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Abstract

This paper reports the outcomes of a study dealing with the evaluation of the equipment used to spray plant protection products in olive groves. We performed experimental tests in an intensive olive orchard situated in the province of Reggio Calabria to determine under field conditions according to machine operating parameters 1) foliar deposition, from both quantitative and qualitative point of view, and 2) ground losses. Hence, we applied a solution of a food dye on olive trees as to simulate a plant protection product mechanical distribution. Spray quantitative analysis was determined according to the colorimetric method using a bench spectrophotometer, while, image analysis of water-sensitive paper allowed qualitative analysis. A significant effect of the trial conditions was found at the $p < .05$ level on both normalized foliar deposit D_n ($\mu\text{L}\cdot\text{cm}^{-2}$), [$F(2, 65) = 8.58, p = 0.0005119***$] as well as on ground losses [$F(2, 25) = 3.931, p = 0.00328*$].

Keywords
(separated by '-')

Foliar deposit - Ground loss - Olive growing - Plant protection product - Sustainability

Analysis of Spraying Equipment Performances in Olive Orchards



Souraya Benalia, Giuseppe Zimbalatti, Lorenzo M. M. Abenavoli, Antonio Fazari, and Bruno Bernardi

Abstract This paper reports the outcomes of a study dealing with the evaluation of the equipment used to spray plant protection products in olive groves. We performed experimental tests in an intensive olive orchard situated in the province of Reggio Calabria to determine under field conditions according to machine operating parameters 1) foliar deposition, from both quantitative and qualitative point of view, and 2) ground losses. Hence, we applied a solution of a food dye on olive trees as to simulate a plant protection product mechanical distribution. Spray quantitative analysis was determined according to the colorimetric method using a bench spectrophotometer, while, image analysis of water-sensitive paper allowed qualitative analysis. A significant effect of the trial conditions was found at the $p < .05$ level on both normalized foliar deposit D_n ($\mu\text{L}\cdot\text{cm}^{-2}$), [$F(2, 65) = 8.58$, $p = 0.0005119^{***}$] as well as on ground losses [$F(2, 25) = 3.931$, $p = 0.00328^*$].

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1 Introduction

The growing consciousness of consumers regarding health properties of olive products has manifested, in recent years, through an increase in the consumption of olives and olive oil even in those countries where their use was not usual until recent years. The International Olive Council (COI) has, in fact, estimated for the 2021/2022 campaign a consumption of more than 3.2 million tons of olive oil and 2.7 million tons for table olives, globally [1, 2]. This scenario undoubtedly offers great investment margins to meet market demand and guarantee requests both from quantitative and qualitative points of view. However, production fluctuations that olive and olive oil sector suffered in recent years, because of the effects of climatic trends on the spread

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25 of diseases and pests, engendered the intensification of crop protection interventions,
26 to guarantee profitable levels.

27 Crop protection represents a key intervention without which it would be difficult to
28 achieve production objectives. Although progress, strategies and tools have reached
29 a remarkable technological level, particularly regarding the formulations, it is quite
30 difficult to affirm the same concept regarding the implemented equipment for the
31 application of plant protection products. Indeed, most of the times, only a part of
32 the mixture containing the active substance can reach the target, while applying a
33 treatment. The remaining part is lost on the ground or due to drift with considerable
34 risks for the environment [3]. This low effectiveness of application is often due to
35 obsolete, malfunctioning or incorrectly calibrated and adjusted equipment.

36 Considering the Directive 2009/128/EC [4], it becomes clear that machines
37 used for the distribution of pesticides play a strategic role to guarantee treatment
38 effectiveness, operator safety and environmental preservation.

39 In this context, this work focuses on the evaluation of spraying equipment perfor-
40 mances in olive orchards. Particularly, quantitative and qualitative analysis of the
41 foliar deposit and losses on the ground were determined under filed conditions
42 according to machinery operating parameters.

43 2 Material and Methods

44 2.1 Field Description

45 Experimental trials were conducted in a private olive farm located in the province
46 of Reggio Calabria (38° 23'16.02 "N, 16° 4'19.31" E). Three tests were carried out
47 in three different plots of about 1,000 to 1,300 m², grown with *Olea europaea* L.
48 cv. 'Carolea' having a planting layout of mostly 6 m × 8 m. The following Table 1
49 shows the dimensional characteristics of the plants.

Table 1 Field and tree dimensional features

Planting layout (m)	Tree age (year)	Trunk height (m)	Canopy volume (m ³)	Tree height (m)	Branche number
6 × 8 / 6 × 4	30	1.3	78.5	5	3



Fig. 1 The sprayer used in experimental trials

2.2 Equipment Description

Experimental trials based on the application of a dye solution on olive trees were performed by using the DSM Turbo spray 1500, towed by a NEW HOLLAND 82–86 tractor (Fig. 1). The sprayer, which tank capacity is 1,500 L, is equipped with a centrifugal fan and n. 7 + 7 active nozzles with a ceramic plate having 1.5 mm hole.

