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Julius-Kühn-Archiv

SuproFruit 2015 - 13th Workshop on Spray Application in Fruit Growing

15. - 18. July 2015
Lindau / Lake Constance, Germany

- Proceedings -

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Bundesforschungsinstitut für Kulturpflanzen

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Section 1

Influence of the tractor driving speed on the sprayer air flow

R. Almbauer, K. Lind, W. Matzer

The deflection of air flow of an orchard sprayer due to the driving speed of the tractor influences the spray application in the orchard. In order to get a sufficient protection of the trees avoiding unnecessary drift losses to the air and the soil the whole process has to be optimized. In addition the noise annoyance and the fuel consumption will become more important. As the flow field and the droplet transport is complex experimental investigations are indispensable.

The paper describes the activities and results achieved in the research work carried out in a co-operation of the Graz University of Technology (TUG) as well as by the Association of Styrian fruit growers (VStE). The main objective of this research was to investigate the influence of the driving motion to the spray application in the orchard. In addition, this effect should be included into the existing rating of orchard sprayers.

So far, the influence of the driving speed has been hardly taken into account in the spread of the air stream in the orchard. This was less important due to low tractor speeds and lower tree heights. Nevertheless, this important effect for droplet transport at high speeds (up to 12 km / h) in combination with trees up to 5m high has been investigated in this research project. Based on the results, a practical guide for the user of the sprayer has been developed, in order to arrive at a resource-conserving crop protection.

With the purchase and installation of a new air test rig, the most important prerequisite for the experimental detection of the wind influence has been created. Following an intensive phase of comparing air measurements in two round robin tests with the South Tyrol Consulting Agency (I), the market community Bodenseeobst (D), the adjustment work on the hardware and software was carried out. Simultaneously with the stationary measurements the preparation work for air measurement in drive was done. A correspondingly large hall was available at a fruit store company for the measurements in motion. In a three-day measurement campaign an extensive program was successfully carried out with four different sprayer types from several manufacturers. The analysis shows that the relationship between stationary measurement and measurement in drive is device dependent and therefore a simple conversion factor cannot be applied.

Another important aspect of the project was to investigate the "optimal" sprayer-settings for the spraying in the orchard. Two measurement campaigns were carried out in an orchard in leafless and full leafy state. They were carried out as realistically as possible with spray at appropriate meteorological conditions for different driving speeds. In order to provide a resource saving spraying the following main influencing parameters have been found: fan type , power take of shaft(PTO-) speed and thus blade speed, driving speed, distance between the rows of trees and height of the trees. Different sprayer types applying different concepts are available on the market. They differ in the fan type (radial or axial) , the deflection of the air stream up to the cross section of the spray nozzles, and in the form of the air flow after exiting from the blower (for example a larger width at lower speeds or narrow at higher speeds, different direction of flow with droplets). It will also generate the above-mentioned different deflection behaviour of the airflow of individual sprayers in driving. By the use of a statistical analysis a uniform interpretation of the measurements has been done, so that a conclusive link between stationary measurement at the air test rig and the behaviour in the orchard does exist. It is now possible, when specifying the above mentioned boundary conditions (blower type , spacing of rows of trees and height of the trees), to provide an optimum PTO-speed for a given driving speed. This information for the adaptation to actual conditions during the spraying process can be provided to the farmers through a special software. This gives the farmer the corresponding PTO-speed for the currently used sprayer for a selected fruit culture for a given tractor speed. In addition, x-comply provides the complex administration and documentation of the spraying.

Based on these results a test method was developed on the basis of stationary air measurements, so that the sprayers can be developed by the manufacturers. In addition, all the individual sprayers can be checked with the testing procedure at independent testing centres. Precondition that this onetime-measurement is sufficient for the entire useful life of the sprayer is that the air-carrying parts cannot be altered anymore. Using the data from the stationary measurement provides all the information for the settings for the spraying. So the prerequisites for an economical and environmentally friendly application of pesticides in fruit crops are now given at maintaining full effectiveness.

Design and evaluation of a manual device for air flow rate adjustment in spray application in vineyards

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Introduction

Air assisted sprayers (mist blowers) is the most common technology used for pesticide application in vineyards. An accurate calibration process is always requested to obtain a uniform distribution, avoiding problems such as drift and pesticide losses to the soil. During the calibration process one of the key aspects affecting the quality of the process is the air assistance characteristics (air flow and air speed). However, while different methodologies have been already established to determine the optimal amount of liquid/pesticide depending on canopy characteristics, very few data exist concerning the best relationship between air assistance and canopy. The purpose of this research was to evaluate the effect of air assistance on spray distribution/deposition in a traditional vineyard in Spain.

Material and Methods

A special device for air adjustment was designed and implemented in a multi row sprayer Ilemo Hardi Iris-2 (Ilemo-Hardi, S.A.U., Lleida, Spain). The system allowed to adjust the air characteristics (air flow rate) from 0 (no air) to its maximum level (4750 m^3/h per side) using a manual adjustable valve (Fig. 1). Four air flow rates (0%, 25%, 50%, 75% ad 100%) were selected during the spray application of a constant volume rate of 260L/ha (4.4 km/h; 12ATR lilac nozzles, 7 bar, 3 m working width).

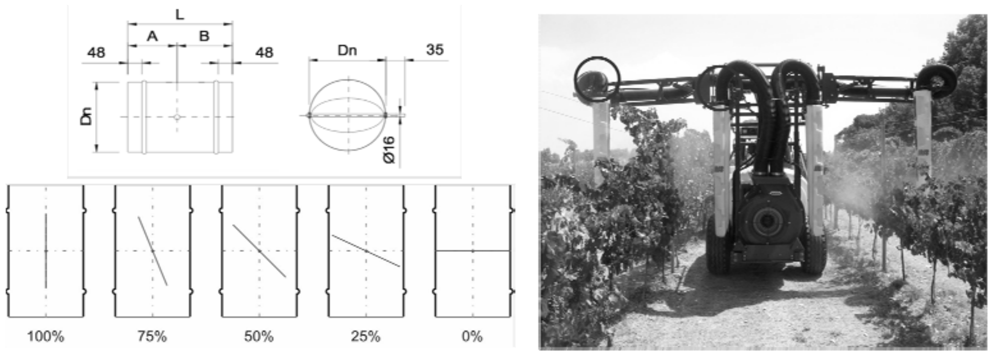

Figure 1. Technical characteristics of the adjustable valve (left) and Iris 1500 L sprayer (Ilemo Hardi S.A.U.) modified for the trials (right).

Spray deposition and coverage were evaluated using three different collectors: real wine leaves filter paper for deposition and water sensitive paper for coverage. Nine sampling zones (three heights and three depths) were selected in five replicates. For deposition, absolute values of deposition (l/cm^2) were determined using a constant amount of tracer (E-102) in the spray tank and measuring the collector's area (leaf area or filter paper surface), following the procedure previously established (Llorens *et al.,* 2010). Water sensitive paper coverage was measured by image analysis using Image J software (Rasband, 2014). Deposition and coverage data were analyzed by one-way analyses of variance considering the air flow rates as a source of variation followed by Tukey-Kramer post hoc test.

Results and discussion

Results (Fig. 2) indicated a very good correlation between collectors (leaves and filter paper) as tools for evaluation of deposition. The same tendency was observed when water sensitive papers were used. Concerning the effect of air flow rate, it was observed that no statistical differences were detected between maximum air flow rate (100%) and 75% in deposition values in grape leaves. Using filter paper as collectors, there were no significant differences between 75% and 50% of maximum air flow rate. This tendency was also observed analysing the coverage values obtained in WSP.

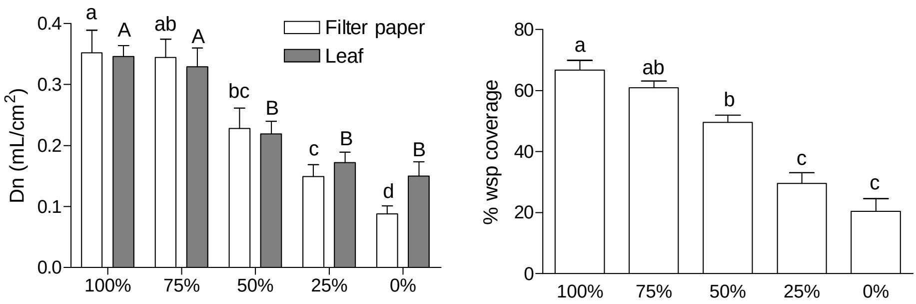

Figure 2. Deposition (mL/cm^2) on filter paper or wine leaves according to the air flow percentage (left). Water sensitive paper coverage according to the air flow rates(right). Different letters mean significant differences among air flow rates.

Conclusions

It is clear that an accurate air flow rate adjustment represents an important benefit both in economic and environmental aspects, while spray distribution quality is not affected considering the direct influence of air flow rate and direction in risk of spray drift (Gil *et al.,* 2014) and the important variation of tractor fuel consumption at different air flow rates.

Acknowledgements

Thanks to Ilemo Hardi, S.A.U. and AgriArgoIbérica for supporting this research. This project was partially financed by AgVANCE project (AGL2013-48297-C2-1-R) under Spanish Ministry of Economy and Competitiveness (MINECO).

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Optimization of air velocity in the plant protection product application in viticulture

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State of the art

At the Department of Viticultural Engineering, different plant protection machinery from different manufacturers in terms of air distribution, vertical distribution, application quality, drift potential, energy consumption and noise emission are surveyed. While the differences in the deposition distribution, the drift behavior and the vertical distribution remain in the expectable extent, the spread between the lowest and highest values concerning energy consumption is surprisingly far. They reached, based on the usable m^3 air flow at the target area, a factor of 5 between the most economical blower and the one with the most intense power consumption. This is even more astonishing against the background that the highest power consumption doesn't mean highest performance in terms of air velocity or flow rate. Beyond that, like many experimental results demonstrate, the quality of deposition with increasing air flow rate tends to decrease.

How much air is enough?

According to relevant literature, the air flow in the plant protection treatment in the vineyard is among other things necessary to open the canopy and to transport droplets on the target surface. Ideally, the leaves of a canopy should be set in motion, so that the droplets of the spray can wet them from all sides. If the blower is too strong, the leaves fold up and remain in this position with significantly reduced surface until airflow breakaway.

Figures 1-3: Behavior of a vine leaf in the air stream (Bräuninger, 2015)

Figures 1 to 3 show how a vine leaf behaves is an air stream. The elapsed time between the first and the third image is 138 ms, ie after 0.14 seconds, the leaf is completely folded and the lower side then is impossible to be reached. Worth noting here is that this behavior is observed already at an air velocity of about 8.5 m/s, with the sprayer passing at a speed of 6 km/h. For larger and older leaves, the required air velocity increases up to 11 m/s, while in practice values less than 12 m/s are considered insufficient and 20 m/s are quite common.

Surveys concerning deposition distribution quality have shown that, regardless of the type of device, reducing the PTO speed and thus the air flow rate doesn't lead to a significant deterioration of the deposition quality. Figures 4 and 5 show the measured leaf depositions in six elevation zones, respectively on the upper (ULS) and lower (LLS) leaf side. Striking in both variants is insufficient deposition on the lower leaf sides, which is typical for vineyards. However, this is observed at all the measured devices, regardless of the blower type and the air flow rate. Figure 4 shows the leaf deposition with a 28 inch axial fan with approximately 6.3 kW power demand, Figure 5 with the Geisenheim prototype with app. 2.7 kW.

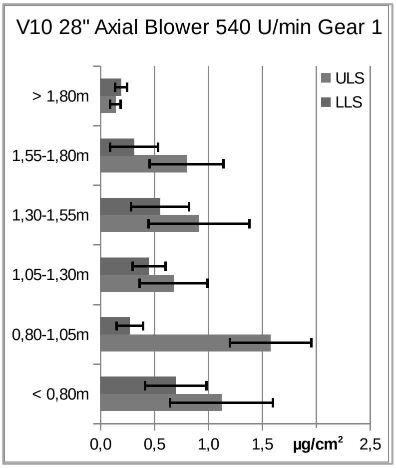

Figure 4: 28 "axial blower, 6.3 kW power demand

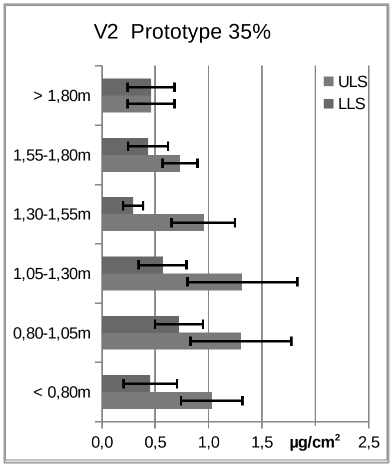

Figure 5: prototype electric drive, 2.7 kW power demand

With efficient machinery and reduced air power not only the power demand and thus the fuel consumption can be significantly reduced, but also the drift behavior is improved. Thus, as shown in Figure 6, the Geisenheim prototype equipped with air injection nozzles reaches 75% drift reduction without any additional restrictions.

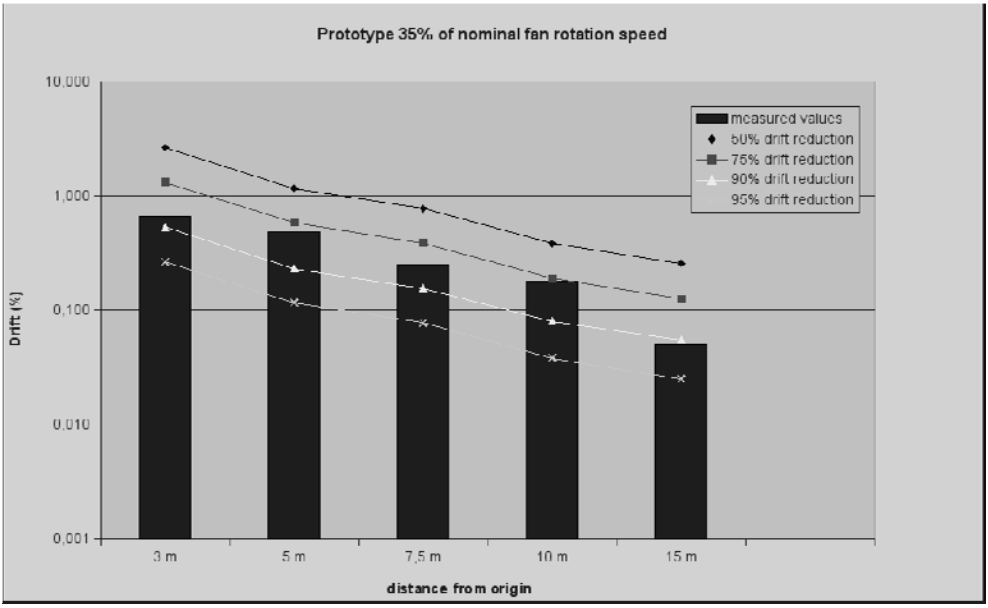

Figure 6: drift behavior Geisenheim prototype

Conclusion

A reduction of air power can reduce fuel consumption and noise emissions, improve the drift behavior and thus, without reduction of application quality, both protecting the environment as well as reduce the cost of the plant protection measurements.

Improvements of spray applications in greenhouses using hand-held trolleys with air assistance

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Introduction

Hand-held spray guns and lances are the most widely used methods of crop protection in greenhouses despite the heavy workload and high risk of operator exposure associated with these techniques (Foqué 2012). These spray application techniques have also proved to be less effective than spray boom equipment under many conditions while the advantages of using vertical boom sprayers compared with using hand-held sprayers or lances have been widely reported in terms of coverage and uniformity of spray distribution (Sánchez-Hermosilla, 2012). However, problems with penetration capacity have been described with vertical boom sprayers without air-assistance (Derksen 2001). The purpose of this research was to improve spray application techniques in greenhouses considering the spray quality on canopy by using hand-held trolley with vertical boom an including an air assistance system.

Material and Methods

Two trials in different greenhouses with similar characteristics (LAI and plant layout) were carried out in comparable field conditions but with a hand-held trolley prototype with several improvements and variations. Experiment 1 compared the spray deposition of the hand-held trolley prototype with and without an air assistance system, while experiment 2 studied the spray deposition of the sprayer prototype using two different air flow rates.

Experiment 1 was carried out in a commercial tomato greenhouse in El Ejido (Almería, South Spain).Canopy characteristics were: LAI: 5.96 and TRV: 10868 $m^3 \cdot ha^{-1}$. The sprayer had two vertical spray booms with flat fan nozzles spaced 0.3 m working at a 5.2 bar pressure, and was tested with and without air assistance. The air delivery system consisted of an air output for each spray nozzle with an average air velocity of 14 $m \cdot s^{-1}$. The volume application rate was 1000 $L \cdot ha^{-1}$(according farmer experience) at a forward speed of 3 $km \cdot h^{-1}$. In the mixture sprayed a tracer (Helios SC 500, Syngenta Crop Protection AG, Basel, Switzerland) was used at a concentration of 0.1% v/v. Twelve samples of 5 leaves each were randomly collected along the sprayed row from three heights and from the external and internal side of the canopy along de row. Values of deposition were expressed in $ng \cdot cm^{-2}$ of leaf.

Experiment 2 was carried out in a commercial tomato greenhouse in Viladecans (Barcelona, North East Spain). Canopy characteristics were: LAI of 5.46 and TRV 10468 $m^3 \cdot ha^{-1}$. In this case, the sprayer had two vertical booms with flat fan nozzles spaced 0.35m working at a pressure of 2 bar. A similar air assistance system to the first experiment was fitted up with the possibility to change the air blower unit: blower A consists of a motor engine turbine that generates 20 $m \cdot s^{-1}$ air speed; and blower B was an electric engine turbine that generates 14 $m \cdot s^{-1}$. An intended volume application rate of 800 $L \cdot ha^{-1}$ was set-up at a forward speed of 3.5 $km \cdot h^{-1}$. Tartrazine (E-102) was used as tracer at a concentration of 15 $g \cdot L^{-1}$. To assess the spray distribution, artificial collectors (filter paper) were placed at three heights and two sides of canopy (internal and external) in nine replicates along the canopy row. Results were also expressed in $\mu L \cdot cm^{-2}$.

Data from both experiments were normalized by tracer tank concentration and volume application rate.

Results and discussion

The results of Experiment 1 shows a significant increase of global spray deposition when air assistance is included (Figure1, left). Moreover, deposition of the internal part of the canopy was higher with air assistance(1.14 and 2.19 ng·cm^{-2}with no air and air, respectively). In Experiment 2, blower B (14 m·s^{-1}) gave both the highest deposition on the canopy(Figure 1, right) and also the highest canopy penetration (0.09 and 0.11 µg·cm^{-2}for blower A and blower B, respectively).

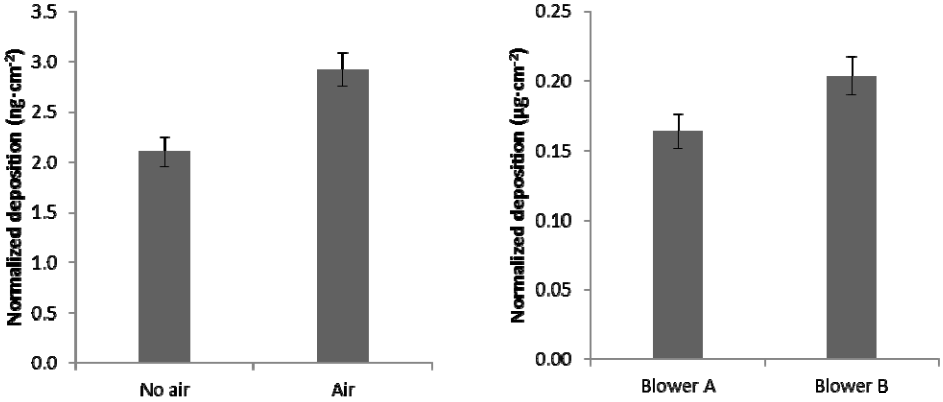

Figure1. Experiment 1: average spray deposition on leaves (left); Experiment 2: average spray deposition on filter paper (right).

Conclusions

The use of air assistance increased the deposition on the canopy and further improved penetration inside the crop. Comparing different air speed settings, there was no advantage increasing the air speed above 14 m·s^{-1}.

Acknowledgments

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Evaluation and optimization of spray application in apple and pear trees

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Introduction

The application process of plant protection products has not changed significantly over the last decades. Applications are affected by the different types of orchard sprayers, training systems and ambient conditions. The goal of the project was to optimize the deposition of plant protection products at the trees and to reduce the losses caused by drift. An optimized deposition might improve the biological efficiency.

Method

We performed deposition and drift measurements to optimize the orchard spraying process and achieve better distribution and a reduction of spray drift. We considered different types of training systems of apple and pear, sprayer types, fan speed settings and nozzles. A standard axial sprayer, a cross-flow sprayer and a sprayer with individual spouts were compared. The project was supported by the development of a computational fluid dynamics model (CFD) (1). As input for the model tree structure and dimensions were scanned. By indoor measurements we observed nozzle and sprayer characteristics as droplet size, liquid flow rate, outlet air flow patterns and liquid distribution. Indoor drift and deposition tests on artificial trees were used to optimize the model, after which it was validated by drift and deposition measurements in the orchard.

Results

We measured a strong relationship between the air flow rate of the sprayer and the deposition in the trees. The sprayer with individual spouts had a low air flow rate, which resulted in a high deposition on the target. The axial and cross-flow sprayers, producing a higher air flow rate resulted in less deposition. For the ground deposition behind the trees, a similar effect was noticed.

For drift we found a strong relationship with the air flow rate of the machine. We observed this for the different sprayers and for different settings of the fan speed. The axial sprayer resulted in a higher drift than the cross-flow sprayer. Extended trials with the cross flow sprayer (figure 1 and 2) demonstrated the positive effect of drift reducing nozzles. A lower fan speed setting had a similar effect. Only replacing the three upper nozzles by drift reducing nozzles had a smaller effect towards drift compared to the test with the standard nozzles. The drift reducing nozzles had a similar deposition on the trees as the standard nozzles (figure 3 and table 1). Spraying the trees from both sides remains necessary with both types of nozzles. Based on the results obtained from the trials we were able to provide guidelines to the growers regarding the use of their sprayer and differences in sprayer types.

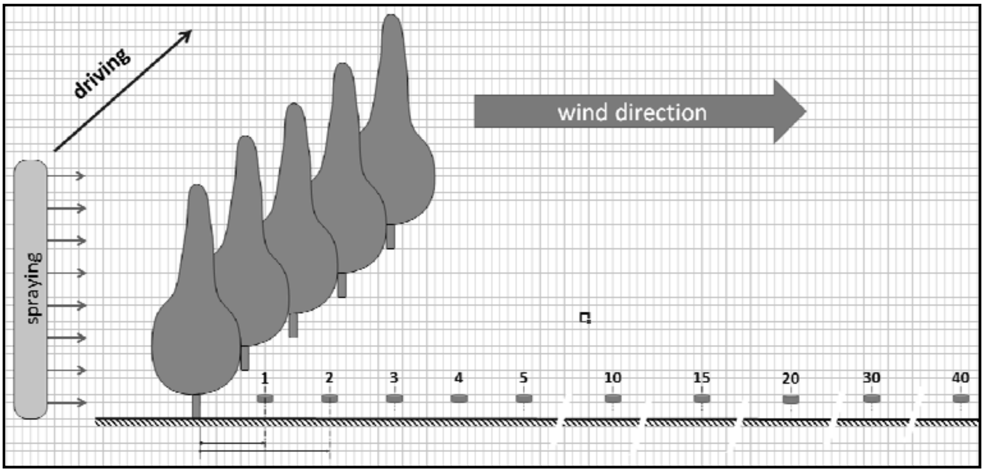

Figure 1. Drift trials were performed by spraying in the direction of the last row. Tracers were placed in open field at various distances behind the last row.

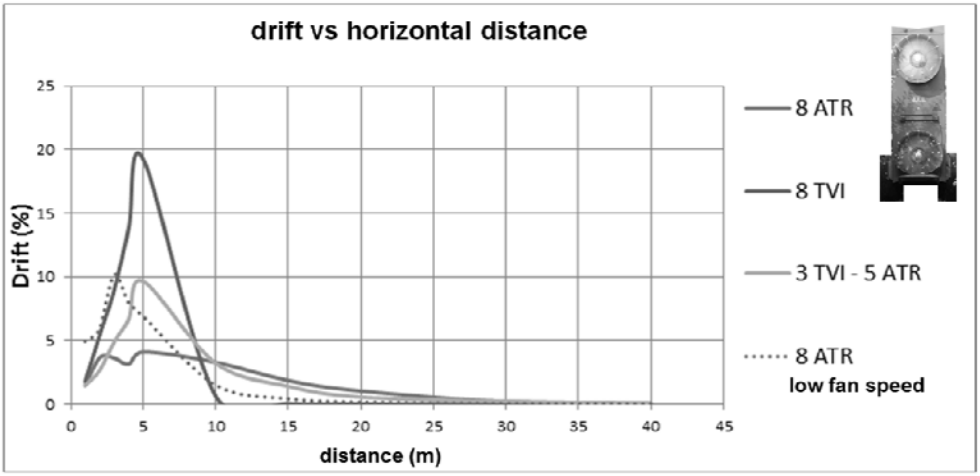

Figure 2. Drift deposition as a percentage of the used water volume in the orchard after application with the cross flow sprayer. Different nozzle types and fan speed were performed.

