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Influence of liquid-volume and airflow rates on spray application quality and homogeneity in super-intensive olive tree canopies

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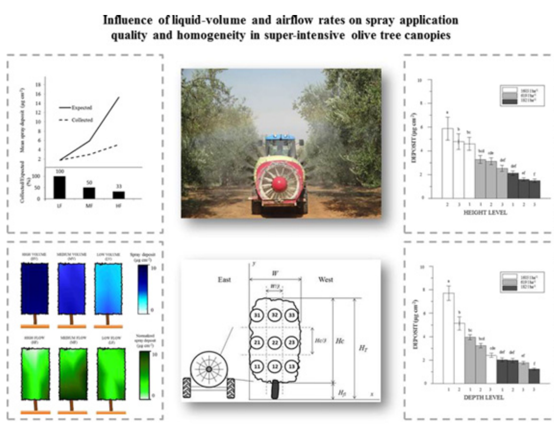
HIGHLIGHTS

- We tested the effect of volume and airflow rates on spray applications.
- The tests were carried out in a super-intensive orchard.
- Increased application volume resulted in increased spray deposit and coverage.
- Increased volume decreased the application efficiency and deposit homogeneity.
- The volumetric airflow rate had a lower influence than the volume.

GRAPHICAL ABSTRACT



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ABSTRACT

Olive is a key crop in Europe, especially in countries around the Mediterranean Basin. Optimising the parameters of a spray is essential for sustainable pesticide use, especially in high-input systems, such as the super-intensive hedgerow system. Parameters may be optimised by adjusting the applied volume and airflow rate of sprays, in addition to the liquid to air proportion and the relationship between air velocity and airflow rate. Two spray experiments using a commercial airblast sprayer were conducted in a super-intensive orchard to study how varying the liquid volume rate (testing volumes of 182, 619, and 1603 l ha^{-1}) and volumetric airflow rate (with flow rates of 11.93, 8.90, and 6.15 m^3 s^{-1}) influences the coverage parameters and the amount and distribution of deposits in different zones of the canopy.. Our results showed that an increase in the application volume raised the mean deposit and percentage coverage, but decreased the application efficiency, spray penetration, and deposit homogeneity. Furthermore, we found that the volumetric airflow rate had a lower influence on the studied parameters than the liquid volume; however, an increase in the airflow rate improved the application efficiency and homogeneity to a certain threshold, after which the spray quality decreased. This decrease was observed in the high-flow treatment. Our results demonstrate that intermediate liquid volume rates and volumetric airflow

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rates are required for the optimal spraying of pesticides on super-intensive olive crops, and would reduce current pollution levels.

1. Introduction

Olive oil production in Europe represents 71.7% of the worldwide production (www.internationaloliveoil.org), with the olive oil sector being particularly important in southern European countries (surrounding the Mediterranean Basin). According to the Directorate-General of Agriculture and Rural Development of the European Commission (EC), the main areas of olive oil production are in Spain (2.4 million ha), Italy (1.4 million ha), Greece (1 million ha), and Portugal (0.5 million ha). France is a much smaller producer, with only 40,000 ha (http://ec.europa.eu/environment/agriculture/). Of importance, the production process used influences the level of environmental pollution generated by all the inputs used in the crop management. Traditional olive plantations are considered to pose the lowest environmental contamination risk, and still cover the largest surface area (Miranda-Fuentes et al., 2015). In contrast, the area dedicated to intensive and semi-intensive plantations pose high environmental contamination risk (Beaufoy, 2001), with coverage increasing in recent years. For instance, semi-intensive plantations now constitute 22% of the total cultivated area in Spain, representing 550.000 ha (AEMO, 2012). Semi-intensive olive tree plantations are characterised by medium to large row distance (5–8 m), considerable distance between the trees (3–7 m), and low tree density per hectare. The wide spacing of trees hampers the spray application process, while low tree density leads to formation of high canopy volumes that cause crop management difficulties. According to the EC (1999), the olive sector is one of intensified production causing certain negative effects on the environment.

