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Welcome to the symposium

This 14th Workshop on Spray Application in Fruit Growing offers the floor for presenting the scientific results and for discussing the societal context of the application of plant protection products in orchards and vineyards. As science evolves by open minded discussions and by exchanging results and opinions, we hope to offer you in this workshop an optimal scene for fruitful discussions.

The principal organiser of this conference is the Research Station for Fruit npo, mostly abbreviated as 'pcfruit npo'. Pcfruit was started in 1997 as a coordinating structure of three former research institutes and demonstration gardens, all specialized in fruit growing and located in Sint-Truiden, the heart of the fruit growing area of Belgium. The oldest of these comprising institutes was founded in 1943. Pcfruit is recognized as a reliable, neutral and science-based partner active in various domains of fruit growing. Pcfruit covers applied scientific research, demonstration activities to growers, co-development programs with various kinds of industries and services for fruit growers. All these activities are centralized at one central location with suitable infrastructure like labs, greenhouses, storage facilities, plastic tunnels, shelters, warehouses and orchards. High level of specialism and understanding of the fruit practices have over time been developed in areas as crop protection, biological control, IPM, plant nutrition, application technology, variety evaluation, precision agriculture.

Co-organizers of the 14th Workshop are the University of Louvain with a Faculty of Bio-engineering and ILVO, the Flemish Institute for Agricultural and Fisheries Research, which both have a specialised research team working on spray application technology.

The Workshop is taking place in the former prison of Hasselt, which serves now as the faculty of Law of the University of Hasselt. Hasselt is the capital of the Belgian province of Limburg, of which the south offers the most suitable soil and climate for fruit production. More than 50% of the Belgian fruit is growing in this area. Hasselt is a relatively small city of about 80.000 inhabitants. Today Hasselt traditionally welcomes a lot of short stay tourists and shoppers.

Inge Moors
Deputy of the Province of Limburg for Agriculture
Chairman of pcfruit

www.pcfruit.be
www.ilvo.be
http://www.biw.kuleuven.be/m2s/biosyst/mebios
www.hasselt.be
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Picture: pcfruit vzw

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Program

Tuesday May 9th, 2017	
16:30-18:30	Registration Hasselt University - Aula Louis Roppe Martelarenlaan 42, 3500 Hasselt
19:00-20:00	Welcome reception at the Gouverneurshuis of Hasselt (we walk (+/- 15 min) together from the registration desk)

Wednesday May 10th, 2017	
Opening Session	Hasselt University - Aula Louis Roppe Martelarenlaan 42, 3500 Hasselt
08:00-09:00	Registration
09:00-10:00	Welcome to the Symposium

Oral Session 1 : Pesticide dosing			**Wed May 10**
Time	**Oral Abstract Number**	**Title**	**Presenter**
10:00-10:20	1	Harmonization of pesticide dose expression is a key to dose adjustment	Doruchowski, Grzegorz
10:20-10:40	2	Towards a new model of dose expression in viticulture: Presentation of an experimental approach based on deposition measurement to test the relevance of different scenarios	Codis, Sébastien
10:40-11:00		Coffee and snack break	
11:00-11:20	3	Pesticide dose in persimmon orchards: Bases for its adjustments	Chueca, Patricia
11:20-11:40	4	Adjusting spay volume rates to the canopy vigour from aerial images in a vineyard	Román, Carla
11:40-12:00	5	Effect of formulation and spray application characteristics on the biological efficacy of a contact fungicide	Bakache, Adel
12:00-13:30		Lunch	

Oral Session 2 : Spray coverage			Wed May 10
Time	**Oral Abstract Number**	**Title**	**Presenter**
13:30-13:50	6	Spray deposition and distribution of a cross-flow fan orchard sprayer in spindle apple trees	Michielsen, Jean-Marie
13:50-14:10	7	First results of a campaign for the optimization of spray patterns of orchard sprayers by a moving test bench	Claes, Ruben
14:10-14:30	8	Improving spray deposition in orchard spraying by a Munckhof multiple row sprayer	Wenneker, Marcel
14:30-14:50	9	Basic experimental investigations of different influencing parameters on the quality of the vertical distribution of sprayers	Pelzer, Tanja
14:50-15:10		Coffee and snack break	
15:10-15:30	10	PulvArbo: a French project to improve spray application in fruit growing	Verpont, Florence
15:30-15:50	11	Sprayer classification in viticulture according to their performance in terms of deposition and dose rate reduction potential	Vergès, Adrien
15:50-16:10	12	Spray deposits from a recycling tunnel sprayer in vineyard; effects of the forward speed and the nozzle type	Carra, Mathilde
16:10-16:30	13	Leaf surface topography affecting the dynamic impact behaviour of spray droplets	Delele, Mulugeta Admasu
16:30-16:50	14	Assessment of aerial spray deposition on banana crop based on flight conditions	Cotteux, Eric

Oral Session 3 : Air support of sprayers for three dimensional crops - Part 1			Wed May 10
Time	**Oral Abstract Number**	**Title**	**Presenter**
16:50-17:10	15	Lidar vs. test bench for measurement of drift as affected by sprayer type, air flow, nozzle type and density of vine canopy	Gil, Emilio
17:10-17:30	16	Characterization of the air-flow and liquid distribution of orchard sprayers	van de Zande, Jan

Thursday May 11th, 2017	
Field day	
08:00	Departure in Hasselt by bus Kattegatstraat 1, Hasselt (in front of the Holiday Inn Hotel)
09:00-12:00	Visit Proefcentrum Fruitteelt, SintTruiden
12:00-13:30	Lunch at Proefcentrum Fruitteelt, Sint-Truiden
13:30-18:30	Visit BAB Bamps, Sint-Truiden Orchard visit, Wamoss bvba, Hakendover Vineyard visit, Kluisberg, Assent
19:30-22:30	Symposium dinner at Holiday Inn, Kattegatstraat 1, Hasselt

Oral Session 3 : Air support of sprayers for three dimensional crops - Part 2			Fri May 12
Time	**Oral Abstract Number**	**Title**	**Presenter**
08:30-08:50	17	2D CFD simulations of the air profile of three sprayers adapted to tomato crops in greenhouse conditions	Salcedo, Ramón
08:50-09:10	18	Adjustment of vertical spray pattern of orchard sprayers with Ve.S.Pa. 2.0 application	Tamagnone, Mario

Oral Session 4 : Spray drift / Spray loses			Fri May 12
Time	**Oral Abstract Number**	**Title**	**Presenter**
09:10-09:30	19	Potential spray drift evaluation of airblast sprayers	Grella, Marco
09:30-09:50	20	Spray drift of a cross-flow fan sprayer with wind-dependent variable air assistance	Stallinga, Hein
09:50-10:10	21	First assessments of spray drift in poplar plantations	Marucco, Paolo
10:10-10:30		Coffee and snack break	
10:30-10:50	22	Increasing droplet size in pneumatic cannon-type nozzles to reduce spray drift	Miranda-Fuentes, Antonio
10:50-11:10	23	Spray quality, droplet velocity and spray drift potential of sprays sprayed with additives through standard and venturi nozzles	Rodrigues da Cunha, João Paulo
11:10-11:30	24	Development of a National Spray Application Work Group	Hoheisel, Gwen-Alyn
11:30-11:50	25	Perceptions on how to reduce the risk of Plant Protection Products (PPP) losses to water in fruit production. Results from the European TOPPS stakeholder survey 2016	Roettele, Manfred
12:00-13:30		Lunch	

Oral Session 5 : New technologies on spray applications			Fri May 12
Time	**Oral Abstract Number**	**Title**	**Presenter**
13:30-13:50	26	Measuring canopy density in orchards and vineyards	Landers, Andrew
13:50-14:10	27	Crop characterization by Lidar sensor in different French orchards: preliminary results at early stages	Douzals, Jean-Paul
14:10-14:30	28	Variable rate orchard sprayer based on Lidar sensor	Xiongkui, He

14:30-14:50	29	ICT platform for fruit growing sector in Belgium	Ruysen, Kris
14:50-15:10	30	Field testing and monitoring of newly designed airblast sprayers in traditional olive orchards	Miranda-Fuentes, Antonio
15:10-15:30		Coffee and snack break	
15:30-15:50	31	Optimization of the fogging application of biological control organisms in fruit cold stores	Dekeyser, Donald
15:50-16:10	32	How to stimulate the installation and use of on farm bioremediation systems to avoid point pollution?	Koopmans, Kim
16:10-16:30	33	The electronic measurement of spray coverage	Landers, Andrew
16:30-16:50	34	CFD modelling of spray applications in cool rooms	Delele, Mulugeta Admasu
16:50		End of Symposium	

Saturday May 13th, 2017	
Werktuigendagen SOLV Tuinbouwschool, Diestersteenweg 146, Sint-Truiden	
09:30	Departure in Hasselt by car Kattegatstraat 1, Hasselt (in front of the Holiday Inn Hotel)
10:00-18:00	Visit Open Field Fair for Fruit Growing Equipment (Werktuigendagen), Sint-Truiden

Oral Session 1
Pesticide dosing

Session Chairs: Jerry Cross and Dany Bylemans

Oral Abstract 1
Harmonization of pesticide dose expression is a key to dose adjustment

Greg Doruchowski

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INTRODUCTION

Reduction of PPP use is of the public, environmental and political concern. In high growing crops, such as fruit and vine growing, it is best achieved by adjusting the PPP dose according to the target characteristics, i.e. size and density of the crop canopy. From the product label the applicator must obtain information on the efficient dose per reference unit. This may be Canopy Height-CH (amount/ha/m_{CH}), Leaf Wall Area-LWA (amount/10000 m^2_{LWA}) or Tree Row Volume-TRV (amount/10000 m^3_{TRV}). The dose expression is determined by the data obtained from the efficacy trials and the corresponding efficacy assessment at the very start of the PPP registration process. Harmonisation of dose expression at this stage is needed for the appropriate interpretation and possible conversion of dose expression when the product is authorised at the national level and the label recommendation is specified.

EPPO WORKSHOP

Upon request from EPPO Member Countries the **Workshop on *Harmonized dose expression for the zonal evaluation of plant protection products in high growing crops* took place in Vienna o**n 18-20 October 2016. The focus was on harmonization of the unit in which the dose is expressed (dose expression) rather than the adjustment of the dose to the specific target characteristics (dose adjustment). The dose adjustment based on the harmonised dose expression was considered as an important aspect for the PPP label recommendations at a national level.

Different approaches of dose expression for pome fruit, citrus and olives, grapevine, as well as high growing vegetables were considered both during plenary sessions and in the crop-specific Working Groups. The glossary of terms used in the context of dose expression as well as crop structure parameters that need to be measured and reported during the efficacy trials were discussed. The Excel tool for conversion between different dose expressions and for dose adjustment was proposed (Fig. 1).

OUTCOMES AND CONCLUSIONS

In order to link the dose expression for plant protection products to the crop structure parameters it has been agreed that the LWA will be promoted as an appropriate reference to be used in the zonal efficacy trials for pome fruit, grapevine and high growing vegetables. However, the dose per ha of ground area is to be reported in the GAP table (table of use).

The LWA approach may be used also for double row systems, however its use may be limited in case of the “globular”, isolated trees (i.e. trees/crops that do not form the “leaf walls”, such as citrus, olive, and some stone fruit trees). For such crops additional canopy parameters may need to be collected to enable calculation of canopy width (i.e. the third dimension) that should also be taken into account.

During the efficacy trials all relevant parameters of the three-dimensional crop should be measured according to the EPPO Standard PP 1/239 (*Dose expression for plant protection products*), and made available in order to allow conversion of different dose expressions. An illustrated guideline on how to measure in the field all types of parameters for different crops and training systems will be elaborated, and the proposed dose conversion Excel tool will be further developed. The glossary of terms used for crop characterisation and dose expression will be elaborated in order to provide a common language for communication between the involved parties.

The revision of EPPO Standard PP 1/239 is to be discussed on the EPPO Panel on General Standards. It should include an improved scheme of "Conversion of different dose models for high crops". Two Working Groups were established by EPPO: (i) for improving and further development of the dose conversion Excel tool, and collecting further information on national crop parameters: (ii) for elaboration of the glossary of terms and the guideline on measurement of crop parameters.

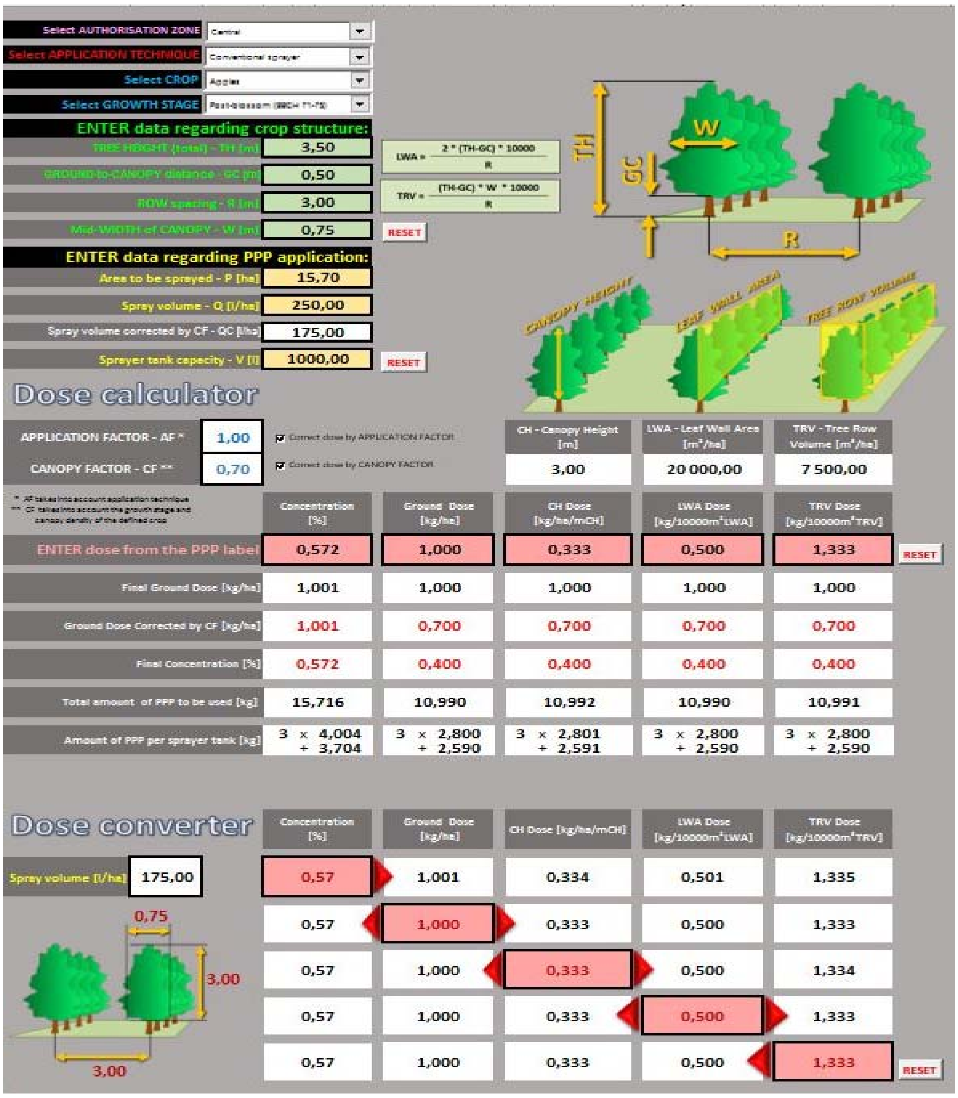

Fig. 1. The Excel tool for conversion between different dose expressions and dose adjustment.

Oral Abstract 2
Towards a new model of dose expression in viticulture: Presentation of an experimental approach based on deposition measurement to test the relevance of different scenarios

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INTRODUCTION

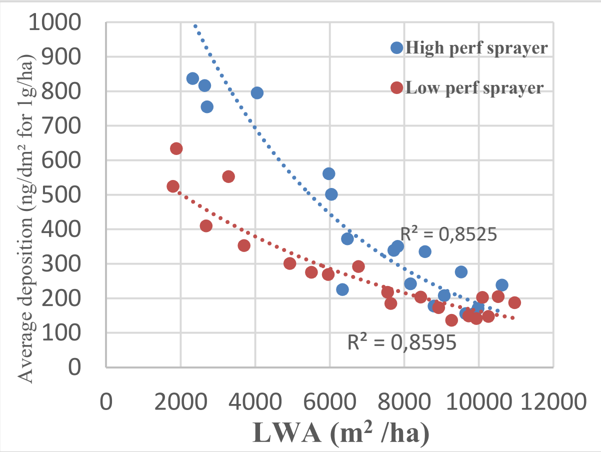
The current regulatory context, in particular the implementation of the national action plan Ecophyto (Directive 2009/128/EC) and the high societal demand for the reduction of the use of pesticides, have led to reconsider the whole plant protection process. Among the questions raised is the dose expression of the products used for plant protection. This topic has been identified as one priority of the version 2 of the national action plan (report Ecophyto v.II; 2015): "The procedures for plant protection products registration will be reviewed in order to define differentiated doses based on crop development ". The current system of dose expression in France is based on a fixed dose, defined per unit area of ground (L or Kg/ha). This single dose does not depend on any technical considerations related to application conditions, vegetation volume or even row spacing. The advantage of this system is its simplicity for farmers. However, when compared to countries (DE, CH) implementing a dose modulation according to BBCH growth stages (Toews and Friessleben, 2012; Cross, 2009), the French dose expression system leads in practice to quantities of deposition per unit area on the target (leaves and bunches) which highly vary depending on the amount of vegetation to be protected. Thus, this fixed dose, which effectiveness has been demonstrated in most cases by registration efficacy trials, is systematically used, whereas a reduced dose would be equally effective in many situations (less vegetation to be covered in particular). An ideal dose expression system would be defined according to crop parameters and would lead to constant and sufficient deposits per unit area on the target in order to ensure protection efficacy. In order to identify the best combination of crop parameters on which a new dose expression could be based, IFV (French Wine and Vine Institute) and IRSTEA (French Research Institute for Environment and Agriculture) have launched a new approach dedicated to assess spraying performance through deposition measurements in a wide range of field conditions (vigor, training system, vegetation architecture, ...).

MATERIALS AND METHODS

In 2016, spray deposit measurements have been carried out according to ISO22522:2007 on a vine estate (Domaine Mas Piquet, 15 ha, Languedoc). On this estate, plots vigor ranges from low to medium compared to other vineyards. On 4 days (28th April, 25th May, 23rd June and 18th July), spray deposition has been measured on 5 plots of different vine varieties chosen for their distinct vigor. Two different sprayers have been used: a low performance sprayer (pneumatic arch sprayer used every 4 rows: Voûte Calvet®, representing the most common practice in the French vineyard) and a high performance sprayer (air assisted side by side sprayer (Precijet, Tecnoma®) fitted with hollow cone nozzles :TXA Teejet®, Pressure 5 bars). Spray deposition was measured using a tracer (Tartrazine E102) sprayed on sampling PVC collectors: on each plot, 4 trees have been sampled. On each tree, collectors were positioned on leaves within the canopy according to a profile perpendicular to the row, following a grid 20cm high and 10cm wide with one collector per pixel. A total amount of 3077 collectors have been analyzed individually. Results provide the normalized deposit expressed per unit of leaves area for one gram of tracer sprayed per hectare (unit: $ng.dm^{-2}$ for 1 $g.ha^{-1}$). The distribution of tracer within the canopy (CV,%) was also assessed. In parallel, crop parameters have been measured manually on each sampled tree: height, average and maximum of thickness, TRV (Tree Row volume), LWA (Leaf Wall Area).

RESULTS AND DISCUSSION

Figures 1 and 2 present the correlations between the average normalized deposit per plot and the values of crop parameters (LWA fig. 1 and TRV fig. 2). The data for the 5 plots, the 4 dates and the 2 sprayers are represented. Whatever the sprayer considered, exponential models provide good correlations (R^2>0,85) between average deposition and the crop parameters for both LWA and TRV. This work shows that modulating the dosage according to crop parameters is an important lever to achieve chemical use optimisation (normalized deposition varying from 1 to 5 during the growth season).



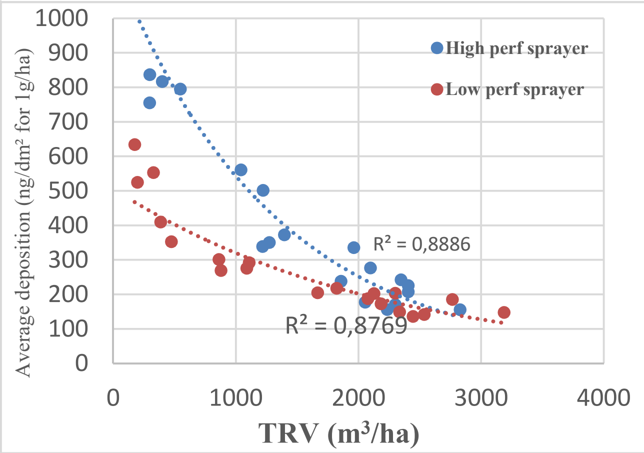


Fig. 1. Correlation between spray deposits and LWA at plot level. Fig. 2. Correlation between spray deposits and TRV at plot level.

Nevertheless, concerning the relation between LWA and deposit, we have to consider that the low to medium range of vigor that has been explored did not allow to reveal the likely influence of thickness of canopies on deposit. Next years, trials will be carried out in a wider range of plot vigor and row spacing. Measurements of deposit obtained at collector's scale also allowed to establish relations between not only the average deposition but also the different percentile of deposition (10th percentile, 20th percentile, …). This set of data will allow to test different scenarios of dose expression. The final goal is to set up a grid of dose adjustment for which entry parameters can be easily documented at field level by users with for instance distance between rows, growth stage, height of the crop, average of thickness…

ACKNOWLEDGMENTS

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REFERENCES

Cross, J., 2009. Outline Report of the 1st Meeting of the Tree Fruits Dose Expression and Adjustment Discussion Group, Wageningen (NL), 09-15.

Ecophyto version II, ministère de l'agriculture, 2015 [*http://agriculture.gouv.fr/sites/minagri/files/151022_ecophyto.pdf*](http://agriculture.gouv.fr/sites/minagri/files/151022_ecophyto.pdf)

Toews R-B., & Friessleben R., 2012. Dose Rate Expression - Need for Harmonization and Consequences of the Leaf Wall Area Approach. Erwerbs-Obstbau June 2012, Volume 54 , 49-53.

Oral Abstract 3
Pesticide dose in persimmon orchards: Bases for adjustment

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INTRODUCTION

In Spain, production of persimmon (*Diospyros kaki* Thunb.) has increased by 80% in the last decade. New phytosanitary problems emerged, which required foliar spray applications. Current spray programs in persimmon orchards in Spain consist of applying large amounts of spray volume. In this work, the bases for the dose adjustment of spray applications to the singularities of persimmon orchards in Spain are presented.

MATERIALS AND METHODS

The study was carried out in two commercial established orchards with different framework cultivated with persimmon 'Rojo Brillante' located in L'Alcúdia (Valencia, Spain). Spray distribution assessment was carried out during real pesticide applications. Spray timing was decided by the crop advisor in each orchard depending on the application target. Pesticide treatments were based on pest population, risk of disease development, or harvest management strategy. During applications, the conventional spray volume rate was compared with reductions of 20% and 40% (Table 1). Treatments were carried out with an axial fan air-blast sprayer with standard disc and core nozzles. The set up of the sprayer was the same for both orchards except the nozzle orientation, resulting in the same flow rate (L/min) but different spray volume (L/ha).

Table 1. Application dates, phenological stages (BBCH), pesticides and spray volume rates evaluated in orchards of persimmon 'Rojo Brillante' at L'Alcúdia (Valencia, Spain).

Year	Date	Objective	Product**	BBCH	Spray volume (L/ha)					
					Conventional		80%con		60%con	
					Orch. 1	Orch. 2	Orch. 1	Orch. 2	Orch.1	Orch. 2
2015	30/04-05/05	*M. nawae*	-	67	1300	1500	-		790	950
	28/05-04/06	*M. nawae* + Mealybug complex*	-	73						
	18-25/09	Harvest advance	-	87						
2016	23-24/05	*M. nawae*	Score (25 ml/hl)	73	1300	1500	1000	1200	790	950
	16/06	*M. nawae* + Mealybug complex*	Ortiva (67.5 ml/hl) Reldan (350 ml/hl)	75						
	02-03/08	Mealybug complex*	Movento Gold (100ml/hl)	79	2500	3000	2000	2300	1500	1800

*Mealybug complex= *Planococcus citri* + *Pseudococcus viburni*
***Indicated only in treatments were efficacy was evaluated.*

Spray distribution in the canopy was estimated through coverage on water sensitive papers. In parallel, persimmon canopy of the two orchards was characterized each time of application by estimating canopy volume and foliar density (Fig. 1).

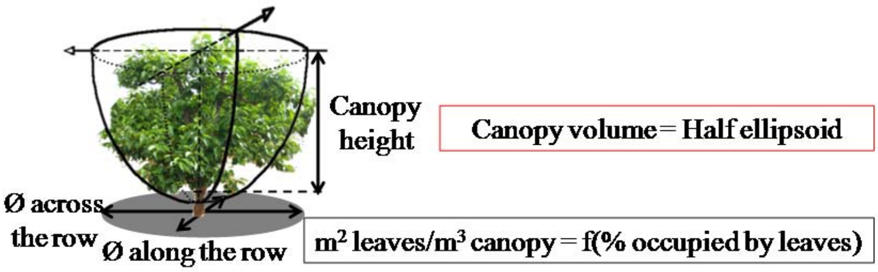

Fig. 1. Characterization of persimmon canopies.