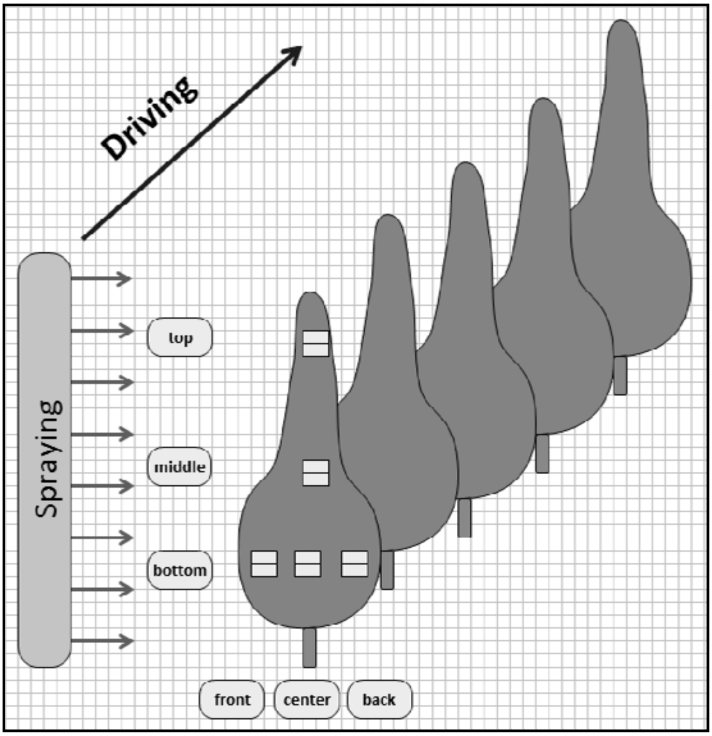

Figure 3. Deposition trials were performed by spraying in one direction. Tracers were placed on the upper and lower side of the leafs at each position.

Tabel 1. Deposition values after application with the cross flow sprayers with different nozzle types and fan speed.

Deposition in µl/cm²		8 ATR			8 TVI			8 ATR low fan speed		
location in tree	side of leaf	front	center	back	front	center	back	front	center	back
top	upper		0,036			0,076			0,116	
	lower		0,504			0,585			0,703	
middle	upper		0,543			0,711			0,570	
	lower		0,463			0,635			0,543	
bottom	upper	0,248	0,130	0,114	0,399	0,129	0,042	0,449	0,209	0,077
	lower	0,426	0,153	0,133	0,485	0,191	0,094	0,435	0,176	0,085

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Testing the influence of the air flow rate on spray deposit, coverage and losses to the ground in a super-intensive olive orchard in southern Spain

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Introduction

Olive tree is a key crop in the whole Mediterranean basin, and especially in Spain, where its economic and social importance rises as it is the main World producer. Nevertheless, pesticide application still exhibits an important lack of knowledge about the optimal parameters setup in commercial air blast sprayers. Even though the European Directive for the sustainable use of pesticides (Directive 128/2009, EP) refers to dose adjustment, low attention is paid to other key factors involved in the application quality as the Air Flow Rate (AFR).

Due to the high canopy volume and tree spacing existing in traditional olive tree crops (Miranda-Fuentes et al., 2015), most farmers tend to use a very high AFR, assuming the pesticide penetration of the canopy to be higher. This assumption induces the use of high power tractors and increases of pollution. Therefore, a trial was set up to determine the optimal AFR to be applied to obtain the optimal spray deposit on leaves, homogeneity and coverage.

Materials and methods

Three AFRs of 11.93, 8.90 and 6.15 $m^3 s^{-1}$ were tested in a field trial performed with a commercial air blast sprayer with axial fan (model 2200 l, Osuna Sevillano, Jauja, Spain) and hollow cone nozzles Albuz ATR Series (Albuz, Saint-Gobain Ceramiques Avancees Desmarquest, Evreux, France) in a super-intensive olive tree crop in a commercial field in Pedro Abad, Córdoba, Spain. Other application parameters are listed in table 1.

Table 1. Work parameters of the trial

Parameter	High Flow (HF)	Medium Flow (MF)	Low Flow (LF)
Nozzle type and colour	Albuz ATR Orange	Albuz ATR Orange	Albuz ATR Orange
Number of open nozzles	14 (2 x 7)	14 (2 x 7)	14 (2 x 7)
Pressure (bar)	15.0	15.0	15.0
Liquid flow rate ($l \cdot min^{-1}$)	24.01	23.11	24.71
Spray volume ($l \cdot ha^{-1}$)	768.2	744.2	778.2
Forward speed ($km \cdot h^{-1}$)	4.90	4.98	5.03
VMD* (µm)	136	136	136
PTO speed (rpm)	458.6	420.4	280.0
Air volumetric flow rate ($m^3 \cdot s^{-1}$)	11.93	8.90	6.15
Fan gear	2	1	1

Before the treatments, basic characteristics of the trees were measured. Food dye E-102 (tartrazine) was used as spray tracer to measure the normalized deposition inside the canopy and losses to the ground, and Water Sensitive Papers (WSP) were clipped to the leaves to determine the coverage and the number of impacts per area unit. Nine sampling zones were established inside the tree canopy, dividing it into three heights and three depths, and four sampling zones were established on the ground (fig.1).50 leaves and two WSPs, were collected from each sampling zone in the canopy, and an absorbent paper sheet of 260 x 210 mm from each sampling zone on the ground.

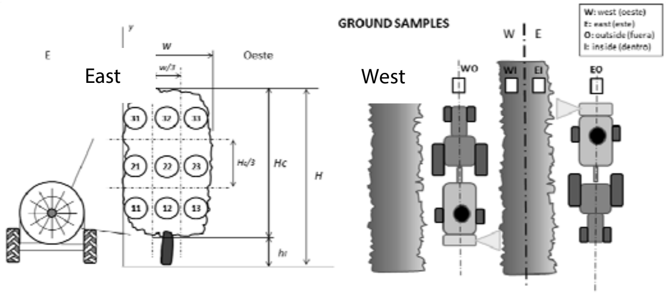

Figure 1. Sampling distribution in the canopy (left) and on the ground (right).

Results and discussion

Results show that AFR has significant effect on the mean spray normalized deposit, corresponding the highest deposit (13.0 µg cm^{-2}) to the Medium Flow (MF) treatment. The lowest mean deposit (10.5µg cm^{-2}) was found in the High Flow (HF) treatment, and the Low Flow (LF) produced the intermediate mean deposit (11.1µg cm^{-2}).About the percentage penetration of the spray, calculated as the inner zones' mean deposit divided by the mean of the outer zones' mean deposit, the HF treatment gave the lowest penetration percentage (79.1 %) while the highest penetration was obtained with the MF treatment (91.4 %). LF gave the intermediate value (82.2 %).In terms of homogeneity of distribution of the applied spray, measured by the CV (%)of deposition values in the whole canopy, the three tested AFRs gave similar results: the HF gave the lowest homogeneity (CV = 37.0 %) in opposition to LF, which gave the highest homogeneity (CV = 32.2 %). The LSD All-Pairwise Comparisons Test (α = 0.05) showed no significant differences between treatments for homogeneity.

Losses to the ground did not vary significantly with the AFR, with deposits of 3.58, 3.44 and 4.21 µg cm^{-2} for the HF, MF and LF, respectively. Nevertheless, the highest losses to the center of the track were found to be produced, significantly, with the HF treatments (4.41 µg cm^{-2}), while the lowest were produced by the LF treatment (2.54 µg cm^{-2}). The opposite case is found under the trees, where the LF presents the highest deposits (5.89 µg cm^{-2}) and the HF the lowest (2.74 µg cm^{2}).

The mean percentage coverage of the upper side of the leaves, with 77.4%, 66.5% and 58.9% for the HF, MF and LF treatments respectively, did not present significant differences for the tested AFRs, but the underside did. The highest coverage was achieved with the HF (71.0 %), whilst the lowest (37.2 %) corresponded to the LF treatment. The MF produced mean underside coverage of 57.4 %. Nevertheless, the number of impacts did not present significant differences in any case.

Conclusions:

The tested AFRs produced differences in deposits and their distribution. The medium air flow rate of 8.90 m^3 s^{-1} seems to be the most balanced regarding the high deposits, the best penetration and the medium losses to the ground and coverage quality parameters. Special attention should be paid to the upper parts of the canopy, where deposits are much lower and located application could be an interesting choice for future sprayer designs. The trial results are against the popular beliefs of the Spanish farmers in the sense that highest AFRs are not the best at penetration and mean deposits, and generate excessive leaf coverage.

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Development of a software for supporting the adjustment of vertical spray pattern of air-assisted sprayers

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Introduction

One of the key aspects related to an appropriate adjustment of sprayers for pesticide application in orchard is the correct choice of the vertical spray profile, which should always be adapted to the geometric characteristics of the target. Nevertheless the research of the most appropriate spray profile is normally an empiric activity, based on the registration, using ad hoc vertical patternators, of the different spray patterns that one can obtain from a sprayer modifying different operating parameters (e.g. number and position of active nozzles, liquid flow rate, orientation of spray jets, amount and direction of the air flow, etc.). This operation requires time and usually does not allow to examine all possible sprayer adjustment options, but just some of them.

Objective of the present work was therefore to build a software tool enabling to rapidly foresee the geometry of vertical spray profiles generated by any type of sprayer just on the basis of some information about the operating parameters adopted (number and position of active nozzles, flow rate, air flow amount and orientation, etc.).

Methodology of work

The software was developed on a web platform using the PHP5.0 language. It is possible to access the software from the web page of DiSAFA – Crop Protection laboratory.

The tool consists of two main databases: one concerns the information about the sprayer, the second one contains the data referred to the spray profile generated by the nozzles. About the sprayer, the position of each single nozzle (expressed in Cartesian coordinates having their origin on the ground in correspondence of the center of the sprayer, with transverse X axis and vertical Y axis), the air velocity and the air direction measured in proximity of the nozzle (positive numbers for the air addressed upwards and negative numbers for the air addressed downwards) were considered. Concerning the spray profile, for each nozzle the data related to the spray profile measured on a horizontal test bench at 0.50 MPa pressure, expressed in ml/degree, were stored in the database.

The software user selects the sprayer type, then provides the size characteristics of the vineyard/orchard to apply (e.g. inter-row distance, minimum and maximum height of the vegetation, eventual transverse slope of the rows). The software draws a graphical representation of the system sprayer/orchard (or sprayer/vineyard) with a set of boxes to be filled in with the active nozzles and with the operating parameters (pressure and forward speed). For each box related to nozzles it is possible to select from a list the type and size of the nozzle to be mounted on the sprayer, if nothing is selected it means that the nozzle is not active.

At the end of the selection of active nozzles and operating parameters the software user press the button “process” and it appears the spray profile overlapped to the scheme of the trees with the calculation of the corresponding volume rate.

The user may repeat several attempts until when he obtains a spray vertical profile adequate to his needs.

After this simulation it is necessary to check directly on the sprayer conveniently setup that the real spray profile corresponds to the intended one.

At the moment it is not possible the web update of the database.

Results and discussion

To validate the diagrams resulting from the calculation tool a comparison was made with the corresponding spray profile really measured using an air-assisted sprayer and a vertical patternator. Thanks to the assessment of an Index of Similarity (IS), ranging from 0 to 100, it was possible to state if the diagram virtually obtained was similar or not to the one measured at the test bench.

Results were good (IS always higher than 60) and therefore a user friendly software was realised. It could be used by farmers and technicians to easily foresee the vertical spray distribution profile obtained from an air-assisted sprayer in function of the operative parameters selected.

The software will be available in several languages.

Results of Measuring the Air Distribution of Sprayers for 3D-Crops and Parameters for Evaluating and Comparing Fan Types

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Introduction

The realisation of an efficient crop protection in three dimensional crops with respect to work rate, avoidance of visible deposits on the fruit, minimized risk for phytotoxicity, minimized number of fillings per spray trip, minimized pesticide consumption and minimized costs, requires low volume spray application with small droplets. To keep their high potential for spray drift low and reduce spray drift to levels obtained with air induction nozzles, officially registered combinations of techniques and methods for drift reduction are available in Germany and Austria since a number of years. Basic requirement for drift reduction from small droplets is a fan with cross flow characteristics and rectangular air distribution over working height. The former reduces long distance vertical spray drift while the latter allows adaptation of the horizontal reach of the air stream by forward speed and fan speed to canopy width, so that almost no more spray mist spews from the canopy into the next alley way, resulting in a maximized deposition at the target and a reduction of short distance horizontal spray drift.

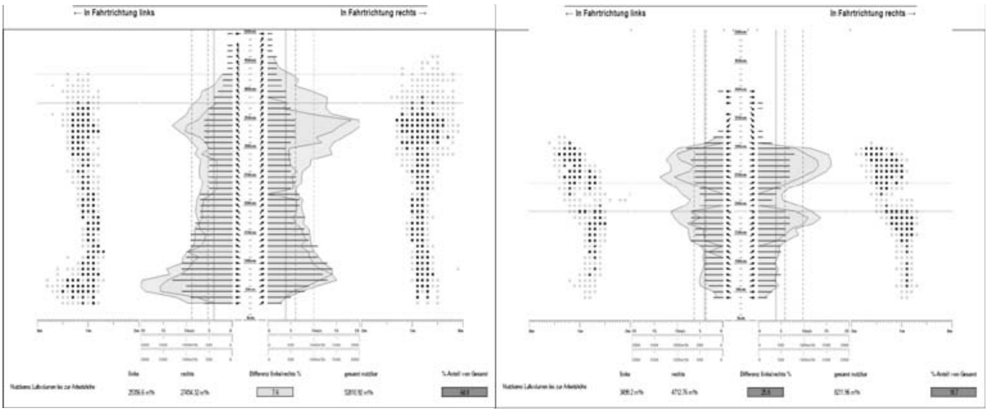

Figure 1: Unusable vertical air distribution patterns of fans with cross flow characteristics from orchard sprayers for canopy adapted spray application

Besides the reduction of spray drift, a canopy adapted air stream remarkably improves the efficacy of pesticide deposition, allowing canopy adapted dosing and canopy adapted spray application at high forward speeds of up to 12 km h^{-1} in slim canopy structures which increases work rate once more and reduces fuel consumption and noise emissions enormously. The adaptation of fan speed to canopy width therefore offers a whole range of important benefits to the fruit and wine grower, explaining the increasing interest in this technique.

A major obstacle of applying this technique at the grower level is an uneven horizontal reach of the air stream of most fan types produced for three dimensional crops (**figure 1**), because in the past only fan power has been of interest since it was and still is a wide spread misbelief that successful crop protection requires high air flow rates. Unfortunately the operation of a fan with an uneven air distribution at a combination of fan speed and forward speed where the horizontal reach of the air stream at one or more specific sections of the fan is too low to properly penetrate the canopy at the corresponding positions, causes infestation from pests and diseases. Without having the chance to measure and correct this defective distribution, the only chance for avoiding spray application related infestation is an increase of fan speed and/or a reduction of forward speed to increase the horizontal reach at the section where it has been too low. All three cases result in a reduced quality of the spray cover and increased spray drift, but also raise fuel consumption and noise emission; if forward speed has been reduced in addition to an increase of fan speed, also time consumption is increased. In any case costs for crop protection are rising because of a poor air distribution. Excessive fan speed and a necessity to reduce forward speed because of a poor air distribution also increase the risk of complaints from bystanders and settlement areas next to orchards and vineyards, potentially leading to serious public conflicts. Therefore the adaptation of the spray application to canopy characteristics by adapting fan speed and forward speed to canopy width is considered absolutely essential for a highly efficient application of pesticides and the minimization of a range of negative side effects in three dimensional crops.

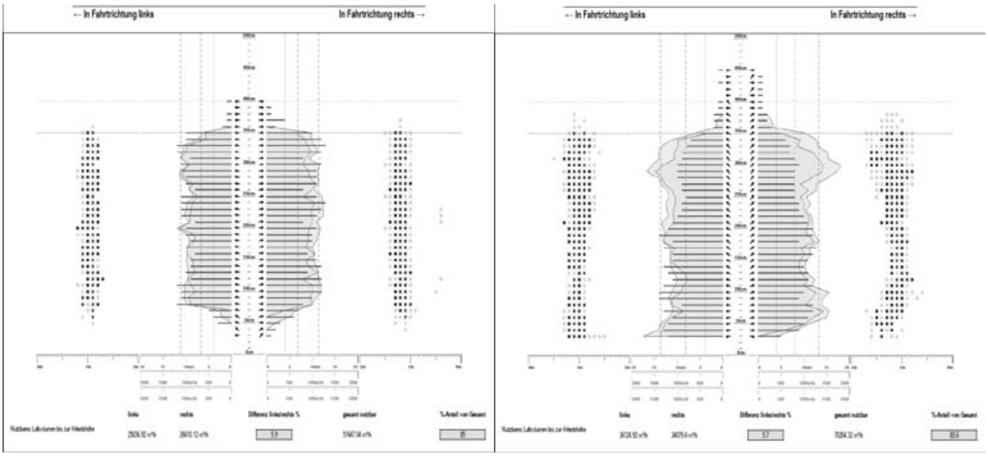

Figure 2: Almost perfect vertical air distribution patterns from orchard sprayers adjusted to a working height of 3.5 m

Material and Methods

To measure the air distribution of a fan, but also to individually adjust working height to the tallest structures that are going to be treated at the buyer´s farm and to straighten the horizontal reach of the air stream over farm specific working height to obtain a rectangular distribution, test benches are required. Improving the air distribution of fan types in general requires a close cooperation with sprayer manufacturers since many fan types require extensive constructive modifications to improve the vertical air distribution. At the begin of a fan type testing procedure the maximum working height is identified after which the horizontal reach of the usable air volume is straightened within this working height in order to obtain a rectangular air distribution. After the fan has passed the air distribution test at 460 PTO speed and high fan gear (**figure 2**), it is tested again at 540 PTO high gear and 300 PTO low gear to gain data about the changes in usable and non usable air volume and working height as fan speed varies. In a next step energy consumption and noise emission are measured at the PTO shaft at all three fan speed settings to obtain "environmental data", important for the calculation of energy consumption, CO_2-footprint, several efficiencies, and noise emission, allowing the direct comparison of fan types from various brands.

From energy consumption, amount of usable air volume and maximum working height at defined settings of the fans, first universal parameters for the comparison of all kinds of fans have been developed, as there are the "*usable air volume per hour and meter of maximum working height*" describing the strength of the fan and the "*specific fuel consumption per m^{-3} of usable air and hour*", describing the energy efficiency of the fan, but also total fuel consumption including the tractor to give the growers an idea about total Diesel consumption per hour.

This comparison is important for advisors and growers to select the most suitable fan type for the farm specific situations concerning working height, required usable air volume, fuel consumption, noise emission and other parameters. The protocol delivered with the new sprayer proves that the sprayer reaches the desired working height and provides a rectangular air distribution pattern at both fan sides, enabling the buyer to adapt fan speed to any canopy width on the farm without the risk of producing stripes of infestation from pests and diseases at minimized spray drift, fuel consumption and noise emission.

Air flow influence on agricultural sprays: application to a specific vineyard sprayer

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Introduction

Agricultural hydraulic nozzles are generally classified according to mean values of spray droplet diameter, like Dv10, Dv50 (*i.e*. Volume Median Diameter) or Dv90 measured on vertical sprays without any air co-flow. In vineyards, some sprayers deliver sprays that are horizontally oriented, and may be surrounded by an air flow. A previous study showed that median diameter was not affected by nozzle orientation (horizontal versus vertical), but gravity effect was noticeable regarding spatial repartition of droplet diameter and velocity [1]. The objective of this study was to investigate the effects of air flow on horizontal sprays, regarding droplet diameter and droplet velocity.

Materials and Methods

Three different nozzles were used, namely a standard hollow cone nozzle TXA 80 0067 khaki (Teejet, USA), an air-induction hollow cone nozzle TVI 80-0050 violet (Coors Tek Solcera, USA) and an air-induction flat-fan nozzle IDK 90 01 orange (Lechler, Germany). Nozzles were mounted on a vertical boom taken from a vineyard sprayer (Vectis, Tecnoma, France). The injection pressure P of each nozzle was such that the delivered flow rate of water was identical, equals to 0.37 $l.mn^{-1}$ (P = 5.7 bar for the TXA, P = 10 bar for the TVI and P = 2.6 bar the for IDK nozzle).

Two series of measurement were carried out within a plane at a distance x = 40 cm from the nozzle exit, the first one without air flow, the second one with an air flow (maximum velocity of 12 m/s at x = 40 cm). This distance corresponds to the usual spraying distance in vineyards. There was an angle between nozzle axis and air flow axis (parallel to x) of 30 degrees (see Figure 1).

Droplet diameter and one velocity component were measured using a Phase Doppler Particle Analyzer (Dantec, Denmark). The velocity component corresponded to the projection of the droplet velocity vector along the x axis. The measurements were performed at room temperature (T=24°C, relative humidity H = 70%).

Results

Values of Dv10, Dv50 and Dv90 of the three nozzles without and with air flow are presented in Table 1. Values were only slightly changed by air flow addition. This first result shows that nozzle assessment without air is appropriate.

Nozzle Type	TXA @5.7 bar		TVI @10 bar		IDK @2.6 bar	
	Without air	With air	Without air	With air	Without air	With air
DV10 (µm)	73	72	235	214	327	331
DV50 (µm)	121	118	405	385	577	572
DV90 (µm)	173	172	621	583	830	828

Table 1: Dv10, Dv50 and Dv90 measured by PDPA at 40 cm from the nozzle exit.

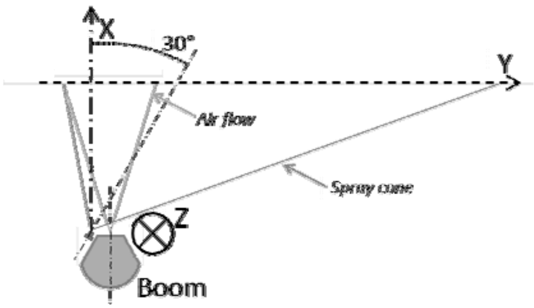

Figure 1: Top view of the Experiment

Profiles of the averaged velocity component (left) and the averaged diameter (right) are presented for the three nozzles with (blue dotted line) and without (red solid line) air flow in Figure 2. Average was calculated on droplets caught for all z values.

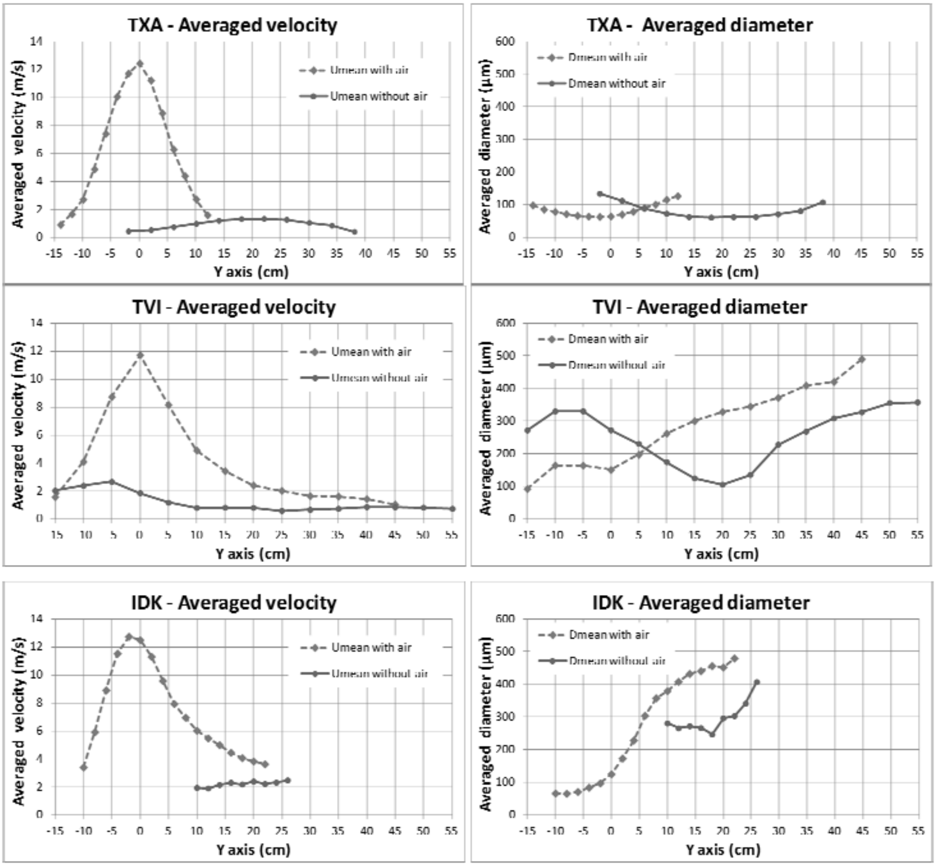

Figure 2: Averaged velocity (left) and averaged diameter (right) of the three nozzles TXA, TVI, and IDK, with air (blue dotted line) and without air flow (red solid line).

