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Full Length Research Paper

Effect of air assistance on deposition distribution on spraying by tunnel-type electrostatic sprayer

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Pesticide drift has always been a serious threat to both living things in the fields and people who are indirectly affected by it. There are many types of pesticide application machines for decreasing of the pesticide drift. One of them is tunnel type pesticide application machine. In this study, increasing the success of the spray application by tunnel-type electrostatic sprayer was targeted. For this purpose, an air unit on the system was mounted. Measurements were made at different points. This article presents the results of tests to determine the appropriate spray nozzle type and pressure values for this machine. Tests were conducted under two operating pressures namely 2 - 3 bar and 6 km/h operating speed conditions in Semillon vineyards. Tartrazine was used as spray liquid, and before its use, it was sprayed on filter papers. When air support was used on the sprayer, increasing in spray deposits into the plant canopy inside was determined according to results. A homogeneous distribution was observed. In the amount of residues in the bottom of the plant also increased. Increasing of the spray deposit on the plant was caused to decrease in the amount of residues on the ground and decreased the amount of spray deposit exposed drift.

Key words: Air assisted sprayers, deposit, losses, spraying, tunnel sprayers.

INTRODUCTION

Legislation is progressively leading towards a reduction in pesticide use in order to lessen the environmental pollution caused by agricultural chemicals (MAFF, 1998; EN, 2003). The solution most often proposed in recent years is to improve the targeting ability of the sprayer by optimizing its adjustment according to the canopy characteristics (Kaul et al., 2004). Several studies have been done on this subject using patternators (Pergher, 2004; Kaul et al., 2003; Balsari et al., 2002, 2004). The results have been shown that it is often difficult to reach a good compromise between high biological efficacy and low environmental impact (Walklate et al., 2002).

Research into reducing the dispersal of liquid has focused on the design of innovative machines like tunnel sprayers (Holownicki et al., 1995; Thériault et al., 2001; Cross and Berrie, 1995; Peterson and Hogmire, 1995) and on pinpointing a relationship between the pesticide dose and biological effect (Walklate et al., 2003; Furness, 2003).

Recent studies on tunnel sprayers have demonstrated that these machines strongly reduce losses to the ground and aerial drift (Bäcker, 1993; Huijsmans et al., 1993; Siegfried et al., 1999; Doruchowski, 1993). However, their popularity is impeded by the difficulty in adjusting them to the plentiful array of training forms, although this is becoming less important due to increasingly standardized cultivation techniques.

In order to assess the chemical quantity to be distributed, a model for calculating the dose was set up for orchard crops (Walklate et al., 2002, 2003). However, the relative amount of spray retained by the plants was difficult to estimate as this parameter was influenced by the spray flow rate and canopy characteristics, such as plant size, leaf density, and row spacing. The limitation of the method was the necessity of evaluating the dose through the buildup of pictography of the different growth stages and crops, which made practical application of the

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method difficult.

Electrostatic sprayers are commonly used in agricultural applications to apply pesticides and other agricultural chemicals to crops. Electrostatic sprayers typically work based on the following basic principles. Compressed air and liquid (this is typically pesticide for agricultural applications) are separately piped into a nozzle, where the two mix in the process of atomization, forming small droplets of the liquid. The atomized liquid then passes through a charged electrode, in the process of induction, which charges the droplets. The droplets spray out to crops due to the airflow. The charge on the droplets causes the individual droplets to repel from each other scattering the spray for an even and wide spread application. The charge on droplets also leads to better application by causing droplets to better adhere to crops, which are at ground potential and electrically attract the charged droplets.

The nozzle needs a high voltage power source of generally one kilo-volt or higher, make sufficient charge on the liquid in an electrostatic sprayer. Electrostatic sprayers designed for using in the field where can be used only a low voltage power supply, such as a 12 V battery (typically the tractor battery), that is hooked up to a power supply that generates a high voltage signal. Some sprayers use one power supply for many nozzles, but have some problems about distributing high voltage to several nozzles. Many sprayers use one power supply per nozzle to keep the uniformity of high voltage level at ever nozzles but have the disadvantage of the high cost and maintenance of the many power supplies.