In the season 2016, biological efficacy was assessed: The level of mealybug complex (*P. citri* and *P. viburni*) 14 days after treatment, and the incidence and severity of circular leaf spot, caused by *Mycosphaerella nawae,* at harvest.

RESULTS AND DISCUSSION

The reduction of spray volume induced a decrease of the coverage in all applications (Fig. 2A). On the other hand, canopy volume and foliar density increased along the season, and consequently coverage decreased along the season. Despite the reduction of coverage, reduction of spray volume did not affect the biological efficacy of pesticide applications against *M. nawae* (Fig. 3B) and mealybug complex.

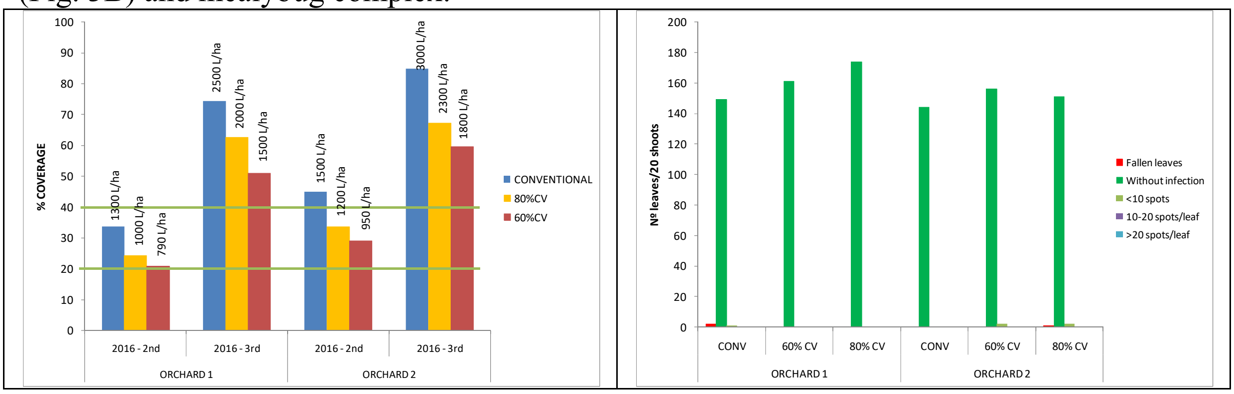

Fig. 2. A) Estimated coverage for each application and orchard in the season 2016. B) Incidence of circular leave spot produced by *M. Nawae* for each application and orchard in the season 2016.

Sprayer calibration together with the reduction of spray volume improved the efficiency, and thus resulted in costs savings and environmental pollution decreases, due to the reductions of pesticide use and drift losses.

Oral Abstract 4
Adjusting spray volume rates to the canopy vigour from aerial images in a vineyard

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INTRODUCTION

One way to reduce the risk associated with the use of pesticides in tree and tall row crops is to adjust their doses to the canopy dimensions (Gil et al., 2014; Pergher and Petris, 2007; Planas et al., 2015; Walklate et al., 2011). At present, the use of remote images in viticulture is only devoted to differential management of the irrigation and fertilization. Remote detection is only starting to be used for pests and diseases control. This work is a first evaluation of a new use of remote images for differential space dosing of pesticides in vineyards. For this purpose, a pilot trial was conducted in 2016.

MATERIALS AND METHODS

The trial was conducted in a trellis Tempranillo vineyard (13.0 ha) in Lleida-ES at the ripening of berries (83-85 BBCH).

Plant Cell Density index obtained from aerial images and its subsequent analysis enabled the differentiation of two vigour classes: High Vigour (HV) and Low Vigour (LV) (Fig. 1 left). Differences in leaf area index (LAI) were confirmed by defoliating and measuring three vines for each class. The spraying volume rates were adjusted for each class by the DOSAFRUT system (Planas et al., 2015) according to the LAI. The sprayer used was a multi-row Ilemo Hardi Iris equipped with 24 Albuz ATR yellow cone nozzles (Fig. 1 right). The forward speed was 6.5 km h^{-1} and the working pressure was quickly changed via a bypass switched by the operator every time the area border was crossed over in accordance with the onboard GPS. Previously, the sprayer had been calibrated for both working pressures (Table 1).

Figure 1. PCD index map for two vigour areas: High and Low (left) and Ilemo Hardi IRIS sprayer (right).

Table 1. Spraying operative parameters and absolute leaf deposition (mean ± SE) for High and Low vigour classes, different letters are significantly different (LSD test, $P < 0.05$).

Class	Dimension (ha)	LAI	Volume rate ($L\ ha^{-1}$)	Mn^{++} ground dose ($g\ ha^{-1}$)	Working pressure (bar)	Absolute deposition ($\mu g\ cm^{-2}$)
HV	10.4	1.45	418	843	14	3.1±1.3 a
LV	2.6	0.98	318	642	8	3.5±1.3 a

Leaf depositions and losses to the ground were measured in three replicates using Mn chelate as a tracer (2.02 g L^{-1}). In each replicate, leaf depositions from nine different sampling zones (three heights and three depths) of two vines were analysed. Ground losses were evaluated with seven artifical collectors per replicate and expressed as a percentage of the liquid sprayed. Mn^{++} concentration from the samples and spray tank were determined by atomic absorption spectrometry. Depositions on leaf and ground collectors were related to the surface of the sample. A two-way ANOVA was run using vigour (V) and canopy zone (Z) as factors. Spray leaf recovery was normalized by LAI.

RESULTS AND DISCUSSION

In the area of the LV class there was a 24% reduction in the dosage, representing a 5% saving for the whole vineyard.

The interaction between factors did not show significant differences ($P_{Vigour * Zone} = 0.65$). Regarding the single effects, there were non-significant differences on the absolute leaf deposition (Table 1). This result is interesting since the therapeutic dose per leaf surface is not compromised when applying at LV dose. Studying the sampling zones, there were no differences on deposition for height, but there were for depth, the higher value being in the outer part of the canopy. This fact reemphasizes that the barrier effect of the vine leaves complicates spray penetration. The absolute spray depositions had similar zonal distributions in both vigour classes (Fig. 2 left).

Spray leaf recovery was similar for both vigour zones; however the ground losses were higher in LV due to their lower targeting surface (Fig. 2 right).

Accordingly, this study lays the groundwork for the adjustment of dosage for 3D crops through the use of aerial images.

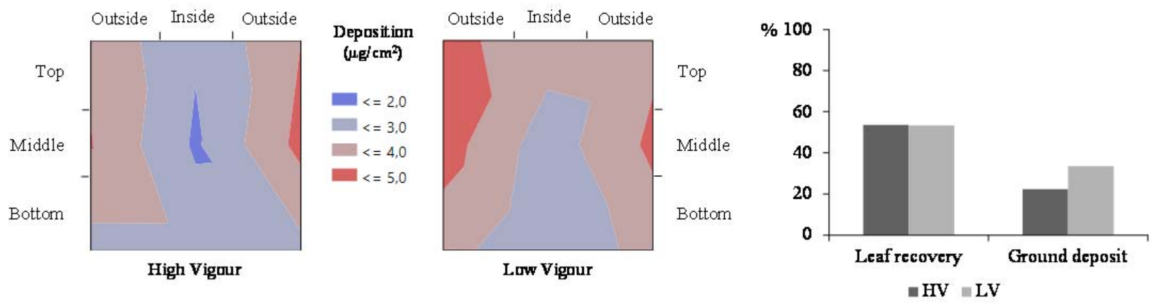

Figure 2. Mn^{++} absolute deposition ($\mu g\ cm^{-2}$) on canopy zones achieved in each vigour class (left) and leaf recovery (efficiency) and ground deposits as percentage of the total liquid sprayed (right).

ACKNOWLEDGEMENTS

Thanks to Codorníu SA and AgroPixel SL for the aerial images and logistic support. This project has received funding from the EU Horizon 2020 programme under grant agreement No 633999 (EUCLID project).

REFERENCES

Gil, E., Arnó, J., Llorens, J., Sanz, R., Llop, J., Rosell-Polo, J.R., Gallart, M., Escolà, A., 2014. Advanced technologies for the improvement of spray application techniques in Spanish viticulture: An overview. Sensors (Switzerland) 14, 691–708. doi:10.3390/s140100691

Pergher, G., Petris, R., 2007. Canopy Structure and Deposition Efficiency of Vineyard Sprayers. J. Agric. Eng. 31–38. doi:10.4081/jae.2007.2.31

Planas, S., Sanz, R., Camp, F., Solanelles, F., Rosell, J.R., 2015. The new concept of dose adjustment in tree crops, in: Suprofruit'2015 – 13th Workshop on Spray Application in Fruit Growing.

Walklate, P.J., Cross, J. V., Pergher, G., 2011. Support system for efficient dosage of orchard and vineyard spraying products. Comput. Electron. Agric. 75, 355–362. doi:10.1016/j.compag.2010.12.015

Oral Abstract 5
Effect of formulation and spray application characteristics on the biological efficacy of a contact fungicide

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INTRODUCTION

Black Sigatoka induced by *Mycosphaerella fijensis* can cause losses in banana production ranging from 20 to 50 % (Stover, 1987). The use of contact fungicides is widespread because of their preventive effect on the development of fungus spores, and the low risk of development of resistant strains, unlike systemic fungicides.

Many methodological approaches are used to assess physical efficacy of a spray application (Bonicelli, 2015) but a few studies reviewed the relationship between spray application characteristics and their effect on banana black sigatoka control (Washington, 1997).

The aim of this study was to assess the effect of formulation and spray application characteristics on the biological efficacy of a contact fungicide to control banana black sigatoka. The first step of the study was to test the effect of those factors on a small scale, the final objective was to optimize aerial applications at banana plantation level.

MATERIALS AND METHODS

Experiments were carried in Njombé Cameroon on young banana trees (4 leaf stage, 1m height). An artificial infestation was performed at the beginning of each trial by suspending necroses above banana trees. The experiments were carried out from February to June 2016.

Spray applications were applied using an electrical sprayer specifically developed for our experimentation with an application rate of 20l/ha.

Each plot contained a raw of 10 young banana trees for different modalities and a raw of controls (untreated samples) as presented in Fig.1.

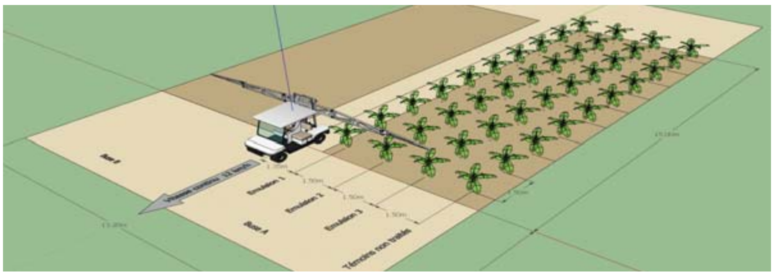

Figure 1: Experimental design

Two nozzle types (Teejet FF even jet TP95015E and Teejet AI even jet AI95015EVS) were used on each side of the boom respectively and three formulations including paraffinic oil were tested on each side.

- Dithane 60 OS (mancozeb) + water
- Dithane 60 OS +Water+15% of paraffinic oil (Maxpar) + 0.1% of Triton X45
- Dithane 60 OS +Water+35% of paraffinic oil (Maxpar) + 0.1% of Triton X45

Altogether three plots were set up with respective fungicide dosage of 50, 25 and 10% of the rated dosage.

Disease assessment:

Disease severity ratings were assessed on all banana trees using a lesions counting protocol that takes into account the number of black Sigatoka lesions on the plant's leaf 1.

Biological efficacy was calculated using the following formula

$$\text{Treatment efficacy (\%)} = \frac{\text{Nb of lesions local control} - \text{Nb of lesions banana tree leaf}}{\text{Nb of lesions local control}}$$

Data analysis:

Collected data was analysed using non parametric tests, comparisons where done using Kruskal Wallis test and Dunn's rank sums test at 5% level of significance.

RESULTS AND DISCUSSION

The experiments were conducted to determine the effect of the formulation, of the spray quality and dosage of a contact fungicide on biological efficacy. All treatments reduced disease severity without any phytotoxicity.

The global infestation on control groups was heterogeneous from one plot to the next because of the uneven distribution of the pathogen. Treatment efficacy was then calculated according to the mean of the local group control of each plot; this method was used in order to normalize data from different trials.

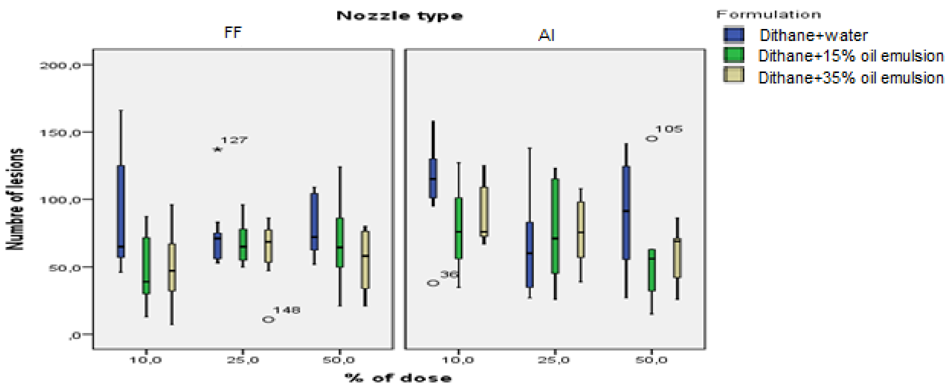

Fig. 2 : Biological efficacy of the different modalities for one trial

Results showed no significant effect of the nozzle type on biological efficacy when comparing all modalities. In contrast, formulation had the most significant effect on biological efficacy. Mancozeb used with paraffinic oil was more effective than when applied with water, due to fungistatic and spreading effects of paraffinic oil formulation.

Indeed, the importance of taking spatial distribution of the pathogen on treated and untreated samples into account to avoid any spatial bias when analyzing the data was demonstrated.

CONCLUSION

Globally, these experiments demonstrated the effects of the factors influencing biological efficacy. However, the protocol may be improved in order to better qualify the individual contribution of each parameter.

Optimal conditions will be applied at a larger scale using aerial application in order to reduce applied doses.

REFERENCES

Bonicelli, B., Cotteux, E., & Douzals, J. P. (2015). Pesticides applications assessment in banana crop conditions: a methodological approach. Environmental Science and Pollution Research, 22(21), 17255-17259.

(Stover, 1987) Stover, R. (1987). Somaclonal variation in grand naine and saba bananas in the nursery and field. In Banana and plantain breeding strategies, volume 21, pages 136–139. ACIAR Proc. 21, ppl36-139.

(Washington, 1997) Washington, J. R. (1997). Relationship between the spray droplet density of two protectant fungicides and the germination of mycosphaerella fijiensis ascospores on banana leaf surfaces. Pesticide Science.

Oral Session 2
Spraycover

Session Chairs: Paolo Balsari & Marcel Wenneker

Oral Abstract 6
Spray deposition and distribution of a cross-flow fan orchard sprayer in spindle apple trees

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INTRODUCTION

To improve the current practice of spray application in fruit crops a research programme was setup assessing spray and liquid distribution of nowadays often used single- and multiple-row orchard sprayers and spray deposition and distribution in orchard trees. Potential pathways of improvement are; air amount, air distribution, nozzle type and therefore liquid distribution as the spray is transported by the moving air into the tree canopy. Improved spray deposition can lead to reduced use of agrochemical and therefor reduced emission to the environment while maintaining high levels of spray drift reduction and biological efficacy. In this paper results are presented for a single row cross-flow fan sprayer.

MATERIALS AND METHODS

Spray deposition measurements were performed in an apple orchard (Randwijk, The Netherlands) to quantify the effect of a reference cross-flow fan orchard sprayer (Munckhof) in a full leaf situation (June-October 2016). Apple trees (Elstar) are of the spindle type spaced at 1 m in the row and at 3 m row spacing. The sprayer was equipped with standard hollow cone nozzles (Albuz ATR lilac) and a 90% drift reducing venturi hollow cone nozzle (Albuz TVI8001) both operated at 7 bar spray pressure and a forward speed of 6.7 km/h. Eight nozzles were used on both sides of the sprayer resulting in a spray volume of resp. 200 l/ha and 290 l/ha. Air setting during the experiments was in the high or low setting of the fan gear box. To measure the spray deposition in the apple tree a single row was sprayed with a fluorescent tracer (BSF 0.3 g/l) from both sides spraying consecutively from the left and right hand side of the sprayer (same driving direction). To sample the spray distribution the tree was divided in 7 compartments: top, middle-east, middle-west, bottom-east-outside, bottom-east-inside, bottom-west-outside and bottom-west-inside. From four trees the leaves in each compartment were counted and every tenth leaf was picked and put in a sample bag. Number of leaves per compartment were recorded and in the laboratory 10 leaves were taken from the sample and washed with a fixed amount of deionised water to recollect the tracer from the leaf surface. The surface area of the individual leaves was measured (Li-cor). Tracer amount in the solution was measured using a fluorimeter (Perkin-Elmer LS50) and expressed as $\mu l/cm^2$ and % of applied spray volume per tree compartment and for the whole tree. Specific parameters as mean, median, CV of leaf samples per compartment of 40 leaves, CV per compartment in the tree and CV between mean total deposition in the trees can be presented.

RESULTS AND DISCUSSION

The average liquid and air speed distribution at the left and right hand side of the crossflow fan sprayer is presented in figure 1 for the full air fan setting and the Albuz ATR lilac nozzles (7 bar). Liquid distribution over height is different for both sides and not similar. Air speed distribution is also not similar on the left and right hand side and shows a gap at 2-3 m height.

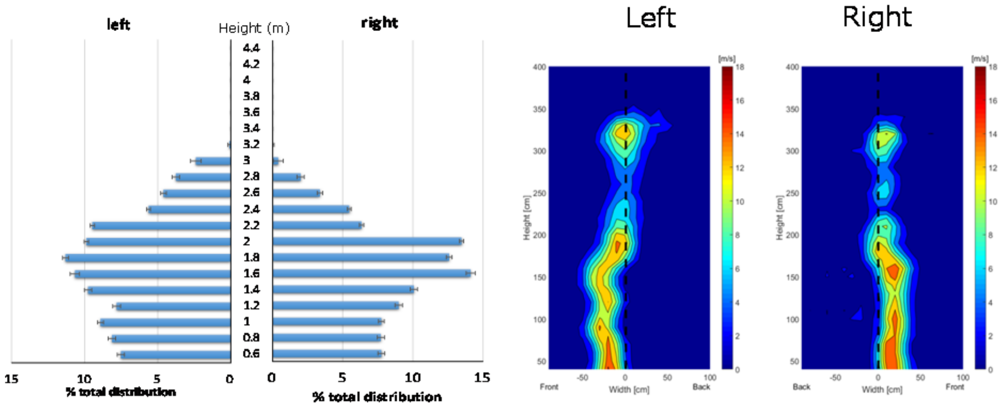

Figure 1. Liquid (left; % of total spray volume) and air speed (right; m/s) distribution over height (m) at 1.5 m distance from the centre line of the sprayer of the left and right hand side of the cross-flow fan sprayer (Munckhof ATRlilac@7 bar; full air).

The result of the liquid and air distribution (fig. 1) is the input for the measured spray deposition in tree canopy of an apple orchard. As an example the results of June 9th 2016 (fig. 2) are given for the Munckhof ATR lilac (7 bar) at full air setting presented as the average spray deposition per compartment of the four sampled trees (10 leaves per compartment). Spray deposition was between 0.45 µL/cm^2 in the top of the tree and 0.20 µL/cm^2 in the bottom-inside compartment of the tree. Average spray deposition for all compartments of the four trees was 0.31 µL/cm^2 with a coefficient of variation (CV) between the 4 trees of 7%. Variation in spray deposition between the compartments of the four trees varied between 7% in the top of the tree and 26% in the bottom inside part of the tree. Within a compartment the variation between spray deposition at individual leaves was large. CV for the 40 leaves per compartment picked was between 39% in the bottom outside compartment to 79% in the top of the tree. Spread in spray deposition in the top of the tree was between 0.06 and 1.49 µL/cm^2, which is a 25-fold difference. On average only 30-40% of applied spray volume was traced back in tree canopy.

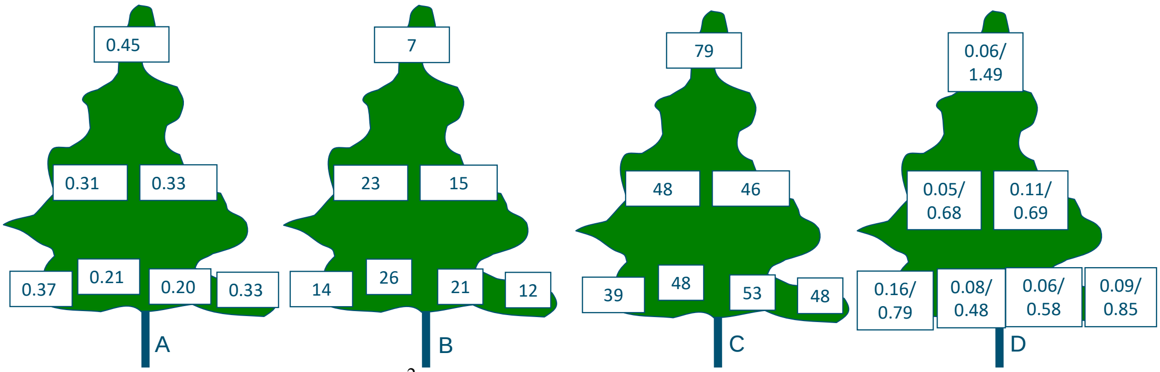

Figure 2. Spray deposition (µl/cm^2) of a cross-flow fan sprayer (Munckhof ATRlilac at 7 bar; full air) in full leaf apple tree (9 June 2016); distribution in compartments (A), coefficient of variation per compartment of 4 trees (B), coefficient of variation inside a compartment (C) and min/max per compartment of 4 trees (D).

Oral Abstract 7
First results of a campaign for the optimization of spray patterns of orchard sprayers by a moving test bench

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INTRODUCTION

Farmers pay a lot of attention in their the choice of Plant Protection Products (PPP). They follow the advised dose and select the optimal application moment. However, sometimes it happens the biological efficacy is not what they expected. This situation gave rise to the question how well the spraying technology of the growers fits to their orchard and the planting system. Assessment a dozen of sprayers in the orchard with water sensitive paper, demonstrated that there was room for improvement on the adjustments of spraying equipment to the specific orchard characteristics. We also intend to advise about the adequate maintenance of the orchard sprayers.

MATERIALS AND METHODS

We used the moving test bench from AAMS-Salvarani which allows measurement of the spraying cloud in a grid from 0.6m to 4.4m in steps of 0.2m. The test bench is moving through the spray cloud of a stationary working orchard sprayer and by collecting water in a collector grid to measure the vertical spray distribution of the sprayer.

Tests were done with vertically mounted water sensitive paper at different heights. These results were compared with the results of the moving test bench..

Adjusting sprayers we use the possibilities present on the sprayers as there are: air ducts, positioning of nozzles, different nozzle sizes.

RESULTS AND DISCUSSION

To test whether the moving test bench is an adequate measuring system we made a comparison of this test compared to tests with water sensitive paper in our experimental orchards. We compared ten new orchard sprayers, each time in 4 planting systems. This test showed that the measured distribution in the moving bench matches the spray patterns on the water sensitive papers. We compared the maximum height which could be reached and the positions with an over- and under dose.

Furthermore, we did a check-up of 4 sprayers of farmers who had problems with apple scap. In all cases we found a strong correlation to the position of the disease and lower depositions in certain regions of the canopy. These imperfections were adjusted to optimize the distribution.

At the beginning of the 2016 season we started with an on farm service to adjust sprayers of as a commercial service. In 2016 we tested 80 orchard sprayers, both axial and cross-flow sprayers. Most of the problems are caused by air duct problems and the position of nozzles relative to the air stream. On top of that there are problems due to inadequate maintenance of the sprayers like blocked nozzles and polluted air system or fans. All spraying machines had to be adjusted. Growers are willing to pay a fee of 190 euro for the adjustment because they are convinced of the advantages like a better efficacy of the PPP, of which the total costs are 2000-2500 euro per ha.

Oral Abstract 8
Improving spray deposition in orchard spraying by a Munckhof multiple row sprayer

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INTRODUCTION

It is proven that multiple row sprayers reduce spray drift significantly (Wenneker et al., 2014, 2016). This is due to the spraying system that sprays tree rows from both sides at the same time, in contrast to standard orchard sprayers that spray the tree row only from one side. It is assumed that spray deposition is improved when spraying with multiple row sprayers and dose can therefore be reduced accordingly, without reducing biological efficacy.

To improve the current practice of spray application in fruit crops a research programme is setup assessing spray and liquid distribution of nowadays often used orchard sprayers and spray deposition and distribution in orchard trees. Potential pathways of improvement are; air amount, air distribution, nozzle type and therefore liquid distribution as the spray is transported by the moving air into the tree canopy. Comparative measurements of a reference spray technique and multiple row techniques are compared for liquid distribution, air distribution and spray deposition in apple trees.

The objective is to find the optimum combination of application parameters for different stages of canopy development to improve spray deposition. In the experiments multiple row orchard sprayers of two manufacturers (Munckhof and KWH), were compared to a conventional cross-flow fan sprayer (Munckhof). In this abstract the first results of the Munckhof multiple row sprayer are described.