Concerning the TXA nozzle, the averaged diameter profile is only translated along the y axis due to the air flow. Concerning the TVI nozzle, without air the averaged diameter profile is a classical one, composed of smallest values near the spray centre and larger values at the edges. With air, there is a spatial redistribution of droplets along the y axis: largest droplets provided with highest kinetic energy go through the air flow whereas smallest ones can not and stay in the region $y<0$.

Concerning the IDK nozzle, without air, averaged diameters of 300 microns along the minor axis of the ellipse are obtained (y between 10 and 25 cm) whereas with air, the spray spreads (y between -10 cm and +20 cm). The same diameter gradient along y axis as for the TVI nozzle is found: smallest averaged diameter values for $y<0$ and larger averaged diameter values when increasing y).

These results are consistent with those previously obtained by our colleagues from IFV/Irstea using the EvaSprayViti test bench, which show that deposits are increased by air flow addition using TXA nozzle.

References

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Section 2

Field Data of Pesticide Spray Drift on Coffee Crop

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Introduction

Coffee (*Coffea arabica* L.) production represents an important agricultural activity in South America and Brazil is the biggest world producer and exporter of coffee. The crop is subject to various pests and diseases that, in many cases, require chemical control. However, little information exists about technology for the application of insecticides and fungicides on coffee. Knowledge of the performance of pesticide-spraying equipment is very important for appropriate application, ensuring both biological efficacy and environmental safety. Coffee plant architecture is different from the most common orchard crops. The plant is a woody perennial dicotyledon, cylindrical shaped and with high leaf area index. Despite the scenario of environmental risk from pesticides, there is a lack of studies evaluating pesticide spray drift under the specific conditions of coffee production, especially under tropical conditions. The objective of this work was to determine spray drift curves generated by traditional and low-drift applications of pesticides on coffee plants.

Materials and Methods

This study was performed at the Coffee Production Sector of the Federal University of Uberlândia (Minas Gerais, Brazil). All the applications used a hydropneumatic airblast sprayer (Arbo 360, Montana, Brazil) with 12 nozzles (6 on each side) coupled to the hydraulic system of a tractor (265E, Massey Ferguson, Brazil). The evaluated nozzles were of the hollow cone jet type with and without venturi, corresponding to the ATR 80° Orange 3.0 nozzle (Albuz, France) (traditional application) and the TVI 8002 nozzle (Albuz, France) (low-drift application), respectively. A spray volume of 400 L ha^{-1} was used. The displacement velocity of the machine was 8.2 km h^{-1} and the air flow rate was 1.61 m^3 s^{-1}. The working pressures for the ATR and TVI spray nozzles were 1.567 MPa (227.5 lb in^{-2}) and 1.447 MPa (210 lb in^{-2}), respectively. For the drift study, the rhodamine B tracer was used (Synth, Brazil) at a concentration of 100 mg L^{-1} added to the spray for later quantification by fluorimetry. The applications were conducted in an area planted with Catuaí Vermelho coffee (LAI: 4.38) spaced 3.8 m between lines and 0.7 m between plants. The experimental design consisted of randomized blocks in a 2 x 20 split plot with 10 replicates, with the first factor referring to the spray nozzles and the second referring to the number of distances evaluated in relation to the last line sprayed. Prior to the applications, blotting papers (Jprolab, Brazil) were fixed at ground level in an area adjacent to the crops outside of the target area perpendicular to the direction of the sprayer application and in the main direction of the wind (downwind). The papers were placed from a distance of 2.5 m from the center of the last pass of the sprayer up to 50 m, spaced 2.5 m from each other, totaling 20 distances in relation to the last sprayed line. The four lines of plants adjacent to the drift-evaluation area were sprayed, for a total length of 50 m. Meteorological conditions were monitored during the applications. With the deposition data from the collectors, the percentage of drift for each distance was calculated, relating the deposit to the quantity applied in the field. The data were subjected to analysis of variance and the nozzles were compared to each other for each distance using Tukey's test at 0.05 significance, while a regression analysis was performed for the distances. The spray drift curves obtained for each nozzle were compared to each other using the confidence interval of the equation parameters. For this comparison, the data were linearized using the log(x) function and subjected to regression analysis. The upper and lower limits of each equation parameter were identified, and if the intervals were not superimposed at the 95% confidence level, the curves were considered different.

Results

The applications made on coffee plants with the venturi hollow cone nozzle (TVI) caused less spray drift than those with the ATR nozzle up to 20 m of distance from the last line sprayed (Table 1). Beyond this distance, there was no difference between the nozzles. Thus, the TVI nozzle reduced spray drift for the areas closest to the crop. Based on regression analysis, the power model showed good fit to the data for both of the sprayer nozzles, although the R^2 for the TVI nozzle is lower than for the ATR nozzle, which is most likely associated with the difference between the value observed and the value estimated for the 2.5 m distance (Figure 1). The application with hollow cone nozzle results in 6.68% of maximum spray drift in the nearest collectors of treated area.

Acknowledgements

To National Council of Scientific and Technological Development (CNPq), Brazilian Enterprise for Agricultural Research (Embrapa), National Council for the Improvement of Higher Education (CAPES) and Research Foundation of the State of Minas Gerais (Fapemig) for the financial support.

Table 1. Drift percentage (Field data) resulting from the use of sprayers with standard hollow cone (ATR) and venturi nozzles (TVI) in coffee plants applying a spray volume of 400 L ha^{-1} (1)

Distance from the treated area (m)	Spray nozzle	
	ATR[1]	TVI[2]
2.5	6.68 b	5.06 a
5.0	2.75 b	1.59 a
7.5	1.67 b	0.85 a
10.0	1.33 b	0.63 a
12.5	1.03 b	0.47 a
15.0	0.82 b	0.40 a
17.5	0.69 b	0.35 a
20.0	0.52 b	0.30 a
22.5	0.45 a	0.29 a
25.0	0.41 a	0.31 a
27.5	0.37 a	0.30 a
30.0	0.35 a	0.29 a
32.5	0.33 a	0.28 a
35.0	0.32 a	0.30 a
37.5	0.30 a	0.30 a
40.0	0.30 a	0.33 a
42.5	0.30 a	0.30 a
45.0	0.28 a	0.31 a
47.5	0.29 a	0.30 a
50.0	0.29 a	0.32 a
F_{nozzle} = 8.282*; F_{dist} = 108.860**; F_{int} = 2.965*		
OR: F_{Levene} = 23.267**; K-S = 0.272**; F'_{Tukey} = 858.318**		
T: F_{Levene} = 13.567**; K-S = 0.164**; F'_{Tukey} = 351.741**		

(1)Means followed by equal letters, in the rows, do not differ by Tukey's test, at 5% probability. F_{nozzle}, F_{dist} and F_{int}: values of F calculated for the nozzle, distance and interaction, respectively. **Significant at 1% probability; *Significant at 5% probability. F_{Levene}, K-S and F'_{Tukey}: values of the F statistic for the Levene test, K-S for the Kolmogorov-Smirnov test and F for Tukey's test for the additivity of the blocks, respectively, which test the assumptions of the original data (OR) and the data transformed (T) by arc-sin√(x/100). [1]ATR: hollow cone jet nozzle; [2]TVI: venture hollow cone jet nozzle.

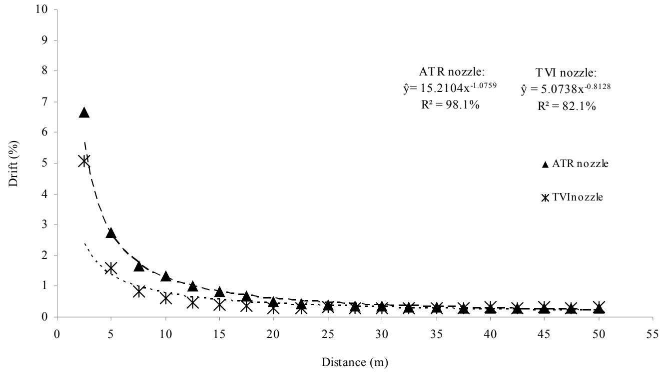

Figure 1. Drift curves from applications on coffee plants made with standard hollow cone (ATR) and venturi (TVI) spray nozzles applying a spray volume of 400 L ha^{-1}.

Spray drift measurements in Italian vineyards and orchards

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Introduction

Also in Italy, following the indications of the EU Directive 128/2009/EC on sustainable use of pesticides, it is foreseen the introduction of mandatory buffer zones. Agrochemical companies, in the registration process of new PPP, shall evaluate also the eventually required buffer zones width and mention it in the PPP label. In this evaluation process due to the lack of national drift value references also in Italy are used procedures and models based on the "Ganzelmeier curves" (now known as Julius Kuhn Institute drift reference curves) that have been realized thanks to experimental data acquired in Germany, therefore in an agricultural and environmental context that is quite different from the Italian one.

Scope of the present study was therefore to collect a representative set of experimental drift measurements referred to the Italian context in vineyard and in orchard, using axial fan sprayer models that are the more diffuse at national level, with using conventional set-up or adopting spray drift reduction techniques (SDRT), such as air induction nozzles.

Material and Methods

Experiments following the ISO 22866 methodology for measurement of spray drift in the field were carried out in apple orchards and in vineyards located in two different Italian regions: Emilia-Romagna and Trentino Alto Adige (Tab. 1). Conventional axial fan and tower shaped air-assisted sprayers were used in trials, comparing different sprayer setups, which included the adjustment of the vertical spray profile, of the air flow rate and the selection of the nozzles (conventional vs. air induction hollow cone nozzles). Tests were made at two different growth stages (end of flowering, BBCH 69 and fully developed vegetation, BBCH 81-91). For each growth stage, 8 sprayer configurations were tested in orchard and 8 sprayer configurations were tested in vineyard. A solution of yellow Tartrazine E 102 was applied in the experiments and spray deposits collected on the artificial targets (filter clothes material and plastic Petri dishes) positioned on the ground at different downwind distances were measured by spectrophotometric analysis. Tests were carried out with air temperature ranging from 13°C to 35°C, air humidity ranging from 25% to 75% and average wind speed ranging from 1.1 to 4.8 m/s.

Region	Crop type	Cultivar	Training system	Layout
Emilia-Romagna	Vineyard	Barbera	GDC	4 x 1 m
Emilia-Romagna	Apple orchard	Golden Delicious	Vaso	4.2 x 1.1 m
Emilia-Romagna	Apple orchard	Red Chief	Vaso	4.5 x 1.2 m
Trentino	Vineyard	Muller Thurgau	Pergola semplice	2.7 x 1 m
Trentino	Apple orchard	Fuji	Spindel	3.5 x 1.1 m
Trentino	Apple orchard	Golden Delicious	Spindel	3.5 x 1.1 m

Table 1 – Main characteristics of the vineyards and apple orchards where spray drift measurements were carried out.

Results and discussion

Results pointed out that the use of an appropriate adjustment of the sprayer, in terms of spray profile and/or air flow rate, contributed to reduce the amount of spray drift with respect to the standard sprayer configuration. Most effective drift reduction however, especially at distances over 10 meters from the applied field, was achieved by the use of air induction nozzles.

Independent of the growth stage, the use of SDRT enabled to reduce spray drift in vineyard by 75% on average (Fig. 1A). The average spray drift curve obtained in Italy using the standard sprayer configuration resulted much higher with respect to the JKI reference curve for vineyard (Fig. 1B).

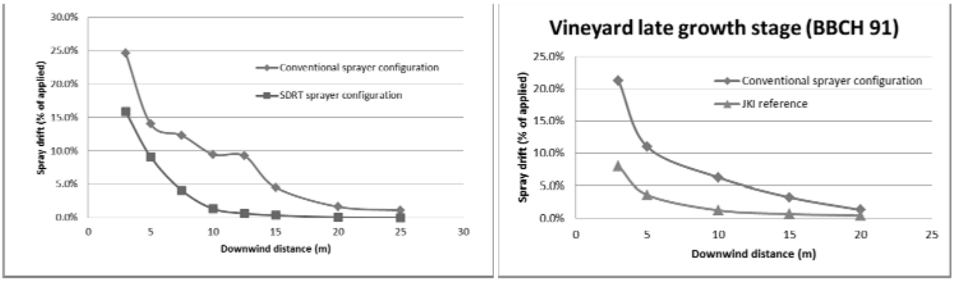

Figure 1. A) Comparison of average spray drift curves obtained in Italian vineyards using conventional sprayer configurations and sprayer configurations equipped with SDRT. B) Comparison of the average spray drift curve assessed in the Italian vineyards at late growth stage (BBCH 91) with the curve of reference JKI basic drift values.

On the other hand, in orchard, independent of the growth stage, the use of SDRT allowed to reduce spray drift by 46% on average (Fig. 2A). The average spray drift curve obtained in Italy using the standard sprayer configuration resulted much lower with respect to the JKI reference curve for orchard (Fig. 2B).

The differences registered between the amount of spray drift measured in orchard and in vineyard in the Italian context with respect to that reported in the JKI reference curves can be due to the different characteristics of the vegetation, especially in terms of layout and of training system, to the wind conditions during the execution of the trials and to the different technical features of the sprayers.

Considering the huge variety of layouts and training systems present in Italy, especially concerning vineyards, but also orchards, further drift measurements are necessary to get reference spray drift curves representative of the national context.

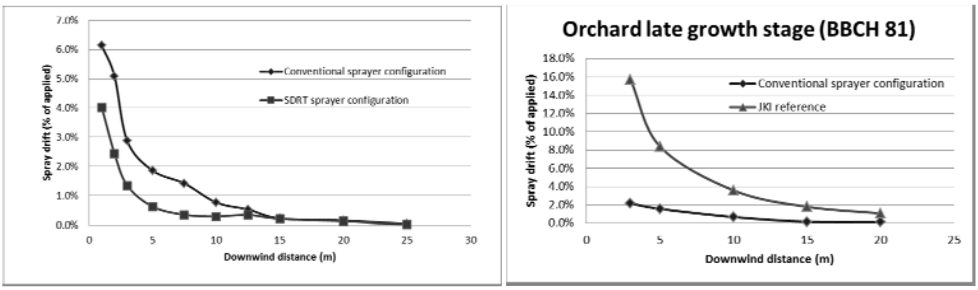

Figure 2. A) Comparison of average spray drift curves obtained in Italian orchards using conventional sprayer configurations and sprayer configurations equipped with SDRT. B) Comparison of the average spray drift curve assessed in the Italian orchards at late growth stage (BBCH 81) with the curve of reference JKI basic drift values.

Acknowledgment

Authors wish to thank Dow AgroSciences company for funding this study.

Vertical and horizontal spray distribution of hollow cone nozzles in a wind tunnel. A preliminary study to mitigate spray drift in orchard applications.

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Introduction

Hollow cone nozzles are still widely used in orchard spray applications because of their small droplet sizes, visible sound coverage without air assistance on early vegetation stages. However, drift mitigation issues along water courses, sensitive crops and public areas generally imply the use of larger droplets generated by air injection hollow cone nozzles [Polveche et al., 2011]. This preliminary study aims at better defining the correlation between spray distribution patterns [Tamagnone et al, 2011] and drift curves both measured in IRSTEA wind tunnel equipped with a 9 m long distribution test bench. Vertical and horizontal spray orientations were compared with wind velocities of 0-2-4 and 5 m.s-1.

Materials and methods.

Nozzles

4 hollow cone nozzles from ALBUZ Company were tested: ATR Yellow, ATR Red, TVI Lilac, TVI Green, TVI Orange. Spray angle was 80°. Droplet sizes were measured by using a Dantec PDPA device (Power 2.5W, diffusion mode, 600 mm optics).

Table1 : Nozzle characteristics Nozzle type – injection pressure 10 bar

	Flowrate (l.min-1) at 10 bars	VMD (µm)
ATR Yellow	1.03	143
ATR Red	1.72	173
TVI Lilac ISO 80-025	1.83	542
TVI Orange ISO 80 - 010	0.73	581
TVI Green ISO 80 – 015	1.10	702

Wind tunnel

All experiments were conducted in IRSTEA wind tunnel under temperature and air humidity control of 20°C and min. 90% respectively. Each modality (1 nozzle, 1 position, 1 pressure, 1 height) was tested 3 times (3 repetitions). Flow distributions were measured at 1 m height without any wind following 2 positions of nozzles. When wind speed is operated in the wind tunnel, sedimentation values are accumulated along the distance and the opposite value is calculated as a drift ratio [Douzals et al.,2014].

Results

Vertical distribution without wind (1 m height)

Fig 1a and 1b show the distribution patterns of tested nozzles in vertical and horizontal position. Recovery rates were found to vary from 93% (ATR Yellow, TVI Lilac), up to 97% (ATR Red, TVI Orange, TVI Green). Horizontal spray distribution patterns were logically found to be dependent on droplet size with expected differences between ATR and TVI nozzles.

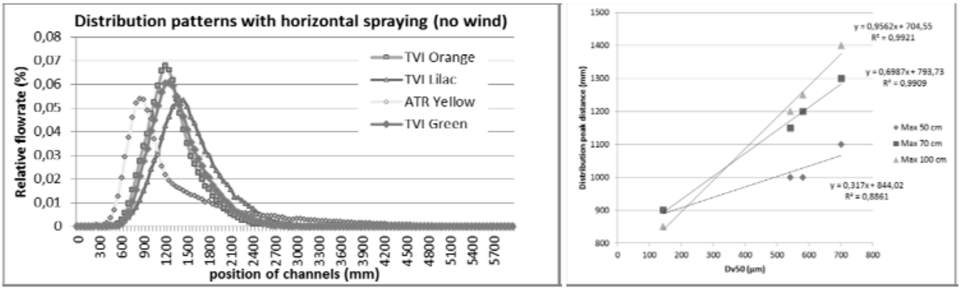
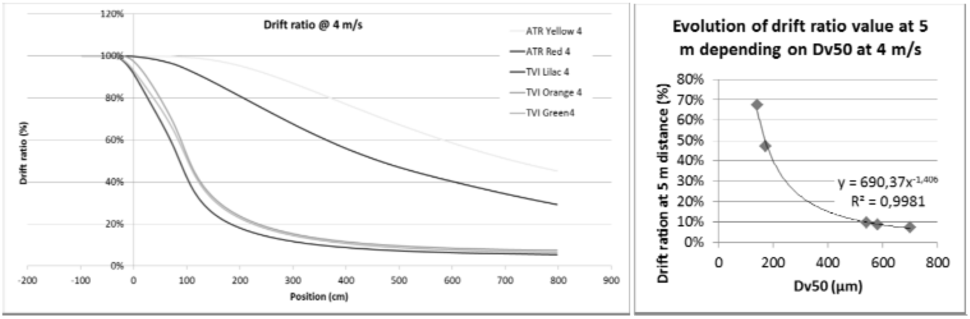


Fig 1a and 1b: Distribution patterns form horizontal spraying (1 m height) and correlation between droplet size and the peak distance

Drift measurements of Hollow Cone nozzles under windy conditions

Fig 2a introduces the relative drift obtained in the wind tunnel for a wind velocity of 4 m.s-1. (horizontal spraying) and Fig. 2b, the correlation between Dv50 and the drift ratio value at 5 m distance.



Drift ratio curves (Fig 2a.) are given as an example among the different wind speeds and nozzle orientation tested. A clear discrimination is observed between nozzle types (ATR vs TVI).

Conclusion

These preliminary results aimed at defining different hollow cone nozzles behavior on a distribution test bench with or without wind. When nozzles are oriented horizontally, the position (distance) where the peak occurs seems a relevant indicator of droplet size. Furthermore, when wind is applied, the spray pattern is modified but the drift ratio at a given distance is quite similar and also related to droplet size.

Acknowledgments

Authors are grateful to Albuz Company for their support and the Ministry of Agriculture (Etude sur l'optimisation de l'utilisation des pesticides et fertilisants, 2013).

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Challenges for CFD modeling of drift from air assisted orchard sprayers

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Introduction

Plant protection products (PPP) play an important role in providing high crop yields by minimizing risks associated with the occurrence of pests. Some of the sprayed material may however move beyond the intended target and results in drift to non-target objects. Modeling approaches help to understand, characterize and minimize spray drift using computer simulations rather than field experiments. However, modeling drift from orchard spraying presents particular challenges: (1) the moving spray interacts with the canopy before reaching the drift area and thus the airborne fraction of spray is reduced by tree interception (Duga et al., 2014); (2) the vertical wind profile changes from the orchard to the neighboring field that has a different vegetation (Duga et al., 2015); (3) the moving airjet from the air assistance cannot be ignored because the magnitude of the air jet velocity is typically higher than the wind velocity (Duga et al., 2015). As a result the modeling becomes rather complex. Here we present a CFD model of spray drift to calculate sedimenting and airborne drift from orchard sprayers in a typical apple orchard in Belgium that attempts to take these challenges into account. Preliminary results are shown that help to understand the spray drift modeling issues and are a basis for further model refinement and validation against orchard field drift measurements.

Materials and Methods

A CFD orchard drift model was developed based on a model for predicting the on-target spray distribution in orchards (Duga et al., 2015). The model considers the real architecture of the trees, the canopy wind flow and the moving sprayer outlet with dedicated spray nozzles. It then computes the tracks of representative droplets of the nozzle size distribution from the nozzle to the target, non-target surfaces directly around the tree and remaining in the air. This model was validated with on-tree measurements of deposition (Duga et al., 2015). The model considered trees within the bulk of the orchard and was restricted to a small domain around a single tree and two neighboring trees. For drift, however, a larger domain needs to be considered to predict the ground and airborne drift at larger distances behind a side row of trees. Ina first attempt, a computational domain having 12m height and 40 m length was used to represent the drift area next to the row of three orchard trees. The wind and the air flow from the sprayers were modeled using the Unsteady Reynolds Averaged Navier-Stokes (URANS) equations and the k-ϵ turbulence model which were solved using the unstructured finite volume method in a CFD code of ANSYS-CFX (ANSYS, Inc., Canonsburg, Pennsylvania, USA). The path of the spray droplets within the turbulent air flow field were tracked using the Lagrangian particle tracking multiphase flow model combined with acanopy deposition model(Duga et al., 2014).Architectural data of the trees was collected during field trials and used in the model simulations. We solved the model for a crossflow sprayer (DuoProp, BAB Bamps, Sint-Truiden, Belgium) in an apple orchard. The model can be easily adapted to other sprayer types and training systems (Duga et al., 2015). The calculations took a total CPU time of 144hours using two computing nodes on a KU Leuven HPC Linux cluster each having 64GB RAM.

Results

Fig.1 shows the predicted airflow, particle track and deposition contour plots of the one-sided spray application of the apple classical training system with the crossflow sprayer under a wind flow of 1.5 m/s (10 m height) and 85° angle to the spray direction. What is seen is the accumulated spray tracks emitted from 8 nozzles on the machine as the machine drives along the 3 trees. The combined effect of this wind and the spray jet results in a complex airflow through, around and beyond the tree that strongly affects the deflected spray. Within the canopy there is a considerable amount of deposition, but certainly a large amount of mainly smaller particles moves beyond the trees into the drift zone. Definitely, drift from orchard sprayers is a complex three-dimensional process that requires to include temporal dynamics (driving), tree interception, wind direction and magnitude, and machine and nozzle characteristics. However, we can also see the following limitations from this simulation result. First, the domain must be sufficiently wide to account for the deflected spray to deposit in the drift area such that accumulated drift curves with distance from the row can be established. Now, a significant part of the spray is still airborn when it leaves the CFD domain. Second, note that this simulation does only consider 3 trees in the row for computational reasons. As a result, air and spray are allowed to flow around the trees (avoiding their resistance). Thus, improved models must minimize this erroneous effect by modeling a longer row, which may not be computationally feasible, or implementing a simplified representation of the row. The CFD model will be adapted accordingly and validated against drift measurements from orchards.