2.3 Spray Distribution and Quantitation in the Field

As previously mentioned, a dye solution, particularly a tartrazine yellow (E102, 85%) solution at $10 \text{ g}\cdot\text{L}^{-1}$, was sprayed using the above-described sprayer in three different plots (Fig. 2), considering different configurations (Table 2), to assess spray distribution from both quantitative and qualitative point of view as performed in Benalia et al. [5].

Once the solution was applied, the samples were collected and stored individually in hermetic containers until subsequent analysis as performed by Bernardi et al. [6]. Particularly, olive tree leaves were collected to determine the foliar deposition, Petri dishes, previously placed between the rows, were used as collectors to determine losses on the ground and water sensitive paper, previously put into olive tree canopies were used for spray qualitative evaluation. Leaf sampling considered three vertical and two horizontal sections in the canopy as shown in Fig. 3.

Subsequently, we applied the colorimetric method to determine foliar deposit and losses on the ground. This included: 1) washing each sample with a known amount of demineralized water, 2) analyzing each recovered solution with the spectrophotometer to determine the concentration of tartrazine yellow in it, 3) determining the



Fig. 2 Tartrazine solution application in olive orchard for spray assessment

Table 2 Machinery characteristics implemented in field trials

	Trial 1	Trial 2	Trial 3
Engine speed (rpm)	1,800		
Power take-off (rpm)	540		
Nozzle number	14		
Advancing speed (km·h ⁻¹)	2.34	3.46	3.01
Exercise pressure (MPa)	1.5	1.3	1.5
Observed area (m ²)	1,124	1,008	1,296
Application rate (L·ha ⁻¹)	1,307.19	1,190.48	1,543.21

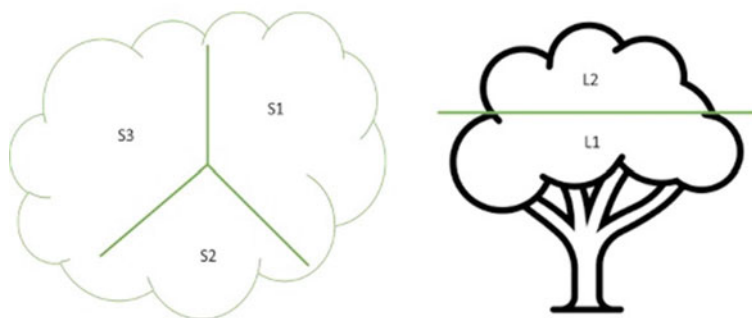


Fig. 3 Leaf sampling positions considered for the trial purposes

72 volume of the solution intercepted by each sample, 4) measuring sample area and
73 express the deposit in terms of $\mu\text{L}\cdot\text{cm}^{-2}$.

74 2.4 Data Analysis

75 Prior to data analysis, performed using the software R (version 3.3.1), spray foliar
76 deposit and losses on the ground values were first normalized to $1,000 \text{ L}\cdot\text{ha}^{-1}$
77 according to the following formula “Eq. (1)”:

$$78 \quad D_n = \frac{V_n}{V_d} \times D_{ef} \quad (1)$$

80 With

- 81 D_n : normalized deposit value ($\mu\text{L}\cdot\text{cm}^{-2}$);
- 82 V_n : normalized application rate equal to $1,000 \text{ L}\cdot\text{ha}^{-1}$;
- 83 V_d : application rate in field ($\text{L}\cdot\text{ha}^{-1}$);
- 84 D_{ef} : effective deposit value ($\mu\text{L}\cdot\text{cm}^{-2}$).

85 While, scanned images of water-sensitive papers were processed using ImageJ
86 1.45 s software with Java (1.6.0–20).

87 3 Results and Discussion

88 According to the considered operating conditions, the spray application rate was of
89 $1,307.19 \text{ L}\cdot\text{ha}^{-1}$ in trial 1; $1,190.48 \text{ L}\cdot\text{ha}^{-1}$ in trial 2; and $1,543.21 \text{ L}\cdot\text{ha}^{-1}$ in trial 3.

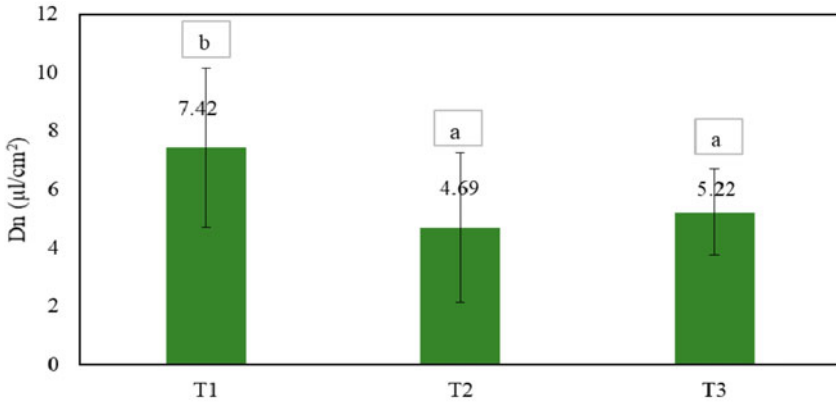
90 The determination of spray application rate depends on several factors such as,
91 crop features (species, layout, training, and vegetation characteristics), the biotic
92 agent to be controlled, the chemical to be used as well as climatic conditions. Appli-
93 cation rate recommended by Calabrian authorities [7] when applying a plant protec-
94 tion product in olive growing is $1,200 \text{ L}\cdot\text{ha}^{-1}$, with maximum values not exceeding
95 $1,500 \text{ L}\cdot\text{ha}^{-1}$. Such amounts of plant protection products aim at ensuring a high
96 biological efficacy, however, they also engender huge product loss [8].