MATERIALS AND METHODS

Spray deposition measurements were carried out following the ISO-22522 protocol. The spray deposition measurements were performed in an apple orchard (Randwijk, The Netherlands) to quantify the effect of a reference cross-flow fan orchard sprayer (Munckhof) and Munckhof multiple row sprayer in a full leaf situation (June-October 2016). The reference sprayer was equipped with a standard hollow cone nozzle (Albuz ATR lilac), operated at 7 bar spray pressure and a forward speed of 6.7 km/h. Eight nozzles were used on both sides of the sprayer resulting in a spray volume of 200 l/ha. Air setting during the experiments was in the high fan gear box setting of the sprayer. Also, for the multiple row orchard sprayer (used as 2-row sprayer) the spray pressure was 7 bar, 4 x eight nozzles (Albuz ATR lilac) were used, applying a spray volume of 200 l/ha. Air assistance was set to full air (540 rpm PTO) and reduced air (400 rpm PTO).

To measure the spray deposition in the apple tree both sprayers sprayed the tree rows with a fluorescent tracer (BSF 0.3 g/l). For the reference sprayer a single row was sprayed from both sides spraying consecutively from the left and right hand side of the sprayer (same driving direction). For the multiple row sprayer two tree rows were sprayed at the same time. In all cases four individual trees were sampled; i.e. spraying 30 m of a single tree row from both sides for the reference and two tree rows with two sample trees in both rows for the multiple row sprayers. Leaf samples were taken by counting all leaves in seven tree sections: Top, Middle East side, Middle West side, Bottom Inside West, Bottom Outside West, Bottom Inside East, Bottom Outside East and putting every 10th leaf in a bag. The picked leaves were analysed in the laboratory for spray deposition of the sprayed fluorescent tracer BSF. The leaf areas were determined, and the spray deposition was calculated and expressed as $\mu l/cm^2$ and % of applied spray volume per tree compartment and whole tree.

RESULTS AND DISCUSSION

On average spray deposition in the whole tree is for the Munckhof multiple row sprayer in low and full air (respectively 0.59 and 0.67 µl/cm^2) higher than for the standard Munckhof cross-flow fan sprayer full air (0.53 µl/cm^2). In some of the tree compartments the Munckhof multiple row sprayer increased spray deposition by 50-90%, compared to the reference sprayer; especially in the tree compartments Top, Bottom Inside West, and Bottom Outside West.

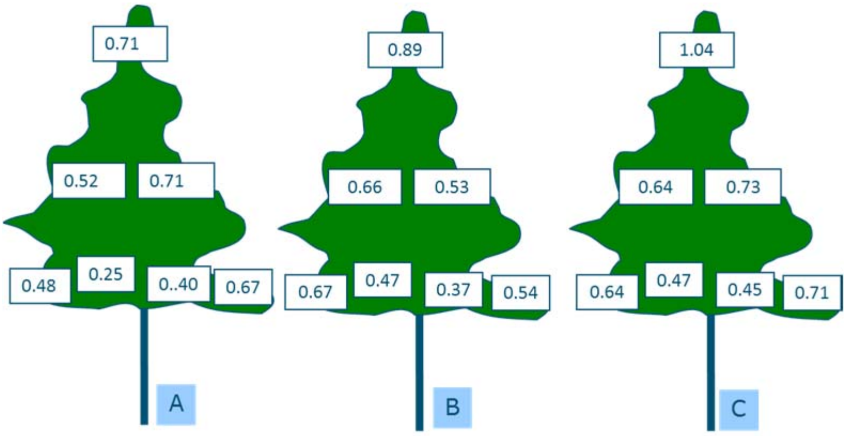

Figure . Spray deposition (µl/cm^2) in seven tree section in apple trees spraying with; A - reference sprayer (Munckhof ATRlilac@7 bar, full air); B – Munckhof multiple row sprayer, ATR lilac@7 bar, low air; C - Munckhof multiple row sprayer, ATR lilac@7 bar, full air.

It is assumed that spray deposition is improved when spraying with multiple row sprayers and dose can therefore be reduced accordingly, without reducing biological efficacy. Further research is needed to adjusted sprayer configurations for a further improvement of spray deposition in the tree canopy.

REFERENCES

Wenneker M, Zande van de JC, Stallinga H, Michielsen JMPG, Velde van P, Nieuwenhuizen AT. 2014. Emission reduction in orchards by improved spray deposition and increased spray drift reduction of multiple row sprayers. Aspects of Applied Biology 122, International Advances in Pesticide Application 2014: 195-202.

Wenneker M, Zande van de JC, Michielsen JMPG, Stallinga H, Velde van P. 2016. Spray deposition and spray drift in orchard spraying by multiple row sprayers. Aspects of Applied Biology 132, International Advances in Pesticide Application 2016: 391-395.

Oral Abstract 9
Basic experimental investigations of different influencing parameters on the quality of the vertical distribution of sprayers

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INTRODUCTION

In the application of plant protection products to vertical crops technical challenges to achieve a uniform distribution of the spray liquid on the target surface are significantly higher than in field crops. The reasons are numerous. Whereas the application in horizontal crops can be conducted with nearly uniform distance to the target area, the distance between the nozzle and the target area in vertical crops can vary considerably during the application. The transport of the droplets onto the target area is mostly realized by active air support, whereas this method is the exception in field crops. In addition, the adjustment possibilities of spraying devices are considerably more complex which is also due to the high diversity of cultivation methods in vertical crops which stand for differently designed equipment to fulfill all needs.

MATERIALS AND METHODS

The reason for carrying out an experimental investigation at a vertical distribution test bench is to determine whether and, if so, how much different parameters affect the quality of the vertical distribution of sprayers.

The aim of the study is to generate more basic knowledge about the specific influence of different technical parameters on the spray behavior in order to take this knowledge into consideration in the further development of spraying technology and in the future elaboration of recommendations for the optimal adjustment of such devices. For this purpose, an experimental setup was designed to investigate the technical parameters as pressure, distance to target area, nozzle-to-nozzle distance, nozzle type and air-supported vs. application without air regarding their effect on the vertical distribution. All five parameters could be varied. The distributions, achieved at the test bench, were then assessed using the coefficient of variation.

RESULTS AND DISCUSSION

The results show that all of the parameters considered have an influence on the vertical distribution, which however is at different levels. The observed high standard deviations in the results of the measurements suggest that the parameters also influence and interact with each other. However, these effects were not quantified fully yet. The result of the analysis suggest that the nozzle type has the greatest influence, the distance to the target surface as well as the distance from nozzle to nozzle influence the distribution also significantly, while the injection pressure as well as the air support have a smaller influence during the application. The latter is presumably due to the type of fan used in the measurements (cross flow). These experiments demonstrated that it could be very useful to investigate these and maybe some more parameters in order to optimize sprayer adjustment in future. Therefore, a lot of different parameter combinations have to be analyzed in further experiments.

Oral Abstract 10
PulvArbo: a French project to improve spray application in fruit growing

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INTRODUCTION

Over the last fifteen years, French research focussed on the implementation of alternative methods in fruit growing based on (i) the use of biocontrol products, (ii) the use of mechanical protection techniques and/or (iii) the use of resistant varieties. However, these methods are not adequate to overcome the use of plant protection products. All these works contribute to achieve a part of the objectives of the national action plan Ecophyto (reduce the use of PPP with25% in 2020 to 50% in 2025). Another way to achieve this goal is to improve the spray application techniques. A national multidisciplinary project, called PulvArbo, managed by Ctifl and different partners, started in June 2015 and will last until 2020.
The two main aims of the project are:

1. To identify the technical means to be used to limit the losses in environment.
2. To develop a method of dose adjustment taking into accounts the development of the vegetation.

A better knowledge of spray distribution in air, in the canopy and on the soil surface depending on the sprayers and setting parameters is essential to accompany the fruits growers towards optimal practices. And it is such a necessary prerequisite for the study of the implementation of a safe dose reduction approach.

IDENTIFY THE MOST EFFICIENT SPRAYERS, SETTINGS AND PRACTICES

The first objective of the research is to answer to the following questions: what is the quantity of spray deposit per unit of leaf area to protect and per unit of soil depending on the sprayer, its setting and the practice? What is the quantity of spray drift? What is the distribution of the spray in the three compartments canopy, soil and air? The answers to these questions will allow us to classify the sprayers, the settings parameters and the practices according to their performance in terms of spray deposition quality and in terms of drift reduction, and promote the best practices among the fruits growers.

Material and methods:

The assessment of the spray application techniques are carried out in apple orchards located at 4 different experimental sites in France. Trials are done following the same methodology (ISO22522, 2007). A reference application technique has been defined as an axial sprayer, forward speed of 6-7 km/h, hollow cone nozzle, full fan speed and a spraying volume of 400 l/ha (whatever the stage of vegetation) In each trial, the reference is compared to a different setting (different forward speed, different fan speed, mixed nozzles set, cross flow sprayers…).Three indicators of spray application quality are defined: the average deposits per unit leaf or area and per unit of soil surface? for one gram of tracer sprayed per hectare (ng/dm² for 1g/ha), the coefficient of variation of deposits measured in each compartment of the canopy, the percentage of the spray intercepted by the trees and the soil. To complete these assessments, works are done to simplify the actual drift measurement method used in France for the official registration of the drift reduction techniques. The aim is to validate an easier method of drift measurement based on horizontal collect instead of the actual vertical collect.

First results:

14 trials have been set up in 2016. The first observation is that air blast sprayers deliver very variable deposits depending on the commercial model and the applied settings and practices: within same growth stages of the trees, the spray deposits vary from single to double resulting in very variable interception rates by the canopy : 17% to 80% for the best one. The losses on the ground from each part of the row vary between 2 to 35%.

DEVELOPMENT OF A METHOD FOR DOSE ADJUSTMENT

In France the applied dose of plant protection products (PPP) in fruit growing is a real concern. Orchards have a high diversity of canopy structures (e.g. fruit hedge for pome fruits, gobelet for stone fruits, and large volume for nuts), and also for each structure there is a significant change in the vegetation volume between bud break and harvesting. –Currently, the French dose expression used for the registration of PPP's is a fixed dose / ha. This expression leads to variable deposits per unit of foliage area depending of the vegetation. Dose adjustment to crop growth is a clear goal of reducing inputs, as required by the French government. Therefor the second aim of PulvArbo is to create a supportive tool for practical implementation of dose adjustment.

Material and methods:

The different steps of this work are : characterization of orchards by different indicators; i.e. treated height of the trees, width of canopy, distance between tree rows, Leaf Wall Area (LWA), Tree Row Volume (TRV), both measured manually and by LIDAR, measurements of deposits linked to the canopy structure (ISO22522, 2007), biological efficacy trials with different dose adjustment scenario's during a complete growing season.

First results:

230 orchards have been characterized at different growth stages: 72% of fruits hedges (pome fruits : apple and pears), 26% of globular shapes (stone fruits), 2% of big volumes (nuts trees). A data base has been created (10000 individual data and more than 1000 average data). For each specific tree crop it is possible to link the crop parameters and the description of the orchards (training, age, variety and location) and for each orchard it is possible to establish vegetation evolution curves during the season.120 orchards on the 230 have been scanned with LIDAR (cf. abstract of JP Douzals, IRSTEA). Based on these data it is possible to define a value of standard orchard for each crop expressed as LWA or TRV. This value will determine the maximal dose to be applied. A first scenario of dose adjustment taking into account the LWA was tested in 2016 in apple orchards on 9 experimental sites located in the different regions of apple production in France. This scenario was based on a standard orchard of apple of 15000 m² LWA/ha. This value was given by ECPA (European Crop Protection Association) but the first observation is that the value of standard orchard for France is too low: on 5 sites the LWA was more than 15000 m² at the end of the winter so no adjustment on this principle was possible. In the case where that method could be applied, the reduction of the PPP use varied between 7 to 24% for a same quality at the harvest than the reference treated at full dose.

This project will continue until 2020. Achieving reduced use of pesticides through effective application techniques is one thing, making this reduction possible at the producer level is another thing. Implementation of these evolutions of practices will only pass through information, awareness and training of the different actors.

Figure 1 : Partners of the French project PulvArbo

ACKNOWLEDGEMENTS

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Oral Abstract 11
Sprayer classification in viticulture according to their performance in terms of deposition and dose rate reduction potential

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INTRODUCTION

The French national action plan EcoPhyto aims at reducing the total amount of pesticides used in France by 50% between 2006 and 2020. The strong interest of spray application techniques improvement in viticulture in order to comply with the plan EcoPhyto objectives has been demonstrated (Verges et al., 2015). Indeed, the assessment of several spray application techniques showed that the best technique could achieve five times more deposition than the worst one.

In order to assess the spray application techniques performances at different growth stages of grape vines, IFV and IRSTEA developed the EvaSprayViti test bed which is a standardized artificial vine vegetation able to mimic three growth stages (early, medium and full). A total of 116 tests with 19 different sprayers were carried out on this test bed at the 3 different growth stages. Based on the results a classification of sprayers according to dose rate reduction potential is proposed.

MATERIALS AND METHODS

For each spray application technique assessed, tests on EvaSprayViti bed provided two indicators values: average normalized deposition ($ng.dm^{-2}$ for $1g.ha^{-1}$) and coefficient of variation of deposition as previously defined in Codis et al., 2013 and Verges et al., 2015.

Most types of sprayers on the French market are represented in the assessments (table 1). For each type of sprayer, reference settings have been defined according to most common field practices and sprayer manufacturer recommendations (Verges et al., 2015).

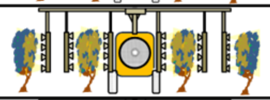
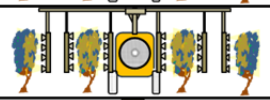
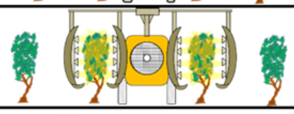
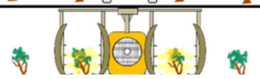
Kind of sprayer	Drawing	Number of sprayers tested
Pneumatic arch sprayer		4
Pneumatic multi-row side by side sprayer		3
Air assisted multi-row side by side sprayer		3
Air assisted shielded sprayer		3
Airblast sprayer.		4
Hoop early growth stage sprayer. (no air assistance)		1
Shielded early growth stage sprayer (no air		1

Table 1: Sprayers assessed.

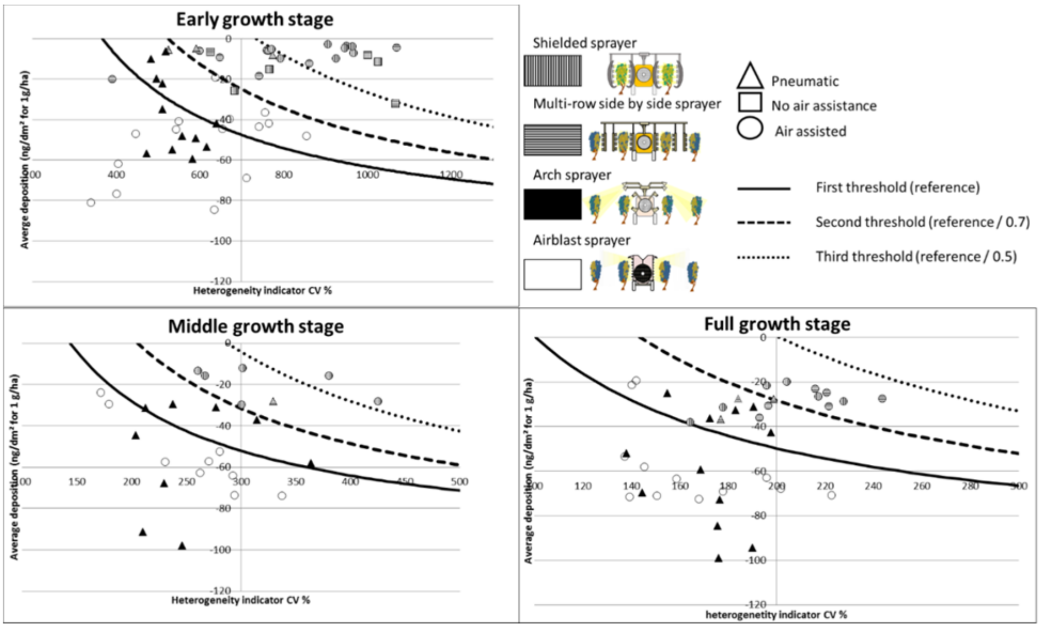
In order to build a classification for sprayers taking into account both average normalized deposition and its coefficient of variation, an aggregated indicator has been proposed. Named "normalized corrected deposition" this indicator is defined by: ***normalized corrected deposition = normalized average deposition – standard deviation***.

Then, a first threshold of performance considered as a reference level (RL) has been defined. It corresponds to the average performance of pneumatic arch sprayers which are the most common sprayers used in vineyards (70% of the fleet) when they are used in compliance with manufacturer's recommendations (a path every two rows). Afterwards, compared to this reference level (RL), two other classification thresholds have been defined by RL/0.7 for the second one and RL/0.5 for the third one.

The three classification thresholds defined previously allow getting a four classes classification of spray application techniques. The relative position of a sprayer to the three thresholds reveals its ability to keep or not an equivalent level of deposition to the reference level when considering a dose rate reduction. For example, a spray application technique that reaches the second threshold (RL/0.7) when used with a dose rate of only 70% of full dose rate will provide the same level of *corrected deposition* that the reference technique used with the full dose rate.

RESULTS AND DISCUSSION

The figure below is a graphic representation of the proposed classification method results. For each growth stage, the spray application technique performances are represented by a point which coordinates are the two indicators of spray quality (average deposition; coefficient of variation). It can be demonstrated that the three classification thresholds defined previously can be represented by the curves plotted in these graphics.



This synthetic view of the spray application techniques classification shows that promoting the use of the most efficient sprayers would allow to make a large improvement in terms of pesticides reduction compared to the current situation. It appears that the configuration of the sprayer is a major factor determining deposition and that sprayer's technology (air assisted or pneumatic) has a secondary influence on spray deposition.

ACKNOWLEDGMENTS

This research was partially funded by ONEMA with the credits attributed to funding Ecophyto.

REFERENCES

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

Vergès A., Codis S., Bonicel JF., Diouloufet G., Douzals JP., Magnier J., Montegano P., Ribeyrolles X., Ruelle B. Sprayers' classification according to their performance in terms of spray deposition quality, Suprofruit 2015 pp. 64-65.

Oral Abstract 12
Spray deposits from a recycling tunnel sprayer in vineyard; effects of the forward speed and the nozzle type

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INTRODUCTION

The French Ecophyto national action plan (Directive 2009/128/EC) aims at reducing significantly the amount of Plant Protection Products (PPP) used in agriculture. The use of efficient spray application techniques seems to be a concrete way to reach this objective for vine crops. More specifically, recycling tunnel sprayers have been identified as combining protection efficiency, people and environment respect. Tunnel sprayers decrease drift by 50% to 90% compared with axial sprayers (Doruchowski and Holownicki, 2000; Planas *et al.*, 2002). Recycling tunnel sprayers recover the part of spray that is not intercepted by the crop and redirect it to the tank (Doruchowski and Holownicki, 2000), thus allowing for a reduction in PPP input. However the use of a two-rows tunnel sprayer can be time consuming because of cleaning time and maneuvering time during half turns. This is a significant economical obstacle for their adoption in vineyards. Our hypothesis was that it could be at least partly remedied to this situation, thanks to an increase of forward speed. The underlying hypothesis is that spraying quality can be maintained due to confinement provided by panels. In 2016, IFV (French Wine and Vine Institute) and IRSTEA (French Research Institute for Environment and Agriculture) have carried out field tests with a tunnel sprayer in order to test this innovative hypothesis. The experimental test carried out in a vineyard compared spraying efficiencies of recycling tunnel sprayer for 3 forward speeds and 2 nozzle types, air induction flat fan nozzle and classical hollow cone nozzle. Air induction nozzles are known to improve drift reduction, so this was a consistent complementary factor to forward speed.

MATERIALS AND METHODS

In July 2016, spray deposits have been measured according to ISO22522:2007 on a vine plot (BBCH79 growth stage) in the Domaine du Chapitre located in Languedoc area (France). The vegetation was characterized by a high vigor (over the average level of the region): the average height of the vegetation was 1.38m, its average thickness was 0.67m, and porosity was very low. A two-rows recycling tunnel sprayer was used: the Arcobaleno model from Bertoni manufacturer. The experimental plan was drawn in order to analyze two cross factors:

- Forward speed: 5.3km.h-1 (usual/reference forward speed), 7.8km.h-1 and 10.4km.h-1
- Nozzle type: air induction flat fan nozzle (Lechler IDK model), classic hollow cone nozzle (Teejet TXA model). All nozzles had size 01 (orange color code) according to ISO10625. Applications were made using a pressure of 5 bars, with all nozzles opened. Spray deposit was measured using a tracer (Tartrazine E102) diluted at about 5 $g.L^{-1}$ and recovered on PVC collectors according to the methodology described in Codis *et al.* (2013). The collectors were positioned on leaves within the canopy according to a sampling grid perpendicular to the row. Each cell of the grid, had a 20cm height and a 10cm width, and was fitted with a collector per pixel. A total amount of 1172 collectors have been analyzed individually. Tracer concentration analyses provided the normalized deposit expressed per unit of leaves area for one gram of tracer sprayed per hectare (unit: $ng.dm^{-2}$ for 1 $g.ha^{-1}$). The distribution of tracer within the canopy was evaluated by splitting grid cells into 2 compartments: canopy edge and inside canopy. The side of collectors has been considered in order to check the effect of nozzle type on leaf upperside and underside deposit.

RESULTS AND DISCUSSION

Whatever the nozzle considered, results show that increase in forward speed did not cause a decrease in foliar spray deposits (Figure 1). However, deposits in the inside compartment of the canopy were higher when using air induction nozzle Lechler IDK compared to classical hollow cone nozzle Teejet TXA (Figure 1). Deposit ratios between upperside and underside of the leaves were not different for the two types of nozzles (Figure 2).

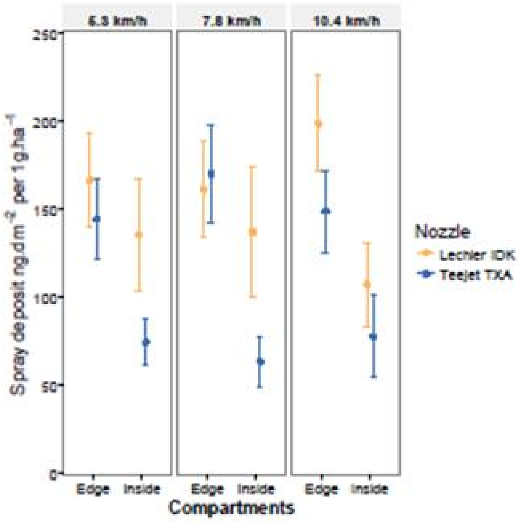

Fig. 1. Mean spray deposits according to the compartment, the nozzle type and the forward speed. Vertical arrows represent confidence intervals at 5%.

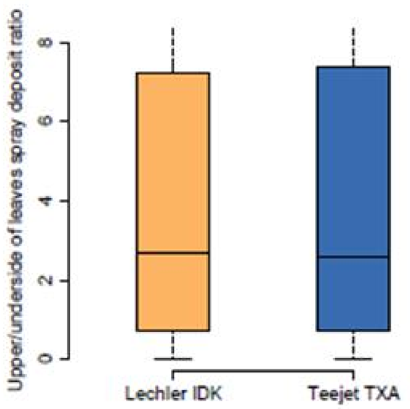

Fig. 2. Upper/underside of leaves spray deposit ratio according to nozzle (forward speed : 5km.h-1)

Air induction nozzles offered higher amount of spray deposition compared to classical hollow cone nozzles with the tunnel sprayer tested. These results in real vineyard conditions are in line with results of trials carried out in 2015 and 2016 using EvaSprayViti tests bed with tunnel sprayers (Vergès *et al.*, 2015). With this machine, forward speed could be increased to decrease work time without lowering deposits and their homogeneity within the canopy. In addition, deposits on underside of leave were not affected by nozzle type. The perspective is to complement this physical assessment of deposition by an analysis of recovery rate and biological assessments.

ACKNOWLEDGMENTS

Domaine du Chapitre for setting trial on their vineyard.

REFERENCES

Codis, S., Bonicel, J., Diouloufet, G., Douzals, J., Hébrard, O., Montegano, P., Ruelle, B., Ribeyrolles, X., Vergès, A., 2013. EvaSprayViti: a new tool for sprayers agroenvironmental performance assessment. 12th Workshop on spray application techniques in fruit growing (SuproFruit 2013), Valencia (Spain).

Doruchowski, G., Holownicki, R., 2000. Environmentally friendly spray techniques for tree crops. Crop Protection 19, 617-622.

Planas, S., Solanelles, F., Fillat, A., 2002. Assessment of Recycling Tunnel Sprayers in Mediterranean Vineyards and Apple Orchards. Biosystems Engineering 82, 45-52.

Vergès, A., Codis, S., Bonicel, J., Diouloufet, G., Douzals, J., Magnier, J., Montegano, P., Ribeyrolles, X., Ruelle, B., 2015. Sprayers' classification according to their performance in terms of spray deposition quality. Julius-Kühn-Archiv, 64.

Oral Abstract 13
Leaf surface topography affecting the dynamic impact behaviour of spray droplets

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INTRODUCTION

Improper spray deposition of crop protection chemicals can cause suboptimal biological efficacy, and damage to the environment and human health. The dynamic impact characteristics of the droplet on the leaf may lead to retention, rebound or splash. The final fate of the droplets after impact is determined by the interaction of droplet and surface parameters. Modelling has been suggested to assist understanding of the process. We have developed a computational fluid dynamics (CFD) model (Delele et al., 2016) that allows computing the transient deformation process of droplets during impact on different leaf types for a wide range droplet diameters and velocities at impact. The aim of this study was to apply the CFD model to verify the effect of leaf surface topography on the dynamic impact behaviour of the spray droplets on leaves, compared to flat surfaces.