In the Viticultural Research Institute of Tekirdag, a prototype tunnel sprayer designed to match the shape and dimensions of vines and it was manufactured. Field trials demonstrated that the tunnel sprayer with internal air circulation produced very low losses to the ground, and given the small amount of product not recovered also produced low values of drift losses. The trials also pointed out that the sprayer settings had to be determined by analyzing the relationship between deposits and foliage density. The analysis of the deposits showed a good uniformity of distribution at different heights and depths and also a sufficient biological efficacy (Ade et al., 2005).

The purpose of this research is to compare two sprayers: The electrostatic sprayer with air supported and the electrostatic sprayer without air supported. Spray deposition on different parts of canopy were investigated.

MATERIALS AND METHODS

Vineyard

The trials were performed on a vineyard trained to spur-pruned cordon with 3.0 m row spacing and distance between plants of 1.5 m. Cordon height was measured as 1.2 m. The measurements were taken at July vine growth stages in the test conditions reported in Table 1. It can be observed that the leaf area index (LAI) values in the section of the row have the same shape (Table 1).

Table 1. Vineyard characteristics and environmental conditions during tests.

Trial date	19 July
Temperature (°C)	24
Relative humidity (%)	75
Wind speed ($m\ s^{-1}$)	1.0
Leaf area index ($m^2\ m^{-2}$)	0.79

Sprayer

The tunnel sprayer which was used of the trials was a pre-industrial version of the one developed at the Viticultural Research Institute of Tekirdag. The sprayer is a double-row, mounted type machine with a spraying section composed of a 400 L polythene tank, a membrane pump, and constant pressure regulator. The sprayer was attached to a 55 kW tractor, and the forward speed was constant 6 km h^{-1} during the trials. Figure 1 illustrates the position and distance of the spraying nozzles with respect to the vines.

The electrostatic system was powered by an accumulator. The electricity was transmitted to the ring-shaped metal panels via cables. The liquid sprayed by noozles was charged positively.

Electrostatic sprayer system

The electrostatic sprayer system was composed of a tunnel sprayer, a high voltage source, an electrode and a nozzle. Vineyard sprayers have about 50 ℓ/min discharge rate at 2 bar spraying pressure. The high voltage source attaches at operation to the upper tank.

A square wave at a pulse power of 0 ~ 17 kV, 1 ~ 20 kHz was used as a high voltage source that has DC12V input voltage and 40A current. It was applied to the induction electrode of the proposed nozzles, thus allowing positively charged droplets to be sprayed onto the crops.

1 mm thickness of the electrode made of sheet brass was used. The body of a plastic nozzle was placed into an opening of 40 mm on the metal plate, and the body of the nozzle was twisted in a circular way. The electrode from the nozzle end of the plastic body 20 mm attached in point. The front line planned in order to connect to the end of the panel. The body prevents the electric leakage due to sprayed droplets.

Tunnel parts

The tunnel consisted of two plastic panels. Panels were placed on each side of the row in a parallel way to avoid friction. Spray nozzles sprayed the liquid through circular openings on the panels. Air nozzles were placed in front of the panels parallel to the spray nozzles. The distance between shields was adjustable mechanically, as was the system for folding the external panel backwards for turning and displacing. The shields were 2.0 m length and 0.5 m width. During trials, a 1 m distance was setted between the panels. The airflow was produced by the fan enclosed in each shield and powered by hydraulic motors. The air flowed out through a vertical outlet, which included a boom bearing four nozzles per side. The air flow speed was measured as 5.6 m s^{-1} at air nozzle outlet.

