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Researches regarding the reduction of pesticide soil pollution in vineyards

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ABSTRACT

Phytosanitary treatments with pesticides are widely used for pest and disease control in vineyards. When performing the treatment an important part of the dispersed pesticide falls on the ground, affecting the microorganism and fauna, producing quantitative and qualitative changes in both the structure of the edaphic population and in its physiological activities. In order to diminish soil pollution experimental field tests concerning pest and disease control in vineyard were performed, using a spraying machine provided with an equipment which aims to recycle the pesticide liquid that is not retained by the vine foliar system. The equipment was built up based on a commercial TARAL 200 PITON TURBO air-assisted sprayer, used for pest and disease control in vineyards and orchards and was equipped with two recycling panels, placed on each side of the vine row. CFD simulations were used in order to optimize the dimensions, geometry and position of the recycling panels.

The experiments were performed for different vegetation stages, forward speeds and operating pressures; for the first vegetation phase (bud opening), the pesticide recycled volume reached 45% of the total applied volume; in phases VI and VII the recycling rate was lower than 25%.

For the vegetation phase V and for the forward speeds and operating pressures taken into account the quality of the treatment was evaluated using the mean foliar deposit. The results obtained by the means of ImageJ processing software indicated an adequate operating process of the spraying equipment; the values of this index were ranged between 21.4% and 36.2% for the upper side of the leaves and between 18.6% and 29.7% for the lower side of the leaves. The best indices were attained for low forward speed and an operating pressure of 0.6 MPa.

1. Introduction

Pest and disease control is determinant in maintaining the wealth of the vineyards and obtaining high production levels and a good quality of the harvest. Production losses due to pests and diseases can reach up to 35% and, in some cases, the entire production can be compromised. In the meantime the direct and indirect energy consumption for pest and disease control can reach 28–35% of the total yearly energy consumption. It is for theses reasons that the machinery and equipments used for pest and disease control are continuously improved, aiming to raise the efficiency of the treatments and to decrease the quantity of pesticide per surface unit.

The repeated application of pesticide treatments (7–10 during one production cycle) has a negative impact on the environment and especially on the soil (Arias-Estévez et al., 2008). Pesticide treatments endanger the beneficial species that feed on insects, may induce genetic mutations of insects and fungus, making them resistant to pesticide action, destroy the edaphic fauna and microorganism that

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play a key role in incorporating the organic matter into soil, produce water pollution, followed by an exaggerated growth of algae, which finally suffocate the life forms from the ecosystem. These negative effects are amplified by the fact that many pesticides are persistent pollutants, some of them with prominent human and animal toxicity; therefore, some pesticides have been banned (DDT, HCH, Aldrin, Dieldrin) (Malschi, 2009). At the same time the use of pesticides increases the resistance of pathogenic agents and pests, imposing the use of higher doses or their substitution with new and sometimes, highly toxic products.

Soil pollution with pesticides was increased by the advance of industrialized agriculture due to the scientific and technical achievements of modern society. Consequently, new technological solutions are constantly searched in order to prevent the environment (air, water, soil) pollution. The challenge that our society is facing today is to produce more without affecting the environment.

Under these circumstances the pesticides must be applied exactly on target, in the right amount and with the correct pressure (Ros and Gheres, 2008). But despite the technological advancements, a significant part of the dispersed liquid does not reach the canopy and falls on ground (Viret et al., 2003); up to 30...50% of the applied substance falls on the ground or is lost into the atmosphere (Van den Berg et al., 1999; Gil and Sinfort, 2005; Gil et al., 2007). Although pesticide loss and spray drift were the subject of numerous studies, they continue to be a major problem when referring to pest and disease control in vineyards (Fox et al., 1998; Molari et al., 2005; Baldoin et al., 2008). Spray drift is considered to represent one of the major causes for soil pollution (Yates et al., 1976; Farooq et al., 2001; Gil and Sinfort, 2005; Gil et al., 2007), these losses being accounted to represent up to 10% of the total applied volume.

