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Opening

Session 4: *Reduction of risks*
Chairman: Jean Paul Douzals

Friday 28/06/2013

Session 5: *Drift assessment*
Chairman: Peter Walklate

OPENING SESSION

Orchard spray application in Europe – state of the art and research challenges

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Abstract

Axial fan airblast sprayers are still the most commonly used for orchard spray applications in Europe because they are of comparatively low cost, robust, durable and flexible for use in a wide range of orchard types though they are gradually being replaced by more efficient and better targeted designs. Axial fan sprayers normally produce a large radial spray plume that is poorly targeted and which results in high spray losses to the ground and as spray drift, and growers rarely make adequate adjustments to optimise sprayer performance in particular orchards.

A wide range of other machine types are also in use including cross-flow designs and those with ducting which aim to better target the spray plume to the tree, with varying degrees of success. Several designs of tunnel sprayer to reduce spray losses are available but tunnel sprayers are only used by a few growers because of their high cost and practical difficulties of use. Multi-row sprayers are being increasingly adopted to increase work rates. Sprayers with canopy sensors that adjust sprayer output (spray liquid and/or air flow rate) in real time in response to the physical characteristics of the target and/or environmental conditions are currently at the cutting edge of spray machinery development. There has been a gradual evolution from simple machines where nozzles are switched off in response to gaps in the canopy to those that make adjustments in real time in response to target canopy size and density. Such sprayers have been shown to be considerably more efficient and there is a key need to foster adoption into practice.

Spray drift and environmental contamination rates from orchard spraying are high compared with arable crop spraying and a range of methods of drift mitigation of varying degrees of effectiveness and practicality have been developed, some of

which are now legally required, notably mandatory buffer zones on pesticide labels and the use of low drift air induction nozzles which produce very coarse spray qualities. There is considerable variation in mandatory schemes in different EU countries, which need to be harmonised. There are important changes in the way dose rates are being expressed on pesticide labels and efforts are underway to develop methods of adjusting dose rates to suit the very wide range of orchard canopies to achieve deposits that are more uniform between different canopy sizes at different growth stages. Regular sprayer testing is now mandatory in many countries, to ensure that sprayers are adequately maintained and calibrated.

There is extensive scope to improve many aspects of orchard spray application by research. The three most important key challenges are 1) Improving machine design and crop adaptation to improve deposition/reduce losses including in real time 2) Understanding spray deposits/quality/cover and their effects on efficacy 3) Dose adjustment.

In this paper, the state of the art of orchard spraying practice in Europe including machinery, air adjustment, atomisation/nozzles, canopy sensing, drift mitigation, dose expression and adjustment and sprayer testing are broadly overviewed and the main technical and research challenges presented.

SESSION 1

Field measurements of drift

Comparison of vertical and horizontal collecting methods for spray deposits in crop canopy and airborne spray drift assessment

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Introduction

The extent of the application of plant protection products (PPP) on various fruit crops showed that in some cases up to over 50% of the PPP does not reach the target (Salyani et al., 2007). Due to side wind, a fraction of the product can be found downwind on a spray drift area but simultaneous measurements on the target crop and on the spray drift area indicates that a fraction remains undetected (Douzals, 2012). In the particular case of high crops, like banana, the difference in height between the drift collection plane and the canopy questioned of an evaluation based only on ground deposition of spray drift is relevant. In practice, a downwind area of more than 100 m limits spray drift measurements especially when the wind direction may displace the spray plume outside the collecting area. A complementary method is then specified by ISO 22866 standard through the use of a vertical array of collectors close to the crop boundary for the assessment of airborne drift flux. The present work aims first at evaluating the collection efficiency of two vertical array of collectors with PVC strings of 2 mm diameter placed close or far from the sprayed area. Second a horizontal array of collector device is implemented to measure ground deposits between the two vertical collectors devices. On the horizontal one, PVC strings collection efficiency is compared to Petri dishes and PVC stripes which represent respectively discrete and integrative collectors. PVC strings are placed at different distances from the spray release point. The collection efficiency is studied indoor. Measurements are made for both aqueous and mineral oil-based mixtures (Banole®). Finally the implementation of the complete spray drift measurement protocol for a banana field is presented.

Materials and Methods

Indoor measurements

An original mistblower was specifically developed for ground-based banana crop spraying (Cotteux et al., 2011). Either water or Banole® added with the fluorescent tracers *BSF or CFS 00-6* were respectively applied on experimental vertical and horizontal patternator devices (Table 1. Figure 1a&b). Spray direction is horizontal with a release height of 1 m. The spraying device is composed of two nozzles specifically placed so as to obtain the most homogeneous footprint in terms of application volume along the spray range. Sprayer flow rate, operating pressure, air temperature and relative humidity are recorded every second. The tractor speed is 4.5 km/h travelling over a distance of 11 m for indoor experiment

Table 1. Characteristics of array collector device

Devices	Collector	Distances	
		Horizontal from sprayer	Vertical from ground
Horizontal	Petri dishes Ø 8.6 cm	Every 0.5m up to 10 m then every 1m up to 15 m	0.25 m
	PVC stripes 5x50 cm	Every 0.5m up to 5 m	0.25 m
	PVC strings Ø2 mm / 4 m length	Every 0.5m up to 5 m	0.25 m
Closest Vertical 1	PVC strings Ø2 mm / 50 cm length	Different positions up to 10 m	every 20 cm from 0,5 m up to 2,5 m
Farthest Vertical 2	PVC strings Ø2 mm / 4 m length	15 m	every m from 1 m up to 8 m

Outdoor measurements

For crop experiment tractor speed is around 4 km/h over a distance of 80 m (Figure 2 a&b). The crop area treated corresponds to about 0.5 ha (80 x 60 m). Only Banole is sprayed for crop experiment. The air speed generated by the mist blower is about 55 m.s^{-1} at the spout outlet.

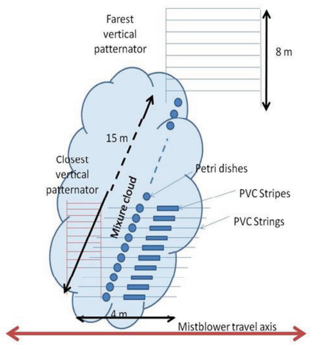

Figure 1a: Experimental patternator devices (indoor)

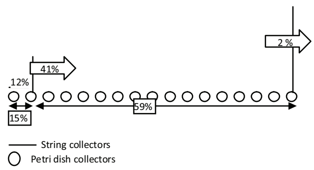

Figure 1b : Results for % of collected product on different array of collector for water test (indoor test)

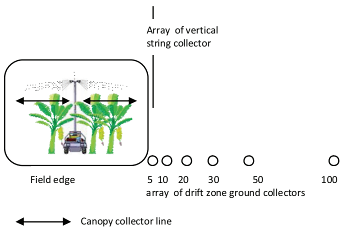

Figure 2a: Experimental patternator devices (banana crop)

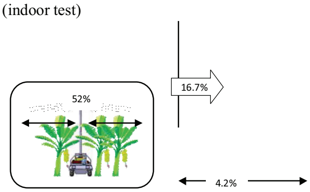

Figure 2b : Results for % of collected product on different array of collectors for banole test on banana crop

Laboratory analysis

Collectors are washed with water for aqueous mixture or dearomatized oil for Banole® respectively. BSF and CFS 006 concentration was quantified by fluorimetry. Recovery efficiency corresponds to the ratio between the total collected volume compared to the sprayed volume normalized for 1 m of travel.

Results

For indoor experiments, when water is sprayed, only 74 % of sprayed volume was recovered on the 15 m horizontal collectors device; 12% were collected on the first 1.5 m with string collectors and 15% on Petri dishes. Recovery rate appears quite similar for both Petri dishes and strings on horizontal array of sampling collectors along the 5 first meters from spraying point (respectively 48% and 45%). Meanwhile vertical collectors placed at 1.5 m from spraying points collected only 41% of products compared to 62% expected (74-12=62). At maximum distance, only 2% of sprayed volume is recovered on vertical patternator located at 15 m from sprayer with water solution compared to 26% sprayed volume which is missing. When Banole® is sprayed, much product is collected on the farthest vertical array of collector (6%) and less product is collected on ground collectors (50%). Those results confirm also that Banole® tends to be more sensitive to air assistance than water (Douzals et al., 2010). Based on these preliminary results an experimental setup has been tested in banana crop in the objective of a mass balance assessment with a combination of collectors. The first results indicate that much product is collected on a 12 m height vertical array of string collectors placed at 5 m downwind of a crop than product collected on ground collector placed on the downwind drift zone.

For experiment on banana crop, a complete mass balance has not been achieved. But it was shown that the vertical array collectors device allow a better quantification of airborne drift compared to ground measurement device.

References

Cotteux E, Rombaut M, Douzals JP (2011) Development of a ground-based system applied banana spraying in French West Indies. Suprofruit 2011. 11th Workshop Sustainable Plant Protection Techniques in Fruit Growing, Book of abstracts, Ctifl. Lanxade. France. 120-121.

Douzals JP, Sinfort C, Cotteux E (2010) Spraying quality assessment of a mist blower used on banana crops. Proceedings of AgEng 2010 Clermont Ferrand., Cemagref Ed.

ISO 22866 (2005) Methods for field measurement of spray drift. International Standardisation Organisation, Geneva.17p.

Salyani M, Farooq M, Sweeb RD (2007) Spray deposition and mass balance in citrus orchard applications. Transactions of the Asabe 50(6): 1963-1969.

Spray drift measurement using a UV lidar system

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Introduction

Range-resolved lidar systems, principally the elastic ones, have been used in a number of studies for pesticide spray drift monitoring in both aerial and ground spray treatments (Gregorio et al., 2011). In most cases, lidar was used to study the movement and dispersion of the pesticide plumes at a qualitative level. However, the application of lidar to quantify droplet concentration in pesticide clouds has scarcely been addressed before (Hiscox et al., 2006; Khot et al., 2011).

This article shows an experimental study of the relationship between spray drift measurements obtained with an elastic-backscatter lidar system and those obtained using passive collectors.

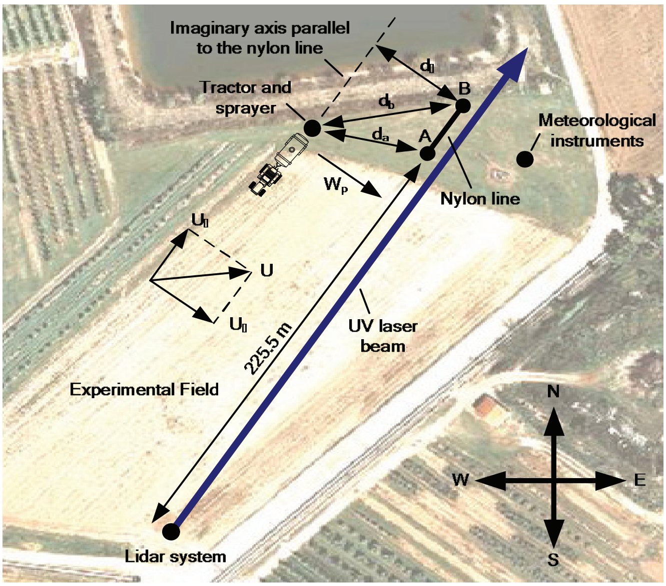

Fig. 1. Experimental setup. U is the wind speed and $U_\perp$ and $U_\parallel$ are respectively the wind components orthogonal and parallel to the nylon string. W_p is the component of the plume drift speed, orthogonal to the nylon string.

Materials and Methods

Ten spray tests were performed between September 18 and 21, 2009, at a field in Gimenells (41º39'11''N, 0º23'28''E, elev. 259 m) located 25 km away from Lleida, Spain. Fig. 1 shows a map of the field as well the position of the instruments and machinery used during the trials. At the time of the trials, there was no crop in the field.

The spray was generated by an axial fan air-assisted sprayer (Ilemo Arrow F-1000, Ilemo/Hardi SA, Lleida, Spain) operating at 1 MPa. The spray liquid was an aqueous solution of brilliant sulfoflavine. Two types of collectors were used in each test: a 2 mm diameter nylon string 25.5 m long and 16 water-sensitive paper sheets 26×76 mm. The nylon string was positioned horizontally 1.7 m above the ground, covering the distance from point A to point B (Fig. 1). The water-sensitive paper sheets were attached to the nylon string at a distance of 1.5 m from each other, matching the range resolution of the lidar system.

A 355-nm 16-mJ polarization lidar system (ALS 300, Leosphere, Orsay, France) was used for pesticide spray drift monitoring. The lidar was pointed horizontally with its laser beam aligned with the nylon string. In all the tests the separation between laser beam and nylon string was less than 30 cm.

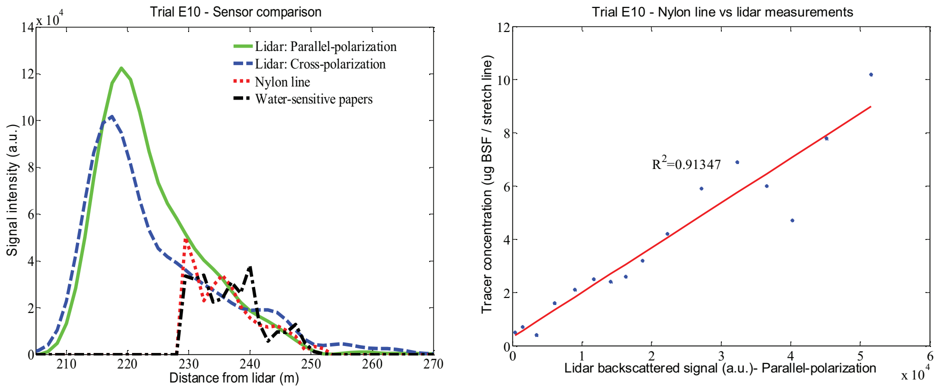

Fig. 2. (left) Range profiles of time-integrated lidar signals (parallel and cross-polarized channels), tracer mass captured by nylon strings and spray coverage on the water-sensitive papers. (right) Tracer mass [µg] deposited on each nylon string segment vs backscattered lidar signal in parallel polarised channel.

Results

Fig. 2 (left) compares the backscattered signal received by the lidar system with the measurements taken with the passive collectors in one of the tests. Passive collectors only measured the drift for distances ranging between 225.5 and 251 m, where the support posts were positioned. This entails a disadvantage with respect to the lidar system which enables monitoring of the whole plume.

Fig. 2 (right) represents the tracer mass deposited on each nylon string segment (1.5 m) versus the time-integrated lidar signal (parallel polarised channel) corresponding to the same segment. A significant linear relationship is observed between both variables with R^2=0.91. The remaining tests showed similar R^2 (data not represented). These results provide a basis for fast and accurate measurement of spray drift using range-resolved lidar.

Acknowledgements

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References

Gregorio E, Solanelles F, Rocadenbosch F, Rosell JR, Sanz R (2011) Airborne spray drift measurement using passive collectors and lidar systems. Proceedings of the SPIE 8174, 8174IL1-12.

Hiscox AL, Miller DR, Nappo CJ, Ross J (2006) Dispersion of fine spray from aerial applications in stable atmospheric conditions. Transactions of the ASABE 49: 1513-1520.

Khot LR, Miller DR, Hiscox AL, Salyani M, Walker TW, Farooq M (2011) Extrapolation of droplet catch measurements in aerosol application treatments. Atomization and Sprays 21(2), 149-158.

Methodology for a fast, in field estimation of the efficiency of antidrift measures

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Introduction

During the application of phytosanitary products, only a fraction of the spray reaches the appropriate part of vegetation due to excessive application, runoff, product washing, evaporation or drift, contaminating the environment. Both farmers and pesticide manufacturers try to optimize treatments, encouraged by legislative initiatives designed to reduce to a minimum the risks associated with the use of plant protection products, i.e. Directive 2009/128/EC (OJ, 2009). This Directive promotes the use of buffer zones to reduce environmental contamination. The size of a buffer zone depends on the product to be applied and how the application is performed (machinery and its set up, wind during the application, etc.). The more an application method is able to reduce drift, the lower the width of the buffer zone.
Low drift air injection nozzles, hereafter referred as antidrift nozzles, have a great potential for the reduction of drift. Other simple ways of reducing drift are: using lower working pressures, closing the nozzles not directly pointed towards the tree, adjusting the spray application volume to the amount of vegetation being treated, using an adequate working speed or properly adjusting the fan airflow.
It is very important to establish an easy and fast methodology to estimate how much drift can be reduced in order to assess its efficacy and to determine an adequate size for buffer zones. This work proposes a simple method for in field evaluation of a drift reduction method.

Materials and Methods

Field experiments were performed in commercial orchards growing peaches, platerines and lemons. In these trials we compared drift levels generated by current phytosanitary treatments (conventional treatment) with those generated by proposed drift reduction methods (antidrift treatment). After inspecting and calibrating the equipment of each orchard, antidrift nozzles producing similar flows to those used in the conventional treatment were chosen and the operative conditions of both treatments were set (working pressure, number of nozzles open, working speed and actual spray application volume).

The proposed methodology consisted in performing one application of the conventional treatment and one application of the antidrift treatment. In each application a fluorescent tracer (Brilliant Sulfoflavine) was added at 1 g/l concentration. Applications were performed over a 50 m path between the tree rows, with both sides of the sprayer open. Atmospheric conditions were monitored during the applications to ensure that both treatments were applied in similar conditions.

Drift measurements consisted on quantification of (a) spray deposition on the ground in tracks adjacent to the sprayed track, four tracks on each side of the sprayer, and (b) deposition on vertical nylon thread collectors in adjacent tracks, two tracks on each side of the sprayer. Each vertical thread was cut into sections 1 m long. The vertical distribution of the spray was divided in two parts: 1) The zone protected by the vegetation (with horizontal displacement of the spray cloud); and 2) The zone over the canopies (spray cloud exposed to atmospheric air movements and with a higher risk of spray drift).

A drift risk reduction factor was calculated from the data of the deposits of atmospheric drift, as the ratio of the overall deposition in the antidrift treatment to the conventional treatment. Another parameter calculates the symmetry of the distribution of the atmospheric drift.

Results

In general, with the antidrift treatments, ground deposits on the first track next to the sprayer were higher than those produced by the conventional treatment. However, in the following tracks, these deposits were lower with the antidrift treatment. These data demonstrate that the droplets produced by the antidrift treatment are larger and travel less, falling in the immediate surroundings of the tractor path. The conventional treatments produced greater deposits from the second track on, which may provide an approximation to the required width of a buffer zone. The data showed that the buffer zone had to be wider for conventional treatments, given that spray deposits were found until the fourth track.

Regarding the deposits on threads, in both treatments the lower zone received much more deposits in peach (Figure 1) and platerine plots, given that the vegetation opposed a slight resistance to the spray movement. However, in the lemon orchard the lower zone received less deposits due to the dense vegetation. In all cases a large correlation ($r>0,7$) between soil and thread deposition was observed.

On the upper zone of the threads, the conventional treatment produced higher deposits, which reflects the higher likelihood of droplet drift, with potentially higher atmospheric drift. All the antidrift treatments reduced drift, in the case of peach up to 54%.

Moreover, the distribution of the spray produced by the antidrift treatment was less dependent on wind, given that deposits had a more symmetrical vertical distribution. In the case of the example, the symmetry coefficient of the conventional treatment was 77% while that of the antidrift one was 95%.

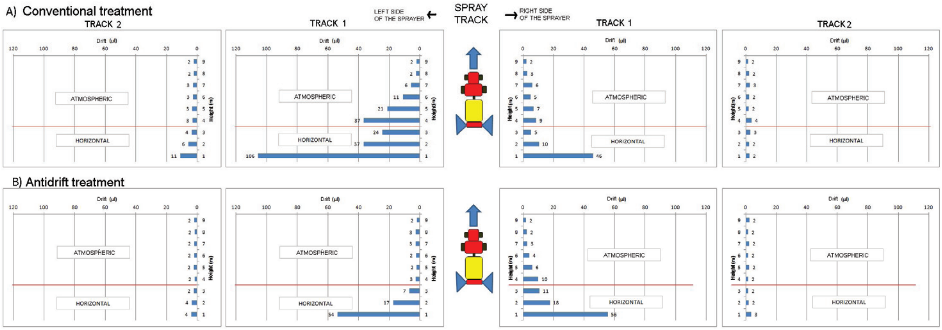

Figure 1. Drift produced by A) conventional treatment and B) antidrift treatment in a peach trial.

The work shows the potential of this method to estimate drift reduction and can be a valid tool for a fast assessment of drift when comparing different drift mitigation approaches.

Acknowledgements

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References

OJ (Official Journal of the European Union) 2009. Directive 2009/128/EC of the European Parliament and the Council of the European Union of 21 October of 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Official Journal of the European Union L309 of 24 November of 2009, 71-86.

Spray drift and spray drift reduction of the KWH three-row orchard sprayer. Effect of variable levels of air assistance and nozzle type

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Introduction

From the 2004 evaluation of the Water Pollution Act (LOTV) in the Netherlands it was clear that the aim to reduce the emission to surface water with 90% was not met. Therefore additional regulation to adapt the LOTV came in force in 2007. The minimal crop-free buffer zone width was increased from 3 m to 9 m for standard spray application techniques in fruit growing. The width of the crop-free buffer zone can be reduced when additional spray drift reducing measures are used; e.g. . using venturi nozzles and spray the outside tree row only from the outside to the inside of the orchard. The efficiency of three row orchard sprayers is higher than conventional ones for pest and disease control because they reduce costs for the farmer. 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. The expected higher drift reduction of three row orchard sprayers, because of spraying a tree row from both sides at the same time is assessed, taking into account the effect of drift reducing nozzles and reduced fan airflow levels.

Materials and Methods

Field spray drift measurements from the outer 24 m (8 rows of trees) at the downwind side were performed in an apple orchard (Elstar), using Brilliant Sulpho Flavine (BSF) as a tracer. Spray drift deposition on the ground was measured on a grass strip next to the orchard up to 25 m from the last tree row. Filter collectors (Technofil TF-290) of 0.50x0.10 m in a continuous line from 3 m to 15 m and 1.00x0.10 m collectors at 20 m and 25 m distance of the last tree row were used. Airborne spray drift was measured at 7.5 m distance from the last tree row on a mast of 10 m height using ball shaped collectors (Siebauer Abtrifftkollektoren) every meter. Different treatments were compared: a) the standard cross-flow fan orchard sprayer (Munckhof) equipped with Albuz ATR Lilac hollow cone nozzles operated at 7 bar (reference); b) the same sprayer equipped with 95% drift reducing nozzles (Albuz TVI80025) and one sided spraying of the outside row; c) the KWH three row orchard sprayer equipped with Albuz ATR Lilac nozzles; d) as c with

90% drift reducing TVI 80015 nozzles; e) as d and manual setting of the air in the outer two swaths; f) as e and reduced air assistance (400 rpm pto); g) as d and variable air assistance system (VLOS) controlled by an wind anemometer; all at 7 bar. All measurements were performed during a) full leaf stage and b) dormant leaf stage of the fruit trees. Air settings for the reference sprayer were low in the dormant and high in the full leaf situation.

Results

High spray drift reductions were achieved with the different settings of the KWH three row orchard sprayer. Tree rows sprayed from two sides at the same time resulted in higher spray drift reduction levels compared single path applications. Spray drift reduction of the different settings of the KWH three row orchard sprayer relative to the reference Munckhof cross-flow fan sprayer are presented (Table 1) for the surface water area next to the orchard (bank to bank) at 3-7 m and for the water surface at 4.5-5.5 m distance from the last tree row.

Table 1. Spray drift reduction of KWH three row orchard sprayer settings at surface water (3-7m) and water surface (4.5-5.5m) in the dormant and full leaf stage

	Dormant tree stage		Full leaf stage	
Technique	3-7 m	4½-5½ m	3-7 m	4½-5½ m
KWH ATR Lilac	46	50	80	81
KWH TVI 80.015	88	91	98.3	98.6
KWH manual #	97.8	98.1	98.0	98.5
KWH 400 rpm #	94.9	96.1	99.2	99.4
KWH VLOS #	94.5	95.8	94.2	95.0

In the dormant stage spray drift reduction of the KWH three row orchard sprayer equipped with Albuz ATR Lilac nozzles was 50% when compared to the Munckhof cross-flow fan sprayer equipped with the same nozzle and spray pressure and a 3 m crop-free buffer zone. Spray drift reduction increased to 81% in the full leaf stage. The KWH three row orchard sprayer equipped with the Albuz TVI 80015 venturi nozzle resulted in spray drift reductions of 91% in the dormant and of 98.6% in the full leaf stage. Using the three row KWH variable air assistance system (VLOS) in combination with the TVI80015 nozzles resulted in a spray drift reduction of 96% in the dormant and 95% in the full stage. Similar effects were found for airborne drift. It is therefore advised to setup additional spray drift reduction classes of 97.5% and 99% in the spray drift reduction classification system. Further research is needed to assess spray deposition in the tree canopy and biological efficacy.

Acknowledgements

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Spray drift and drift reducing spray techniques for weed control in nursery tree and fruit growing

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Introduction

For downward directed spray applications in nursery trees and fruit crops the Dutch authorisation procedure for Plant Protection Products (PPP) uses spray drift data originating from boom sprayers spraying a potato crop (Zande et al., 2012). However weed control in fruit and nursery tree crops is performed by ‘weed sprayers’ equipped with small (<2 m) spray booms at a maximum height of 30 cm above soil surface. It is expected that spray drift from these applications is similar to band treatments (Zande et al., 2000) and lower than spraying a 50-75 cm high crop from 50 cm above the canopy. Spray drift with this equipment was measured in nursery trees to compare with the values used in current legislation (1% spray drift deposition at surface water). To do comparative spray drift measurements a reference spray technique for downward directed spraying in nursery trees was defined as a hitched or trailed weed sprayer having a maximum spray boom height of 30 cm above soil surface, a nozzle spacing of 30 cm using standard flat fan nozzles (TeeJet XR11004) operating at a maximum pressure of 2 bar. With a forward speed of 5 km/h a spray volume of 450 l/ha is generated.

Materials and Methods

With the reference spray technique for weed control in fruit and nursery tree spraying spray drift measurements were performed to determine the typical reference spray drift curve. Spray drift of drift reducing measures were determined relative to this reference spray technique. Comparative spray drift measurements were performed using a 50% drift reducing nozzle (TeeJet DG11004 at 2 bar spray pressure) and a 90% drift reducing nozzle (TeeJet AIXR 11004 at 1 bar spray pressure) both using an end nozzle (Agrotop Airmix OC 11004) in the outside nozzle-body spraying the outside path.

Spray drift measurements were performed spraying the downwind outer 20 m of a nursery tree field using the fluorescent tracer Brilliant Sulpho Flavine (BSF). Spray drift deposition was measured on soil surface next to the field up to 20 m from the last tree row. Used collectors were filter cloths (Technofil TF-290) of 0,50x0,10 m in a continuous line of 2 m to 11 m distance and at 15 m and 20 m collectors of

1,00x0,10 m. Airborne spray drift was measured at 10 m distance from the last tree row using a mast with collectors (Siebauer Abtrifftkollektoren) up to 6 m height.

Results

Spray drift deposition of the reference spray technique for weed control in tree nursery is in combination with the nowadays used 5 m crop free buffer zone on surface water area (top of bank – top of bank area; 5-9 m from last tree row) 0.026% and on surface water area 0.023% (6.5-7.5 m from last tree row).
Measured spray drift deposition of the weed sprayer in nursery trees is 98% lower than of the nowadays used 1% spray drift in the authorisation procedure for field boom spray applications. This gives proof that a typical spray drift deposition curve can be used for this typical situation: downward spray applications using a weed sprayer in nursery tree growing.
Using the weed sprayer up to 0.5 m from the top of the bank spray drift deposition on the water surface area (2-3 m distance from the weed sprayer) is 0.062% using the XR11004 standard flat fan nozzle type. It is suggested to use this application situation as a standard for weed control in nursery tree growing as it coincides also with a similar application situation as for other field crops in the Dutch Water Pollution Act. When the weed sprayer is equipped with (50% drift reducing) DG11004 nozzle types (in combination with an end nozzle in the outside nozzle body, outside swath spraying) spray drift deposition is respectively 0.026% for the DG11004 and lower than 0.010% (spray deposition lower than detection level, no measured spray drift deposition) for the AIXR11004 nozzle type.
It is shown that the DG11004 and the AIXR11004 nozzles give a drift reduction of respectively 58% and more than 88% (not higher quantified as the limit of the detection level was reached) which is similar to the drift reduction class as classified for use in field boom sprayers, the existing nozzle classification system can be used for applications with weed sprayers in fruit and nursery trees too.

Acknowledgements

The research was funded by the Dutch Horticultural Board (PT project 13935), the Ministry of Economic Affairs and the Waterboards Rivierenland, Brabantse Delta and De Dommel and the Farmers Union (LTO) Nursery tree group.

References

Zande JC van de, Holterman HJ, Huijsmans JFM (2012) Spray drift assessment of exposure of aquatic organisms to plant protection products in the Netherlands. Part 1: Field crops and downward spraying. Wageningen UR Plant Research International, Plant Research International Report 419, Wageningen. 84pp.

Zande JC van de, Stallinga H, Michielsen JMGP (2000) Spray drift when applying herbicides in sugar beet and maize using a band sprayer. Mededelingen Faculteit Landbouwwetenschappen, Universiteit van Gent, 65/2b. 945-954.

Spray drift of an experimental mast sprayer spraying high nursery trees

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Introduction

In high trees it is often difficult to reach the top of the tree when spraying plant protection products. Especially in crops with narrow tree rows and tree spacing in the row and dense leaf structures. Often (very) high capacity axial fan sprayers are used to blow the fine mist of spray as far up as possible into the air, hopefully reaching the target in the top of the tree also. In apple fruit growing where dwarf trees are more common often a cross-flow fan sprayer is used to target the spray more towards the tree leaf canopy instead. This concept has shown to be relevant also for high trees like alley trees in nursery tree growing (Zande et al., 2005), but also relevant for other high crops with narrow row spacing and dense leaf structures. The development of a tower cross-flow sprayer for high trees (up to 6m) was systematically and stepwise approached and is now evaluated for spray drift in comparison with a standard axial fan sprayer.

Materials and Methods

In a series of field experiments spray drift of an experimental mast sprayer (Figure 1) was assessed and compared with a standard axial fan sprayer (reference), spraying a high (> 5 m) nursery tree crop. The reference sprayer was equipped with 6 hollow cone nozzles (TeeJet TXB 8003) at 8 bar spray pressure and a speed of 4.2 km/h applying a spray volume of 410-460 l/ha. The mast sprayer was a prototype built on a Dragone Krümm axial fan sprayer with an extended cross-flow air box of 6 m high. The mast sprayer was equipped with standard flat fan nozzles (TeeJet XR80015) and low-drift venturi flat fan nozzles (Lechler ID90015) of which 22-30 nozzles were used depending on the height of the trees. Both nozzle types were operated at 3 bar spray pressure. The mast sprayer applied 540-710 l/ha at a driving speed of 4.0 km/h. Also the effect of a 5m spray-free buffer zone was measured.
Measurements were performed in a nursery tree crop (plane, chestnut, lime, and maple): row spacing of 1.8-2.0 m, tree size 6 m high, with leaf canopy starting at 1.6-2.0m, tree spacing in the row around 1 m. The 20m downwind rows of the field were sprayed alternating the paths in between the rows and spraying the outside row only field inward. The fluorescent tracer Brilliant Sulpho Flavine (BSF) was used

and spray drift deposit on a bare soil surface strip next to the field to a distance up to 25 m from the last tree row (figure 1) was measured10 times in time during the full leaf period of the trees. Collectors used were filter material cloths (Technofil TF-290) of 0.5x0.10 m in a continues line up to 11 m from the last tree row and of 1.0x0.1m at points 15m, 20m and 25m. At 10 m distance a 10 m high measuring pole was placed with double lines of boll shaped collectors (Siebauer 00140) at 1 m intervals.

Results

Despite the high output points of the spray and spraying sideways towards the tree canopy a mast sprayer reduced spray drift compared to when the spray was blown into the air with an axial fan sprayer. In the standard situation (5 m crop-free buffer zone) the mast sprayer equipped with standard flat fan nozzles (XR 80.015) reduced spray drift deposition at 6½-7½ m from the last tree row with 16% and when equipped with the venturi flat fan nozzles (ID90015) with 72%. A 5m spray free buffer zone in combination with a 5 m crop-free buffer zone reduced spray drift deposition by 64% for the mast sprayer combined with standard flat fan nozzles (XR110015), by 85% for the axial fan sprayer with TXB03 nozzles and by 94% with the mast sprayer combined with venturi flat fan nozzles (ID90015). Future development for the mast sprayer is on detecting tree crown areas and gaps between trees to switch on/off nozzles to reduce spray drift further and to minimise plant protection product use.

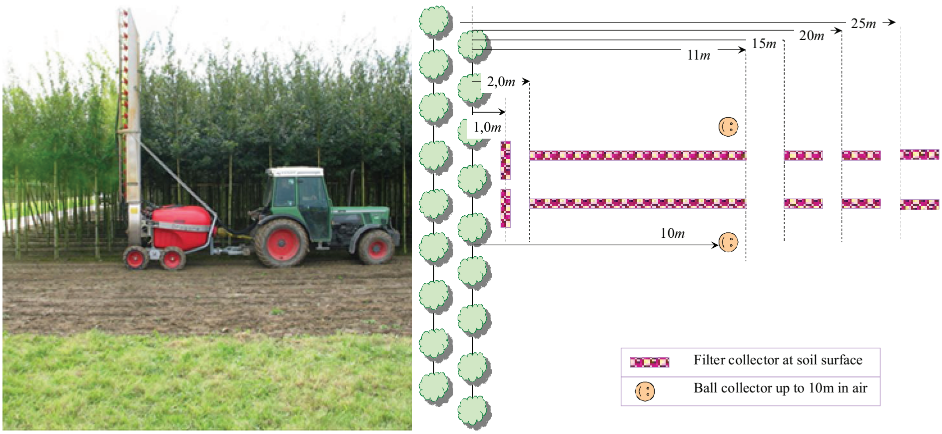

Figure 1. mast sprayer used in high nursery trees (left) and schematic lay-out of spray drift experiment

Acknowledgements

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SESSION 2

Evaluation of deposition

EvaSprayViti: a new tool for sprayer's agro-environmental performance assessment

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Introduction

In Europe, National Action Plans from the CE/128/2009 Directive aim to reduce significantly the amount of Plant Protection Products (PPP) used in agriculture as well as the risks resulting from their use. In vine growing, optimization of spray application seems to be a concrete step to reach those objectives. Indeed, through the analysis of several tens of thousands of collectors placed in vines during many sprayer field tests carried out according to *ISO22522:2007*, IFV showed that PPP doses could be optimized through an adjustment according to Leaf Area Index (LAI) which is dependent on growth stage. Besides, some sprayers are two to three times more efficient than the others with respect to the quantity of product effectively deposited per unit area of target (leaves or bunches). In order to identify the most relevant combinations of sprayers and setting parameters ensuring both protection efficacy and losses reduction to air and soil, IFV and IRSTEA are developing a structure for agro-environmental characterization of sprayers and application practices.