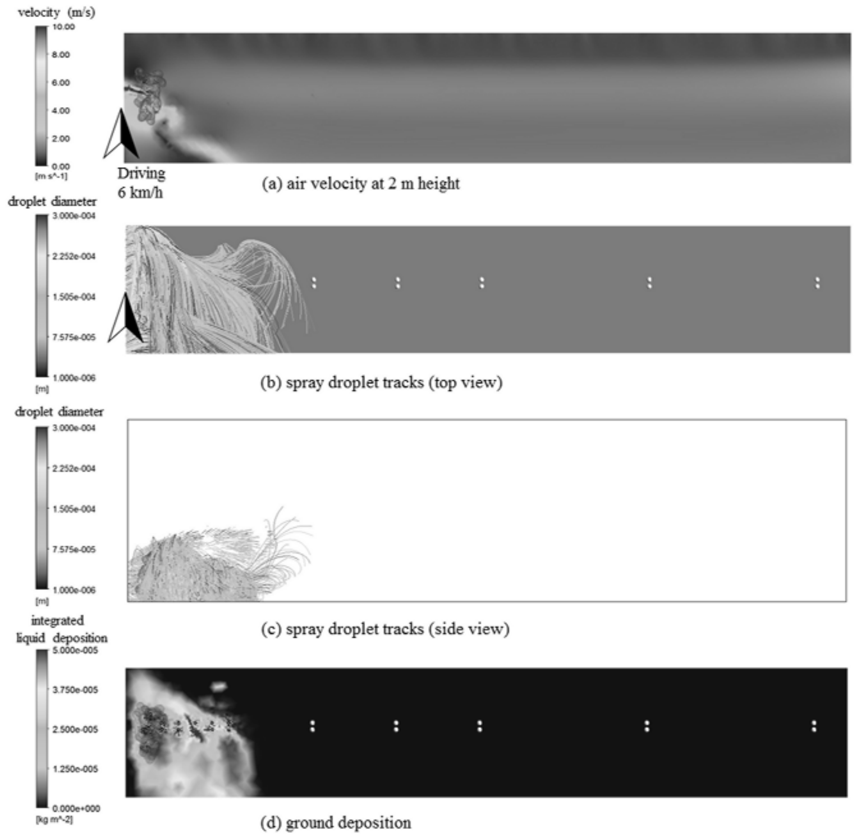

Fig. 1. CFD spray drift simulations

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First Measurements with a Lidar System Specifically Designed for Spray Drift Monitoring

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Introduction

Pesticide spray drift is usually measured by means of passive collectors and tracers. However, there are several drawbacks to their use, related to the fact of being a time-consuming, single-point and time-averaged sampling methodology. Alternative methodologies are being searched in order to overcome these difficulties. In this line, lidar technology is one of the most promising alternatives since it can measure the spray drift in real-time, with high range resolution, requires little labour and low time consumption, and it does not need chemical analysis (Gregorio et al, 2014). In spite of these advantages, so far lidar systems have been used in a limited number of spray drift studies (Hiscox et al., 2006; Khot et al., 2011) due to its high cost, complexity and the fact that most systems are not eye-safe. This article compares the measurements obtained with a new lidar system specifically developed for spray drift monitoring with those obtained using passive collectors following the ISO 22866 standard.

Fig. 1. Lidar system (foreground) measuring the spray drift generated by the sprayer (background).

Fig. 2. Horizontal and vertical collectors distribution (ISO 22866), and the mirror.

Material and Methods

The spray tests were carried out between November 11 and 21, 2014, at a field site in Gimenells (41º39'11''N, 0º23'28''E, elev. 259 m) located 25 km away from Lleida, Spain. The trials were performed in an intensive apple orchard (growth stage, BBCH:92) with tree rows at right angle to the prevailing winds (Fig. 1). The spray was generated by an axial-fan air-assisted sprayer (Teyme Eolo 2091) operating at 1 MPa. Two nozzle types were tested: standard (Albuz ATR 80 Grey) and low-drift nozzles (Albuz TVI 80-03, Blue). The sprayed volumes were 810 and 860 l/ha for the standard and for the low-drift nozzles, respectively. The spray liquid was an aqueous solution of brilliant sulfoflavine. For the measurement of ground drift, filter papers (horizontal collectors) were placed every 2.5 m up to 20 m downwind from the last tree row and every 5 m from 20 to 40 m. For the measurement of airborne drift, 6-m height nylon lines (vertical collectors) were placed at 5 and 10 m downwind. Also, water-sensitive paper sheets attached to the vertical pole at 5 m were used for measuring the airborne drift.

The lidar system is based on a 1534-nm wavelength, 3-mJ pulse-energy erbium-glass laser (Gregorio et al., 2015). It is an eye-safe system, with high range (2.4 m) and temporal (100 ms) resolution, scanning capability and easy to carry. The lidar was placed at a distance of 70 m from the trees and pointing to a mirror (45º of inclination) placed near the pole at 5 m (Fig. 2). The laser beam is emitted horizontally with a path parallel to the horizontal collectors. The mirror reflects the beam vertically so its path is parallel to vertical collectors. This experimental set up allows a simultaneous comparison of lidar measurements with both horizontal and vertical collectors.

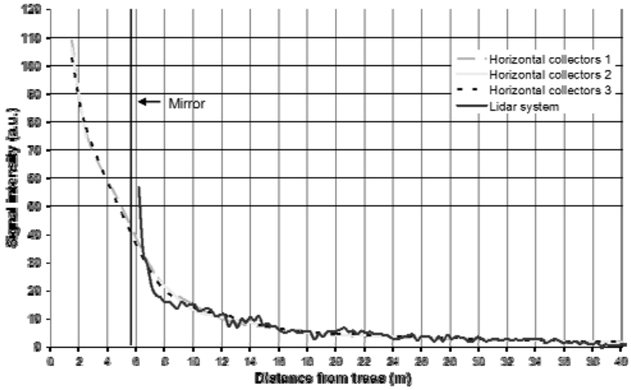

Fig. 3. Time-integrated lidar signal and tracer mass captured by horizontal collectors at each downwind distance from the last tree row (arbitrary units).

Results

Figure 3 compares the received lidar signal with the measurements carried out by horizontal collectors for a standard nozzle test. A high coefficient of determination ($R^2 \approx 0.90$) between both measurements is observed. Similar high determination coefficient figures are obtained with low-drift nozzles (not shown in the figure) while in this case the signal is lower, as was expected. It can be concluded that the lidar system is able to differentiate between both cases. Preliminary analysis demonstrates that the lidar has also measured airborne drift. Currently, data processing is being carried out in order to compare these measurements with those obtained by vertical collectors. These first results are encouraging to propose a new lidar-based methodology alternative to current ISO 22866 standard methodology with passive collectors.

Acknowledgements

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Drift reduction of low drift nozzles in spraying citrus orchards

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Key words: Spraying pesticides, Drift prevention, Citrus orchards.

Introduction

Drift is especially critical when spraying fruit, vine and citrus orchards where pesticides are intensively used. In this context, cone low drift nozzles (LDN) intended for spraying tree crops, have been evaluated relating to cone standard nozzles (STN) in laboratory and deciduous fruit orchards (Van de Zande et al. 2012); (Planas et al., 2013).

In citrus orchards, it has been shown that drift depends on several variables like sprayer design and spraying volume (Salyani et al., 2013). But the potential benefits of the LDN are yet unknown. This is, probably, because citrus orchards are mainly located in regions where, for the time being, the use of LDN is just beginning. A set of field trials have been carried out to evaluate LDN (spray drift and efficacy) when spraying citrus. In this publication only the results on drift are reported. LDN have been also tested in insecticide applications for the control of California red scale (CRS) *(Aonidiella aurantii)*. Efficacy of the treatments is equivalent for STN and LDN. These results are reported in a complementary communication (Garcerá et al., 2015).

Materials and Methods

Trials were carried out in two orchards of Clementine cv. Clemenules (*Citrus clementina* Hort. ex Tan.), located respectively in Roquetes (Tarragona, Spain) and Montserrat (Valencia, Spain). Nozzles were fitted to air-blast sprayers (Figure 1). Five replications for each nozzle were conducted. Experimental conditions are reported in Table 1.

The percentage of volume of drops having a diameter smaller than 200 µm, V_{200}, was calculated by dimensioning droplet spectrum for each nozzle at the experimental work pressure by means of a Phase Doppler Particle Analyzer (57X10 Dantec Dynamics A/S. Skovlunde, Denmark).

Following ISO 22866 methodology, drift was measured for the LDN Albuz TVI 8003 vs. STN Albuz ATR 80 grey and vs. STN Teejet D3DC35.

Airborne spray deposition onto horizontal surface collectors placed outside of the treated area was measured and expressed as the percentage of the spraying volume. Moreover, drift reduction with each LDN tested was calculated.

Results and conclusions

Drift values were higher for both STN and LDN in Trial 1, which could be explained through the factors determining drift (Figure 2). In Trial 1, drift was favoured by the lower canopy volume (crop interception), counteracting the theoretical reduction effect on drift due to the lower fan air volume rate. This fact points out that, besides nozzles, these factors must be taken into account to prevent drift.

However, regardless the operating conditions, LDN significantly reduced drift in both trials (Figure 2). Drift reduction in each trial was 35.5% and 22.8%, respectively. In consequence, LDN can be clearly recommended in order to reduce spray drift in citrus orchards. Nevertheless, before its wide adoption, LDN should be progressively validated according to the efficacy of the treatments against the main pests and diseases of citrus.

		Trial 1 Roquetes		Trial 2 Monserrat	
Orchard	Tree spacing (m x m) (between rows x between trees)	6.00 x 4.00		5.00 x 3.50	
Canopy	Height (m)	2.85		2.75	
	Width along row (m)	2.80		2.90	
	Width crossing row (m)	2.50		3.70	
	Volume (ellipsoid) (m^3)	10.4		14.6	
	Volume occupied* (%)	15.2		30.3	
Sprayer	Operating nozzles (number)	20		16	
	Forward speed (km h^{-1})	2.02		1.58	
	Spraying volume rate (l ha^{-1})	2400		2600	
	Fan air volume rate (m^3 h^{-1})	29700		69700	
Nozzles	Type	Albuz TVI 8003 Blue	Albuz ATR 80 Grey	Albuz TVI 8003 Blue	Teejet D3DC35 Brown
	Work pressure (MPa)	1.3	1.5	1.0	1.0
Wind	Velocity (m s^{-1})	1.91 ± 0.46	2.17 ± 0.52	2.37 ± 0.85	2.72 ± 0.78
	Direction (º to spray track)	-20.22	-20.83	8.42	14.4

*volume of the canopy (ellipsoid) related to the orthogonal volume (tree spacing x canopy height).

Table 1. Experimental parameters and operating conditions

Figure 1. Operating sprayer on Trial 1

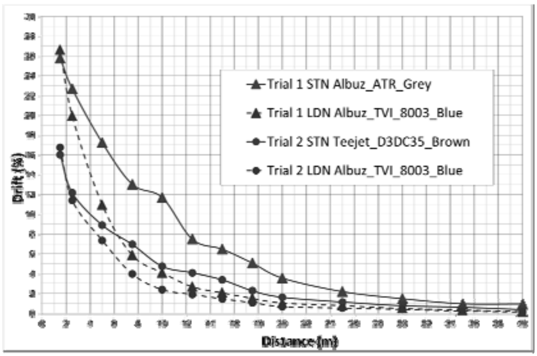

Figure 2. Sedimenting drift at each downwind distance from the last tree row

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Spray drift and resident risk in orchard spraying; reference and spray drift reducing techniques

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Introduction

In the Netherlands spray drift experiments for orchard spraying were carried out on a uniform basis comparing a reference spray technique and to be classified drift reducing techniques. Due to the large number of measurements a discrimination could be made based on the BBCH code for pome fruit development during the year distinguished between the periods full leaf (BBCH 74-92), the intermediate periods (BBCH 61-73and 93-0) and the dormant (BBCH 0-60) period (Zande & Wenneker, 2013). As spray drift measurements were done both as ground deposition next to the orchard and as airborne drift at one distance from the last treated tree row of the orchard spray drift curves could be generated both for surface water and for bystander and residents risk analysis (Zande et al., 2010, 2014).

Materials and Methods

Spray drift measurements were carried out according to the ISO standard (ISO 22866; 2005) adapted for the situation in the Netherlands (ground deposits, ditch, surface water next to the sprayed field) following the Dutch protocol (TCT, 2003). Apple trees were sprayed with a solution containing the fluorescent dye Brilliant Sulpho Flavine (BSF) and a non-ionic surfactant (Agral) to the spray agent. Spray drift deposition was measured using collectors (synthetic cloths of 0,05m^2/0,1 m^2) which were placed at several distances up to 25 m from the centre of the last tree row on ground surface on the downwind edge of the orchard. At 7.5 m distance from the last tree row, collectors (Siebauer Abtriftkollektoren) were fit to vertical lines up to 10 m height to collect airborne spray drift. The spray drift was measured by quantifying the BSF deposition on the collectors. The extrapolation of airborne spray drift at 7.5 m measuring distance to different distances is based on results of individual tree row sprayings (full leaf and dormant situation) with a cross-flow fan sprayer (Michielsen et al., 2007).

The reference technique for orchard spraying is a cross-flow fan sprayer (Munckhof), equipped with Albuz ATR lilac nozzles, which at 7 bar spray pressure produces a Very Fine spray quality (Southcombe et al., 1997). The experiments were carried out from early (dormant) to late growth stages (full leaf, leaf fall) of the trees. In the early growth stages (developing foliage), air assistance was supplied with low gear settings for the fan. In the fully developed foliage stage, experiments were carried out with high gear fan settings. In total 316 spray drift measurements of the reference sprayer were analysed with 144 measurements in the full leaf stage (BBCH 74-92), 140 measurements in the dormant stage (BBCH 0-60) and 32 measurements in the intermediate (BBCH 61-73, 93-0) period. Drift Reducing Techniques can be grouped in drift reduction classes of 50%, 75%, 90% and 95% drift reduction compared to the reference (ISO22369-1). Entries in the drift reducing classes in the Netherlands for orchard spraying (based on spray drift deposition at 4.5-5.5 m from the last tree row in the full leaf situation) are determined. The results are based on comparative field measurements and are grouped in the different drift reduction classes.

Results

Measured spray drift deposition on ground surface and estimated airborne spray drift (% of sprayed volume per unit area at 0-2 m height) based on measured airborne spray drift at 7,5 m downwind of the orchard at of the reference spray technique and the Drift Reducing Techniques of the classes 50%, 75%, 90%, 95% for fruit orchard spraying are presented in respectively Figure 1 and Figure 2at distance from the last tree row.

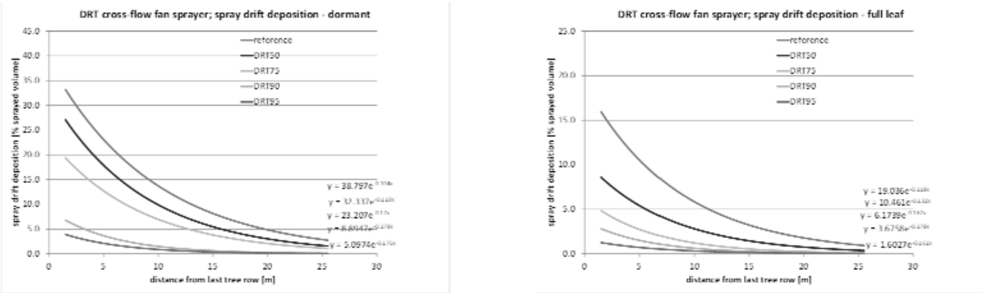

Figure 1. Measured ground deposition of spray drift (% of sprayed volume per unit area) downwind of the sprayed orchard in the dormant (BBCH 0-60; left) and full leaf situation (BBCH 74-92; right) at distance (m) from the last tree row for the reference cross-flow fan sprayer and Drift Reducing Technologies classes (DRT50, DRT75, DRT90, DRT95)

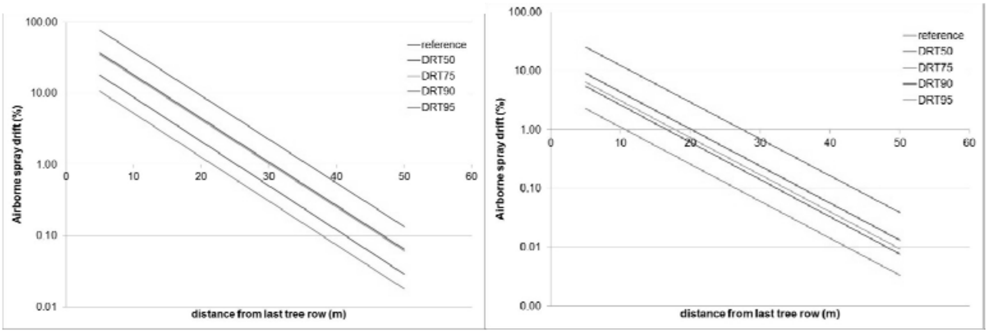

Figure 2.Estimated airborne spray drift (% of sprayed volume per unit area at 0-2 m height, log-scale) downwind of the sprayed orchard in the dormant (BBCH 0-60; left) and full leaf (BBCH 74-92; right) situation at distance (m) from the last tree row for the reference cross-flow fan sprayer and Drift Reducing Technologies classes (DRT50, DRT75, DRT90, DRT95) based on measured airborne spray drift at 7.5 m distance from last tree row

Results show that a 1% spray drift deposition at ground level occurs for the standard application technique at 35 m distance from the last tree row in the dormant situation and at 25 m in the full leaf situation of the trees. A 1% airborne spray drift level at 0-2 m height is estimated at 36m distance from the last tree row in the dormant situation and at 28 m in the full leaf situation of the trees. These distances can be reduced to resp. 10 m and 3 m for the ground deposition and 22 m and 11 m for the airborne spray drift using a DRT95 spray technique.

For the next years a research programme is set up for quantification of the residents risk from orchard spraying in the Netherlands. In this research the spray drift path way from the orchard to residents living around orchards will be quantified. Special attention will be paid to get further knowledge of especially the airborne spray drift over distance from the orchard boundary to the residents at different distances. Measurements will be done on spray drift (airborne and ground deposition), vapour drift during and directly after spraying and volatilisation from the crop after spraying.

Acknowledgements

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Measuring of spray drift by an electrostatic method

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Abstract

This paper presents a new method for the measurement of the spray drift of the atomized stream of a sprayed liquid. Existing test methods - measuring the weight of the liquid during spraying or catching the drops of above-all water, do not allow to quickly and accurately measure the exchanges in spray drift caused by environmental conditions. The traditional methods do not provide possibilities to measure the quantity of spray drift during a normal operation of the sprayer in an orchard or in the open field. The purpose of the study was to examine the possibility of using the effect of electric charged liquid particles to measure the quantity of spray drift. The method of measuring the quantity of spray drift by measuring electrical charges carried by the microdroplets, will eliminate the disadvantages of traditional methods, and also open new possibilities for the measurement and statistical analysis of the measurement results. This method is based on the measurement of the electric charge carried by water drops e l e c t r i c a l l y charged . The electrostatics sensor to measure the droplet size, is associated with a system scanning the sprayed surface. The electric charge carried by the droplet, depends on its size and charging voltage. Thus, by measuring the amount of charge at a constant voltage supply it is possible to determine the movement of the atomized liquid stream and the size of the droplets.

The amplified and conditioned signals from the electrostatic sensor are send to the computer system to analyse the size and spatial distribution of the droplets.

The high sensitivity of the instrument allows the detection of very small spray drift liquid particles which are most susceptible to spray drift, and are often undetectable by conventional methods. Performing real-time measurement provides instantaneous observations of the effect of sprayer s e t t i n g s , t h e spray distribution and spray drift.

Keywords: lateral spray drift,electrostatic, measurement systems

Preliminary investigation of Phase Doppler derived flux measurements in a wind tunnel for the sampling of orchard spray drift

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Introduction

Air-assisted spray equipment used for horticultural cropping systems depend on high air velocities to project the spray as well as to open the canopy for greater droplet penetration and deposition. However, these sprayer-types are also at a heightened risk for spray drift as they possess the potential to place drift prone droplets in the atmosphere where they can be carried to off-target locations. Unfortunately, quantifying these droplets can be difficult and expensive using samplers such as high-volume air samplers, rotating rods and strings. However, while these measuring techniques may give some idea of flux, no particle information can be gained which is imperative to predicting the mass which may be the most prone to drift. In wind-tunnels and field studies, polyester and nylon strings have proven to be an efficient collecting surface. Therefore, it was the objective of this study to assess the potential for the use of a novel, field grade Phase Doppler Interferometer (PDI) as a replacement for strings as a sampler for driftable mass for orchard type sprayers.

Materials and Methods

This study was conducted at the University of Queensland, Wind Tunnel Facility (Gatton, Australia) 19 and 20 March 2014. Tunnel wind conditions were set to deliver 1.34, 2.24, or 4.47 m s^{-1} (3, 5, or 10 mph, respectively) laminar air flow. Examined nozzles consisted of the XR110-02 and XR110-04 flat fans which were pressurized at 3 bar (43.5 psi). The spray solution for string sampling procedure included a 0.4 gm/L pyranine solution and spray timer set at 10s; water only was used for PDI measurements and sampling time was extended to 40s to allow for more samples and statistical validity. String flux measurements were assessed using the 1,600mm x 2mm nylon strings whereas strings were stretched taunt and parallel to the tunnel floor, 2m away from the spray nozzle at 0.1, 0.2, 0.3, 0.4, and 0.5 m high. Once individual treatments were complete, the strings were given ≥5 minutes in the running wind tunnel to dry before harvesting. Samples were then directly analysed or placed in the freezer for later analysis. Analysis consisted of adding 60 mL directly to the bag in which the coiled string was stored. The bag was then pinched closed and solution distributed to extract florescent material from the string. Once this was sufficiently accomplished, a subsample was added to a test tube/cuvette and fluorescence read. These readings were compared to a base curve from a subsample taken from the spray tank before the commencement of the experiment. Once these data points were made and calculated into the percent applied, the deposition was then calculated using the diameter and length of the string, and the time exposed. PDI flux measurements were acquired at three static points measured from the tunnel wall (centre/800 mm, 528 mm and 264 mm) and at the aforementioned heights. The three flux points were then averaged and doubled to encompass the whole width of the tunnel. These data were then divided by their specific sampling time to determine a deposition reading. Finally, an analysis of variance was conducted to determine similarities between the two sampling techniques as the conducted($P \geq 0.05$).

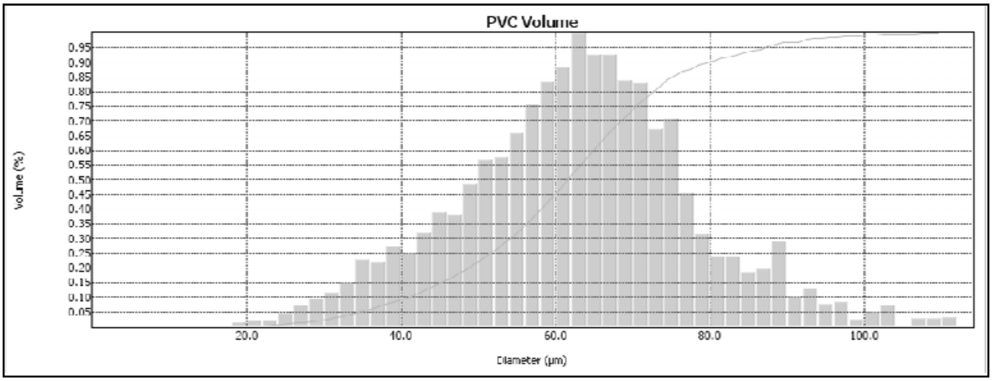
Results

P-values (Table 1) indicate no statistical differences between the strings' deposition data and the converted flux data of the PDI for the two nozzles, three wind speeds and five heights. One disadvantage to the use of the PDI in the wind-tunnel is that the number of droplet/sample counts that is typically required is impractical; the sheer volume of solution that is needed to receive an "adequate" reading inundates the tunnel, ergo flooding the facility. Past researches have suggested sampling between 2,000 and 10,000 counts might be sufficient. Counts from the present study varied largely (0 to 4,000), however no differences were observed and it was quickly determined that it was essential that time be the constant factor in this instance. It is also important to note that while there may be a discrepancy in the number of samples that this is preliminary work for orchard spray research where air velocity and sprayer volume will immediately increase the number of counts. For field sampling it is predicted that PDI technology will not face the same issues as strings and will perform better as the PDI will not become saturated or have particle effects such as droplet shatter and bounce from the string surface. Lastly, other pertinent information is accrued via the PDI technique such as droplet size distribution (Fig 1) and velocity, for example.

Table 1. Statistical summary of PDI versus string flux data for two nozzles.

Wind Speed	Height	P-value	
m/s	cm	XR110-02	XR110-04
1.34	10	0.735	0.678
1.34	20	0.487	0.566
1.34	30	0.484	0.675
1.34	40	0.802	0.260
1.34	50	na	na
2.24	10	0.361	0.788
2.24	20	0.175	0.134
2.24	30	0.823	0.308
2.24	40	0.646	0.237
2.24	50	0.076	0.694
4.47	10	0.364	0.878
4.47	20	0.580	0.538
4.47	30	0.565	0.900
4.47	40	0.976	0.723
4.47	50	0.779	0.725

Figure 1. Example of droplet spray distribution of driftable mass using phase Doppler technology.



Section 3

Efficacy of standard and low drift nozzles for insecticide applications against Aonidiella aurantii (Maskell) in citrus

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Introduction

The use of low-drift nozzles (LDN) is the cheapest and easiest method to reduce drift. However, use of LDN may affect the efficacy of plant protection products for controlling targeted pests. Studies characterizing LDN efficacy in apples have been described (Heinkel et al., 2000; Frießleben, 2004; Lešnik, 2005; McArtney & Obermiller, 2008), but none have been published in citrus. This is significant because in contrast to apples, citrus trees have a globular shape and a very dense canopy. For these reasons, the aim of this work was to investigate the efficacy of insecticide applied using LDN or standard cone nozzles for the control of California red scale (CRS) (*Aonidiella aurantii* (Maskell) (Hemiptera: Diaspididae)) in citrus.

