Crop Protection 91 (2017) 34–48

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Foliar spray deposition in a “tendone” vineyard as affected by airflow rate, volume rate and vegetative development

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ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form
8 September 2016
Accepted 11 September 2016

Keywords:
Air-assisted sprayer
“Tendone” trained vineyard
Sprayer calibration
Plant protection products
Pesticide application
Crop protection

ABSTRACT

The objective of this study was the evaluation of the effect of airflow rate and volume rate on foliar spray deposition in a “tendone” vineyard using an air-assisted sprayer with two counter-rotating fans and anterior intake. Experimental tests were carried out considering two airflow rates (2.43 and 5.71 $m^3 s^{-1}$), two volume rates (335 and 625 L ha^{-1}) and keeping the forward speed constant (1.1 m s^{-1}). To take into account the effect of vegetative development of the vineyard, experiments were replicated in two phenological stages (full flowering and berry touch), characterised by different Leaf Area Indices (2.21 and 5.83). The sprayer was calibrated using a patternator purposely designed for “tendone” vineyards, assuming the vineyard Leaf Area Index (LAI) pattern as a reference.

Sprayer calibration was accomplished achieving a close correlation between LAI pattern and the quantity of liquid intercepted by the patternator (coefficients of linear correlation ranged from 0.95 to 0.99, all significant at $p < 0.05$). Measurements on vines showed that volume rate did not affect foliar spray deposition at either phenological stage, whereas airflow rate had an opposite effect at the two phenological stages. At full flowering, the increase in airflow rate produced a significant decrease in foliar deposit (from 0.986 to 0.693 μL cm^{-2} on the most exposed vegetation, −30%); on the contrary, at the berry touch growth stage the increase in airflow rate produced a significant increase in foliar deposits (from 0.339 to 0.484 μL cm^{-2}, +43%).

1. Introduction

Apulia, having a cultivated land of over 32,000 ha (hectares), is the main region of Southern Italy for table grape production, accounting for 61% of the total Italian production (ISTAT, 2012). In Apulia, the typical vine training system used for table grapes is the “pergolato” or “tendone” with a standard vine spacing of 2.5 m × 2.5 m, giving a density of 1600 vines ha^{-1}. This form of vine training is suitable for the sunny climatic conditions of the south of Italy: it maximises the exploitation of solar radiation, shades the grape bunches from excessive insolation, protects the grape bunches from excessive humidity, and therefore ensures their long preservation on the plant.

The main feature of the “tendone” system is the canopy location, arranged on an unbroken horizontal plane sustained by a trellis system: a high stake at each vine with two orthogonal steel wires fixed 1.7–1.8 m above ground level and a grid of steel wires to hold up the shoots. The canopy density is not homogeneous due to different elements such as agronomic practices, grape variety, pruning system, climatic conditions.

The wire grid individualises an ideal boundary between two layers: the upper layer, reserved solely for the canopy, and the lower layer, where the bunches extend for all or part of the width of the inter-row. In some vineyards (double-grid “tendone”), an extra horizontal grid of steel wires splits in turn the canopy pertinent to the upper layer into a higher level that sustains the growing shoots and a lower level that sustains the fruit-bearing shoots and the grape bunches.

Conventional air-assisted sprayers fitted with an axial-flow fan and an arc-shaped spray boom, or pneumatic sprayers equipped with a centrifugal fan and air shear nozzles, producing an airflow through fixed or adjustable diffusers along an arc of 180°, are the most employed machines for Plant Protection Product (PPP) applications in Apulian “tendone” vineyards. Pneumatic electrostatic

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http://dx.doi.org/10.1016/j.cropro.2016.09.009
0261-2194/

sprayers are also used for targeted treatments commonly carried out for the application of biostimulants of bunches growth (Pascuzzi and Cerruto, 2015a, 2015b).

The efficacy of PPPs depends on many factors: dose of active ingredient, magnitude of deposits, number of deposits and mean deposit on the leaf surface are very important elements for successful control of diseases (Siegfried et al., 2007). Deposition quantity and quality may be improved by using adjuvants, but their concentrations must match application volumes on the spray target to achieve maximum spray deposition (Van Zyl et al., 2010). The spray application technique also affects spray deposition: as an example, Dekeyser et al. (2014) report that sprayer design causes major differences in spray distribution and off-target losses and Wise et al. (2010) report that water volumes do not affect the total deposition, but only the percent surface coverage. Finally, efficacy is also affected by other crop-related factors, such as growth stage and spatial distribution of the canopy.

Therefore, with the aim of increasing the efficiency of PPP applications, sprayer setting must be adjusted in agreement with crop growth stage (Salyani and Serdynski, 1993; Cross et al., 2001a, 2001b; Balsari et al., 2008; Wachowiak and Kierzek, 2009), pesticide formulation (Balsari et al., 2007) and with the peculiar morphological features and canopy patterns of the vineyard (Walklate et al., 2002; Solanelles et al., 2006; Gil et al., 2007; Siegfried et al., 2007; Brown et al., 2008; Llorens et al., 2010; Duga et al., 2015). Moreover, the sprayer must be used correctly by properly choosing the operative parameters such as forward speed, airflow rate, and volume rate.