Materials and Methods

A structure, composed by four 10 meters long rows of two different types has been used: collection rows and edge rows. It has been designed with an adjustable height and width in order to be able to characterize three distinct growth stages: early stage, medium and full growth stage. The first studies have been carried out considering a row spacing of 2.5 m. (Figure 1).

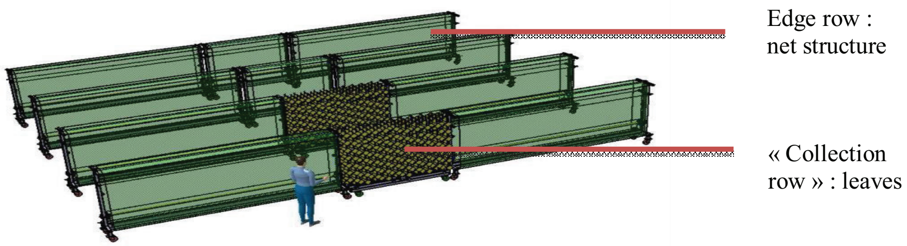

Figure 1. Structure used.

Collection rows composed of leaves are dedicated to capture and assess spray deposit on the canopy. Tartrazine (E102) is used as tracer. After spraying, all the leaves are collected in box before analysis. The analyses of the boxes provide 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 is evaluated by segmenting the vegetation structure into compartments: 2 for early stage, 6 for medium stage (left and right at 3 heights: low, middle, high), 9 for full growth stage (left, center and right at 3 heights: low, middle, high). The table 1 describes these configurations considering 2.5m row spacing.

Table 1. Characteristics of the vegetation simulated by the three possible "vegetation stages" of the collection rows.

Growth stage	*Early*	*Medium*	*Full*
Leaf Area Index (ha/ha)	0,24	0,88	1,68
Number of leaves	120	440	840

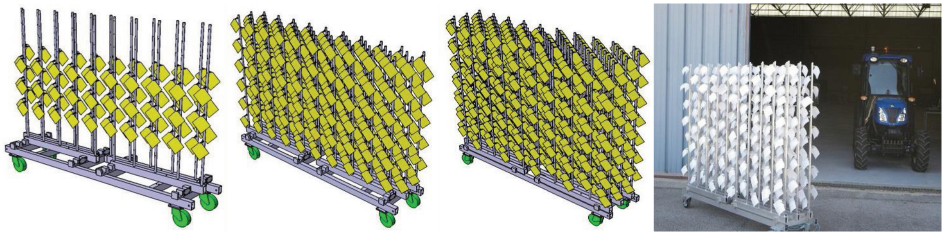

Figure 2. Characteristics of the "collection row" at different growth stages. From left to right: early, medium and full growth stage.

Edge rows are net structures that aim at reproducing the general characteristics of canopy and at limiting edge effects. Using collectors placed at soil level through the four vine rows allows measuring the losses of product on the soil by unit area (unit: ng/dm^2 for 1g sprayed per ha). Then, a mass balance allow assessing the percentage of product lost in the air by difference between the total amount of tracer sprayed and the amount collected on soil and leaves. The first experiments were carried out during summer 2012. Reproducibility trials have been carried out on the three growth stages. For each stage 3 replicates with the same sprayer (Tecnoma Vectis Precijet) were carried out.

Results

The results of the three replicates started to demonstrate a good reproducibility of the method. Indeed, for each growth stage, the difference between the smallest and the highest value of average deposit on the leaves, of the three replicates is lower than 4%.

The capacity of the structure to give a good representation of the deposits on a real vine has been assessed with two other sprayers. At the moment, 4 sprayers have been assessed with the structure. At full growth stage, the most efficient sprayer provides a 41% higher average deposit than the less efficient sprayer. More generally, the ranges of average deposits for the full, medium and early stage were respectively 365 to 520, 654 to 802, and 1406 to 2100 ng/dm^2 for 1 gram of tracer sprayed per hectare.
The next developments will deal with the improvement of the assessment of deposit on the soil and the mass balance for calculation of losses to the air (evaluation of total drift).

Acknowledgements

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References

ISO22522:2007, ISO (2007) Crop protection equipment - Field measurement of spray distribution in tree and bush crops.

Chueca P, Moltó E, Garcerá C (2011) Mass balance in spray application of citrus in Spain. Assessment of the influence of the nozzle. Suprofruit Bergerac 2011.

Multiplex®: An innovative tool for real-time quantitative evaluation of spray deposit

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Introduction

Under French climate, the use of pesticides is essential to produce quality grapes. Blacklisted by consumers, their use is increasingly contested and regulated by the legislation. Therefore the improvement of spray deposition is essential in order to reach a significant reduction in the use in chemical inputs.

Two types of methods exist to assess the spray deposition:

Qualitative methods (mainly using water-sensitive tickets) that are commonly used can show product deposits, but cannot quantify it or allow to compare different sprayers or to perform their adjustments.

Quantitative methods are used to quantify the deposits. They can be made using different markers but they all have the double disadvantage of being time-consuming and not providing results in "real-time", which makes it impossible to assess the interactive changes in sprayer settings.

Preliminary investigations conducted by FORCE-A and CIVC (Comité Interprofessionnel du Vin de Champagne) allowed us to think that it was possible to estimate the quantity of fluorescent deposit using the Multiplex® sensor.

Materials and Methods

Multiplex® is a portable sensor developed by FORCE-A which measures the intensity of fluorescence (Figure 1). Thus, the use of the Multiplex® coupled with a fluorescent tracer allows a real-time measurement of the deposit. The data are stored on an SD card which can easily be transferred to a computer.
Deposit collectors used in this work are of two types:
- Artificial ones when spraying an artificial vine;
- Natural ones (leaves) to study the spray deposits directly in the vineyard.

Figure 1. The Multiplex®.

Figure 2. The artificial vine Pulvé Top®.

In order to standardize the conditions of the measurements, IFV, in partnership with BASF, has developed an artificial vine (Pulvé Top®) to be able to compare sprayers on a same basis (figure 2). A fluorescent tracer was sprayed on one of the two faces of this artificial vine. Samples were placed on the artificial vines and then submitted to double analysis:

- Measurement of the fluorescent tracer quantity with the Multiplex® sensor;
- Measurement by the reference method (extraction and quantification with a laboratory fluorometer).

Results

A set of collected data was used to compare the values obtained with the two methods (reference method and Multiplex®). Figure 3 shows good correlation between the reference method and the Multiplex® measurement. Multiplex® measurement has the advantage of providing real-time results. From these data, it is relatively easy to produce a map showing the deposit distribution on the vine and visualize the homogeneity of this deposit on artificial vines (Figure 4).

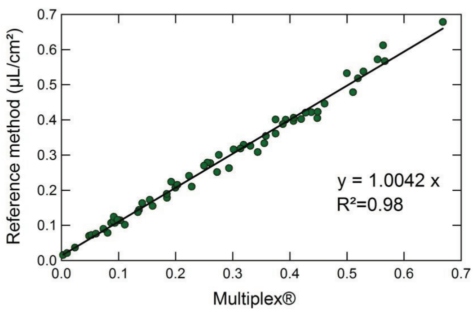

Figure 3. Comparison of the estimate of the amount of solution deposited with the two methods (data after standardization of the Multiplex®).

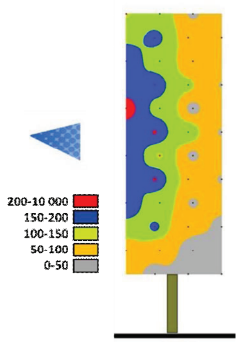

Figure 4. Mapping of deposits of a fluorescent tracer by the Multiplex® (cross section of the artificial vine Pulvé Top®).

In Figure 4, we can see the impact of the treatment performed on one side of the vine row.
Measurements were also performed on leaves on a vine (Merlot) (Figure 5). Different quantities are deposited with a micropipette. The leaves are dried and then measured with the Multiplex®. The fluorescent tracer is then extracted and quantified in the laboratory using a spectrofluorimeter.
The comparison between Multiplex® data and extractions is shown in Figure 5. In this range, there is a good linear relationship between the two analyses.

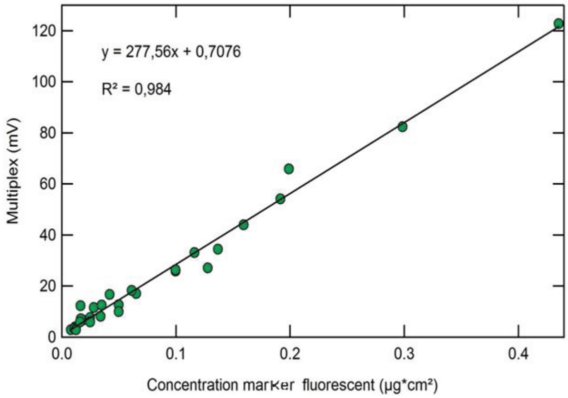

Figure 5. Comparison of the estimate of the amount of solution deposited on Merlot leaves with the two methods.

Although many methodological issues are still to be resolved, particularly using natural collectors, investigations conducted jointly by IFV and FORCE-A suggest the possibility of fast spray deposit quantification on artificial vines or directly on vineyards. This methodology could be widely used in the near future.

References

Codis S, Debuisson S (2011) Comparison of different sprayers and settings for early-stage applications in viticulture Experimental results and perspectives for dose reduction, SUPROFRUIT June 2011, Bergerac France

Force A - CIVC - Decembre 2007 - Rapport final de l'étude Quantispray sur une nouvelle méthodologie de quantification de la pulvérisation

Effect of spray application technique on spray deposition and coverage in artificial pear trees

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Introduction

Numerous researchers have attempted to understand the orchard spray application process via field experiments. The use of an artificial canopy allows researchers to conduct spray experiments in a defined uniform canopy, allowing a substantial reduction of experimental area and the possibility to perform the test indoor under controlled climate conditions. Additionally, these trees are easier to characterise and to be used in CFD modelling (Dekeyser et al., 2012). The objective of this study was to investigate the effects of spray application technique on spray deposits and coverage and their distributions on artificial pear trees, ground deposits and spray losses behind the tree.

Materials and Methods

7 orchard spray application techniques were compared in terms of within-tree distribution quality and off-target losses to the ground and behind the artificial pear trees. The studied techniques included sprayer type, fan speed and air deflector setting (Table 1). Filter and water-sensitive papers were used to evaluate deposition and coverage. All measurements were conducted indoor and are used as an input and to validate a CFD orchard spray model. Spray results are linked with the corresponding spray liquid and airflow patterns (Dekeyser et al., 2012)

Table 1. Selected orchard spray application techniques.

Nº	Sprayer	Nozzle type	Pres-sure	No. of nozzles	Speed ($km.h^{-1}$)	Spray volume	Fan speed	Deflector
1	axial	ATR orange	6.0 bar	16	6	532 $L.ha^{-1}$	low	optimal
2	axial	ATR orange	6.0 bar	16	6	532 $L.ha^{-1}$	low	extreme
3	axial	ATR orange	6.0 bar	16	6	532 $L.ha^{-1}$	high	optimal
4	axial	ATR orange	6.0 bar	16	6	532 $L.ha^{-1}$	high	extreme
5	cross-flow	ATR orange	6.0 bar	16	6	532 $L.ha^{-1}$	low	n/a
6	cross-flow	ATR orange	6.0 bar	16	6	532 $L.ha^{-1}$	high	n/a
7	individual spouts	ATR red	8.0 bar	10	6	532 $L.ha^{-1}$	n/a	n/a

Results

Results pointed out that spray application technique has an effect on spray deposition and coverage. Although the sprayer with individual spouts gave the highest average depositions, the conventional axial fan sprayer seemed to be best suited for this type of orchard training system as it gives a more uniform distribution (Figure 1). A significant portion of the spray liquid was lost to the ground and behind the trees with all spray techniques. The axial fan sprayer and sprayer with individual spouts caused higher ground deposits, where the cross-flow sprayer gave higher losses behind the trees, especially when a high fan speed was applied.

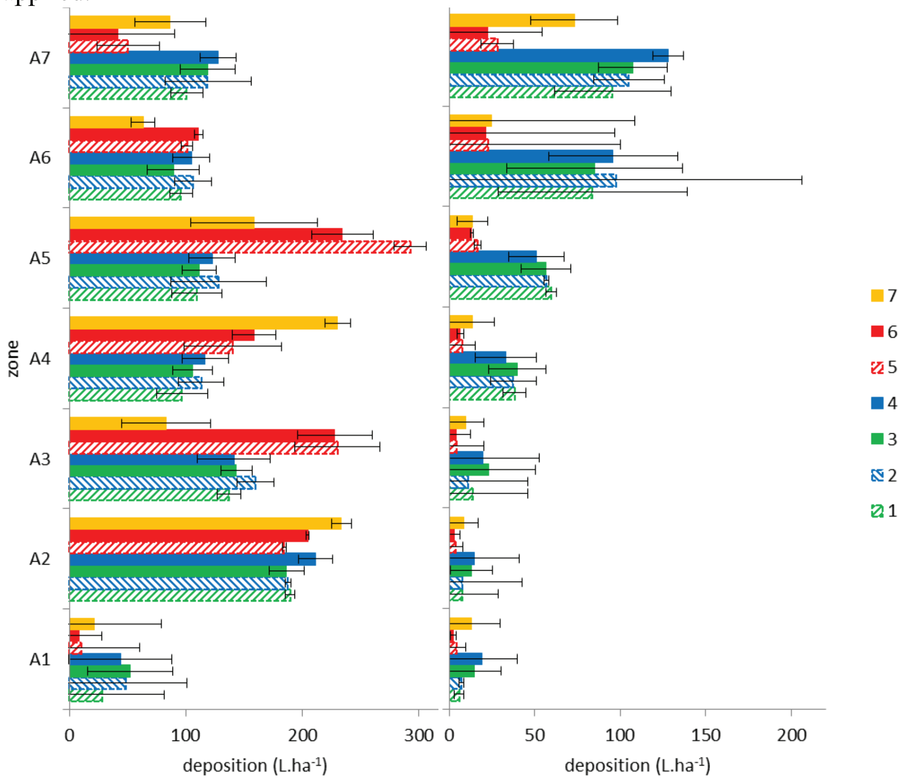

Figure 1. Deposition (L/ha) on the front (left) and back (right) of the trunk (mean ± sd) for seven sampling heights (A1-A7) and seven application techniques.

References

Dekeyser D, Duga A T, Verboven P, Hendrickx N, Nuyttens D. 2013. Assessment of orchard sprayers using laboratory experiments and computational fluid dynamics modelling. Biosystems Engineering. Doi: 10.1016/j.biosystemseng.2012.11.013.

Spray distribution produced by a hand-held trolley boom sprayer in greenhouses

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Introduction

Pesticide application in greenhouses in Spain represents one of the most important sectors in terms of amount of pesticides (Gil, 2006) and risk of contamination for both, operators and environment (Sánchez-Hermosilla *et al.* 2011, Balsari *et al.* 2012). Also it is important to remark the importance of an accurate pesticide distribution in these types of crops in order to reduce the risk of residues on vegetables for fresh market. In the last years different improvements have been developed in the spray technology widely used in Spanish greenhouses. Assuming hand held sprayers (spray gun) as a reference technology some developments have been carried out in order to improve efficacy and efficiency values during the spray process. A manual trolley equipped with two vertical spray booms has been promoted as an adequate alternative allowing reducing the risk of operator's contamination and a better spray distribution according the canopy structure. However the official recommendation of the use of such a new device still maintain the high volume rates applied with the traditional method (spray gun) with high working pressure and flat fan nozzles. The objective of this research was to improve the manual trolley spray boom for pesticide application in greenhouses based on the adequate selection/modification of nozzle type and nozzle distance depending on canopy characteristics.

Materials and Methods

A manual trolley equipped with two vertical spray booms was characterized in laboratory. Two different spray nozzles (ATR yellow and brown hollow cone and ISO 110-02 and 110-015 flat fan nozzles) were compared at two different distances between nozzles (0.3 and 0.5 m). In all cases the vertical spray liquid distribution was determined in laboratory using a vertical patternator (AAMS-Salvarani,Maldegem, Belgium) at two distances (0.3 and 0.5 m) from the vertical patternator (Figure 1a). Four replicates were carried out for every combination of described parameters.

Figure 1. Determination of vertical distribution of spray using a vertical patternator (left) and evaluation of spray deposition on artificial canopy (right).

These same combinations of working parameters were also evaluated in terms of deposition on crop and penetration capacity on the canopy. For this purpose a 2 m x 2 m artificial vegetation sample was developed (Figure 1b). Four replicates of each combination were arranged simulating in laboratory conditions a complete spray process (both sides of the artificial canopy). 9 water sensitive papers were placed at different canopy positions varying the depth (external, internal) and height (top, middle, and low). Values of coverage (% of covered area) and droplet density (droplets/cm^2) were evaluated.

Results

Distribution uniformity measured on vertical patternator indicates that, for 30 cm distance from vertical patternator, the most uniform distribution is obtained with flat fan nozzles (XR 110015) at 30 cm distance between them. Uniformity of vertical distribution obtained with the two selected hollow cone nozzles was significantly lower than the obtained with flat fan nozzles. Vertical distribution uniformity at 50 cm distance from the vertical patternator was still better in the case of flat fan nozzles. Averaged recovery values obtained after WSP analyzed with Image J® indicate no significant differences among nozzle type. The analysis of distribution uniformity on the target indicates higher values of deposition in the internal part of the canopy for ATR nozzles at 30 cm distance from the canopy, but no statistical differences were observed in any case. Those results are in accordance with Nuyttens *et al*. (2004) and Sánchez-Hermosilla et al. (2003).

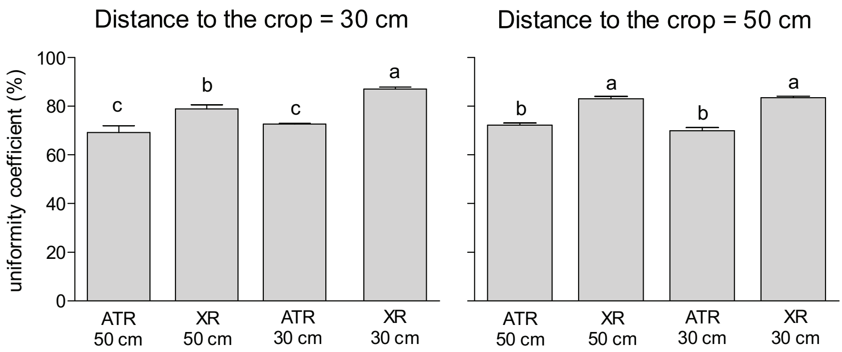

Figure 2. Uniformity coefficient for each configuration (nozzle type, distance between nozzles, distance to the crop).

References

Balsari, P., Oggero, P., Bozzer, C., Marucco, P. 2012. Au automomous self-propelled sprayer for safer pesticide application in glashouse. Aspects of Applied Biology, 2012, ***114****.*

Gil E.2006. Inspections of sprayers in use: a European sustainable strategy to reduce pesticide use in fruit crops. Applied Engineering in Agriculture, **23** *(1): 49-56.*

Nuyttens, D., Windey, S., Sonck, B., 2004. Optimisation of a vertical spray boom for greenhouse spray applications. Biosyst. Eng. 89, 417-423

Sánchez-Hermosilla, J., Medina, R., Gázquez, J.C., 2003. Improvements in pesticide application in greenhouses. VIIth Workshop in Spray Application Technique in Fruit Growing 54-61

Sánchez-Hermosilla, J., Rincón, V. Páez, F., Agüera, F., Carvajal, F. 2011. Field Evaluation of a self-propelled sprayer and effects of the application rate on spray deposition and losses to the ground in greenhouse tomato crops. Pest Manag. Sci. ***67****: 942-947.*

Canopy Density Spraying in strawberries in the Netherland

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Introduction

The reduction of the emission of plant protection products (PPP) to the environment is an important issue when applying agrochemicals in the Netherlands. Much attention always has been paid to spray drift reduction, however an application having a use reduction in combination with the same level of spray drift reduction implicitly means higher levels of emission reduction of PPP to the surface water, as the amount of spray drift is from a smaller amount of used PPP. Therefore more attention is paid nowadays to more precise application methods of PPP applying only to the areas where the PPP is needed, the plant (Zande *et al*., 2008). In strawberries Canopy Density Spraying (CDS) was used under practical conditions (Nieuwenhuizen & Zande, 2012). The benefits for the environment are shown by means of reduced use of plant protection products (PPP) in order to maintain comparable spray distributions as with standard application techniques and maintain good biological efficacy.

Materials and Methods

To show the differences between a CDS-sprayer and a standard application technique spray deposition measurements were done in different crop growth stages of a strawberry crop. Ground surface area on top of the bed varied from almost not covered (BBCH 19, start of growth) to almost completely covered (BBCH 73, fruit picking). The CDS-sprayer was a Sensispray-Horti (Homburg) based on a Hardi Twin air sleeve boom sprayer with a working width of 4,8 m. To adjust spray volume, based on the Greenseeker sensors measured vegetation index (NDVI), four nozzles (Unigreen 650033, 650050, 2*650067 at a spray pressure of 3 bar) mounted in a Lechler Varioselect nozzle body were switched on or off individually or jointly. Nozzles were positioned in the nozzle bodies in such a way that in the smallest growth stage only the nozzles on top of the crop row were spraying. As crop canopy increases in size in time more nozzles were opened to the left and right hand side until the total bed on which the strawberries grew was sprayed. The paths in between the beds were not sprayed at all. The grower’s standard sprayer was a 24 m Hardi Twin Force air-assisted sleeve boom sprayer equipped with Hardi F03-110 flat fan nozzles (3 bar spray pressure). In different growth stages of the strawberry crop (BBCH 19, 65 and 73) spray deposition was assessed on the strawberry leaves, the flowers and the fruits, and on soil surface in between and underneath the crop on top of the bed and in the paths in between the beds.

Results

Emission reduction - In all three growth stages spray deposition on the leaves was similar for the standard and the CDS spray technique. This also was the case for the flowers and the fruits. Loss to soil surface underneath the crop on top of the bed was for the Sensispray-Horti sprayer lower at growth stages BBCH 65 and 73. On the paths in between the beds spray deposition was for all growth stages lower for the Sensispray-Horti than for the standard sprayer. At early growth stage (BBCH 19) total spray deposition on soil surface was for the Sensispray-Horti 35% lower than for the standard sprayer. At start of flowering (BBCH 65) and full production (BBCH 73) spray deposition on soil surface was for the Sensispray-Horti 45% lower than for the standard sprayer. These lower spray deposits on soil surface reduce the risk for leaching to ground water and through drainage to surface water with 35% to 45% for the Sensispray-Horti compared to the standard sprayer used.

Use reduction (deposition measurement) - At early growth stage (BBCH 19) of the strawberry crop spray volume based on the Greenseeker sensor was 140 l/ha whereas the standard spray technique applied 300 l/ha, resulting in a 54% use reduction of PPP. At start of flowering (BBCH 65) spray volume was 190 l/ha and at full production growth stage (BBCH 73) spray volume was 230 l/ha applied to the beds, respectively showing use reductions of 37% and 23%. Including the not sprayed path areas use reductions were respectively 62%, 49%, and 38%. On average for the crop growth season of strawberries the reduction in PPP use on the beds was 38% and including non-sprayed paths 49%.

Use reduction (in practice) - At a 5 ha strawberries field a part of the spray applications were performed with the Sensispray-Horti. No differences in disease infection were detected. The reduction in applied spray volume of the Sensispray-Horti was 36% to 57% and on average 49% for the whole growing season.

Acknowledgements

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References

Nieuwenhuizen AT, Zande JC van de, (2012) Development of sensor guided precision sprayers. International Advances in Pesticide Application. Aspects of Applied Biology 114(2012): 121-128.

Zande JC van de, Achten VTJM, Michielsen JMGP, Wenneker M, Koster AThJ (2008) Towards more target oriented crop protection. International Advances in Pesticide Application, Aspects of Applied Biology 84(2008): 245-252.

SESSION 3

Dose adjustment

Reducing pesticide residues in fruit crops by means of improving spray application techniques

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Introduction

Plant protection product (PPP) residues in fruit crops can be a major drawback for their commercialisation. Consumers are becoming more concerned about the presence of pesticides in fruits and the market keeps on asking for lower amounts of chemical residues, even below the accepted EU maximum residue levels - Regulation (EC) No 396/2005. Fruit.Net is a project developed by the Catalan agriculture administration and different professional stakeholders with the aim of reducing PPP levels in fruit crops, by means of using a better pest and disease management, based on new research of specific topics, and a programme of technology transfer. To demonstrate this effect, a network of commercial orchards was set up in 2011 throughout the Catalan fruit producing areas, to test the new pest management strategies in comparison with the standard ones. The use of spray application equipment has also an important effect on the residue level found in fruits (Poulsen *et al*., 2012). The application conditions have to be adjusted to the actual needs of the fruit crops, which show a large range of variation. Therefore, the improvement of spray application techniques was also included in Fruit.Net in 2012.

Materials and Methods

Different workshops were organised with plant protection advisers and fruit growers, involved in Fruit.Net, to show the best way of adjusting sprayer working conditions –e.g. spray volume application rate, working speed, air flow rate, etc.- to different orchard geometrical features. Beyond the compulsory sprayer inspection (Directive 128/2009/CE), operators were advised to check the sprayer during the spray application season, to assure that all the components work properly. Only in this way, the spray application efficiency can be guaranteed and the volume application rate is known. Several kits for checking the sprayer by the operator were distributed to grower associations, so that the operators could check the sprayers used in the Fruit.Net orchards and record the application conditions.

When the PPP dosing is based on a concentration in the spraying liquid, the final PPP dose depends on the volume application rate. In this case, the best way to adjust the PPP dose to the needs of the crop is to adjust the spray volume application rate. Dosafrut is a decision support system designed to adjust the volume application rate to the fruit orchard characteristics, based on the use of the leaf area index (LAI) of the tree canopy (Planas *et al.*, 2011). The use of Dosafrut was tested, in the Fruit.Net framework, in a pear orchard, *cv.* Williams, during 2012. A 1 ha orchard plot was divided in two plots. The same PPP application programme was used in the whole plot, but in one half the spray volume application rate and, therefore, the PPP dose, was decided according to Dosafrut (Table 1). The incidence of pests and diseases was checked twice –in June and before harvest in early August. In addition, the evolution of *Psyla piri L.* as a key pest for this crop was assessed during the whole growing season. At harvest, fruit samples were collected and the PPP residues on the fruits were measured.

Table 1. Spray application in the Dosafrut field tests in a pear orchard. No PPP applications were made after mid-June, because pears were used for baby food.

Date	Spray volume application rate. Standard. (L/ha)	LAI	Spray volume application rate. Dosafrut (L/ha)	Savings (%)
19/04/2012	700	1,37	420	40
10/05/2012	700	2,14	560	20
23/05/2012	800	2,43	620	23
28/05/2012	800	2,58	700	13
01/06/2012	800	2,65	720	10
06/06/2012	800	2,65	720	10
11/06/2012	800	2,69	720	10
TOTAL	5.400		4.460	17

Results

Checking the sprayers used in the Fruit.Net orchard network helped to improve the application efficacy and, so, it allowed a better assessment of the new plant protection strategies. Moreover, the use of Dosafruit to adjust the PPP dose meant a total 17% reduction of the PPP used during the whole season. The most important savings (40% and 30%) were achieved in the first applications after blooming (Table 1). The control of the pests and diseases was similar for the Dosafrut and standard application strategies, with even a better control of *P. piri* during some periods of the growing season when using Dosafrut. No PPP residues were found on both the standard and Dosafrut orchard plots.

References

Planas S, Camp F, Solanelles F, Sanz R, Escolà A, Rosell JR (2011) Validation of DOSAFRUT, pesticide dose adjusting system in intensive fruit orchards. Suprofruit 2011. Book of abstracts, 86-87. Ctifl. Lanxade. France.

Poulsen ME, Wenneker M, Withagen J, Christensen HB (2012) Pesticide residues in individual versus composite samples of apples after fine and coarse spray quality application. Crop Protection, 35 5-14.

Dose adjustment of different types of orchard spraying product

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Introduction

This paper presents the output from a regulated dose adjustment model we have developed to support more sustainable use of commercial orchard spraying products. The model is based on the generalised system for efficient dosage of orchard and vineyard spraying products (Walklate et al., 2011). Orchard standards (i.e. the selected values of orchard structure parameters of this model) are used to represent the constraints equivalent to the operational limits for spraying, namely: the maximum Ground Area (GA) dose rate for safe product use and the manufacturer's Leaf-Wall-Area (LWA) dose rate for efficacious product use. The orchard standard for the ratio of sprayed target height to row spacing determines the intersection between the limits for safe and efficacious product use (Walklate and Cross, 2012). The orchard standard for the special canopy density determines the extent of LWA dose rate adjustment associated with each type of spraying product.

Materials and Methods

Recordings of different commercial pome-fruit orchards with a scanning LiDAR system (Walklate et al., 2002) are used to quantify a sample distribution of the parameters of the generalised system for efficient dosage. Orchard recordings are selected for this purpose to represent a wide range of sprayed targets with different combinations of: tree height, planting density, branching density, growth-stage, cultivation-method, age and variety. The method of analysing the LiDAR recordings uses an optical analogue of orchard spraying as the basis for similarity between the cumulative distributions of light interception and spray volume capture by the primary target (Figure 1). Measurements of dosage parameters (i.e. the ratio of sprayed target height to row spacing and the special canopy density), derived from each orchard recording, are used to regulate dose adjustment of different products within the limits for safe and efficacious use based on different standards.

Results

Examples of dose adjustment distributions of different products are plotted (Figure 2). The limits for safe and efficacious product use (99.5th percentile) are represented by the solid horizontal and diagonal lines. The broken vertical line represents the standard for the ratio of sprayed target height to row spacing at the intersection between the limits for safe and efficacious product use. The broken diagonal line represents the lower limit for dose adjustment based on the primary target exposure model (Walklate et al., 2011).

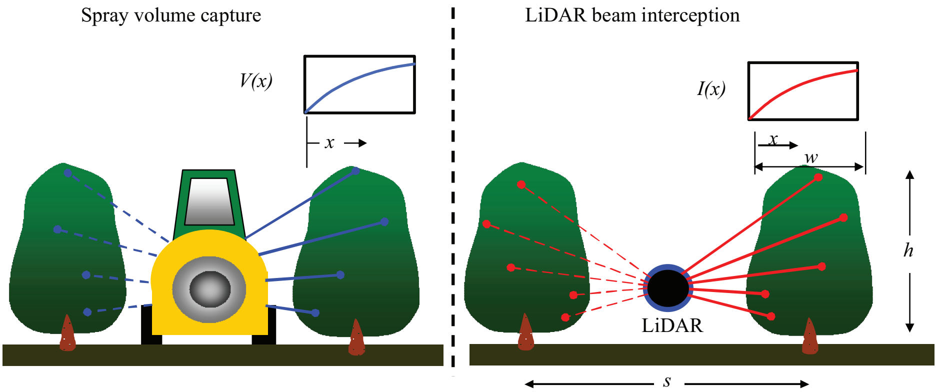

Figure 1. Cross-section of the primary target depicting the similarity between the cumulative distributions of spray volume capture and LiDAR beam interception.

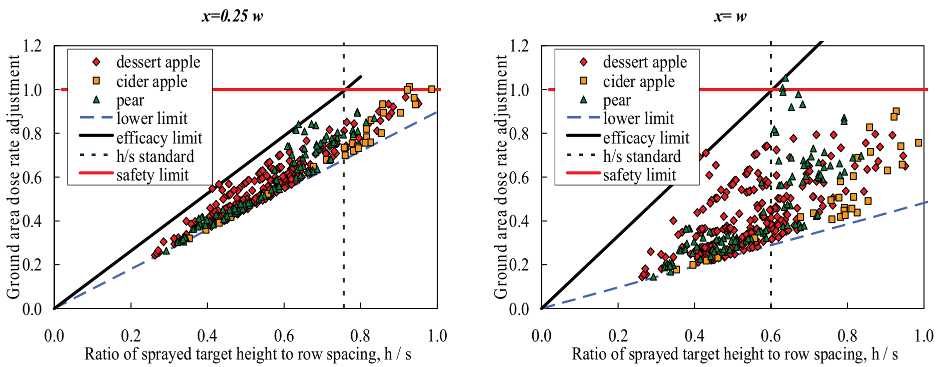

Figure 2. Ground area dose rate adjustment distributions for different generic products where the deposits for efficacious pest/disease control and efficient product usage are maintained across different target widths.

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References

Walklate P J, Cross, J V (2012). An examination of Leaf-Wall-Area dose expression. Crop Protection 35, 132-134.

Walklate P J, Cross J V, Pergher, G (2011). Support system for efficient dosage of orchard and vineyard spraying products. Computers and Electronics in Agriculture 75, 355-362.

Walklate P J, Cross J V, Richardson G M, Murray R A, Baker DE (2002). Comparison of different spray volume deposition models using LiDAR measurements of apple orchards. Biosystems Engineering 82, 253-267.