Spray nozzles

Lechler 110 - 02 spray nozzles were used at the 2 bar pressure and

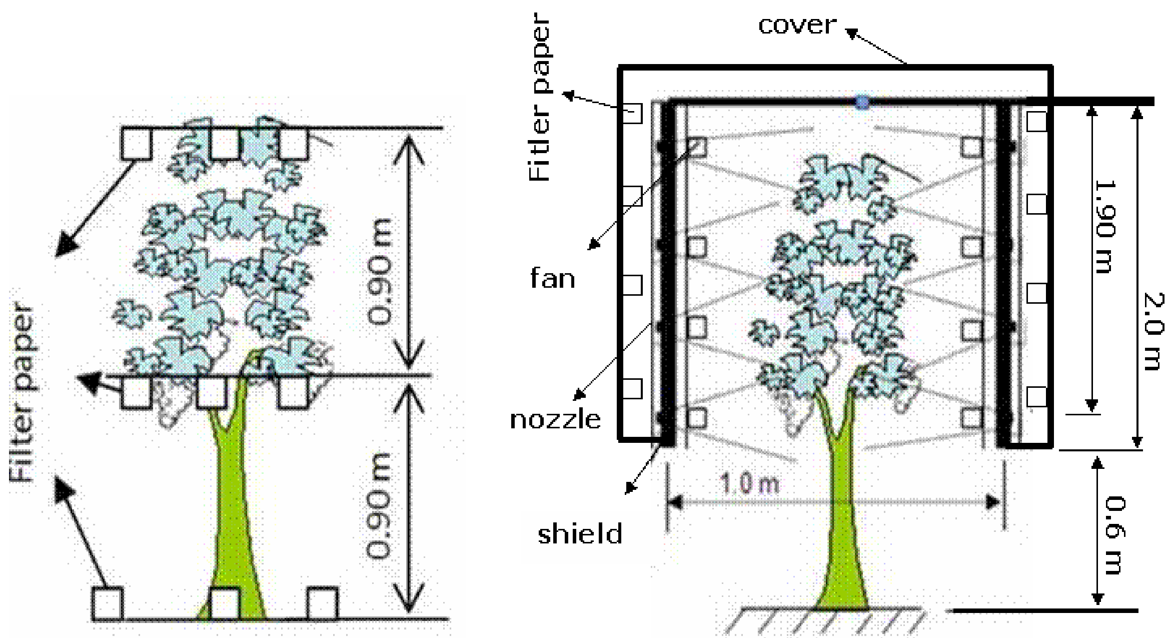

Figure 1. Diagram of the sprayer and vineyard during the trials.

0.65 l min^{-1} flowrate conditions in the tested tunnel-type sprayer.

Air supported system

In order to to facilitate the penetration of spraying drops into the plants canopy, an air support unit was used; achieve better drops stick leaves on the plant, an electrostatic system was employed; for help avoid the spray drift and prevent drops from sticking to unwanted plant areas, a tunnel system were used.

The air support system sprayed air into the tunnel, air was produced using a fan and directed into the tunnel with pipes. The diameter of the fan was 710 mm, fan airflow rate 600 l min^{-1} and air velocity 36 m s^{-1}, respectively.

Thanks to the effect of the charged air flow in the tunnel, the sprayed liquid scattered around the surface of the plant and sticked to the neutral plant surface.

Testing pattern

During the tests, kestrel type windmeter, TFA Diva Go temperature and humidity meter were was used to determine the level of humidity, the degree of temperature and the speed of wind. The measurements were made at a height of 2 m and randomly in different sections of the field. Measurements were taken at full vegetation period and the application pressure and the type of nozzle were used as variables. Suspension points of grapevines based on their distance from the ground and the skipped leaves were determined as the side factors at measurements. The air temperature, the relative humidity, and the speed of wind were recorded on a regular basis during tests.

Any change at environment conditions could cause some changes at measurements; as a result, for the selected parcel of the field, the variable combinations were measured during one pass of the field, which was 100 m in length. The selected suspended grapevines were determined at every 10 meters and a representative sample of each grapevine was collected.