Materials and Methods

A season-long trial was conducted during 2014 on a commercial Clementine cv. Clemenules orchard, located in Valencia (Spain). Trees were planted at 6.5 x 3.5 m spacing and averaged 2.7 m in height, with a crown projection of 3.7 x 4.7 m. Three treatments, one with standard hollow cone nozzles TeeJet D6-DC23, another with LDN Albuz TVI 80 02 and a control treatment of no insecticide application, were performed. All applications were made at a volume rate of around 2500 l/ha. Treatments were applied by an axial fan air-assisted sprayer (model Futur 3000, Pulverizadores Fede S.A., Cheste, Spain) operating at 1 Mpa, 1.45 km/h, 490 rpm at PTO, and maximum air flow of 14.1 m^3/s. Treatments were applied three times during the season, when peaks of susceptible stages of each CRS generation were identified. In spring, a mixture of Reldan® E (Dow AgroSciences Ibérica S.A., Madrid, Spain) and Atominal® 10 EC (Sumimoto Chemical Co. Ltd., Tokyo, Japan) was applied; in summer Reldan® E was used straight, and in autumn a paraffinic oil (Agroil. Sipcam Inagra, S.A., Valencia, Spain). All products were used at the registered label rate.

The trial was performed in a randomized complete block design with four replicates. In each replicate, the 8 central trees were used as the sample trees, and the outer trees were used as a buffer between treatments. Treatments were assigned to four replicated plots based on densities of CRS at harvest time in the previous season (2013), so that there were no statistically significant differences in the initial infestation between treatments.

The biological efficacy of each treatment was evaluated by estimating the level of infestation 45 days after the treatment (DAT) against the first generation and the second generation and just prior to harvest. The level of infestation was obtained by counting the scales present in 30 fruits around the canopy of each sample tree (30*8= 240 fruits sampled per replication). The percentage of fruits with more than 10 scales was calculated. Fruits were selected from two heights (top and bottom) and five locations per height, corresponding to the four faces and the interior of the tree. The distribution of CRS infestation over the canopy at harvest time was studied.

Results

No statistical differences between treatments with standard and low-drift nozzles were found on the number of scales present on the fruit and on the percentage of infested fruits with more than 10 scales (Figure 1) in any of the samplings carried out. However, they differed significantly from the Control treatment in the second and third sampling. These differences increased with time showing a very fast CRS infestation over the control fruits.

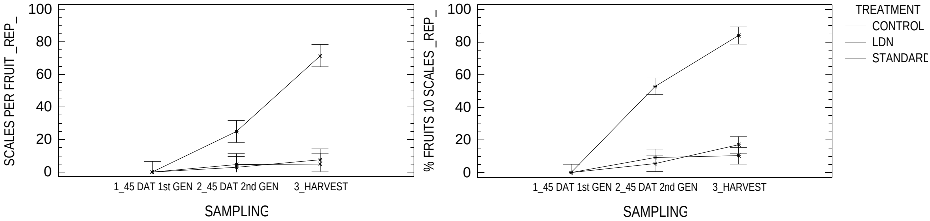

Figure 1. Number of scales/fruit (Left) and percentage of fruits with more than 10 scales (Right) for the Control, Standard and Low-drift treatments in each sampling. Mean ± 95% LSD interval. Means whose LSD Intervals do not overlap are significantly different.

At harvest, the distribution of the pest inside the canopy was similar for standard and low drift treatments but different from the Control treatment (Figure 2). Control treatment showed the highest infestation in the southern face of the trees, both in the top and the bottom of the canopy. The sides between trees within the row (East and West) showed the second highest infestation. Treatments with standard and low-drift nozzles achieved the higher reduction of infestation in the outer sides of the tree (between the rows), which faced the sprayer (North and South) (97%). In the centre of the canopy the reduction was 88% and in the sides between trees 90%. Comparing CRS distribution in height, it was observed that in the bottom of the canopy, infestation was the lowest, for any treatment, and this part of the canopy achieved the highest reductions of infestation with both nozzles (90% in the top vs 95% in the bottom).

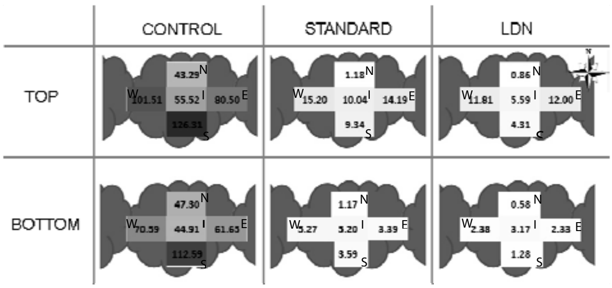

Figure 2. Cross section view of the distribution of the pest at two canopy heights (Top and bottom) for the Control, Standard and Low-drift treatments at harvest time number of scales/fruit. The intensity of red color indicates the level of infestation, the higher the intensity, the higher the infestation. N: North, S: South, E: East, W: West, I: Inner

This work concludes that low-drift air-injection nozzles are the solution to reduce drift when applying insecticides against CRS in citrus with no efficacy comprise.

Acknowledgements

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Optimization of early growth stage treatments of the vine: experimentations on the artificial vine EvaSprayViti

S. Codis[1], A. Vergès[1], C. Auvergne[3], J.F. Bonicel[2], G. Diouloufet[2], R. Cavalier[4], J.P. Douzals[2], J. Magnier[2], P. Montegano[2], X. Ribeyrolles[2], B. Ruelle[2]

[1] Institut Français de la Vigne et du vin (IFV) 361, rue J.F. Breton, 34196 Montpellier(France). E-mail : sebastien.codis@vignevin.com;
[2] IRSTEA Montpellier (UMR ITAP); (3) Chambre d'agriculture de l'Hérault ; (4) Chambre d'agriculture du Gard.

Introduction

The reduction of the use of plant protection product is an important objective of research and development in the French vine sector. Improvement of spray application techniques appears to be a tangible way to achieve a significant part of this objective. It also appears that spray applications carried out during first growth stages of the vine (3 to 10 leaves unfolded) are the one offering the more important leeway. Indeed, practices of spraying are not often specifically adapted to the development of the vegetation. Actually, in most cases the same sprayer is used whatever the growth stage and the settings of this unique machine are not often done in an optimal manner according to the nature of the targeted foliage. Moreover, the French legislation do not encourage to adapt the spraying practices to the conditions of the treatment because the dose rate is defined by unit of soil area, independently of other factors.

In order to deliver advices to vine farmers concerning the adaptation of spraying practices to the vegetation features, IFV, IRSTEA and the network of Chambers of Agriculture from Hérault, Gardand Pyrénées-Orientales areas have carried out several experimental tests on the artificial vine EvaSprayViti. A focus has been made on the early growth stage treatments for which room for improvement is the widest.

Materials and methods

Spray deposition was assessed for different spray application techniques on the artificial vine EvaSprayViti at early growth stage. The row spacing implemented was 2,5meters and the leaf area index of EvaSprayViti at early growth stage was 0,24 ha/haas it is described in *Codis et al.* 2013.

The distribution of tracer deposition within the canopy of the vine row was evaluated by segmenting the vegetation structure into 4 compartments corresponding to 4vegetation depth ranges. One measure is made for each one of the four compartments. When required by the sprayer conformation, two rows were assessed. The performance of three sprayers was assessed for several settings specified in the table 1 below.

Results

The histograms below, fig. 4, 5 and 6 respectively show the deposits (per unit of leaf area) measured in each compartment of vegetation (first to fourth "curtain") for the three sprayers.

Considering that most treatments are done at full dose rate using a pneumatic arch sprayer circulating every four rows which is the main common practice, the minimal deposit (among the 2 x 4 compartments) inherent to this application technique have been considered as the minimal reference. Then dose reduction possibilities have been evaluated according to this reference. A fifty percent dose rate reduction has been advised for pneumatic arch sprayers or air blast sprayers circulating every two rows. No dose reduction has been advised for the other ways of using these two sprayers whereas it was advised to carry out treatments with the hoop early stage sprayer using the third of the dose (66% dose reduction).

During the last season, no difference in terms of epidemiologic results was observed in a monitored plot where these advices of dose reduction were tested.

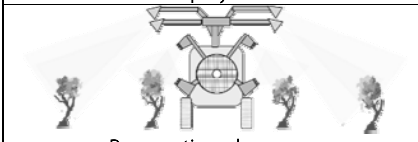
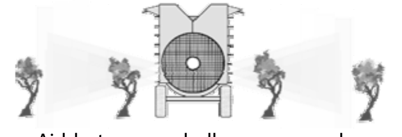
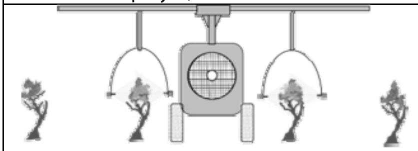
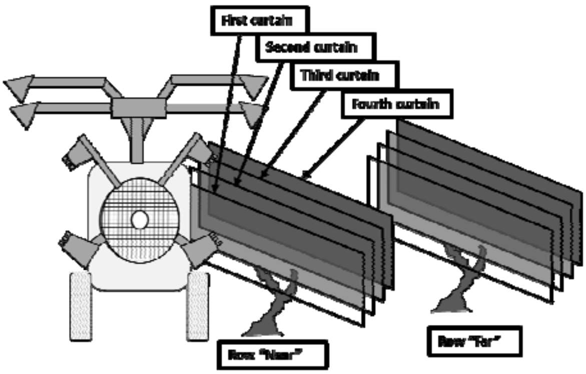
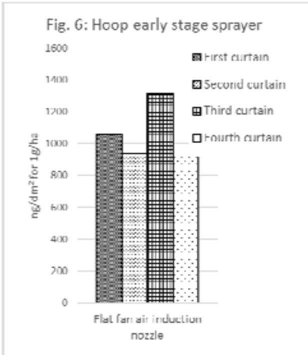
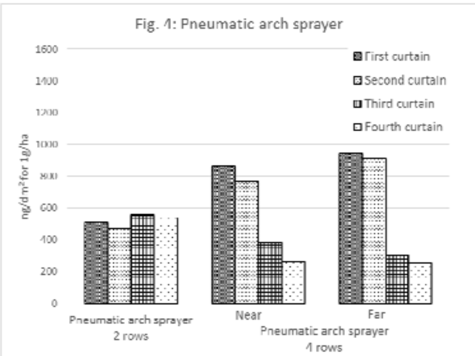
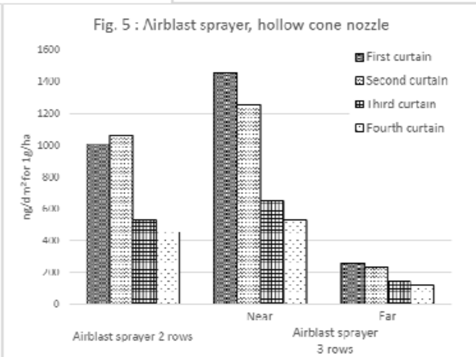
Sprayer	Settings assessed	Comment
 Pneumatic arch sprayer	*Circulating every two rows (specification of the machine) * Circulating every four rows (most common practice)	This kind of sprayer represents 70 to 80 % of sprayers used in the French large vineyard.
 Airblast sprayer, hollow cone nozzles	* Circulating every two rows * Circulating every three rows	In accordance with the most common practices, trials were carried out when the sprayer is circulating every two or three rows.
 Hoop early growth stage sprayer	*Circulating every two rows and associated with flat fan air induction nozzles.	This sprayer do not produce air assistance, it is composed by a hoop supporting two nozzles, one on each side of the row.

Table 1: Sprayers and settings assessed.









Acknowledgments

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Codis S., Bonicel JF., Diouloufet G., Douzals JP., Hébrard O., Montegano P., Ruelle B., Ribeyrolles X., Vergès A., 2013, EvaSprayViti: a new tool for sprayer's agro-environmental performance assessment, Suprofruit 2013 pp. 23-25.

First evaluations of different pesticides distribution techniques in Piemonte Region hazelnut crops

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Introduction

The achievement of high quality hazelnut productions is related to adequate agricultural practices and a correct management of crop protection against the main pests: *Phytoptus avellanae*, *Curculio Nucum*, *Palomena prasina* and *Gonocerus acuteangulatus* (Corte et *al*., 2013). Most of the insecticides used in hazelnut orchards are curative, therefore their action is explicated on populations of parasites already present in the crop, that if not limited, may cause severe economic damages (AliNiazee, 1998). Hazelnut orchards in Piemonte region - which is the third hazelnut producer region in Italy with 15000 hectares (ISTAT 2010) – generally represent an additional crop in vineyard farms and the pesticide application is carried out with the same sprayers used in vineyards, without any sprayer adjustment change. This could lead to ineffective spray distribution on the target and low efficacy of treatments.

With the aim to improve the spray application techniques in hazelnut crop, an ad hoc experimental study was carried out, divided in two parts: part a) assessment of the present quality of spray distribution in some representative hazelnut farms in Piemonte region; part b) evaluation of spray distribution quality applying different volume rates and using two different orchard sprayer models.

Material and Methods

Concerning part a) experiments were carried out in hazelnut plantations located within nine farms that cultivated both vines and hazelnuts trees (cultivar "Tonda Gentile Trilobata" trained at "bush" system, Tab. 1) while part b) trials were made just in farm 9 comparing a conventional farm orchard axial fan sprayer adjustment with an orchard axial fan sprayer Nobili Geo 90 S UT, equipped with a double fan outlet enabling to optimize air distribution, set up to apply three different volume application rates.

Hazel orchard	**Farm 1**	**Farm 2**	**Farm 3**	**Farm 4**	**Farm 5**	**Farm 6**	**Farm 7**	**Farm 8**	**Farm 9**	
surface (ha)	3.72	2.13	2.25	12.00	1.63	0.22	0.41	7.75	19.42	
total years old	28	20	25	20	30	7	7	23	16	
density (m)	4.5 x 5.5	4.0 x 5.8	3.0 x 6.0	5.0 x 5.0	4.0 x 5.0	5.0 x 5.0	4.5 x 5.5	4.3 x 5.5	5.0 x 6.0	
Sprayer	*test "a"*								*test "a"+ "b"*	*test "b"*
used also in vineyard	yes	yes	yes	yes	yes	yes	yes	no	no[1]	no[2]
nozzles type	disk core	disk core	pneumatic	disk core	disk core	disk core	disk core	disk core	disk core	HCI 80°
nozzles/spouts number	8	8	8	8	8	8	8	5	10	10
working pressure (bar)	18	20	2	22	20	25	20	24	30	12
fan type	axial	axial	centrifugal	axial	axial	axial	axial	centrifugal	axial	axial
pulverisation	hydraulic	hydraulic	pneumatic	hydraulic	hydraulic	hydraulic	hydraulic	hydraulic	hydraulic	hydraulic
speed (km/h)	4.8	4.5	5.5	4.4	4.0	2.8	6.5	4.9	6.0	4.0
volume sprayed (l/ha)	850	950	390	1140	720	620	460	1260	1080	570-930-1400

Tab. 1 – Main characteristics of the hazel orchards and of the sprayers used in the tests.

Results and discussion

Concerning part a), the use of an orchard sprayer (farm 9) enabled to get a more uniform spray deposition on the hazelnut canopies (CV = 33%) and a better spray coverage of the external leaves positioned on the top of the trees, that are more difficult to reach with the spray, even if the average spray deposit resulted low (Tab. 2). On the other hand, vineyard sprayers (employed in farms 1 to 7) provided very high spray deposits on the leaves positioned at the bottom of the hazelnut canopies but they provided a poor spray coverage of the top of the plants. The average spray deposit resulted lower according to the increase of the spray volume but a high average deposit, especially on plants like hazelnut trees that are not trained as walls, does not guarantee a uniform spray coverage. The relationship between the spray deposit measured on the leaves and the spray volume applied resulted very much influenced by the deposits measured on the external leaves of the canopy, which are easier to reach with the spray and may start to drip, originating ground losses.

			normalized deposit (µl/cm2)							
			external leaves			internal leaves				
Farm/sprayer	TRV (m3/ha)	volume (l/ha)	1.3 m	2.3 m	4.8 m	1.3 m	2.3 m	4.8 m	CV	average (µl/cm2)
1	22900	850	1.61	1.40	0.44	0.87	0.72	0.38	58%	0.89
2	2280	950	1.50	1.18	0.45	1.22	1.08	0.16	55%	0.92
3	27400	380	2.30	1.78	1.38	2.28	0.53	0.18	68%	1.41
4	23600	1140	0.92	0.67	0.28	0.53	0.40	0.18	54%	0.58
7	8800	460	2.61	3.01	1.36	0.80	0.75	0.18	83%	1.48
9	27800	1080	0.83	0.67	0.86	0.50	0.50	0.40	33%	0.65
5	32400	720	3.36	1.77	0.23	1.72	1.13	0.28	84%	1.48
6	7000	620	1.99	1.00	0.33	0.71	0.20	0.01	102%	0.71
8	37700	1260	2.49	2.37	0.16	2.54	2.15	0.22	69%	1.66

Tab. 2 – Comparison between the results obtained in the 9 farms where part a) of the experiments were carried out: farms 6 and 8 are listed apart due to the particular spray application technique adopted (only one side oft he row sprayed in farm 6) and to the sprayer pulverisation type (pneumatic. sprayer in farm 8).

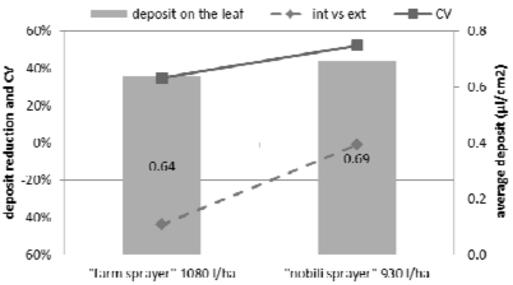

Fig. 1 – Part b) of experiments: comparison between *farm sprayer* and N*obili sprayer adjusted to apply 930 l/ha.*

Concerning the trials carried out in part b) of the experiments, the Nobili Geo 90 S UT orchard sprayer adjustment which considered the application of a volume rate of 930 l/ha resulted the best one. Comparing this result with that obtained using the conventional farm sprayer it was observed that, even if there was not a statistically significant difference in terms of average spray deposit on the target, the orchard sprayer adjusted to apply 930 l/ha (150 l/ha less than the volume usually applied by the farmer) enabled to guarantee a better spray coverage of the internal leaves at the bottom and in the mid part of the canopy trees. In the top part of the trees, instead, the farm sprayer enabled to get higher spray deposits. The Nobili orchard sprayer was nevertheless more efficient in terms of spray penetration in the canopy, especially thanks to the better evenness of the air stream generated by the fan.

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Reduced volume spray application in South African citrus orchards: effects on deposition quantity, quality and uniformity

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Introduction

Spray application forms the backbone of pre-harvest pest and disease management strategies in South African citrus production. Due to zero tolerance status of Citrus black spot (caused by *Phyllosticta citricarpa*) (McAlpine) for export to the European Union, growers tend to use high application fungicide volumes ranging from 8000 to 12000 l ha^{-1}. These high volumes realise good disease control whilst growers are hesitant to risk compromising disease control by applying at reduced volumes. Moreover, high spray volumes act as a “safety buffer” for poor sprayer maintenance, calibration and application techniques.

However, high spray volumes are costly in terms of off-target losses (run-off and drift) and environmental pollution, amount and cost of water, fuel and plant protection product (PPP), the strain on equipment, and it is more labour intensive and therefore ultimately less efficient than reduced volume applications. Uptake of more efficient spray application strategies is generally slow due to a number of factors: poor understanding of the process of spray application; fear of loss of disease control (especially with quarantine pathogens and pests) with use of ‘different’ or ‘new’ control strategies; legal aspects constraining change due to outdated legislation in South Africa; PPP labels mostly registered as dilute, high volume applications; and the use of obsolete equipment. Thus growers need *confidence* through *evidence* to be *convinced* to change their ways.

The deposition assessment protocol (van Zyl *et al*.,2014) involving fluorometry, photomacrography and digital image analysis is a superb tool to evaluate deposition quantity, quality and uniformity, and is used to help researchers and spray technicians visualise and quantify deposition following spray application; additionally, it can be used to better advise growers. This protocol was used to evaluate novel sprayersat reduced spray volumes in relation to conventional high volume sprayers in various citrus orchard spray trials.

Material and Methods

Orchard spray trials were conducted with two novel sprayers, a Martignani Whirlwind KWH M612 (high profile mist blower; air speed ≈80 ms^{-1}; air volume ≈20000 m^3 h^{-1}; www.martignani.com)and a CIMA T55 Super(high profile venturi atomiser; air speed ≈170 m s^{-1}; air volume ≈14000 m^3 h^{-1};www.cima.it) at 1000 to 4000 l ha^{-1}. To serve as control treatments, various conventional sprayers were evaluated at spray volumes ranging from 8000 to 11000 l ha^{-1}. A yellow fluorescent pigment (40% EC; SARDI Yellow Fluorescent Pigment, Loxton, Australia) (1ml l^{-1}), were added to the spray mixture. Pigment concentration was maintained as a dilute application (1×) for all treatments, but in certain trials was also amended (2×; 4×) at reduced volume applications to realise the same dosage of pigment as that of a high volume ‘dilute’ spray at 8000 l ha^{-1}. Forward spray speed and PTO speed (540 rpm)were kept constant throughout trials with only pressure [conventional sprayer (10 bar) and reduced volume sprayer(1.5 to 1.8 bar)]and when applicable, nozzle selection, used to manipulate spray volume. Sprayers were set-up carefully to ensure that the spray plume was adequately intercepted by the spray target from the top to bottom of the canopy [depending on trial site, tree size of 4-5 × 2.8-3.5 m (H×W); 5-7x2-3.5m row spacing].After application, 12 leaves were randomly sampled from the inner and outer canopy at the top, middle and bottom tree positions. According to the methods described for the deposition assessment protocol (van Zyl *et al*., 2014), high quality digital images were taken of sampled material illuminated by UV-A ≈ 365 nm light source (www.labino.com) in a dark room and the following deposition parameters determined by means of digital image analyses: deposition quantity, measured as percent of total leaf area covered by pigment particles (percentage fluorescent particle coverage; %FPC);

deposition uniformity, measured as the coefficient of variation (CV%) of deposition quantity between leaves at various positions in the tree; and deposition quality, measured as the interquartile coefficient of dispersion (%ICD) of deposition quantity measured in each 100 × 100 pixel square of each leaf image (3888×2592 pixels). A previously developed FPC benchmark model (van Zyl *et al*., 2014), was used to evaluate the effectiveness of deposition in relation to theoretical disease control. The FPC_{50} (2.07 %FPC) and FPC_{75} (4.14 %FPC) benchmarks respectively indicated 50% and 75% theoretical control of a fungal disease Alternaria Brown Spot on mandarin leaves.

Results and discussion

As was found in previous trials, high spray volumes (> 8000 l ha^{-1}) at 1×pigment concentrations with conventional sprayers realised the highest deposition quantity and lowest variation in deposition uniformity. Higher spray volumes did not improve deposition quantity and uniformity, indicating high losses due to run-off and drift.

Reduced volume applications (1000 to 4000 l ha^{-1}) with the Martignani and Cima sprayers at 1×pigment concentrations realised significantly lower deposition quantities and in some cases varying deposition uniformity. However, by increasing the pigment concentration (2×, 4×) at these reduced spray volumes relative to a similar dose as 8000 l ha^{-1}, deposition quantity and qualitylevels were better than those of conventional high volume 1× sprays . Similar levels of deposition quality were observed at dilute application concentrations with spray volumes ranging from 4000 to 8000 l ha^{-1}; better than 1× sprays at 1000 and 2000 l ha^{-1}. However, sprays at 2000 l ha^{-1}at 2× and 4× realised improved deposition quality, indicative of a more optimal calibration.

Reduced volume sprays were therefore much more efficient with much less off-target losses. Canopy density was highlighted as an important factor as dense citrus canopies impeded deposition uniformity and canopy penetration. Deposition quality on hard-to-reach targets (such as top and inner canopy leaves) also varied with spray machine, volume and concentration, with quality improving at increased concentrations at lower volumes.

These results support the change toward reduced volume application for PPPs in South African citrus production. However, bio-efficacy trials are needed to demonstrate comparable disease and pest control following reduced volume application strategies. Furthermore, PPP labels in South Africa commonly prescribe dilute, high volume application rates (l or g product hl^{-1}), with off-label recommendations at higher concentrations being illegal due to outdated legislation. Harmonisation to more effective dose rate expression (Leaf-Wall-Area or Tree-Row-Volume) together with accurate canopy geometry and density characterisation is also needed in South Africa to facilitate change to more efficient spray application methods.

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Fixed spraying system: a future potential way to apply pesticides in an apple orchard?