Relationship between actual copper deposition and control of the peacock spot disease in olive trees

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Introduction

Peacock spot disease (PSD) of olives is caused by *Fusicladium oleagineum* (Castagne). It reduces yield and may produce severe defoliation of trees. It is distributed in all olive tree growing regions of the world and it greatly affects the Mediterranean Basin (Trapero and Blanco, 2008). Although great advances in spray application technologies have been made, and modern farmers make important efforts in learning how to properly adjust sprayers, there is still an important lack of information about the amount of active ingredient that is actually deposited after a treatment. However, this amount of deposited active matter is supposed to be the most important cause of the observed level of control of the targeted pathogen. The objective of this paper is to estimate the amount of active ingredient deposited after treatments and assess their effect on disease control and defoliation.

Materials and Methods

Experiments were carried out on commercial olive orchard (*Olea europaea*) in Córdoba (Spain) in an experimental random blocks design with four replicates. Before the experiments, no significant differences in infestation were found neither between replicates nor blocks. Seven different treatments were performed in spring and autumn 2011 and 2012 with commercial fungicides based on copper oxychloride at different concentrations plus a control (no fungicide treatment) at a volume rate of 1000 l/ha.

Copper on leaves before and after treatments was assessed quantitatively using a conventional analytical technique (atomic absorption spectrometry) and expressed in µg Cu/cm^2 leaf. The canopies were divided in three heights (upper, medium and lower) and two depths (exterior and interior). Copper concentration in the mixture during the treatments was assessed by taking 3 samples from the tank at the beginning, in the middle and at the end of each treatment. The agitator was on during the application to provide a uniform concentration.

Control of PSD was estimated by counting the percent of leaves having symptoms of the disease and calculating the amount of defoliated leaves in winter.

Adequate machine set up was ensured by a conventional technical inspection of the manometer, nozzles, tractor speed, air flow and filters. Adequate coverage of the tree after treatments was confirmed using water sensitive papers.

Results

Significantly higher copper depositions were found in lower zones of canopy ($p<0.001$), probably due to more deposition after treatments, probable lower washing and reception of copper from higher zones (Figure 1). Foliar levels of Cu in autumn before treatments were significantly related to Cu deposits produced in spring.

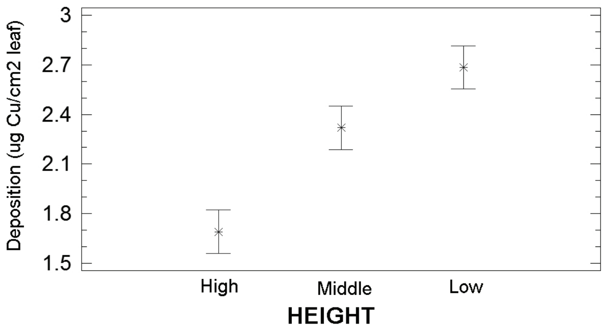

Figure 1. Copper deposition on leaves (µg Cu/cm^2 leaf) (Mean±95% LSD intervals) at each height of the canopy considered (High / Middle / Low)

A high relationship between copper concentration in tank and copper deposition on leaves was found (R2= 0.90) (Figure 2).

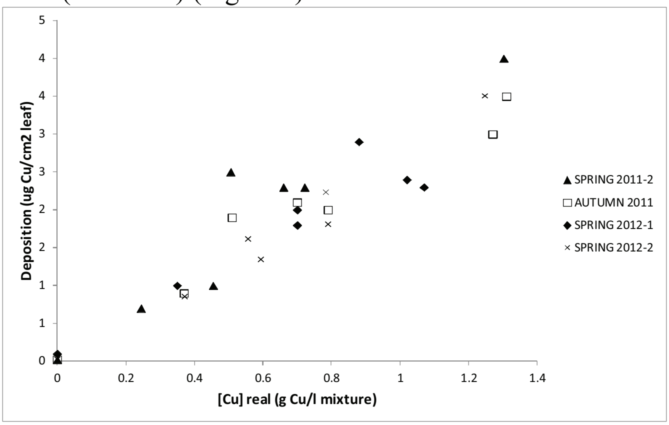

Figure 2. Relationship between actual copper concentration in tank (g Cu/l) and copper deposition on leaves (µg Cu/cm^2 leaf).

A negative relationship was found between the percentage of leaves affected by PSD and Cu deposited on leaves in spring and in autumn for each treatment. It could be observed that the higher the disease pressure (estimated from the control, Cu deposit close to 0), the higher the strength of the relationship (Figure 3 left). However the amount of infestation could not be predicted from Cu deposited on leaves, thus indicating that other uncontrolled factors are probably affecting efficacy.

Furthermore, a significant negative relationship between copper deposition and defoliation can be established ($p= 0.0453$; correlation coefficient= -0.523) (Figure 3 right). These results can be used as the basis for adequate dosage of copper fungicides.

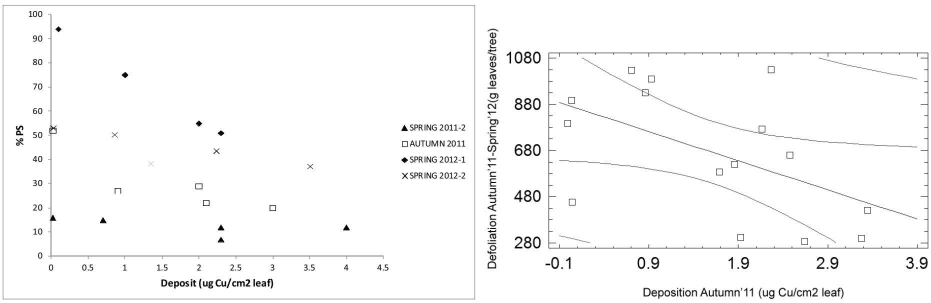

Figure 3. Relationship between copper deposition (µg Cu/cm^2 leaf) and 1) percentage of leaves affected by PSD for each application (left), and 2) weight of defoliated leaves (g leaves/tree) between the applications performed in autumn 2011 and March 2012 (right).

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References

Trapero, A., and Blanco, M. A. 2008. Enfermedades. Pages 595-656 in: El Cultivo del Olivo. 5th ed. D. Barranco, R. Fernández-Escobar, and L. Rallo, eds. Junta de Andalucía/Mundi-Prensa, Madrid, Spain.

Product deposition and distribution on Citrus from application with different equipment and the effect of air and water volumes

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Introduction

Citrus nowadays is one of the highest-value fruit crop in terms of international trade. Brazil, China, USA and Mexico together produce about 60 million tons - about half of the world's total. The major citrus types grown are oranges (55%), tangerines (23%) and lemons/limes (11%). Citrus trees are generally grown or pruned in a central modified shape; its canopy will be commonly formed not only by an external layer of functional leaves and branches, but also of several layers of dead branches and old dried leaves. This thick and very dense canopy is one of the most challenging fruit crops to spray. Although technology has developed very fast during the last years and today some tools are available or under investigation to improve application quality in Citrus, traditional growers are still facing the same challenges and using the same techniques to tackle this problem. Spraying equipment or air and water volume increase are the most frequent parameters that growers modified to improve penetration into the canopy centre. In order to investigate and quantify the effect of these parameters in product penetration and distribution field trials have been carried out by Syngenta in several countries. The effect of these parameters on labor efficiency was also evaluated.

Materials and Methods

All experiments were carried out in different locations using normal parameters used for commercial applications. Crop parameters are summarized in table 1.

Table 1. Citrus crop parameters of application trials applied in Spain and Chile.

Location	Variety	Planting distance (m)	Crop Height-width (m)	Crop Volume (m^3/ha)	Crop Stage (BBCH)
Montserrat, Spain	Lane Late	6.5 x 3.0	2.5 - 3.7	14’200	77
Panquehue, Chile	Clemenules	5.5 x 3.0	3.8 – 3.4	23’198	74

Different combinations of air and water volume, as well of axial sprayer or manual applications were compared to know the effect of these parameters in product deposition and distribution on the tree. To evaluate product deposition a fluorescent tracer (Helios 500 SC, Syngenta Crop Protection) was added to the mixture. All applications were done at fruit development (BBCH 72-74) either with a hand gun or an axial sprayer. Samples were collected on 3 levels of the tree; top, mid and bottom when plant height was more than 3 meter or on two levels; top and bottom if it was less. From each position leaves samples were collected in plastic bags separately from the canopy centre or periphery. Artificial collectors were placed on twigs and branches to evaluate penetration into the canopy centre. Samples were washed with an organic solvent to measure tracer deposits on leaves and filter papers. Results were expressed in µg of tracer/cm^2 according to the surface area calculated for each sample. All trials and treatments were normalized to a 1 g/ha of tracer applied in order to allow results comparisons.

Results

On average, product deposition for all trials and treatments is within an expected range for citrus application. Differences observed between canopy positions are higher when canopy height increases confirming the big influence the crop has on application quality. The magnitude of these differences can be up to 15 times in product deposition on the same plant. Most difficult parts of the plant to reach and where most likely problems occur are the canopy centre and also the top part in trees grown high. Most frequent parameter that growers use to improve application quality in these difficult positions is increments on water volume. Large water quantities used as carrier not only not improve application quality but also lower the labor efficiency; increasing downtime for tank and product refilling and decreasing the number of hectares covered by day. Results show, that in Clemenules with a dense canopy and a higher crop volume (23’198 m3/ha), water volume have a negative effect in product deposition in all parts of the tree. Water volumes higher than 1000 l/ha lead to an increase in product run off and therefore lower product deposition mainly in the canopy periphery (Table 2). In the case of oranges with lower crop volume, best overall deposits were achieved with high volumes of 3000 l/ha. In this case a very dense canopy but well pruned will allow the crop to retain and better distribute the water across the canopy. The air volume moved by the axial fan is another factor commonly used by growers to improve application quality. Results showed that an air volume increase has a positive effect in product deposition on wooden crop parts at the canopy centre. Best penetration was obtained from treatments where the ratio air volume and crop volume was between 2 and 3. Nevertheless, this increase in penetration also results in a decrease in leaves deposits, both, on canopy periphery and centre mainly at the bottom level (Tables 2 and 3). Too high air volume seems to have a negative impact on the product deposition on leaves; the droplets are blown through the tree with too much energy and cannot impinge on the target. A combination of low water volumes and high air volumes could lead to better deposits results in both leaves and the wooden central part of the tree. Application quality via manual spraying will highly depend on the applicator, thus it will decrease during the day as the workers are getting tired. Although manual spray results showed the best penetration into the canopy centre (artificial collectors) for all trials, it also showed in most cases the lowest average leaf deposits, achieving run off very quickly at the canopy periphery, reducing deposits on these positions (Table 2). Manual application results depend not only on applicator experience but also on tree shape, this type of application has proven to be highly inefficient having a huge impact on costs. Finally, canopy adaptation as a parameter to improve application quality is normally not observed. Since this showed to be one of the most influencing factors it would be highly recommended to evaluate its real effect, not only in terms of application quality, but labor costs and productivity.

Table 2. Mean standardized tracer deposits on leaves on different canopy positions ((µg/cm^2)/(g/ha)) and 95% confidence interval (U95-L95)[b] from Citrus application with different water and air volumes. Panquehue, Chile (N=12)

Treatment [a]	Canopy Periphery			Canopy Centre		
	Bottom	Mid	Top	Bottom	Mid	Top
Axial;1000l/ha;1.18	5.31 (5.7-4.9)	2.56 (2.8-2.3)	0.57 (0.8-0.5)	1.86 (2.3-1.4)	0.89 (1.3-0.5)	0.33 (0.4-0.3)
Axial;2000l/ha;1.21	4.33 (4.8-3.9)	1.88 (2.1-1.7)	0.51 (0.6-0.4)	0.98 (1.2-0.8)	0.14 (0.2-0.1)	0.08 (0.1-0.1)
Axial;3320l/ha;1.17	3.23 (3.6-2.9)	1.49 (1.8-1.2)	0.68 (0.9-0.4)	1.84 (2.4-1.3)	0.14 (0.2-0.1)	0.12 (0.2-0.1)
Axial;3600l/ha;2.08	2.37 (2.5-2.2)	1.49 (1.6-1.4)	0.78 (1.0-0.6)	1.51 (1.7-1.3)	0.52 (0.7-0.3)	0.16 (0.2-0.1)
Handgun;3700 l/ha	1.71 (2.3-1.2)	1.64 (2.2-1.3)	0.81 (1.3-0.3)	1.24 (1.8-0.7)	0.91 (1.9-0.1)	0.15 (0.2-0.1)

[a] Application equipment; water volume in liters per hectare; ratio between air volume and crop volume.
[b] In parenthesis are indicated upper and lower end points for a 95% confidence.

Table 3. Mean standardized tracer deposits on leaves on different canopy positions ((µg/cm^2)/(g/ha)) and 95% confidence interval (U95-L95)[b] from Citrus application with different air volume ratios. Montserrat, Spain. (N=15)

Treatment [a]	Canopy Periphery		Canopy Centre	
	Bottom	Top	Bottom	Top
Axial; 2540 l/ha; 1.99	2.01 (2.85-2.42)	2.01 (2.12-1.90)	0.86 (1.01-0.71)	1.80 (2.18-1.41)
Axial; 3000 l/ha; 2.63	2.31 (2.47-2.15)	1.73 (1.87-1.59)	0.99 (1.08-0.90)	1.56 (1.72-1.41)
Axial; 3000 l/ha; 3.22	1.82 (2.03-1.61)	1.74 (1.89-1.59)	1.02 (1.18-0.86)	1.21 (1.39-1.03)
Axial; 3000 l/ha; 5.03	1.63 (1.73-1.53)	1.38 (1.49-1.26)	0.9 (1.02-0.78)	1.01 (1.16-0.86)

[a] application equipment; water volume in liters per hectare; ratio between air volume and crop volume.
[b] In parenthesis are indicated upper and lower end points for a 95% confidence.

References

Meier U. (2001). Growth stages of mono-and dicotyledonous plants. BBCH-monograph. Blackwell Wissenschafts- Verlag, Berlin, Wien.

United States Departament of Agriculture (USDA). Foreign Agricultural Service. Citrus: World Markets and Trade. July, 2011.

Rationalized pesticide applications against *Aonidiella aurantii* Maskell in citrus

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Introduction

Despite the growing environmental awareness of the society, pesticides are still essential in agriculture. There is high legislative pressure to promote measures for minimizing their impact on the environment and reduce their risks, i.e. Directive 2009/128/EC (OJ, 2009). This Directive encourages the dose adjustment to specific conditions of the application (targeted pest, characteristics of the product and vegetation surface to be treated), in order to fulfil the actual needs with the lowest risk. However, most current practices in the field consist of applying large amounts of products, regardless of unnecessary excess depositions that contaminate the environment and reduce the economic benefit. For this reason it is crucial to study the relationship between the amount of active material deposited on the vegetation, how it is deposited, and how it affects the pest population, in order to rationally adjust the amount of plant protection product to be applied in a treatment.

This work is aimed at modelling and validating these relationships for the control of one of the key pest in citrus, California red scale, *Aonidiella aurantii* Maskell (Hemiptera: Diaspididae) (CRS), in its different developmental stages. The objective is to provide scientific criteria for a rational dosage of organophosphate and mineral oil based pesticides and a method for a fast assessment of the expected efficacy of a treatment.

Materials and Methods

Laboratory trials on different developmental stages of CRS were conducted to study the effect of spray volume on (1) deposition, and (2) efficacy. Two organophosphate pesticides (one Chlorpyrifos based product (CBP) and one Chlorpyrifos-methyl based product (CMBP)), and two mineral oils were tested. Deposition and efficacy models were extracted from these trials, and the minimum deposits for maximum efficacy were established for each stage of the insect.

Treatments derived from the models, taking into account the leaf area index and volume of the targeted canopies, showed a possible reduction of current applied volumes, and were later validated under field conditions. For this purpose, their efficacies (infestation index at harvest) (Townsend and Heuberger, 1943) and spray distribution in the canopy (estimated through coverage on water sensitive papers) were compared to those obtained by standard treatments (volumes close to run-off), in four commercial plots.

In a third step, we determined which variables had more influence on modelling the field efficacy. Variables under study were pest pressure (infestation index of the control treatment), coverage (%), spray application volume (l/ha), water volume applied per tree (l/tree) and water volume applied per volume unit of canopy (l/m^3). Finally, a parameter was proposed to estimate the quality of a field treatment in terms of expected efficacy, based on measuring coverage on water sensitive papers.

Results

An example of efficacy vs. deposition data is shown in Fig. 1 for CMP and CMBP. From these, minimum deposits to achieve the maximum possible efficacy were inferred. For example, minimum deposits of about 1.01 µl/cm^2 of these insecticides are required for maximum control of young stages of CRS. Similar models showed a minimum deposit of 3.41-4.72 µl/cm^2 for optimal control of these stages with mineral oils. Deposits to control adult stages increased up to 4.72 µl/cm^2 in all cases (Garcerá et al., 2011, 2012).

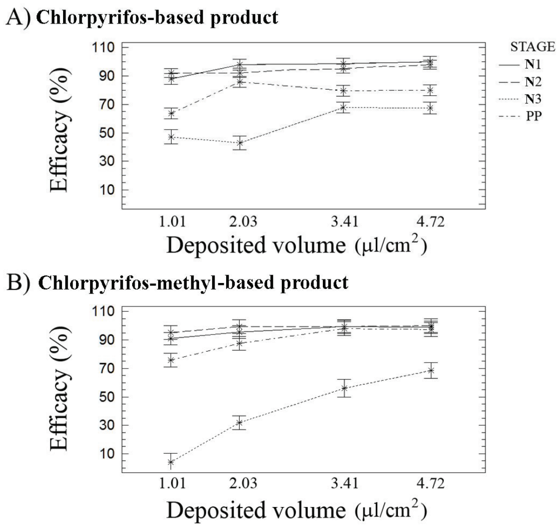

Figure 1. Response models for organophosphate insecticides: Interaction between the factors "deposited volume" and "stage" for the efficacy of CBP (A) and CMBP (B). Different stages were grouped and labelled as follows (each group included the growth stages shown in brackets): N1 (nipple stage and first molt), N2 (second instar and second molt), N3 (third instar and gravid females) and PP (prepupal and pupa males).

This work also showed that greater coverage did not lead to greater efficacy in field conditions. In spite of achieving a lower coverage with the proposed treatments (60-70% versus 90% with standard treatments), significant differences in efficacy were not found (an example is shown in Table 1). However, the proposed treatments saved about 40% of pesticide. Furthermore, the proposed parameter to measure the quality of a treatment was validated, showing its high potential for its application in real conditions (Garcerá et al., 2013).

Table 1. Infestation Index (%) of each treatment in plot A (mean ± SE). Significance of differences of Infestation Index in the applications of Oil A, CBP and CMBP treatments with the Control (Dunnett's test). Significance of the application volume for each treatment (ANOVA & LSD test).

Treatment	[A]Infestation Index (%)		
	CBP	CMBP	Oil A
Proposed (3000 l/ha)	40.92±4.35* a	46.93±4.9 a	35.14±4.35* a
Standard (5000 l/ha)	39.21±3.62* a	47.57±2.93 a	34.71±5.18* a
[B]F	0.09	0.01	0.00
[B]df	1, 19	1, 19	1, 9
[B]P	0.7652	0.9116	0.9510

*There are significant differences with the Control (no treatment) in the same plot (Dunnett's test, $P<0.05$)

[A]Means within a column followed by a different letter are significantly different (LSD test, $P < 0.05$)

[B]F: F-ratio; df: degrees of freedom; P: p-value

Acknowledgements

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References

Garcerá, C., Moltó, E., Chueca, P. 2011. Effect of spray volume of two organophosphate pesticides on coverage and mortality of Aonidiella aurantii Maskell. Crop Prot. 30, 693-697.

Garcerá, C., Moltó, E., Zarzo., M. Chueca, P. 2012. Modelling the spray deposition and efficacy of two mineral oil-based products for the control of California red scale, Aonidiella aurantii (Maskell). Crop Prot 31, 78-84.

Garcerá C., Moltó E., Chueca P. 2013. Factors influencing the efficacy of two organophosphate insecticides in controlling California red scale, Aonidiella aurantii (Maskell). A basis for reducing spray application volume in Mediterranean conditions. Submitted to Pest Manag. Sci., 2013, in press.

OJ (Official Journal of the European Union) 2009. Directive 2009/128/EC of the European Parliament and the Council of the European Union of 21 October of 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Official Journal of the European Union L309 of 24 November of 2009, 71-86.

Townsend, G.R., Heuberger, J.W. 1943 Methods for estimating losses caused by diseases in fungicide experiments. Plant Disease Rep. 27: 340-343.

Optimisation of spray application in South African citrus orchards: challenges and progress

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Introduction

South Africa is the third largest exporter of fresh citrus fruit in the world, and accesses more markets than any other citrus exporting country. Production of high quality disease and pest free citrus fruit is therefore a major priority. As a consequence, high volume spray application of plant protection products (8000 to 16000 L/ha) has become an industry norm, but with the concomitant success of producing export quality fruit.

High volume spray application is, however, very costly in terms of water, plant protection products, labour, time and equipment. Moreover, mature citrus trees are reported to hold sprays to a maximum of 2300 L/ha only (Cunningham and Harden, 1998). As much as 85% of the excessive spray volume is lost to run-off and drift, which results in considerable environmental pollution of soils and air, reduced spray cover and therewith reduced spray efficacy (Furness et al., 2006; Fourie et al., 2009).

The objective of this research programme is to study the optimisation of spray application in southern African citrus orchards by focussing on the optimal use of conventional and novel spray applicators (high and low volume applications), and optimal use of spray adjuvants. A novel spray deposition assessment protocol was developed using fluorometry, photomacrography and digital image analysis. In order to interpret the biological relevance of varying deposition quantities on citrus leaves in orchard spray trials, benchmarks for biological efficacy were determined using control of Alternaria brown spot (ABS) of mandarins with copper oxychloride as model system (van Zyl et al., 2013).

Materials and Methods

Benchmarks for biological efficacy. In 18 laboratory spray trials, detached young 'Nova' mandarin leaves were sprayed with copper oxychloride and SARDI Yellow Fluorescent Pigment (Furness et al., 2006) at different concentrations and spray deposition assessed. Subsequently, leaves were spray-inoculated with *Alternaria alternata* (causal agent of ABS), moist-incubated and symptoms digitally rated. Treatment concentration, deposition quantity [leaf area covered by fluorescent pigment particles (%FPC)] and Cu residue levels were correlated to indicate the suitability of the fluorescent pigment as tracer. ABS control was modelled on %FPC values using non-linear regression statistics and benchmarks indicating 50% and 75% control were calculated.

Optimal use of spray applicators. Orchard spray trials were conducted with conventional and novel tractor-mounted or -drawn sprayers at a range of calibration settings (mostly adjustments to nozzle selection, spray pressure and tractor speed), which effected spray volumes with SARDI Yellow Fluorescent Pigment (100 mL/hL) ranging from 200 to 24 000 L/ha. Leaves were randomly collected from the inner and outer canopy at bottom, middle and top tree positions. Deposition quantity and quality of pigment on upper and lower surfaces of these leaves were determined by means of a deposition assessment protocol using fluorometry, high detail digital photomacrography and image analysis (van Zyl et al., 2013). The coefficient of variation (CV%) between leaves was used to indicate spatial spray uniformity in trees. Spray efficiency was expressed as the mean quantitative deposition per leaf value per 1000 L of spray volume to compare different sprayers operating at different spray volumes.

Optimal use of adjuvants. Selected adjuvants were evaluated in 18 laboratory trials for their effects on deposition quantity and quality on ‘Nova’ mandarin leaves, as well as ABS control with copper oxychloride. These adjuvants were also evaluated in orchard spray trials on different citrus cultivars using different spray volumes.

Results and discussion

Benchmarks for biological efficacy. A very good linear relationship was found between fungicide concentration, deposition quantity (%FPC) (r = 0.879) and Cu residue analysis (r = 0.992). A von Bertalanffy growth function best fit the relation between of ABS control and %FPC data (91.04% proportion percentage variance explained) with a good correlation between observed and predicted values (r = 0.825). Benchmarks for 50% and 75% disease control were calculated as 2.07 %FPC and 4.14 %FPC, respectively. These corresponded with Cu residue levels of 59.38 and 91.02 mg/kg, respectively.

Optimal use of spray applicators. From five orchard spray trials, it was clear that the highest deposition quantities at the best uniformity were generally obtained with higher spray volumes using tower sprayers. However, it was obvious that deposition quality on individual leaves declined with increasing spray volumes due to more run-off. A constant fluorescent pigment concentration was used when comparing the different sprayers and calibration settings, even though spray volumes differed. Hence, the pigment dosage per hectare differed substantially between treatments. Using spray efficiency and spray uniformity as well as the benchmarks as criteria, it was clear that excessively high spray volumes (>10 000 L/ha) did not result in better spray deposition, but indicated clear losses in deposition due to run-off.

Similar and even improved spray deposition quantity and uniformity at better spray efficiency were obtained at lower spray volumes through optimal use of equipment or through the use of more efficient sprayers.

Optimal use of adjuvants. In orchard spray trials, most adjuvants improved uniformity and spray penetration to inner canopy leaves, but with significant differences between adjuvants in quantity of pigment retained. Canopy density profoundly affected spray deposition, with more open spray-friendly canopies showing superior adjuvant benefits. In laboratory trials, adjuvant treatments varied significantly in deposition quantity and ABS control achieved, but these parameters were poorly correlated; also with control levels predicted from the %FPC benchmark model. Therefore, deposition quantity and Cu-residues could only partially explain the level of control achieved following the addition of adjuvants. Based on available literature, these anomalous results could be attributed to the effects of adjuvants on deposition quality, on pathogen development and synergistic effects between adjuvant and fungicide. These effects are being studied further to elucidate these findings and to improve the accuracy of the deposition benchmark system for practical use.

Acknowledgements

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References

Cunningham GP, Harden J (1998) Reducing spray volumes applied to mature citrus trees. Crop Protection 17: 289 - 292.

Fourie PH, du Preez M, Brink JC, Schutte GC (2009) The effect of run-off on spray deposition and control of Alternaria brown spot of mandarins. Australasian Plant Pathology 38: 173-182.

Furness GO, Thompson AJ, Manktelow DWL (2006) Multi-fan spray towers to improve dose efficiency and spray coverage uniformity in citrus trees. International Advances in Pesticide Application, Aspects of Applied Biology 77: 481-488.

Van Zyl JG, Fourie PH, Schutte GC (2013) Spray deposition assessment and benchmarks for control of Alternaria brown spot on mandarin leaves with copper oxychloride. Crop Protection 46: 80-87.

POSTER SESSION

Bayer´s drift reduction project

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Introduction

At the beginning of this project, in autumn 2009, there was a limited use of techniques to reduce drift in high crops in Spain. There were good reasons to change this situation: while only a portion of the water volume sprayed is deposited on the intended target, the portion that is lost is either deposited on adjacent trees in next rows, misplaced directly in the ground (run-off) or drifted away from the site, polluting the environment (soil, water courses…) (Chueca et al., 2011). One of the factors affecting drift is the application technique used (Ganzelmeier et al., 1995; Salyani et al., 2007) and, a priori, one of the easiest ways to reduce drift is the use of air induction nozzles, with high potential to reduce drift because they produce coarser droplets, less prone to be carried away by wind. In the Directive 2009/128/EC for the Sustainable Use of pesticides (OJ, 2009) and in its transposition to Spanish regulations by the Real Decreto 1311/2012 (BOE, 2012), low drift nozzles are considered as a mitigation measure to reduce risk of water pollution.
The aim of this project was to increase the knowledge and use of this type of nozzles in Spain.

Activities

All the activities included in this project have been developed by Bayer CropScience. Some of them have been carried out in collaboration with the Universitat Politècnica de Catalunya, the Universitat Politècnica de València and the Instituto Valenciano de Investigaciones Agrarias. The activities started in autumn 2009 and continue nowadays. The different works have been focused on four aspects: Training, Efficacy Trials, Calibration and Quantification of drift.

Training: one of the key factors to change attitudes is training; 30 training sessions have been organized along these years in different areas of Spain: Galicia, Cataluña, Castilla la Mancha, Comunitat Valenciana, Andalucía, Extremadura, Murcia, Islas Baleares and Aragón, with a total amount of 1200 participants, considering both technicians and farmers. The aim of these sessions of training is to create awareness on the importance of simple practices to avoid water pollution coming from the use of agrochemicals, such as an adequate calibration of the sprayer and a switch to low drift nozzles.
In these sessions there is a theoretical part and a practical part. In the practical part, the participants learn how to calibrate the equipment and check the difference

between the droplets produced by conventional nozzles in comparison to low drift nozzles, by means of water sensitive papers located on different parts of the crop, combination of different levels of height and depth inside the canopy.

Efficacy Trials: one of the concerning issues arising from the use of low drift nozzles is whether the efficacy is comparable to that obtained when using conventional nozzles, due to the coarser droplets produced. For this reason some efficacy trials were conducted in different crops to compare the performance of conventional versus low drift nozzles in terms of efficacy, keeping constant the rest of the operative conditions (pressure, application volume, advance speed…).
In 2010, trials were carried out in two peach orchards in different areas of Spain (Lleida and Murcia) and two citrus orchards in Valencia. In 2011, trials were conducted in two peach orchards in the same areas of 2010 trials, one cereal field in Sevilla and one citrus orchard in Valencia (Dólera et al., 2012). In 2012, a trial was started in olive orchards, comparing Albuz ATR nozzles, usually used in this crop, with two different low drift nozzles. The air induction nozzles used in the trials were Albuz AVI 80 for peaches, Albuz TVI for citrus and both for olives. This task continues along 2013 with a trial in a vineyard orchard with the same objective, to obtain conclusive results to support recommendations in the use of low drift nozzles.
The general conclusion is that the efficacy in all the cases is comparable to the conventional hollow cone nozzles, or even better, due to a deeper penetration inside the tree (in the case of citrus orchards).

Calibration of the sprayer: training sessions raised the necessity of growers to improve their applications, so Bayer CropScience started to offer a service to promote the calibration and regulation of the sprayers as a prerequisite for a quality application, checking the parameters used in the application and adapting them to each particular condition, to get the best performance of the products. More than 450 equipments, mainly in Comunitat Valenciana, have been checked, giving recommendations on the adequate parameters and nozzles to be used. Around 50 of them have switched to low drift nozzles to apply the treatments in their orchards. To offer this service, Bayer CropScience distributors have been provided with which is called a “Calibration kit”, consisting of a flow meter, a manometer, a measuring tape, a chronometer, and a graduated tube. They have been provided as well with an on-line tool to facilitate the selection of nozzles depending on the parameters used, which is called “Nozzle selector” (http://www.agroservicios.bayercropscience.es/).

Quantification of drift: it is accepted that air induction nozzles reduce considerably drift, but it is necessary to quantify the actual reduction obtained when using them. ISO 22866 (ISO, 2005) establishes internationally recognized methods for the measurement of drift, but its requirements are difficult to be accomplished in a common situation. So it is interesting to have an easy and fast methodology to estimate such reduction of drift in the field, in real conditions of application.

In 2012, field experiments to evaluate the efficacy of different drift reduction methods were carried out in different crops (lemons and peaches). Drift measurements consisted on quantifying losses to the ground and to the air and comparing conventional and air induction nozzles, while keeping constant the rest of the parameters of the applications. Low drift applications reduced drift up to 54% (Chueca et al., 2013).

Acknowledgements

These activities have been done in collaboration with Universitat Politècnica de Catalunya (Dr. Emilio Gil), Universitat Politècnica de València (Dr. Luis Val) and Instituto Valenciano de Investigaciones Agrarias (Dr. Enrique Moltó).

References

BOE (Boletín Oficial del Estado) 2012. Real Decreto 1311/2012, de 14 de septiembre, por el que se establece el marco de actuación para conseguir un uso sostenible de los productos fitosanitarios.BOE N. 223 of 15 September of 2012, 65127-65171.

Chueca P., Moltó E., Garcerá C. 2011. Influence of nozzles on mass balance of spray applications in citrus. Suprofruit 2011, International Workshop on Spray Application Techniques in Fruit Growing, Bergerac (France) June 8-10, 2011.

Chueca P., Garcerá C., Masip P., Moltó E. 2013. Methodology for a fast, in field estimation of the efficiency of antidrift measures. Suprofruit 2013, International Workshop on Spray Application Techniques in Fruit Growing, Valencia (Spain) June 26-28, 2013.

Dólera L., Vercher R., Garcerá C., Soler J.M., Val L. 2012. Spraying citrus orchards with Antidrift nozzles. Poster presented in the International Conference of Agricultural Engineering CIGR-AgEng 2012. Valencia (Spain), 8-12 de July 2012. Book of papers ISBN: 978-84-615-9928-8.

Ganzelmeier H., Rautmann D., Spangeberg R., Streloke M., Herrmann M., Wenzelburger H.J. 1995. Studies on the spray drift of plant protection products, Blackwell Wissenschafts-Verlag GmbH, Berlin.

ISO, 2005. Equipment for crop protection — Methods for field measurement of spray drift. ISO/FDIS 22866. Geneva. 22p.

OJ (Official Journal of the European Union) 2009. Directive 2009/128/EC of the European Parliament and the Council of the European Union of 21 October of 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Official Journal of the European Union L309 of 24 November of 2009, 71-86.

Salyani M., Farooq M., Sweeb R. 2007. Mass balance of citrus spray applications. ASABE Annual International Meeting. Paper number: 071037.

Spray deposition on coffee crop (*Coffea arabica* L.): influence of nozzle type

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Introduction

Coffee (*Coffea arabica* L.) is an important crop in Brazil but one with enormous technological challenges. Coffee plants have dense foliage and a large foliar area and consequently, applications to control pests and phytopathogens need to penetrate the foliar canopy. This also applies to product applications that act systemically. One way to achieve good deposition on biological targets is in the correct selection of spraying technique and application volume.

However, there is very little information regarding application technologies for coffee crops and especially for the spray volume and distribution needed to effectively control pests and phytopathologens (Silva et al., 2008). A failure to adapt application volume to specific crop requirements is one cause of agricultural waste (Cunha et al., 2005). For similar reasons, structural aspects of the crop canopy must also be considered (Rosell Polo et al., 2009). Nozzle selection is also important and consequently, nozzle manufacturers have launched new products to improve application technologies. It is important to combine deposition uniformity with drift control. In most cases, great concern is given to pesticide selection and too little concern to application technique.

Thus, the objective of this study was to study spray deposition on coffee crops using different spray volumes and nozzles.