The amount of liquid residue and the distribution of the liquid were was recorded on the same side of sprayer and always done following the same sampling position. At every 100 m, filter papers were attached to the sides of the plants and on the surface of the soil. The papers were located on the surfaces of plants on the different heights at 90 cm intervals (Figure 1). Sampling surfaces were placed on each test plant based on the lowest, highest and middle level of the leaves. In doing so, the distribution of the spray liquid was better observed when it was permeating through leaves. Filter papers were placed on the tips of the leaves using paper clips. Since papers could easily move at the tip of the leaves, the liquid could permeate through both sides of the leaf. Total 9 filter papers on each plant were placed: 3 on regions and 3 on positions highest, lowest and middle positions. The liquid was sprayed 3 times, and so after the test a total of 27 sample leaf area was collected on which to determine the amount of liquid residue.

In order to identify the spray amount outside of canopy, 16 of the filter paper as sample surface, as seen in Figure 1, were placed around 30 cm distance from tunnel. Total residual amount is the amount that collected at all sampling surface.

The operating principle was the same with the previous tunnel model. The main technical difference was the inclusion of the air circulation and electrostatic system at the new model.

Measurements

Treatments were applied to plots composed of single row that has 30 m length, and the samples were collected in a 2 m long section in the centre of the plot. Four replicates were done to obtain a fully randomized experimental design. Replicates were reciprocally separated by four untreated rows to avoid any interference between treatments.

LAI

When the spray coverage of leaves is required; ideally an estimate of the leaf area index (LAI) can be used. The LAI is the ratio of leaf area to ground area and will vary at different crops according to the stage of plant growth. The LAI seldom exceeds about 6-7, as leaves without adequate light are usually shed (Matthews, 1992). Leaf area index is calculated by the following equation:

$$LAI = TYA/YA$$

Here;
TYA: total leaf area (cm^2),
YA: cultivation area (cm^2) (Matthews 1992).

In order to calculate the leaf area, 75 leaves were collected from the grapevines. The leaf area for each sample leaf was measured using a leaf area meter (model 3100, Li-Cor, Inc., Lincoln, Neb.). The number of all leaves was determined to be the average number and accordingly the leaf area was measured.

Leaf density was used to measure the leaf distribution based on plant regions. In order to determine leaf density (L_d) number of leaves were measured in each leaf region and position. Based on this, the density value was calculated by the following equation (Pergher et al., 1994):

$$L_d = 10^{-4} \times L_a / s \times h$$

Here;
$L_{d:}$ leaf density,
L_a: the lef area in a region (cm^2),
s: the length of the sample region (m) (1 m in these trials),
h: the range of region heights (m)

Tracing material and sampling surface

Tartrazine, a registered food dye (Neelikon Food Dyes and Chemicals, Ltd., Bombay, India), was used as a tracer to quantify spray deposit because it can be easily and completely recovered from artificial and natural targets (Pergher, 2001). The concentration of the tracing material was adjusted according to the liquid rate, and at each application the same tracing material rate (g/ha) was attained. In trials, it was observed that when the filter papers used as sample surfaces or leaves were kept in water, tartrazine was absorbed by water in high percentages (100% on filter paper and 95% on grapevine leaves). This property made the use of dye as a tracing material easier. Filter paper (∅ 0.125 m, Schleicher and Schuell, 5892, white ribbon, ashless, 30.664 cm^2) was used as tracing materials.

Colorimetric methods were used to measure the concentration of the tracing material (Ade et al., 2005). During trials, after the completion of each test, in order to separate the tracing material from the filter papers 80 ml pure water was added to the plastic boxes. After being kept 15 h in the washing water away from the sunlight, filter papers were taken out of the boxes. A fluorimeter's sensitivity enough to measure dye concentration as low as 1 ppm was used to measure the tartrazine food dye concentration in the washing water. Before working on the readings of the washing water values for trials, a standard series with certain concentrations were prepared. The degree of concentrations for each field test showed variations depending on the amount of dye on filter papers collected in the washing waters. The measurement of the dye concentrations was taken using the values of the standard series.