MATERIALS AND METHODS

Computer simulations using the CFD model were conducted to analyse droplets impacting on an explicit surface geometry of tomato leave compared to that of a flat surface with the same properties. The leaf geometry was obtained by means of X-ray computed laminography (Verboven et al., 2015), a non-invasive imaging method that allows to reconstruct the three-dimensional internal volume of the leaf. The resulting 3D images obtained from X-ray method are a stack of thin cross sections through the leaf and surrounding air, in which the grayscale is proportional to variations in density in the image field of view. Thereby, the images provide good contrast between the air volumes in- and outside the leaf and the leaf cells, at micrometer resolution.

For this work, 3D X-ray image stacks of tomato leaves with pixel resolution 0.75 µm were further processed to obtain an accurate CAD model of the adaxial leaf surface. To this end, the leaf tissue volume was segmented from the grayscale X-ray images. Using subsequent opening and closing operations a completely closed leaf volume was obtained from which the surface was rendered by means of a high resolution mesh. The surface mesh file was used as a boundary for a 3D CAD model of the layer of air sitting on the leaf through which the spray droplet is tracked by means of the CFD model during the impact process. The CFD model uses the Volume Of Fluid (VOF) approach for computing the liquid droplet shape as it deforms during impact. The transient continuity, momentum and volume fraction equations were solved using ANSYS Fluent 17.2 (ANSYS, Inc., Pennsylvania, USA). Time discretization was done using first order implicit method with sufficiently small step size (in the order of 10^{-7} s) were required on a high density spatial discretization mesh with element size in the order of 5 µm resulting in more than 4 million elements. The contact angle of the droplets on tomato surface was taken as 97.9º (Lu et al., 2015) and applied to both the true tomato and flat surfaces. Calculations were performed on a 64-bit, Intel® Core™ i7-4790 CPU, 3.60 GHz, 32 Gb RAM, Windows 7 Professional with a CPU time up to 52 h.

RESULTS AND DISCUSSION

The CAD model resolves the surface topology that exhibits curvatures that follow the turgid cell contours of the leaf epidermis (Fig. 1a). A typical checkerboard pattern of epidermis cells can be recognised that can also be seen on, for example, electron micrographs. Two simulation cases are shown for one diameter and impact velocity: using the true leaf surface (Fig. 1a) compared to assuming a flat surface (Fig. 1b). In both cases the same contact angle was used. The snapshot at the time of maximum spread (top) shows that on the real surface the effective spread diameter is less than on the flat surface. This is likely caused by the fact that more energy is lost on the curved leaf surface. As a further effect, during recoil higher energy loss occurs than on the flat surface, leading, for these conditions, the droplet to retain on the leaf surface, while the droplet on the flat surface is able to bounce back into the air. These observations are in agreement with earlier work (Sun et al., 2012). These simulations demonstrate that surface topography contributes to surface wettability by spray droplets. Further investigations should help to better understand the interplay of surface topology and roughness caused by wax structures affecting leaf hydrophobicity.

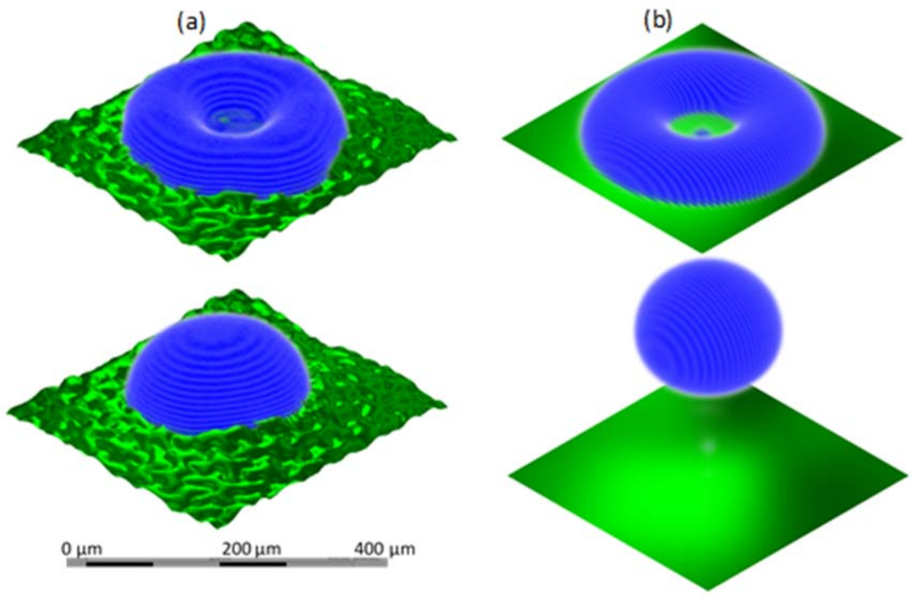

Figure 1. Snapshots of the transient process of impact of a 200 µm diameter water droplet with a tomato leaf, at an impact velocity of 2 m s^{-1}: (a) True tomato surface, (b) Flat surface; The top snapshot is at the time of maximum spread, the bottom at the end of the simulation.

REFERENCES

Delele MA, Nuyttens D, Duga AT, Ambaw A, Lebeau F, Nicolai BM, Verboven P. (2016). Predicting the dynamic impact behaviour of spray droplets on flat plant surfaces. Soft Matter 12, 7195—7211.

Lu L, Ku K-M, Palma-Salgado SP, Storm AP, Feng H, Juvik JA, et al. (2015) Influence of Epicuticular Physicochemical Properties on Porcine Rotavirus Adsorption to 24 Leafy Green Vegetables and Tomatoes. PLoS ONE 10(7): e0132841.

Sun M, Liang A, Watson GS, Watson JA, Zheng Y, et al. (2012) Influence of Cuticle Nanostructuring on the Wetting Behaviour/States on Cicada Wings. PLoS ONE 7(4): e35056.

Verboven, P., Herremans, E., Helfen, L., Ho, Q. T., Abera, M., Baumbach, T., Wevers, M. and Nicolaï, B. M. (2015), Synchrotron X-ray computed laminography of the three-dimensional anatomy of tomato leaves. Plant J, 81: 169–182.

Oral Abstract 14
Assessment of aerial spray deposition on banana crop based on flight conditions

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INTRODUCTION

Mapping spray applications has gained interest in recent years for different crops. However, if commercial software or apps are generally able to represent spray on/spray off areas based on GPS localization, the quantity deposed on the crop requires relating flight conditions (mainly altitude and forward speed) to the respective deposition patterns. Banana crop is one of the largest fruit productions in the world and aerial spray application is the main route to spray fungicide against Black Sigatoka (*Mycosphaerella fijiensis*) (Bonicelli et al., 2015). Since previous studies showed that the deposition fraction from aerial sprayers was sometimes low (Douzals et al, 2013), this study aimed at determining the effect of flight conditions on the deposition profile.

MATERIAL AND METHODS

Figure 4 describes the experimental setup located at Plantation du Haut Penja (PHP), Djombe, Cameroon. A gantry was installed at the canopy level and supported a 40 m long PVC sheath used as collector. A water based mixture composed of mancozeb (Dithane 60 OS) supplemented with a fluorescent tracer (Brilliant SulfoFlavine 0.5% w/w) was sprayed by aTurbotrush aircraft (SR2 T Ayres Trush) at the theoritical application volume of 20 L ha^{-1} – 200 km h^{-1}. The aircraft flight data such as forward speed, application rate, and GPS traces have been recovered from the Statlock® software.

After exposition, the sheath was recovered and cut into 50 cm pieces and analyzed qualitatively by image analysis of a portion of the section with Depositscan software (ARS USDA). Subsequently, each portion was then rinsed with deionized water and the quantity of tracer was determined by using a spectrofluorimeter. The calibration from both measurements was achieved on 2 sets of swath samples but main results (14 swaths) were analyzed considering the impact size and density analysis solely. Flying data (flowrate, pressure gauge, position) are recorded in a data logger.

RESULTS

9 trails have been performed to investigate deposition for different configurations of flying altitude and forward speed.

From the results obtained (Fig. 2), a simple model has been developed in order to express the recovery percentage on the crop versus the flight altitude. This model has been implemented in Qgis software so as to visualize the amount of product along the aircraft trajectory. Figure 5 corresponds to the spraying map based on raw data from the boom (open/close positions).

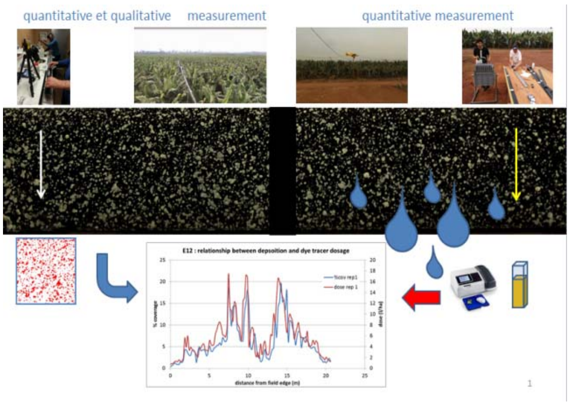

Figure 4: qualitative and quantitative deposition measurement

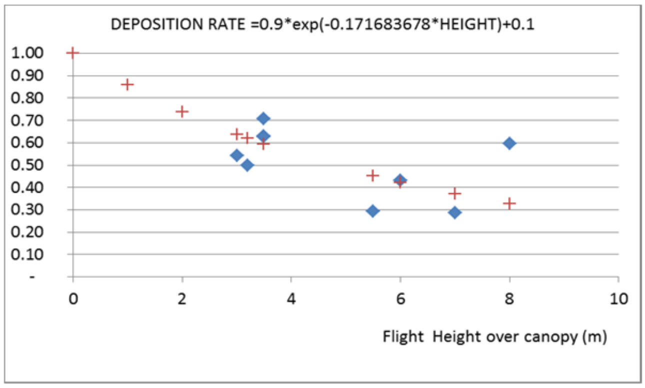

Figure 3 : model for deposition rate vs height of flight

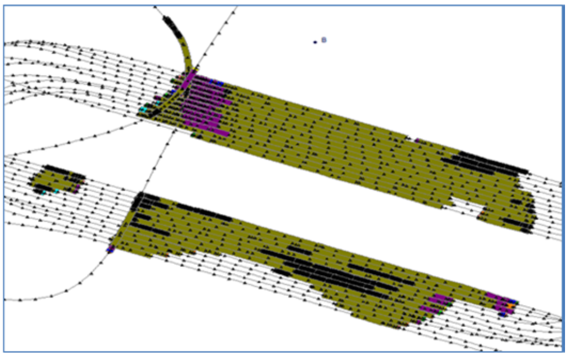

Figure 5 : basic spraying representation

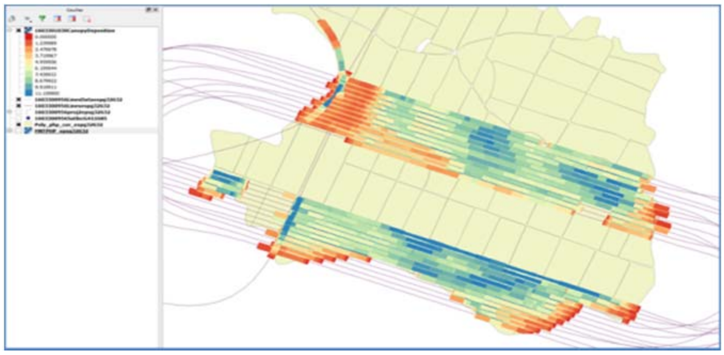

Figure 6 : model deposition spraying representation as function of flight height

On Figure 6, each GPS position was affected by a spraying efficiency based on the flying altitude. Red areas correspond to low deposition as blue areas indicate higher deposition. This representation will help the development of spray application strategies to determine which part of the field should be sprayed for example by using a ground base spraying device or how aircraft pilots may adjust flying parameters with regards to terrain constrains.

CONCLUSION

The visualization of simulated deposition efficiency may offer a smart support to decision makers. The validation of the procedure will improve the spray application strategy for a better recovery rate, lower pesticide consumption and easier application work for pilots.

REFERENCES

Bonicelli, B., Cotteux, E., Douzals, J.P., 2015. Pesticide applications assessment in banana crop conditions: a methodological approach, Environ Sci Polut Res. 22: 17255-17259. DOI 10.1007/s11356-015-4953-1.

Douzals,J.P.,Cotteux, E., Rombaut, M., 2013. Mass balance from aerial spray applications: a global approach on banana crop. 12th Suprofruit, Valencia, ESP, 26/06/2013. Editorial Universitat Polytecnica de Valencia, 2013.

Oral Session 3
Air support of sprayers for three dimensional crops
Session Chairs: Grzegorz Doruchowski and Pieter Verboven

Oral Abstract 15
Lidar vs. test bench for measurement of drift as affected by sprayer type, air flow, nozzle type and density of vine canopy

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INTRODUCTION

Sprayer types, as well as working parameters, have direct influence on the amount of spray retained on the canopy. This research was focused on the quantification of spray amount that exceeded the last canopy row during the spray application in a vineyard parcel.

LIDAR sensor was selected as alternative method for drift measurements, following the previous research (Gil et al., 2013). The objective of this research was to evaluate the effect of canopy characteristics on drift, by measuring the amount of liquid exceeding the last sprayed row, and compare the ground deposition out of the target area with the measurements obtained with LIDAR sensor.

MATERIALS AND METHODS

A conventional mistblower sprayer (Talleres Corbins, S.A., Lleida, Spain) and a multi row sprayer (Hardi Iris, Ilemo Hardi, Lleida Spain) were tested at high and low air flow rate respectively, applying spray volume rate in the range of 369-398 l/ha. Conventional hollow cone (ATR Albuz) and air induction nozzles (TVI Albuz) were used separately maintaining the same working parameters as shown in table 1. Water solution of tracer (Tartrazine, E-102, SIGMA) at concentration 0.2% was applied. Deposition of tracer on petri dishes placed on the test bench was analysed by spectrophotometry. Canopy characteristics of the complete nine last rows of the parcel were obtained using a LiDAR SICK LMS 200. Previous circulation on the field with the tractor equipped with LiDAR sensor allowed to obtain the canopy maps with detailed information about canopy density, canopy height, and canopy width along the row lines.

Table 1. Sprayers settings during the field trials

Sprayer	Air flow		Nozzle type (n°)	Pressure	Droplet	Application rate	
	$m \cdot s^{-1}$	$m^3 \cdot h^{-1}$		(bar)	size(1)	$L \cdot min^{-1(2)}$	$L \cdot ha^{-1}$
Master 2000	24.4	27,507	ATR yellow (10)	8.0	VF	0.92	369
		27,507	TVI 80015 (10)	8.0	C	0.98	393
Master 2000	31.1	34,959	ATR yellow (10)	8.0	VF	0.92	369
		34,959	TVI 80015 (10)	8.0	C	0.98	393
Iris-2	14.6	6,423	ATR orange (16)	8.0	VF	1.24	398

(1) According to BCPC classification (VF: Very Fine; C: Coarse); (2) Flow rate per single nozzle.

The amount of spray liquid exceeding the canopy was measured using two different methodologies: a) two horizontal 10 m long drift test benches were placed parallel to the last row line at 1.6 and 3.2 m respectively (half and full row distance, respectively). Petri dishes were placed over the bench at 0.5 m spacing distance, in order to catch the amount of spray liquid exceeding the canopy; b) LiDAR scan was also placed on the ground close to the drift test bench in order to measure the amount of droplets exceeding the canopy. For this purpose, LiDAR laser beams were directed vertically parallel to the canopy vegetation, with a view angle range of 180º. The density of spray droplets exceeding the canopy was measured for every field trial.

RESULTS AND DISCUSSION

Results indicated good relationship between air settings, canopy density and drift exceeding the target. The high air flow gave the greatest spray losses away from the target. Effect of air induction nozzles on drift reduction was observed. Drift measurement with LiDAR sensor can be considered.

Effect of canopy density on spray drift through the canopy was evaluated for the two tested sprayers (Fig. 1).

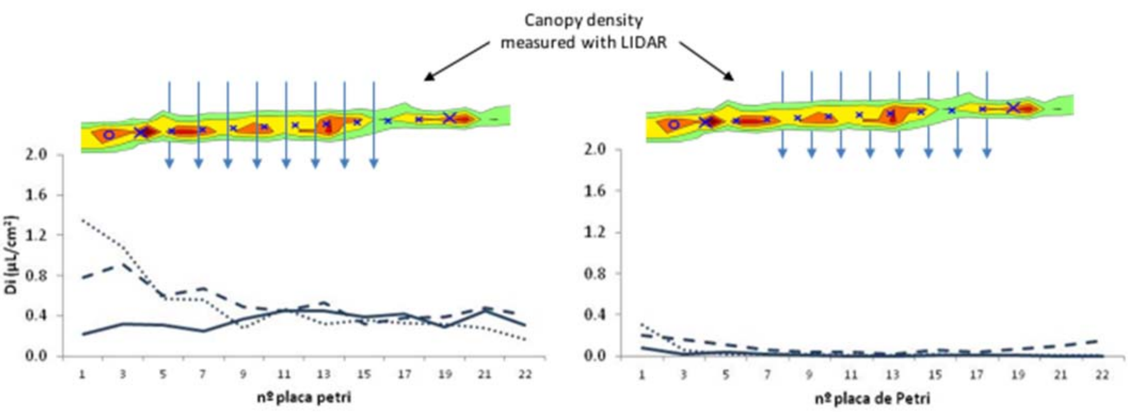

Figure 1. Evaluation of spray drift through the canopy for the two tested sprayers: conventional mistblower (left) and multi row sprayer (right).

REFERENCES

Gil, E., Llorens, J., Llop, J., Fàbregas, X., Gallart, M. 2013. Use of a Terrestrial LIDAR Sensor for Drift Detection in Vineyard Spraying. Sensors, 13(1): 516-534

Oral Abstract 16
Characterization of the air-flow and the liquid distribution of orchard sprayers

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INTRODUCTION

In order to identify and improve the current practice of spray application in fruit crops a research programme was setup assessing air and liquid distribution of nowadays often used orchard sprayers and spray distribution in orchard trees. Potential pathways of improvement are air amount and air distribution and therefore liquid distribution as the spray is transported by the moving air. Improved spray deposition can lead to reduced use of agrochemical and therefore reduced emission to the environment while maintaining high levels of spray drift reduction and biological efficacy. In order to be able to quantify the air and liquid distribution in a 3D space together with AAMS-Salvarani (Maldegem, Belgium) a measuring platform was developed. The setup and first results of these 3D air- and liquid distribution measurement platforms are presented.

MATERIALS AND METHODS

The base part of the measuring device consists of a two-rail traverse system positioned parallel (x-axis) alongside the sprayer on which a measuring platform can move up and down and a two rail traverse system on which the traverse system can manually be positioned at distances up to 5 m from the centre (x) axis of the sprayer. At the traverse system the measuring platform can move stepwise in 10 cm steps over a range of 6 m length or in a continuous way at a set speed up and down the traverse system. The stepwise mode is used for the air-flow distribution measurements. The continuous speed is used for the liquid distribution measurements using an AAMS-Salvarani patternator with discs (4.5 m height) which is moved up and down (x-axis) through the spray fans until measuring tubes are filled for 80%. With a double sided discs distribution also multi-row orchard sprayers

Figure 1. 3-D liquid distribution setup (left) and air-flow distribution setup (right)

can be assessed.The air distribution measurement uses three ultrasonic anemometers (Gill Windmaster) which sample air speed in 3 directions (x,y,z) at 20 Hz positioned above each other at 50 cm spacing (y-axis). The combined three ultrasonic sensors can be positioned manually from 40 cm height (lowest sensor) up to 4.5 m height (highest sensor) in 10 cm steps (z-axis). Through steering and data sampling electronics and software the three sensors are moved through the air flow in 10 cm steps sampling the air flow at each x,z-axis position for 30 sec. In this way a full scan of the air flow at one side of an orchard sprayer can be made. Measurements are repeated for the y distances 1.00 m, 1.25 m, 1.50 m, 2.0 m, 3.0 m and 4.5 m from the centre axis of the sprayer. Results can be presented as a grid (matrix) presentation showing mean vector air speed per grid cell, as interpolated speed distribution charts per y-distance, as speed vector distributions in the x,y or y,z planes.

RESULTS AND DISCUSSION

The average liquid distribution at the left and right hand side of a crossflow fan sprayer is presented in figure 2. Showing that liquid distribution over height is different for both sides and the maximum liquid deposit is climbing with height at further distances.

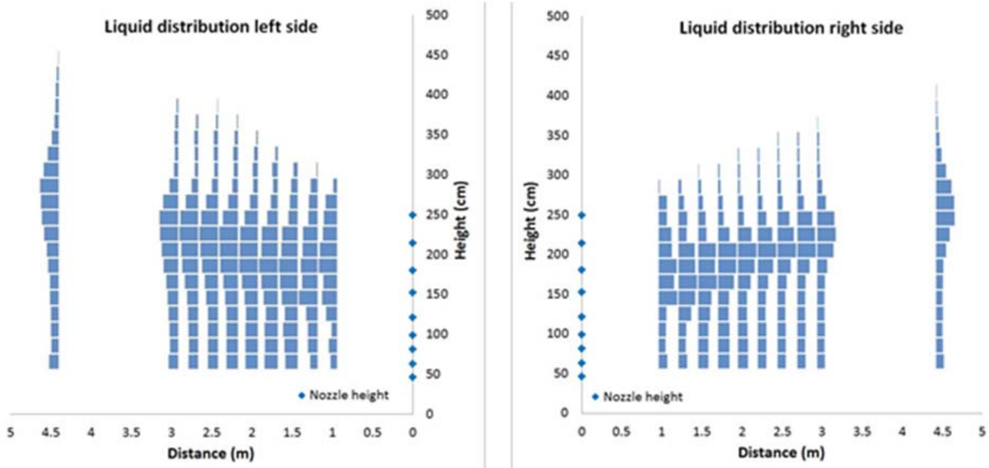

Figure 2. Liquid distribution in the x,z plane of the left and right handside of a cross-flow fan sprayer

The air distribution, at the right hand side of a cross-flow fan sprayer (figure 3) shows a gap in air speed at 2.0-2.5 m height which widens at larger y-distances from the sprayer. The gap however also rises to higher heights (z) up to 2.5-3.0 m at 3 m y-distance and 3.5 m at 4.5 m y-distance.

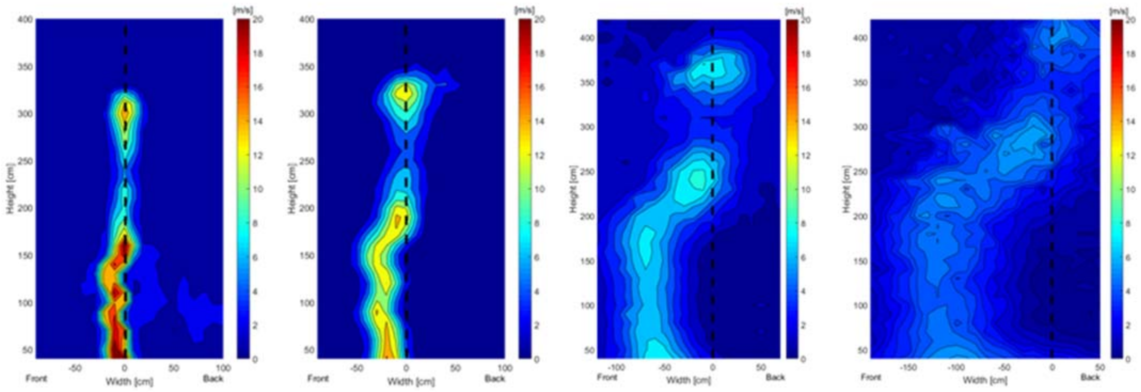

Figure 3. Air distribution (m/s) in x,z plane at 1.0 m, 1.5 m, 3.0 m and 4.5 m from the centre axis (x,z plane) of a cross-flow fan orchard sprayer (right hand side)

Oral Abstract 17
2D CFD simulations of the air profile of three sprayers adapted to tomato crops in greenhouse conditions

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INTRODUCTION

The airflow generated by fans of air-blaster affect the efficiency of the spray applications. The influence of the air currents from different air-assisted sprayers adapted to greenhouse conditions on the spray distribution on tomato plants grown has been assessed by Llop et al. (2015). However, these experiments are limited by the number and the situation of measurement sensors and they do not allow to study all the spatial behaviour of the spray plume.

Computational Fluid Dynamics (CFD) modelling can be a good complementary tool to these studies, enabling the visualization of the complete phenomenon. This technic has been applied to study pesticide applications with air-assisted sprayers in tree crops in field conditions (Salcedo et al., 2016) or greenhouses (Wang et al., 2015). There are not simulations comparing the air profile produced by different adapted equipment to treatments on tomato crops in greenhouse including a turbulence model analysis.

This work aimed at designing and simulating 2D CFD models of the airflow of three air-assisted sprayers as a first step to reproduce the applications in greenhouses.