Materials and Methods

The experiment was conducted at the Setor de Cafeicultura (Coffee Crop Sector) belonging to the Federal University of Uberlândia, Uberlândia, Minas Gerais (Brazil) and targeted an eleven-year-old *Coffea arabica* crop (cultivar IAC 99), spaced 3.5 x 0. 7 m (LAI = 5.9). An axial fan air-blast sprayer (Montana model ARBO 360) was used for all treatments.

The experiment was completely randomized in a 2 x 2 factorial model with 40 replications: two nozzles and two spray volumes (Table 1).

After spraying, deposition was evaluated on the upper and lower parts of the targeted plants. Each plot consisted of four rows of coffee, 160 m in length and meteorological conditions were monitored throughout the test.

Blue food coloring (FD&C Blue no.1), was used as a tracer compound at a rate of 300 g ha^{-1} and was detected by absorbance spectrophotometry. After detection, the quantity deposited in µg cm^{-2} of foliage was calculated dividing the total amount detected by the area from which it was collected.

Table 1 – Description of treatments

Treatments	Spray volume (L ha^{-1})	Spray nozzle	Pressure (kPa)	Volume Median Diameter*
1	500	Hollow cone (ATR Orange)	1207	151 µm (1000 kPa)
2	500	Air induction hollow cone (TVI 8002)	1158	544 µm (1000 kPa)
3	200	Hollow cone (ATR Yellow)	345	148 µm (500 kPa)
4	200	Air induction hollow cone (TVI 80015)	296	646 µm (500 kPa)

* According to manufacturer specifications, based on the pressure closest to that used in the test.

Results

In the upper part of the canopy, interaction between spray volume and spray nozzle was significant (Table 2). The ATR nozzle performed slightly better than the TVI nozzle at 200 L ha^{-1} but not at 500 L ha^{-1}. Deposition from coarse droplets (TVI nozzle), was best at high volume (500 L ha^{-1}) whereas deposition from fine droplets (ATR nozzle) was best at low volume (200 L ha^{-1}).
In the lower part of the canopy, where good coverage is hardest to obtain, there was no difference between treatments (Table 3). The results showed that it is technically feasible to use air induction nozzles (coarse droplets) for phytosanitary treatments on coffee crops. Biological efficacy studies are in progress to complement this test.

Table 2. Spray deposits on coffee crop foliage (µg cm^{-2}) on the upper part of the canopy, using different spray nozzles and spray volumes.

Spray volume (L ha^{-1})	Nozzle	
	ATR	TVI
200	1.0297aA*	0.8041bB
500	0.8824aB	0.9028aA

Table 3. Spray deposits on coffee crop foliage (µg cm^{-2}) on the lower part of the canopy, using different spray nozzles and spray volumes.

Spray volume (L ha^{-1})	Nozzle		Mean
	ATR	TVI	
200	1.0501	1.0039	1.0270A*
500	0.9887	1.0758	1.0322A
Mean	1.0194a	1.0397a	

*Values in the same column with the same upper case letter are not significantly different at $\alpha = 0.05$ using Tukey's mean separation test. Two values within the same row with the same lower case letter are not significantly different at $\alpha = 0.05$ using Tukey's mean separation test.

Acknowledgements

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References

Cunha JPAR, Teixeira MM, Vieira RF, Fernandes HC (2005) Deposição e deriva de calda fungicida aplicada em feijoeiro, em função de bico de pulverização e de volume de calda. Revista Brasileira de Engenharia Agrícola e Ambiental 9: 133-138.

Rosell Pólo JRR, Sanz R, Llorens J, Arno J, Escolà A, Ribes-Dasi M, Masip J, Camp F, Gràcia F, Solanelles F, Pallejà T, Val L, Planas S, Gil E, Palacín J (2009) A tractor-mounted scanning LIDAR for the non-destructive measurement of vegetative volume and surface area of tree-row plantations: A comparison with conventional destructive measurements. Biosystems Engineering 102: 128-134.

Silva AR, Leite MT, Ferreira MC (2008) Estimativa da área foliar e capacidade de retenção de calda fitossanitária em cafeeiro. Bioscience Journal 24: 66-73.

Estimation of the Concentrated Endurances Occurring on the Outer Surface of the Sprayers

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Introduction

Plant protection is one of the indispensable operations in agricultural production, as it influences the income of the farmers (high prices of pesticides, damages caused by insects, wild or other pathogens etc.). The bad technical state of plant protection machines, wrong adjusting, and the negligence of maintenance and cleaning can harm the income possibilities, and increase the endurance of the environment.

There have been important steps made to avoiding such problems on European level. As a result of it the DIN/EN 12761 standard (2001) has been created, which prescribes the providing of inner cleaning machines with a rinsing water reservoir in case of new sprayers. The connection of outer cleaning device is also possible, so the cleaning will be quick and water-saving (Csizmazia et al., 2006). The International Organization of Standardization (ISO) created a work group managed by the Julius Kühn Institute of Plant Protection Application Technology. Their task is to work out measuring methods by which the pollution of the sprayers with pesticides and the efficiency of the cleaning equipment can be measured. The result of their work came the ISO/DIS 22368 standard draft to light, which consists of three parts. The first part deals with the complete inner cleaning of the plant protecting machine, the second part with the external washing of the machine, the third part deals with the internal rinsing of the liquid tank (Herbst and Ganzelmeier et al., 2002; Wehmann et al., 2008). The standard draft plan was recognized as international standard in July 2012 and nowadays the team is working on the determination of the achievement criteria.

Our department researches nowadays concentrate on the second chapter of the standard. We are looking for an answer about the quantity and relation of chemicals on the sprayer by using different settings. We also give advice about the increasing of the efficiency of the measuring methods which were used according to the standard, as well as the reduction of expenses and the time consumption.

Materials and Methods

The subject of the measuring is a Berthoud ARBO 1000 plantation sprayer with axial ventilator which has 1000 l nominal volume and has adjustable deflectors too. The tests were made with Saphirex disk-core type circulation nozzles, which have wide spraying angle (65°), on high pressure (10, 15, i.e. 20 bar), with and by removing the deflectors. The aim of the research is the measuring of the chemical

sediment issued from the spraying on the outer surface of the plant protecting machines. It is also the checking of the accomplishment of the standard and making offers to increase the efficiency of the measurements, and eventually elucidate measurement errors. According to the standard we used Tartrazine 85% (E 102), a yellow food colouring. Its main characteristics are good solubility, good adhesiveness, it is easy washable, so is proved to be ideal for the measurements.
The measurement begins with the filling up of the machine. We fill as much reference liquid into the machine as it is necessary for the spraying, according to the standard. Meanwhile the mixing equipment is working. Then, simulating a spraying process, we spray the liquid in a radius circle given in the standard (in case of an axial ventilator min. r = 10 m), for 10 minutes clockwise, then backwards to compensate the wind effect. Then we let the technical rest out and we wash the wheels, so that they do not deform the concentration of the patterns. Then we put the sprayer in a catchment pool to clean the outer surface with a high pressure cleaner. We collect the cleaned liquid and we take samples and then we repeat the process. After registering the concentration of the liquid samples it is possible to define the quantity of the chemicals sedimented on the sprayer according to the sprayed quantity with the help of spectrophotometry (ISO/DIS 22368-2:2004 et al., 2004). Beside the conditions and the circumstances described by the standard we also examined the machine in real circumstances, which is in an orchard. We made the measurements, and then we also washed it and took samples.

Results

During the measurements by the survey of the machine, the plant protecting material appears in larger quantity on the boom, which is on the inlet and outlet openings on the axial fan. This can be explained by the fact that the fine spray is taken away with the suction effect of the ventilator, and that gets into the ventilator through the turbulent stream. Moreover the drift was also observed, which got the fine spray not only on the sprayer but also on the prime mover. This can be important from the point of view of work protection and environment protection. If it were a substance which could be absorbed by the skin the person working with the machine could even get a slight poisoning. If the machine were cleaned in the yard the chemical could get into the soil and pollute drinking water, too.
The result of the measurements proved that while using the adjustable deflectors the degree of pollution at 15 bar working pressure was the smallest compared to the quantity of the sprayed chemicals (0.1%; 10 bar – 0.16%; 20 bar – 0.13%).
At the measurements made without the deflectors there has been only a comparing test at a working pressure of 15 bars. Then the degree of pollution was slightly higher due to the lack of directing effect of the air (0.15%; +50 %).
At the end, the measurements in the orchard, without deflectors, based on the test results are the degree of contamination, although not significantly, decreased (0.13%; -13%; Figure 1).

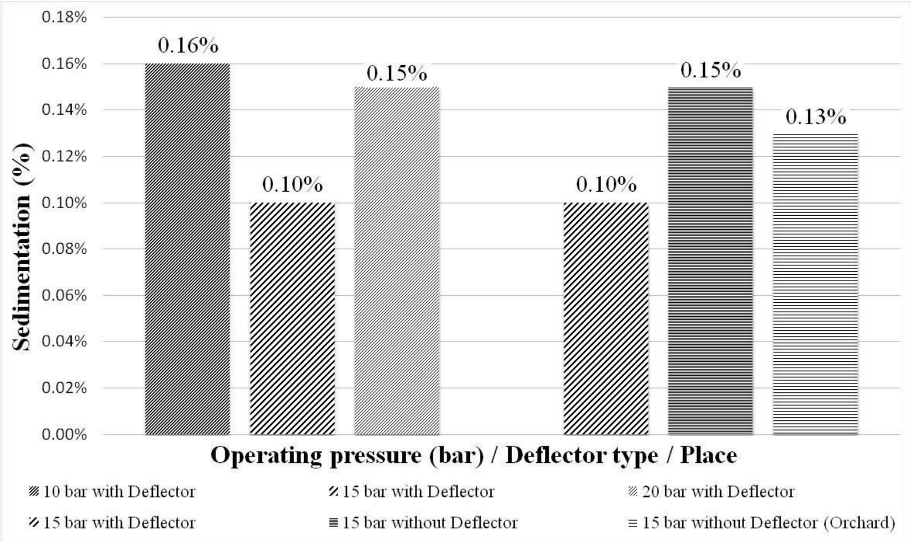

Figure 1. Sedimentation on the sprayer in relation to the operating pressure

All in all, the description of the process given in the standard is acceptable, though it is time and work consuming and it needs small adjustments (e.g. the gathering of the washed up liquid and sample taking from the catchment pool). However it can give good direction to the producers of machines for discovering bigger spots of sediment on the sprayers.

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References

Csizmazia, Z. (2006). A növényvédelem gépei (Machines of plant protection), Mezőgazda Kiadó, Budapest, p: 137-138, ISBN 963-286-150-7

Herbst, A. and Ganzelmeier H. (2002). International Standards and their Impact on Pesticide Application, Aspects of Applied Biology 66, January 2002. Warwick, UK. 2002.

Wehmann, H.J. 2008: Reinigung von Pflanzenschutzgeräten – ISO Norm und erste Ergebnisse (Cleaning of sprayers – ISO standard and first results), Nachrichtenblatt des deutschen Pflanzenschutzdienstes, 60 (3). pp 62 – 67, ISSN 0027-7479

ISO/DIS 22368-2:2004 - Crop protection equipment – Test methods for the evaluation of cleaning systems – Part 2: External cleaning of sprayers (2004). Worksheet, International Organisation for Standardization

Site-specific plant protection using precise canopy gap detection

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Introduction

Currently, the application of pesticides is an essential part of plant cultivation to maintain fruit quality and yield. With regards to economic and environmental aspects, site-specific applications to horticultural crops have been reported in order to reduce the amount of pesticides without decreasing the biological efficacy (Koch et al., 1997). However, for precision fruit growing, reliable sensor technologies are required, which accurately detect the plant's characteristics and their environmental conditions. For this purpose, optical sensors have been shown to be suitable for canopy gap detection (Kaul et al., 2010).
Through an adjustment of infrared (IR) signals to a single or groups of nozzles the application of pesticides can be switched off in canopy gaps while the plant protection equipment is passing by the trees. But if the number of sensors is lower than the number of nozzles, the detected canopy area would be significantly smaller than the canopy area to treat. Consequently, thin tree branches and twigs with minor foliage become left out which decreases the biological efficacy in early growth stage. In addition, the sensitivity of the IR-sensor needs to be high enough to detect fine tree structures in the first tree row and separate noise signals from background.
The aim of this study is to develop an improved system using an increased number of IR-sensors that scan a larger area and identify the accurate shape of trees and gaps. Currently used optical systems do not entirely fulfil these requirements in fruit production.

Requirements

The knowledge from former projects and results from pre-tests clearly show that a precise application is mainly based on an accurate matching of IR-sensors, air stream and nozzles. In more detail:

- each single nozzle should be attached to one IR-sensor
- horizontal and vertical dimensions of air stream and spray pattern shall correspond to the scan direction and area

Because of this, the proposed system should have 18 IR-sensors, nine sensors on each side of sprayer, and 18 electromagnetic valves, one for each nozzle. The

higher number of sensors needs to be validated in practice concerning the function and limits of the new system in comparison to currently used plant protection equipments. Further tests with variable backgrounds in orchards and natural objects have to verify the response of IR-sensors and the results of measurements under specially defined conditions. However, the sensitivity concerning the background and the influence by interfering light also needs to be confirmed under practical conditions. In addition, sensors should be adapted to the respective air flow. For this reason modifications of nozzle settings as well as air stream are needed to determine an effect on the precise application.
The improved detection of trees and gaps by an increased number of IR-Sensors allows the scan of a larger area which improves the switching processes and in consequence could offer further savings of pesticides (Figure 1).

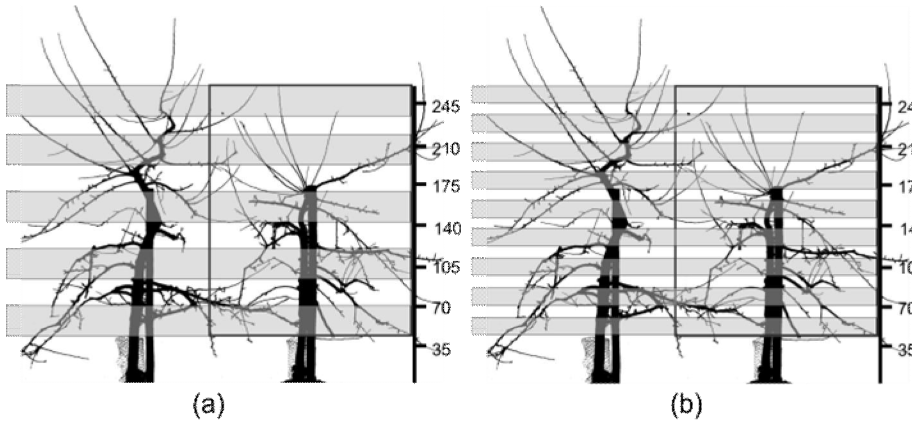

Figure 1. (a) Example of scan bands (detected area) of IR-sensors, (b) Enhanced area of detection (sampling area is likely increasing about 30%)

Therefore, for a precise tree canopy detecting system an exact interaction of the IR-sensor, the air stream and the spray direction is necessary. Currently, work is under progress which should provide an IR-sensor system sensitive enough for detecting thin tree branches and twigs.

Acknowledgements

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References

Koch, H., P. Weisser and H. Funke (1997). Sensors for fruit tree sprayers. A new technique for reducing pesticides. Obstbau 22.

Kaul, P., Gebauer, S., Dröge, K., Ralfs, J.-P., Christophliemke,T. (2010). Requirements to the gap switch when spraying in orchards-Aspects of pesticide reductions. Land.Technik 2010, VDI-reports No. 2111, 11-117

PPE Required during Overhead Spraying in Orchards

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Pesticides, also known as plant protection products, are regulated around the world. Regulatory bodies in the respective countries are responsible for reviewing a dossier provided by the product manufacturer to determine potential risk as a result of the use of a product. The risks to the operator when handling (e.g., mixing, loading, and applying) pesticides are typically a part of the risk assessment process. The toxicity of the product and exposure are commonly used to determine risk. The toxicity of a product remains constant regardless of its use; however, the exposure is entirely dependent on how the product is used. Factors such as application rate, equipment, and technique used for spraying affect the potential exposure and therefore the level of protection provided by use of Personal Protective Equipment (PPE). Protection factors assigned to different types of PPE are used for risk mitigation. These protection factors either are based on exposure study data or are estimates extrapolated from the studies. For example, the Occupational Pesticide Handler Unit Exposure Surrogate Reference Table, published by the US Environmental Protection Agency, Office of Pesticide Programs, provides information on the exposure scenario (activity, equipment, formulation, site, etc.). The footnote included with the table states that "Exposure monitoring data representing all levels of PPE for all scenarios is unavailable. In order to represent different PPE levels, exposure values are calculated using assumptions for the protection afforded by additional layers of clothing, chemical-resistant gloves, or respirators. Exposure assessors should be mindful of the uncertainties that this convention introduces into the overall calculations. In all cases, estimates based on direct measurements representing the PPE-level specified are the most reliable" (US EPA 2012).

Overhead orchard spraying is prevalent in various parts of the world, but application equipment and techniques can vary considerably within a region/country and between regions/countries. Thus, the dataset used to determine PPE should be representative of practices prevalent in the region/country in which the product is being registered. It is important that the regulatory bodies responsible for exposure assessment be well-versed with the prevalent application practices. A good understanding of the studies used to develop exposure models is imperative to determine the PPE requirements. If engineering controls are used to reduce exposure, a lower level of PPE may be required. Similarly, if the exposure is high, additional protection may be required. For example, in the United States, the statement "For overhead exposure wear chemical-resistant headgear" has to be included as part of the label for all products that may involve overhead exposure such as overhead orchard spraying of tree fruits (US EPA 2009).

Protective clothing requirements on pesticide products vary considerably. In the United States garment type and layers of clothing (long-sleeved shirt and long pants; coveralls worn over short-sleeved shirt and short pants; coveralls worn over long-sleeved shirt and long pants) and in a few cases chemical-resistant coveralls are stated as requirements on the pesticide product labels. In Brazil only certified garments that meet the minimum performance requirements can be used. Compliance with Plant Protection Product directive is required by member states of the European Union. Standard phrases such as "wear suitable protective clothing and gloves" are stated on the product labels. Conformité Européenne (CE) marked Type 6 and Type 4 chemical protective clothing as well as garments that fulfill the Deutsches Institut für Normung (DIN) requirements are typically used to meet the protective clothing requirements. In many other countries around the world, general statements that provide little guidance to the user are included on the pesticide product labels.

The presentation will include information and examples of how exposure studies/models and protection factors affect PPE information on pesticide product labels. As PPE is required for mitigation, clear, concise text regarding PPE requirements should be stated on the pesticide product label. International, performance-based standards to differentiate among the different levels of garment performance would assist in communicating the requirements to users. The ASTM (2012) and ISO (2011) performance requirements and certification standards based on those requirements will be covered in the presentation. Examples will be provided to demonstrate how these standards can be used to communicate PPE requirements based on protection factors to the user. Orchard spraying scenarios (including use of engineering controls) for tree fruit spraying in the state of Washington will be used as examples for the presentation. In addition, examples of orchard spraying scenarios, label requirements, and PPE worn during application in different parts of the world will be used to highlight the similarities and differences in various regions.

Acknowledgements

This research was partially funded by the Washington State Tree Fruit Research Commission (WTFRC) (2013). Carol Black was recipient of a grant from WTFRC.

References

ASTM International: ASTM F2669-12 Standard Performance Specification for Protective Clothing Worn by Operators Applying Pesticides, West Conshohocken, PA, www.astm.org.

International Organization of Standards: ISO 27065:2011, Protective clothing – Performance requirements for protective clothing worn by operators applying liquid pesticides Geneva, Switzerland.

United States Environmental Protection Agency. (2009) Label Review Manual. Chapter 10. http://www.epa.gov/oppfead1/labeling/lrm/

United States Environmental Protection Agency, (2012) Occupational Pesticide Handler Unit Exposure Surrogate Reference Table, http://www.epa.gov/opp00001/science/handler-exposure-table.pdf

Preliminary trial on spray deposition with a fixed spraying system in an Apple orchard

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Introduction

In fruit growing, plant health protection is essential to assure an acceptable and cost-efficient production. Traditionnally growers use airblast sprayers to apply pesticides on apple trees, creating 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 ineffective disease or insect control, off-target drift leading to environmental pollution and economic inefficiency (Agnello and Landers, 2007, Panneton et al 2011). The application of products via an overhead micro-sprinkler system could be an interesting alternative to traditional sprayers and could have several advantages : less exposure of the applicator (Van der Gulik, 2007), application of products at the most appropriate time, economics in labor and fuel, reduction of soil compaction and noise. Some countries, like the United States and Canada, have specific regulations to this type of spray. In Europe, this technique was developed in Austria, in organic orchards, to control apple scab. In 2012 a fixed spraying system was installed in an apple orchard at the Technical Institute for fruits and vegetable (Ctifl – Centre technique interprofessionnel des fruits et legumes). At first, the aim is to study deposition quality on the leaves and on the soil with fixed micro sprinklers. In the five next years we will study the biological efficacy of this technique on the major pests and diseases of apples compared to conventional nozzles.

Materials 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. The experimental plots were laid out following a randomized complete block design with three replicates. Each plot had five rows of trees and at least 10 trees in each row. Micro-sprinklers are installed above the canopy, one sprinkler for one 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 bars. The selected model delivered 35l/h. To obtain an application volume of 400l/ha they were turned on for 20 seconds. A check valve is installed at each sprinkler to allow filling and rinsing the pipes at a low pressure. The injection of the product is done via a pump, DOSATRON®. Flow tests were conducted using food coloring (Tartrazine) as a tracer, to determine the uniformity of tracer concentrations all along the row, as well as time necessary to fill and apply the product, and to rinse the system. A first set of measurements was also performed to quantify spray distribution on the tree and on the soil. The collectors are sticky vinyl discs glued onto leaves (three trees per block). The sampling location is illustrated in figures 1 and 3. At each position, 10 discs were glued onto 5 leaves (1 disc on the lower surface and one disc on the upper surface of each leaf) (Figure 2). Each set of 5 discs were collected together in a tube to form a single sample. After extraction of the tracer, absorbance was measured with a spectrophotometer.

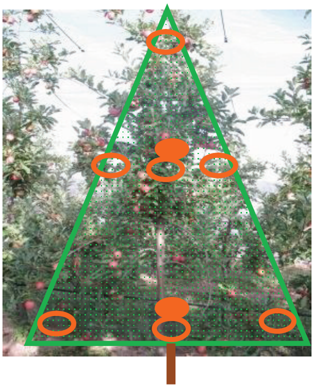

Figure 1. 9 areas sampled on each face of the tree, near the trunk (full circles) and at the periphery of the tree (empty circles).

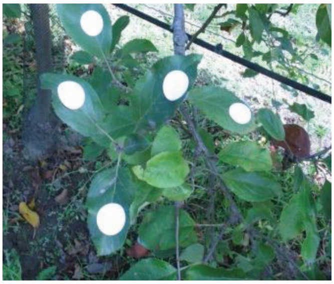

Figure 2. On each area, 5 vinyl disc on the top and under the leaves.

Figure 3. Deposit measurement on the soil with filter papers.

Results

The first results are encouraging. The flow rates are uniform for each position of the sprinkler on the line and the tartrazine concentration at the outlet of the sprinkler are also homogeneous. At row scale, there is no difference between the deposits on

West and East side. On the other hand, we measured a high variability of the total deposits from a tree to another. At tree scale, the sprinklers delivered 15% more spray on the top (3.50 m to 4 m) than the medium and low height while deposits are equal in the outer and inner areas. Finally, at leaf scale, the deposits on the tops surfaces are on average equal to the deposits on the lower surfaces. Although the system is functional, it needs to be optimized taking into account the technical anomalies encountered during these first tests.

References

Agnello A, Landers AJ (2007) Optimization of a fixed spraying system for commercial high-density apple plantings, Final Report 2007 to North East IPM Center.

Panneton B, Piché M, Philion V, Chouinard G (2011) Leaf Deposition with fixed sprinklers, low drift nozzles and conventional nozzles in apple orchard. ASABE Paper No. 1110798. 11 pp.

Van der Gulik TW (1993) Chemigation: guidelines for British Columbia. Abbotsford: B.C. Ministry of Agriculture, Fisheries and Food, Soils and Engineering Branch, pm - ISBN: 0772617279.

SESSION 4

Reduction of risks

How equipment and spray technologies are regarded in National Action Plans on sustainable use of pesticides

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Introduction

The European Union's Directive 2009/128 EG, on sustainable use of pesticides requires that the member states shall develop national action plans fulfilling its requirements by 26 November 2012. The Directive lays down minimum requirements for these plans and it is up to the member states to define their national regulations.

Equipment for application of pesticides and application technology are considered in the article 8. Inspection of equipment in use, 9. Aerial spraying, 11. Specific measures to protect the aquatic environment and drinking water and 13. Handling and storage of pesticides and treatment of their packaging and remnants.

Article 8 states that Member States shall ensure that pesticide application equipment in professional use shall be subject to inspections at regular intervals. All equipment shall be inspected at least once by 26 November 2016. After this date only pesticide application equipment having successfully passed inspection shall be in professional use.

The inspection of sprayers shall cover all aspects important to achieve a high level of safety and protection of human health and the environment. Full effectiveness of the application operation should be ensured by proper performance of devices and functions of the equipment to guarantee the following objectives are met. Minimum requirements of the sprayers are defined in Annex 2: Health and safety and environmental requirements relating to the inspection of pesticide application equipment.

Equipment must be reliable and used properly for its intended purpose, ensuring that pesticides can be accurately dosed and distributed. The equipment must be filled and emptied safely, easily and completely and prevent leakage of pesticides. It must permit easy and thorough cleaning. It must also ensure safe operations, and be controlled and capable of being immediately stopped from the operator's seat. Where necessary, adjustments must be simple, accurate and capable of being reproduced.

The annex specifies a list of components and features tin which special attention should be paid i.e. nozzles. Nozzles must work properly to control dripping when spraying stops. The flow rate of each individual nozzle shall not deviate significantly from the data provided by the manufacturer in order to ensure the homogeneity of the spray pattern. The distribution of the spray mixture in the target area must be even, where relevant. The fans must be in good condition and must ensure a stable and reliable air stream. The European Commission has given a mandate to European Committee for Standardisation (CEN) to develop the needed standards. National programs on voluntary- or mandatory inspection of sprayers in use have need in force since the 1980-ies. Based on experience from the existing programs it can be assumed that many sprayers will not fulfil the requirements will require to be upgraded or taken out of use.

In addition to the inspection of equipment the owner shall conduct regular calibrations and technical checks of the equipment. This shall be done in accordance with training received in courses that the countries have to offer. How often checks and calibrations shall be done as well as details in check and how to calibrate is to be defined in national action plans.

The Article 11 on specific measures to protect the aquatic environment and drinking water states that Member States shall insure adoption of appropriate measures to protect the aquatic environment and drinking water supplies from the impact of pesticides e.g. by giving preference to the most efficient application techniques such as the use of low-drift pesticide application equipment especially in vertical crops such as hops, orchards and vineyards or the use of mitigation measures to minimise the risk of off-site pollution caused by spray drift, drain-flow and run-off. These shall include the establishment of appropriately-sized buffer zones for the protection of non-target aquatic organisms and safeguard zones for surface and groundwater used for the extraction of drinking water, where pesticides must not be used or stored.

The Article 13 on handling and storage of pesticides and treatment of their packaging and remnants states that Member States shall adopt the necessary measures to ensure that a number of defined operations by professional users and where applicable by distributors do not endanger human health or the environment: storage, handling, dilution and mixing of pesticides before application; handling of packaging and remnants of pesticides; disposal of tank mixtures remaining after application; cleaning of the equipment used after application; recovery or disposal of pesticide remnants and their packaging.

The situation over Europe varies a lot before the development and implementation of national action plans. On drift reduction techniques there are countries without legal- or advisory-systems for drift reduction, others have developed certification systems for approving nozzles, sprayers and/or adjustments that allow to reduce buffer zones. These systems may be independent or integrated in the approvals for pesticides. Buffer zones have been defined at a fixed distance to water or dependent to wind direction. Sizes of buffer zones vary from less than 1 m to 100 m. The efficacy of drift reduction techniques are based on field measurements or wind tunnel measurements.

The methodology varies between countries causing confusion to nozzle, sprayer and pesticide manufacturers because they are not standardised.

Denmark and France have already regulations on maximum concentrations of remnants in sprayers after cleaning (2% respectively 1%), while others do not. Collection, handling and incineration of packages are not uniformly regulated.

This work shows an overview of how sprayers and application techniques are regulated in member states, based on a survey conducted in spring 2013, when all national action plans should have been developed.

References

Directive 2009/128 EG, on the Sustainable Use of Pesticides, Official Journal of the European Union L 309/71.

How pesticides get into surface water: a case study of emission pathways in fruit growing in the Netherlands

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Introduction

The reduction of the emission of plant protection products (PPP) to the environment is an important issue when applying agrochemicals in fruit growing in the Netherlands; e.g. label restrictions for use along water ways. Legislation is set into force, in which it is specified that fruit growers have to achieve 90% drift reduction to surface water compared to standard spray applications. However, the measurements of the water control organizations showed that pesticide concentrations in surface water decrease less than was expected based on the model calculations implementing the drift reduction measures. Possibly, the implementation rate of spray drift reducing techniques is overestimated in the model calculation or the impact of point sources is under estimated. However, although the relevance of different sources should be clear, the quantification of pathways is difficult. Pesticide inputs in surface waters come from diffuse sources (e.g. spray drift and leaching) and point sources, e.g. losses due to bad management practices of farmers at the farm when mixing, loading, and cleaning (Carter, 2000). Recent outcomes of surface water monitoring in one of the major Dutch fruit growing areas (Province of Utrecht) showed high concentrations of typical pesticides used in fruit growing. A study was carried out with emphasis on sources and transport routes that contribute most to the pesticide loads in surface water.

Materials and Methods

In this study the (relative) contribution of different emission pathways was estimated for 4 different pesticides that were found in high concentrations in surface water (i.e. captan, boscalid, thiacloprid and glyphosate). The contributions were calculated based on the Dutch Environmental Risk Indicator for Plant Protection Products (NMI 3; Kruijne et al., 2011). The NMI 3 focusses on indicators for emissions to surface water and the related aquatic risk resulting from agricultural use of pesticides in the Netherlands. The model calculates indicators for emission to surface water resulting from atmospheric deposition, spray drift, and leaching. The model combines a wide range of information about pesticide sales, pesticide usage, spray drift mitigation, emission factors, crop maps, surface water, soil, climate, and substance properties. Also, the effect of spray drift mitigation measures was taken into account. Another model was developed for point source contamination to discriminate between the sources to contamination of surface waters; the POint Source SUrface waters Model (POSSUM; Wenneker et al., 2010). Special attention regarding point sources was given to discharges from fruit sorting installations.

Results

The actual situation of the fruit growing area in the Province of Utrecht has a combination of adverse factors as the presence of a narrow grid of ditches, tree rows close to the ditches, high treatment frequency as well as spray drift prone application techniques (air blast sprayers) that might lead to extremely high surface water inputs. Spray drift appeared to be the major emission path way for captan and glyphosate. For boscalid and thiacloprid leaching (drainage flow) was the main path way in terms of total grams to the surface water system. Calculations show a high risk for high peak concentrations if (obligate) drift mitigation measures are omitted by the growers. This can lead to larger inputs from drift than from point source contaminations. The outcomes of the study (Wenneker et al., 2012) were discussed with representatives of the local waterboard (HDSR), the Province of Utrecht and the Dutch Fruit Growers Organization (NFO). As a result a covenant was signed in December 2012 between the stakeholders. In this covenant appropriate mitigation measures are described. In a project (2013-2015) the stakeholders will work intensively together in order to implement effective emission management plans. Outcomes of the study, the covenant and multi stakeholder project will be presented in more details.

Acknowledgements

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References

Carter, A.D., 2000. How pesticides get into water – and proposed reduction measures. Pesticide Outlook 11: 149 – 157.

Kruijne, R., Van der Linden, A.M.A., Deneer, J.W., Groenwold, J.G., Wipfler, E.L., 2011. Dutch Environmental Risk Indicator for Plant Protection Products. Alterra, Wageningen UR, Report 2250.1, 80 p.

Wenneker, M., Beltman, W.H.J., Werd, H.A.E. de, Zeeland, M.G. van, Lans, A. van der, Weide, R.Y. van der, 2010. Quantifying point source entries of pesticides in surface waters. International Advances in Pesticide Application, Aspects of Applied Biology 99: 69 – 74.

Wenneker, M., Kruijne, R., Vissers, M., 2012. Emission path ways of crop protection products from fruit growing in Utrecht (In Dutch). Wageningen, WUR PPO, Business Unit Bloembollen, Boomkwekerij & Fruit, Rapportnr. 2012-10, 154 p.

Growth stage dependent spray drift in orchard spraying; reference situation for surface water and bystander risk analysis

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Introduction

In the Netherlands spray drift experiments for orchard spraying was carried out on a uniform basis. Spray drift deposition measured with the reference spray technique was in the period 1990-1993 7 % for the full leaf situation (after 1st May). No measurements were available for the dormant tree situation (before 1st May) in that period. In the period 1993-2011 additional measurements were done comparing drift reducing measures with the reference spray technique. As spray drift measurements became available for the dormant situation (before May 1st) a reference curve based on measured data could be determined for this situation as well. Due to the large number of measurements discrimination could also be made for the intermediate period between the dormant stage and the full leaf stage. Discrimination was 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 61-73 and 93-0) and the dormant (BBCH 0-60) period. As drift measurements were done both as soil deposition next to the orchard and as airborne at a distance from the last treated tree row of the orchard spray drift curves could be generated both for surface water and for bystander risk analysis.

Materials and Methods

Drift measurements were carried out according to the ISO standard (ISO 22866: 2006) adapted for the situation in the Netherlands (ground deposits, ditch, surface water next to the sprayed field) following the Dutch protocol. 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) which were placed at several distances 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 Abtrifftkollektoren) 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 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. 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 was analysed with 144 in the full leaf stage (BBCH 74-92), 140 in the dormant stage (BBCH 0-60) and 32 in the intermediate (BBCH 61-73 and 93-0) period.

