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Spray deposition in "tendone" vineyards when using a pneumatic electrostatic sprayer

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ABSTRACT

The objective of this study was to evaluate the effect of electrostatic charge on foliar spray deposition in an Apulian "tendone" vineyard using an innovative pneumatic electrostatic sprayer. The sprayer was fitted with nozzles that linked the pneumatic atomization of the liquid, obtained using compressed air, to the electrostatic induction charge, thereby producing a stream of charged fine droplets. Furthermore, the sprayer was designed for low volume treatments, and the experimentation was carried out during a phenological stage with high leaf density to evaluate the performance of the machine under particularly challenging operative conditions.

The sprayer was studied at three forward speeds (4, 5, and 6 km h^{-1}), and gave poor deposition inside the canopy, whether or not the electrostatic system was activated. Forward speed did not significantly affect the mean foliar spray deposition, whereas activation of the electrostatic system significantly increased the deposit only on the layer of foliage nearest to the sprayer (lower layer), but had no effect on deposition on the layer of foliage inside the canopy (upper layer). The ratio between the deposits on the two layers (lower:upper) was 6.5:1 when the electrostatic system was switched off, and 9.0:1 when it was switched on.

However, this behaviour may allow targeted treatments on grapes, such as with Plant Protection Products (PPP) or bio growth stimulants. Furthermore, the small droplets produced by the machine are suitable for table grape protection because the droplets do not mark the grapes, which would reduce the quality of the product and its commercial value.

1. Introduction

Apulia (Southern Italy) is Italy's leading region for table grape production, with a yield of about 6.5×10^8 kg accounting for 61% of the total Italian production (ISTAT, 2012). In Apulia, the most common vine training system used for table grapes is the "pergolato" or "tendone", an overhead canopy supported by a trellis system. The trellis consists of a high stake at each vine with two orthogonal steel wires attached 1.7–1.8 m above ground level, and a grid of steel wires supporting the shoots. The standard vine spacing is 2.5 m × 2.5 m, giving a density of 1600 vines ha^{-1}; each vine has a 1.2–1.4 m high trunk, with two branches and two fruit-bearing shoots per branch, aligned orthogonally or parallel on the grid.

The wire grid partitions the canopy into two areas: the upper area is exclusively for the foliage canopy, and the lower area is for the bunches, distributed on all or part of the width of the inter-row. A further horizontal grid of steel wires divides the foliage canopy in the upper area into two layers (double-grid "tendone"): the higher layer supports the growing shoots and the lower layer supports the fruit-bearing shoots.

Only the lower side of the canopy is directly exposed to the spray during application of Plant Protection Products (PPPs), whose action is affected by the spatial distribution of the canopy (in terms of height, depth, leaf density, discontinuity along the rows) and of the grape bunches (Cerruto et al., 2008).

The sprayers generally used for PPP applications in Apulian "tendone" vineyards are conventional air-assisted sprayers with an arc-shaped spray boom and an axial-flow fan, or pneumatic sprayers with air shear nozzles and a centrifugal fan producing an airflow through fixed or adjustable diffusers along an arc of 180°.

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These machines must be adjusted correctly to avoid non-uniform deposition, over dosage, off-target spray and environmental pollution, such as drift and run-off (Pascuzzi, 2013).

There have been various proposals for improvement, innovation, differentiation and specialization regarding the sprayers used in this type of vineyard, according to the characteristics of the "tendone" training system and of the product destined for the fresh market. Further stimuli to innovation arise from the European Regulations concerning sustainable use of pesticides (Directive 2009/128/EC) and, with the progressive introduction of seedless cultivars, from the monitoring of the physiological processes of grapevines: sustainable use of synthetic pesticides, reduction of doses and volumes per hectare, use of microbial antagonists, distribution of bio stimulants of plant growth, etc.

These numerous factors require new sprayer designs and uses, able to link effective improvement of the traditional qualitative parameters (improvements in uniformity of distribution, recovery, coverage, etc.) to localized distribution of bio stimulants (e.g. cyanamide, gibberellic acid, etc.) or microbial antagonists without compromising efficacy.

Air-assisted electrostatic sprayers may meet these needs by improving the overall deposition and distribution on the foliage canopy and reducing spray drift (Machowski and Balachandran, 1997; Esehaghbeygi et al., 2010), because electrostatic force fields guide and govern the trajectories of charged spray droplets, although not necessarily in the way desired (Maski and Durairaj, 2010). Other studies report that electrostatic charging of spray droplets may also provide better deposition on the undersides of leaves (Western et al., 1994; Wolf et al., 1996).