MATERIALS AND METHODS

For the 2D CFD models, a rectangular domain consisting in a vertical plane, 3 m high and 6 m long, was designed (Fig. 1). The domain was limited by the ground and the air. The was placed in the section A represent the air inlet produced by each of the three sprayers studied: 1) a handheld trolley sprayer (Carretillas Amate, Almería, Spain) modified with an air generator (Nuvola 5HP, Cifarelli S.P.A., Voghera, Italy), 2) the same handheld sprayer with another blower (B&D 3000W, Stanley Black&Decker Inc., New Britain, UK), 3) a self-propelled sprayer (Unigreen, Maschio Gaspardo S.p.A., Campodarsego, Italy). For the sprayers 1 and 2 it was between 0.11 and 2.21 m high, meanwhile in the sprayer 3 it was between 0.27 and 1.87 m high.

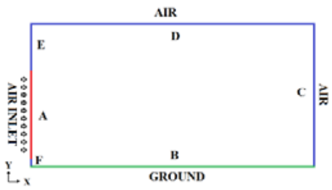

Fig 1. Scheme for the geometric domain.

ANSYS Fluent® software (ANSYS, Inc. Canonsburg, PA, USA) was used to simulate the airflow. Turbulent air model choice affects simulation accuracy. For this reason, three models were compared: standard k-ε, Re Normalisation Group (RNG) k-ε and Realizable k-ε model. Nine simulations were run combining the three turbulence models and the three air-assisted sprayers. For the simulations, the experimental velocity data (magnitude and direction) in front of each sprayer estimated by Llop et al., 2015 was introduced, as well as the experimental kinetic energy k (m^2/s^2) and the dissipation rate ε (m^2/s^3). At the end of the simulation all parameters showed a minimum value of 10^{-4} of the normalized residual in second order. Weather conditions and ground roughness were not considered for these simulations.

The objective variables of the simulations were the air velocities at all the rest of experimental measuring points. For the sprayers 1 and 2, 60 experimental points were located in three vertical and parallel lines placed at 0.7, 0.17 and 0.27 m from the section A respectively. For the sprayer 3, 30 points were located in two vertical and parallel lines placed to 0.10 and 0.20 m to the section A. When the simulation converged, the velocity magnitudes in each point were compared to the experimental ones. It was also studied the lineal relationship between experimental and simulated data in each line, by means of the coefficient R^2, and the root mean squared error of prediction (RMSEP).

RESULTS AND DISCUSSION

All the simulations presented similar air velocity profiles for each measurement line compared with experimental data. The differences between simulated and experimental velocities were lower for the sprayer 3 (Fig. 2).

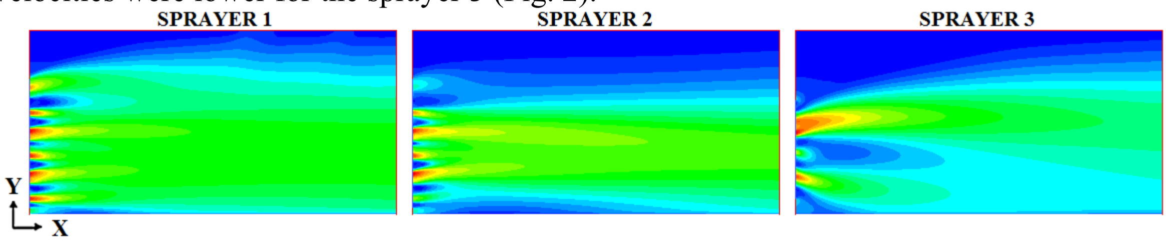

Fig. 2. Simulated air velocity magnitudes using standard k-ε model.

When turbulence models were compared, in general, standard k-ε model adjusted better to the real behaviour than the other two models (Table 1). Simulations were more approximated for sprayers 2 and 3. The RMSEP bigger than 1.00 m/s in sprayer 1 was explained because specific differences in determined points.

Table 1. R^2 and RMSEP (m/s) for each measurement line (‘x’ is distance in m)

Model	Term	Sprayer 1			Sprayer 2			Sprayer 3	
		x=0.07	x=0.17	x=0.27	x=0.07	x=0.17	x=0.27	x=0.10	x=0.20
Stand.	R^2	0.93	0.68	0.66	0.77	0.86	0.80	0.94	0.85
RNG		0.92	0.67	0.61	0.76	0.82	0.74	0.94	0.88
Real.		0.91	0.64	0.58	0.76	0.80	0.74	0.94	0.88
Stand.	RMSEP	0.73	1.10	0.93	0.64	0.63	0.62	0.27	0.40
RNG		0.76	1.21	1.03	0.69	0.67	0.65	0.31	0.44
Real.		0.78	1.23	1.05	0.67	0.69	0.65	0.29	0.42

REFERENCES

Llop, J., Gil, E., Llorens, J., Gallart, M., Balsari, P. (2015). Influence of air-assistance on spray application for tomato plants in greenhouses. Crop Prot, 78, 293-311.

Wang, J., Qi, L., Xia, Q. (2015). CFD simulation and validation of trajectory and deposition behavior of droplets around target affected by air flow field in greenhouse. T CSAT, 31, 46-53.

Salcedo, R., Vallet, A., Granell, R., Garcerá, C., Moltó, E., Chueca, P. (2016). Eulerian–Lagrangian model of the behaviour of droplets produced by an air-assisted sprayer in a citrus orchard. Biosyst Eng (in press).

Oral Abstract 18
Adjustment of vertical spray pattern of orchard sprayers with Ve.S.Pa. 2.0 application

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INTRODUCTION

The use of a vertical patternator for the adjustment of vertical spray distribution profile of air-assisted sprayer is a useful practice in order to improve the quality of pesticide application. The main purpose of determining the vertical spray distribution profile is the verification of the correct height of distribution to avoid dispersions of the spray mixture above the vegetation (Pergher *et al.*, 2002). A free web application to help the operator to setup the sprayer properly for different target crops is nowadays essential for both environmental and economic aspects.
A software was developed to predict vertical spray profiles generated by sprayer using hydraulic nozzles (Tamagnone *et al.*, 2015). A scaled graphical representation of the system sprayer/tree to be treated was created in order to permit the nozzles selection. The output of the software was the spray vertical pattern and the amount of liquid off the target. The software was based on 3 databases (language, sprayer, nozzle) and required some input data (row distance, height of the tree, forward speed, spray pressure).

The objective of the reported works was to upgrade the software by adding new functions:

- user settings of the nozzle position and air direction/speed
- possibility to use different nozzles at the left side and right side of the sprayer
- simulation of the vertical pattern not along the axis of the row, but in function of the tree profile.

MATERIALS AND METHODS

PHP5.0 language was used to develop the Ve.S.Pa. 2.0 software, integrated with html code for web managing.

RESULTS AND DISCUSSION

In the earlier version of the software all settings related to the sprayer (nozzles coordinates, nozzles direction, air speed near the nozzle) were downloaded from the sprayer database and the operator could not change them. This is a limit, because there are some sprayers that have adjustable nozzles and it is useful to change the nozzle inclination to optimize the vertical pattern. For these reasons now the user can modify the sprayer settings in each working session.

Some sprayers generate a non-symmetrical air flow pattern to the right and left side of the fan. In order to obtain a symmetrical spray pattern this may be compensated by different nozzle size and angle setting at the left and right side of the sprayer. The option that allows to define different nozzles settings on both the sprayer sides was included in the Ve.S.Pa. 2.0 version.

One of the limit of the vertical patternators is their use for the adjustment of sprayers used for applying pesticides on large canopies. In such case, if the vertical patternator is placed, as usually, at the half row distance from the sprayer axis, part of the vegetation to be treated could be out of the spray liquid intercepted by the patternator and the obtained vertical distribution profile could not represent the real sprayed diagram (Fig. 1). In order to solve this problem, a function that simulate the liquid distribution at the tree boundary was implemented in Ve.S.Pa. 2.0. The user may select the shape of the tree canopy to be considered during the simulation from the gallery of images. Before sprayer setting the user enters the dimensional parameters that define the tree size.

The tool is free available at the web site http://www.laboratorio-cpt.to.it/. Nozzles and sprayers data are approved by their manufacturers. Ve.S.Pa. 2.0 has been tested by several technicians that appreciated both the input windows and the graphical output.

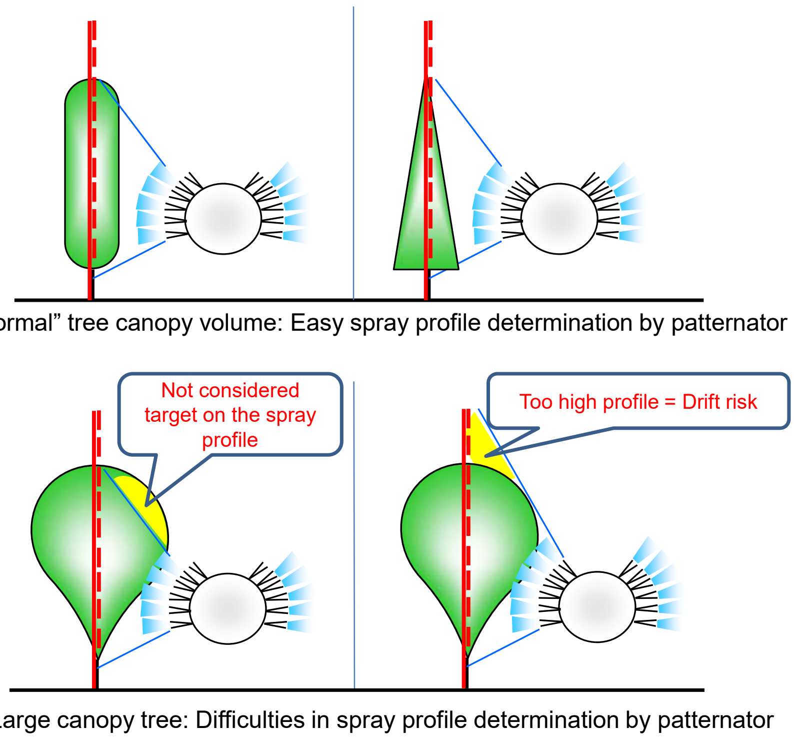

Fig. 1. Example of vertical patternator limits.

REFERENCES

Pergher G., Balsari P., Cerruto E., Vieri M. (2002). The relationship between vertical spray patterns from air-assisted sprayers and foliar deposits in vine canopies. Aspects of Applied Biology 66, International advances in pesticide application, 323-330.

Tamagnone, M.; Calvo, A.; Savoia, S. (2015). Development of a software for supporting the adjustment of vertical spray pattern of air assisted sprayers. In: Julius Khun Archiv vol. 448, 19-20.

Oral Session 4
Spray drift / Spray loses
Session Chairs: Jan van de Zande and David Nuyttens

Oral Abstract 19
Potential spray drift evaluation of airblast sprayers

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INTRODUCTION

Spray drift reduction measures are essential to avoid the risk of environmental contamination, which is directly related to the spray application technology. Therefore, a strong need has emerged for objective methods for spray drift evaluation and for the classification of sprayers according to spray drift risk. This study proposes a new method to quantify and calculate the potential spray drift generated by airblast sprayers, using an ad hoc test bench.

MATERIALS AND METHODS

A test bench analogue to the one described in ISO22401 (ISO, 2015) was used. A 20.0 m test bench, long enough to catch all the spray deposition (less than 1% of total spray deposit assessed on the collector placed at 20 m) was placed transverse to the sprayer forward direction. Petri dishes aligned in an array transverse to the sprayer forward direction were placed along the test bench slots. The first collector was positioned at 1.5 m distance from the sprayer outer nozzles. All collectors were initially covered. The actuator of the pneumatic system for opening the collectors was activated by the sprayer pass and it was placed at a relative distance from the test bench line, so that 4 s after the sprayer passed the perpendicular line of the bench the collectors were revealed. All tests were conducted with an average wind speed < 0.5 m s^{-1}. Test bench estimates the spray drift risk during pesticide application through the evaluation, in calm of wind conditions, of the free floating fraction of spray cloud falling time after its discharge. The procedure is based on the assumption that longer free floating droplets lingering times might lead to a larger risk of spray drift generation in case of windy conditions. 60 s after the opening of the system, the samples were collected and then the spray amount was determined quantifying the tracer (E-102 Tartrazine) recovered, by means of a spectrophotometer. The deposit on each artificial collector (µL cm^{-2}), was then calculated to obtain the spray drift profile according each tested configuration. From these drift profiles, the related Drift Potential Values (DPVs) were calculated applying the following equation:

$$DPV = \sum_{i=1}^{n} D_i * Coeff$$

where *DPV* is the drift potential value in µL cm^{-2} m; D_i is the spray deposit on a single deposit collector, in µL cm^{-2}; *n* is the number of collectors (40); and *Coeff* is a variable coefficient which takes into account the distance to which the spray cloud susceptible to drift is projected; it is calculated based on the cumulative deposition curve obtained from the spray deposit measured on every single collector. The *Coeff* value calculation includes the distance reached by the spray drift, and it is calculated as follows:

$$Coeff = \sum_{n=1}^{10} Dst_{n*10}$$

where *Coeff* is the variable coefficient in m, and Dst_{n*10} corresponds to the value equal to the distance in meters from the outer sprayer nozzle where $_{n*10}$ % of the cumulative spray drift deposit calculated is achieved (i.e., from 10% to 100% in intervals of 10%).

To evaluate the consistence of the methodology proposed and before described and its applicability in sprayer drift classification process an axial fan Nobili sprayer equipped with conventional nozzles and high fan air flow rate was chosen as a "reference" and an axial fan Fede sprayer set in four different configurations was tested as the "candidate" (Tab. 1). The configurations of the candidate sprayer included the selection of nozzles (conventional *Vs.* venturi hollow cone nozzles) and the adjustment of air flow rate (Tab. 1). All tests were performed at forward speed of 6 km h^{-1} (1.67 m s^{-1}). The spray drift reduction (%) achieved by each candidate configuration, versus the reference one, was calculated based on the DPVs according to ISO 22369-1 (ISO, 2006) formula.

Table 1. Parameters of configurations examined: reference and candidates.

Test	Configuration ID	Sprayer	Nozzles				Fan air flow rate (m^3 h^{-1})
			Type	Pressure (Mpa)	Active nozzles (n°)	Tot. Flow rate (L min^{-1})	
Reference	TXA6H	Nobili GEO 90	TXA8001VK	1.5	9	23.40	51,000
Candidate	ATR6H	Fede Qi 90 Futur 2000	ATR80 red	1.5	8	18.64	46,000
Candidate	ATR6L	Fede Qi 90 Futur 2000	ATR80 red	1.5	8	18.64	29,000
Candidate	TVI6H	Fede Qi 90 Futur 2000	TVI80025 lilac	1.5	8	17.92	46,000
Candidate	TVI6L	Fede Qi 90 Futur 2000	TVI80025 lilac	1.5	8	17.92	29,000

RESULTS AND DISCUSSION

In accordance to field trials performed by many authors following ISO22866 (ISO, 2005), results achieved using the new proposed drift measurement methodology pointed out that the use of Spray Drift Reducing Technologies (SDRTs) (air injection nozzles and low air flow rate) enabled to reduce the spray drift (Fig. 1-left graph-). Furthermore, the coefficient used in DPV proposed calculation allows configurations featured by the same total deposition, but with different shapes of deposition along the distance, to be discriminated. Most effective drift reduction was achieved by the use of venturi nozzles; the use of reduced fan air flow rate corresponded to strong drift reduction only in combination with conventional nozzles (Fig 1-right graph-). In particular, the drift reductions achieved by candidate configurations were 96% -B class-, 90% -C class-, 74% -E class- and 30% -F class- respectively for TVI6L, TVI6H, ATR6L and ATR6H (ISO, 2006). Furthermore good repeatability of the data is shown by the SE of the mean (Fig 1-right graph-); noteworthy better repeatability is achieved testing air injection nozzle. Use of the drift test bench showed promising results to evaluate drift potential of airblast sprayers and then the drift risk derived from different SDRTs tested. Using the proposed methodology, information about potential drift can be obtained easily and quickly and therefore this procedure could be successfully adopted for classifying airblast sprayers according to drift risk.

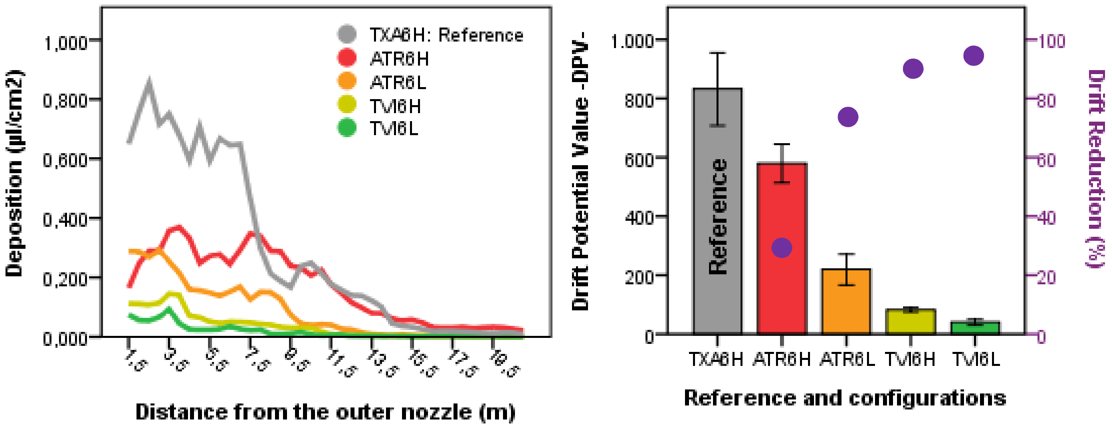

Figure 1. The left graph shows the spray deposit profiles (µL/cm^2) obtained testing the reference and the candidates configurations. The right graph shows the related DPVs obtained and bars ± SE of the mean; the dots shown the drift reduction (%) achieved by each candidate configuration respect to the reference configuration.

REFERENCES

ISO, 2005. ISO 22866:2005: Equipment for crop protection - Methods for field measurements of spray drift. International Organization for Standardization, Geneva, Switzerland, 17 pp.

ISO, 2006. ISO 22369–1:2006, Part 1: Classes in Crop protection equipment – Drift classification of spraying equipment. International Organization for Standardization, Geneva, Switzerland, 1 p.

ISO, 2015. ISO 22401:2015: Equipment for crop protection - Method for measurement of potential drift from horizontal boom sprayer systems by the use of a test bench. International Organization for Standardization, Geneva, Switzerland. 12 pp.

Oral Abstract 20
Spray drift of a cross-flow fan sprayer with wind-dependent variable air assistance

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INTRODUCTION

In order to minimise the spray drift risk the Dutch manufacturer of orchard sprayers KWH has developed a crossflow fan sprayer, the KWH Mistral, which measures the wind direction with a sensor and adjusts the air support to the left and right hand side of the sprayer accordingly. The principle of the Variable Air Balance System (VLBS) is that when spraying against the wind more air assistance is given and in the downwind direction of the wind less air assistance. The KWH Mistral equipped with VLBS, 90% drift reducing nozzles (Zande et al., 2008; TCT, 2017) and utilizing a lower level of air assistance (with 400 rpm instead of 540 rpm PTO) was expected to obtain a drift reduction of 90% or even 95% even when the outer row of the orchard is sprayed from two sides (Wenneker et al., 2005). To underpin this claim field drift measurements were carried out.

MATERIALS AND METHODS

A comparison was made between spray drift of the Mistral KWH orchard sprayer with VLBS and 90% drift reducing venturi hollow cone nozzle (Albuz TVI80015 at 7.0 bar spray pressure) in combination with standard and a lower level of air assistance (540 rpm and 400 rpm of the PTO) and a standard cross-flow fan orchard sprayer (Munckhof; Albuz ATR lilac at 7.0 bar spray pressure). VLBS consists of an air pressure sensor at the top of the cross-flow air box measuring the left and right hand side pressure of the wind and steering a valve in the air conduct to guide air assistance more or less to the left/right hand side of the sprayer. The difference in left/right wind pressure sets the valve in the air conduct at the bottom of the cross-flow air box directing air assistance more against the wind and less in the downwind direction. Both sprayers were driving 6.5 km/h applying resp. 390 l/ha and 207 l/ha. Spray drift measurements were designed to meet the established requirements of the authorization of pesticides (Ctgb), the Environmental Activity Decree (I&M, 2012; CIW, 2003) and the international ISO standards for spray drift measurements and classification (ISO 22866, 2005; ISO 22369, 2006).

Spray drift measurements were made by spraying the fluorescent tracer Brilliant Sulpho Flavine (BSF) in the leeward outside 24 m (8 rows) of an apple orchard (Elstar) in the full leaf stage (BBCH 91/92). Spray drift deposit measurements were made on a short cut grass strip downwind of the orchard at distances up to 25 m from the last tree row. The collectors used consisted of filter material (Technofil TF-290) of 0.50 x 0.10 m arranged in a continuous line from 3 m up to 15 m and two single collectors of 1.00 x 0.10 m at 20 m and 25 m. At 7.5 m distance from the last tree row a 10 m high measuring pole was placed with double lines of ball shaped collectors (Siebauer Abtrifftkollektoren) at 1 m intervals up to 10 m height. The spray drift measurements were for each of the three techniques repeated 10 times over 3 days. Differences in spray drift deposition were statistically tested using Genstat procedure IRREML at specific evaluation zones and for airborne spray drift. Drift reduction of both the KWH Mistral was calculated in comparison with the spray drift deposition of the reference spraying.

Weather conditions during application were recorded with sensors at a measuring pole positioned 7.5 m downwind of the treated orchard. Average temperature during the experiments was 12.5°C, mean wind angle was 14° from cross to the tree row direction, mean wind speed at 2 m height was 1.5 m/s and 2.5 m/s at 4 m height (about 1 m above the top of the trees).

RESULTS AND DISCUSSION

The KWH Mistral with the VLBS system equipped with the 90% drift reducing nozzle and 540 rpm PTO compared to the standard cross flow sprayer gave at 4.5-5.5 m distance from the last tree row (3 m crop free buffer zone) a drift reduction of 91.2%. With this result this application technique can be classified in the drift reducing technique (DRT) class 90 (without the necessity of one sided spraying of the last tree row when using 90% drift reducing nozzles). For the same technique but with a reduced level of air assistance of 400 rpm PTO a drift reduction of 96.5% was obtained at the same position. With this result this combination can be classified in the drift reduction class 95 (without one sided spraying of the last tree row). Results of these spray drift experiments led to a certification of these spray drift reducing techniques in the Netherlands and are therefore allowed to be used with a crop-free buffer zone of 3m (distance between last tree row and top of bank of waterway). Measurement of airborne spray drift averaged over 0-10 m height resulted in a spray drift reduction of 91.1% at 540 rpm PTO and 97.3% at 400 rpm.

REFERENCES

CIW, 2003. Beoordelingsmethodiek emissiereducerende maatregelen Lozingenbesluit open teelt en veehouderij. Commissie Integraal Waterbeheer, Ministerie van Verkeer en Waterstaat, Werkgroep 4 Water en Milieu, Den Haag. 82pp.

I&M, 2012. Environmental Activities Decree. (Activiteitenbesluit Milieubeheer), Staatsblad 2012 441/643.

ISO 22866. 2005. Equipment for crop protection – Methods for the field measurement of spray drift. International Standardisation Organisation, Geneva. 2005.

ISO-22369, 2006. Crop protection equipment – Drift classification of spraying equipment. Part 1. Classes. International Organization for Standardization, Geneva.

TCT, 2017. List with spray drift reducing nozzles and techniques in the Netherlands. Internetsite: http://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftarme-doppen/@3575/lijst-driftarme/

Wenneker M, Heijne B, Van de Zande JC, 2005. Effect of air induction nozzle (coarse droplet), air assistance and one-sided spraying of the outer tree row on spray drift in orchard spraying. Annual Review of Agricultural Engineering, Vol. 4 (1): 116 – 128.

Zande, J.C. van de, H.J. Holterman & M. Wenneker, 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, 2008. http://www.cigrjournal.org/index.php/Ejounral/article/viewFile/1256/1113

Oral Abstract 21
First assessments of spray drift in poplar plantations

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INTRODUCTION

In Italian poplar plantations about 208 tons of pesticides are annually applied (73.4% fungicides and 26.6% insecticides). According to a survey carried out by DiSAFA in 2013, spray applications in Italian poplar plantations are generally carried out using air-assisted cannon sprayers, which enable to reach even the upper parts of the canopy at 20 m height and more. For this purpose, a high air fan speed and liquid pressure are needed that could additionally increase the drift risk for this type of pesticide application. This study aimed at acquiring a first experimental data set of ground spray drift values for pesticide applications in poplar trees using an air-assisted cannon sprayer.

MATERIALS AND METHODS

Drift measurements in the field applying ISO 22866 standard protocol were carried out when the foliage was fully developed (BBCH 91) in an adult (8 years, 18 m canopy height) as well as in a young poplar plantation (3 years, 6 m canopy height). All trials were made using a mounted air-assisted sprayer Tifone VRP 600 equipped with a 600 L polyethylene tank, a radial fan (450 mm diameter) and with a swivel cannon spray unit ("Cannone 50S") where the nozzles (4, 6 or 10) are placed at the cannon (300 mm x 250 mm) air outlet. In the adult poplar plantation four different treatments were examined, applying volume rates ranging from 600 to 1200 L/ha, comparing the use of conventional hollow cone nozzles with that of air induction nozzles and two different modes of spray application, applying each single row from both sides or just from one side (alternatively towards the inner and towards the outer side of the poplar plantation) (Table 1). The air flow rate adopted was always about 13000 m^3/h.