Results

Spray drift deposition (% of sprayed volume per unit area) downwind of the orchard and airborne spray drift at 7.5 m distance from the last tree row of the reference spray technique for fruit orchard spraying is presented in Figure 1. These curves are the basis for determining the spray drift deposition and airborne spray drift of the standard in the authorisation procedure of plant protection products in the Netherlands. The classified spray drift reducing technologies from the drift reducing classes 50%, 75%, 90% and 95% will be presented relative to the spray drift curves of the standard spray technique in the different periods. At surface water distance (5 m from the last tree row) spray drift deposition was 12% in the full leaf and 24% in the dormant period. Airborne spray drift was in the full leaf period 19% (at 2 m height) and 53% (at 1 m height) in the dormant period.

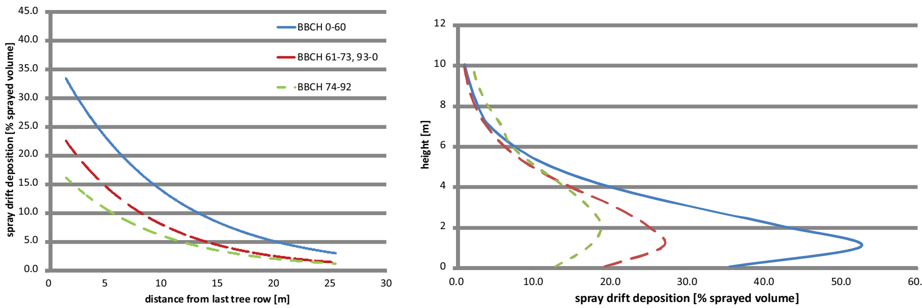

Figure 1. Spray drift deposition (% of sprayed volume per unit area) downwind of the sprayed orchard (left) and airborne spray drift at 7.5 m distance from last tree row (right) for the reference sprayer at dormant (BBCH 0-60), intermediate (BBCH 61-73, 93-0) and full leaf (BBCH 74-92) periods (apple).

Acknowledgements

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Assessing interest in new woven pesticide applicator protective garments with repellent finish in Washington State

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Introduction

Orchard spraying with an open-cab tractor often results in applicator's back, neck, and head being exposed to pesticide being applied. There is anecdotal evidence that pesticide applicators in the Washington State's tree-fruit industry (apples, cherries, pears, stone fruit) wear chemical-resistant garments even though the pesticide labels, based on risk assessment, requires use of chemical-resistant hat and pant/shirt or coveralls over pant and shirt. It is unknown whether the decision to wear air-impermeable garments is based on perceived risks of pesticide exposure, protection from becoming wet during the application, or a result of past habits. In the United States, chemical-resistant clothing is required only for a few products as use of air-impermeable clothing can result in heat stress.

The United States' Environmental Protective Agency relies on garment layers, not garment performance for its risk assessment/label statements (USEPA, 2009). Use of layers rather than performance was established in 1980's when research on protective clothing for pesticide operators was just being initiated. Recently, performance-specification standards were published by ASTM International (2012) and ISO (2011). They provide testing requirements for three levels of garment performance. Cotton and cotton/polyester blend garments worn by applicators in most exposure studies are examples of Level 1 garments and air-impermeable chemical-resistant suits are examples of Level 3 garments. Cotton and cotton/polyester pant and shirt with repellent finish are an example of Level 2. These air-permeable garments are designed to provide a balance between protection and comfort. Level 2 garments are being used as certified garments in Brazil; certified in accordance with ISO. These certified garments are being used routinely by pesticide applicators when applying pesticide in closed and open-cab tractors in orchards. In Europe these garments performed very well in exposure studies conducted in high exposure scenarios in greenhouse applications (Tsakirakis, 2010). A study is underway to determine the user acceptance of cotton and cotton/polyester garments with repellent finish by the certified tree fruit applicators in Washington State, USA. This project works directly with affected growers to assess their willingness to embrace garments with repellent finish. To make changes in the United States, the new clothing must be acceptable to growers prior to working on fabric types, wear studies, and clothing design/styles.

Materials and Methods

Using a subset of the label data collected by Shaw (2012), personal protective statements for garments were characterized for Washington's tree fruit industry (Beers, 2012). Working with both English and Spanish-speaking applicators in eastern Washington, needs assessment was implemented during spring of 2013. Personal interviews were conducted with tree-fruit growers, farm managers, and pesticide applicators. Data was collected on a) type of product mixing system (mechanical closed-system vs. no system), b) type of tractor (enclosed tractor cab vs. no cab), c) type of protective clothing (long-sleeved shirt/long pants, coveralls over long-sleeved shirt, long pants, water-resistant coverall, or chemical-resistant rain suit, and d) their reasoning for garment selection.

Tree-fruit growers, farm managers, and pesticide operators were presented with the data on label statements and shown sample European and Brazilian garments with repellent finish. A standard set of questions was asked about the potential to adopt new water-repellent garments. An open-ended discussion also was recorded. They were surveyed for their interest in adopting new garment technology into their operations.

This project sets the stage for future work with textile researchers and manufacturers to develop headgear and garments suitable for use in the tree-fruit industry. User need and acceptance data is extremely important to considering both regulatory and marketplace changes. Any future work on garment function and protection would directly relate to the performance-based protection levels in the ASTM standards for garment type.

Results

Long sleeved shirt and long pants were required for the 147 products (N=178), while 13 and 16 products required coveralls over short-sleeved shirt/short pant or long-sleeved shirt/long pant, respectively. Only one product, with the active ingredient azinphos-methyl, required a chemical-resistant coverall over long-sleeved shirt/long pant; this product will not be in use after the 2013 spray season. *The rest of the user acceptance data will be collected in April-May 2013.*

Acknowledgements

This research was partially funded by the Washington State Tree Fruit Research Commission (WTFRC 2013). Carol Black was recipient of a grant from WTFRC.

References

2012 International Symposium on PPE for Agricultural Pesticide Operators, Campinas, Brazil. Synopsis posted at http://www.ppesymposium.com.br/

ASTM International: ASTM F2669-12 Standard Performance Specification for Protective Clothing Worn by Operators Applying Pesticides, West Conshohocken, PA, www.astm.org

Beers E.H., et. al. (2012) Crop Protection Guide for Tree Fruits in Washington. Washington State University. Pullman, WA. http://jenny.tfrec.wsu.edu/eb0419/

International Organization of Standards: ISO 27065:2011. Protective clothing – Performance requirements for protective clothing worn by operators applying liquid pesticides. Geneva, Switzerland.

Shaw A. and C. Harned (2012), PPE Requirements on Pesticide Labels in the United States, International Symposium on PPE for Agricultural Pesticide Operators, Campinas, Brazil.

Tsakirakis A.N. et. al. (2010) Determination of operator exposure levels to pesticides during greenhouse applications with new type multi-nozzle equipment and the use of two different protective coverall types . Hellenic Plant Protection Journal 3: 9-16.

United States' Environmental Protection Agency. (2009) Label Review Manual. Chapter 10. Tables 1 and 7. http://www.epa.gov/oppfead1/labeling/lrm/

Inspection of the spraying equipment mounted on trains – the Polish approach

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Summary

The inspection of agricultural sprayers is conducted in Poland since 1999. At the present the mandatory inspection of the self-propelled and tractor mounted, field and orchard sprayers is carried out. Directive 2009/128/EC on the sustainable use of pesticides requires EU member states to start with the inspection of the other spraying equipment. Such equipment includes, among others, spraying equipment mounted on the trains (simply: railway sprayers). Since the European standard is not developed yet, it is necessary to develop an inspection methodology and the criteria for testing that kind of the spraying equipment, taking into account the specificity of the railway. Railway sprayers perform their duties, and in most cases are also stored in the areas of railway, with the limited access and available only to authorized persons. This situation enforces the necessity to take that into account in the training process of sprayers inspectors.

In order to conduct the inspection of railway sprayers it is necessary to identify the types of spraying equipment used on the railways and to develop the appropriate methodology for them. Inspection procedure should be developed in sufficient time for examination railway sprayers at least once before 2016.

The national railway network is managed by the Polish company PKP Polskie Linie Kolejowe S.A. (Polish Railway Lines). In 2011 the total length of railway lines in Poland was about 19,300 km, which gives 37,400 km of track (Anonim, 2011). The track width of the line depends on the railway category, the number of tracks and their mutual axial distance, and varies from 4.5 m to 10.9 m for double track lines. Taking into account the total length of railway track in Poland it can be estimated that about 19,000 ha should be sprayed, which is about 1 ‰ of the farmland in Poland.

In view of the need to comply with the provisions of Directive 2009/128/EC, the European Commission asked the European Committee for Standardization (CEN), giving to it a mandate (order) on the development of standards that include requirements for sprayers in use, including train sprayers. For the moment European standards for the inspection of railway sprayers do not exist yet, so it is necessary to take own decision on the procedures and criteria for testing railway sprayers. The framework for these activities is limited by the Directive and national legislation (Plant Protection Product Act and few Regulations on general rules of the inspection of sprayers in use) and previous experience in the implementation of sprayers inspection in Poland.

The most important rules governing weed killing on the Polish Railway Lines contains the internal instruction Id-1 "Technical conditions of railway road maintenance", which requires: "the destruction of vegetation on the entire width of the prism and railway benches on the tracks of all classes" and "the destruction of vegetation should be done with chemicals registered to use them on the railroad tracks". There is no detailed information about the internal procedures for the chemical weed killing on the track.
The Polish Ministry of Agriculture and Rural Development which is responsible for the implementation of the Directive 2009/128/EC in Poland ordered the expertise on the spraying equipment used on the railways in Poland. The additional activities, supplementary to the covered by the expertise, was to look for the specificity and the survey of different kinds of the railway spraying equipment at the owner place.
The equipment used to control the vegetation on the tracks of intensive passenger traffic or cargo must be mounted on a vehicle moving at a speed that allows the implementation of the timetable. Therefore, such vehicles have to work at a speed not less than 30-40 km/h (Wisniewska and Polinski 2012). The proper performance of the railway sprayer depends on the appropriate spray volume and good distribution (even and hitting the target). For that purpose the few special railway sets for Chemical Weed Control On the Tracks (abbreviation from the polish name is CHOT) are used. They use injection systems and special nozzles (with the higher flow rate).
On the tracks of the slower and less frequent movement, the sprayers similar to the field crop sprayers are used. This are brand sprayers and self made sprayers, made with the sprayers spare parts and/or with the other suitable elements (pumps, valves) used for not-spraying purposes. Therefore the elaborated methodology contains some parts with inspection procedures for two kinds of the railway sprayers: CHOT's and the others.
After the survey, the assumptions of the inspection procedure were elaborated. That proposal will be consulted with the stakeholders before the suitable Regulation will be elaborated.
The main difference between the sprayer inspection methodology for agricultural sprayers and railway sprayers comes from the driving speeds used (up to 30-40 km/h) and sprayed swath width (about 5.0 m). The accuracy of the injection system mostly used in CHOT's has to be checked too. It has been proposed to inspect the nozzles by the output measurement. Because of the one nozzle flow reaching several liters per minute and (sometimes) special shape of the nozzles, the equipment used so far for that purpose may be not suitable. Therefore the 20 liters containers of the user-friendly shape and the weight measurement of the spray volume (acc. to ISO 5682-2) was proposed. The symmetry of the flow for the nozzles placed on the left and right hand side of the rail track should be kept (15% deviation allowed). For the comparison with the nominal flow (if such data is available) may be done passing over the thermal expansion of water, which is smaller than the measurement accuracy. The accuracy of the injection of the

herbicide should be checked too. The clean water test at the same time as the nozzle flow measurement is proposed (to save water). The maximum values settings used during spraying railways are checked. The 10% deviation of accuracy is allowed.

Acknowledgements

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References

Anonim (2011) The annual report of PKP Polskie Linie Kolejowe S. A. for 2011.

Directive 2009/128/EU on sustainable use of pesticides.

Instrukcja Id-1 (D-1) „Warunki techniczne utrzymania nawierzchni na liniach kolejowych”, PKP Polskie Linie Kolejowe S.A., as at 1.09.2010 (http://www.plk-sa.pl/) (Railway instruction on „Technical conditions of railway road maintenance”).

Wisniewska K, Polinski J (2012) Expertise: „Wymagania techniczne dla sprzętu montowanego na pojazdach szynowych służącego do stosowania środków ochrony roślin oraz zasady jego kontroli” – Instytut Kolejnictwa, nr pracy 4480/11, s. 28, 2012 (http://bip.minrol.gov.pl/)..

SESSION 5

Drift assessment

Validation of a CFD model of the effect of an orange tree canopy on the air flow produced by an air-blast sprayer

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Introduction

There is a growing interest in quantifying spray drift because it poses risk to the environment. Although experimental measurements in field conditions are standardized (ISO 22866, 2005), they are very complex, time consuming and expensive. Different physical-mathematical models of spray drift are under development for a better understanding and assessment of this phenomenon. One of the numerical approaches is Computational Fluid Dynamics (CFD). This method enables the simulation of the influence of the vegetation during the applications. In current fruit growing, plant protection products are mostly applied with air blast sprayers. The air flow generated by the fans is highly affected by the canopies, affecting the trajectories of spray droplets, which has important consequences on drift. Usually, air flow behaviour within vegetation has been modelled by means of k-ε turbulent models (Endalew et al., 2010a; Da Silva et al., 2006). Endalew et al. (2010a) also indicate that the current trend is to consider the canopy as a porous body. Present authors presented a preliminary approach for citrus canopies in previous work (Salcedo et al., 2012). However experimental data showed that the high resistance of the canopy to air penetration produces a different behaviour on the air flow and a new model is presented here.

Materials and Methods

Air velocities produced by a conventional air blast sprayer facing an orange tree were measured in the field by means of one moving ultrasonic anemometer. Measurements were performed in four vertical parallel planes (Figure 1).

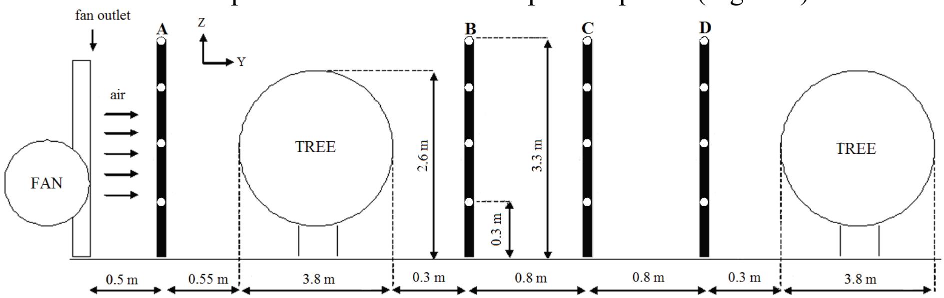


Figure 1. Elevation sketch of the field test

Plane A was situated between the machine and the tree, plane B immediately behind the canopy, plane C in the middle of the next track and plane D next to the further canopy in the next track.
Measuring points were distributed in height every 30 cm, from 0.3 m to 3.3 m in each plane. The points were lined up with the centre of the tree. Horizontal U(y) and vertical W(z) components of air velocity were acquired for 60 s and averaged.
First canopy was considered as a solid body with a porous medium in the space between the canopy and the ground. The following canopies were modelled as porous bodies. The size and geometry of the canopies was approximated from field measurements except for the first tree, whose geometry was empirically deducted. Air velocities measured in plane A were introduced as inlet boundary conditions. Air was allowed to leave the whole domain except through the ground (Fig. 2).

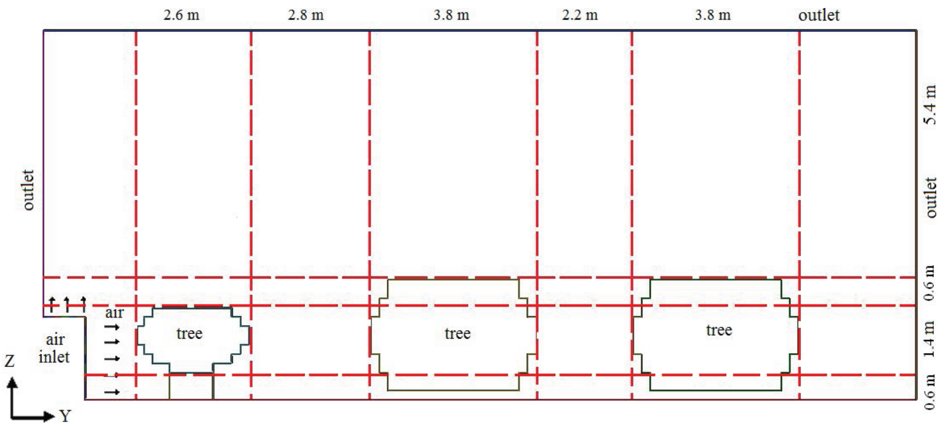


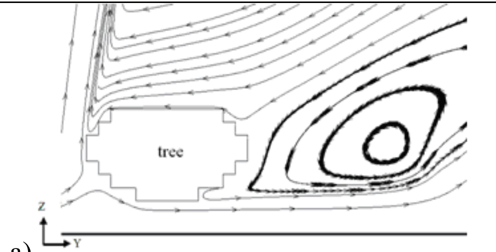
Figure 2. Geometry of the model

CFD simulations were performed based on a SST k-ω turbulent model (Menter, 1993) reported as having an excellent behaviour on separated flow due to obstacles. Turbulent kinetic energy (k) was deducted from experimental data. Default specific dissipation (ω) was assumed. Air was considered incompressible, isothermal and Newtonian. Simulations were iterative processes that converged to a minimum residual normalized scale of 10^{-4} using ANSYS Fluent 12.0 (ANSYS, Inc. Canonsburg, PA, USA). The numerical scheme was second order in space and time and the SIMPLE algorithm (Ferziger and Peric, 2001) was used.
Simulated velocities after the first canopy were compared to experimental data in planes B, C and D by calculating the average determination coefficient (R^2) and the root mean standard error of prediction (RMSEP) for each velocity component. Two arbitrary zones in each plane were differentiated: Upper and Lower zone, (UL) between 0,0 and 0,6 m and between 2,0 and 3,3 m; and Middle zone (M), between 0,6 and 2,0 m.

Results

Horizontal air velocity was dominant in field data and also in the simulations. Experimental vertical velocities were always towards the ground (negative sign), but were positive in the first 0.6 m of plane B and in the first 2.1 m of plane D.

Field data showed two vortex: one behind and one above the first canopy (figure 3a) that were not detected with our first model (Salcedo et al., 2012). The new approach fitted these two vortex much better (higher R^2 in the two zones) (Fig. 3b).



a)

	RMSEP (m/s)		R^2	
	U(y)	V(z)	U(y)	V(z)
UL	1,43	0,23	0,84	0,77
M	0,67	0,25	0,40	0,36

b)

Figure 3. a) Modelled air flow b) Average R^2 and RMSEP values in UL and M zones

Acknowledgements

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References

Da Silva, A., Sinfort, C., Tinet, C., Pierrat, D., & Huberson S., (2006) A Lagrangian model for spray behaviour within vine canopies. Aerosol Science 37: 658-674

Endalew M.A, Debaer C, Rutten N, Vercammen J, Delele M.A, Ramon H, Nicolaï B.M, Verboven P (2010) A new integrated CFD modelling approach towards air-assisted orchard spraying. Part I. Model development and effect of wind speed and direction on sprayer airflow. Computers and Electronics in Agriculture 71,128-136.

Ferziger, J. H, Peric, M. (2001) Computational Methods for Fluid Dynamics. Springer – Verlag.

ISO TC 23/SC 06 N 22866. (2005) Equipment for crop protection—methods for the field measurement of spray drift.

Menter F.R, (1993) "Zonal two equation k-ω turbulence models for aerodynamic flows", AIAA Paper 93-2906.

Salcedo R, Granell R, Garcerá C, Palau G, Moltó E, Chueca P (2012) CFD model of the effect of canopy on air velocity in air-assisted treatments in mandarin orchards. CIGR-EurAgEng International Conference of Agricultural Engineering. Valencia (Spain). 2012.

Model to predict spray deposition and losses in citrus applications

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Introduction

In Florida citrus applications, approximately 74-82% of the applied spray deposit on trees, 9-20% fall on the ground, and 6-14% drift away from application site (Salyani et al. 2007). The amounts of these spray components depend on the design and operational parameters of the sprayers, tree characteristics, tank mix properties and weather conditions (Salyani 1997). An empirical model (Larbi and Salyani 2012a,b) has been developed to predict on-canopy deposition and spray losses from commonly used air-blast applications. It is based on the earlier developed model (Farooq and Salyani 2004) and accounts for droplet evaporation, spray drift, and ground deposition. It incorporates the effects of the sprayer design, operating variables, tree structure, and weather parameters on the outcome of spray applications. This paper discusses the model structure and the results from test simulations.

Model Development

Figure 1 shows the Forrester diagram of the model. It assumes spray cloud movement through several connected spatial compartments: a) between the sprayer and tree boundary layer (spray dispersion) and b) within the tree canopy (spray deposition). Those compartments have equal thicknesses but increasing cross sections in the direction of spray movement. Application related parameters including sprayer model, type and number of nozzles, operating pressure and flow rate, nozzle orientation, tank mix properties, sprayer airflow rate and speed, and ground speed, are incorporated as system inputs. Tree canopy sub-model accounts for the foliage distribution in the direction of spray application, which in turn represents the canopy resistance to spray transport and deposition. The model assumes no slip between spray droplets and airstream and no contribution to the sprayer air velocity from spray droplets. Using MATLAB 7.6.0, the model equations were solved by Euler integration. The model response was observed under no-tree (spray dispersion in free space) and with-tree (dispersion both in free space and inside canopy) conditions. Using spray volume rate, air velocity, sprayer ground speed, target canopy distance, and canopy foliage density as input factors, each at three levels, simulated deposition values were obtained for a complete factorial experiment.

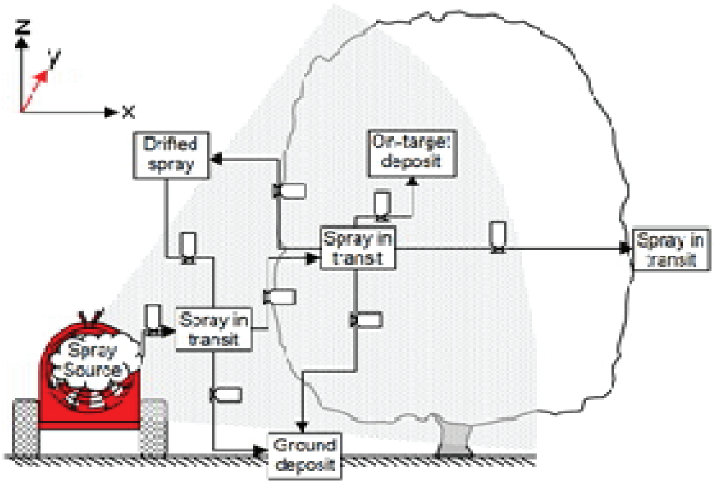

Figure 1. Forrester diagram of the spray model to predict on-canopy deposition and spray losses from conventional air-assisted sprayer used in citrus applications.

Results

Global sensitivity analysis on the data showed that target canopy distance is the most important factor contributing to the variation of mean deposition. Spray volume rate and canopy density were also significant factors, while sprayer ground speed and air velocity effects were not significant. The results were validated by field experiments. With 78% efficiency (r=0.92), model predictions compared well with the field data for canopy deposition. The model, packaged in an expert system, has the potential to assist spray applicators in effectively planning spray programs by maximizing on-target deposition and minimizing spray losses. However, it has to be validated for different application conditions.

References

Farooq M, Salyani M (2004) Modeling of spray penetration and deposition on citrus tree canopies. Trans. ASABE 47(3): 619-627.

Larbi PA, Salyani M (2012a) Model to predict spray deposition in citrus airblast sprayer applications-Part 1: Spray dispersion. Trans. ASABE 55 (1): 29-39.

Larbi PA, Salyani M (2012b) Model to predict spray deposition in citrus airblast sprayer applications-Part 2: Spray deposition. Trans. ASABE 55 (1): 41-48.

Salyani M (1997) Performance of sprayers in Florida citrus production. Proc. 5th Int.. Symp. on Fruit, Nut, and Vegetable Production Eng., Davis, CA, 6 p.

Salyani M, Farooq M, Sweeb, RD (2007) Spray deposition and mass balance in citrus orchard applications. Trans. ASABE 50 (6):1963-1969.

Sprayer-canopy characterization using field experiments and CFD modeling

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Introduction

Different tree architectures developed with the intention of only increasing the fruit yield and quality might may have different effects on the efficiency of plant protection product applications. The aim of this work was to develop and validate modeling approaches to assess the pesticide distribution in different training systems and compare the performance of different spraying machines. Four training systems and three different spraying machines were studied and compared using the deposition profiles on the different parts of each training system (leaf and stem) and on the ground.

Materials and Methods

Orchard sprayers. Three trailed, air-assisted orchard sprayers with PTO driven fans were considered in this work, each with a different type of air-blast system. The first sprayer was a classical single axial fan sprayer (Condor V, Hardi, Taastrup, Denmark). The second type was a cross-flow sprayer (DuoProp, BAB Bamps, Sint-Truiden, Belgium) with two axial fans. The last sprayer (Tango, Hardi, Taastrup, Denmark) was equipped with a centrifugal fan and 5 individual air spouts for each side connected to the air outlet by flexible ducts. The sprayers were fitted with fully characterized Albuz (Saint-Gobain Solcera, Évreux, France) ATR hollow cone nozzles. Before each trial, the liquid flow rate from the nozzles was measured using a mechanical measuring device (A.A.M.S. NV, Maldegem, Belgium). All machines were operated for the same application rate of 500 l/ha at a driving speed of 6.2 km h^{-1}.

Orchards. In this study, four different training systems were considered, three for pear and one for apple. The Hedge of Tienen (pear classical) were nine-year old trees build up by one main vertical branch containing 10 horizontal oriented side braches. Pear V-hedge were nine-year old trees containing 4 main vertical branches. Parallel to the rows, two branches give a V-shaped profile. Bush-spindle (pear T-hedge) were nine-year old trees build up by one main vertical branch with three side branches giving rise to a spindle form. Vertical axe (apple classical) consisted of 21-year old trees build up by one main vertical branch with numerous weaker fruiting branches. Planting distance was 1 to 1.5 m and row distance 3.2 to 3.5 m, depending on the training system.

CFD model of the spray application process in orchards. A computational fluid dynamics (CFD) model was developed to predict the flow and deposition of pesticide sprays applied in orchards. To this extend, the methodology of Endalew et al. (2010) was adapted. The model calculates the track of droplets in the spray emitted from the nozzles on the machine and supported by the forced airflow from the orchard sprayer. The air jet velocity distribution of the machine and spray characteristics of the used nozzles were measured (Dekeyser et al.,2013) and used in the model simulations. The model also takes into account the wind profile in the orchard that was measured at the time of the experiment. The model then calculates both the turbulent airflow and spray flow fields from the sprayer and their interaction with trees in the orchard. To this end, trees of the different training systems are represented in the model by their representative tree architecture and leaf cover (Endalew et al., 2010). The tree architecture was measured for 3 representative trees in each training system on which deposition measurements were conducted. The model was solved in ANYS-CFX (ANSYS, Canonsburg, Pennsylvania, USA).

Orchard validation experiments. Deposition measurements were performed in an experimental orchard field (pcfruit vzw,Sint–Truiden, Belgium) in October 2010 on fully leafed trees immediately after harvest. Three trees were sampled for each training system. The trees were divided in zones of 0.5m in height containing three samplers per zone to assess deposition. The protocol was in accordance to the ISO standard (ISO/FDIS 22522) and used metal tracers (Hendrickx et al.2012). Wind speed and direction, temperature and relative humidity were also measured at 10m height.

Results

The model predicts the spray flow field from the sprayer into the orchard canopy where it deposits on leaves, branches and ground or drifts elsewhere (Fig 1a). The experimental and model results of the normalized vertical spray depositions compared well for the different machines and training systems as exemplified in Fig 1b. The different machines clearly have a different deposition profile on a particular training system (Fig. 1c). The cross flow Duoprop sprayer resulted in a more uniform profile across the entire height, while the other sprayers gave a high deposition in the lower part of the tree.

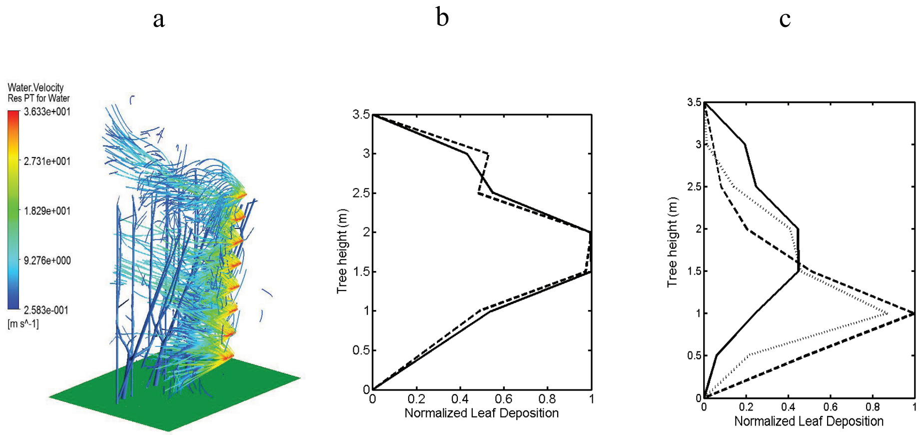

Fig.1 (a) Visualization of the spray distribution in the V-hedge canopy and drift, color of spray is droplet velocity in m s^{-1}, (b) Comparison of the experimental and model normalized leaf deposition on the V-hedge training system sprayed with the Duoprop sprayer (solid lines represent model and broken lines represent the experiment), (c) Model based comparison of the normalized leaf deposition profile on the V-hedge training system for the three different machines (solid lines are used for Duoprop, broken lines for CondorV and dotted lines for Tango sprayers).

Conclusions

A CFD model was applied to study the effects of training systems on uniformity and quantity of deposition from different orchard sprayer types. Predicted differences were confirmed experimentally, rendering the model approach valid for improving the spray application process in a next step.

Acknowledgement

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References

Dekeyser D., Duga A. T., Verboven P., Endalew A. M., Hendrickx N., Nuytens D. 2013.Biosystms Engineering 114, pp 157-169.

Endalew A. M., Debaer C., Rutten N., Vercammen J., Delele M. A., Ramon H., Nicolaï B. and Verboven P. 2010. Computer and Electronics in Agriculture 71, pp 128-136.

Hendrickx N., Goossens T., Endalew A. M., Dekeyser D., Nuytens D., Verboven P. 2012.Aspects of Applied Biology 114, pp 405-412.

Mass Balance from Aerial Spray Applications - A global approach on Banana crop

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Introduction

Banana crop in French West Indies represent about 9000 ha that is still protected by using aerial applications. Preservation from Yellow & Black Sikatoga (resp. *Mycosphaerella musicola* & *Mycosphaerella fijiensis*) requires about 10 applications during crop development (8 to 10 months). Half of these applications consist of pure Banole® (paraffinic oil) with a fungistatic effect; fungicides with oil are used for curative applications. A 3 year program Optiban aimed at the optimization of aerial spraying (Cotteux et al., 2011a) as well as the development of ground based spraying (Cotteux et al., 2011b) in the perspective of the ban of aerial spraying according to EU Directive 2009, 128 EC. This paper introduces the methodology and results of a mass balance definition for aerial applications on banana crop.

Materials and Methods

Application mass balance consisted of the parallel evaluation of crop deposits and drift for different settings as shown on Table 1. Crop deposits were estimated in a 1 ha field by using 60 collector lines (Petri dishes 58 cm²) placed on telescopic masts at canopy height (about 5 m). Recovery rate was calculated considering the ratio between average deposit and the total amount sprayed. Drift was estimated in accordance with ISO 22866 and ISO 23369 – part 2 standards with 20 collectors (Petri dishes 58 cm²) placed every 2 m at 5 -10 – 20 – 30 – 50 and 100 m) from the field edge downwind. Meteorological conditions (Temperature, relative humidity, wind speed and direction) were monitored by using a Vaisala® 2D US sensor placed at 6 m height with a frequency of 0.3 Hz. Hollow cone nozzles as Albuz ATR and Teejet D6 were considered as references; optimized settings consisted of air induction nozzles Albuz CVI and AVI for the helicopter and airplane respectively. Spray mixes include ad hoc tracer (BSF for water and Radglo CFS 006 for Oil) at 1 g/l^{-1}.

Table 1. Application conditions and spraying settings – 3 replicates per modality

Aerial vector	Spray Mix	Spraying configuration	Boom settings	Speed ($km.h^{-1}$)
BELL 47	Water 15 $l.ha^{-1}$	Albuz ATR Yellow 2 bar	65 % rotor 36 nozzles	90
		CVI 110 015 2 bar		
	Oil 15 $l.ha^{-1}$	Albuz ATR yellow 2 bar		
		CVI 110 015 2 bar		
CESSNA 188	Water 15 $l.ha^{-1}$	Teejet D6/DC45 2 bar	63 % wing span 56 nozzles	200
		AVI 110 03 2 bar		
	Oil 15 $l.ha^{-1}$	Teejet D6/DC45 2 bar		
		AVI 110 03 2 bar		

Results

Spray mix distribution on the different compartments (Canopy, Drift sedimentation and unrecovered fraction) are shown on Figure 1.

