Study of a “Self-calibrating” Sprayer for Pesticide Application in Vineyard

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Abstract
With the aim to facilitate the correct adjustment of the sprayer according to the features of the vine canopy (size, density, growth stage, etc.) a sprayer prototype, fitted with an electronic equipment able to automatically adjust the spraying parameters according to the features of the vineyard to be treated, has been developed at DEIAFA – University of Turin. Information about the parameters of each vineyard to be sprayed are recorded in a transponder, fixed on the ground, in a predetermined position at the border of the field; the sprayer is able to acquire these information via a receiver mounted under the shaft, elaborate them by the central unit and, according to the forward speed selected by the operator, is able to adjust the number of active nozzles, the operating pressure, the amount of air flow and its direction. A first set of experimental trials aimed at verifying the performance of the sprayer prototype have pointed out its suitability according to the different canopy shapes and sizes.

INTRODUCTION
An accurate calibration of sprayers is essential to optimise pesticide product effects and to reduce the environmental damage related to this operation. The spray jet and the volume of liquid and air applied shall be adequate to the morphological characteristics of the vineyard/orchard (i.e. layout, canopy size and density, number of leaf layers) and to the growth stage (Schmidt and Koch, 1995; Holownicki et al., 2000; Walklate et al., 2000; Pergher et al., 2002). Especially in the Mediterranean countries, where a wide variety of training systems is present, the sprayer calibration should be frequently adjusted according to the features of the plant target. Unfortunately this operation is often neglected by farmers, who generally prefer to set up their sprayer with the same configuration for the whole farm. In most cases, the only regulation is the opening/closing of one-two nozzles in function of the plant growth stage.

This choice has however negative consequences both on the quality of spray distribution on the target and on the incidence of spray losses. Drift and ground losses are in fact emphasised by the not proper calibration of the sprayer according to the features of the plant rows. Environmental risks related to pesticide application are therefore increased.

Also during the activity of inspection of sprayers in use, in most of European countries, very few time is dedicated to teach farmers about the optimised calibration of their sprayers (Balsari et al., 2004; Bjugstad et al., 2004). The sensibility of farmers with respect to sprayer calibration and adjustment is therefore poor.

With the purpose to facilitate the adjustment procedures for orchard/vineyard sprayers by means of electronic systems provided with the machines, a prototype has been developed at DEIAFA – University of Turin, with the support of ENAMA (National Board for Agricultural Mechanisation).
MATERIALS AND METHODS

The prototype has been developed on the basis of a conventional trailed air-assisted sprayer for orchard and vineyard (Unigreen T10, Fig. 1), featured by a 1000 l polyethylene main tank and by an axial fan of 700 mm in diameter.

Thanks to triple nozzle holders, the machine is equipped with three sets of hollow cone nozzles (Albuz ATR) featured by different size: for each sprayer side 6+6 nozzles are positioned in correspondence of the air outlet (Fig. 2a). The activation of each single nozzle is managed via motorised valves (6 for each side of the machine, Fig. 2b) in order to obtain different spraying configurations. This allows to adequate the spray pattern to the canopy profile. The system indicates on the display of the central unit which nozzle size is to be set (the operator shall verify if the nozzles indicated are in the working position and eventually turn them manually).

With the purpose to keep the applied volume per surface unit constant, independently of the forward speed adopted, a 3 way motorised valve has been mounted in the hydraulic circuit. This latter valve is managed by one pressure sensor, positioned above the regulation system in the hydraulic circuit, and by some controls able to verify the entity (at least ± 3%) and time (at least 10 seconds) of pressure variations, so to activate the valve just when necessary.

The fan is fitted with a 2 speed gear-box electronically managed. Fan rotation speeds corresponding to the two gears are 1890 rev/min and 2160 rev/min respectively. An adjustable diaphragm mounted on a frame in front of the fan suction area allows to adjust the air flow rate according to the density and to the growth stage of the vine rows. Thanks to a piston electronically controlled the diameter of the air suction area can be continuously calibrated from 500 to 700 mm (Fig. 3a).

A couple of air deflectors are mounted on the top of the air outlet enable to calibrate the wideness of the air stream generated by the fan (Fig. 3b). Their automatic movement is guaranteed by a piston electronically controlled.

To allow the sprayer to recognise the features of the vineyard/orchard to be treated, transponders (100 ÷ 500 bytes capacity, loaded with a calendar and the information related to its specific vegetation parameters in the different growth stages) have been used (Fig. 4a). Main information stored in the transponders are: plants layout, training system, canopy height, LAI and number of leaf layers.

The transponder has to be placed on a support at the border of the field. On the sprayer, under the frame holding the main tank, a receiver is able to acquire the data loaded in the transponders (Fig. 4b). The sprayer has to pass close to the transponder, whose maximum transmitting distance is about 1 meter, for acquiring the information. The acquisition time is about 100 seconds. Then the data acquired are processed by the central unit present on the sprayer in order to identify the most suitable set-up for the specific situation. This is achieved using algorithms taking in account also the day of the application. Once this adjustment is defined, the corresponding operating parameters (nozzles size, number of active nozzles, operating pressure, air flow rate, wideness of the air stream) are selected sending the necessary information to the actuators mentioned above (Fig. 5).

Tests aimed at assessing the vertical spray patterns obtained according to the different nozzle configurations achievable using the prototype were carried out by means of a vertical test bench provided with trays (Fig. 6) and sliding on a motorised rail at a forward speed of 0.5 m/s. The test bench was positioned at a distance of 1.6 m from the
centre of the sprayer, in order to simulate an inter-row distance of 3.2 m. For each test, 6 passes of the test bench in front of the spray jet were carried out. All tests were made using ATR brown nozzles at an operating pressure of 0.10 MPa, working with the fan suction area completely open (700 mm diameter) and with the slow fan rotation speed (1890 rev/min) set up.