In the young poplar plantation three different treatments were tested, always applying a volume rate of 300 L/ha and each single row just sprayed from one side, comparing the use of conventional hollow cone nozzles with that of air induction nozzles and the use of a high air flow rate with a reduced one (Tab. 2). A water solution of yellow dye Tartrazine E102 [5 g/L] was sprayed. Drift ground sediments were collected downwind of the last tree row at 17 different sampling distances on a bare soil: 5, 6, 7, 8, 9, 10, 12.5, 15, 17.5, 20, 22.5, 25, 30, 35, 40, 45, 50 m from the last row. At each sampling distance, six plastic Petri dishes (14 cm diameter) were placed, every 1 m, flat on the ground and for each treatment three test replicates were performed. The amount of deposits on the collectors was determined by spectrophotometric analysis.

Table 1. Spray application parameters examined in the adult poplar plantation.

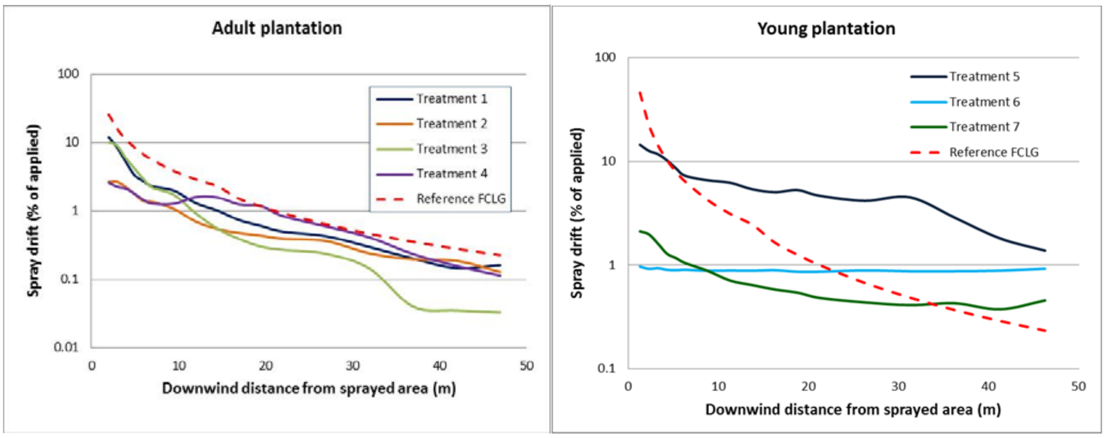
Treatment	Active nozzles [n°]		Nozzle type	Operating pressure [Mpa]	Forward speed [m s^{-1}]	Passes per single row [n°]	Volume rate [L ha^{-1}]	Orientation of spray cannon unit
1	10	6	1.8 ceramic discs	1.2	1.75	2	1 190	Vertical 90°
		4	1.8 arrow nozzles					
2	6		1.8 ceramic discs	1.5	1.19	2	1 200	Vertical 90°
3	6		TVI 80 04	2.0	1.19	2	1 200	Vertical 90°
4	6		1.8 ceramic discs	1.5	1.19	1	600	Inclined 40°

Table 2. Spray application parameters examined in the young poplar plantation.

Treatment	Active nozzles [n°]	Type of active nozzles	Operating pressure [Mpa]	Forward speed [m s^{-1}]	Volume rate [L ha^{-1}]	Orientation of spray cannon unit	Fan air flow rate [m^3h^{-1}]
5	4	1.8 ceramic discs	1.5	1.25	300	Inclined 45°	13 000
6	4	1.8 ceramic discs	1.5	1.25	300	Inclined 45°	7 800
7	4	TVI 8004 red	2.0	1.25	300	Inclined 45°	13 000

RESULTS AND DISCUSSION

All tests were conducted with an average wind speed higher than 1.0 m/s and an average wind direction between 73° and 115° relative to the travel direction of the sprayer, complying with ISO 22866 requirements. For all treatments, the spray drift amounts measured in the adult poplar plantation were below those of the reference drift curve for fruit crops at a late growth (FCLG) stage (Rautmann et al., 2001). The use of air induction nozzles enabled to reduce spray compared with conventional nozzles only at distances above 15 m from the applied area (Fig. 1A). In the young poplar plantation the spray drift curve registered for Treatment 5 (conventional nozzles and high air flow rate) was above the reference one for fruit crops at a late growth stage. Both reducing the air flow rate and using of air induction nozzles enabled to drastically reduce spray drift (between 85% and 90%) with respect to Treatment 5 (Fig. 1B), even if drift deposits were still between 0.4% and 0.9% of the applied volume at distances above 30 meters from the applied field.



A B

Figure 1. Spray drift curves obtained in the adult poplar trees (A) and in the young poplar trees (B); the broken curve represents the reference spray drift curve for fruit crops at a late growth stage.

These first experimental results provided some preliminary information about spray drift in poplar plantations and possible drift reducing measures. Further studies are needed in order to: i) define a spray drift reference curves for this type of crop; ii) verify if the use of spray drift reduction technologies affects the pesticide deposition on the target and consequently the biological efficacy.

REFERENCES

Rautmann, D., Streloke, M., Winkler, R., 2001. New basic drift values in the authorization procedure for plant protection products. Mitteilungen aus der Biologischen Bundesanstaltd fur Land - und Forstwirtschaft. 83, pp. 133–141.

Oral Abstract 22
Increasing droplet size in pneumatic cannon-type nozzles to reduce spray drift

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INTRODUCTION

Spray applications with pneumatic sprayers are very common in vineyards all around Europe. In these applications, cannon-type nozzles are mounted in the top part of the sprayer to reach the consecutive row in order to double the spray width and save time. Nevertheless, pneumatic spraying is known to produce very fine droplets, usually below 100 µm in diameter (Márquez, 2007) which are very drift-prone (Cunha et al., 2004). In addition, the finer the droplet, the more likely to be evaporated (Oliveira et al., 2007). In pneumatic spraying, the most important parameters affecting droplet size are the air flow rate, the air speed and the liquid flow rate (Di Prinzio et al., 2010). An increase in air flow rate and air speed reduces the droplet size while an increase of liquid flow rate increased droplet size. Air speed is the least controllable parameter by the farmer, because it depends on the spout internal diameter. However, it should also be adjustable because of its influence on spray penetration into the canopy. Therefore, reducing this parameter could lead to a coarser droplet size spectrum reducing spray drift risk. The objective of this work was to evaluate the changes produced in the droplet size and homogeneity by changing the insertion position of the liquid hose as a tool for drift prevention.

MATERIALS AND METHODS

A test bench was developed to simulate the operating conditions of a real pneumatic sprayer. The bench consisted of both hydraulic and pneumatic systems mounted in laboratory conditions. The hydraulic circuit was driven by a membrane pump and, at its end, a cannon-type pneumatic nozzle (TC.SAV2C, CIMA SpA, Pavia, Italy) was mounted. A regulatory disc changed the liquid flow rate for a given pressure. The pneumatic system consisted of a centrifugal fan (CIMA SpA, Pavia, Italy) with a control box to manually set its rotary speed.

The droplet size was measured with a laser-based instrument (SprayTec ®, Malvern Instruments Ltd, Worcestershire, UK) (Fig. 1a) equipped with a 300 mm lens. Measurements were taken at 1 Hz frequency. Four air flow rate values (0.280, 0.312, 0.348 and 0.376 $m^3 s^{-1}$) and three liquid flow rate values (1.00, 1.64 and 2.67 L min^{-1}) were tested for two insertion positions of the liquid output hose inside the spout: the conventional (CP) and an alternative position (AP) where the internal spout diameter was wider (70 mm instead of 50 mm) (Fig. 1b). This made 24 different combinations of parameters. The studied variables were tested in a completely randomized design. For each combination of parameters, a total of 180 droplet size measurements were taken, with three replications of 60 measurements each. The studied variables were D50 (VMD), as a measurement of the droplet size, and the Relative Span Factor (RSF), that was calculated from D10, D50 and D90 parameters, as a measurement of the droplet size homogeneity. The results were analysed with a T-test (α=0.05) after checking their normality (Shapiro-Wilk test, α=0.05) and homocedasticity (Levene test, α=0.05).

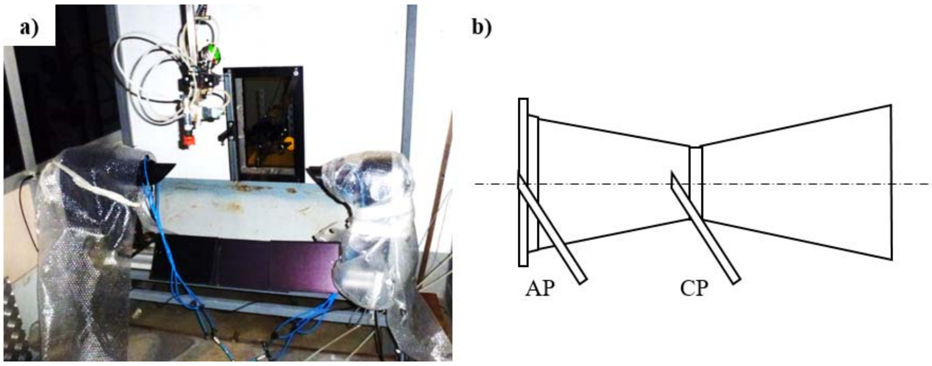

Fig. 1. a. Laboratory configuration for droplet size measurement. b. Insertion positions of the liquid output hose inside the air spout.

RESULTS AND DISCUSSION

The T-test showed a clear effect of the hose insertion position on droplet size ($p < 0.001$). Average D50 values calculated from the whole dataset increased with 59.4% from the conventional to the alternative nozzle position (from 74.26 µm to 118.39 µm, Fig. 2a). The droplet size also depended on the air flow rate ($p < 10^{-4}$) and the liquid flow rate ($p < 10^{-4}$), decreasing with the first parameter and increasing with the second one. It was also observed that the difference in the droplet size produced by the hose position change increased with the liquid flow rate and decreased with the air flow rate up to 30%. T-test showed significant differences between both treatments also concerning RSF, with average values slightly higher for the AP with respect to the CP (1.65 vs 1.78) (Fig.2b).

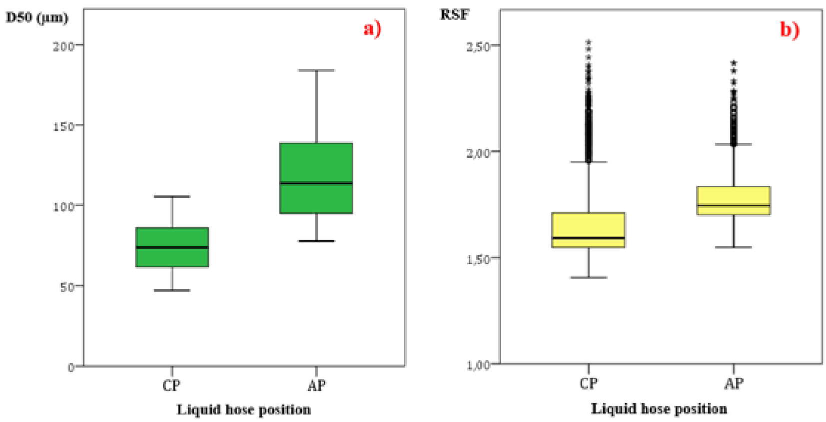

Fig. 2. a. D50 values and b. RSF values for both positions of the liquid hose.

BIBLIOGRAPHY

Cunha, J.P.A., Teixeira, M.M., Vieira, R.F., Fernandes, H.C.; Coury, J.R., 2004. Espectro de gotas de bicos de pulverização hidráulicos de jato plano e de jato cônico vazio. Pesquisa Agropecuária Brasileira, Brasília, 39 (10): 977–985.

Di Prinzio, A., Behmer, S., Magdalena, J.C., 2010. Equipos pulverizadores terrestres. In: Tecnología de aplicación de agroquímicos. Argentina: Área de comunicaciones del INTA Alto Valle, pp. 107–120.

Márquez, L., 2007. Pulverización y pulverizadores neumáticos, Agrotécnica, February 2007: 34–41.

Oliveira, A.R., Boller, W., Forcelini, C.A., Blum, R., Lopes, A., 2007. Fungicidas, doses e volumes de calda no controle químico da ferrugem da folha da aveia (Puccinia coronata f. sp. avenae). Engenharia Agrícola, Jaboticabal, 27, special number: 48–55.

Oral Abstract 23
Spray quality, droplet velocity and spray drift potential of sprays sprayed with additives through standard and venturi nozzles

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INTRODUCTION

The use of venturi nozzles and additives in pesticide applications has increased worldwide due to spray drift reduction and environmental contamination. Coarse sprays are less driftable than fine and medium sprays. In turn, coarse sprays reach nontarget areas more difficult.

Besides droplet size, its velocity effects also the spraying process (Miller and Butler Ellis, 2000). The higher the drop velocity, the lower is the spray drift potential.

Therefore, the objective of this research was to evaluate size, velocity and spray drift potential of droplets from spray solutions with and without mineral oil sprayed through standard and venturi nozzles.

MATERIALS AND METHODS

The experiment was performed in a completely randomized design with five replications, in a 2 x 2 factorial scheme, being two nozzle types and two spray compositions. Flat-fan nozzles with and without air induction/venturi, ADIA 11003 and AD 11003 (Magnojet®, Brazil), respectively, were used at 300 kPa pressure.

In both solutions, the surfactant Agral® (Syngenta, Switzerland) was used at 0.05% v v^{-1}, to simulate de field conditions in the presence of pesticides. The mineral oil Assist® (BASF, Germany) was added to the solution at 1.5% v v^{-1}.

For droplet size spectrum evaluation, the Dv0.5 was considered (the droplet diameter for which 50% of the total spray volume is in droplets of equal or lesser size, also known as volumetric median diameter – VMD), the relative span (RS) and the average droplet velocity. The measurements were made using VisiSize D30 (Oxford Lasers Imaging Division, England). The nozzles were mounted on a carriage 50 cm above the laser beam and automatically traversed, allowing the spray to be directed down into and across the beam. The system counts ten thousand droplets in each repetition to provide the average spray parameters.

Spray drift evaluations were performed in a wind tunnel, at 2.5 m s^{-1} wind speed, following the methodology proposed by Moreira Júnior and Antuniassi (2010).

The data were subjected to analysis of variance and when significant differences were observed, the treatments were compared to each other using Tukey's multiple comparison test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Relative span, droplet velocity and drift potential depend on the combination of the nozzle type and spray composition. For the standard nozzle (AD), the RS is lower, and more homogeneous than a spray produced by a venturi nozzle (ADIA) (Table 1). The addition of the mineral oil reduced the RS and increased the droplet velocity for both nozzles. However, the droplet velocity produced by ADIA nozzle was greater than that produced by AD when mineral oil was added to the spray solution. The addition of mineral oil reduced the spray drift potential by 2.3 and 3.8 times for ADIA and AD nozzles, respectively, when compared to the solution without mineral oil. Spray solution effect and interaction between nozzle and spray solution were not significant for the VMD. The ADIA nozzle produced droplets coarser than droplets produced by AD nozzle.

Table 1. Relative span, average droplet velocity (m s^{-1}), spray drift potential (%) and volumetric median diameter (VMD, µm) from two spray solutions sprayed through standard (AD) and venturi nozzles (ADIA).

Spray solution	Nozzle	
	AD	ADIA
	Relative span	
Surfactant	1.10 aB	1.44 bB
Surfactant + mineral oil	0.97 aA	1.05 bA
	Droplet velocity (m s^{-1})	
Surfactant	2.48 aB	2.58 aB
Surfactant + mineral oil	2.92 bA	3.12 aA
	Spray drift potential (%)	
Surfactant	4.85 bB	1.56 aB
Surfactant + mineral oil	1.28 bA	0.69 aA
	VMD* (µm)	
Surfactant	148.76 bA	357.82 aA
Surfactant + mineral oil	171.14 bA	329.70 aA

Averages followed by the same letter, lower case in the rows and upper case in the columns, do not differ using Tukey's test at $\alpha = 0.05$.
* Spray solution effect and interaction between nozzle and spray solution were not significant.

ACKNOWLEDGEMENTS
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REFERENCES

Miller P C H, Butler Ellis M C (2000). Effects of formulation on spray nozzle performance for applications from ground-based boom sprayers. Crop Protection 19, 609-615.

Moreira Júnior O, Antuniassi U R (2010). Construção e validação de um túnel de vento para ensaios de estimativa da deriva em pulverizações agrícolas. Energia na Agricultura 25, 118-136.

Oral Abstract 24
Development of a National Spray Application Work Group

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INTRODUCTION

Changes in spray application technology create both a need and an opportunity for research and extension to improve targeted deposition and reduce drift (Kaine and Bewsell, 2008). Few growers benefit from the existing body of knowledge and new technologies, because of two limitations. First, there is a lack of comparative data on the relative costs and benefits of new technologies in specific regional and horticultural settings. Second, budget cuts have virtually eliminated extension specialists in perennial crop spray application technology, leaving extension generalists to deliver education in this field. These personnel lack the training necessary to help growers and thus growers lack access to objective, research-based information.

In certain regions of the US, like the Northeast, there has been progress in adoption and proper operation of sprayers because research and extension activities of an engineer, Dr. Andrew Landers of Cornell University, with a significant extension appointment. In other regions, extension educators and pest management researchers working in specialty crops are attempting to develop educational programs on application technology but have been hampered by limited to no training in agricultural engineering. Our objective is to provide a foundation for education in spray application technology by creating a national network of trained extension personnel who will share research-based information about the effectiveness of newer technologies with growers.

MATERIALS AND METHODS

We established a national spray application work group (SAWG) through three face-to-face trainings and sustained it through monthly phone calls and shared documents. In 2013 and 2014, 15 participants from Washington, Oregon, California, Pennsylvania, New Hampshire, and British Columbia Canada participated in a 4-day train-the-trainer workshop at Cornell University conducted by Dr. Andrew Landers. Aimed at county extension educators and farm consultants with little or no knowledge of the engineering aspects of application technology, the course showed participants how sprayers can be adjusted to minimize drift and increase canopy coverage. The course included sprayer components, calibration, canopy deposition, and worker safety. Specific topics in sprayer components included pump maintenance and selection, pressure regulation, nozzle selection, droplet formation and deposition, and technologies for drift reduction. Calibration topics included nozzle replacement, aligning spray patterns to match the canopy, and measuring canopy volume. Canopy deposition focused on the effects of forward speed, air speed/volume and application rate upon the amount of material on the target. Worker safety addressed proper methods for filling and cleaning the sprayer that minimize operator contamination, time, and environmental pollution.

Included with all of the engineering lessons were also lessons on effective methods of teaching farmers and operators similar information about application technology.

In 2016, we conducted an additional 3-day training led by Dr. Emilio Gil, University of Catalunya, Spain. Attendees included approximately half of the SAWG members, 10 other regional trainers and consultants, as well as manufacturers from Spain and Belgium. This training include some of the previous topics but was focused on more targeted topics like tree row volume and proper use of testing instruments from AAMS-Salvarani.

Participants were expected to conduct at least one grower-focused workshop in their local regions within a year and participate in SAWG monthly phone calls. Through SAWG, we have shared presentations and current education techniques. We also review and discuss key engineering papers on drift and evaluation of technologies.

RESULTS AND DISCUSSION

There have been two foci of this program. First was to educate and inspire an engaged group of professionals to devote time to application technology. The second focus was to develop and deliver educational opportunities for producers.

After each Cornell course, the participants were surveyed to determine their knowledge gained and change in activities. Prior to the training, only three participants had a majority of their program focused on application technology. The others were not regularly giving presentations or workshops on application technology. Participants identified these specific lessons learned: 1) differences in sprayer designs, 2) the function of sprayer components, 3) the role of air as it leads to better deposition and less drift, 4) technologies to reduce off-target drift. Specific methods to enhance their educational programs included: 1) techniques for demonstrating drift potential, 2) use of fluorescent tracers to show coverage, 3) use of a vertical "Patternator", and 4) faster sprayer calibration techniques. The information gleaned from each training differed, so the monthly phone calls have increased knowledge sharing across both classes.

By providing training to extension professionals, we significantly increased the number and quality of workshops available to producers. A total of 39 workshops, nine more than expected, were conducted with 1577 producers attending which represented more than 3,642 hectare of fruit and vegetable farms. Educators also calibrated 86 individual sprayers that would be used on over 2981 hectare. Trainees also gave 42 shorter (i.e. 20-30 minute) presentations at fruit and vegetable meetings reaching approximately

2923 producers. Additionally, the Washington State educators have developed a 1-day sprayer calibration/optimization course that is now funded through the state Department of Agriculture and from the Washington Specialty Crop Block Grant (K1782). Over two years, 232 farm managers and operators were trained in Washington through eight workshops. The course is offered in Spanish and English and focuses at least half the time to hands-on learning activities in the field. Lastly, agricultural engineers with significant Extension appointments have been hired in California and Washington, resulting in increased capacity and research in those regions.

REFERENCES

Fox, R.D., R.C. Derksen, H. Zhu, R.D. Brazee, and S.A. Svenssson. 2008. A history of air- blast sprayer development and future prospects. Trans. ASAE. 51(2):405-410.

Kaine, G. and D. Bewsell. 2008. Adoption of integrated pest management by apple growers: the role of context. Int. J Pest Man. 54(3): 255-265.

Oral Abstract 25
Perceptions on how to reduce the risk of Plant Protection Product (PPP) losses to surface water in fruit production
Results from the European TOPPS stakeholder survey 2016

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INTRODUCTION

The TOPPS project started in 2005 and focuses on the development of risk diagnosis tools and mitigation measures to reduce the risk of PPP losses to surface water. Best Management Practices being disseminated through information, presentations, workshops and trainings. The current project is executed in 12 EU countries through local partners, addressing the main emission routes of PPP to surface water: point sources (from farmyards) and diffuse sources (from treated fields). In order to better understand the local training needs regular stakeholder surveys being conducted.

MATERIALS AND METHODS

In winter 2015/2016 a questionnaire was developed by the TOPPS partners representing 12 EU countries. The questionnaire was translated into the local languages and sent by E-mail, through the partners and local crop protection associations to stakeholders. Questionnaires were collected via the internet and data processing was organized and coordinated at the Univ. Polytechnic Cataluña; analysis of the responses was done by BetterDecisions.

Some statistical questions were asked to segment the sampled stakeholders:
a) Interaction intensity with farmers: regular contact = once a week / in contact = once per month / few contacts = few per year and no contact.
b) Organization: public service, private company, semi private organisation
c) Professional background: Farm advice, Control/Monitoring, Education, Research /Development, Stewardship, Water quality, Application technique, Politics, Others.
d) 12 Countries (number of participants): PL(279), ES(135), DE(119), FR(116), BE(98), SK(82), HU(75), IT(63), GR(58), PT(51), RO(51), NL(34) - (total responses received n= 1161).

RESULTS AND DISCUSSION

The presented results will focus on aspects of general importance and specific ones related to fruit growing. About 63% of the respondents are in regular contact with farmers, 15% are in contact. It can be assumed that the respondents having contacts (63% + 15%) have a good understanding of the general practices on the farm. On average 52% respondents work in public services, 40 % in private companies and 8% in semi-private organizations.

a) Perception of PPP entry routes to surface water.

On average the contribution of point sources to total water pollution with pesticides is estimated to be 47% versus 51% for diffuse sources. Some countries (BE,DE,GR,NL,ES) see point sources contribution above 50%, while SK and HU see the highest contribution with > 60% for diffuse sources.

Perception of diffuse sources (runoff, spray drift and drainage) vary strongly among countries. Spray drift is ranked most important in Italy, equally high to runoff in Spain. Respondents of most other countries perceive runoff as the major diffuse emission route.

Emissions from drainage systems are seen as more significant than spray drift in DE, GR, RO and SK.

b) Perceived significance of use areas relevant for PPP water protection.

In all countries the orchard and vine crops are seen as the most important area relevant for PPP water contamination, followed by arable crops and mixed farming. Some specific situations in countries are highlighted: Glasshouses, covered production in NL, ES and PT; Railway uses in DE and FR; Home & Garden and Urban areas in BE and NL

c) Reduction potentials if BMPs being implemented.

Biggest reduction potentials are seen in better remnants management, sprayer cleaning procedures and spray drift reduction in fruit crops. It can be concluded that respondents see the reduction of point sources as an opportunity for fast wins followed by reducing spray drift. Reduction potentials for runoff are seen generally lower as it will require more effort and time due to more complexity.

d) Efficiency of spray drift reduction measures in bush and tree crops.

Across all countries, anti-drift nozzles are rated as most efficient measure to reduce spray drift. For second position, opinions vary a lot among countries about efficient measures, suggesting that there is a lot of insecurity in the judgment. On average, tunnel sprayers and cross-flow sprayers are rated as second and third most efficient measure. This would mean that crop training systems need to be adapted to respective sprayer technologies, but in the survey shaping fruit trees to the techniques is rated very low. In some countries adjustment of spray and air profile is among the first three mitigation measures, indicating a growing awareness for more precise adjustments of bush & tree crop sprayers (IT, ES, NL, PT, GR).

e) What investments result in best returns on investments to reduce PPP losses to surface water.

Respondents are very consistent across countries: Investment in sprayers, investment in awareness, and investment in infrastructure are most important.

f) Best method to implement BMPs to reduce water contamination? Most preferred is to demonstrate BMPs to farmers and advisers. Demonstrations have a theory and a practical part. Next is a stronger integration of BMPs in the education system and farmer meetings. Results from NL are different reflecting specific local situations. They would see incentives linked with achieved targets and a concentration on vulnerable areas as key elements for implementing BMPs.

ACKNOWLEDGEMENT

All TOPPS partners in countries to help realize the survey (visit www.topps-life.org for more details on TOPPS).

Oral Session 5
New technologies on spray applications
Session Chairs: Emilio Gil and Jean-Paul Douzals

Oral Abstract 26
Measuring canopy density in orchards and vineyards

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INTRODUCTION

Keeping the spray cloud within the fruit crop canopy is the goal of all good sprayer operators in order to reduce spray drift and increase spray deposition.