Despite substantial research in this area, the use of charged agricultural sprays is still very limited, although electrostatic spraying is commonly used in industrial applications, in which a charged cloud of droplets is sprayed towards an earthed substrate and deposited on it. However, the characteristics of agricultural electrostatic sprayers are very different from those used in industry, because agricultural sprays must charge droplets of conductive liquids and then propel them deep into three-dimensional canopies. Furthermore, it is necessary to consider the safety hazards to untrained farm-workers using mobile systems for outdoor applications.

The most widely used method for charging agricultural sprays is induction charging, in which a positively charged electrode is positioned near to where the spray conductive liquid is emitted from a nozzle. The water-based PPP spray at earth potential, because of the attraction of electrons, receives a negative charge induced on the surface of the droplets and this charge is retained on them. The level of charge induced per unit area of surface is proportional to the voltage applied to the electrode (Matthews, 1989).

The amount of electrostatic charge carried by the droplets affects the action of the charged spray. The chargeability of the droplets, i.e. their capability to acquire charge, is evaluated in terms of the amount of electrostatic charge per unit mass of the droplet, known as the Charge-to-Mass Ratio (CMR). The CMR defines the relative ability of the electrical forces to overcome the forces of gravity and the kinetic energy imparted to the droplets, and then makes it possible to predict the behaviour of a charged particle exposed to inertial, electrical and gravitational forces (Toljic et al., 2008; Maski and Durairaj, 2010). A high CMR is usually required for air-assisted induction-charged PPP spraying to guide droplet trajectory and thereby increase underside leaf deposition (Zhao et al., 2008). On the other hand, the charge that can be retained by each droplet surface, and therefore the CMR, is restricted by the known Rayleigh limit, beyond which the droplet disintegrates because the charge is so high that the inward stress due to surface tension cannot balance the outward stress due to the electric field. The CMR_{max} levels corresponding to the Rayleigh charge limit are plotted in Fig. 1 for droplets with a diameter ranging from 20 to 100 μm, and for several surface tension values γ_l ranging downward from that of water (Cross, 1987; Law, 1978).

As known, droplet motion from the nozzle to the target is dominated by the drag force $\vec{F}_d$ created by the surrounding air, the electromotive force $\vec{F}_e$ caused by the electrostatic field, and the gravity body force $\vec{F}_g$ (Colbert and Cairncross, 2005). The electrostatic force is the most important force for the spray motion. However, a large number of droplets with the same polarity repulse each other and form a rapidly growing spray cloud; this cloud then creates its own electrical field, which affects the trajectory of each droplet (Matthews, 1989).

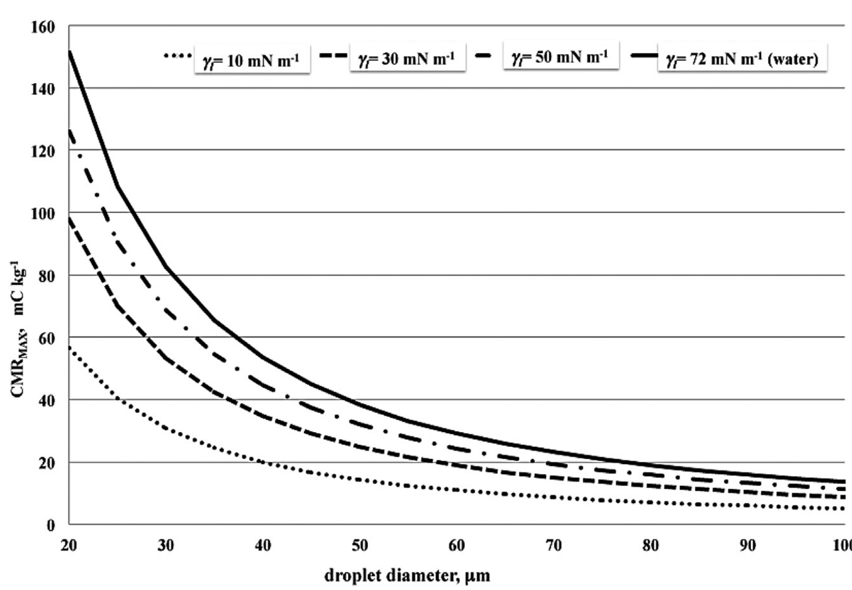

Fig. 1. CMR_{max} corresponding to the Rayleigh limit for several values of surface tension γ_l.