Tests according to ISO 9898 methodology were made to assess the amount of the air flow rate obtained according to the speed rotation of the fan and according to the diameter of the suction fan area selected.

RESULTS AND DISCUSSION

The vertical spray patterns obtained with the prototype according to the number of active nozzles allowed to match different canopy profiles resulting from the combinations of vine training systems and growth stages (Fig. 7÷10).

In the early growth stages (e.g. flowering) the use of two nozzles for the Casarsa training system resulted sufficient to match the canopy profile (Fig. 7). Three active nozzles resulted necessary to join the profile of Guyot trained vineyard at the end of flowering growth stage (Fig. 8).

In the late growth stages (e.g. majority of berries touching) three active nozzles enabled to match the Casarsa trained vineyard profile (Fig. 9), and four active nozzles were necessary to cover the canopy of a Guyot trained vineyard (Fig. 10).

To employ all six nozzles available on each sprayer side resulted appropriate for spraying semi-dwarf fruit trees with vegetation fully developed (e.g. BBCH 77 for apple trees, Fig. 11).

The air flow rate measured according to ISO 9898 adopting the low fan rotation speed (1890 rev/min) ranged between 15000 m$^3$/h and 27000 m$^3$/h, depending on the diameter of the suction fan area (Fig. 12). At each step of 50 mm in the diameter suction area adjustment corresponded on average a 3000 m$^3$/h variation in the air flow rate.

When the fan rotation speed was increased up to 2160 rev/min, the air flow rate ranged from 18000 m$^3$/h to 33000 m$^3$/h according to the size of the fan suction area (Fig. 13). At each step of 50 mm in the diameter suction area adjustment corresponded on average a 3800 m$^3$/h variation in the air flow rate.

The criteria to modulate the air flow rate in function of the canopy features takes into account the density of the vegetation, expressed in terms of number of leaf layers and percentage of gaps in the canopy. The denser is the canopy, the higher is the air flow rate. In an analogue way the adjustment of the liquid flow rate is based on the total canopy surface to be treated, expressed in terms of LAI.

Thanks to the automatic adjustment of the spray profile in function of the canopy shape and size, especially in vine farms featured by different types of vineyard training systems, the sprayer prototype developed is able to significantly reduce the average amount of spray mixture applied per hectare, if compared with a conventional air-assisted sprayer. This means a better timeliness of application around the vine farm and a higher operating capacity of the machine. First field tests have indicated that the sprayer prototype enables an average time saving for making one single application between 15% and 20% with respect to a conventional machine. This advantage has been followed by a considerable reduction of environmental contamination.

Further improvement of the prototype will be focused at providing the sprayer with a unique set of hollow cone nozzles fitted with variable flow rate system (e.g. Lechler Vario® system).
Literature Cited


Figures

Fig. 1 – Prototype of self calibrating air-assisted sprayer.
Fig. 2 – A) Set of nozzles mounted on the prototype; B) motorised valves used to select the active nozzles.

Fig. 3. – A) Adjustable diaphragm able to regulate the air suction area of the fan; B) air deflectors automatically adjustable.

Fig. 4. – A) Transponder used to load the vineyard/orchard parameters; B) receiver mounted under the frame of the sprayer.
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Fig. 5 – Scheme of the functioning of the sprayer prototype.

Fig. 6 – Vertical test bench used to assess the sprayer spray pattern.

Fig. 7 – Spray profile for applications on Casarsa trained vineyard in the early growth stages.
3 active nozzles: positions 2, 3, and 4

Fig. 8 – Spray profile for applications on Guyot trained vineyard in the early growth stages.

3 active nozzles: positions 3, 4 and 5

Fig. 9 – Spray profile for applications on Casarsa trained vineyard in the late growth stages.

4 active nozzles: positions 2, 3, 4 and 5

Fig. 10 – Spray profile for applications on Guyot trained vineyard in the late growth stages.
Fig. 11 – Spray profile for applications on semi-dwarf apple trees in the late growth stages.

Fig. 12 – Prototype air flow rate measured according to the suction area diameter, adopting the low fan rotation speed (1890 rev/min).

Fig. 13 – Prototype air flow rate measured according to the suction area diameter, adopting the high fan rotation speed (2160 rev/min).
Etude d’un pulvérisateur adaptatif pour l’application de pesticides sur vignes.

Mots clés : Agriculture de précision, feuillage de vigne, pulvérisateur à jet porté, ajustement.

Résumé

L’université de Turin (DEIAFA) a développé un prototype de pulvérisateur doté d’équipement électroniques permettant d’ajuster automatiquement les paramètres de pulvérisation aux caractéristiques de la vigne en cours de traitement. L’objectif est de faciliter un ajustement correct du pulvérisateur en fonction des caractéristiques du feuillage de la vigne (taille, densité, stade de croissance ...).

Les informations concernant chaque parcelle de vigne à traiter sont enregistrées sur un transpondeur fixé au sol à une position pré-déterminée en bordure du champ. Le pulvérisateur peut acquérir ces informations via un récepteur fixé sur la flèche. Une unité centrale peut alors traiter ces informations et en accord avec la vitesse d’avancement fixé par l’opérateur, ajuster le nombre de buses actives, la pression de pulvérisation, la quantité et la direction de la ventilation. Un premier ensemble d’essais expérimentaux ayant pour objectif de vérifier les performances de ce prototype ont permis de démontrer sa capacité à s’adapter à différentes formes et tailles de feuillage de vigne.