97 Application rate slightly exceeded the maximum threshold in trial 3, while oper-
98 ating parameters considered in trial 2 enabled to keep it around the advised one.
99 Godoy-Nieto et al. [9] applied similar spraying volumes in conventional olive
100 orchard, while in intensive orchards; the application rate was slightly lower.

101 Normalized foliar deposit (D_n) values, expressed as $\mu\text{L}\cdot\text{cm}^{-2}$, were statistically
102 analysed by performing a two-way analysis of variance. A significant effect of trial
103 conditions was found at the $p < 0.05$ level [$F(2, 65) = 8.58, p = 0.0005119***$].
104 However, no effect due to leaf sampling height was encountered in all trials (Table
105 3). Figure 4 (Fig. 4) shows normalized foliar deposit mean values. These values

Table 3 Results of a two-way analysis of variance applied on normalized foliar deposit results

	Sum Sq	Df	F value	Pr(>F)
Trial	96.04	2	8.5838	0.0005119 ***
Leaf sampling height (LSH)	1.95	1	0.3485	0.5571032
Trial * LSH	4.85	2	0.4336	0.6501512
Residuals	346.85	62		

**Fig. 4** Normalized foliar deposit mean values in the performed trials

106 are higher than those obtained by Godoy-Nieto et al. [9] are, in intensive olive
 107 orchards. The coefficient of variation (CV) was equal to 45.32%, 59.02%, and 41.63%
 108 respectively in trials 1, 2, and 3.

109 From qualitative point of view, spray distribution parameters, obtained through
 110 image analyses of water sensitive paper, reveal a very heterogeneous distribution,
 111 considering the number of spots (impacts) per unit area, which varied from 168 up
 112 to 1,987, as well as the percentage of area covered with spots, which ranged between
 113 34% and 52.5%. These parameters were very different between trials and within each
 114 trial (Fig. 5).

115 Trials conditions also had a significant effect on the losses on the ground at the
 116 $p < 0.05$ level [$F(2, 25) = 3.931$, $p = 0.00328^*$]. Figure 6 reports losses on the
 117 ground mean values. They amounted to 39.25% in trial 1, 15% in trial 2 and 22% in
 118 trial 3.

Fig. 5 Water sensitive paper obtained in trial 2 used for spray qualitative analysis

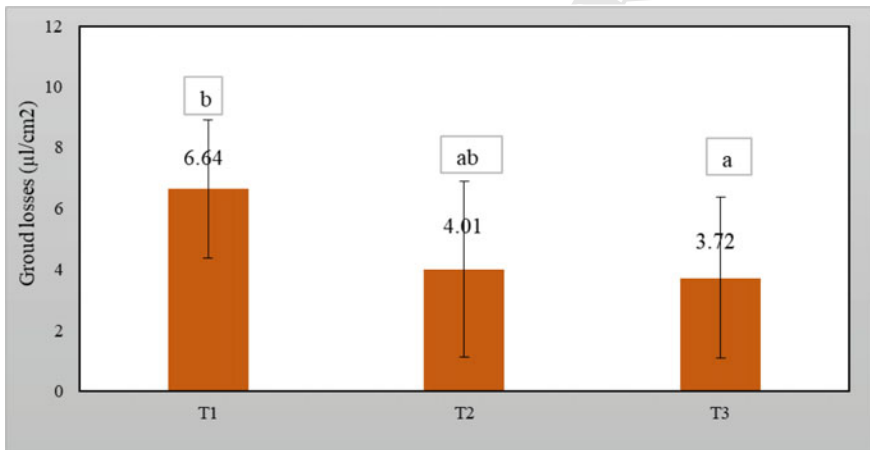
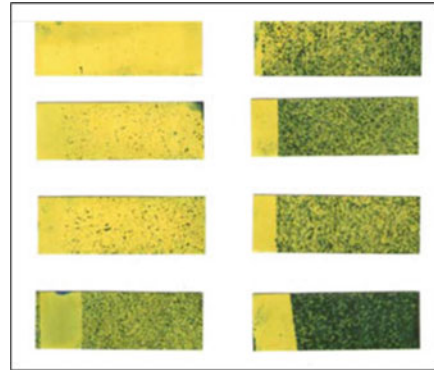


Fig. 6 Normalized losses on the ground mean values in the performed trials

4 Conclusions

According to the obtained results, we can state that spray vertical distribution was quite homogeneous, as we did not register any significant difference according to foliar sampling height.

Spray application rate and consequent foliar deposit, as well as losses on the ground were higher than those obtained in other studies were. In addition, qualitative evaluation of the spray suggests performing PPP application considering equipment adjustments according to crop features and operating conditions.

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