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Introduction

The traditional use of airblast sprayers to apply pesticides in fruit growing creates a vast cloud of spray with a variable proportion that reaches the target. The result is often more or less poor distribution within the canopy leading to more or less effective disease or insect control, off-target drift leading to environmental pollution and economic inefficiency. The application of pesticides by a Solid-Set Canopy Delivery System could have several advantages, such as: the short application time, the application of the product at the most appropriate time, the economics in labor and fuel, the reduction of soil compaction, the minimal drift and also the quieter operation. In 2012, a fixed spraying system was installed in an apple orchard at the Technical Institute for fruits and vegetables (Ctifl – Centre technique interprofessionnel des fruits et légumes). This abstract presents the main results obtained in 2013 and 2014 on biological efficacy of this technique on the major pests and diseases of apples compared to conventional nozzles and also the results obtained on the quality application in our trial conditions.

Material and methods

The experiment is carried out in a Brookfield®Baigent/Pajam1 orchard with a planting distance of 4 m × 1.25 m planted in 2004/2005. Micro-sprinklers are installed above the canopy, one sprinkler per tree (2000 micro-sprinklers/ha). This type of sprinkler (SUPERNET™ from NETAFIM) maintains a constant flow rate on a pressure range from 1.7 to 4.5 bar. After different control tests, the selected model delivered in our trial condition 35,5 l/h. To obtain an application volume of 400 l/ha they were turned on for 20 seconds. A check valve is installed on each sprinkler to allow filling and rinsing the pipes at a low pressure. The injection of the product is done via a pump, DOSATRON®.

The first objective was to study the effectiveness of this technique on pests (rosy apple aphid, mites) and diseases, especially apple scab, compared to a conventional application with an airblast sprayer equipped with conventional nozzles. The choice was made to use conventional products. The applications are all carried out on a basis of 400 litres / ha, whether with the airblast sprayer or a fixed overhead system, under the same conditions (same day, same hour). The assessments are made, in each case, on 3 replicates of10 trees (30 trees for each application technique).

The second objective was to study the quality of application using two approaches: the quantification of deposits into different areas of the canopy, made under the existing normalized methodology ISO 22522 (use of a food tracer and artificial collectors placed at different levels in the canopy), and the evaluation of the coverage using water sensitive cards.

Biological efficacy: first results

In our climatic conditions, scab is the main disease. In 2013, scab pressure was very high: 99% of shoots and 98.5% of fruits affected in the untreated block (control). In 2014, the scab pressure was lower with 24% of shoots and 11% of fruit affected at harvest in the untreated block. Results are very promising with a fixed spraying plot providing scab control equivalent (no significantly differences) to an airblast sprayer plot (Table 1). At the harvest in august 2013, 3% of fruits had scab damages in the airblast and fixed spraying system against 98.5% in the untreated block.

	2013 (assessment of July 31)			2014 (assesment of July 23)		
	Untreated	Airblast sprayer	Fixed spraying system	Untreated	Airblast sprayer	Fixed spraying system
% scab damage on shoots	99,0	0,3	0,3	23,9	0,3	0,3
% scab damage on fruits	98,3	0,8	2,2	10,5	0,2	0,2

Table 1: Average % scab damage on shoots and fruits at the last assessment before harvest in 2013 and 2014.

Spray quality: first results

Figure 2 presents the comparison of the results of the spray deposit quantification obtained in the fixed spraying system plot and in the airblast sprayer plot (trials carried out after harvest in autumn 2013). And Figure 3 presents the coverage obtained with water sensitive cards (left: airblast sprayer, right: fixed spraying system).

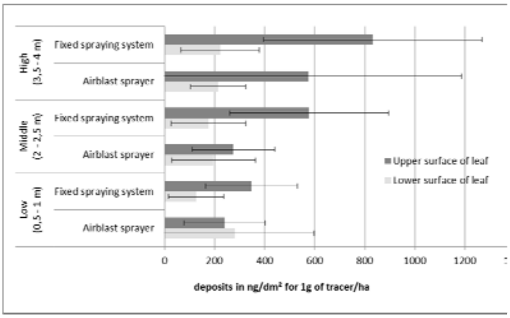

Figure 2: deposit quantification

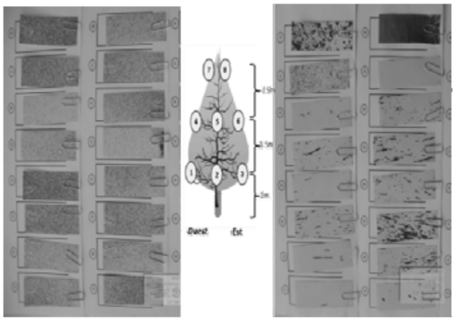

Figure 3 : spray coverage (left : airblast sprayer, right : fixed spraying system)

The results show a very strong variability on average deposits of product regardless of the technique: conventional spray, or the fixed system. Deposits on the upper leaf surface are more important than on the lower leaf surface whatever the application technique: the ratio between upper and lower surface ranges between 1 and 3.8.Finally, the fixed spraying system improves the deposits, especially in the middle and the top of the canopy. Concerning the coverage, the impacts obtained with micro-sprinklers are very heterogeneous and coarse. If we stick to the accepted reference, we could say that the distribution of droplets is not satisfactory. However, quantitative measurements of deposits show that fewer and coarser impact don't mean that there is less active substance per leaf area unit. The fact that the measured efficiency does not match the qualitative ranking reference observed on water sensitive cards leads us to question the relevance of this assessment method for this application technique. It is possible that in addition to the big impacts, there are also small impacts that, even if they do not lead to discoloration of the paper, may have a biological effectiveness.

A lot of future research…

The efficacy results obtained in 2013 and 2014 with the fixed spraying system are very encouraging, even though the quality of application is far from the generally accepted references in terms of recovery of vegetation and type of drops (size and distribution). This application system has been the subject of several demonstrations during field days in 2014. In view of the interest of producers, it is now necessary to optimize the system and to quantify the advantages of this technique using environmental, technical and economic indicators.

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Section 4

Volume rate and dose units for spraying application in orchard fields with huge variations in size, shape and density

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Introduction

When spraying 3D row crops like apple trees and strawberry plants, the dose expression on the pesticide label often is difficult for the operator to understand completely. One reason is the difficulty to adapt the dose correctly due to different mass of leaves and sizes of canopy. In some countries, it is used a constant GA (ground area) dose of pesticide in spite of different numbers of trees, tree sizes, differences in row spacing and mass of leaves per ha. This may be caused by different reasons; this is defined by law, this is a problem difficult to solve with the spraying equipment in use or a lack of knowledge by the authorities approving the labels.

Among others, the label dose in 3Drow crops often is expressed as a concentration only, without being linked to any specific volume rate of spray. However, this is correct only if the growers apply a similar volume rate to a similar plant canopy and type of application. But frequently this is rather not the case. Thus, the concentration given on the label has to be linked to a certain volume rate, the so called normal rate. When another rate is used at similar conditions, the concentration has to be changed in the opposite proportion. If a dose is written on the label instead of concentration, this could better ensure a correct dose of pesticide than by the use of a concentration.

In older days, the common way of spraying 3D crops was to apply spray fluid with a hand held lance and spray until run off. In this way, the applied volume rate was more or less adapted to the crop size and leaf density. The normal concentration was based on a volume rate of 2000 l/ha for the biggest trees. However, the risk of run off was high, which resulted in environmental pollution. Additionally, the coverage of leaves was poor. The sprayer capacity was also low. Thus we today use methods with a lower volume rate, e.g. by using mist blowers, which cause a better coverage of droplets, minimum risk of run off and have a higher capacity.

Objectives

How can a correct and equal dose per leafcm^2 surface better be obtained in practice?

How can this volume rate unit ensure a correct dose in spite of variations in tree size and density?

Are the volume rate units used today easy understandable for the growers?

What kind of units may be additionally introduced?

Some volume rate units in use

TRV (Tree Row Volume) unit

In some countries, a TRV value is used with good results. However, such a unit may cause problems where the trees are changing quickly in shape, size and density over time and between fields. For smaller conditions and for more irregular tree shape the TRV-unit may not be that easy to adapt in practical use. When the shape differs strongly from rectangular shape, this value may lead to poorer result.But for uniform orchards and huge areas where the operator almost is spraying throughout the whole season, he may be well skilled to use such a unit and thus ensures acorrect dose. In some countries instructive computer programs are made (Planas et al, 2012) as well as modeling (Triloff, 2005) to help the growers to adjust and optimize the sprayer correctly and ensure a correct dose.

LWA (Leaf Wall Area)

As an alternative to TRV, some countries are now using a LWA unit (Koch, 2007). This is a volume rate in liters per ha, but against a vertical wall of leaves and not a horizontal area. In modern orchards, the trees may make more or less a vertical wall of leaves, and then this value is correct to use. But for none rectangular shaped trees, it may give wrong results. Some growers may also have problems when using ha unit as an expression for a vertical surface. However, the value focuses on the tree wall and not the interrow and takes also different tree height into account.

UCR (Unit Canopy Row), e.g. volume rate per 100 m tree row

For smaller orchards like in Norway where the conditions often are changing as well as the type of spraying equipment in use, a more practical and understandable volume rate unit has been missing. Thus, a working group consisting of several fruit growers, evaluated all existing units available and concluded already in 1993 that a volume rate per 100 m tree row would be of most practical and suited use for such conditions. This value is easy understandable, the row spacing is not necessary to measure and a calibration of the volume rate is very easy to execute in the orchard. In combination with a check list, the growers are skilled how to adapt correct volume rate and dose due to variations in tree size, tree shape as well as tree density (Bjugstad, 1993). The procedure of an updated checklist will be shown at the workshop. A calibration of the volume rate per 100 m row may be found within 5 min (only 1 min to run the sprayer stationary the time to go 100 m). The check list also ensures the grower/operator to adjust the sprayer and forward speed optimally due to existing conditions in the field regarding tree size, density, as well as climate conditions. The UCR uni tis also studied and used in other countries (Barani et al, 2008; Furness et al, 1998) with good results.

Conclusions

By using a suited volume rate unit like amount per 100 m row as well as adapted concentration factor and by adjusting the nozzle- and air pattern due to the height of trees, the growers are able to apply pesticides adapted to the tree size and density in a practical manner. This means that the pesticide ground area dose could be reduced from 100% to below 40% due to tree size, mass of leaves and also due to differences in row spacing. Most of the countries are obliged to report the use of pesticides expressed as an amount per ground area. However, such a recalculation is easy for the authorities to perform in the after hand. When choosing a volume rate unit in orchards, the level of understanding and simplicity for the growers should be more highlighted than today. Especially where the tree shape and density are differing between the fields and through the season, a UCR unit has proved to be suited.

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PACE into fruit tree spraying practice

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Introduction

A concerted effort was made over a 2 year period (2012-13) to transfer the webpage linked PACE (Pesticide dose Adjustment to the Crop Environment) (Walklate and Cross 2013a) system into commercial practice in the UK and to test the results of its implementation on 7 commercial tree fruit farms, feeding back the results to growers and industry. The aim of PACE is to support low pesticide-input to pest management called for in the Sustainable use Directive (2009/128/EC) through efficient use of orchard spraying products. PACE seeks to minimise crop-to-crop variation of spray deposits above the minimum for efficacious use (i.e. the deposit achieved by spraying a standard orchard (1, 2, 3 & 4) at the maximum label dose using a farm sprayer operating at the calibrated reference settings). PACE utilises information about: the number of open nozzles used for the reference setting of the farm sprayer, the selected pesticide type, the tree row spacing and at each of three growth-stages requires the grower to assess the target orchards to determine canopy density and the number of working nozzles to treat the target orchard to the full tree height.

Methods and materials

Seven pome fruit growers agreed to implement PACE on their farms in 2012 and 2013. They were each visited in the late dormant period and assisted in the PACE assessment of their orchards, set up of sprayers and inputting the data into the PACE webpage for dose rate recommendations. This exercise was repeated after blossom and again at full leaf each year. At the end of each season the spray programmes applied by the growers were collated and the actual doses of each pesticide application were compared with those given by PACE. The spray programmes were fully costed and the savings the growers made compared to those recommended by PACE relative to full dose applications were calculated for each pesticide type. The growers were questioned about their satisfaction with pest and disease control and with PACE.

Results and discussion

The growers found making the canopy density assessments from the PACE pictogram key and the measurement of tree height quick and easy. However, the LiDAR measurements at two of the farms in 2012 indicated there was a tendency to be too cautious and to over-estimate canopy density. The value of making a formal orchard and sprayer assessment was particularly illustrated on two of the farms where the sprayer set up was found to be incorrect, resulting in scab infection. Dose adjustments for different orchards at the same spray round were mainly made by making proportionate adjustments to the spray volume, by adjusting the number of nozzles according to tree height (as required by PACE) and by adjusting pump pressure. This approach is not suitable for making large dose adjustments for orchard density without additional adjustment of tank concentration. Growers found implementing PACE for a tank mix of different product types with differing proportional dose adjustment in different orchards to be complex. Further software to help with this planning would be helpful in the future.

Although all the seven farms evaluated the use of PACE, the degree to which they actually implemented it in their spray programmes in 2012 and 2013 varied greatly for mixed reasons (Table 1). One grower with orchards of variable structure, though unwilling to reduce insecticide doses pre-blossom beyond cuts proportional to reduced tree height, implemented PACE more or less fully reducing doses by 34% and 36% and saving £574 and £503 per ha and a total of £13,113 and £9,913 for the farm in 2012 and 2013, respectively. On another farm the orchards were more uniform in structure and PACE dose recommendations were generally for full dose. PACE was also implemented more-or-less fully, the grower reducing doses to 84% in both years and saving £198 and £155 per ha in 2012 and 2013, respectively. PACE could not be implemented at another of the farms in 2012 because of the unusually wet weather from April onwards made spray application at the required intervals very difficult. Sprays thus were applied when they could be at the full dose and insufficiently frequently to prevent significant scab infection in some orchards. The legacy of this experience at this farm resulted in full doses being used in 2013. The grower at another of the farms was also very cautious because of the wet weather in 2012 which resulted in some scab infection. However, this grower still made substantial average reductions to 70% and 82% dose, amounting to £290 and £202 per ha 2012 and 2013, respectively. In contrast the growers at three other farms were unwilling to change their normal dose reduction practice and implement PACE, though they were very interested in its outputs, making comparisons with their own. At two farms the PACE dose was considered to be somewhat illogical as they reduced for orchards with wider row spacings with the same canopy density assessment. This undermined the growers trust in the scheme. Nonetheless, the doses used at one of the farms in particular were considerably less than those recommended by PACE, and at another they were similar. Actual doses on this former farm averaged 66% and 60% in 2012 and 2013, respectively. The grower at the remaining farm, which had exceptionally uniform, intensive and high-yielding orchards on narrow row spacings, did not implement PACE. This grower, who used the most robust and costly spay programmes, was particularly cautious about dose rate reductions considering the potential savings to be made to be small compared to the high value of the crop. Because of the orchard structures, the PACE dose recommendations were generally for full dose, though one young orchard received lower doses for reduced tree height. The actual average doses applied on this farm averaged 96% and 90% compared to PACE average doses of 77% and 80%. Another reason that the grower at Farm 4 did not implement PACE was because of the logistical difficulties of applying different proportional reductions for different pesticides in different orchards with the same tank mix.

Table 1. Mean numbers of pesticide applications and average % doses recommended by PACE and actually applied by grower and mean actual costs (£) of spray programmes and savings (£) made in in comparison to the cost of the same programme had it been applied at the full dose

Pesticide applications	Fm 1	Fm 2	Fm 3	Fm 4	Fm 5	Fm 6	Fm 7
				2012			
Mean PACE dose %	89	82	82	94	69	80	90
Mean grower dose %	84	66	77	96	66	79	68
Total no. apps	31.5	24.5	36.1	28.0	35.8	23.3	40.6
Mean actual cost (£/ha)	1091	623	1024	1230	1038	610	1065
Mean PACE saving (£/ha)	142	142	263	82	446	165	226
Mean actual saving (£/ha)	198	415	290	68	574	150	931
	2013						
Mean PACE dose %	89	78	80	77	59	73	78
Mean grower dose %	84	60	80	90	64	77	75
Total no. apps	23.9	21.5	32.2	38.0	24.7	22.3	33.7
Mean actual cost (£/ha)	823	633	960	1617	560	564	1039
Mean PACE saving (£/ha)	86	248	277	331	443	187	320
Mean actual saving (£/ha)	155	431	202	139	503	155	307

Thus the actual implementation of PACE varied greatly between the seven farms for a wide variety of reasons. In most cases the overall mean % grower dose was within 5% of the PACE calculated dose, though the overall mean values in Table 1 hide considerable spray-to-spray round and orchard-to-orchard variability. Greater actual dose reductions than those given by PACE were achieved on Farms 2 and 7 in 2012 and on Farm 2 in 2013, partly because of a tendency to use plant growth regulators at low doses.

All the growers found the webpage calculator helpful and intend to use it or refer to it in future. A label requirement for growers to consider adjusting dose rate according to canopy size and density will help to force dose adjustment into practice, particularly if it becomes a requirement of produce Quality Assurance schemes. Two updates of the PACE webpage calculator (i.e. V3 and V4) were released during the lifetime of this projects (Walklate 2014). These updates responded to grower feed-back about: reducing the amount of time required to input data and manage previous records, making available dose adjustment estimates for the full growing season based on a simple growth model and orchard assessment at any one of three key growth-stages (Walklate & Cross 2013b).

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Effect of spray application parameters on viability of rhizobacteria used as bio-pesticides in organic fruit production

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Introduction

The biocides, either synthetic pesticides or biopesticides, are applied with agricultural sprayers in form of an atomised spray liquid, being usually a solution or suspension of the control agent, i.e.: synthetic active ingredient, microorganism or extract of naturally occurring material. Prior to the atomisation the spray liquid is subject to a turbulent flow and series of processes taking place in different sprayer components. In the pump the liquid is in turns compressed and decompressed at the frequency of 10-50 Hz (diaphragm or piston pumps) or subject to mechanical rotation at high speeds of 1500-3500 RPM (centrifugal pumps). In the filters the compressed liquid passes the mesh, in the control devices such as valves and gauges it flows at high speed passing sharp edges, and finally in the nozzles it is atomised by mechanical breaking or tearing apart. During all these processes the sprayer components and their working parameters harshly interact with the particles suspended in the liquid and usually they cause an increase of the liquid temperature. The leaving micro-organisms in biopesticides are subject to unfavourable conditions being far from those of their natural habitat. Thus, the question about viability of microbes under these conditions is very important for the efficacy of biopesticides. The objective of this study was to evaluate the survival of two strains of PGPR (Plant Growth Promoting Rhizobacteria), showing potential of application in organic fruit growing, by performing the stress tests simulating spray application process with both the hydraulic and the pneumatic atomisation system.

Material and Methods

Two strains of the Gram-negative bacteria, *Pseudomonas fluorescens* (PS49A) and *Enterobacter nimipressuralis* (K50XA), were isolated from the rhizosphere of two species of the genus *Fragaria*, respectively: *F. ananasa* (garden strawberry) and *F. vesca* (wild strawberry). For the bacterial viability evaluation tests appropriate volumes of spray liquid were prepared, being a bacterial suspension with the concentration of bacteria $40 \div 100 \times 10^4$ CFU/ml (colony forming units per millilitre of suspension). A test stand was designed and developed to control and measure the parameters of flow of bacterial suspension during the simulated spray application (Fig. 1). The stand included two independent application systems used in fruit crop sprayers: (i) hydraulic atomisation system with a high pressure diaphragm pump and 16 hydraulic hollow-cone nozzles TR80 (Lechler) - in the experiment tested at the pressures 0.5, 1.0 and 1.5 MPa and at the spray volume rate 450 $l \cdot ha^{-1}$ (in the additional tests also at spray volume 55 $l \cdot ha^{-1}$); (ii) pneumatic atomisation system with a low pressure centrifugal pump, a radial fan and four Paraflow pneumatic atomisers (Hardi) - tested at the pressures 0.1 and 0.25 MPa and at spray volume rates 55 and 125 $l \cdot ha^{-1}$. Each system consisted of adequate pressure control devices and components assembled and linked as in commercial sprayers in order to best simulate spray application in real situations. In both systems the critical parameters of the liquid flow and atomisation, such as flow intensity, liquid pressure, and air jet velocity were all controllable. The pressure, the temperature and the flow of liquid in different sites of the liquid circuits were monitored and registered by a software application. While the application systems were operating the samples of the bacterial suspension were taken at different sampling sites, at 15 minute intervals. The samples were serially diluted (10^{-1}, 10^{-2},..., 10^{-4}), and the diluted samples were spread (0.1 ml each) on petri dishes, containing KingB agar medium. After 72 hours of incubation at a temperature of 28°C the bacteria colonies growing on the agar medium were counted. The population of bacteria was expressed as the colony forming units (CFU).

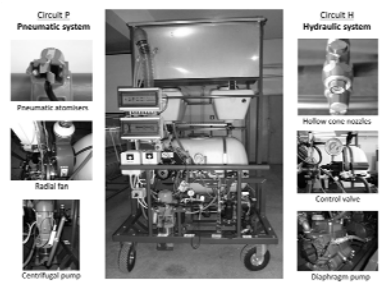

Fig. 1 Test stand with two independent liquid circuits to simulate application parameters during the stress tests on viability of rhizobacteria in biopesticides: Circuit P with the pneumatic atomization system; Circuit H with the hydraulic atomization system

Results

The viability of bacteria applied at normal application conditions imposed by both atomisation systems was in most cases above 90%, and with only a single low viability of 82%. In such conditions the temperature of the bacterial suspension was only slightly increased during the sprayer operation and therefore it was not considered a crucial factor. Neither application pressure nor the components of the liquid circuits and atomisation systems of the test stand showed alone any decisive effect on the viability. The bacterial mortality was mainly due to the interaction of the pressure, time, and the components. In the extremely harsh conditions of very intensive circulation of bacterial suspension in the liquid circuit of the hydraulic application system (additional test: the worst case condition; spray volume rate 55 $l \cdot ha^{-1}$) the temperature of the bacterial suspension increased dramatically, thus in combination with a high pressure caused 50% bacterial mortality after 70 minutes, and total mortality after 100 minutes.

Conclusions

The two evaluated strains of bacteria *Pseudomonas fluorescens* (PS49A) and *Enterobacter nimipressuralis* (K50XA) can be successfully applied by sprayers equipped with either hydraulic or pneumatic atomisation system, which are commonly used in fruit growing. The viability of bacteria applied in form of bacterial suspension was satisfactory when applied at normal application conditions. Only situations imposing very harsh conditions, e.g. long and intensive liquid circulation in the sprayer liquid system should be avoided in order to maintain satisfactory viability of the two evaluated bacteria strains.

The new concept of dose adjustment in tree crops

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Key words: Dose adjustment, Spraying pesticides, Tree orchards, LIDAR

Introduction

The lack of a harmonized method to establish the suitable dose in accordance to the real orchard conditions is one of the most important constraints affecting the sustainability of the use of pesticides in tree crops. Several attempts to introduce new dosing methods, such as canopy height or LWA (Wolhlauser, 2009) have appeared in high density fruit orchards and vineyards. Nevertheless when trees are conducted in wide canopies these methods are not adopted. This affects the production of apple, pear, peach, nectarine, citrus, almond and vine in the main fruit regions located worldwide.

For these conditions, the above mentioned dosing methods seem too much simplified and risky because canopy structures determining leaf density aren't, in any case, comparable to the low hedgerows where the new methods have been developed. Consequently, the concentration of the spraying liquid remains as the common dosing method and the amount of applied pesticide is directly linked to the volume sprayed. But, which volume rate ($l \cdot ha^{-1}$) has to be sprayed for an efficient and effective control of pests? The objective of the present paper is to present DOSAFRUT, as a new concept of dose adjustment and the results of the validation tests carried out in recent years.

Material and Methods

After considerable experimental work using ground-based LIDAR sensors, a simple, practical, and reliable method for estimating leaf area index (LAI) has been developed (Sanz et al., 2013). This estimative method takes into account the canopy solid housing (refers to the surface of the two vertical planes and the top horizontal plane closing the canopies) (Figure 1).Further improvements are being implemented based on additional field tests and latest sensor advances conducted in 2014 and 2015.

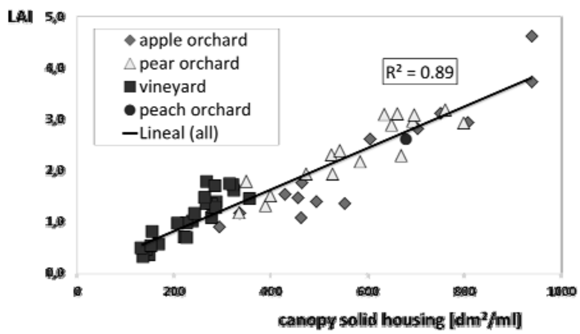

Figure 1. Correlation between the orchard structure (obtained with the LIDAR sensor) and the LAI for four tree crops.

