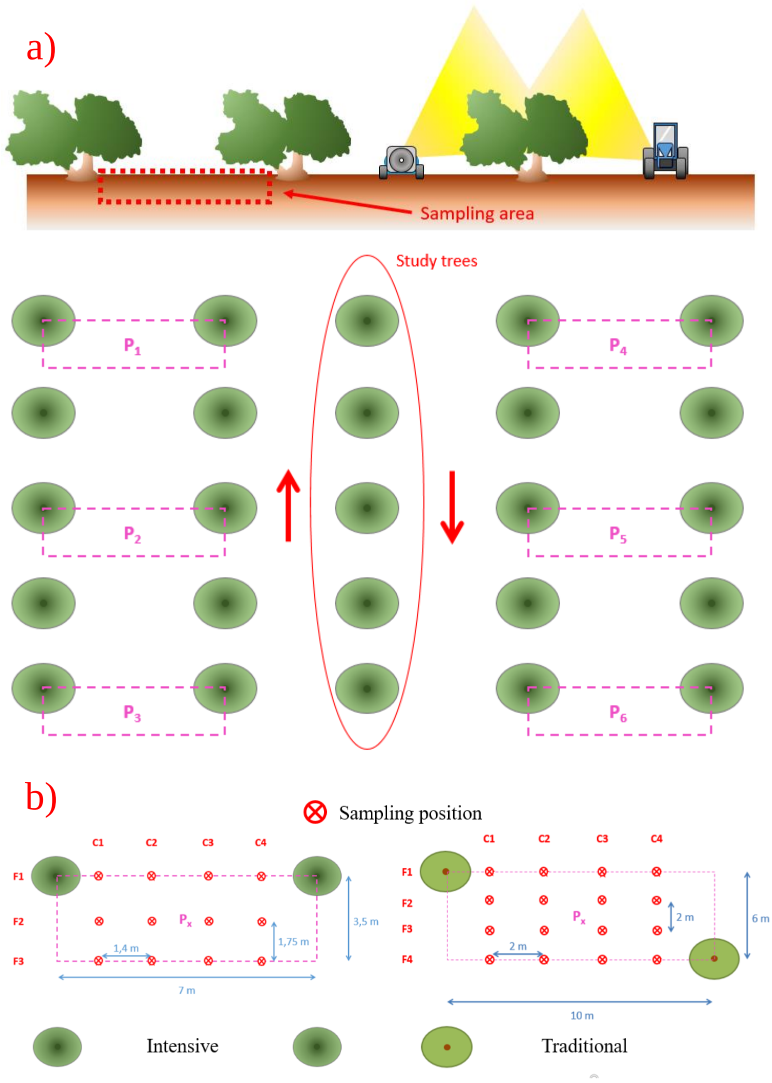

Fig. 5. a. Field disposal of the 6 sampling areas for the spray drift comparative assessment. b. Arrangement of the sampling positions for both cultivation systems.

The drift collectors were Petri dishes of 15 mm in diameter, placed on horizontal wooden boards. These were set at different depths and profiles, ranging from the back part of the trees to the centre of the space in between two consecutive trees in a row. In the case of the intensive orchard, there were 12 sampling positions per single sampling area. In the case of the traditional, there were 16, as shown in Figure 5b.

Trial performance and data analysis

The treatment order was randomized in each case. The real forward speed and liquid flow rate were measured on the field, and samples of the tank content were collected before and after each treatment to check the tank real concentration. Once the trials were done, every sample was collected in darkness conditions and carried to the laboratory. Once there, the filter paper samples were washed with 100 ml of distilled water. The Petri dishes required a variable washing volume, depending on the deposition, to enter in the measuring range of the 96 well plate spectrophotometer (Synergy HTX, BioTek Instruments, Inc., Winooski, VT, USA). The WSP samples were analysed with the free image analysis software ImageJ (National Institutes of Health, Bethesda, MD, USA).

The parameters obtained from the samples were the absolute spray deposition on the leaves and on the ground dishes (d_l and d_g, µg · cm^{-2}), the percentage coverage (*SC*, %) and the impact number per area unit (N_i, cm^{-2}).

Results and discussion

The two plantation systems resulted in very different crown volumes. Thus, intensive trees showed to have a volume of 23.86 m^3 in average and the traditional ones had 90.34 m^3 in average. These values were obtained from the Mean Vector, which resulted in 2.00 and 3.10 m for the intensive and traditional trees, respectively. Intensive trees had a mean canopy height (discounting the height of the lower leaves) of 3.54 m, and traditional ones had a mean canopy height of 4.82 m.

As to the weather conditions, the wind speed was irrelevant, keeping under 0.3 m · s^{-1} all the time that the trials left, so it can be considered that it did not affect the trials. The air temperature ranged from 21.5ºC in the treatment with the conventional sprayer in the intensive orchard and 26.5ºC in the treatment with the prototype in the traditional trees. The relative humidity was comprised between 45% and 52%.

As to the deposition, coverage, impacts and drift results, they are all comprised in Table 2. As it can be seen, spray deposition on leaves, d_l, was not affected in practice in intensive trees, with mean values that were very similar for the two sprayers. Different results were obtained in the traditional trees, where the prototype increased the amount of spray that was deposited on the leaves, increasing the mean value by nearly 25%. This matches the results of Holownicki et al. (2000), who reported that the airblast sprayer is less efficient in big-sized isolated old trees, as those found in traditional olive orchards.

Similar results were obtained with the spray coverage, *SC*, but in this case, significant differences were also obtained for the intensive cultivation system, resulting in better results for the prototype. As it can be drawn from Table 2, the increase in coverage was similar to that obtained in the d_l parameter in the traditional orchard, and much more marked in the intensive one. In this case, the relative increase was 22.2 % for the intensive trees and 23.1 % for the traditional ones.