It has been suggested that enhancing the accuracy of the volume rate (VR) represents an important measure to increase spray (i.e. pesticides) application efficiency to crops. For olive trees, this measure represents one of the most crucial parameters for reducing environmental problems. For instance, the adoption of an accurate spray volume that is adapted to the canopy characteristics of different tree crops could reduce the applied volume by 20%, while maintaining the quality of treatment (Pérez-Ruiz et al., 2010). The authors demonstrated a close relationship between canopy characteristics and optimal application volume, supporting the need to adjust spray application according to tree structure. However, research is required to determine the optimal VR for different tree characteristics. Recently, different methods for canopy characterisation in olive tree plantations have been reported, based on methods established for other tree crops (Llorens et al., 2011; Jang et al., 2008; Tumbo et al., 2002). These methods range from simple, manual approaches to sophisticated procedures using electronic devices (Miranda-Fuentes, et al., 2015; Moorthy et al., 2011). The results of studies on VR optimisation generally indicate that the recommended VR mostly is lower than that currently applied by farmers, and that the use of optimised spraying saves costs and generates environmental benefits through considerably lower pesticide use (Gil et al., 2011; Landers, 2012; Moltó et al., 2001). Manktelow et al. (2004) found that deposit variability between the outer and inner parts of the canopy in a vineyard tended to decline with increasing spray volume, especially when the outer canopy was wetted beyond the point of runoff, which led to an associated reduction in spray efficiency. The authors concluded that if the chemical application rate is held constant and the application volume is adjusted, the highest overall deposits are achieved at low volumes, at which runoff losses are minimised. This conclusion was corroborated by Gil et al. (2005), who demonstrated that the deposition values were not different for VRs ranging from 150 to 800 L ha^{-1} in different vine plantations.

Ozkan (2009) suggested that sustainable agriculture, good water quality, profitability and increasing health, safety, and ecological and sociological concerns require a more prudent use of pesticides. Current methods and equipment have considerably improved the accuracy of chemical application; however, inefficiencies and many unanswered questions remain. Well-adapted spraying equipment, improvement of best management practices, and training seem to be key factors in this process. In 'three-dimensional crops', such as olive trees, precise air-assisted spraying has been identified as one of the most profitable best management practices to reduce drift (ECPA, 2014). Both airflow rate (AFR) and air velocity are directly linked to drift and, subsequently, to environmental contamination (Landers, 2012; Landers and Gil, 2006). Marucco et al. (2008) concluded that medium air velocity and VR generated better spray deposition results on peach trees than high air velocity and VR. In another study, Triloff et al. (2012) adapted the air stream to the canopy structure by altering the fan speed and forward speed, which results, in most cases, in reducing the deposition gradient between the surface and centre of the canopy, thus leading to more uniform spray deposition over the canopy width. Large reductions in volumetric AFR, based on accurate analysis, may substantially reduce spray drift from axial fan sprayers, without adversely affecting the overall spray deposits on the leaf surface (Cross et al., 2003). However, the mean relative amount of spray on the upper versus the lower leaf surface may change substantially. In general, low travel speed and high air output power improve air penetration (Svensson et al., 2003). García-Ramos et al. (2012) showed that high air velocities obtained with a dual-fan orchard sprayer caused vegetation movement to increase, enhancing the penetration and deposition of the sprayed product. However, detailed characterisation of the canopy and the accurate adjustment of all involved parameters are necessary for spray optimisation.

Here, we investigated how varying the volumetric air flow rate (AFR) and applied volume (VR) influences spray deposits and their distribution on leaves, spray coverage. The intention of this research was to determine the effect of air assistance and liquid volume rate on deposition (uniformity and penetration) in olive trees, trying to obtain an objective relationship between those fluids and canopy characteristics.

2. Materials and methods

2.1. Experimental plots and canopy characterisation

Two experiments were carried out in a commercial farm with the super-intensive cultivation of *Olea europaea* cv. Arbequina. The farm is located in Pedro Abad, Córdoba, Spain (37° 57′ 38.94″ N, 4° 27′ 57.04″ W). The trees were planted at a density of 1975 trees/ha with a between-row spacing of 3.75 m and a between-tree spacing of 1.35 m. The super-intensive olive tree crop system was chosen because of its geometric regularity compared to the considerable heterogeneity found in traditional olive groves. This phenomenon facilitates studying the homogeneity of spray deposits inside the tree crown. The size of the test field was 3350 m^2. Two rows of 110 trees and three rows of 45, 51, and 117 trees were selected for the VR and the AFR tests, respectively. All of the rows were separated by at least 5 intermediate rows to avoid contamination.

For canopy characterisation, the tree row volume (TRV; m^3 ha^{-1}) (Buyers et al., 1971; Sutton and Unrath, 1984, 1988) was determined by randomly selecting 64 trees from crop rows next to the experimental plots and measuring their maximum height, the distance from the soil