From the estimated *LAI* and the predicted overall efficiency *(E)*, the volume application rate *(V)*in $l \cdot ha^{-1}$can be calculated by means of the following expression:

$$V = \frac{120 \cdot LAI}{E} \qquad (2)$$

Where *LAI* is the leaf area index and *E* the application efficiency, considering the spraying parameters. To be reliable, the system assumes that, for effective control of pests, an impact density of 100 pesticide droplet·cm^{-2}is required having a representative diameter of 225 μm. Easy and user-friendly tool to estimate *E* and calculate *V* is provided in DOSAFRUT website (Figure 2).

Field tests

Field tests have been conducted to validate DOSAFRUT volume rates. Twenty field tests have been carried out over three successive seasons, 2009–2011, with the objective of assessing the efficacy of chemical treatments to control *Psyllapiri* (psylla), *Tetranychusurticae* (spider mite), and *Frankiniellaoccidentalis* (thrips) in pear, apple, and peach orchards, respectively. In 2012, one multiple chemical treatment for the control of *Psyllapiri* was applied in order to evaluate the chemical residues on fruits at harvest. DOSAFRUT provided adjusted doses, enabling pesticide savings of between 14% and 53% (volume reduction) as compared to the volumes usually adopted by farmers (standard dose) (Planas et al., 2013)

The difference in efficacy between dosing methods was not significant. In the last season (2012), no pesticide residues were detected on fruit from trees treated with pesticide doses determined using either DOSAFRUT or standard dosing. Additional tests have been carried out in 2013 in a Flat Queen peach orchard.

Figure 2: Pictogram of DOSAFRUT website available at www.dosafrut.es.

Conclusions

The DOSAFRUT decision dosing system sets significant savings of pesticide in effective treatments. In consequence, it can be very helpful to harmonize dose recommendations and for implementing the national action plans according to the Directive 2009/128 on the Sustainable Use of Pesticides who advocates a significant reduction in the quantity of pesticides used.

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Acknowledgements

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Sprayers' classification according to their performance in terms of spray deposition quality

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Introduction

The French national action plan EcoPhyto aims to reduce the amount of plant protection products used in agriculture. Several studies carried out in the vineyard have shown that the ability of the sprayer to target precisely the sprayed vegetation and to mitigate the losses in the environment, is an important lever to achieve dose reduction without any loss in terms of crop protection reliability. Nevertheless, the lack of objective assessment of spray quality do not allow advisers and vine growers to take properly into account this criteria when choosing a new sprayer. To answer an order of the French institutions, the objectives of work was to classify the sprayers according to their performance in terms of spray deposition quality.

In order to assess the diversity of spray application techniques in standard conditions, IFV and IRSTEA developed an artificial vine called EvaSprayViti. This test bed can mimics three different growth stages of the vine. During 2013 and 2014, 11 sprayers were tested with different settings at the three standard growth stages. The total amount of tests realized during these two seasons is about 200.

A summary of these tests is analyzed in order to propose a method of multi-criteria classification of sprayers' performances in terms of spray application quality.

Materials and methods

The artificial vine EvaSprayViticonsists of four 10 meters long rows that aim at reproducing the characteristics of canopy and at limiting edge effects (Codis*et al*. 2013).The row spacing implemented was 2.5 meters.

Collection rows were composed of artificial leaves dedicated to capture and assess spray deposit on the canopy. Tartrazine (E102) was used as tracer. After spraying, all the leaves were collected in box before analysis. The analyses of the boxes provided the quantity of deposit per unit of leaf area for one gram of tracer sprayed per hectare (unit: ng/dm^2 for 1g/ha). The distribution of tracer within the canopy was evaluated by segmenting the vegetation structure into compartments: 4for early stage (4 depths), 6 for medium stage (left and right at3 heights: low, middle, high), 9 for full growth stage (left, center and right at 3 heights: low, middle, high).

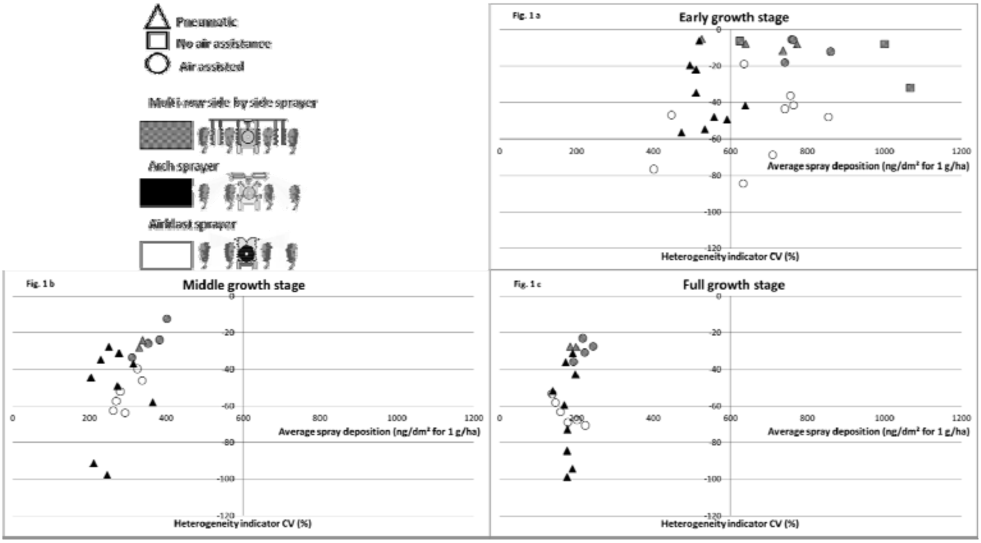
Two indicators of spray application quality were defined:

- the average quantity of deposit per unit of leaf area for one gram of tracer sprayed per hectare (unit: ng/dm^2 for 1g/ha) calculated for the whole vegetation;
- the coefficient of variation of deposits measured in each compartment of vegetation expressed in % of the average deposit.

In order to build a method of classification of sprayers according to spray deposition quality, the performance of 11 sprayers was assessed at three different growths stages for several settings of the machines. Considering the fact that spray quality offered by a given sprayer highly depends on the settings implemented, reference settings had to be defined for each kind of sprayer. For any parameter likely to be set, the definition of reference settings has been carried out taking into account two factors: the range of variation currently run into the field and the manufacturer recommendations. Then, for each assessed sprayer, a performance evaluation was carried out for every defined reference setting.

Results

For each reference application technique, defined as a couple (sprayer model; reference setting), the related performance was represented by a point which coordinates are the two indicators of spray quality (average deposition; coefficient of variation). The figure 1a, 1b, 1c below represents the measures carried out at respectively early, middle and full growth stage using EvaSprayViti.



This synthetic representation enables to get a global view of vineyard sprayers' performance. The same scale has been voluntary used in the three graphics in order to view the effect of vegetation growth stage on deposits amount. At full growth stage, the gaps of performance between the different applications techniques are mainly linked to the homogeneity indicator whereas both indicators are showing differences of performance at early growth stage.

Whatever the growth stage and the technology (pneumatic, air assisted or not), multi-row side by side sprayers appear to be the typology offering the best spray quality according to both criteria, average amount of deposits and homogeneity of deposits (representative points located on the top right of the figures). It appears that pneumatic arch sprayers and airblast sprayers are offering very variables quality of spray depending on the commercial model and the applied settings and practices.

In order to answer the order of the French ministry of agriculture to classify the different sprayers according to their performance, an aggregation of the multiple indications obtained has to be considered. To achieve a relevant choice of an aggregated indicator, epidemiologic knowledge will be mobilized.

Acknowledgments

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A LiDAR crop scanner for managing pesticide dose adjustment

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Introduction

This paper gives a brief description of a LiDAR Crop Scanner (LCS) and associated software for recording and processing sequential range measurements of tree-row structures. The data processing methods have been described in previous publications (Walklate et al., 2002 and Walklate and Cross, 2013). The results of apple orchard measurements show examples of outputs from the software that are aimed at improving grower access to information about Pesticide Adjustment to the Crop Environment (PACE) for making orchard-to-orchard dose adjustments with conventional sprayers and for making tree-to-tree dose adjustments with precision sprayers.

Materials and Methods

The photograph of atypical tractor mounted LCS (Fig.1a) identifies the off-the-shelf systems that are used (i.e. PC, LiDAR and GPS). In this case the PC is mounted inside the tractor cab for operator convenience. The LiDAR is mounted 1 m above the ground at the front of the tractor to facilitate scanning of two tree-rows during a single traverse of a typical orchard. The GPS is mounted above the tractor to minimise the potential degradation of the satellite signal by the surrounding trees and windbreaks. In addition to these systems special software has been developed to facilitate: (1) - the simultaneous recording of sequential output from the LiDAR (Sick LMS100) and sequential output from the GPS (SiRF Star IV chipset) and (2) - the analysis of recorded data and presentation of different types of summary output.

The software uses published methods of analysis (Walklate et al., 2002) based on the formation of gridded data models to describe the distribution of key aggregates of LiDAR output (Fig.1b and Fig.1c). The aggregated data for different path-lengths of tractor movement may be used for different applications. For conventional spraying the path-length of data aggregation should be large enough to represent the full orchard. For precision spraying the path-length of data aggregation is equal to the spacing of trees along the tree-row. The gridded data models are filtered to remove ground interception data before they are aggregated further to determine the values of PACE dose adjustment (Walklate and Cross 2013).

Results

Examples of gridded data models, based on aggregates of LiDAR output from a 100m tree-row recording, are presented (Fig.1b & 1c).The cumulative probability of transmission (Fig.1b) decreases with distance from the LiDAR (i.e. from right-to-left) and in this case the local differential probability of interception (Fig.1c)is distributed almost symmetrical about the tree-row centre-line. Examples of output from further processing of gridded data models are presented (Fig.2). The orchard-to-orchard variation of PACE dose adjustment versus tree height to row spacing ratio, are presented (Fig. 2a & 2b). These examples are based on replicated LiDAR recordings of 14 different orchards at various growth stages. Different PACE orchard standards are used to simulate pesticide registration of products with different uses: pre-blossom(Fig. 2a) and post-blossom(Fig. 2b). The predicted range of dose adjustments are compared with two characteristic lines of constant Leaf-Wall-Area (LWA) dose (i.e. different coloured diagonal lines; where the black line represents the full LWA dose and the blue line represents75% of the full LWA dose). Some exceptional orchards (2 of 14 post-blossom orchards in Fig.2b) show PACE dose adjustments that exceed the maximum dose per hectare (i.e. the red horizontal line). Therefore, the efficacy of treatment of these two exceptional orchards may be compromised when the maximum dose per hectare is applied. Better management of tree growth could be considered in the future to improve post-blossom pest control in these two orchard. Finally, an example of output showing the tree-to-tree variation of PACE dose adjustment is presented (Fig.2c). Here the LiDAR and GPS summary data have been transformed into KML formatted files for Google Earth to display a colour coded decision-map, where light green areas identify trees suitable for dose reduction and orange areas identify trees with excessive growth where the efficacy of pesticide applications at full-dose may be compromised.

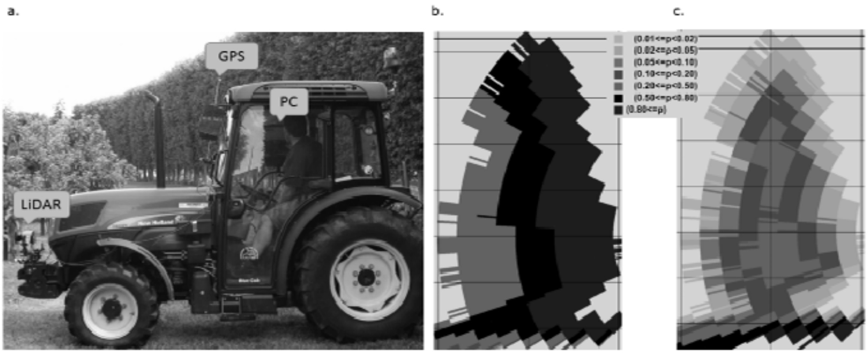

Figure1. (a) The off-the-shelf systems of a tractor mounted LiDAR Crop Scanner,
(b) cumulative probability of the LiDAR beam transmission,
(c) local differential probability of the LiDAR beam interception.

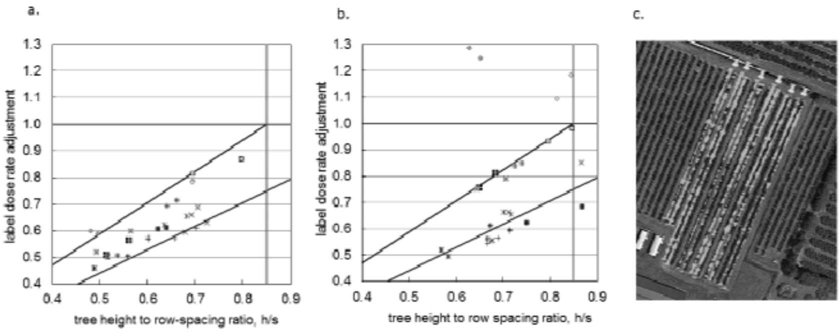

Figure 2. (a) PACE dose adjustments: pre-blossom label dose,
(b)PACE dose adjustments: post-blossom label dose,
(c) Google Earth decision-map of the tree-to-tree variation of PACE dose adjustments within a single orchard.

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Section 5

Technical performance of fogging applications of biological control organisms in fruit cold storage rooms

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Introduction

In the control of storage diseases of pome fruit, several methods are available for the fruit grower. The available pre- and post-harvest treatments, however, all have their limitations. Biological control of storage diseases using biological control organisms (BCOs) may provide a safer and more environmental friendly alternative. The objective of this work was to develop an appropriate application technique using cold fogging devices. The results will also be used as input for computational fluid dynamics (CFD) models to investigate the interaction between storage room, equipment and BCOs.

Materials and Methods

Characteristics and performances of the machines were measured. Four commercially available cold fogging devices were tested using different settings as presented in Table 1.

Table 1. Selected fogging application techniques.

Brand	Type	Air support	Settings
Veugen	Coldfogger	compressed air	3.5 bar
Arend-Sosef	Cyclomatic	turbine	
Swingtec	Fontan Starlet	turbine	LV nozzle 74
			LV no nozzle
			ULV nozzle 74
Veugen	Turbofogger	turbine	nozzle 1.0
			nozzle 2.0

The produced spray plume of each fogger was fully characterised by measuring droplet sizes, droplet velocities and spray angle using a PDPA laser at distances of 0.10, 0.30 and 0.50 m from the outlet opening. At the same distances, the air flow velocities, produced by the devices, were measured using a 1D hotwire anemometer. Liquid flow rate was determined by measuring the weight difference of the solution in the tank before and after spraying. The spraying was for a predefined duration.

Secondly, the performance of the foggers in terms of spray distribution and deposition was measured in a cold storage room loaded with 33 bins filled with apples. Nine bins were sampled, 3 layers (top, middle and bottom) per bin. In each sampling layer, three filter-paper wrapped apple fruits were placed. Mineral chelates were applied as tracer liquid.

Results

The measuring results reflect important differences in spray characteristics between the different techniques. Figure 1 for example, shows the droplet size distributions, measured at 0.50 m from the nozzle for the different application techniques.

The relation between application technique and sample position was investigated in the cold storage room. Figure 2 shows the effect of application technique on average spray deposition on the apple fruit surfaces in the 9 sampled bins. In general, foggers producing a finer droplet spectrum, resulted in a higher deposition on the fruits than devices producing a coarser spray plume. However, devices producing a similar droplet size showed also different deposition levels, suggesting that other factors than droplet size are also important.

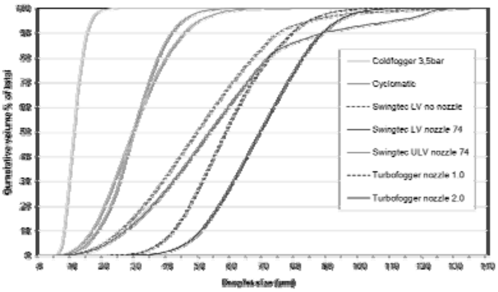

Figure 1. Cumulative volumetric droplet size distribution of the four foggers and different settings used. Measured at 0.50 m from the nozzle outlet.

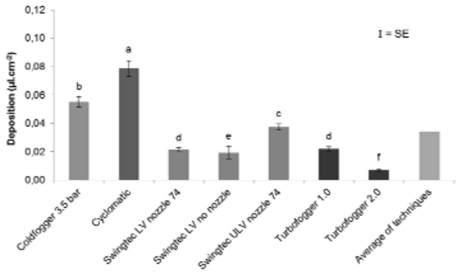

Figure 2. Spray deposition on the apples for the 7 spray techniques. Average of the 9 sampled bins. Letters denote statistical differences.

Project LIFE-FITOVID- Implementation of Demonstrative & Innovative Strategies to reduce the use of plant protection products in viticulture.

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Pesticides are used in viticulture to obtain quality grapes and high worthwhile productions. They are essential to maintain a good prophylaxis in vineyard. Among them, fungicides are the more applied chemical compounds to control fungal pathogens causing devastating diseases, as the case for grapevine downy and powdery mildews. These diseases are more difficult to control in endemic areas, as every growing season appear and are reiteratively treated along it. This fact generates resistance in pathogens, supposing a higher dose for future treatments and more aggressive fungicides; to more exposition of growers to these compounds, decreasing their quality of life because of the latent risks; to an increasing presence of toxic molecules in grape, must and wine, making possible the presence of them in humans by consumption of these products; to affect negatively the surrounding environment, by soil and water flows pollution.

In this context, the LIFE project Fitovid entitled "Implemention of Demostrative & Innovative Strategies to reduce the use of plant protection products (PPP) in viticulture" (LIFE13 ENV/ES/000710) starts in September of 2014. The project is performed in two endemic regions for downy and powdery mildew placed in the Basque Country (North of Spain; Figure 1) that differ in climatic and geographic characteristics, and can be considered as representative of other European regions with similar characteristics, such as, mostly, areas classified under zones C according to Council Regulation (EC) No 479/2008 (i.e. Bordeaux, Languedoc-Rousillon, Portugal, part of Slovenia, Bulgaria, etc.) or coldest and more humid areas such as the zones A or B (U.K., Alsace, Czech Republic, Slovakia, etc.).

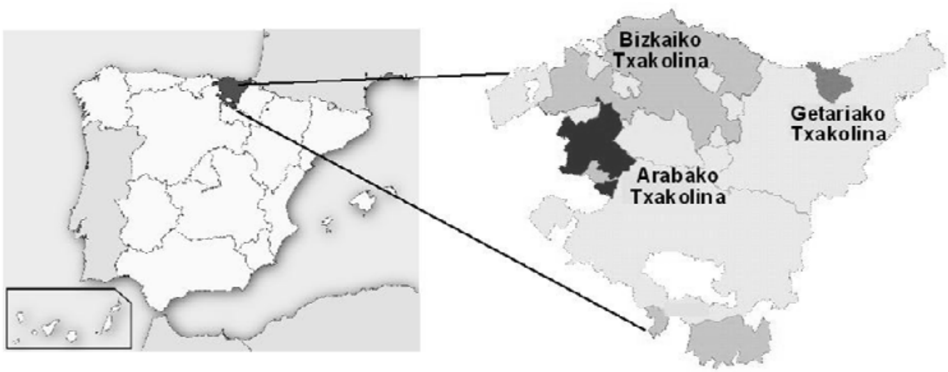

Figure 1. Area where the project is conducted

As a main action included in the project, related with spray application techniques, a voluntary pre-inspection campaign of about 150 sprayers will be arranged. Also a significant number of sprayers/farmers will be selected for a complete follow up during season about the sprayer's use procedure, and the implementation of Best Management Practices. Training sessions will be arranged in the two selected zones in order to demonstrate the benefits of the inspection process and increasing the general knowledge and awareness about Sustainable Use Directive. An important objective has been also defined as demonstrating the benefits of a well efficient application process by good calibrated and adjusted sprayers and beneficial of spray inspections. This point is put in value to winegrowers, by showing the effectiveness of the spray application using a well-adjusted and inspected sprayer. Information is a key factor in the general objective of improving pesticide phase-use. Farmers are more willing to "accept" information when given personally and adjusted to site-specific conditions than when received through general letters and flyers, etc.

Other than the inspection of sprayers' process, there are complementary actions and strategies programmed in the project in order to reduce the number of spray applications. In particular: 1) Monitoring different meteorological parameters in order to identify the treatment time point and also the corresponding disease risk. This strategy includes the installation of weather stations that transmits in real time the registered data, allowing the establishment disease risks emitted by weather stations or more common methods such as Goidanich or degree-day accumulation, defining the moment for fungicide application.2) Monitoring spore concentrations, by collecting samples by passive spore traps, which remains a good disease control strategy that, integrated with the use of meteorological data, provides a valuable tool to establish the basis for an accurate, modern Integrated Pest Management strategy in the vineyard.3) Creating a prototype to detect the pathogen before disease symptoms appear using techniques ofhyper spectral imaging. This technology is suitable to be deployed on field as a portable system allowing the detection of the disease even when it is still unseen and, in the future, as part of the farming machinery for automated detection and spraying.

The intended reduction of pesticides will contribute to a better quality of life of the applicator, as the time of contact with this kind of unhealthy chemical molecules will be reduced. A reduction in the fungicide load will favour to the microbiota to develop rapidly for the degradation processes and it will make possible to increase the bacteria population for wine fermentation. Economic costs will be decreased so as the inputs to disease control, as number of tasks will decrease along the season, saving in fungicides, water, oil, machinery wearing and workforce.

From a short term perspective, as far as the economic effects of the project are concerned, the direct economic positive impacts expected will be linked to two key issues for the wine industry and wine or grape growers. First of all, the better calibration of agriculture machinery for spraying, and the better planning and anticipation through a more appropriate schedule, that will allow a better spraying to a better target, should contribute to reduce, at least, one third of the quantity of the PPP used to prevent mildew, and thus, one third their correlative costs. Considering the strictly economic aspect, fungicide applications represent important costs: it was reported for Rioja region in Spain that fungicide application means over 320 euros per ha per growing season (without taking into account the cost of motor oil, nor the workforce). In regards to the incidence of fungicide treatments in grape and wine quality, we could mention several effects of their use, as residues in grapes, musts and wines influence on fermentation and organoleptic characteristics of wine and the health and hygienic quality and toxicological effect on the consumer.

Precision spraying techniques using an automatic infrared system to detect the target in a Chinese orchard

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Abstract

There is an urgent need for new chemical application techniques and sprayers in Chinese orchard spraying, because of the requirements of environment, safety for food and operator during chemical application in Chinese orchards. A new tractor-mounted, automatic target-detecting system was designed and developed which incorporates electrostatics and infrared sensor is fitted to an air-assisted orchard sprayer. The spraying system was developed to meet the demand of chemical pest control in orchards. This sprayer is lightweight, highly efficient, reduces pesticide use and is environmentally-friendly.

The techniques of automatic target detection, electrostatics, and air-assisted spraying were combined within this system. The infrared ray sensor was used for this system to detect the target, the sprayer can automatically open and stop the nozzle for spraying chemical liquids, when the infrared sensor find target of tree, the nozzle will be opened, when the infrared sensor find the interstitial space between the trees, the sprayer will automatic stop to spray.

The electrostatically charged droplets are projected towards the target by the assistance of an air stream that increases droplet penetration into the canopy. Experimental results show that the new automatic target-detecting orchard sprayer with an infrared sensor can save more than 50 to 75% of pesticides, improve the utilization rate (above 55%), control efficiency, and significantly reduce environmental pollution caused by the spray application. At the same time the key technological problems related to air-assisted low volume and electrostatic spraying are solved.

Acknowledgements

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Key words. Precision spraying, Orchard sprayer, automatic plant detection, air assisted spray, electrostatic spray

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The development of a spray monitoring system for fruit crops as an aid to farm management and traceability

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Introduction

How does a farmer or manager know how much spray has been applied in the orchard or vineyard? Current methods rely upon the integrity of the operator and machine. How does the operator know which row has been sprayed and which hasn't? In many European countries recording pesticide use is a mandatory requirement and many farmers find it a tiresome task manually entering pesticide application data into record books. Traceability in food supplies has become extremely important. Consumers need to be reassured by the grower and the supplier that their food is safe and that pesticide residues are within the acceptable legal limits. Products that are eaten directly without processing, such as apples and table grapes, provide a particular challenge.

Larzelere and Landers (2010) documented the development of a Real Time Kinematics GPS (rtkGPS) sprayer monitoring system. This proved very accurate but was very expensive for many growers and prohibitively expensive for smaller orchards and vineyards.

This paper documents the development of a low-cost, effective recording and documentation system that can be retrofitted to almost any sprayer. The system allows the farm manager to easily download the spraying data at the end of a workday for analysis and use in the compilation of the spraying reports.

Materials and Methods

A detection system was developed using a Radio Frequency Identity (RFID) card reader with 4 antennas (ALR-9680, Alien Technology, Ltd., California, USA). On each side, 2 antennas were fixed at different heights and different directions (Figures 1 and 2) to increase the detection scope and make card capture more likely. The position and direction of the RFID cards on the end posts of the rows was also evaluated by comparing signal strength in relation to direction. Flow rate to each side of the sprayer was detected using Raven RF15 flowmeters (Raven Industries, South Dakota, USA), one fitted to each side.