Spray deposit on the canopy was assessed by distributing a water solution of the dye and picking leaves from different parts of the vine. To prevent contact with the ground, the strips were fixed to plastic frames and distributed under the plants. After treatment, when the spray had dried, the leaves and paper targets were collected in separate labeled plastic bags. In the laboratory, certain amount of distilled water was added to each bag, and the solution absorbance for the dye was measured using a Jenway 6200 fluorimeter. Dye deposits were quantified and expressed as mg cm^{-2} of leaf area or paper target area.

Results were analyzed statistically using ANOVA and Student-Newman-Keuls tests, after verifying the homogeneity of the variances using the Bartlett test (Statistica, StatSoft, Inc., Tulsa, Okla.).

RESULTS AND DISCUSSION

Leaf area index

The leaf index for the field in which trials were carried out was determined as 1.29 ± 0.13 in July. According to measurements, for each sample grapevine, there were 680 ± 50 leaves, and the mean leaf area was determined as 73.4 cm^2.

Deposition and penetration

The amount of deposit on leaves and the ground is the focus for evaluating the results. Information on the deposition made it possible to calculate the aerial losses as a function of difference between the liquid sprayed and that found on the ground and leaves. Liquid depositions by the tunnel sprayer with and without air assisted are given on the Table 2. Percentages were calculated as an average of four replicates. Percentage of the total sprayed was expressed 100%. In the amount of leaf residue, used for air support, increased 7.8%. In fact, a 23.5% decrease was seen in drift.

Deposit distribution on canopy was not homogeneous by conventional sprayer without air assisted system. Spray deposit was measured as 20 - 40 μg/cm^2 on the upper sides in tests. Also 40 - 60 μg/cm^2 were found on the left and right sides. On the ground they were maximum 20 μg/cm^2. Penetration was better when used air assisted system. On upper side, canopy inside, right and left side it was 40 - 60 μg/cm^2. 20 - 40 μg/cm^2 were found in the bottom of canopy. On the ground they were maximum 20 μg/cm^2. But it was less than spraying without air assisted system. Homegenous distribution and increasing in the amount of the spray deposits was determined in the canopy by comparing both applications (Figure 2). This characteristic of the spray deposition indicates the extent of spray penetration in to the canopy.

The variance analyse results are given in Table 3. Results show that Systems, Height, Location, the interaction between Systems and Height, the interaction between Systems and Location, the interaction between Systems, Height and Location were significant on spray distribution at 5% significance level. It is shown that spray distribution are changed with different systems on same height and location.

Table 2. Liquid deposition by tunnel sprayer (SD: Standard deviation).

Air assisted	Liquid on leaves % (SD)	Liquid on ground % (SD)	Outside of canopy %
Without	74.9 (3.7)	10.7 (1.1)	14.4
With	80.8 (6.1)	9.9 (0.3)	9.3