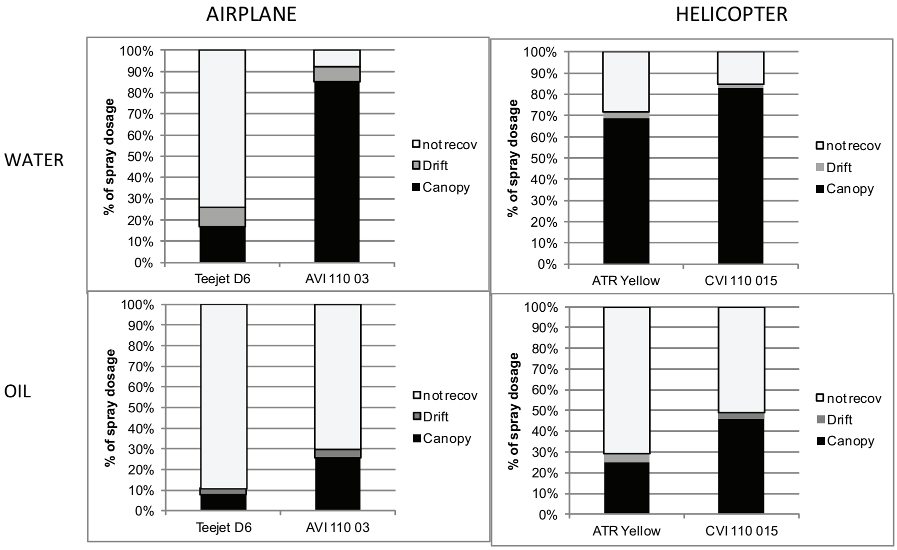

Figure 1 : Mass balance results from aerial applications

Figure 1. Spray mix distribution on the different compartments: Canopy, Drift sedimentation and unrecovered fraction

Great differences are shown between aerial vectors, nozzle types as well as spray mixes. In all situations, the recovery rate was improved by using optimized nozzle setting (combination of nozzle type and boom width) but can be very low. The case of oil will be discussed with a low drift fraction but a high unrecovered fraction as well.

Acknowledgements

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References

Cotteux E., Carre M., Tinet C. and Douzals J.P., 2011a. Investigation of aerial–based treatment efficiency in specific cases of Banana Sikatoga diseases treatment in the French Indies. Proceedings of Suprofruit 2011 8th to 10th June 2011, Lanxade, France, CTIFL Ed. 52-53.

Cotteux E., Rombaut M., Carre M., and Douzals J.P. 2011b. Development of a ground-based system applied banana spraying in the French West Indies. Proceedings of Suprofruit 2011 8th to 10th June 2011, Lanxade, France, CTIFL Ed. 120-121.

ISO 22866, 2005. Spray drift measurement at filed level. 24p.

ISO 22369 – part 2: 2010, Drift Classification of sprayers at field level. 11p.

Influence of wind in citrus drift measurements using ISO 22866

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Introduction

ISO 22866 (ISO, 2005) establishes internationally recognized methods for the measurement of drift generated by equipment for plant protection product applications. Section 5 states that measurements shall be made at wind speeds of at least 1m/s, with wind directions at 90º±30º relative to the spray track, air temperatures between 5ºC-35ºC and following Good Agricultural Practices.
However, atmospheric conditions during a field test are often variable, difficult to predict and almost impossible to replicate. For this reason, ISO 22866 requires a minimum of three measurements in similar conditions of crop and weather for supporting evaluation of environmental risks.
Wind is assumed to be the most important and uncontrolled factor that affects the aerial transport of droplets beyond the field boundaries. Several authors have demonstrated that drift increases with increasing velocity of wind (Göhlich, 1982; Kock, 1898; Kaul et al., 2001). However the effect of wind in drift measures is often neglected, neither in the scientific literature nor in official recommendations (www.sdrt.info) since it is considered that it has little effect on measurements made under the conditions of ISO 22866.
Citrus trees have denser and wider canopies than many other fruit trees which surely affects the air flow produced by the fans, and consequently affects drift in a different way. Moreover, air flow rates during conventional applications are higher than in other fruit cultures and for these reasons they require specific studies. In this work we study the effect of wind on drift measurements in citrus orchards following ISO 22866. .

Materials and Methods

Twenty-one drift field trials following ISO 22866 have been carried out in two commercial orange (*Citrus sinensis* Osbeck) orchards situated in Valencia, Spain, adopting recognized good agricultural practices for citrus cultivation in Spain. Applications were performed with a conventional air-blast sprayer at 1 MPa (mod. Futur 1500, Pulverizadores Fede S.A., Cheste, Spain) simulating standard applications in the region (1.65 km/h, 24.4 m^3/s air flow). Two nozzles were used along the experiments: low drift nozzles (Albuz TVI 80 03), 2989 l/ha application rate, and Teejet D3DC35, 3360 l/ha application rate. A dilution of Brilliant

Sulfoflavine (BSF) was used as a tracer. Drift was collected on blotting paper on the ground in the downwind adjacent plot, with 4 replicates per distance (Figure 1). Meteorological conditions (wind speed, wind direction, temperature, relative humidity) were monitored during the applications. Average wind direction was determined and wind speed component orthogonal to the tractor path was calculated.

Each trial consisted of spraying the dye solution from both sides of the sprayer on 4 border rows. BSF concentration was quantified by fluorometry. Accumulated drift ($\mu l/cm^2$) corrected with respect to the effective spray volume applied was calculated for each test. The relationship between the corrected accumulated drift and the orthogonal wind speed was studied.

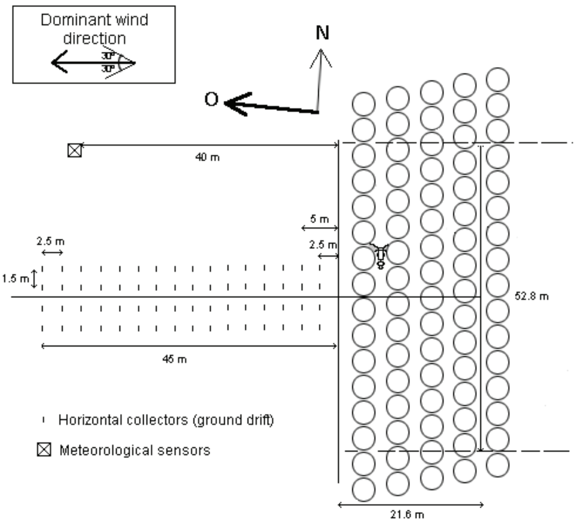

Figure 1. Sketch of the methodological setup.

Results

The study demonstrates a significant relationship (r2 = 0.53) between the average orthogonal wind speed and the corrected accumulated drift using both nozzles (Figure 2). As a consequence, low drift nozzles could generate higher drift measurements than conventional nozzles if orthogonal wind is high enough even under atmospheric conditions of wind speed within the ISO limits. That is, wind speed may have more influence in measured drift losses than the drift reducing technology employed. However, the relationship between accumulated drift and wind speed is stronger for conventional nozzles (r2=0.81) than for low-drift nozzles (r2=0.40) Therefore we suggest that wind speed and wind direction should be considered when measuring drift reduction potential of these technologies and when defining the size of buffer zones for applications in citrus. Moreover, these parameters must be included in any drift model for assessing the environmental risk of an application.

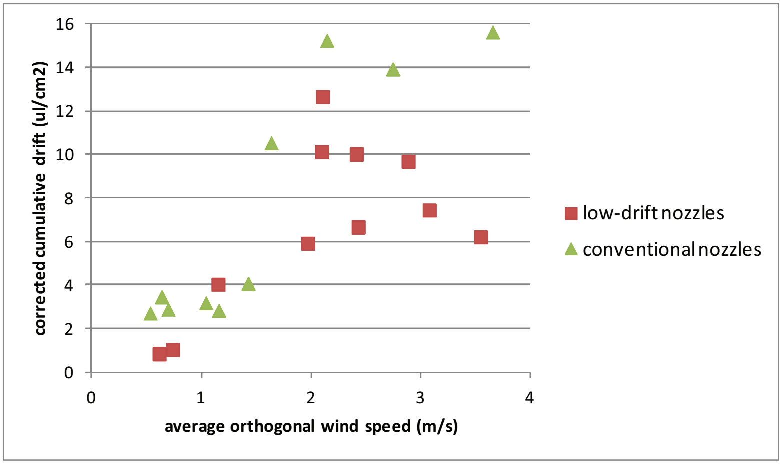

Figure 2. Relationship between 'average orthogonal wind speed' (m/s) and 'corrected accumulated drift' (µl spray mix/cm^2).

Acknowledgements

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References

Göhlich, H., 1982. Pflanzenschutzeinsatz aus der Sicht der Abdrift. Gesuden Pflanzen 34, 91-95.

ISO, 2005. Equipment for crop protection — Methods for field measurement of spray drift. ISO/FDIS 22866. Geneva. 22p.

Kaul, P., Moll, E., Gebauer, S., Neukampf, R., 2001. Modelling of direct drift of plant protection products in field crops. Nachrichtenbl. Deut. Pflanzenschutzd. 53, 25-34.

Koch, K., 1989: Abdrift vermeiden-Wind als entscheidender Faktor. Gesude Pflanzen 41, 108-112.

Proposal of a methodology for assessing spray drift from air-assisted sprayers to enable their classification according to drift risk

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Introduction

Spray drift may cause diffuse contamination of the environment with agrochemicals, therefore in recent years several measures have been adopted to prevent it and to mitigate its pollution risks. Devices enabling to reduce drift generation (SDRT) are available on the machines (e.g. air induction nozzles, shielded sprayers, tunnel sprayers, automatic systems to manage the spray application and the air flow, etc.) and no spray zone, buffer zones, windbreaks, etc. are adopted in several EU countries along the downwind field edges in order to prevent direct contamination of sensitive areas, like water bodies, private houses, parks, public playgrounds, etc. In some European countries buffer zones are already prescribed with specific widths that are defined according to the spraying equipment employed and its conditions of use. This criteria will soon be extended to all EU countries to comply with the requirements of EU Directive 128/2009 on sustainable use of pesticides. It will be therefore necessary to foresee a classification of all sprayers types and configurations according to drift risk following a methodology easy to use and requiring equipment and time costs reasonable from an economic point of view. A first methodology able to follow these requirements has been already proposed at international level for drift measurement of field crop sprayers (ISO FDIS 22369-3), while for orchard sprayers the only available methodology to assess spray drift is actually the ISO 22866, which is difficult to apply for drift classification purposes and is expensive. In order to provide an alternative to this method, a set of preliminary tests were made aimed at defining a new methodology for the assessment of potential drift generated by fruit crop sprayers.

Materials and Methods

As already experimented with field crop sprayers, ad hoc test benches – developed by University of Torino and Salvarani-AAMS company – were used to assess potential drift generated by air-assisted sprayers in open field and in absence of wind. The range footprint was assessed spraying a water solution of E 102 Tartrazine tracer on permanently discovered samplers (plastic Petri dishes 150 mm diameter); the persistence of the spray cloud in the atmosphere after the sprayer pass was evaluated measuring the deposits of sprayed solution on samplers discovered only after the sprayer pass (Fig.1 and 2).

Figure 1. Test benches placed orthogonal to the sprayer pass in order to assess the spray fallout.

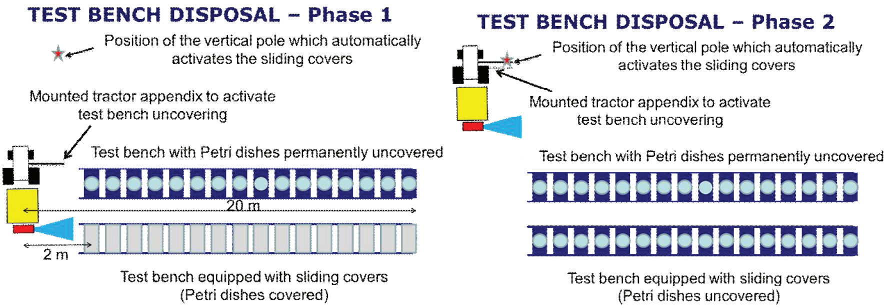

Figure 2. Scheme of the execution of the tests: one array of Petri dishes is left permanently exposed to assess the spray fallout while a second array of samplers is revealed only after the sprayer pass: depending on the distance between the mechanism to uncover the samplers and the test bench, different elapsed times can be evaluated.

Preliminary tests were made employing two different air-assisted sprayer models: a Dragone k2 500 vineyard sprayer and a Nobili Oktopus orchard sprayer. Tests were made comparing the use of conventional and of air induction nozzles and, only for the vineyard sprayer, comparing the use of different air settings (Table 1). Five test replications for each single thesis were made. All tests were made operating at 6 km/h forward speed and four different elapsed times (1.0; 2.5; 4.0 and 5.5 seconds) for uncovering the samplers after the sprayer pass were evaluated in order to select the one enabling to allow the recovery of measurable spray deposits independent of the type and of the configuration of the sprayer used.

Test	Sprayer model	Nozzles	Pressure (MPa)	Sprayer flow rate (l/min)	Fan air flow rate (m^3/h)
1	Nobili Oktopus	Teejet TXB 04	1.0	40.3	14000
2	Nobili Oktopus	Teejet AI 04	1.0	40.3	14000
3	Dragone k2 500	Albuz ATR yellow	1.0	8.4	11000
4	Dragone k2 500	Lechler ID 02	0.5	8.4	11000
5	Dragone k2 500	Albuz ATR yellow	1.0	8.4	16000
6	Dragone k2 500	Lechler ID 02	0.5	8.4	16000

Table 1. List of thesis examined and operating parameters used.

Results

Results of these first tests pointed out that the method proposed is able to provide information useful to estimate the potential drift generated by each sprayer type and configuration, but they also enhanced some difficulties in obtaining a good reproducibility of results between test replicates. Differences between thesis compared resulted more evident considering the data of potential drift obtained uncovering the test bench 4 seconds after the sprayer pass (Figure 3). Further studies are under way to optimize the methodology in order to get affordable results useful to classify sprayers according to drift risk.

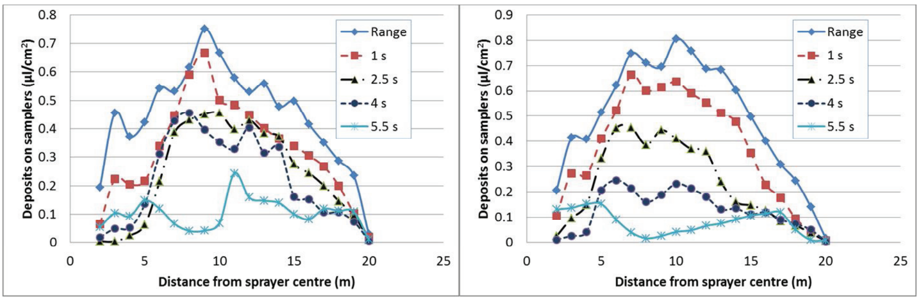

Figure 3. Spray ranges determined for the orchard sprayer Nobili oktopus using conventional hollow cone nozzles (a) and air induction hollow cone nozzles (b) on permanently uncovered samplers and on samplers uncovered 1, 2.5, 4.0 and 5.5 seconds after the sprayer pass.

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Comparing standardized methods of potential drift assessment

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Introduction

Classification of sprayers based on their drift potential is a relevant instrument used by the regulatory authorities for environment risk mitigation. Several measures as pesticide restriction use and dimensioning of buffer zones in sensitive areas are related to the classification of the sprayers. Initial classifications were established for nozzles according to the spray droplet size (BCPC, ASABE). Afterwards, nozzle's drift potential measured in wind tunnel and sprayer field trials were established to classify fan nozzles and sprayers respectively (JKI, WUR). More recently a test bench for measuring the sprayer's drift potential has been proposed (Balsari et al., 2012). At the same time, several international standards for conducting such tests have been developed. The most prominent are ISO 22856:2008 (tunnel test), ISO 22866:2005 (field test) and, under development, series ISO 22369 (drift - classification of spraying equipment, including methodology for test bench). Moreover, ISO 25358, devoted to spray droplet size characterization, is in preparation.

At a practical level, drift reduction classification of spray nozzles is done using wind tunnel measurements in Germany, United Kingdom and France. Methodologies are not fully coincident. On the other hand, drop size measurements are used to classify nozzles in the Netherlands (Huijsmans et al., 2011). Additionally the classification of sprayers in Germany is based on extensive field trials. In Spain and other countries there is no classification yet. So, a harmonized classification system would be much appreciated for evaluation and placing in the market the plant protection products, including the rules on the mutual recognition of authorizations and on parallel trade (Regulation EC 1107/2009).

Materials and methods

The consistency between methodologies has been evaluated by means of comparative trials using two hollow cone nozzles (standard and low drift) in laboratory and in a fruit orchard. The drift potential of one standard nozzle, ATR ALBUZ Orange (10 bar, 1.39 l/min) and one low drift model (air-inclusion) ALBUZ TVI Yellow (9 bar, 1.39 l/min) has been studied by means of three different methods: a) Droplet size spectrum measurement by laser 57X10 PDA Doppler (Dantec Dynamics A/S); b) Dynamic tunnel test according to ISO 22856

(Figure 1); c) Comparative test in an intensive peach orchard following ISO 22866, using an air-assisted sprayer Ilemo-Hardi Arrow (Figure 2). Additionally, the same nozzle models will be forthcoming evaluated in the test bench proposed by Balsari

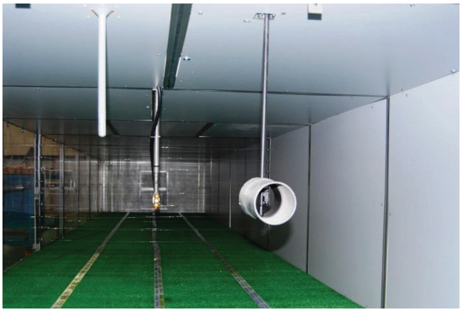

Figure 3. Wind tunnel at Maqcentre.

Figure 2. Drift field measurement.

et al., 2012).

Results

Figure 3 shows the measures of drift related to the deposition of spray onto horizontal surfaces outside of the treatment area at given downwind distances, according to ISO 22866 methodology.

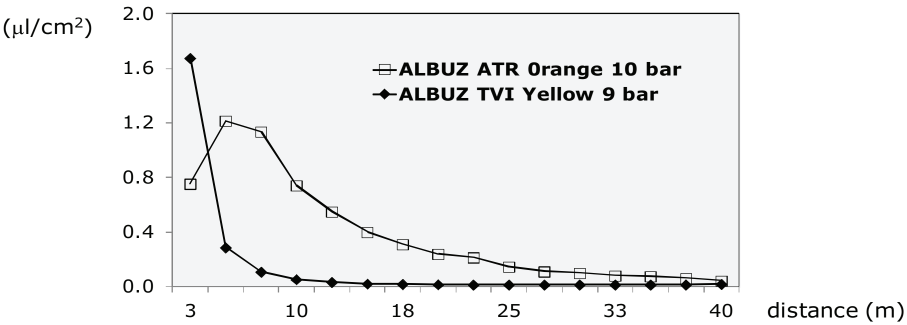

Figure 3. Drift deposition at a distance from the last tree row.

Moreover, for all the different tests, including droplet size measurements, drift reduction has been calculated as follows:

$$DR (\%) = (1- (Dc / Dr)) \times 100$$

Where DR is the potential drift reduction; Dc the measured potential drift of the candidate nozzle and Dr the measured potential drift of the reference nozzle. Values of measured potential drift and DR are expressed in the following table:

Droplet size (*)	**$Dv_{0,1}$** [µm]	**$Dv_{0,5}$** [µm]	**$Dv_{0,9}$** [µm]	**V_{100}** [%]	**V_{200}** [%]
ATR Orange (ref.)	98,8	160,9	270,7	10,6	71,9
TVI Yellow (cand.)	187,6	316,9	409,4	0,4	12,6
Potential drift reduction, DR (%)				96,4	82,4
Wind tunnel measurement (ISO 22856)	**horizontal deposition** (µl/cm²)			**vertical deposition** (µl/cm²)	
ATR Orange (reference)	2,29			2,48	
TVI Yellow (candidate)	0,55			0,62	
Potential drift reduction, DR (%)	75,9			75,1	
Field drift measurement (ISO 22866)	**horizontal deposition** (µl/cm²)			**vertical deposition** (µl/cm²)	
ATR Orange (reference)	0,39			1,34	
TVI Yellow (candidate)	0,15			0,11	
Potential drift reduction, DR (%)	61,8			91,6	

(*) Dv: volumetric diameter; V_{100}: volume fraction of droplets smaller than 100 µm; V_{200}: volume fraction of droplets smaller than 200 µm.

Conclusion

In all cases, the air-injection TVI nozzle reduced drift values. However, the potential drift reduction values are different for the different methods. This fact should be analyzed carefully before deciding the harmonized methodology for determining the classification of nozzles and sprayers according to their potential drift reduction for official purposes.

Acknowledgements

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References

Balsari P, Marucco P, Tamagnone M (2012) study of a test methodology to assess potential spray drift generated by air-assisted sprayers for arboreal crops. Proc.Int. cong. Agric. Eng. CIGR/EurAgEng 2012. València.

Huijsmans JFM, van de Zande JC (2011) Workshop Harmonization of drift reducing methodologies for evaluation and authorization of plant protection products. WUR. 166 pp.

Regulation EC 1107/2009 concerning the placing of plant protection products on the market (0JEU 24.11.2009).

Potential for efficiency increase of crop protection by use of optimised spraying fractions

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Introduction

When assessing the environmental exposure from a spray application to tree and vine crops, it is important to consider all exposure pathways such as airborne drift losses and runoff losses to the ground beneath the canopy (Cross *et al.*, 2001). For conventional sprays, the smaller drops tend to be more drift-prone than larger drops. Some researchers consider "small" in this context to include droplets with diameter below 100 µm ($V_{<100}$) (Guler *et al.*, 2007; Heijne *et al.*, 2002; Nuyttens *et al.*, 2006). While these "fine" droplets can be carried off-target in airborne drift if not appropriately deposited and collected by the canopy, "coarse" drops >500 µm ($V_{>500}$) can be lost to the ground, and can even cause phytotoxicity to the crop (Triloff, 2011). For spray applications at high wind speed, drift reduction technologies are recommended (Hewitt 1997, Hoffmann 2011, Zande *et al.* 2008). A common approach as described by Wenneker *et al*. (2011) is to use air induction nozzles at the necessary flow rate for drift reduction, but with worse spray coverage (Guler *et al*., 2012). Indeed, a comprehensive spray application approach will carefully balance the droplet size spectrum, driving speed, and for air assisted sprayers, the air volume and velocity (Lešnik *et al*., 2005; Panneton and Piché, 2005; Czaczyk, 2012). It is well known that different nozzles and tank mixes deliver different drop size spectra (Guler *et al*., 2007; Zande *et al*., 2008). The present research explored the different spray qualities available for a range of application conditions. We aimed to assess the spray volume contained in drops with diameter 100÷150 µm or 100÷250 µm as required for different targets and conditions for a range of application scenarios.

Materials and Methods

The droplet size analyses were conducted at a wind tunnel at the Areawide Pest Management Research Unit – USDA ARS, College Station, Texas. A Sympatec Helos Vario droplet size analyzer using laser diffraction was used to measure particle size for a range of sprays. The measurement dynamic size range was 0.5 to 3,500 µm in 31 size classes. These measurements were conducted with tap water, and with two similar non-ionic surfactants (Agral® and R11®). The following v/v rates were used: 0.1% Agral, and 0.25% R11. The dynamic surface tension (dST) value was measured with a Sensodyn Maximum Bubble Pressure surface tensiometer were 0.32 mN/m for the Agral spray solution, and 0.33 mN/m for the R11 solution. Nozzles of different types (standard swirl cone jet, air induction swirl cone jet, air induction flat fan, and a standard flat fan nozzle) were tested. The spraying characteristics according to standard ASAE S572.1 were evaluated. The coefficients $D_{v0.1}$, $D_{v0.5}$, $D_{v0.9}$ and RS (relative span) were compared. Zande *et al.* (2008) and Triloff (2011) proposed that orchard sprays be assessed against a standard swirl cone jet nozzle Albuz ATR lilac, at 750 kPa spray pressure, as a baseline reference spray against which drift reduction can be described. The fractions of liquid volume contained in the following droplet size classes were assessed: $V_{<100}$, $V_{100\text{-}150}$, $V_{100\text{-}250}$, $V_{250\text{-}500}$, $V_{>500}$ for the sprays were assessed for drift reduction relative to the ATR lilac (80°) reference spray using Drift Reduction Potential (DRP) as a descriptor for the spray volume contained in fractions: $V_{<100}$ (Zande *et al.*, 2008), and $V_{>500}$.

Results

Table 1 presents a part of data on the spray performance in this study. The working pressure, driving speed and physical properties influenced the volume of theoretical optimal fractions (green columns). The volume differences of optimal fraction ($V_{100\text{-}150}$, $V_{100\text{-}250}$) are larger than 20 l/ha. The drift reduction (and losses) of spray during wind speed increase can be optimized with adjustment of liquid pressure

Table 1. Characteristic comparison of selected nozzles for important fractions droplet size spectra (third column: A – 0.1%$_{v/v}$ of Agral, R – 0.25%$_{v/v.}$ R11 surfactants).

Nozzle type	*P*	*v*	Q_{12}	$V_{<100}$		$V_{100÷150}$		$V_{100÷250}$		$V_{250÷500}$		$V_{>500}$		DRP $V_{<100}$	DRP $V_{>500}$
ASAE class	kPa	km/h	l/ha	$\%_{vol}$	l/ha	$\%_{vol}$	l/ha	$\%_{vol}$	l/ha	$\%_{vol}$	l/ha	$\%_{vol}$	l/ha	$\%_{ATR\ lilac}$	
ATR lilac	450	5.0	144	47.2	68.0	37.4	53.9	52.8	76.0	0	0	0	0	-9.1	0
ATR lilac	450	6.0	120	47.2	56.6	37.4	44.9	52.8	63.4	0	0	0	0	-9.1	0
ATR lilac	500	5.0	148	49.0	72.6	37.2	55.1	51.0	75.5	0	0	0	0	-5.6	0
ATR lilac	600	6.0	134	51.7	69.3	36.6	49.0	48.3	64.7	0	0	0	0	-0.4	0
ATR lilac	600	6.0_A	134	34.7	46.5	64.3	86.2	39.0	52.3	1.0	1.3	0	0	-33	0
ATR lilac	600	6.0_R	134	50.2	67.3	36.0	48.2	49.8	66.7	0	0	0	0	-3.3	0
ATR lilac	750	6.0	151	51.9	78.4	36.9	55.7	48.1	72.6	0	0	0	0	0	0
AXI 8002	450	6.0	332	22.7	75.4	23.9	79.3	59.3	197	18.0	60	0	0	-56	0
TXA 8002	450	6.0_A	332	26.5	88.0	24.5	81.3	61.9	205	11.5	38	0.1	0.3	-49	-0.1
AVI 8002	450	6.0	332	1.9	6.3	3.3	11.0	13.6	45.2	42.3	140	42.2	140	-96	-42
AVI 8002	450	5.0	399	1.9	7.6	3.3	13.2	13.6	54.3	42.3	169	42.2	168	-96	-42
AVI 8002	750	6.0	432	4.4	19.0	6.2	26.8	23.5	102	51.7	223	20.4	88	-91	-20
TVI 800050	750	5.0	132	2.5	3.3	4.0	5.3	19.8	26.1	54.6	72	23.1	30	-95	-23
TVI 800075	500	5.0	160	1.2	1.9	2.4	3.9	11.7	18.8	39.7	64	47.4	76	-98	-47
TVI 800075	750	6.0	161	2.2	3.5	3.9	6.3	18.9	30.4	53.4	86	25.5	41	-96	-25
TVI 800075	750	5.0	193	2.2	4.2	3.9	7.5	18.9	36.5	53.4	103	25.5	49	-96	-25
TVI 800075	750	6.0_R	161	1.9	3.1	5.0	8.0	17.6	28.3	51.3	83	24.2	39	-96	-24
TVI 800075	750	5.0_R	193	1.9	3.7	5.0	9.7	17.6	34.0	51.3	99	24.2	47	-96	-24
AVI 80015	750	6.0	322	6.6	21.2	8.2	26.4	29.3	94.3	52.9	170	11.2	36	-87	-11

AVI 8001	750	6.0	216	9.0	19.4	10.6	22.9	36.9	80	49.3	106	4.8	10	-83	-4.8

and/or through changing the standard nozzle type. Changes the dST with different surfactants can give different results in spraying characteristics.

References

ASAE S572.1. (2009) Spray Nozzle Classification by Droplet Spectra. pp. 4.

Cross J, Walklate PJ, Murray RA, Richardson GM (2001) Spray deposits and losses in different sizes apple trees from an axial fan orchard sprayer: 2. Effects of spray quality. Crop Protection 20, 333-343.

Czaczyk Zb (2012) Influence of air flow dynamics on droplet size in conditions of air-assisted sprayers. Atomization and Sprays 22 (4), 275-282.

Guler H, Zhu H, Ozkan HE, Derksen R, Yu Y, Krause C (2007) Spray characteristics and drift reduction potential with air induction and conventional flat-fan nozzles. Trans. of ASABE 50 (3), 745-754.

Guler H, Zhu H, Ozkan HE, Link P (2012) Characterization of hydraulic nozzles for droplet size and spray coverage. Atomization and Sprays 22(8), 627-645.

Heijne B, Wenneker M, Van de Zande JC (2002) Air-inclusion nozzles don't reduce pollution of surface water during orchard spraying in the Netherlands. Aspects of Applied Biology 66, 193-199.

Hewitt A (1997) The importance of droplet size in agricultural spraying. Atomization and Sprays 7(3), 235-244.

Hoffmann C (2011) Optimizing citrus sprayer operational parameters based on droplet size criteria. SuproFruit 2011, 11th Workshop 8-10th June, Ctifl Lanxade, France, Book of Abstracts 40-41.

Lešnik M, Pintar C, Lobnik A, Kolar M (2005) Comparison of the effectiveness of standard and drift-reducing nozzles for control of some pest of apple. Crop Protection 24, 93-100.

Nuyttens D, Baetens K, De Schampheleire M, Sonck B (2006) PDPA Laser Based Characterisation of Agricultural Sprays. Agricultural Engineering International: the CIGR, Ejournal. Manuscript PM 06 024. Vol. VIII. December.

Panneton B, Piché M (2005) Interaction Between Application Volume, Airflow, and Spray Quality in Air-Assisted Spraying. Trans. of ASAE 48 (1), 37-44.

Triloff P (2011) Verlustreduzierter Pflanzenschutz im Baumobstbau – Abdriftminimierung und Effizienzsteigerung durch baumformabhängige Dosierung und optimierte Luftführung. Ed. Ulrich E. Grauer Stuttgart, ISBN 978-3-86186-563-6. PhD thesis, Hohenheim University, 351 pp.

Wenneker M, van de Zande JC, Poulsen M, Balsari P, Doruchowski G, Marucco P (2011) Pesticide residues in apples sprayed with different application techniques (CASA sprayer-ISAFRUIT), SuproFruit 2011, 11th Workshop 8-10th June, Ctifl Lanxade, France, Book of Abstracts, 142-143.

van de Zande JC, Holterman HJ, Wenneker M (2008) Nozzle Classification for Drift Reduction in Orchard Spraying: Identification of Drift Reduction Class Threshold Nozzles. Agricultural Engineering International: the CIGR Ejournal. Manuscript ALNARP 08 0013. Vol. X. May.

SESSION 6

New technologies on spray application

Autonomous precision spraying in fruit orchards

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Introduction

In fruit growing, spray application is a time consuming operation, mostly consisting of driving back and forth through the orchard. Therefore, a reduction in time consumption directly influences the costs of orchard spray operations by not having an operator in the orchard. Though, autonomous spraying is quite a challenge as has been shown in former projects throughout the world. Our project was started to develop sensor based spraying systems for fruit orchards and to operate these systems autonomously in the field. In fruit orchards the investigated automated sprayer was based on a laser ranger system as sensor. The autonomous operations are performed by a tractor driving on RTK-GPS. Both spraying and autonomous operation systems are being tested and explained in this abstract.

Materials and Methods

The development of the autonomous automated precision sprayer consisted of the following steps. 1) Modular technical setup of the sprayer. 2) Design and evaluation of decision algorithms for automated spray application. 3) Modular design and construction of the autonomous tractor 4) Integration of the sprayer and tractor in one system.

The first step of automated spraying was to identify the canopy characteristics with a laser scanner (Hokuyo URG-04LX). The sensor scans a range of 240 degrees of a circle in 682 steps. This scanning results in 682 distances measured from one central point. The sprayer is divided into five sections in height. Each section consists of two Lechler Varioselect nozzle bodies. These nozzle bodies hold four nozzles that can be individually switched on and off by electro-pneumatic valves. The sprayer controller will adjust the number of active nozzles based on driving speed, tree volume, tree density and orchard characteristics. In addition to canopy characteristics measurements the environmental conditions are also monitored, specifically the wind speed and direction are measured and the air assistance is adjusted accordingly.

The second step was the evaluation of the decision algorithms for automated spraying in orchards. For this purpose several deposition trials were done in 2011 and 2012 seasons. Depositions trials were done in apple and pear orchards with different pruning systems, as the automated spraying system has to perform well in these systems automatically.

The third step was to convert a tractor to an autonomous vehicle. In our project we preferred the adaptations to a tractor over the development of a new vehicle itself. This was mainly supported by the end-users, the farmers themselves. A tractor can always be used in its normal operation mode and will allow more easily the adaptation of autonomous technology in orchard fruit production. The tractor is operated autonomously by the "teach and playback" methodology. This means that the operator first drives and sprays the orchard once by himself and records the route and spray operations. Next times, the system does the operations by itself, and the spray application is adjusted by the sensor system.
The fourth step consists of linking the spraying system and the autonomous operation. This is a challenge, as safety issues are important here. One has to assure that no harm could be done to people and the environment, taking into account the economical constraints as well.

Results

Initial tests with the autonomous tractor proved its performance (January 2013). Deposition trials in 2011 and 2012 showed that pruning type and decision algorithms can be adjusted automatically to obtain optimal spray coverage and reduced usage. Efforts are made in 2013 to measure the surroundings and detect obstacles for a safe operation of the complete system. A modular approach to measuring behaviour of the autonomous system is used and the results will be shown.

Figure 1. Left: Autonomous tractor. Middle: Automated sprayer designed for variable rate application based on laser range measurements. Right: Example of Sensor measurements for safety implementation on integrated system

Acknowledgements

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Development of variable-rate precision spraying systems for tree crop production

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Introduction

The fruit and ornamental nursery industries produce an abundance of food, flowers, shrubs and trees to improve our lifestyle and beautify our environment. This abundance is predicated on the use of pesticides to protect them from pests. However, the application efficiency of conventional pesticide spray technologies for crop protection is very low. Consequently, excessive pesticides are often applied to target and non-target areas, resulting in greater production costs, worker exposure to unnecessary pesticide risks, and adverse contamination of the environment.