Soil pollution may be diminished using technically advanced equipments that reduce the consumption of chemical substances to the minimum amount needed to perform pest and disease control (Delele et al., 2007). In the last 30–40 years the spraying machines were equipped with different implements in order to reduce the losses of toxic substance:

- Over-the-row (wrap-around) tunnel sprayers with spray booms and recovery shields (Shanks et al., 1972; Doruchowski and Holownicki, 2000). Different types of implements, based on the hydraulic spraying principle, were studied (Siegfried and Raisigl, 1991; Siegfried and Holliger, 1996; Pergher et al., 2013). The experimental results led to the conclusion that air assisted sprayers represent a better alternative (Randall, 1971; Hale, 1978; Brazee et al., 1981; Pezzi and Rondelli, 2000; Gil and Sinfort, 2005) as the equipments based on the hydraulic spraying principle are not always efficient (Ade and Pezzi, 2001; Molari et al., 2005).
- Air assisted tunnel sprayers, which prove to be more efficient in diminishing soil pollution. The use of tangential fans on both sides of the vine row led to a better penetration and a more favorable deposition of droplets on the back side of the leaves (Bera, 1984). This solution diminished soil pollution with pesticides by 5–15% (Ade et al., 2005).
- Implementation of target detection systems, which trigger spraying only when the vine canopy is detected, reducing pesticide consumption by 30% and drift by 50% (Ozkan et al., 1997; Doruchowski and Holownicki, 2000; Rautman, 2002; Porras et al., 2005).

The latest researches regarding pest and disease control take into account the use of air induction nozzles and centrifugal fans; systems based on precision agriculture and on recycling spraying tunnels were also developed (Ipach, 1999). The use of recycling spraying tunnels, which recover the droplets that penetrate the canopy, diminishes the consumption of toxic substances (Siegfried and Holliger, 1996; Doruchowski and Holownicki, 2000; Pergher et al., 2013), although some authors consider that their popularity is impeded by the difficulty in adjusting them to the plentiful array of training forms (Celen et al., 2009). The recycling rate is affected by the vegetation phase, the highest rates (50–70%) being achieved in the early stages. The lowest rates (15–30%) are achieved in the last vegetation phase (Siegfried and Holliger, 1996; Doruchowski and Holownicki, 2000; Pergher et al., 2013).

In the above-mentioned context the paper presents the experimental researches performed in order to find technical solutions for reducing soil pollution using the pesticide recycling principle when performing pest and disease control treatments in vineyards. The tests were performed for different vegetation stages of the vineyard plantation with an equipment that recovers the liquid not retained by the canopy. CFD modeling was used in order to optimize the experimental equipment; the ImageJ image processing software was used in order to evaluate the droplets distribution on the leaf surface and the quality of the spraying process.

2. Materials and methods

2.1. *Equipment*

A pesticide recycling equipment, based on the principle of recovering the liquid pesticide that was not retained into the vineyard canopy, was designed and built. The equipment was built up based on a commercial TARAL 200 PITON TURBO air-assisted sprayer, used for pest and disease control in vineyards and orchards. The sprayer is equipped with an axial fan which generates the air current needed to agitate the leaves of the canopy, thus enabling the deposition of liquid pesticide on both sides of the leaves. The main characteristics of the spraying equipment are:

- Capacity of the liquid tank: 200 L;
- Fan air flow rate: 7920 m^3/h;
- Maximum pump flow rate: 55 L/min;
- Maximum operating pressure: 4.0 MPa;

The machine is equipped with two half-booms, each with 4 spraying nozzles (type AMT 1.2-ALBUZ).

The designed recycling equipment (Fig. 1) consists of a metal frame, mounted on the frame of the spraying machine; two recycling panels (12, 13) are mounted on articulated sub-frames. The vertical recycling panels can be mounted at different distances from the longitudinal axis of the machine (d = 1300, 1500, 1700, 1900 and 2100 mm) and at different heights above the ground (h = 300, 400, 500, 600 and 700 mm).

The recycling panels have a concave shape, are made from polycarbonate and are placed, when in operation, aside two vine rows (19, 20). The panels recover the liquid that was not deposited into the canopy; the recovered liquid flows into the bottom collectors of the panels (10, 11) and then is transferred into the graduated cylinders (17, 18) by the means of two electric pumps. The graduated cylinders measure the amount of collected liquid, allowing the calculation of the recycling rate. In transport position the recycling panels are placed behind the spraying equipment, parallel with the machine axis.

In order to measure the liquid flow rate toward the nozzles two flow meters (6, 7) were inserted on the hydraulic circuits of the booms.

2.2. *Mathematical model*

The recycling rate depends on the dimensions and geometry of the recovery panels. CFD simulations with ANSYS (FLUENT and GAMBIT, running on a TYAN graphic station – 2XCPU – Intel Xeon 3.33 GHz; RAM—16 GB DDR3 2600) were performed in order to optimize the dimensions and geometry of the panels. The CFD simulations of the liquid flow were based on a series of laboratory tests, aiming to establish the velocity pro-

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