Table 2. General results of the study

		Cultivation system			
		Intensive		Traditional	
Parameter		*Prototype*	*Conventional*	*Prototype*	*Conventional*
Mean deposition leaves	d_l (µg cm^{-2})	19.00*	18.75	28.20 a	22.6 b
Mean coverage	***SC*** (%)	33.5 a	27.4 b	32 a	26 b
Coverage upper side	***SC up*** (%)	36	36	50 a	33 b
Coverage lower side	***SC lo*** (%)	31 a	20 b	46 a	26 b
Mean impacts	N_i (cm^{-2})	103 a	123 b	106 a	146 b
Impacts upper side	N_i ***up*** (cm^{-2})	102 a	123 b	86 a	131 b
Impacts lower side	N_i ***lo*** (cm^{-2})	103 a	124 b	126 a	155 b
Mean deposition ground	d_g (µg cm^{-2})	0.68 a	1.56 b	0.35 a	0.75 b

* Results with no letter showed no significant differences between prototypes

As to the upper side of leaves, the mean spray coverage, *SC up*, was exactly the same in the intensive system, whilst it was importantly increased by the prototype in the traditional one (+51.5 %). The most important changes come in the lower side (*SC lo*). Some studies performed previously with conventional airblast sprayer in olive trees showed that the underside of the leaf remains markedly less covered than the upper side (Miranda-Fuentes et al., 2015b), and this can be a problem when trying to adjust the spray dose, as the whole leaf must remain completely covered to prevent the entrance of fungal diseases. In the case of the prototype, differences between upper and lower side are importantly reduced, with absolute coverage values much higher than those obtained by the conventional sprayer.

Just the opposite response was obtained with the impacts. The mean value for impacts is significantly higher in the case of the conventional sprayer, both for the mean value, the upper side and the lower side of leaves. This result was not expected, as the pressure and nozzle type were combined to give similar results in terms of droplet size, so this factor should not be the cause. The explanation could be the kind of droplet distribution from both systems. As the prototype included a completely new design, it could affect the way how droplets are distributed.

The most important thing about this study is the mean deposition on the ground, d_g, used to compare the spray drift produced by both sprayers. As it can be seen, this parameter is markedly reduced with the prototype in both systems. Concretely, the spray deposited on the ground collectors was reduced in 57.0% and 52.7% in the intensive and traditional systems, respectively. This fact is very important if considered that the spray deposit and coverage was not reduced with the prototype with respect to the conventional sprayer. It should be pointed out that the operation parameters were optimized for the conventional sprayer, and in fact the coverage and deposition values obtained with this equipment in both plantation systems were appropriate and higher than the ones obtained by the researchers in previous trials.

Figure 6 shows the deposit distribution in depth on the ground (according to the scheme showed in Fig. 5b).

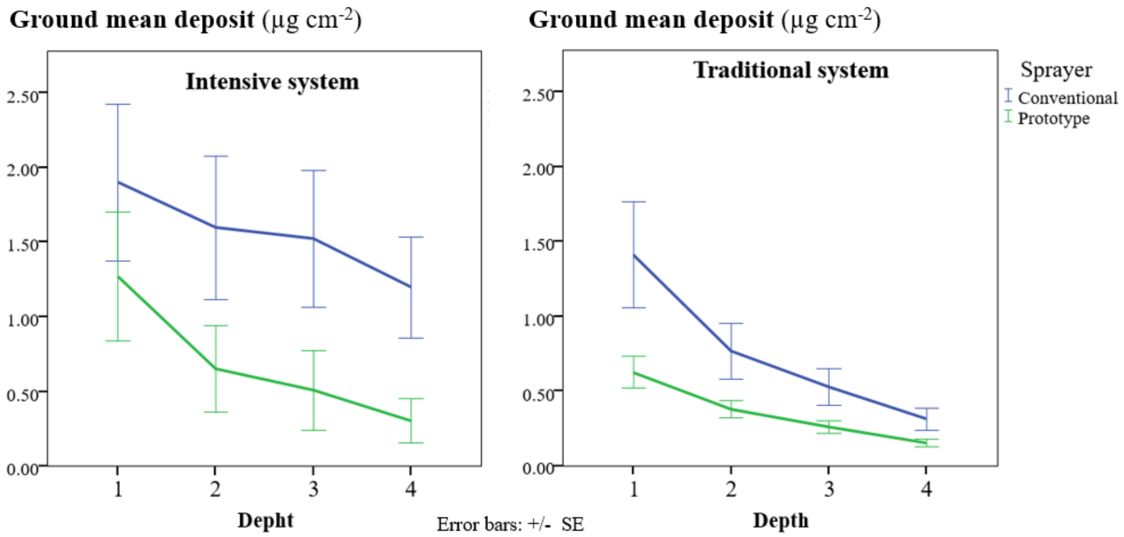

Fig. 6. Ground deposit in depth from the application point (1: minimum distance; 4: maximum distance).

As it can be seen, differences of the ground deposition in depth are much more evident than mean differences. The prototype, in general, makes the spray to reach a lower distance, being the application, therefore, much safer.

Conclusions

As the study showed, the developed prototype has the potential to positively affect the quality of the spray applications in isolated olive trees, being this difference much more evident in the traditional cultivation system. Not only it increments the overall deposit and coverage, but reduces the drift losses as well. In addition, specific aspect like the underside coverage and the ground deposit collected at the maximum distance make it very suitable for its purpose: making spray applications to olive canopies safer and more sustainable, which is what the European guidelines are encouraging.

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