To improve spray application efficiency, two types of variable-rate precision sprayers were developed for tree crop applications (figure 1). The first sprayer was a hydraulic vertical boom spraying system which was proposed to spray relatively small narrow trees such as liners (Jeon et al., 2011; Jeon and Zhu, 2012), and the second sprayer was an air-assisted spraying system which was proposed to spray wide varieties of nursery and fruit tree crops (Chen et al., 2012; Gu et al, 2012).

(a) (b)

Figure 1. Two variable-rate precision sprayers developed for fruit and ornamental nursery crop applications: (a) hydraulic boom spraying system, (b) air-assisted spraying system.

Materials and Methods

The variable-rate hydraulic boom sprayer was the integration of a 20 Hz detecting frequency ultrasonic sensing system, a custom-designed sensor-signal analyzer and a microprocessor controller, and two vertical booms coupled with five opposing pairs of equally spaced variable-rate nozzles. The sensing system detects the occurrence of a plant, its size and volume, and the sprayer travel speed. The controller along with a microprocessor analyzes sensor signals and actuates pulse width modulated (PWM) solenoid valves in real time. This action allows the sprayer to provide variable flows to nozzles automatically based on the canopy structure and presence. Laboratory and field tests were conducted to verify deposition uniformity inside canopies with various sizes of trees at different travel speeds. After the sprayer prototype was tested and confirmed it could reach the expected performances, a retrofit variable-rate spray unit was developed for a conventional high ground clearance vertical boom sprayer and tested in a commercial nursery. For this field comparison test, the half side of the sprayer used the retrofit unit, and the other half side of the sprayer remained the same as the conventional spray setup. Powdery mildew and aphids were evaluated for the comparison between the precision and conventional spray system applications.

The variable-rate air-assisted sprayer prototype implemented with a high-speed laser scanning sensor to control the spray output of individual nozzles to match characteristics of trees on both sides of the sprayer in real time. The sprayer mainly consisted of an automatic control system and an air and liquid delivery system with four five-port nozzle manifolds on each side. Each nozzle in the delivery system, coupled with a pulse width modulation (PWM) solenoid valve, achieved variable-rate delivery based on the occurrence, height, width of the target tree and its foliage density. Other components of the sensor control system included a unique algorithm for variable-rate control that instantaneously processed the measurements of the canopy surfaces. Field tests were conducted in an orchard, three nurseries and a vine yard to investigate spray deposition uniformity inside canopies with different crop varieties, sizes and planting patterns.

Results

Field test results demonstrated that the variable-rate hydraulic boom sprayer could reduce spray volume up to 86 % and 70 % compared to the 935 L/ha application rate and conventional tree-row volume based rate applications, respectively. In 2011 season, there was no significant difference in the control of the powdery mildew or aphids between the conventional and the variable-rate spray systems (fig. 2). Therefore, this newly developed sprayer has great potential to bring great reductions in pesticide use for narrow tree (such as liners) productions.

For the variable-rate air assisted sprayer, its spray coverage and deposition inside canopies were much more stable over different tree structures, and had significantly less spray losses on the ground and beyond target trees than the constant-rate applications. Compared to the 468 L/ha application rate, the new sprayer reduced the application rate by 52 to 70% during the growing season (fig. 3). The pesticide spray volume reduction with the new sprayer was obvious.

Compared to conventional constant-rate sprayers, the new variable-rate sprayers greatly reduced variations in spray deposition due to changes in tree growth, increased consistence of spray deposition uniformity inside canopies at different growth stages, minimized off-target losses, and reduced pesticide use.

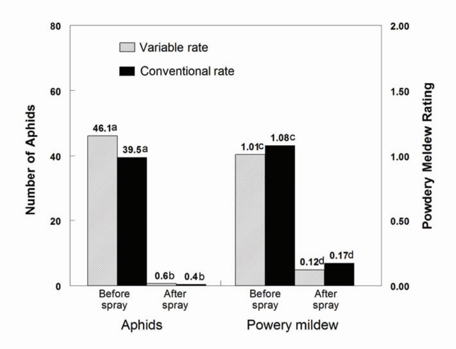

Figure 2. Number of aphids on a red oak leaf and average rating of powdery mildew infection on a Norway maple leaf treated with variable-rate and conventional vertical boom sprayers.

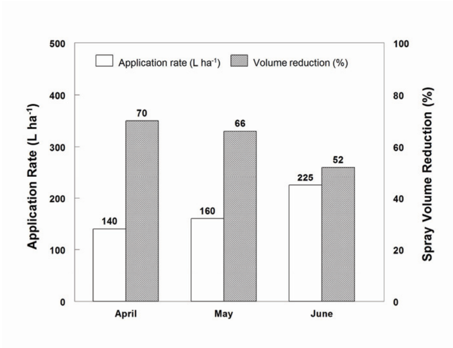

Figure 3. Spray rates and volume reductions by using the air-assisted intelligent sprayer in April, May and June, compared with the conventional 470 L ha^{-1} application rate.

Acknowledgements

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References

Chen Y, Zhu H, Ozkan HE (2012) Development of variable-rate sprayer with laser scanning sensor to synchronize spray outputs to tree structures. Transactions of the ASABE 55(3): 773-781.

Gu J, Zhu H, Ding W (2012) Unimpeded air velocity profiles of air-assisted five-port sprayers. Transactions of the ASABE 55(5): 1659-1666.

Jeon HY, Zhu H, Derksen RC, Ozkan HE, Krause CR, Fox RD (2011) Performance evaluation of a newly developed variable rate sprayer for nursery liner applications. Transactions of the ASABE 54(6):1997-2007.

Jeon HY, Zhu H (2012) Development of variable-rate sprayer for nursery liner applications. Transactions of the ASABE 55(1): 303-312.

Precision fruit spraying: digital canopy measurement for air and liquid control

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Introduction

In the spray application process the key factor to know is the location and volume of the target. It is then possible to make precise adjustments to the quantity of product being applied in relation to the size of the target vegetation. Precision spraying allows growers to apply pesticides only to the target canopy or fruit, to apply the correct quantity according to canopy size, density, growth stage and also to apply products in an economic and environmentally sound manner. We can adjust the liquid spray and the airflow according to the crop canopy.
Current research at Cornell University is to develop methods to allow adjustment of both liquid and air flow for orchard and vineyard sprayers. In both cases this adjustment will be made using the information provided by a multiple array of ultrasonic sensors that scans canopy vegetation.
The problem with the vast majority of traditional axial fan sprayers used in fruit canopy spraying is too much air volume and speed, particularly whilst spraying in early to mid-season when the canopy is still developing. 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.

Materials and Methods

Adjusting airflow

Previous research, at Cornell University, lead to the development of an adjustable louvre to control the air leaving the sprayer. The adjustable louvre on the air outlet of an air blast sprayer reduced drift by as much as 63% in orchards during field trials in early to mid season when canopies are developing (Landers, 2012). When drift is reduced by adjusted air volume or speed, deposition within the canopy or on the fruit increases. Currently the sprayer operator manually adjusts the louvre via an adjustable stroke length actuator that moves the louvre, thus matching airflow to canopy size. Unfortunately in tall trees and heavy canopies it is a challenge to see how far the spray cloud is passing through the canopy. A sensor system to monitor the canopy and adjust the actuator is required. We are using a conventional air-assisted sprayer, Berthoud S600EX (Berthoud, Cedex, France) equipped with the Cornell louvre system for adjusting the outlet of air from the axial-fan (Figure 1).

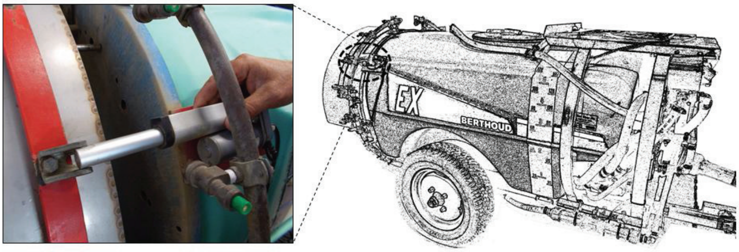

Figure 1. Louvre system mounted on conventional axial-fan sprayer.

Adjusting liquid flow

The canopy of fruit trees changes in size and density as the growing season progresses. The amount of spray needed to adequately cover the target is often a point of discussion, but all agree that good coverage is essential. Many orchards and vineyards have different size crops, growth stages and row widths, so changing liquid flow rate to match the varying parameters is very important. Changing forward speed is the simplest method but also affects air penetration and deposition.

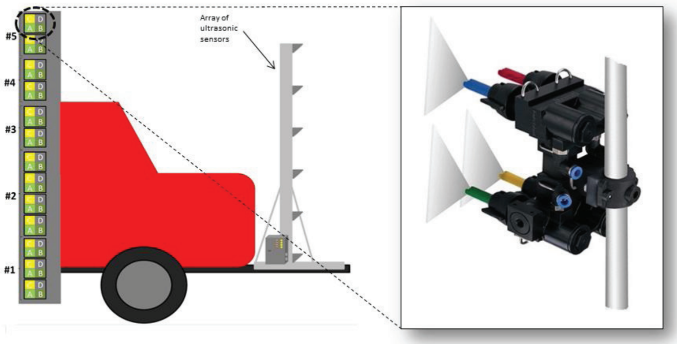

Figure 2. Tower sprayer with detail of mounted Lechler VarioSelect® unit.

We have fitted a John Bean Redline 5284781 Tower sprayer (Durand Wayland, La Grange, GA, USA) with a Lechler VarioSelect® system for proportional liquid application (Figure 2). The system is based on thirteen blocks (at five different heights or manifolds) each with space for four nozzles. The system is equipped with three flat fan nozzles (Position A:110-01 Orange, Position B: 110-015 Green, and Position C: 110-02 Yellow). Every manifold and combination of nozzle is activated in groups by a pneumatic system. These nozzles can be operated individually or in groups. In this tower only there is installed the system for liquid adjustment, but in future improvements can be installed the air control too.

Vegetation sensing

Vegetation detection is based on an array of ultrasonic sensors, Llorens et al. (2010), one array of 6 sensors for orchard characterization and three sensors for vineyard characterization, mounted on a vertical mast. The distance between the sensors is 50 cm for orchard characterization enough to not have interferences 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 nozzle blocks/manifolds. The nozzles can then emit spray according to the canopy. The sensors/controller is also able to position the actuator and then control the position of the louvre.

Results

The ultrasonic sensors are mounted and configured for an accurate reading of vegetation in fruit crops. The electronic system is based on an Arduino board that is able to control the different sectors and nozzles of the Lechler VarioSelect system. The same system is able to operate the position of the actuator on the louvre system. The electronic system can register data from all the systems via a serial port operating at a frequency of 3,33 Hz. This system is ready to conduct field trials during the summer of 2013.

Acknowledgements

This project is funded by the support of the NY Apple Research and Development Board (ARDP), NY Wine and Grape Foundation and Lake Erie Grape Growers. We would also like to thank to Lechler USA and Durand Wayland for providing the nozzles and sprayer.

References

Landers, A. (2012) Drift from fruit sprayers-why not prevent it at source? p. 235–242. In: Aspects of Applied Biology 114. International Advances in Pesticide Application.

Llorens, J., E. Gil, J. Llop, and A. Escolà (2010) Variable rate dosing in precision viticulture: Use of electronic devices to improve application efficiency. Crop Protection 29(3): 239–248.

Further developments of a fixed spraying system for high-density fruit trees

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Introduction

At the Suprofuit meeting in 2005 the authors reported on the development of a novel spraying system for fruit trees, Landers et al. (2005) and subsequently, Landers et al. (2006). The fixed spraying system comprised two 19mm plastic pipes (laterals), positioned through the canopy of the apple trees, following the top wire at 2m and the bottom wire at 1m above the ground. Small emitters, Netafim DAN 7000 series with an 8 mm orifice and flat pattern spreader (Netafim, Fresno, CA) were installed at 0.9 and 1.8m intervals along the length of the pipe (depending on the trial block). A 50 mm main pipe was run along the junction of the rows to a central filling position. Tests were conducted in a 0.32 ha block, of dwarf spindle apple trees, *var.* Gala, a co-operating grower's orchard in Sodus, New York, USA.

In 2011, a multi-disciplinary team of 22 researchers were awarded a multi-million dollar USDA SCRI NIFA grant to further develop the fixed spraying system entitled "The Development and Delivery of Resource-Efficient, Ecologically Sustainable Fruit Production Systems for Apple and Cherry Producers". Researchers are based at Cornell University, Michigan State University and Washington State University, with field trials being conducted in each state. Trials are being conducted in modern apple and cherry orchards and inside high-tunnel hoop houses. Various emitter locations are being tested and various applications rates are being observed for their biological effectiveness. A webpage for this project may be found at: http://www.canopydelivery.msu.edu/.

Materials and Methods

The Cornell University part of the project was started in 2012 on an improved design in a 0.5ha section of super-spindle dwarf (M.9) apple trees in its 5th leaf, in Wolcott (Wayne Co.), NY. The system plot covers 16 rows comprising 4 varieties in 4-row sets (*var*. McIntosh, Gala, Zestar and Honeycrisp), planted on a 3m row spacing with 0.6m between the trees, extending 91m along each row. Spray nozzles are supplied by 25mm diameter polyethylene tubing attached to a support wire above the trees (2.6m height); single or double micro-sprayer (0.58 l/min.) nozzles are suspended on 203mm (Figure 1) or 711mm (Figure 2) lengths of tubing reservoirs alternating every 0.9m along the lateral tubing, and are fitted with anti-drip devices. There are 600 anti-drip devices and 900 microsprayers in the 6 rows. The novel system comprises an input manifold of 1 lateral valve for every 2 rows of trees, therefore 8 valves. There is also a main liquid valve and a main air valve. Water, from a 15,500-litre road tanker, is pumped via a petrol-driven pump into the manifold and out, via the lateral valves, to the laterals running at the top of the rows, above the trees.A 5663 l/min. air compressor provides air for the system. A return pipe brings excess water back from the farthest end of each row to the return manifold. Another set of 8 valves (1 valve for every 2 rows) allows excess water to return back via a large hose to the road tanker. Currently, as it is a field trial, an operator stand by the manifold system and manually operates the valves in the correct order, it is envisioned that an automated system could be developed.

Figure 1. 203mm tubing reservoir and emitter.

Figure 2. 711 mm tubing reservoir and double emitter.

Results

In late August 2012, trials were conducted to test the system operation and the time requirements to fill and empty the tubing. Water was pumped from a road tanker through an input manifold, filling all the tubing reservoirs (45 seconds), and then compressed air at 1 bar was used to push the excess liquid through return lines and back into the tank (4.5 minutes). Finally, compressed air at 2.75 bar was used to open the check valves and spray out the liquid (9-12 seconds).

Conclusions

Without incorporating a reservoir system into the microsprayer assemblies, approximately 3 times as much water (567 litres versus190 litres) would have been needed to fill and spray out the 6 rows of the system's tubing that were used in these tests. As this would have taken considerably longer, it can be concluded that the reservoir design can effect a considerable time reduction in spray operation. Field trials starting with the first sprays of the 2013 season will assess the system's efficacy in applying all of the foliar sprays, and data will be taken on effectiveness of pest and disease control, thinning, and spray coverage and distribution.

Acknowledgements

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References

Landers, A. J., Agnello, A., Shayva,W. (2005). Engineering challenges in the development of a fixed spraying system for high density orchards. In Proc. Spray application techniques in fruit growing. June 29-July 1st p77. Barcelona: Universitat Politecnica de Catalunya.

Landers, A.J., Agnello, A., Shayva, W. (2006) The development of a fixed spraying system for high-density apple trees. Presented at the 2006 ASAE Annual International Meeting, Portland, OR Paper No. 061122, ASABE, 2950 Niles Road, St Joseph, MI 49085-965.

Variable Air-flow Discharge System for orchard sprayers

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Introduction

The spray application in fruit growing is considered to be a very inefficient process because more than a half of applied chemical dose is lost. The spray losses at the full leaf stage may reach 80% of applied spray volume (Holownicki, 2004). Conventional air-assisted sprayers with hydraulic nozzles are the most commonly used in fruit growing. They are not very costly, easy for operation and effective in chemical control of pests and diseases. They were developed when big trees with wide and dense canopies were most commonly grown. These sprayers generate a large radial spray plume which results in large off-target losses and requires a high power consumption (12-20 kW). It is not uncommon to see these machines treating hedgerow plantings. If residential areas are located in the neighbourhood of intensively sprayed orchards the potential hazard from the pesticide exposure causes the conflicts between growers and the local societies. Therefore, the trends of extending the buffer zones and restrictions of using conventional air-assisted sprayers are observed. It requires developing and promoting the use of more precise "environmentally friendly" spray application methods. More target-matched methods as tunnel and sensor techniques result in smaller off-target losses. Significant decrease of spray losses can be obtained with target oriented air-flow adjustment. There were only a few concepts of sprayers developed, which allow to adjust these parameters to the changing weather conditions and morphological characteristics of tree canopies. One of them is EDAS (Environmentally Dependent Application System), which enables real time adjustment of application parameters such as airflow and spray quality to reduce the negative environmental impact of spray applications in orchards (Doruchowski at al, 2009). The objectives of the presented studies were to develop an energy saving Variable Air-flow Discharge system (VAD) with continuous adjustment of air volume independent on right and left side of the sprayer.

Materials and Methods

The Variable Air-flow Discharge system is based on double axial fan system which allows the remote adjustment of air volume produced separately on right and the left side of the sprayer. The functional model of VAD system powered by the electric motor was designed for indoor laboratory tests. The measurements of air-flow distribution with the use of hot wire anemometers were made in the outlet of air duct of the fan (Fig. 1).

Results

The preliminary results seem to meet objectives. The calculated air output of 22000 m3/h, typical for dwarf and semi-dwarf orchard was obtained with 5.8 kW power consumption (Table 1). The air-flow profiles on right and left side are very close to symmetric. It can be expected to achieve the symmetry in a wide range of the impeller revolution (1100-2459 rev/min). As the optimal vertical air distribution has not been defined the intention is to obtain the air profile corresponding with geometry of the tree canopy, similar to that recommended for the evaluation of spray distribution measured on vertical paternator (Fig. 1). The measurements of air profile showed that the results did not confirm these assumptions yet. Therefore, the efforts on modification of air duct design will focus on the alignment of the vertical air distribution. Future measurements of air-flow profile will be carried out in apple orchard at different growing stages. For practical implementation the VAD system can be assembled on intelligent sprayers with adjustment of spray plume referring to the tree density as well as to the wind direction during the chemical treatment in orchards.

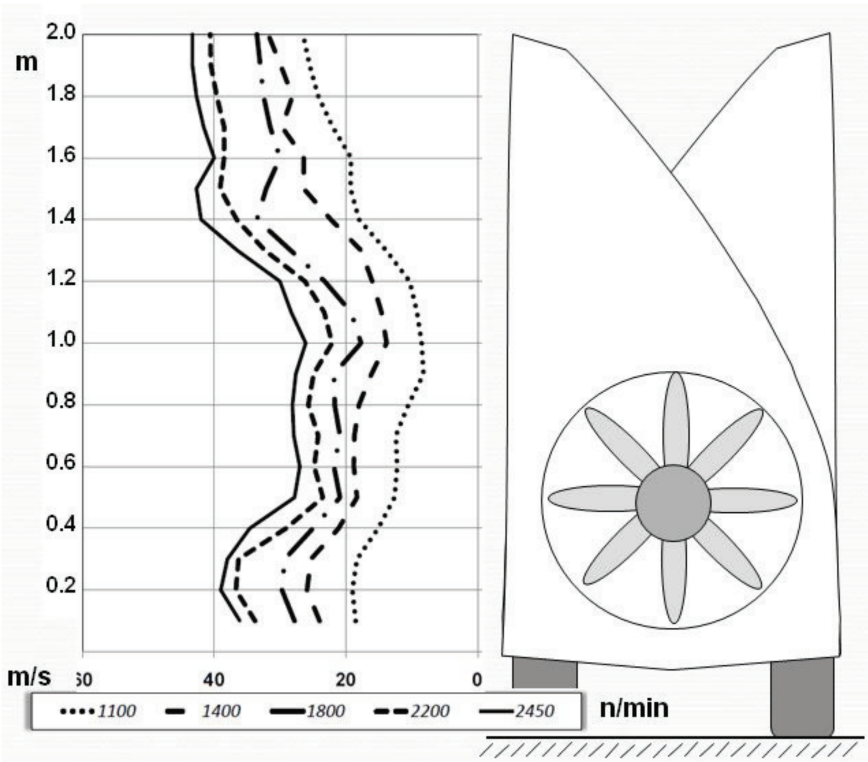

Figure 1. Air velocity profile for the VAD (Variable Air-flow Discharge) system

Table 1. Parameters of VAD (Variable Air-flow Discharge) system

Parameters		Revolution of propeller (n/min)				
		1100	1400	1800	2200	2450
Power consumption	kW	1.88	4.17	5.80	8.76	9.78
Average air velocity	m/s	15.2	22.7	26.7	32,0	34,6
Fan capacity*	m^3/h	12 700	18 900	22 300	26 700	28 900

(*) – calculated

References

Doruchowski G., Swiechowski W. , Godyn A., Holownicki R. (2009). GPS Navigated and Automatically Controlled Orchard Sprayer with Environmentally Dependent Application System (EDAS) to Implement Drift Reducing Application Strategies. International Commission of Agricultural and Biological Engineers, Section V. Conference "Technology and Management to Increase the Efficiency in Sustainable Agricultural Systems", Rosario, Argentina, 1-4 September 2009.

Hołownicki R., Doruchowski G., Świechowski W., Godyń A. (2004). Automatic self adjusting air-jet sprayer concept for fruit trees. Annual Review of Agricultural Engineering 3(1)/2004: 5 -13.

Foliar spray deposition in the vineyard from an air-assisted tunnel sprayer fitted with lamellate separating panels

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Introduction

Tunnel sprayers for orchards and vineyards have the potential of reducing both soil contamination and airborne spray drift (JKI, 2013), while recovering and recycling most of the spray fraction that has not been retained by the canopy, thus making efficient pest control possible even at reduced pesticide dose rates (by 15%-70%, depending on the growth stage of the crop; Siegfried and Holliger, 1996). However, unsatisfactory deposition uniformity over the foliage, particularly on leaf under sides, has also been reported (Planas et al., 2002; Viret et al., 2003).

The objective of the present research was to assess foliar spray deposition in the vineyard from a novel, air-assisted tunnel sprayer, developed in 2006 by Agricolmeccanica s.r.l. (Torviscosa, Udine; Pergher and Petris, 2009).

Materials and Methods

The two-row tunnel sprayer (Figure 1) was fitted with external axial flow fans (airflow rate: 2.23 $m^3 s^{-1}$ per row) and lamellate separating panels, designed to filter the excess spray and recover its liquid fraction for recycling, while discharging the air to the outside. The reference sprayer used for comparison was a trailed, three-row model (Dia-Tris, Agricolmeccanica s.r.l.) (air flow rate: 3.49 $m^3 s^{-1}$).

Two field tests were performed, at end of flowering (BBCH 69) and beginning of ripening (BBCH 81), in a vineyard (cv: Merlot), trained to a horizontal spur-cordon; planting distances were 2.4 m between the rows, and 0.8 m between the vines. The leaf area index (LAI) was 0.62 and 1.66, respectively. Spray application was performed using four Albuz ATR orange nozzles per side at 0.9 MPa, or six yellow nozzles per side at 0.7 MPa (tunnel sprayer only at BBCH 81). Travel speed was 1.73 $m s^{-1}$, and the application rate between 423 and 444 L/ha.

Mean normalised deposits on the leaves and on leaf undersides at twelve canopy locations (three height ranges, two depths and the two sides of the row) were assessed using a soluble colour dye (Tartrazine) as a tracer. Deposit assessment was performed separately on 144 whole leaves per sprayer and per experiment, and on the undersides of 144 other sample leaves, using 100 ml deionised water or 15 ml, respectively, to remove the tracer. Deposits were expressed in µl per cm^2 leaf area, measured with a photometric area-integrating meter (Model LI-3100C, LI-COR Inc.). The LAI was assessed based on twelve vines per experiment, whose leaves were counted, taken one every fifth leaf, and leaf area measured.

The day following each field experiment, two rows in the same vineyard were sprayed with the tunnel machine, with three replicates (total area: 0.3024 ha), to assess the recycling rate (expressed in % of the applied volume).

Figure 1. The tunnel sprayer used in the vineyard spray deposition measurements.

Results

Mean foliar spray deposition from the tunnel sprayer and the reference sprayer was not statistically different at either growth stage. However, the tunnel sprayer gave increased deposit variability on leaf undersides at the end of flowering. This was depending on both uneven distribution over the canopy heights, and to differences between the right-hand and left-hand sides of the row, owing to a wrong adjustment of the orientation of air outlets. The new adjustments performed in the second test (BBCH 81), including a different inclination of the air outlets both in the vertical and in the horizontal plane, proved effective in reducing spray deposit variability, so that the overall performances of both sprayers could be considered quite comparable, averaging 0.735 µl cm^{-2} and 0.714 µl cm^{-2} for the tunnel and reference sprayer, respectively. Penetration into the canopy was similar despite smaller airflow rate of the tunnel sprayer, and coverage of undersides was also comparable, i.e. 0.882 µl cm^{-2} and 0.909 µl cm^{-2}, respectively. The deposit ratio underside / upperside was, for both sprayers, in line with previous tests performed with air-assisted vineyard sprayers.

The recycling rate of the tunnel sprayer was 50.1% of spray volume applied in the first experiment (BBCH 69), and 34.0% in the second experiment (BBCH 81). This confirmed the potential of this new developed tunnel sprayer concept for substantial spray saving and reduction in chemical input, without compromising spray deposition and therefore also biological efficacy.

References

JKI (2013). Offizielles Verzeichnis Verlustmindernde Geraete 29 Januar 2013. http://www.jki.bund.de/.

Pergher G, Petris R (2009). An air-assisted tunnel sprayer for vineyards: spray recovery rate under static and dynamic conditions. In: M. Wenneker & J.C. van de Zande. SuproFruit 2009, 10th Workshop on Spray Application Techniques in Fruit Growing. September 30 - October 2, 2009 Hof van Wageningen, Wageningen The Netherlands,48-49

Planas S, Solanelles F, Fillat A. (2002). Assessment of recycling tunnel sprayers in Mediterranean vineyards and apple orchards. Biosyst. Eng. 82 (1), 45-52.

Siegfried W, Holliger E (1996). Application Technology in Fruit-growing and Viticulture. Report (1996), Swiss Federal Research Station, Wädenswill, Switzerland.

Viret O, Siegfried W, Holliger E, Raisigl U (2003). Comparison of spray deposits and efficacy against powdery mildew of aerial and ground-based spraying equipment in viticulture. Crop Prot. 22 (8), 1023-1032.

Low Loss Spray Application A Concept for More Efficient and Safer Crop Protection in Tree Fruit

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Introduction

In some large fruit growing areas in Europe (Austria, The Netherlands, United Kingdom, Germany) low volume spray application with small droplet nozzles has become standard in the early 1990ies. Reasons for this technique to rapidly spread amongst professional fruit growers have been the high work rate, enabling the use of limited time windows with suitable climatic conditions for spray application on a large acreage, a good coverage with no visible deposits, low risk for phytotoxicity, the potential of reduced dose rates, with more hectares per filling less chances per spray round for contamination of the operator with concentrated pesticides during preparation of the spray liquid, and also lower costs. This technique has increasingly been threatened as particle drift deposits became an issue during the 1990ies and high volume spray application with large droplets from air induction nozzles has officially been introduced as the exclusive way to reduce spray drift. Based on the spray drift reduction obtained by air induction nozzles and deflector plates to shut off or redirect the air stream on the down wind facing fan side, buffer zones to water courses can officially be reduced by the operator. This technique, resulting in water volumes of approximately 500 - 600 l ha^{-1} created a significant advantage for growers using higher water volumes before but would have created severe problems for growers using low volume spraying techniques of less than approximately 250 l ha^{-1} since many years.

Materials and Methods

To maintain this highly efficient spray application technique for tree fruit and wine growers, an alternative method of spray drift reduction resulting at least in a 75% reduction according the German drift reduction classification has been developed. This method combines fans with cross flow characteristics, a mixed set of nozzles with four low flow rate air induction nozzles (Albuz AVI 8001 or Lechler AVI 9001) at the two top most nozzle positions of the fan and hollow cone nozzles (Albuz ATR purple) at any other positions and a fan speed adapted to canopy width at any forward speed. In a range of forward speed from 6 to 12 km h^{-1} an average spray drift reduction of 83% was obtained, allowing a classification in the German

75% drift reduction class. The method developed combines the enormous advantages of small droplets and low water volumes for the growers with the demands for a significant reduction of spray drift. It is an answer to growers needs since for many growers relying on low water volumes it prevents the serious problems arising from a change towards classical spray drift reduction with a full set of air induction nozzles and high water volumes. Therefore this method has to be considered in future regulations concerning spray drift reduction in tree crops and grape vines.

To assess the influence of a canopy adapted fan speed on spray deposition, trials have been carried out with an axial fan with cross flow characteristics and a full set of hollow cone nozzles (Albuz ATR purple). The sprayer has been operated in three different canopy systems after a dosing model calculating pesticide dose rate, water volume and forward speed according canopy and orchard parameters. Fan speed at each forward speed has been adjusted to the canopy so that only very little spray mist left the canopy into the opposite alley way. The trial revealed a considerable increase of the efficiency of spray deposition; especially on the upper leaf surface. Changes in the efficiency of spray deposit parameters compared to classical spray application with high fan speed and relatively low forward speed, calculated per liter ha^{-1} of liquid sprayed, are shown in table 1. As side effects fuel consumption and noise emissions both are reduced by up to 80%; cutting fuel consumption and preventing complaints from urban settlements close to the orchards.

Table 1. Changes of parameters of the spray cover of an axial fan with cross flow characteristics comparing operation with canopy adapted fan speed and forward speed to full fan speed and relatively low forward speed.

Changes in efficiency	3-row Bed	Slender Spindle	Super Spindle
Spray deposit (entire leaf) µg cm^{-2} per liter of liquid sprayed	+14%	+29%	+35%
Relative Spray Cover (upper leaf surface) µg cm-2 per liter of liquid sprayed	-29%	+26%	+67%
(lower leaf surface)	-27%	-3%	+7%
Droplet Deposit Density (upper leaf surface) Number per cm^{-2} per liter of liquid sprayed	-5%	+27%	+55%
(lower leaf surface)	+17%	+28%	+27%

Unfortunately the vast majority of fan types with cross flow characteristics showed a very uneven vertical air distribution unusable for this method which requires a uniform horizontal reach of the air stream over the working height. As this appeared to be a wide spread and severe problem preventing the introduction of “Low Loss Spray Application”, a joint venture of advisory services in Austria (Verband der steirischen Erwerbsobstbauern), Italy (Südtiroler Beratungsring für Obst- und Weinbau) and Germany (Marktgemeinschaft Bodenseeobst eG) for testing, adjusting and improving the air distribution of orchard sprayers with an air distribution test stand has been founded. The equipment is based on ultrasonic

sensors which amongst other parameters measures and calculates the usable air stream and creates an automated assessment of the fan according to predefined parameters. Guidelines developed by the cooperation define the requirements for a vertical air distribution suitable for canopy adapted spray application as the basis of "Low Loss Spray Application".
In order to guide the grower in correctly applying "Low Loss Spray Application", an electronic field book complying with the current systems for quality assurance has been developed. With this software growers compose a "recipe" with the blocks to be sprayed and the products to be used, and the software calculating water volume, dose rates and forward speed for any individual block. After the spray round, the software documents the treatment and updates the stock of the products used, calculates potential harvest dates and updates a number of parameters from the registration as e.g. the number of sprays per indication and vegetation period, for any individual orchard block.
Finally on annual meetings with sprayer manufacturers participating in the concept, results and observations concerning fan performance are discussed. The staff managing sprayer testing is trained after improvements of the hard- and software while growers are trained in meetings, seminars, through written information, during sprayer testing and before purchasing new sprayers.
With this final part, the concept of "Low Loss Spray Application" is complete, comprising a suitable air and spray liquid distribution, a method for spray drift reduction with low water volumes and small droplets, a software for canopy related dosing and spray application, the education of the growers and a continuous dialog with the sprayer manufacturers

References

Triloff, P (2011) Verlustreduzierter Pflanzenschutz im Baumobstbau - Abdriftminimierung und Effizienzsteigerung durch baumformabhängige Dosierung und Luftführung. Dissertation, Institut für Agrartechnik, Universität Hohenheim, Stuttgart, 351 S., Verlag Ulrich E. Grauer, Stuttgart, ISBN 978-3-86186-563-6.

Knoll M, Lind K, Triloff P (2012) Low Loss Spraying. In: Heinz Ganzelmeier, Hans-Joachim Wehmann: Fourth European Workshop on Standardised Procedure for the Inspection of Sprayers in Europe - SPISE 4 - Lana (South Tyrol), Italy, March 27 - 29 2012, Julius-Kühn-Archiv 439/2012, 122 – 126.

Triloff P, Knoll M, Lind K, Herbst E, Kleisinger S (2012) Low Loss Spray Application.- The Scientific Basis. In: Heinz Ganzelmeier, Hans-Joachim Wehmann: Fourth European Workshop on Standardised Procedure for the Inspection of Sprayers in Europe - SPISE 4 - Lana (South Tyrol), Italy, March 27 - 29 2012, Julius-Kühn-Archiv, Braunschweig, 439/2012, 127 – 134.

Tank agitation device performance: overview of the present situation in some new sprayers

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Introduction

Experiences made during the functional tests to certify new sprayers according to ENTAM requirements have brought up the shortcomings of the agitation systems in sprayers' tanks. In this work, an overview of the data acquired on different categories of sprayers is presented.