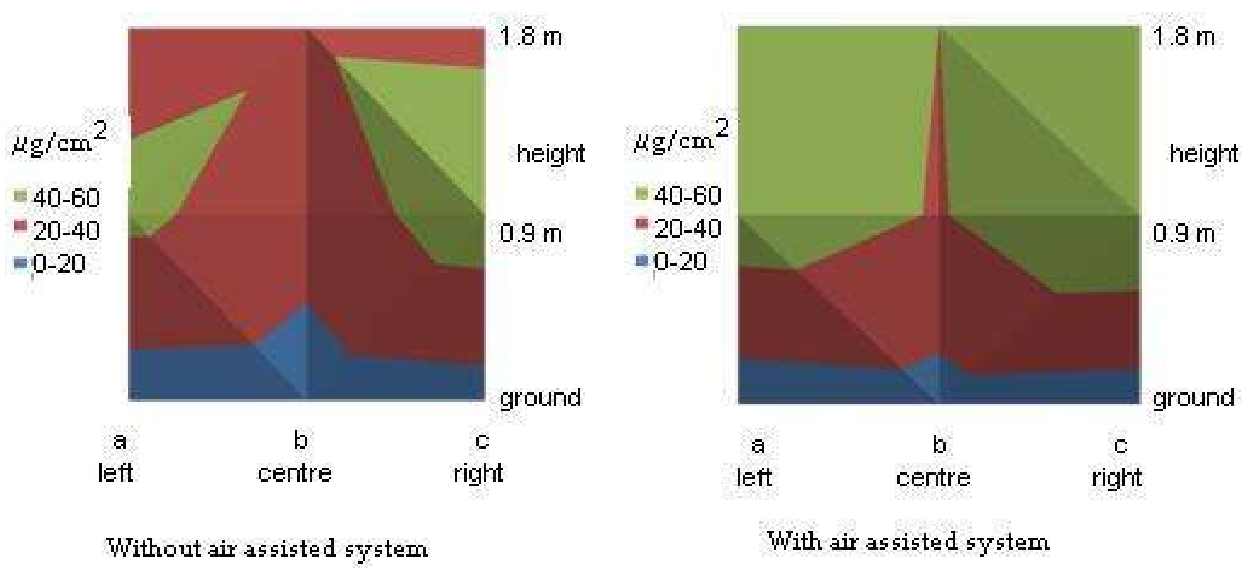

Figure 2. Penetration (mean deposition at canopy depths) of spray in to canopy, with and with air assisted system is used.

Table 3. Effect of systems, height and location on spray distribution.

Source of Variation	DF	SS	MS	F
Rep	2	16.59	8.296	2.42
Systems (With air assisted or not)	1	327.57	327.574	95.4**
Height (1.80-0.90-0 m)	2	687.37	343.685	100.1**
Systems x Height	2	2.93	1.463	0.43**
Location (a-b-c)	2	11591.81	5795.90	1688.02**
Systems x Location	2	130.70	65.352	19.03**
Height x Location	4	831.96	207.991	60.58**
Systems x Height x Location	4	119.30	29.824	8.69**
Error	34	116.74	3.434	-

**5% significance level.

Conclusion

In this study, increasing the success of the spray application by tunnel-type electrostatic sprayer is targeted. For this purpose, an air unit on the system were placed. Measurements were made at different points.

When air support was used on the sprayer, spray deposits into plant canopy increase there is increasing in the spray deposits into the plant canopy inside. Also, a homogeneous distribution was observed. Generally, spray deposits increased. In the amount of residues in the bottom of the plant increased. Increasing of the spray deposit on the plant, was caused to decrease in the amount of residues on the ground. Similarly, decreased the amount of spray deposit exposed drift.

REFERENCES

Ade G, Molari G, Rondelli V (2005). Vineyard evaluation of a recycling tunnel sprayer. Trans. ASAE 48(6): 2105-2112.