Llorens et al (2013) developed a method of adjusting liquid control, using the Lechler Vario-Select (Lechler GmbH,Metzingen,Germany) and a Cornell University adjustable louvre to control the airflow based upon a system which measured the distance from the ultrasonic sensor to the edge of the crop canopy. The low cost system calculated canopy volume based upon the distance and time of the ultrasonic system and the centerline (trellis posts) of the canopy. The assumption being made that the rows of trees and vines were in a straight-line and the tractor was being driven in a straight-line, neither being commonly found.

MATERIALS AND METHODS

The ultrasonic system was further developed (Palleja & Landers, 2015) to account for crop density and was used in the following field trials. The canopy sprayer was a Berthoud S600 axial fan sprayer. It incorporates a set of 4 ultrasonic sensors (XL-MaxSonar MB7092) mounted on a 3 m long mast (Fig. 1). The sensors are distributed along the mast according to the height of the trees or vines. A microcontroller board was used to estimate the canopy density as a function of the ultrasonic echoes. It was tested as the growing season progressed and the data obtained was highly correlated with the season but it was not compared to actual canopy density.

Point Quadrat Analysis (PQA) was used to compare the ultrasonic data with a scientifically accepted method to estimate canopy density, check if the data is correlated, and validate the ultrasonic system. Point Quadrat Analysis (PQA) is an acceptable yet simple field method to measure key parameters of the canopy characteristics. In PQA, a probe is passed through the canopy and any contact with biomass such as leaves or fruit are identified and recorded. The canopy is sampled at specific heights, which is usually at the fruit zone, at consistent intervals along the row. Enhanced Point Quadrat Analysis (EPQA) was a further development of the PQA method by Meyers & Vanden Heuvel, (2008).

Two plastic frames were built to perform PQA in the two vineyards (0.5x2 m, Fig. 2). The frames have 4 horizontal bars, matching the ultrasonic sensors' height. Each horizontal bar has 6 marks spaced 10 cm apart, indicating the position where the operator introduces the probe to count the number of leaf layers.

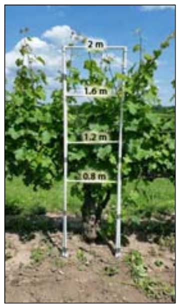

Fig. 1 Berthoud sprayer with mast and sensors. Fig. 2 Vineyard PQA frame.

The experiments were conducted in *V. vinifera* cv. Vignoles and cv. Cabernet Franc vines and c.v Macoun trees during the 2015 and 2016 seasons. The field trials consisted using the ultrasonic system to scan both sides of a row at 4.6 km/h as well as perform PQA. The PQA frame has 24 different positions and it is moved along the row at 4 random locations, making a total 96 samples per row per week. The average 96 PQA samples, named |PQA|, is compared with the average of the 4 sensors' *wc* (the average of the full sum of ultrasonic sound returns, along the row, named |*wc*|. *wc* values are expressed in volts.

RESULTS AND DISCUSSION

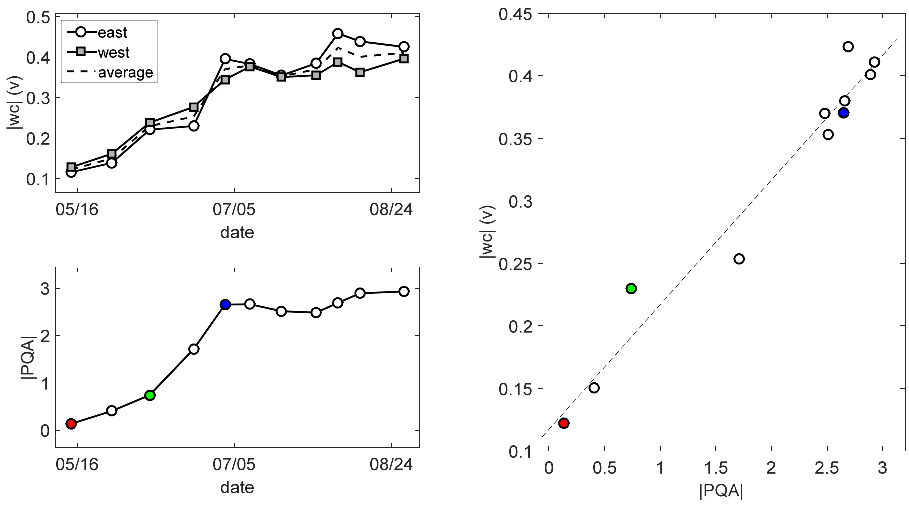

Fig. 3. Comparison of PQA and the Cornell University Canopy Density Sensor in Cabernet Franc vineyards, between May 14th and July 31th, 2015.

The ultrasonic system shows strong correlation to the acceptable, traditional method of Point Quadrat Analysis (PQA). The ultrasonic system allows the rapid determination of canopy density, providing information to allow the variable application of pesticides in real-time.

REFERENCES

Llorens, J., Landers, A. and Larzelere, W. (2013). Digital measurement and actuators for improving spray applications in tree and vine crops. Proc. 9th European Conference on Precision Agriculture. July 7-11 2013. Lleida, Catalonia, Spain

Meyers J M, Vanden Heuvel J E. (2008). Enhancing the Precision and Spatial Acuity of Point Quadrat Analyses via Calibrated Exposure Mapping. American Journal of Enology and Viticulture 59:425- 431

Palleja T. and Landers A J. (2015). Real Time Canopy Density Estimation Using Ultrasonic Envelope Signals in the Orchard and Vineyard. Computers and Electronics in Agriculture, pp. 108-117.

Oral Abstract 27
Crop characterization by Lidar sensor in different French orchards: preliminary results at early stages.

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INTRODUCTION

The National Action Plan (ECOPHYTO) aims at reducing the use of Plant Protection Products in all types of crops. In France, the registration of pesticides used in bush and tree crops is based on a dose expressed by surface area of land (L or kg/ha) whatever both the inter-row distance, the crop stage and structure during the season. Practical adjustments of the application volume or the PPP dosage face the problem of the definition of the target density. Several studies (Walklate et al., 2002; Berk et al., 2016; Escola et al., 2016) already showed the potential of a Lidar sensor to estimate the target structure in structured canopies (vines or fruit wall). The current study was conducted in several orchards (Tab 1) located South East, South West and North West of France in different fruit crop productions (Apples/pears, Cider apple, stone fruits, nuts) leading to 90 experimental fields where Lidar and manual measurements of the crop dimensions were combined. Experiments were conducted from end of April to end of July 2016.

Table 1: Crop characteristics as determined by Lidar

Fruit Crop	Training system	Crop characteristics			Number of rows scanned
		Inter-row	Height* (sd)	Thickness (sd)	
Pome fruits	Fruit wall, axle; drilling	3.3 - 4m	2.75m (±0.30)	1.84 (±0.61)	60
Stone fruits	Gobelet	4 - 6m	2.08m (±0.47)	2.30 (±0.93)	15
Cider apple	Free axle	4.7 - 5.5m	2.60m (±0.80)	2.26 (±0.43)	8
Nuts	Free axle	8 - 10m	5.33m (±1.80)	5.33(±1.34)	7
Total					90

*starting 0.5m above the ground

MATERIALS AND METHODS

A SICK® LMS 100 sensor (Sick, Germany), 905 nm wavelength, was used with a frequency rate of 50 Hz, 270° scan with 0.5 degree angle resolution and at a travel speed of about 5 km.h^{-1}. The Lidar was coupled with a RTK GPS (5 Hz) and a webcam. The blind zone of 90° was oriented downwards so both half rows (left and right hand side) were scanned simultaneously. The spatial resolution was about 3 cm (2.5 – 3.5cm) in length (direction of travel); 1.2cm in height (1.1.- 1.3cm) and 1.2cm in canopy depth (0.5-8cm) leading to average pixels of 3.6cm² and average voxels of 4.3cm^3.

Data were analyzed with Matlab® (Mathworks) with two different purposes. First a complete analysis of each half row was directly done with the statistical definition of crop height and crop depth based on the average height distribution values and 95th percentile of the depth distribution values. Values of Leaf Wall Area and Tree Row Volume were calculated from Lidar measurements considering the global dimensions LWA(L) and TRV(L) similarly to the manual method (LWAman / TRVman) based on the evaluation of the dimension of 10 trees/row (Table 2). LWAopt / TRVopt correspond to optimized data taking into account the 2D porosity factor (discretized LWA or TRV).

RESULTS (EXTRACT)

Table 2: Manual and Lidar based comparison of crop dimension parameters (early stage)

crop – training	LWA_{man}	$LWA_{(L)}$	$LWA_{(opt)}$	2D Porosity	TRV_{man}	$TRV_{(L)}$	TRV(opt)	3D porosity
Apple (young)	12840	10800	5790	46%	5849	6750	3640	54%
Apple	17295	18080	8140	42%	12880	12800	7750	60%
Stone fruits	13080	7680	5540	27%	11550	8650	7310	8%
Nuts	19060	11410	5870	47%	55620	31950	20030	26%
Cider apples	11670	9800	5890	38%	12090	11120	9850	13%

n.a. not available

The results showed that the manual determination of LWA or TRV was rather close to Lidar values ($LWA_{(L)}$ and $TRV_{(L)}$ except for taller trees (nuts and cider apple). However the discretization of the data $LWA_{(opt)}$ and $TRV_{(opt)}$ showed a drastic drop of the values leads compared to Lidar standard values. Two porosity factors were evaluated on either the LWA (2D) and TRV (3D) comparing the Standard Lidar values ($LWA_{(L)}$ and $TRV_{(L)}$) and respective optimized values. Ranges of porosity were from 30 to 50% on the LWA basis and from 10 to 60% on a TRV basis.

CONCLUSIONS

Two main results were deduced from these previous results. First the Lidar data confirmed the manual measurements of the crop wall face or envelope. Second the consideration of the crop porosity analyzed in a 2D or 3D situation explained the differences between the envelope and probably more close estimators of the real leaf surface (Leaf Area Index). Since results for both pome and stone fruits may be directly exploitable, the case of aged nut orchards shows that some improvements in the Lidar scanning methodology are needed to get more usable data. The data obtained with the Lidar may offer a more precise description of the crop for the further adaptation of the PPP dosage and/or application volume.

REFERENCES

Escolà A, Martínez-Casasnovas J.A, Rufat, J et al., 2016. Mobile terrestrial laser scanner applications in Precision Fruticulture/Horticulture and tools to extract information from canopy point clouds. Precision Agriculture. Doi:10.1007/s11119-016-9474-5

Berk P, Hocevar M, Stanjko D and Belsak A, 2016, Development of alternative plant protection product application techniques in orchards, based on measurement sensing systems: A review. Computers and Electronics in Agriculture, 124, 273-288

Walklate P. J.; Cross J. V.; Richardson, G. M.; Murray, R. A. & Baker, D. E. (2002). Comparison of different spray volume deposition models using LIDAR measurements of apple orchards, Biosystems Engineering, vol. 82 (3), 253-267

Oral Abstract 28
Variable rate orchard sprayer based on Lidar sensor

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INTRODUCTION

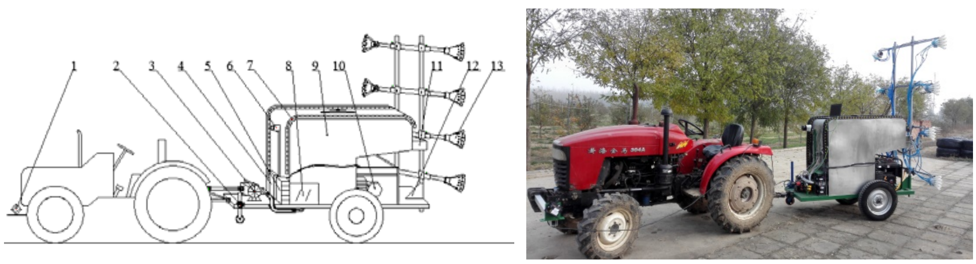
There is an urgent need for new chemical application techniques and sprayers in Chinese orchard spraying because of the requirements of environment pollution and safety for food. The canopy detection technology based on sensor provides theory basis for research of orchard precision sprayer, orchard automatic-targeting sprayer with infrared sensor has been developed in China (He et al., 2003). Gil et al. (2007) modified a conventional air-blast sprayer into a variable rate orchard sprayer using ultrasonic sensors. To make up for the detection accuracy, variable rate orchard sprayer was designed based on laser scanner, which could control the spray output to match the target characteristics. (Chen et al., 2011).

At present, variable-rate orchard sprayer based on sensors can mostly only adjust flow rate. The volume of air mostly full adjusted by central fan rotating speed and area of outlet, partly air volume and use-dosage according to canopy size was not realized so far. In this research, a variable rate orchard sprayer based on lidar sensor, which controlled not only chemical flow rate but also air volume was developed, and the experiment was conducted in Shangzhuang apple orchard in Beijing.

MATERIALS AND METHODS

Prototype

The overall structure of prototype was shown in figure 1, mainly including lidar sensor, gasoline generator, diaphragm pump, ground speed sensor, tank, electromagnetic valve, brushless motor, five-finger atomizer, transformer module and so on. The sprayer was traction type, which forms a complete set of 22kW-power tractor. For the convenience of realizing the function of automatic control, the system power was provided by the gasoline generator.



a. Schematic view b. Photograph of prototype

1.Speed sensor 2.Screw return roller 3.Hydraulic pump 4.Transformer 5.Microprogrammed control unit 6.Lidar sensor 7.Cable drag chain 8.Drive system 9.Sprayer tank 10.Electric generator 11.Solenoid valve1s 12.Boom frame 13.Five-finger atomizer

Fig.1. Overall structure of automatic variable rate orchard sprayer based on lidar sensor

Control system

When the sprayer was working, the sensor scanned the target and transfer the data to PC, PC calculated the air flow and flow rate based on algorithm and the speed information collected by MCU (Microprogrammed Control Unit) from speed sensor. Then the results were sent to the signal-chip microcomputer control module to transform into PWM signal. Electromagnetic valve actuations (40 ways) and brushless motor drivers (8 ways) adjusted duty cycle individually after receiving signals.

Air volume and flow rate

Eight independent brushless motors were adopted as the air power source, which were ranked on both sides of the orchard sprayer. The rotating speed of each brushless motor could be adjusted in real-time by PWM signal according to the canopy parameters of fruit tree. The fan performance was shown as table 1. To meet the design requirement of the five-finger atomizer, HVV-L-8004 fan nozzle was designed and the diameter of nozzle was 6mm. The spray angle was 80°. The flow rate was under the pressure of 0.3MPa and frequency of 25 Hz has a linear relationship with duty cycle, the equation was $q = 1.25a - 0.042$ (q, flow rate, L/min; a, duty cycle, %).

Table 1. Test results of fan performance

Items	Duty cycle/%						
	10	20	40	55	70	85	100
Fan speed/($r \cdot min^{-1}$)	9955	12850	18462	21968	24600	27023	28576
Wind speed of outlet/($m \cdot s^{-1}$)	14.58	21.44	30.35	37.53	45.21	49.74	51.39

Field test

To explore variable rate prototype's application effects, field experiment was conducted in an apple orchard in Beijing, the tree row space was 5×2m and the average height of tree was 4.1m. The test involved spraying from one side only at a forward speed of $2.88 km \cdot h^{-1}$. Tartrazine was used as tracer at a concentration of 2.5 $g \cdot L^{-1}$. To assess the spray distribution, artificial collectors (water sensitive paper, metallic screen mesh) were placed at nine heights and two sides of canopy (front and back). Results were expressed in $\mu L \cdot cm^{-2}$.

RESULTS AND DISCUSSION

This sprayer highly efficient, reduces pesticide use and is friendly to the environment. Conventional PTO-fan was replaced by the single brushless fan with biggest rotating speed of 28000 rpm, which could fast response once receive signal. The field test showed that deposition volume of front and back of tree were $2.52 \mu L \cdot cm^{-2}$ and $1.67 \mu L \cdot cm^{-2}$, and the droplets coverage were 71.1% and 32.4% respectively, the minimum number of droplets was 46.2 cm^{-2}. This study proposes a new equipment of plant protection for fusiform-type fruit tree, and also provides reference for design and performance optimization for plant protection machinery.

REFERENCES

He, X., Yan, K., Chu, J., Wang, J., Zeng, A. ***2003****. Design and testing of the automatic target detecting, electrostatic, air assisted, orchard sprayer. Transactions of the Chinese Society of Agricultural Engineering, 19(6): 78－80.*

Gil, E., Escolà, A., Rosell, J.R., Planas, S., and Val, L. ***2007****. Variable rate application of plant protection products in vineyard using ultrasonic sensors. Crop Protection 26(8): 1287–1297.*

Chen, Y., Zhu, H., Ozkan, H.E. ***2011****. Development of LIDAR-guided sprayer to synchronize spray outputs with canopy structures. ASABE Annual Meeting, Louisville, Kentucky, MI.*

Oral Abstract 29
ICT platform for the fruit growing sector in Belgium

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INTRODUCTION

Fruit growers, as other farmers, have a lot of registration work related to their farm management activities. Fruit growers need to pay attention to, amongst many others, the legal dose and the maximum number of pesticide applications for each product or product family they use. Fruit growers need to make multiple reports of these applications for control organisms, producer organisations and export markets, which is a time consuming and unfavorite must do, usually consuming the little leftover time which was reserved for some family/quality time of the grower. They often write the applications of crop protection products by hand in a notebook, which most growers later on input in a software system. Pcfruit developed a software application which combines the comfort of immediate digital registration with smart features and easy knowledge access.

Moreover, there is a general lack of insight into costs and returns. Cost calculations are rarely made by fruit growers. Questions as which is my crop/field with the highest profit or how many hours of pruning happened in a specific crop, variety or planting system remain unanswered.

ICT tools for registration and costs analysis are available commercially. However they are often too complicated and they are not adapted to the specific needs of vertical crops. Often a grower today needs different ICT applications that are not connected to each other. For each application the grower often has to enter the same data over and over again.

The goal of this project was to investigate how ICT solutions can meet the expectations of the grower in the best possible way. The idea was to start a platform as a base for more applications to guarantee the connectivity between different functions.

MATERIALS AND METHODS

In this project we focused from the beginning on the end-user. During the development of the software we used a structured method to meet the customers' expectations. A group of 10 growers were involved from the start. They were selected because of their open minds and interest in new technologies. Before the development started, we did research on how they currently handle registrations and costs. In the planning and concept phase we discussed our plans and possible solutions with these growers and incorporated their inputs with regards to the ease of use, correct wordings and specialities which were not foreseen in the original concept. We involved these growers to test our prototype development and to evaluate further improvements. At the launch of the software platform on the market, we installed a helpdesk and an internal process of continuous improvement.

RESULTS AND DISCUSSION

From the first meeting with the group of growers it was clear that the priority had to be on the registration of plant protection products (PPP). Besides asking the growers about their expectations, we visited the growers at their sites to study their current way of working. From here we start with generating and evaluating different concepts. Ones we had chosen a certain concept we developed a prototype which was first evaluated by the technicians of pcfruit responsible for orchard management, and later on put in test with the group of growers. They used this version of the APP for one complete season. The main result of this test was that our application had the same issues as many applications have today: too complicated and not adapted to specific fruit growing issues.

With this information we started to improve our development to simplify the user experience and to introduce fruit growing specific functions. This first version was launched in the winter of 2016. Together with the product we offered the growers a practical training of the software and access to our helpdesk. This helpdesk is the base for further improvements. Besides helping growers we use at the same time this helpdesk to ask the users about their experiences and comments on the application. Growers now know this and even call the helpdesk in case they have ideas for improvement. We check the feasibility of these ideas and prioritize the proposals. With every new update the growers receive a newsflash about the new improvements.

In the season 2016 we implemented extensions towards fertilisation, registrations of labour, harvest, plant phenology and the appearance of pests and diseases. Also we implemented additional function on mobile devices. For 2017 we plan more reports and stock control of PPP. Currently, localisation hardware is considered in order to make certain aspects of registration automatically. Further ideas are about adding weather stations, irrigation aids and diseases models.

We experienced already the advantage of the modular developed platform. Additions can be quickly implemented in the software. In future we plan to extend to other crops than fruit and to add other countries.

Oral Abstract 30
Field testing and monitoring of newly designed airblast sprayers in traditional olive orchards

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INTRODUCTION

Different improvements have been made in the last years to make air-assisted sprayers more accurate in releasing the product (Balsari et al., 2008; Doruchowski et al., 2009; Escolà et al., 2013; Gil et al., 2013). Nevertheless, special crops like olive, of which trees present an isolated disposition and very irregular crown shapes, require an increase in the application efficiency, higher than that achieved by airblast sprayers, to make sure that the applied doses are deposited on the leaves and not completely lost. Three air-assisted sprayer prototypes were designed with very promising results in their preliminary tests (Miranda-Fuentes et al., 2017). However, in order to obtain commercial solutions, tests in real field conditions must be conducted. To properly understand the operational characteristics of the prototypes in comparison with commercial equipment, two prototypes were monitored to check their savings in terms of sprayed volume. In addition, the coverage produced by the three sprayers was compared.

MATERIALS AND METHODS

Two air-assisted sprayer prototypes (P1 and P2) (Fig.1a and 1b), well adapted to traditional olive conditions, and a commercial airblast sprayer equipped with ON/OFF ultrasonic sensors (Fig. 1c) were monitored with a system consisting of one liquid flow meter (Rapid Check series; Polmac srl.; Mirandola, MO; Italy) and two pressure sensors (PA-3060; IFM Electronic; Essen; Germany), one per side. The position was registered real-time with the GPS modem (CR-3114; IFM Electronic) and all the data were displayed real-time and stored in the CR-1200 display (IFM Electronic). The four sprayers were operated by an experienced farmer over a 30 ha area field in a commercial farm with a traditional olive orchard (10 m tree spacing and 12 m row spacing). In order to set the spray volume, a total of 30 randomly-chosen trees were manually characterized, and the optimum spray volume for the commercial sprayer was then calculated to be 890 L ha^{-1}. The airflow rate was also optimized for the commercial equipment, and set at 9.0 m^3 s^{-1}. The theoretical forward speed was set at 4.0 km h^{-1}. In order to guarantee that any potential pesticide saving of the tested prototypes was not linked to a reduction in product deposition on the leaves, tree samples were monitored with water sensitive paper (WSP) to check that the coverage values resulting from the prototypes were, at least, equal to those obtained by the commercial equipment. Thus, a total of 60 trees were randomly selected and two WSP samples were placed in one of 16 possible sampling positions throughout the tree crown (Fig. 1d), also selected at random for each tree. All the sampling conditions were kept constant for the three treatments. The order of the treatments was randomly set, and a meteorological station was used to ensure that meteorological conditions were constant for the different treatments. The WSP samples were collected after the treatments had been applied and carried to laboratory, where they were analysed. The flow rate and pressure data along with the GPS position data were transferred to a laptop computer, where they were analysed. The dependent variables were the applied volume and the coverage percentage. An ANOVA test (α=0.05) along with a Tukey's test (α=0.05) were used to establish differences between means of the dependent variables after checking the normality (Shapiro-Wilk test, α=0.05) and homocedasticity (Levene test, α=0.05) requirements for the data. An arcsin transformation of data was applied.

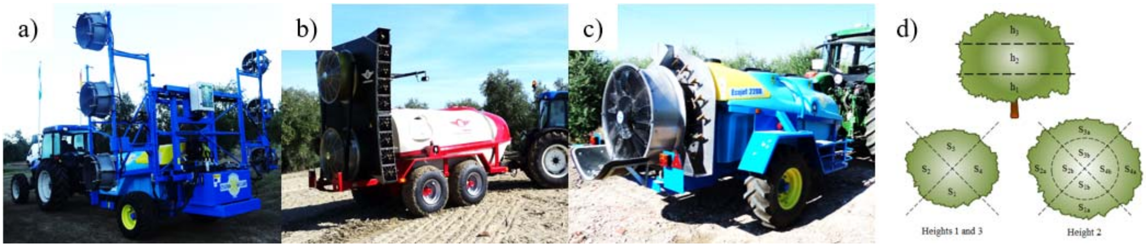

Fig. 1. a. P1 prototype b. P2 prototype, c. Commercial equipment, d. Sampling positions inside the canopy.

RESULTS AND DISCUSSION

The ANOVA test (α=0.05) showed statistically significant differences for the applied volume per ha and the Tukey's test showed that both prototypes did have a difference with the commercial sprayer, but they were not very important in practice. The P1 prototype achieved a mean reduction of 6.0% in the applied volume (mean volume of 533 against 567 L ha^{-1}), whilst the P2 prototype achieved a 5.9% reduction (534 against 567 L ha^{-1}). When looking at the coverage, the mean value for the commercial equipment was 26%, while both P1 and P2 obtained 38% (46% increase, Fig. 2a), which are significant differences according to ANOVA ($p < 0.001$). The prototypes did better for sampling heights H2 and H3 (Fig. 2b), which the commercial equipment did not reach properly. The results show that ON/OFF sensors in the commercial equipment achieve important reductions with respect to the planned spray volumes in olive (40% in average), but the implementation of a higher number of sensors and the adaptation mechanisms of the prototypes achieve a higher deposit and a better distribution throughout the canopy, even when working with the optimal parameters for the commercial equipment.