Materials and Methods

Certification of new sprayers according to ENTAM scheme is carried out at DiSAFA – University of Torino since 1999. Among the functional tests foreseen, the assessment of efficiency of the spray mixture agitation system in the tank is made following the methodology prescribed in ISO 5682-2. A water suspension of copper oxychloride (1% w/w) is used as test material. The sprayer tank is filled up to its nominal volume with this suspension and then it is left to sediment for 16 hours. Then the agitation system is activated for 10 minutes and samples of the liquid inside the sprayer are taken at different heights to verify the concentration of copper oxychloride. The sprayer passes the test when the average concentration of the copper oxychloride is within ±15% of the original concentration. Seventy four sprayers from 22 different manufacturers were examined: 30 boom sprayers (11 mounted, 13 trailed and 6 self-propelled) and 44 air-assisted sprayers for arboreal crops (10 mounted and 34 trailed). Tank capacity ranged between 200 and 4000 litres. In 11% of the machines, the tank agitation system was achieved just through the pump back flow. In 78%, it was achieved by the pump back flow plus one or more horizontal injectors (Venturi hoses). And in 11%, tank agitation was accomplished through the pump back flow plus more vertical injectors. Seven percent of sprayers examined were equipped with a centrifugal pump working at a maximum pressure of 0.40 MPa, while all the other sprayers tested were equipped with a diaphragm pump operating at a maximum pressure of 1.5-2.0 MPa for boom sprayers and of 4.0-5.0 MPa for air-assisted sprayers.

Results

The ratio between the pump flow rate and the tank capacity was therefore 0.3-0.4 l/min for tanks with capacity less than 400 l, then it progressively decreased to 0.10-0.015 l/min up to 1500 l tank capacity and it remained quite constant for bigger tanks (Figure 1).

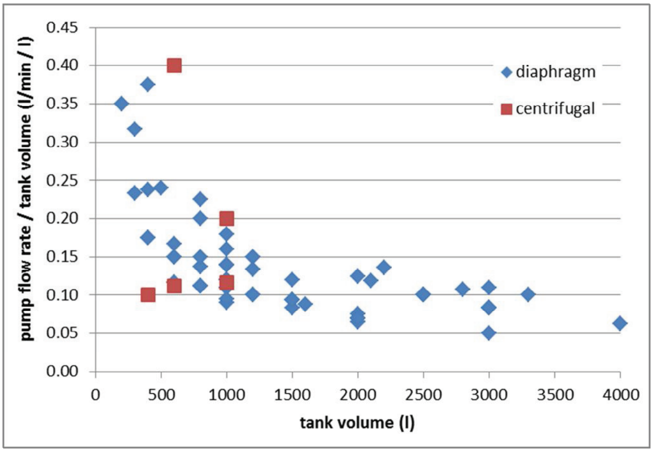

Figure 1. Trend of the ratio between pump flow rate and tank volume according to the capacity of the tank.

Test results of the tank agitation performance showed that only for 28% of the sprayers examined were within the threshold of ±15% with respect to the original copper oxychloride concentration. In 53% of the cases, the sprayers matched the requirement after one modification of the agitation system made by the manufacturer. In 14%, after two modifications of the tank agitation system. And, in 5%, after three interventions. It should be noted that all the sprayers which passed the test at the first attempt came from manufacturers that were already familiar with the certification process. Observing the results as a function of the type of agitation system it was evident that the worst results were obtained with "the only pump back flow" system. Even after some modifications to this type of agitation system, it was possible to satisfy the ISO 5682-2 requirement (Table 1).

	Mean deviation from reference concentration	
Tank agitation system	**Original configuration**	**After modification**
Pump back flow	-24%	-12%
Horizontal injector + pump back flow	-20%	-11%
Vertical injector + pump back flow	-21%	-10%

Table 1. Mean deviance from the reference copper oxychloride concentration according to the tank agitation system in the original configuration of the machine and after the modifications made to pass the test.

The average efficiency of the tank agitation system in the sprayers examined resulted generally poorer for air-assisted sprayers for arboreal crops compared to boom sprayers (Table 2). No significant correlations were observed between tank agitation performance and type of sprayer coupling to tractor.

		Mean deviation from reference concentration			
		Original configuration			After modification
Sprayer type	Coupling	Average	Minimum	Maximum	Average
Boom	Mounted	-15%	-26%	-5%	-10%
	Trailed	-20%	-28%	-10%	-11%
	Self-propelled	-12%	-24%	-6%	-10%
Air-asssited	Mounted	-26%	-36%	-4%	-10%
	Trailed	-26%	-55%	-6%	-12%

Table 2. Mean deviance from the reference copper oxychloride concentration according to the sprayer type and to the sprayer coupling in the original configuration of the machine and after the modifications made to pass the test.

The results revealed general poor efficiency of sprayer tank agitation systems. It can be assumed that most of sprayers put on the market without any certification do not fulfil the requirements of ISO standard. These criticisms are often due to a lack of awareness and knowledge by sprayer manufacturers, who do not know the details of the ISO 5682-2 test procedure and who often address their efforts only to provide a visible tank agitation as currently is required for passing the inspection of sprayers in use (EN 13790).

Acknowledgements

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References

EN 13790-1 (2003). Agricultural machinery - Sprayers - Inspection of sprayers in use - Part 1: Field crop sprayers

EN 13790-2 (2003). Agricultural machinery - Sprayers - Inspection of sprayers in use - Part 2: Air-assisted sprayers for bush and tree crops

ISO 5682-2 (1997). Equipment for crop protection – Spraying equipment - Part 2: Test methods for hydraulic sprayers.

SESSION 7

Train Operators to Promote Best Practices and Sustainability

TOPPS-prowadis: Midterm project update on the mitigation of Plant Protection Products (PPP) losses to surface water from diffuse sources

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Introduction

TOPPS- prowadis funded by ECPA started 2011 in 7 EU member states (BE, DE, DK, ES, FR, IT, PL) and builds on results and experiences from the previous TOPPS projects (Roettele 2008). Focus of TOPPS-prowadis is the mitigation of diffuse entry routes of Plant Protection Products (PPP) to water: Runoff / erosion and spray drift. Studies suggest that point sources represent the most significant entry route (Bach *et.al*. 2001), accounting for more than 50% of PPP entries into water. The remaining entries are attributed to diffuse sources, of which runoff / erosion is estimated to contribute the most (> 35% of total pollution). Contribution from spray drift is lower, but can be locally of high relevance (e.g fruit crops). The first two phases of the project are now completed:

a) Development of the Best Management Practices (BMPs), and;
b) Preparation of training and information materials.

This presentation will give an overview on the whole project and an outlook to future steps. Other presentations in this conference will present further results (Balsari, 2013; Doruchowski, 2013; Gil, 2013).

Materials and Methods

The triangle of (i) correct behaviour, (ii) improvement of equipment and techniques and (iii) infrastructure (Figure 1), which helped to develop the BMPs on point sources (Roettele, 2008) also proved to be useful for the development of the BMPs to mitigate PPP entries to water from runoff / erosion and spray drift.
All three elements are important to achieve overall high mitigation efficiency.
The project is organized in two project streams: Runoff / erosion and Spray drift. Each team is guided by a technical support team which provides specific expertise

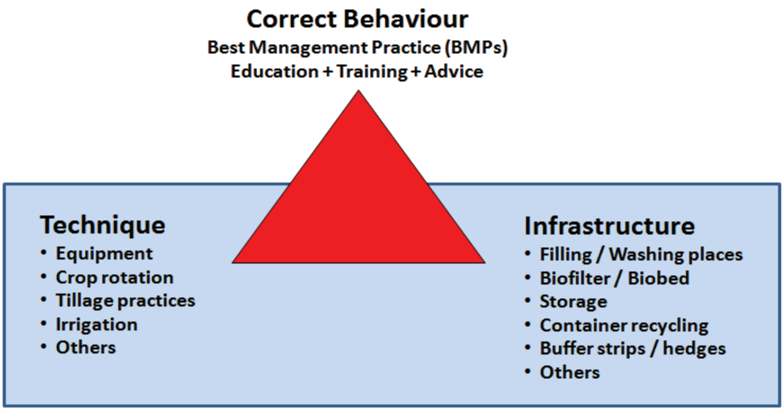

Figure 1. Key elements to build a consistent mitigation strategy.

to the project group. Local partners bring in their local approaches and expertise and adapt the BMPs to their situations. Existing recommendations or legal requirements in countries to reduce runoff and spray drift needed to be considered. As a basis for an EU-wide approach, “Reference BMPs” were developed, which can be considered as a core reference. These reference BMPs were discussed in national and EU wide workshops with stakeholders in order to reach broad consensus and acceptance. Locally adapted BMP versions will be derived from the EU core reference. The conceptual approach for building the BMP - recommendations follows a stepwise procedure:

Risk diagnosis + mitigation measures toolbox = BMPs

Results

Mitigation of PPP losses to water gets increasingly more complex moving from point sources to spray drift and further on to runoff / erosion. Point sources - BMPs can be largely generalized. All relevant factors can be controlled by the operator. In the case of spray drift mitigation the key risk factor is weather (e.g wind), which cannot be predicted. Effective spray drift reducing technology (low drift nozzles) is available but not yet sufficiently accepted and implemented across EU countries. For orchard and vine sprayers low drift technology can be used, but their implementation in practice is still low. Spray drift mitigation needs to address the whole application process. Key is the operator, starting with a thorough planning of the PPP application, the correct adjustment of the sprayer and the selection of risk adapted spray scenarios. Further improvements of spray technology and their introduction are also needed to enable the operator to reduce spray drift risks. TOPPS- prowadis spray drift evaluation tools are expected to create the necessary awareness for key risk factors and on the effects of mitigation measures.
For the different surface runoff situations found in the field, BMPs need to be locally defined and implemented between the farmer and the adviser. The basis for

this is an understandable approach to determine the potential runoff risks. Risk analysis must address both the catchment scale and the field scale. This adds further complexity as typically several farmers operate in a catchment and all need to be involved. Risk analysis tools were developed and linked to mitigation measures. Tools follow the concept of decision trees based on available data and direct field observations. BMPs recommendations need also to consider farm specific and social aspects (e.g. crop rotations, available machinery, work load) to reach acceptance and ensure implementation. The key success factor for TOPPS prowadis is therefore to gain the interest of a significant group of advisers, farmers and stakeholders in the upcoming intense dissemination phase. Information and training should enable them to act as multipliers for the methods and approaches suggested.

Acknowledgements

The contributions of the TOPPS – prowadis partners and experts from crop protection companies are acknowledged.

References

Aquaplaine®, Aquavallee®: Diagnosis - tools developed by Arvalis Inst. du vegetal. in France.

Bach M, Huber A, Frede HG (2001) Modeling Pesticide losses from diffuse sources in Germany. Water Science and Technology 44 (7), 189-196

Balsari P, Marucco P, Codis S, Doruchowski G, Gil E, Herbst A, Pauwelyn E, Petersen PH, Roettele M (2013) TOPPS-prowadis: Best management practices to reduce spray drift. Suprofruit 2013: 12th workshop on spray application techniques in fruit growing, Abstracts, Valencia Spain

Doruchowski G, Balsari P, Gil E, Codis S, Marucco P, Roettele M, Herbst A, Pauwelyn E (2013) Drift Evaluation Tool to raise awareness about risk of water contamination and drift mitigation measures during orchard spraying. Suprofruit 2013: 12th workshop on spray application techniques in fruit growing, Abstracts, Valencia Spain

Gil E, Gallar M, Doruchowski G, Balsari P, Codis S, Marucco P, Roettele M, Herbst A, Pauwelyn E (2013) Drift mitigation training: key point to improve pesticide use. Formative actions under TOPPS-Prowadis project. Suprofruit 2013: 12th workshop on spray application techniques in fruit growing, Abstracts, Valencia Spain

Roettele M (2008) Strategies to reduce point source losses of PPP to water focus on "Behaviour, Techniques and Infrastructure". Lessons learned from the TOPPS – Project. Aspects of Applied Biology 84, Int. Advances in Pesticide Application 84, 357- 368

The Best Management Practices to reduce drift risk developed by TOPPS-Prowadis

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Introduction

Improper use of pesticides in agriculture may cause either point or diffuse sources that can severely contaminate surface water. According to several studies carried out especially in Northern Europe, majority of risks are linked to point sources, that are mainly generated during the filling and cleaning of sprayers and are also related to the practices adopted for remnants management at the end of spray application. Between 2005 and 2008 EU-Life and ECPA (European Crop Protection Association) funded a project named TOPPS (Training of Operators to prevent Pollution from Point Sources) that was carried out in 15 EU countries and was aimed at defining and disseminating common Best Management Practices (BMP) to prevent point sources (www.topps-life.org).
Starting from February 2011, ECPA funded a second project regarding diffuse sources, mainly related to spray run-off and to spray drift. The project is named TOPPS-PROWADIS (Train Operators and Promote best Practices and Sustainability – PROtect Water from Diffuse Sources) and involves 7 European countries (Roettele, 2011). Scope of the project is to develop EU agreed Best Management Practices to mitigate risks of water contamination due to spray run-off and to spray drift and to disseminate them also through training activities and information materials. These activities are in line with the contents of EU Directive on sustainable use of pesticides (128/2009/EC) and were developed by two separate teams (one for drift and the other for run-off) established within the project.

Materials and Methods

After an inventory process, where the local situation was reviewed by the TOPPS-Prowadis partners in their countries it was evident that the level of awareness and of harmonized recommendations across the EU is actually low. Only in some countries Spray Drift Reducing Techniques (SDRT) are really spread and they are tested and categorized by their ability to reduce the spray drift.

The project team for drift made a first proposal for BMPs, which was discussed at national forums with national stakeholders. After this first consultation in all the TOPPS-Prowadis countries, a EU stakeholder workshop was organized in Brussels in April 2012 to discuss and consolidate the draft versions in order to prepare the final BMP document.

BMPs were developed following a two-steps approach:

a) Statements = What to do (brief sentence)

b) Specifications = How to do it (short explanation of possible ways to get the result)

All the statements and specifications contained in the BMPs were funded on scientific results of studies and experiments carried out by academic and research experts of the countries involved in the Project.

The statements are considered to represent “the European core”, which should be followed by all member states (framework). These statements were the main focus in the consultation process.

Specifications should give guidance on how to do things in a correct way. In an “EU” - reference document such specifications cannot address specific recommendations in individual countries. Any specific aspects are included in the national TOPPS-Prowadis information and training materials.

Proposed BMPs do not interfere with the labelled requirements or other legal obligations of the Plant Protection Products (PPP). These need to be respected by all means. BMPs intend to provide practical and consistent guidance to operators, sprayer manufacturers and other stakeholders in order to make the use of PPP more sustainable.

Results

A list of 42 TOPPS–Prowadis spray drift BMPs was produced; they were divided in three main sections:

1. General measures to reduce spray drift (valid for field crop or for orchard sprayers)
2. Measures to reduce drift from field crop sprayers
3. Measures to reduce drift from fruit crop sprayers

Further 11 additional suggestions to reduce drift from field crop sprayers and 4 additional suggestions to reduce drift from fruit crop sprayers were added at the end of the main BMPs list.

Following the requests made by European stakeholders during the consultation process, BMPs are proposed in a certain order of importance to follow. This is achieved by a colour coding of the recommendations:

1) Green: Must be implemented
2) Yellow: Very important to follow
3) Blue: Important, specifications to be adapted to local conditions.

Moreover, the BMPs are grouped by category in order to help the reader to easily find the BMPs.

Six different categories have been selected:

a) Environmental factors
b) Weather conditions
c) Spray generation
d) Spraying equipment
e) Sprayer adjustment
f) Sprayer operation

They take into account both direct and indirect methods to prevent spray drift. Direct methods are focused to reduce drift at source, mainly by the adoption of Spray Drift Reducing Techniques (e,g, use of air induction nozzles, shielded spraying equipment, limited boom height, reduced forward speed, correct air flow adjustment, sensors, etc.). Indirect methods are addressed to reduce exposure to drift, for example adopting adequate buffer zones beside the applied fields and establishing natural or artificial windbreaks to limit spray dispersion outside the sprayed field.

BMPs are being translated in local languages with adaptations of the specifications contents to the country contexts and are being published either on the TOPPS-Prowadis website and in booklets. Their dissemination is under way by means of training courses and publications addressed to authorities, advisers and farmers.

Acknowledgements

The contribution of the TOPPS-Prowadis partners and experts from European Crop Protection Association are acknowledged.

References

Roettele M. (2011). TOPPS –prowadis: a new European multistakeholder project targeted to reduce losses of Plant Protection Products (PPP) to water. Suprofruit 2011, Bergerac (France), book of abstracts, pp. 106-107.

Topps website: www.TOPPS-life.org

Drift Evaluation Tool to raise awareness about risk of water contamination and drift mitigation measures during orchard spraying

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Introduction

The European directives concerning water quality, pesticide use and safety features of machinery set requirements to mitigate risk of environmental contamination by reducing entries of pesticides into water from point and diffuse sources. A variety of technical, organizational and legal instruments to mitigate spray drift are promoted. However, the key factor influencing the risk of contamination of water and sensitive areas is the sprayer operator with his awareness, skills, and ability to make responsible decisions. The existing drift models are too complex for the operators, as they are mainly used for risk assessment during the regulatory process. The objective of the work was to develop a practical tool, to be used as training material to raise awareness of drift risk during orchard spraying, propose measures to mitigate this risk, and by that help the operator to better plan pesticide application and to reduce spray loss.

Materials and Methods

The Drift Evaluation Tool was developed by the team of European experts within the project TOPPS-PROWADIS (*www.topps-life.org*) (Roettele et al., 2013). It is a web based application consisting of three sections (pages): (I) SPRAY APPLICATION SITE; (II) METEO & ORCHARD CONDITIONS; (III) DRIFT RISK MITIGATION (Fig. 1). Within the sections (I) and (II) the user makes selection of the proposed options defining the distance between the application site and the sensitive areas, wind direction and velocity, air temperature and humidity, crop canopy density and the adjacent structures next to the orchard. The selected items describe the actual and objective situation, for which the tool calculates the Drift Risk Value [%] followed by an appropriate recommendation. In section (III) the user can simulate and check the effect of use of drift mitigation measures by selecting one of the classified spray drift reduction technologies (*www.sdrt.info*), or other drift reduction methods such as different types of sprayers and nozzles, adjustments of application parameters according to the crop characteristics and other application scenarios. According to the selection made by the user the tool appropriately modifies the Drift Risk Value and gives the final recommendation. The Drift Risk Value is calculated according to the algorithm using scores assigned to options selected by the user. The scores express drift mitigation effect of each option on drift and they were assigned based on the outcomes of drift models (Kaul et al., 2004; Baetens et al., 2009) and the results of drift experiments (De Schampheleire et al., 2008; Nuyttens et al., 2011). Where data was missing an expert judgement based on the experts' experience in drift was applied to estimate the scores (Walklate, 2012). Thus, the Drift Risk Value has an indicative character to be used for training and planning the spray application activities rather than for scientific or administrative purposes.

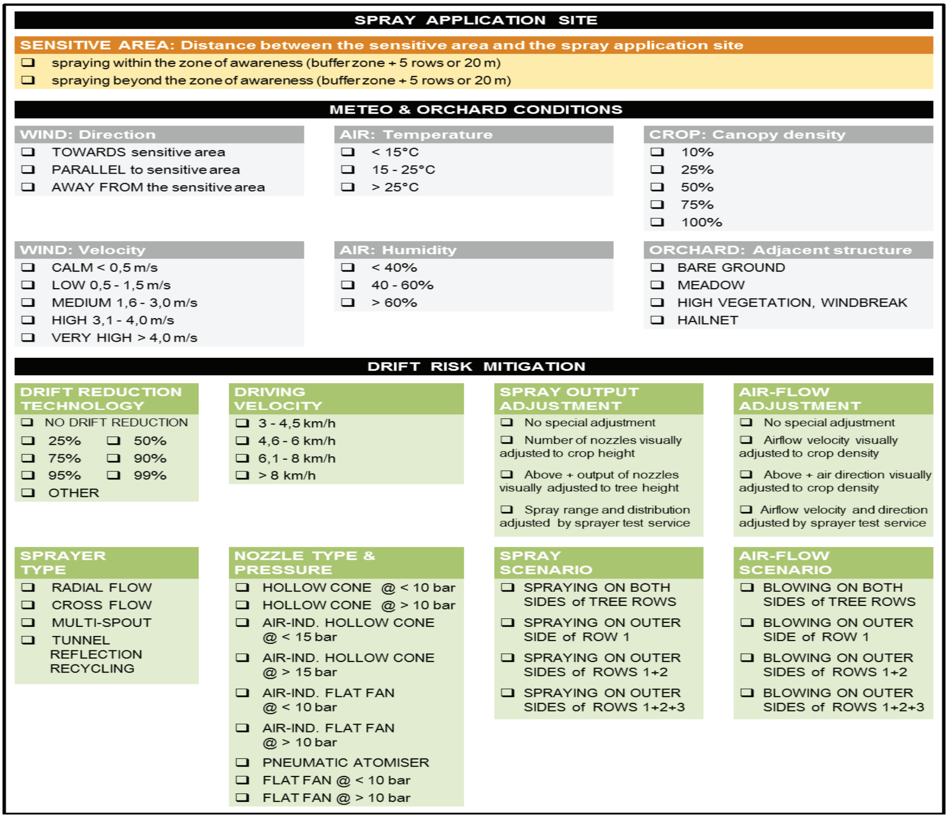

Figure 1. The structure and contents of Drift Evaluation Tool

Results and Conclusions

The structure and contents (sections, factors and options) of the Drift Evaluation Tool are presented in Figure 1. The tool is a web based application, but for more flexibility and users' convenience it may also be operated off-line, or most preferably it could be integrated in the terminal of the sprayer control system.

The tool has been consulted with a wide range of stakeholders, tested by the advisors, and used during the training courses on safe use of pesticides (Gil et al., 2013) to support implementation of Best Management Practices (Balsari et al., 2013) and raise awareness about risk of water contamination and drift mitigation measures during orchard spraying. By its simplicity and yet practicality it was well-received by advisors and farmers, and therefore it is a valuable training material.

Acknowledgements

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References

Baetens, K,. Ho, Q.T., Nuyttens, D., De Schampheleire, M., Melese Endalewa, A., Hertog,.L.A.T.M., Nicolaı, B., Ramon, H., and Verboven, P. 2009. A validated 2-D diffusion–advection model for prediction of drift from ground boom sprayers. Atmospheric Environment, 43: 1674–1682.

Balsari, P., Marucco, P., Codis, S., Doruchowski, G., Gil, E., Herbst, A., Pauwelyn, E., Petersen, P. H. and Roettele, M. 2013. The Best Management Practices to reduce drift risk developed by TOPPS-Prowadis. Suprofruit, 2013, Valencia (Spain)

Gil, E., Gallart, M., Doruchowski, G., Balsari, P., Codis, S., Marucco, P., Roettele, M., Herbst, A. and Pauwelyn, E. 2013. Drift mitigation training: key point to improve pesticide use. Formative actions under TOPPS-Prowadis project. Suprofruit, 2013, Valencia (Spain)

Kaul, P., Gebauer, S., Moll, E., Neukampf, R. 2004. German regulation – drift modelling. In Proc. Int. Conf. Pesticide Application for Drift Management, October 27–29, 2004, Waikoloa, Hawaii, 85–96.

Nuyttens, D., De Schampheleire, M., Baetens, K., Brusselman, E., Dekeyser, D. and Verboven, P. 2011. Drift from field crop sprayers using an integrated approach: results of a five-year study. Transactions of the ASABE, Vol. 54(2): 403-408.

Roettele, M., Balsari, P., Costrop, P., Doruchowski, G., le Henaff, G., King, L., Laabs, V., Maillet-Mezeray, J., Rutherford, S. 2013. TOPPS-prowadis: Midterm update on the mitigation of Plant Protection Products (PPP) losses to surface water from diffuse sources. Suprofruit, 2013, Valencia (Spain)

Schampheleire De, M., Baetens, K., Nuyttens,D. and Spanoghe, P. 2008. Spray drift easurements to evaluate the Belgian drift mitigation measures in field crops. Crop Protection, 27: 577–589.

Walklate, P. 2012. Personal communication: PJWRC - root@pjwrc.co.uk

TOPPS-Prowadis EOS (Environmentally Optimised Sprayer): a tool for raising awareness and for training

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Introduction

European legislation in the last years has focused the attention on prevention of environmental risks related to pesticide application, especially through the issue of three EU Directives: the Water Framework Directive (60/2000/EC), the amendment of Machinery Directive (127/2009/CE) and the Directive on Sustainable Use of Pesticides (128/2009/CE). On the basis of the information acquired in TOPPS Project, aimed at preventing pesticide point sources (Roettele, 2012), and considering also the aspects related to pesticide diffuse sources (spray drift and run-off), a group of European experts including representatives of sprayer manufacturers and of chemical industries, thanks to ECPA support, studied and realised a specific software, named EOS (Environmentally Optimised Sprayer), aimed at assessing the environmental friendliness of sprayers in function of the devices and accessories present on the machines.

This tool is intended to create more awareness among authorities, sprayer manufacturers, advisers and farmers about the importance that an "optimised" sprayer, equipped with more advanced accessories and devices, has in terms of environmental safety. As a consequence, it is intended also to stimulate the research and development of new technical solutions enabling to increase environmental friendliness of sprayers.

Materials and Methods

EOS software was developed as a questionnaire divided in different sections. Users are asked to follow a path through the program screenshots and to select the technical devices, useful to mitigate risks of environmental pollution with pesticides, that are present (or not) on the examined sprayer model. On the basis of the options selected, a score is elaborated (EOS value) which indicates how the sprayer is environmental friendly. In order to define the system for giving the EOS values, possible ways of pesticides water contamination were analysed, taking into account either point or diffuse sources, and sprayer technical devices benefits in mitigating these risks were assessed. Five risk areas were therefore individuated (Table 1), each having a specific weight according to the sprayer type (field crop or

arboreal crop sprayer). For each risk area a list of problems to solve by using adequate devices was individuated and to each problem, too, a weight factor was assigned (Figure 1). For each problem, available technologies were then listed and, again, a specific weight was given to each technology (Figure 1). Finally, for each technology, all technical solutions were proposed, from the less to the most efficient, and they were given a score from 0 to 10. When the user ticks the box corresponding to a specific technical solution present on his sprayer, the software calculates the contribution given to the total EOS value, considering the technical solution score and the weight factors corresponding to the corresponding technology, problem and risk area. Weight factors and scores of technical solutions are within the software structure and cannot be visualised by users. EOS software considers about 80 sprayer elements in total and the EOS value is calculated both as an overall score and specifically for each risk area. In this way the user can verify, for his sprayer, which aspects (e.g. internal contamination, sprayer filling, etc.) present more failures.
The list of available technologies and technical solutions for each of the problems examined was prepared taking into account the suggestions of sprayer manufacturers in order to cover the whole range of technologies present either on sprayers already in use or on new branded sprayers. The highest score within the options listed was always assigned to technical solution proved to be the most efficient on the basis of experimental results.

EOS risk area	Field crop sprayer	Orchard sprayer
Inside contamination	45	35
Outside contamination	10	20
Sprayer filling	20	20
Spray remnant management	15	10
Spray losses including drift	10	15
Total	100	100

Table 1. Weight of EOS risk areas for field crop and for orchard sprayers.

Results

EOS software is intended to raise the awareness of sprayer manufacturers and users about the limits of spraying equipment in terms of prevention of environmental pollution and, therefore, to stimulate the adoption of already existing or new devices and accessories useful to limit pesticide contamination risks. The tool is freely available at the website www.TOPPS-eos.org in different languages of the European Union (English, French, German, Italian, Spanish, Danish, Polish, Dutch and Swedish). Users can save the data inserted step by step, so they can complete the questionnaire in different times. A guide, also available online in the same website, explains the technical words and shows through pictures and schemes what is intended with the different technical solutions, supporting the users in selecting the options more adequate for the sprayer models they are examining. First results obtained in Italy applying the EOS software to the sprayers used in vineyards pointed out that there is still a lot to do in order to improve the environmental safeguard. Often, this is possible just adopting some devices (e.g. induction hopper for introducing chemicals in the main tank) that would allow to minimize the risks without requiring a big cost. Training and dissemination are therefore key elements for reaching this goal and EOS tool will be proposed also in the ambit of trainings foreseen within TOPPS-Prowadis project.

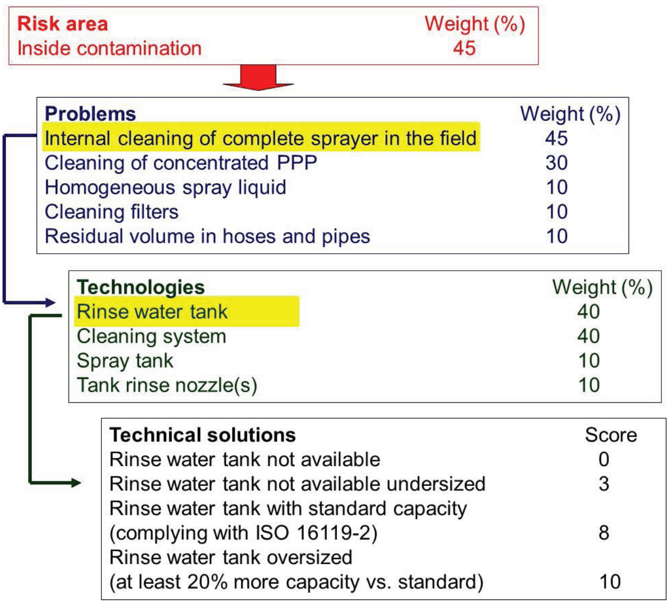

Figure 1. Example of assignment of EOS score for a field crop sprayer.

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References

Roettele M., Balsari P., Doruchowski G., Wehmann H. J (2012). Environmentally Optimised Sprayer (EOS). Evaluation of spray equipment to mitigate point and diffuse source losses of Plant Protection products (PPP) to water. Aspects of Applied Biology 114, International Advances in Pesticide Application, pp. 143-150.

Drift mitigation training: key point to improve pesticide use. Formative actions under TOPPS-Prowadis project

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Introduction

Badly maintained spraying equipment and poor knowledge and calibration practices are major reasons for unintended plant protection products (PPP) losses or overuses. Spray drift, leaching, and run-off are diffuse sources of PPP losses to the environment. These losses may lead to the pollution of soil and water (surface water and ground water), and can be minimized by sprayer inspections and good application practices. All these aspects have been officially addressed in the EU Directive for a Sustainable Use of Pesticides (128/2009/CE), where mandatory inspection of sprayers in use and obligatory training of all involved agents has been enforced aiming at reducing risks derived from pesticide use. With the activities developed under the TOPPS project to reduce point source pollution (2005 to 2008), a wide range of successful actions have been developed in many of the EU Members states. Some have been focused on the development of Best Management Practices (BMPs), their dissemination among stakeholders and trainings and/or demonstrations to operators and advisers. Following these successful actions, the TOPPS-Prowadis project, starting at the beginning 2012, targeted the mitigation of pollution from “diffuse sources”, related to PPP entry routes to water. Information and training intend to create awareness and knowledge about how to optimize the PPP application in order to reduce risks to the environment. Farmers are more willing to accept information sources if they are personally involved and training contents are adjusted to their local specific conditions.

Materials and Methods

TOPPS-Prowadis activity is focused on drift and run-off as main diffuse sources. The already defined *Best Management Practices* to reduce the risk of drift, and the different *Drift Evaluation Tools* to evaluate the risk for drift, must be complemented with an adequate training to guarantee a wide dissemination among users of PPP. The training structure is organized as a “spider web” where the core target include technicians from regional administrations plant protection services, advisors from pesticide companies, contractors associations, advisors from private farms, and research institutes. A one or two days training courses have been designed and planned in all different agricultural areas in the involved EU Members states, following the structure shown in Figure 1. The first part of the courses is dealing with the legislative and official scenario in each country and the EU legislation on pesticide use, the drift problem and its relation to water contamination. Main focus is the presentation of the Best Management Practices to mitigate spray drift. These concentrate on the most relevant aspects: a) the correct behavior of the applicator and b) the optimized selection and adjustment of the application equipment. The second part of the training course is dedicated to show and train the attendants on how to use and benefit from the different tools already developed. *Environmentally Optimized Sprayer* (EOS) (http://www.topps-eos.org/) allows the users to arrange an evaluation of the different spray technologies according to their environmental friendliness. Then, the *Drift Evaluation Tools* (boom sprayers and orchard/vine sprayers) (Doruchowski *et al*, 2013) are presented. These tools create awareness about the spray drift risk factors and the measures to mitigate these risks. Training activities included also an important and well appreciated practical demonstrations where the attendants can see and touch the benefits of the implementation of BMS previously defined: how to use/choose air injection nozzles, how big is the effect of an adequate air flow rate adjustment in orchard/vineyard applications, how to deal with buffer zones depending on the technology, the interest of using water sensitive paper,…Finally, the training course includes the presentation and information on training and materials for advisers , which can be used to further disseminate the Best Management Practices to operators. TOPPS prowadis offers a broad selection of adviser training materials for download in the various languages of the TOPPS project partners. All these material is (or will be) available on the project website (www.topps-life.org) and represent an interesting training tool to complete the intended dissemination actions.

Expected results

Training activities, dissemination of the developed tools and practical demonstrations are very appreciate tools to allow farmers to reach the actual legislative and mandatory framework regarding the use of PPPs. Following the previous actions, the definition and development of the Best Management Practices has been conducted mainly based on aspects related with behavior of the users, more than investment proposals on infrastructures or technology. Obligatory PPP users training on BMP has been chosen as the most efficient procedure to reduce PPP losses into the water, after a European survey (7 countries, 680 answers) conducted prior the definition of the activities.

Figure 1. General structure of training activities arranged under TOPPS-Prowadis project.

Creating awareness for water protection is seen to be reached most efficient by conducting trainings/demonstrations for PPP users and advisers. Most of the stakeholder respondents prefer voluntary trainings for advisers, but obligatory trainings for PPP users Farmers might perceive all proposed official measures as a limitation to their activity. They need to understand that if they don't do anything health authorities might just add other PPP use restrictions of withdrawals. There is a fine line between given advice to farmers and convincing them that it is in their interest to do something. It also needs to be made clear to farmers that some very effective measures do not involve any cost (e.g. sprayer adjustment).

References

Bjugstad N.1998. Control of crop sprayers in Norway. International Conference on Agricultural Engineering AgEng-98, Oslo, Norway, 24-27 August 1998, paper nº 98-A-025, pp. 601-602.

Doruchowski, G.; Balsari, P; Gil, E.; Codis, S.; Marucco, P.; Roettele, M.; Herbst, A.; Pauwelyn, E. 2013. Drift Evaluation Tool to raise awareness about risk of water contamination and drift mitigation measures during orchard spraying. Suprofruit, 2013, Valencia (Spain).

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