Bäcker G (1993). Recent developments in recycling techniques for application in tree and bush crops. In Proc. ENPP-BCPC 2nd Intl. Symp. on Pesticide Applic. Techni., 331-340. Paris, France: ANPP. 50(2): 409–413 413
Balsari P, Pergher G, Ade G, Vieri M, Guarella P, Giametta G, Cerruto E (2002). The usefulness of a test area for the calibration of sprayer for grapevines. Informatore-Agrario 58(8): 97-108.
Balsari P, Pergher G, Ade G, Vieri M, Guarella P, Giametta G, Cerruto E (2004). How to calibrate vineyard spraying machines. Informatore Agrario 60(10): 31-40.
Cross JV, Berrie AM (1995). Field evaluation of a tunnel sprayer and effects of spray volume at constant drop size on spray deposit and efficacy of disease control on apple. Ann. Appl. Biol. 127(3): 521-532.
Doruchowski G (1993). Use of tunnel sprayers in orchards and berry plantations. In Proc. ENPP-BCPC 2nd Intl. Symp. on Pesticide Applic. Techniques, 281-288. Paris, France: ANPP.
EN (2003). Opinion of the European Economic and social committee on the "Communication from the Commission to the Council, the European Parliament, and the European Economic and Social Committee: Towards a thematic strategy on the sustainable use of pesticides." EN2003/C85/24. Official J. European Union, 112-118. Brussels, Belgium: European Union.
Furness GO (2003). Distance calibration and a new pesticide label format for fruit tree and grapevines in Australia. In Proc. VII Workshop on Spray Application Techni. in Fruit Growing,293-303. Torino. Italy: DEIAFA.
Holownicki R, Duruchowski G, Godyn A (1995). Efficient spray deposition in the orchard using a tunnel sprayer with a new concept of air jet emission. Acta Hort. 422: 284-288.
Huijsmans JFM, Porskamp HAJ, Heijne B (1993). Orchard tunnel sprayers with reduced emission to the environment. In Proc. ENPP-BCPC 2nd Intl. Symp. on Pesticide Appl. Tech. 297-304. Paris, France: ANPP.
Kaul P, Henning H, Gebauer S (2003). Nutzung von Vertikalverteilungs-Prufstanden zur Beurteilung von Spruhgeraten im Obstbau. [Use of vertical patternators for assessment of orchard sprayers.] Nachrichtenblatt des Deutschen Pflanzenschutzdienstes 55(5): 101-109.
Kaul P, Koch H, Knewitz H, Schmidt K, Gebauer S (2004). Vorschlage zur Gestaltung der Gebrauchsanleitung von Spruhgeraten im Obstbau: Einsatzgrenzen und Einstellung der Vertikalverteilung. [Proposals for the improvement of orchard sprayer instructions: Limits and adjustment of the vertical distribution.] Nachrichtenblatt des Deutschen Pflanzenschutzdienstes 56(4): 77-82.
MAFF (1998). Code of practice for the safe use of pesticide on farms and holdings (the Green Code). Publication No. PB3528. London, U.K.: Min. Agric., Fisheries and Food.
Matthews GA (1992). Pesticide application methods. 2nd edition, Blackwell, Oxford.
Pergher G, Gubiani R, Gasparinetti P, Del Cont BD (1994). Voluntary testing of plant protection equipment in Northern Italy. Acta Hortic., 372: 59-66.
Pergher G. (2001). Recovery rate of tracer dyes used for spray deposit assessment. Trans. ASAE 44(4): 787-794.
Pergher G (2004). Field evaluation of a calibration method for air assisted sprayers involving the use of a vertical patternator. Crop Prot. 23(5): 437-446.
Peterson DL, Hogmire HW (1995). Evaluation of tunnel sprayer systems for dwarf fruit trees. Appl. Eng. Agric. 11(6): 817-821.
Siegfried W, Viret O, Holliger E, Mittaz C, Crettenand Y, Antonin P (1999). Qualité de l'application des produits phytosanitaires en viticulture et efficacité de la lutte contre les maladies fongiques. Rev. Suisse de Viticulture, d'Arboriculture et d'Hort. 31(4): I-VIII.
Thériault R, Salyani M, Panetton B.(2001). Development of a recycling sprayer for efficient orchard pesticide application. Appl. Eng. Agric. 17(2): 143-150.
Walklate PJ, Cross JV, Richardson GM, Murray RA, Baker DE (2002). Comparison of different spray volume deposition models using LIDAR measurements of apple orchards. Biosys. Eng. 82(3): 253-267.
Walklate PJ, Cross JV, Richardson GM, Baker DE, Murray RA (2003). Pesticide dose adjustment to the crop environment (PACE): Systems development. In Proc. VII Workshop on Spray Application Techni. in Fruit Growing, 285-292. Torino, Italy: DEIAFA.