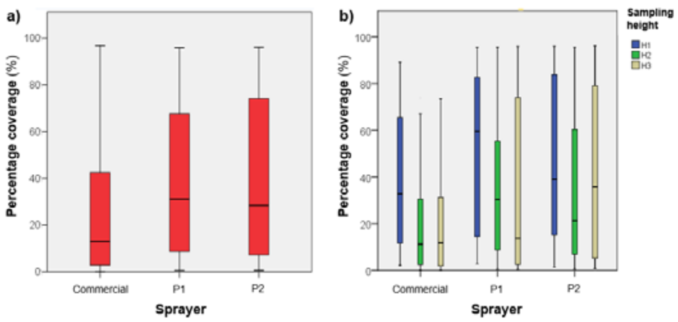

Fig. 2. a. Coverage values of the sprayers, b. Coverage values per sampling height.

BIBLIOGRAPHY

Balsari, P., Doruchowski, G., Marucco, P., Tamagnone, M., Zande, J. Van De, 2008. A System for Adjusting the Spray Application to the Target Characteristics. Agricultural Engineering International: CIGR Ejournal X, 1–11.

Doruchowski, G., Balsari, P., Van De Zande, J., 2009. Development of a crop adapted spray application system for sustainable plant protection in fruit growing. Acta Horticulturae, 824: 251–260.

Escolà, A., Rosell-Polo, J.R., Planas, S., Gil, E., Pomar, J., Camp, F., Llorens, J., Solanelles, F., 2013. Variable rate sprayer. Part 1 – Orchard prototype: Design, implementation and validation. Computers and Electronics in Agriculture, 95: 122–135.

Gil, E., Llorens, J., Llop, J., Fàbregas, X., Escolà, A., Rosell-Polo, J.R., 2013. Variable rate sprayer. Part 2 – Vineyard prototype: Design, implementation, and validation. Computers and Electronics in Agriculture, 95: 136–150.

Miranda-Fuentes, A., Rodríguez-Lizana, A., Cuenca, A., González-Sánchez, E.J., Blanco-Roldán, G.L., Gil-Ribes, J.A., 2017. Improving plant protection product applications in traditional and intensive olive orchards through the development of new air-assisted sprayer prototypes. Crop Protection, 94: 44–58.

Oral Abstract 31
Optimization of the fogging application of biological control organisms in fruit cold stores

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INTRODUCTION

The use of biological control organisms (BCOs) constitutes an alternative to chemical pre- or postharvest treatments which are currently used for the control of storage diseases of pome fruit. In previous work, the suitability of several commercial cold fogging devices was tested for the postharvest application of BCOs (Dekeyser et al., 2015). However, the efficacy of the BCOs depends on the deposited amount on the fruits and the uniformity of the distribution of the spray liquid inside the cool room. The objective of the present work was to optimize the distribution of the spray liquid in the room by assessing the effect of the fogger position and the effect of room air circulation.

MATERIALS AND METHODS

Tests were conducted in an experimental cool room facility (80 m^3), loaded with 33 bins filled with apple fruit. A commercial cold fogging device (Veugen Coldfogger) was used to apply the spray liquid. Two fogger positions were investigated in the experiments (Fig. 1): (a) placing the fogger outside the cool room with the device spraying through an access window in the door of the room, and (b) placing the fogger inside the room on top of the upper bin in the middle of the back stack, with the outlet in the direction of the door of the cool room.

The room was equipped with a cooling unit located near the ceiling at the back of the room. For the air circulation of the cooling air, four axial flow fans are attached to this cooling unit. Two different modes of room ventilation were applied in the experiments with the fogger outside the room: continuous air circulation and intermittent air circulation (one minute switched on followed by four minutes switched off).

Deposition trials were conducted using mineral chelate tracers and filter paper collectors. A spray volume of 5 litres was applied in each experiment, using a different mineral chelate, which allows to use the same samplers for multiple treatments. Deposition on the fruits was measured by wrapping 5 apple fruits in the center of each sampled bin with filter paper on the equator of the apple. From the stack, 16 bins were sampled. Additional samplers were placed on the floor, the walls and the ceiling of the cool room to assess the deposition of spray liquid on these locations. Also on the outside of the 16 sampled paloxes, filter papers were attached to the 4 sides.

RESULTS AND DISCUSSION

Average depositions on the filter papers for the three experiments are shown in figure 2. Spray deposits on the fruit were generally quite low, showing it to be hard for the droplets to reach the inner part of the bins. Placing the fogger on top of the stack gave a higher amount of deposition on the fruit compared to fogging through the access window.
The other sampled locations (walls, ceiling, outside of paloxes) received in general higher quantities of spray liquid than the apples. Especially on the floor, high deposits were measured, showing that a large amount of droplets is sedimenting on the floor before reaching the bins.

No statistical difference in deposition values were observed between the two room air circulation modes. Additional tests with a forced air system, where the air circulation is guided through the bins, were performed. Results of these experiments will be shown on the conference.

FIGURES

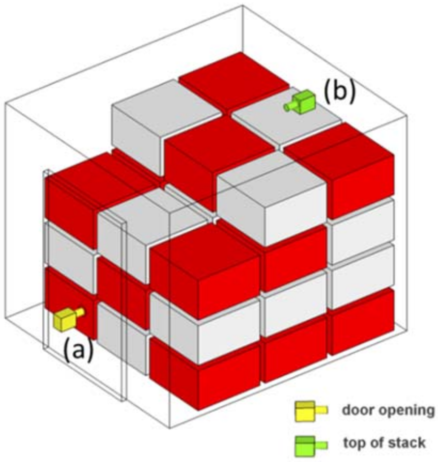

Fig. 1. Schematic view of the cool room setup. Bins in red were sampled. The two experimental positions for the fogger are indicated: (a) fogging through the opening in the door, and (b) placing the fogger on top of the stack.

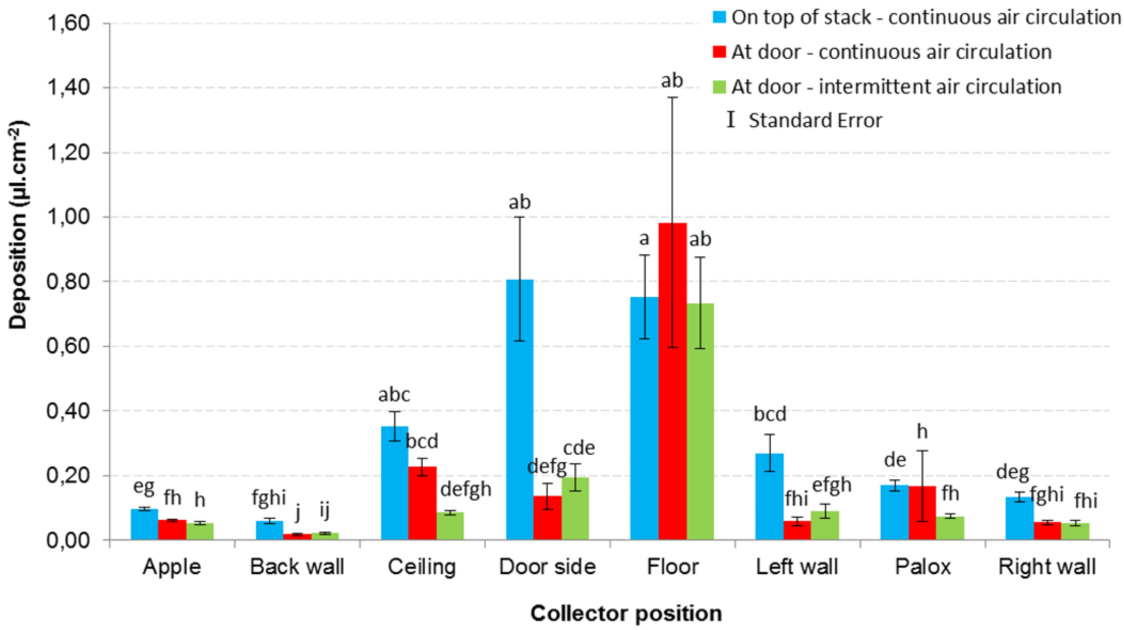

Fig. 2. Average deposition on the filter papers for the 3 experiments: fogger on top of the stack of bins using continuous air circulation, fogger at the door using continuous air circulation, and fogger at the door using intermittent air circulation. Deposition was measured on the apples in the bins, on the outside of the paloxes, on the walls of the cool room, the ceiling and the floor. Letters denote statistical differences.

REFERENCES

Dekeyser, D., Vanwalleghem, T., Ambaw, A., Verboven, P., van Hemelrijck, W., Nuyttens, D.. (2015). Technical performance of fogging applications of biological control organisms in fruit cold storage rooms. Julius-Kühn-Archiv, 448, p. 68.

Oral Abstract 32
How to stimulate the installation and use of on farm bioremediation systems to avoid point pollution?

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INTRODUCTION

Point source contamination of natural water resources by pesticides constitutes one of the most important threats for the ecological and chemical integrity of natural water resources. One of the most important routes of contamination is the mishandling of pesticide-contaminated effluents produced by on-farm and post-farm activities. On-farm activities such as spillage of plant protection products (PPP) during filling of the sprayer, leakage of the spray equipment, poor control of leftovers and internal and external contamination of the sprayer, may result in main direct losses of pesticides to the environment (Basford et al., 2004; De Wilde et al., 2007; Jaeken & Debaer, 2005). Belgium started in 2001 research on biopurification and had in 2005 a major research project funded by the Flemish government elucidating the basic principle of biopurification in these systems (Springael et al, 2009. Optimalisatie en haalbaarheid van bioremediatiesystemen voor de verwerking van spuitresten van gewasbeschermingsmiddelen, KULeuven (B)) The goal of the project was to sensitize the farmers about the importance of handling point sources in a correct way and to try to introduce the biofilter at farmlevel.

MATERIALS AND METHODS

Firstly, a list was made of the different bottlenecks of point sources at farm level. We did a survey with farmers in several sectors of agriculture.

To keep the cost of the installation of a biofilter, a new brochure was made in which we explain step by step how to build bioremediation systems as a biofilter and fytobak along with photos and a list of specific materials for each step. To make it more practical a video was made in which the farmers can see someone making the biofilter and fytobak.
Building biofilter: https://www.youtube.com/watch?v=BeF-B3twQFg
Building Fytobak: https://www.youtube.com/watch?v=6ZcvgExpauI

For events we developed a demo biofilter which we can take along and so the farmers can see the most important parts of the biofilter.

To help the farmers to take the step to make a biofilter, we organised workshops where farmers can build their own biofilter in group, together with advisers of pcfruit vzw. We made it also possible for them to order a package of all the different part, that they can take home and assemble themselves after seeing/helping other farmers at the workshop.

RESULTS AND DISCUSSION

From the survey we noticed that the biggest sources of point pollution at farm level are the filling of the sprayer and the outside cleaning of the sprayer on paved surfaces. Also a lot of farmers weren't aware that cleaning water that goes to the sewer, will arrive, in a lot of cases, in the rivers unpurified or has detrimental effects on water purification systems.

By using all the different developed tools we made at various locations in Flanders in the course of a whole year, we noticed that farmers became more aware of the problem. Several farmers started to contact pcfruit voluntarily to get more information as they feel responsible for their impact on the environment.

At pcfruit, we distributed 600 brochures, wrote 16 articles and presented at 18 events the correct way of filling and cleaning sprayers for a total of 13600 farmers (not only fruit growers). The biggest event was the ‘Werktuigdagen in Sint-Truiden’ in 2014 where 12500 farmers, researchers and people linked with farmer activities attended. For almost 30 farmers we gave personal advice and there were 17 biofilters built during workshops. To make sure the information is available for farmers at different levels, we also informed all the communities of Limburg to make sure that they also inform farmers when they want to renew their environmental permit.

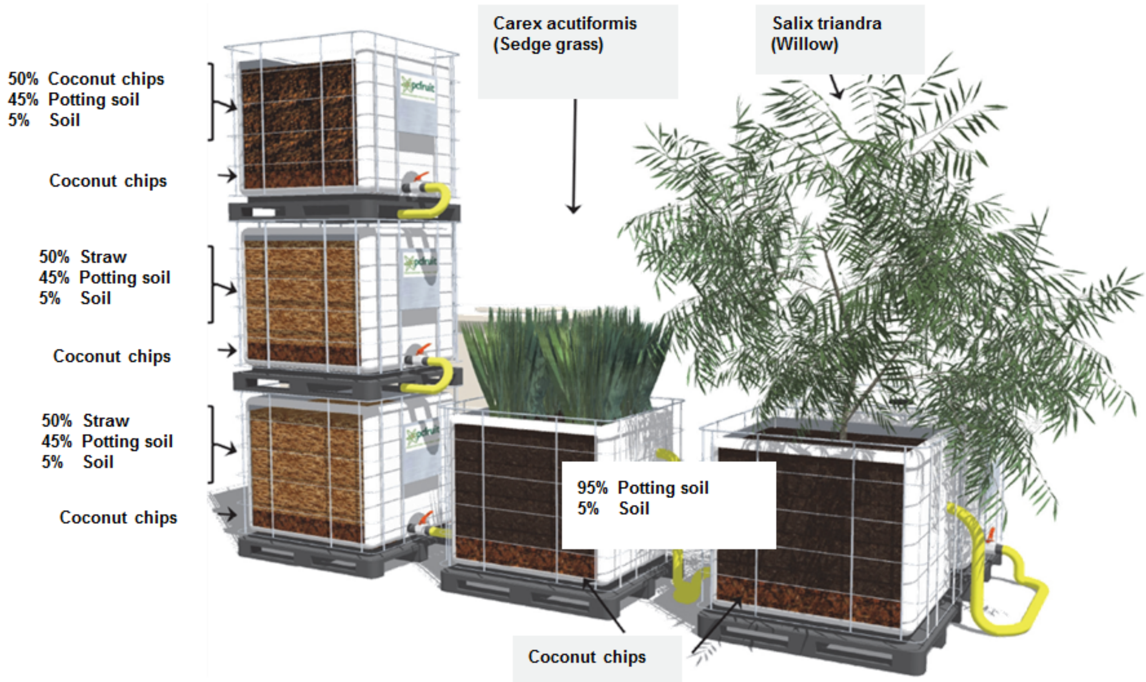

Fig: set up of an on farm bioremediation system ‘biofilter’ to manage spills and leftovers of crop protection products in the Belgian fruit sector. Due to the evaporation of the decontaminated water by Carex or Salix plants, a zero output system is envisaged.

Oral Abstract 33
The electronic measurement of spray coverage

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INTRODUCTION

In crop protection it is very important to apply the correct amount of spray to the target in order to prevent over or under-dosing as this can result in inadequate plant protection; pest resistance, poor insect and disease control, increase costs and risk of chemical contamination. An important goal for spraying crops is the real-time adjustment of the operating parameters (air flow, pressure, active nozzles, etc.) with the aim of keeping the droplets in the canopy, improving deposition and reducing drift (Landers, 2016).

Researchers and extension educators also need to be able to evaluate and demonstrate spray deposition and coverage in order to assess new spraying techniques or modifications to existing sprayers. To ascertain spray coverage, researchers and educators place many water sensitive papers (*WSC)* (Syngenta Crop Protection, Greensboro, NC, USA) into the canopy, and collect them after they are sprayed in order to be scanned and analyzed (Nuyttens et al., 2004). Researchers also use different methods to estimate deposition: Fluorometric, Colorimetric, Atomic Spectrophotometry and Image Analysis. All these methods are however, costly, time consuming, labor intensive, and often require an operator trained in the use of sophisticated and expensive laboratory equipment.

The proposed sensor is subject to a patent application and licensing agreement so the objective of this work is not to describe the whole electronic control system but to introduce a new sensor which can be used to create a feedback signal for real time sprayer adjustment or to evaluate the distribution of the sprayed droplets.

MATRIALS AND METHODS

Following exhaustive laboratory tests, field experiments were performed in a Red Delicious orchard (2.75 m row width), between 1 m and 1.3 m high at Cornell University in the summer of 2016. The sprayer used in this trial was a Berthoud S600EX axial fan (Berthoud, Cedex, France). Table 2 shows the different configuration used to perform the field experiments.

Table 2 Forward speed, nozzle and application rate configuration

Treatment	Nozzle	Flow rate[1] $L \cdot m^{-1}$	Number of Nozzles	Gear[2]	Speed $m \cdot s^{-1}$	Application rate[3] $L \cdot hm^{-2}$
1	Albuz Lilac	0.38	8	4 Low	1.33	141.1
2	Lechler Yellow	1.06	8	4 Low	1.33	393.5
3	Lechler Yellow	1.06	10	4 Low	1.33	491.9
4	Lechler Yellow	1.06	8	3 Low	0.98	534.1
5	Albuz Green	2.04	8	3 Low	0.98	1 028
6	Albuz Green	2.04	8	2 Low	0.72	1 399

[1]Pressure:700 kPa [2]Revolutions: 540 rpm. [3] Row width 2.7 m.

Two sets of experiments where performed to estimate the spray coverage: opened fields and in-canopy, both using tap water. The open field experiment was performed attaching a single senor and 2 *WSCs* on a mast, at 1 m high (Fig. 1, A). The mast was placed in an open area and sprayed 3 times, at 3 m distance, using the 6 treatments in Table 1 above. The in-canopy experiment was performed placing a sensor and *WSCs* (Fig. 1, B) at 10 random positions inside a *Red Delicious* canopy (Fig. 1, C).

Fig. 1. A) Open field. B) In-canopy. C) Ten random positions inside an apple tree, the yellow circles are only illustrative.

RESULTS AND DISCUSSION

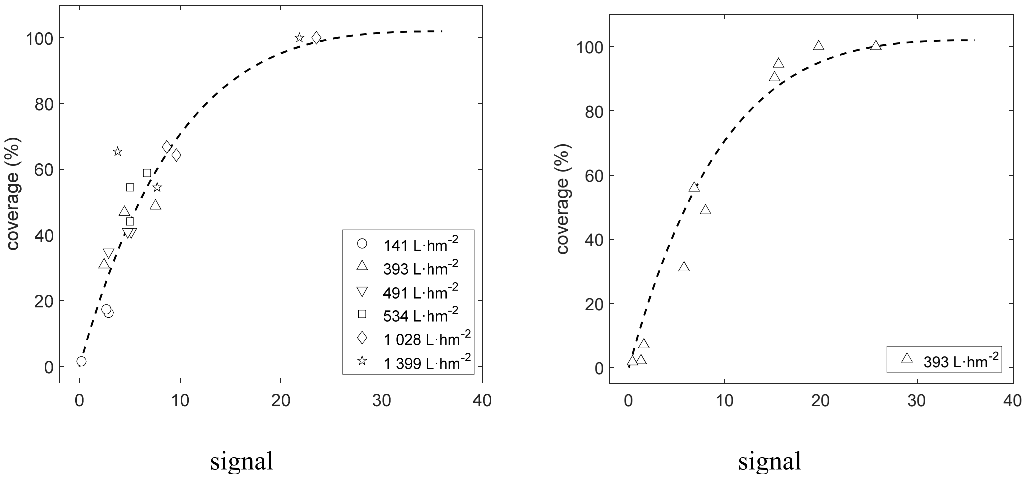

Fig. 2. Coverage obtained in field trials, using stationary sensor

A 3D sensor structure was also developed and tested to analyze depositions all around a spherical object, mimicking large fruits such as apples, oranges, nectarines, etc.
Experiments show that the proposed sensor has a lineal relationship between the sensed signal and the deposition with an average absolute error of 0.084 $\mu L \cdot cm^{-2}$. Nevertheless, it has an exponential relationship versus coverage, with an average absolute error of 2.38 %. This phenomenon could be explained by the difficulty to estimate coverage on *WSCs* greater than 70 %. Two experiments were performed to estimate the effect of chemicals (*NaCL* and *Kaolin*) on the sprayed water. In the first one, the sensors were fully covered by different solutions, in the second trial, the sensors were sprayed with different solutions and different doses. Data shows no significant differences between the solutions tested in this work.

REFERENCES

Landers, A.J. (2016). Effective Orchard Spraying. Keuka Park: Effective Spraying.
Nuyttens, D., S. Windey, and B. Sonck. (2004). Optimization of a vertical spray boom for greenhouse spray applications. Biosystems Engineering, 89 (4): 417-423

Oral Abstract 34
CFD modelling of spray applications in cool rooms

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INTRODUCTION

An emerging application of spraying are chemical and biocontrol treatments after harvest in the cool room, before or during storage of fruit. An important challenge of these applications is achieving the required level and uniformity of deposition by spray penetration into the relatively dense fruit stack in bins. The objective of this study was to develop and validate a multiscale computational fluid dynamics (CFD) model of spray application in cool rooms to analyse the suitability of spray systems for postharvest treatments of fruit stacked in bins. As part of a larger collaborative effort, the model was applied to study how spray droplets are distributed in fruit bins and how the process efficiency and uniformity can be affected by spray nozzle and airflow settings and bin stacking in the cool room. This contribution presents and overview of the obtained results of a 4-year project.

MATERIALS AND METHODS

Computational fluid dynamics (CFD) model was used to investigate the distribution and deposition of postharvest treatment sprays. A two-phase flow model, which consists of one disperse phase (spray droplets) and one continuous phase (air), was used (Ambaw et al., 2017, Delele et al., 2012). The airflow distribution in and around the bins was obtained by solving the single phase Reynolds-Averaged Navier Stokes equations with the SST turbulence model. The droplet dispersion and deposition was modelled by using Lagrangian particle tracking. In most cases, the spray was generated by a commercial spray device (Fontan® Starlet ULV 92 cold fogger with a 6 L spraying tank, Swingtec GmbH, Isny, Germany) of which the spray characteristics were measured and used in the model. The device was selected because of its favourable droplet size spectrum as well as providing sufficiently high volume flow rates. The CFD model was solved on 3D CAD models of the cool room and fruit bins in different settings.

To better understand the spray process in cool rooms, several configurations were investigated, from systems with single bins to fully loaded cool rooms. For different configurations, experiments were conducted for validation of the simulations.

RESULTS AND DISCUSSION

Single bins were first analysed. Low spray deposits on fruit were resulting from spraying using only room air circulation, as droplets mostly bypassed the bin. Using suction airflow that directs the spray through the bin improved spray deposition and uniformity. Depending on the droplet size, different effects were observed in the simulations. Coarse droplets performed best in terms of uniformity of deposition with more lateral dispersion across the bin, while fine droplets had a very limited lateral dispersion but traveled deep into the stack following the high-velocity air. By implementing multiple nozzles the poor lateral dispersion of fine droplets was improved significantly, resulting in a system proposed for single bin treatments before loading into the cool room.

Figure 1 shows a typical result of a CFD simulation of a cool room, illustrating droplet tracks of sprays inside the room completely filled with fruit bins. In the shown case, the droplets were ejected by an array of nozzles in front of the evaporator assembly into the air stream generated by the evaporator fans. A uniform spray was established that distributes across the bin rows more evenly than other configurations with single nozzles at different positions in the room. However, the issue of poor penetration into the bin persisted. This could be to some extent be solved by implementing an air suction system in the room.

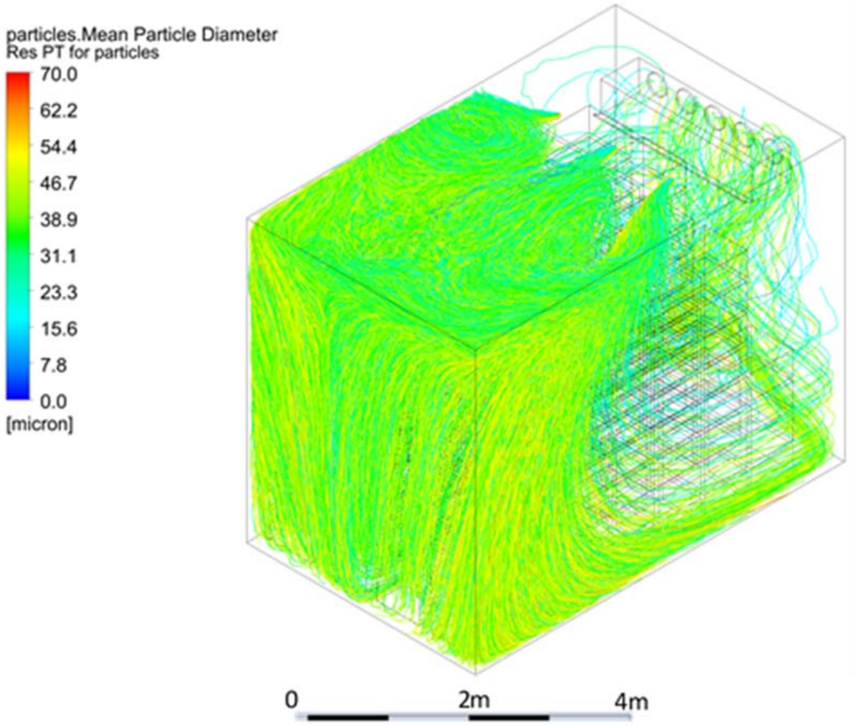

Figure 1. CFD model of the spray distribution inside a typical apple cool room. Predicted particle tracks of droplets are shown during injection in front of the air circulation fan using three nozzles distributed across the width of the room, resulting in uniform distribution of the different rows of bins in the room.

REFERENCES

Delele, M., Vorstermans, B., Creemers, P., Tsige, A. A., Tijskens, E., Schenk, A., Opara, U. L., Nicolaī, B., & Verboven, P. (2012a). CFD model development and validation of a thermonebulisation fungicide fogging system for postharvest storage of fruit. Journal of Food Engineering, 108(1), 59–68.

Ambaw A, Dekeyser D, Vanwalleghem T, Van Hemelrijck W, Nuyttens D, Delele MA, Ramon H, Nicolai B, Opara UL , Verboven P. (2017). Experimental and numerical analysis of the spray application on apple fruit in a bin for postharvest treatments. Journal of Food Engineering. Accepted.