The complete detection system was tested in a vitus vinifera, *var.*Chardonnay, vineyard with 2.45m rows. The tractor and sprayer were driven past the RFID cards, attached to the end posts of the rows, at 0.63, 1.12 and 1.79 m·s-1, 10 replications were made.

Information from the RFID cards (location, row number, left/right hand side) was combined with information from the flow meters. The speed of the sprayer was monitored using a simple GPS device (GPS Magellan eXplorist 210, California, USA). A computer program was written to analyse this information and a tablet computer on the tractor displayed location, application rate, row number and forward speed, Zhai et al (2014).

Figure 1. Test tractor

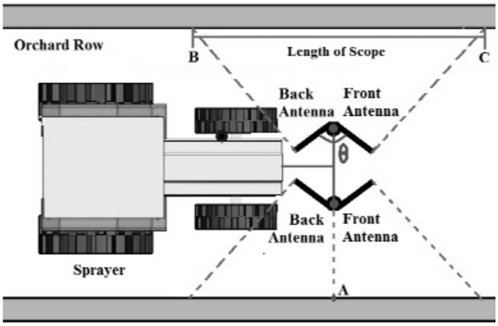

Figure 2. Schematic diagram

Results

Table 1 shows the results of one of many trials conducted in the development of the monitoring device.

Table 1. Test results of the RFID card reading in the vineyard

Speed /MPH	Speed/ m·s-1	Antenna position	Reading Number of RFID Card 1	2	3	4	5	6	7	8	9	10	Average Number Detected
		Front	2	2	2	2	5	3	3	2	3	4	2.8
1.4	0.63	Back	3	4	3	4	5	4	3	3	3	3	3.5
		Total	5	6	5	6	10	7	6	5	6	7	6.3
		Front	1	2	2	2	1	2	1	2	2	2	1.7
2.5	1.12	Back	2	2	2	3	3	3	2	2	1	2	2.2
		Total	3	4	4	5	4	5	3	4	3	4	3.9
		Front	1	1	1	0	1	1	1	1	1	1	0.9
4.0	1.79	Back	2	1	1	2	2	2	1	1	1	2	1.5
		Total	3	2	2	2	3	3	2	2	2	3	2.4

Conclusion

A low-cost sprayer flow monitoring system developed in this research provided consistent data and provides the modern orchard or vineyard manager documentation suitable for farm management and traceability purposes.

Acknowledgments

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Precision fruit spraying: measuring canopy density and volume for air and liquid control

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Introduction

Precision spraying allows fruit growers to apply pesticides only to the target canopy or fruit; to apply the correct quantity according to canopy volume, density, growth stage; and to apply products in an economic and environmentally sound manner. At Cornell University we have conducted research into methods of adjusting both liquid spray and the airflow according to the dimensions of the crop canopy. In both cases this adjustment was made using information provided by a multiple array of ultrasonic sensors that scans canopy vegetation.

Unfortunately, most traditional axial fan sprayers used in fruit canopy spraying create too much air volume and speed, particularly whilst spraying in early to mid-season when the canopy is still developing and is sparse. The result of excess air is spray drift, resulting in environmental pollution to water courses, neighboring properties and damage to susceptible crops. Spray drift means that pesticide is not going onto the target crop resulting in economic waste. Excess air speed also reduces the amount of spray landing on the target fruit due to aerodynamic effects.

Measuring canopy volume

Vegetation detection, based on an array of ultrasonic sensors, was developed and tested by Llorens et al (2013). An array of 6 sensors for orchard characterization and three sensors for vineyard characterization, were mounted on a vertical mast, situated at the front of the canopy sprayer. The distance between the sensors is 50 cm for orchard characterization, to ensure we don't have signal interference between the sensors. With this configuration the system can detect 3 m of height of vegetation in the case of the orchard sprayer.

The sensors send signals to a control board that in turn selects the correct number of nozzleblocks/manifolds, Llorens and Landers (2014). The Lechler Vario Select nozzles can then emit spray according to the canopy. The same sensors/controller is also able to position the actuator and then control the position of the louvre, thus adjusting airflow according to crop volume.

The system we developed measures canopy volume based upon distance between the sensors and the edge of the canopy. If the rows are perfectly straight, the main practical challenge is keeping the tractor in a straight line to ensure accurate readings and distances.

Measuring canopy density

Using the same ultrasonic sensors and control board system described above we have developed an improved sensing method which will measure canopy density as the sprayer moves down the row, irrespective of accurate steering. Field trials were conducted in the 2014 growing season in both apple trees and grapevines.

Results

Figures 1-3 show the effect of canopy growth over the growing season, the reflected sound (presenting itself as voltage) increasing as the canopy density increases. This demonstrates that the sensors were detecting changes in canopy density from sparse canopy in early season to dense in later season. Whilst the hailstorm of 30th July was devastating for fruit quality, the sensor system detected the shredded leaves and the more open canopy, and this is clearly demonstrated in the reduced voltage received.

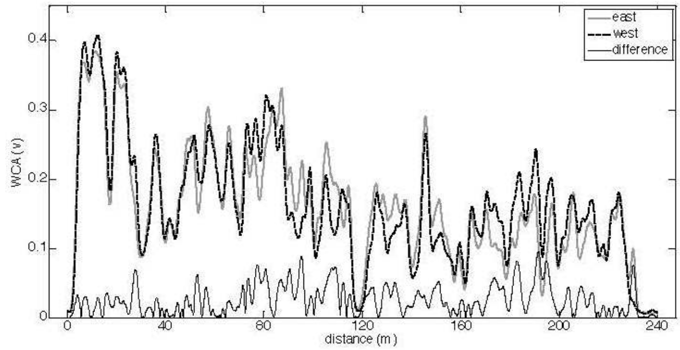

Figure 1: Comparison of the signal (volts) from 6 sensors for each side of the row of trees

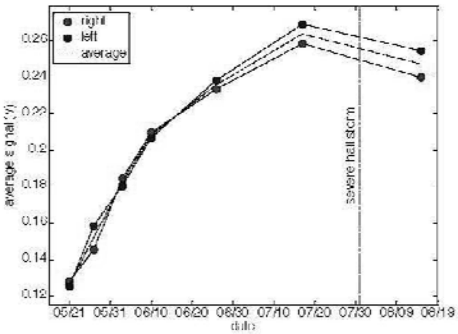

Figure 2: Signal from left and right side of the tree row through the growing season

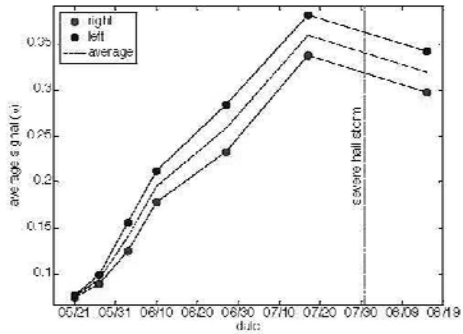

Figure 3: Signal from left and right side of the vine row through the growing season

Further research work will be conducted to relate sensor signal strength to actual canopy measurements using the point quadrat method.

Conclusions

1. The simple ultrasonic sensors detected changes in canopy development over the growing season.
2. The voltage received indicated changes in canopy density.
3. The sensitivity of the sensors is such that it detected the effect of the hailstorm on the canopy
4. The results are very encouraging and indicate that inexpensive sensors can be used to determine canopy density.

Acknowledgements

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Measuring the canopy development of fruit trees for direct spray volume adjustment

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Introduction

In crop spraying the goal is to achieve a uniform spray deposition all over the crop canopy structure or soil surface. Losses to the soil underneath the crop and outside the orchard or field, through spray drift are to be minimised. It is known that sprayer settings are important for spray distribution in tree and crop canopy. Matching spray volume and direction to orchard tree sizes and shapes can reduce chemical application, thus reducing operational costs and environmental pollution. In order to build tailor made decision algorithm to adjust the spray volume based on tree row volume (TRV) more information is needed on the actual situation in the orchard to verify sensor obtained information. The effect of gaps in the crop foliage, differences in amount of foliage in tree canopy segments or between varieties and pruning systems is to be verified before dose algorithms for Variable Rate Application (VRA) or Canopy Density Spraying (CDS) can be developed. Canopy structure information of different sources is compared to evaluate the settings of a CDS orchard sprayer to optimise spray distribution in tree canopy.

Material and methods

We measured the development of the tree canopy on two ways. First we took photographs of the trees and measured the with leaves covered area by image processing using ImageJ (figure1).

figure 1: example of image processing leaf area

original	sample area	processed
		

The same rows were sprayed with the CDS-sprayer with alaser scanner (Hokuyo URG-04LX-UG01 LIDAR) measuring the size and density of the tree canopy at five heights. This sprayer has a variable dosing system based on Lechler VarioSelect nozzle bodies containing pneumatically switchable sets of two standard hollow cone nozzles (Albuz ATR white, ATR lilac) and two spray drift reducing venturi hollow cone nozzles (TVI80-0050, TVI80-0075). The KWH-CDS sprayer can at three height levels in the tree adapt spray volume in four steps to the leaf development of the fruit crop.

The data of the laser measurements and the applied amounts were sampled during the spray application. The laser data was evaluated on the measured canopy and compared with the image analysis.

The characterisation of the orchards as Tree Row Volume (TRV) and the advised spray volume (L/ha) based on extension service advices from the Netherlands (vol 1) and Belgium (vol 2) are given in Table 1following the used two calculation methods:

vol 1 = (TRV x 0.0125) + 125; vol 2 = 25 x TRV/1000.

Table 1. Orchard dimensions and Tree Row Volume (TRV) measured (July) and calculated spray volume accordingly (two methods)

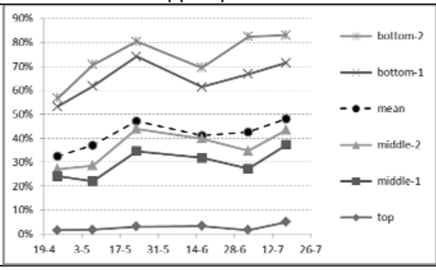
		row width [m]	height [m]	width [m]	TRV	vol 1 [L/ha]	vol 2 [L/ha]
Apple – spindle	Wellant 2010	3	2.1	1.2	8213	228	205
Pear	Conference	3.25	2.0	1.4	8578	232	214
V-hedge	Doyenné	3.25	2.3	1.3	9329	242	233

Results

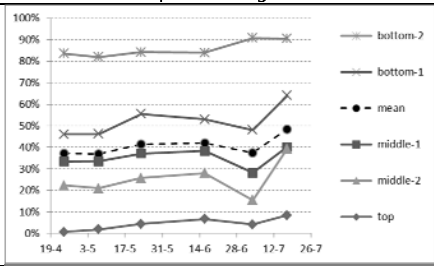
From April till July there is a small increase of amount of leaf, but it is not a complete tight wall of leaves. The apple in full leaf stage had a coverage of 30%. The Doyenné pear had also a coverage of 30% at full leaf stage, the Conference pear was the most dense of the trees but with 65% it also didn't reach a full coverage.

Figure 2: leaf coverage of apple and pear tree canopy calculated from CDS laser data at five heights in the tree canopy

apple spindle



pear V-hedge



In apple: the average leaf density increased from 30% to 50% over the period April - July, in the bottom part the leaf density reaches 80%, in the top it is less than 10%.

In pear: the average leaf density increased from 35% to 50%, in the bottom part of the trees the leaf density reached 90% in July, in the top it was less than 10%.

On all dates the standard spray volume was 200 L/ha. This dose was based on the tree growth stadium with full canopy, which was reached only in June and then only in the bottom parts of the trees.

Efficacious insect and disease control with laser-guided air-assisted sprayer

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Current application technology for floral, nursery, and tree fruit crops requires excessive amounts of sprays to control pests due to a great diversity in canopy structure and leaf density. Critical innovative technology is needed to increase application efficiency and reduce uncertainties for conventional pesticide sprayers to achieve real cost benefits with new pesticide application strategies for these specialty crop producers, consumers and the environment.

An automated variable-rate, air-assisted precision sprayer was developed to minimize human involvement in spray applications (Chen et al., 2012; Liu et al., 2014). The automatically-processed spraying system (fig. 1) is able to characterize the presence, size, shape, and foliage density of target trees and accommodate sprayer travel speed to apply appropriate variable amounts of pesticides based on tree canopy needs in real time. It integrates a high-speed, 270° radial and 30-m range laser scanning sensor in conjunction with a non-contact Doppler radar travel speed sensor, a sophisticated automatic nozzle flow rate controller, an embedded computer, a touch screen, a manual switch box, and 40 pulse-width-modulated variable-rate nozzles on a multi-port air-assisted delivery system.

Automatically-controlled spray capabilities to the sprayer are achieved by the sensors and the embedded computer. The laser scanning sensor, which is mounted between the tractor and sprayer, detects the return distance signals of the bilateral tree structure. An algorithm, written in C++ language, translates these signals along with the sprayer travel speed into tree surface structures and determines the amount of sprays for each nozzle. All 40 nozzles on two sides of the sprayer can independently discharge variable flow rates to their designated canopy sections. The embedded computer, touch screen and switch box operational components are mounted in the tractor cab. The functional touch screen displays the sprayer travel speed, total discharged spray volume, spray width, and active nozzles. The operators can also modify spray parameters through the touch screen as needed.

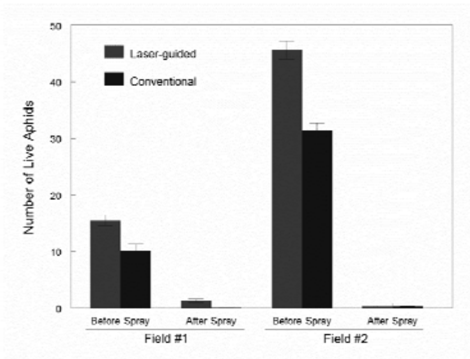
Efficacy of the newly developed variable-rate air-assisted sprayer was investigated for the control of arthropod pests and plant diseases in five commercial nursery fields in three states in 2013 and 2014. Pest control efficiency of the new sprayer was also compared with two conventional air-assisted tower sprayers and three radial air-blast sprayers. Target pests and diseases included aphids, potato leaf hoppers, pod gall midge, sawflies, pear rust, apple scab and powdery mildew on various host plants.

The two-year field biological control tests demonstrated that the laser-guided variable-rate sprayer had comparable insect control efficiencies and comparable or lower disease infection rates than the conventional air-assisted sprayers (figs. 2 and 3). For example, survival rates of aphids on crabapples (fig. 2a) and potato leafhoppers on red maples (fig. 2b) were nearly zero after insecticides were applied with the laser-guided sprayer and conventional tower air-assisted sprayer treatments. There was no significant difference in presence of rusts on 3-year old flowering pears between the laser-guided and conventional radial air-blast sprayer treatments (fig. 3a).

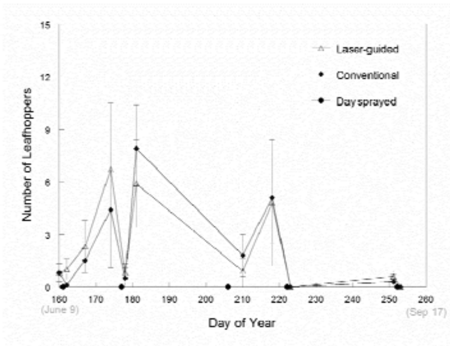
However, there were lower powdery mildew infections on Norway maple trees with the laser-guided sprayer treatment than that with the conventional radial air-blast sprayer treatment (Fig. 3b). This was because the laser-guided sprayer produced the spray deposition distribution across the tree height with lower variations than the conventional sprayer with radial spray patterns.

Figure 1. Newly developed automated variable-rate, air-assisted precision sprayer

With the comparable insect control efficiency and better disease controls or prevention, the average application rates during two growing seasons with the laser-guided sprayer were 412 L ha^{-1} in field #1, 206 L ha^{-1} in field #2, 309 L ha^{-1}in field #3, 174 L ha^{-1} in field #4, and 201 L ha^{-1} in field #5while the average application rates from the conventional constant-rate sprayers in these five fields were 767, 514, 973, 377, and 478 L ha^{-1}, respectively. Moreover, the laser-guided sprayer reduced pesticide use by 46% to 68%. Thus, the new sprayer was able to drastically decrease pesticide usage thus reducing environmental impact and enhancing applicator safety.

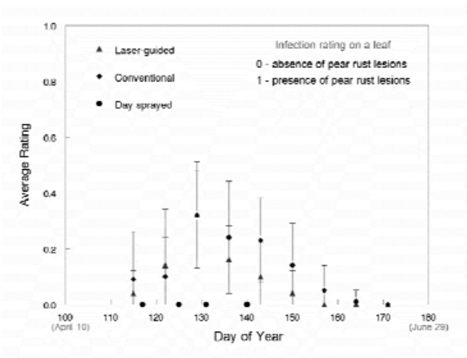


(a) Aphid infestation

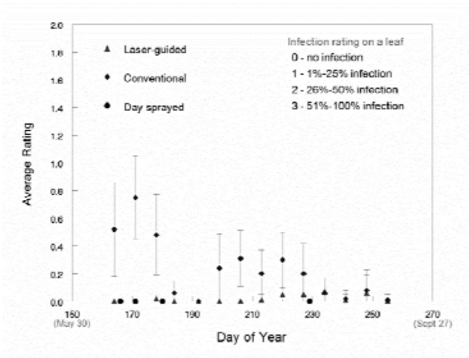


(b) Leafhopper infestation

Figure 2. Comparisons of (a) aphid infestations on a crabapple and (b) potato leafhopper infestation on a red maple between the laser-guided and conventional tower air-blast sprayer treatments.



(a) Rust infection



(b) Powdery mildew infection

Figure 3: Comparisons of (a) rust infections on flowering pears and (b) powdery mildew infections on Norway maple trees between the laser-guided and conventional radial air-blast sprayer treatments.

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Evaluation on savings of plant protection product (PPP) due to optimized gap detection and switching system

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The application of plant protection products (PPP) with sprayers in vertical crops is usually conducted with active air support. The air-assistance implies that the droplets are transported by the air onto the target the leaf/canopy area. In case of gaps in the canopy or missing trees there is no target area in place and therefore the PPP can spread out unwanted into the ecosystem. A good assistance system is the automated nozzle switch off (f. e. by installation of a sensor system) followed by gap detection. Especially in regions with a high population density and/or surface waters these technical devices can ensure a proper application of PPP. One aim of this project is to determine the resulting savings of PPP due to the use of such equipment, as this is an important fact for the grower to buy it. In addition, the approval authorities favor the development of innovative technologies which further protect the environment.

In the project LADUS, funded by the innovation program of the German Federal Institute for Agriculture and Nutrition (BLE), a sprayer (NH 63) with a radial fan was equipped with new optical infrared sensors. Currently, sensor equipped sprayers typically run with axial fans and a limited amount of sensors and therefore are subjected to limitations. The radial fan with air tubes supplies a rather horizontal air stream which corresponds well to the sensor´s field of view. In the project, also the number of sensors was increased and the optical scanning improved. By the optimized sensor system, target surfaces and gaps can be detected more precisely compared to available products (at the market). Consequently, the associated nozzles can be switched as required for the application to reduce the amount of applied PPP. Especially in the leafless stages commercial sensor systems with high sensitivity detect the next row of trees, while at low sensitivity thin branches at close range are mostly not detected. With the new sensors, however, individual leafless thin branches can be reliably detected without scanning into next row. As a result, the gap detection in the canopy is more accurate.

In spring 2014,trials according to the JKI Directive 2-3.1 (April 2013) were carried out in Jork ("Altes Land"), to determine PPP savings. The PPP saving is strongly influenced by the computer-controlled switching operations (on/off) of the nozzles. The experiments were performed with a software-controlled switch-on (SON) and switch-off (SOF) of 0 cm. By spraying the target exactly [- 0 cm; + 0 cm],the application is sharp-edged/precise with high accuracy. Moreover, in a second set of trials both switching operations were shifted[- 20 cm; + 20 cm] to illustrate a treatment with an advanced safety. This set-up is usually used with equipment with f. e. Eco-Reflex under practical conditions. These two different sets of trials were conducted in different development stages of an orchard (dense foliage stock; plant with smaller gaps; younger plants).

Tab. 1: Saved amount of PPP [%] by the use of the gap detection and switching of the LADUS- system

	PPP saving* (SON and SOF[- 0 cm; + 0 cm])	**PPP saving*** (SON and SOF[- 20 cm; + 20 cm])
Dense foliage stocks	41%	0%
Orchard with small gaps	48%	2%
Young plants	69%	30%

*Saving is calculated in relation to a treatment without gap detection and switching system

As expected, these experiments (Tab. 1)demonstrated that the PPP saving depended on the density of foliage. In young plants with sharp-edged application [- 0 cm; + 0 cm], a saving of almost 70% could be achieved. Compared to the strategy of advanced safety application[- 20 cm; + 20 cm], the savings could be increased significantly.

Our goal is to develop a product with a market maturity for new sprayers and for retrofitting of sprayers in use. Therefore, the equipment has to be extremely reliable and robust as well as affordable.

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Improving spray deposition and reducing spray drift in orchard spraying by multiple row sprayers

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Introduction

The evaluation of the latest data on spray drift in orchard spraying in the Netherlands, and measurements of surface water quality parameters show that the current legislation and measures are insufficient to protect the surface water. This can also have implications for the approval of pesticides in fruit growing. To meet the national and European objectives regarding surface water quality also a reduction of chemical input is required.

New strategies have to be developed to retain chemicals for crop protection and a clean environment. Latest developments showed great perspectives for multiple row orchard sprayers. The use of these types of sprayers has increased dramatically in the Netherlands in the recent years. This is predominantly because they require less time to spray an area, and therefore timeliness is higher and anticipation to weather conditions and disease development is better.

It is proven that multiple row sprayers reduce spray drift significantly. This is due to the spraying system that sprays tree rows from both sides at the same time, in contrast to standard orchard sprayers that spray the tree row only from one side. It is assumed that spray depositions are improved when spraying with multiple row sprayers and dose can therefore be reduced accordingly, without reducing biological efficacy. Further research therefore is necessary to assess spray deposition in the tree canopy.

The objective is to find the optimum combination of application parameters for the full leaf stage of apple trees in order to reduce spray drift while improving spray deposition.

Materials and Methods

Treatments

In this experiment different treatments were compared:

Reference sprayer (Munckhof)

1. standard – conventional cross-flow fan sprayer (Munckhof); Albuz ATR lilac at 7 bar spray pressure (Fine spray quality).
2. standard – conventional cross-flow fan sprayer; Albuz TVI 80015 at 7 bar spray pressure (Coarse spray quality - 90% drift reducing nozzle type).

Multiple row orchard sprayersMunckhof and KWH to spray two tree rows from both sides

1. Munckhof equipped with Albuz ATR Lilac nozzles.
2. Munckhof equipped with AlbuzTVI 80015 nozzles.
3. KWH equipped with Albuz ATR Lilac nozzles.

Also, for the multiple row orchard sprayers spray pressure was 7 bar. Measurements were performed during the full leaf stage of the apple trees. Air settings for the reference sprayer (Munckhof) were a high gear box setting and 540 rpm of the pto. The multiple row sprayers were tested at fan settings of 300, 460 and 540 rpm of the pto.

Spray deposition measurements and sampling procedure were carried out following the ISO22522 standard picking leaves from the different tree compartments and ground deposition. Apple trees were sprayed with a solution containing the fluorescent dye Brilliant Sulpho Flavine (BSF; 0,5-1 g/l) and a non-ionic surfactant (Agral; 7,5 ml/100 l).Spray volume was around 200 l/ha for the used spray techniques.

Figure 1. Munckhof 3-row sprayer (left) and KWH 3-row sprayer (right). Both sprayers were tested as 2-row sprayers spraying the tree rows alongside the sprayer from both sides.

Figure 2. Spray deposition measurement on collectors on the ground (left), in the tree as leaf picking (right) following the sampling scheme (centre).

Four repetitions were made, i.e. spraying 30 m of a single tree row from both sides, and analysing leaves samples from four individual trees. Leaf samples were taken by counting all leaves in seven tree sections: Top, Middle East side, Middle West side Bottom Inside West, Bottom Outside West, Bottom Inside East, Bottom Outside East and putting every 10th leaf in a bag. The picked leaves were analysed in the laboratory for spray deposition of the sprayed fluorescent tracer BSF. The leaf areas were determined, and the spray deposition was calculated.

Results

General conclusions and discussions from these experiments are:

- On all sprayers the coarse spray quality nozzles (TVI) increased spray deposition above the standard fine spray quality ATR nozzles.
- Spray deposition varied depending on nozzle spray quality and fan setting.
- Highest spray deposition for the Munckhof two row sprayer was obtained at 460 rpm (pto) with the ATR nozzles and at 540 rpm (pto) with the TVI nozzles.
- Highest spray deposition of the KWH two row sprayer was obtained at 400 rpm (pto) which was about 25% higher than the standard sprayer with ATR nozzles and higher than the standard sprayer with TVI nozzles.

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