The appropriate choice of the operative parameters is particularly important for “tendone” vineyards. In fact, unlike other crops such as hedgerow vineyards, “tendone” is a very specific training system that requires particular carefulness as (a) the canopy is developed on a horizontal plane, PPPs are applied exclusively from the bottom and then only the lower side of the canopy is directly exposed to the spray (Cerruto et al., 2008); (b) the canopy is subdivided into two specialised layers: upper layer with only leaves and lower layer with only fruits; (c) the grapes may be located only in some areas of the lower layer, requiring the adjustment of the sprayer setting when targeted treatments are necessary; (d) being the production mainly destined for the fresh market, the aesthetic appearance of the grapes must be preserved by choosing the nozzles properly (Pascuzzi, 2013).

Forward speed affects working capacity and its influence on the success of PPP applications has been widely discussed in many publications with the main goal of assessing its effects on spray penetration into the canopy, mean foliar deposition, spray drift and uniformity of deposition (Salyani and Withney, 1990; Pergher, 2006; Cerruto, 2007a; Salyani et al., 2013). The most common result is that, even if interaction with airflow rate must be considered, increasing forward speed also increases the variability in foliar spray deposition into the crop, without significant effect on mean deposits. Trials carried out in Sicilian “tendone” vineyards (Cerruto et al., 2008) with velocities in the range 1.1–1.6 m s^{-1}, the forward speeds commonly adopted in field in this type of vineyard, did not highlight any significant variation in the mean foliar spray deposition, but the results were affected by vegetative development, so requiring further investigations.

The advantages of air support for orchard spraying are unquestioned (Pergher and Gubiani, 1995; Pezzi and Rondelli, 2000; Cross et al., 2003; Salyani and Farooq, 2003; Pergher, 2006; Cerruto, 2007a, 2007b; Pergher and Petris, 2008; Marucco et al., 2008). The forced air jet conveys the spray droplets throughout the target, stirring the leaves and allowing a better coverage of the plant surface, including the underside of leaves. Several authors have analysed the outcomes of the airflow rate on the foliar spray deposition in hedgerow vineyards (Casarsa or spurred cordon systems), highlighting lower deposition levels with the increase in the airflow (Pergher and Gubiani, 1995; Pezzi and Rondelli, 2000; Pergher, 2006; Cerruto, 2007b). Conversely, increasing the airflow rate from 4.1 to 11.3 m^3 s^{-1} did not affect the variability of deposits on leaf surface on different size apple trees (Cross et al., 2003), whereas comparable foliar spray deposition with lower and higher airflow rates in most canopy locations was pointed out by tests on citrus groves (Salyani and Farooq, 2003). Trials carried out in Sicilian and Apulian “tendone” vineyards, employing similar sprayers with adjustable diffusers, showed no statistically significant differences in mean foliar spray deposition when the airflow rate was increased in the range 1.81–2.14 m^3 s^{-1} (trials in Sicily, Cerruto et al., 2008) or in the range 1.68–2.73 m^3 s^{-1} (trials in Apulia, Pascuzzi, 2013).

Several mathematical models are reported in literature to determine the optimal volume rate, key point to obtain the best results during the spraying process (Gil and Planas, 2003; Furness and Thompson, 2008; Gil et al., 2014). Trials carried out in hedgerow vineyards pointed out lower foliar spray deposition and greater ground losses increasing the volume rate, particularly at full foliage development (Pergher and Gubiani, 1995). On the other hand, other tests executed at full foliage development in the same type of vines applying volume rates in the range 154–432 L ha^{-1}, did not highlight any significant influence of the volume rate on the mean foliar spray deposition (Cerruto, 2007b).

The objective of this study was to evaluate the effect of airflow rate, volume rate and vegetative development on foliar spray deposition in an Apulian “tendone” vineyard using a towed double-fan air-assisted sprayer.

2. Materials and methods

2.1. Aim of the experimental tests

Protection of Apulian “tendone” vineyards for table grape production requires about 30 treatments over a period of eight months, from the end of April to the end of November, using volume rates in the range 500–1000 L ha^{-1}. Lower volume rates are sprayed in early phenological stages, when the foliage is yet to develop fully, and also in later phenological stages, when the bunches of grapes are present and it is necessary to preserve their aesthetic appearance, preventing any dirtying. In a previous study on a double-grid “tendone” using an air assisted sprayer with adjustable diffusers (Pascuzzi, 2013), two airflow rates (1.68 and 2.73 m^3 s^{-1}) were tested at end of flowering and berry touch phenological stages. The higher airflow rate provided higher deposits in berry touch phenological stage, thus encouraging to test further higher airflow rates at full foliage development.

According to the objective of the research, which is to evaluate the effect of airflow rate, volume rate and vegetative development on foliar deposits, spraying tests were carried out with two airflow rates (the rated airflow rate provided by the two fans of the sprayer in standard conditions and an airflow rate reduced by 50%), two volume rates (a standard volume rate of about 600 L ha^{-1} and another reduced by 50%, thus always ensuring the integrity of grapes) and in two phenological stages characterised by different LAIs. The chosen phenological stages were PS_1 = full flowering, code 23 of the BBCH - Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie - scale (Eichhorn, 1984), and PS_2 = berry touch, code 34 of the BBCH scale. Forward speed was kept unchanged over all the tests ($v = 1.1$ m s^{-1}), because operators always seek to maximise the labour capacity adopting the maximum speed allowed by the environmental conditions (around 1.0–1.5 m s^{-1} for PPP applications in “tendone” vineyards).