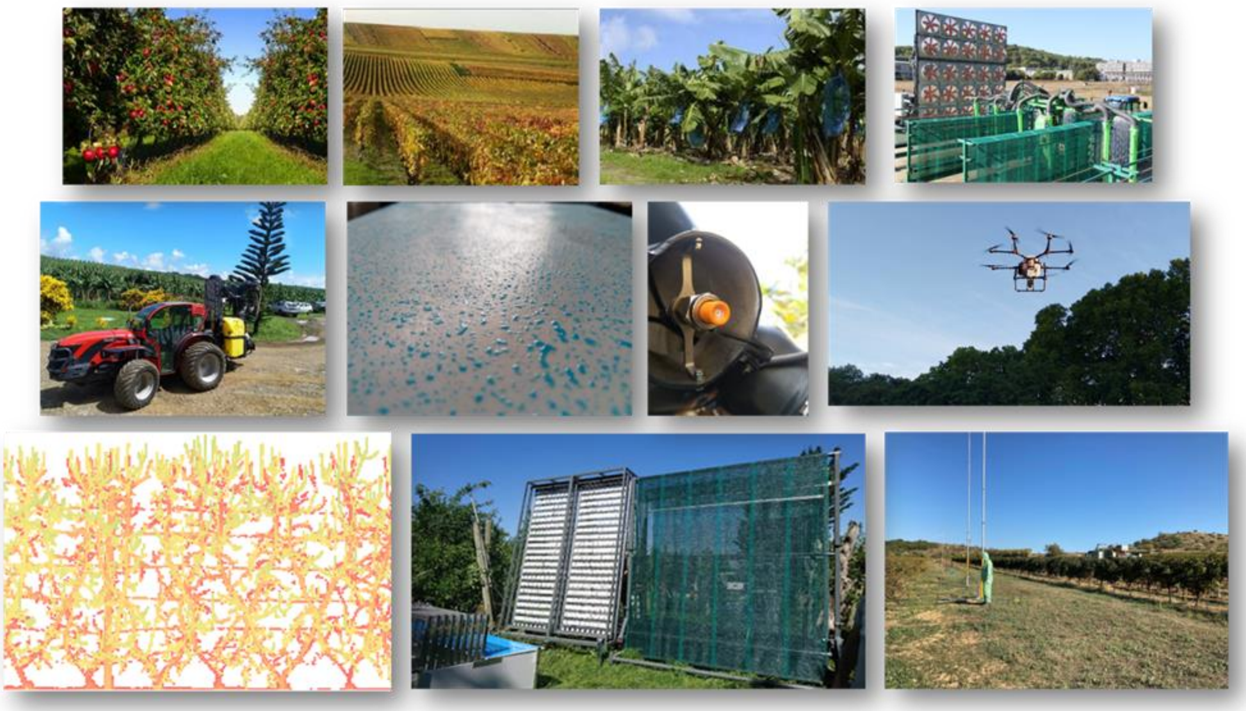
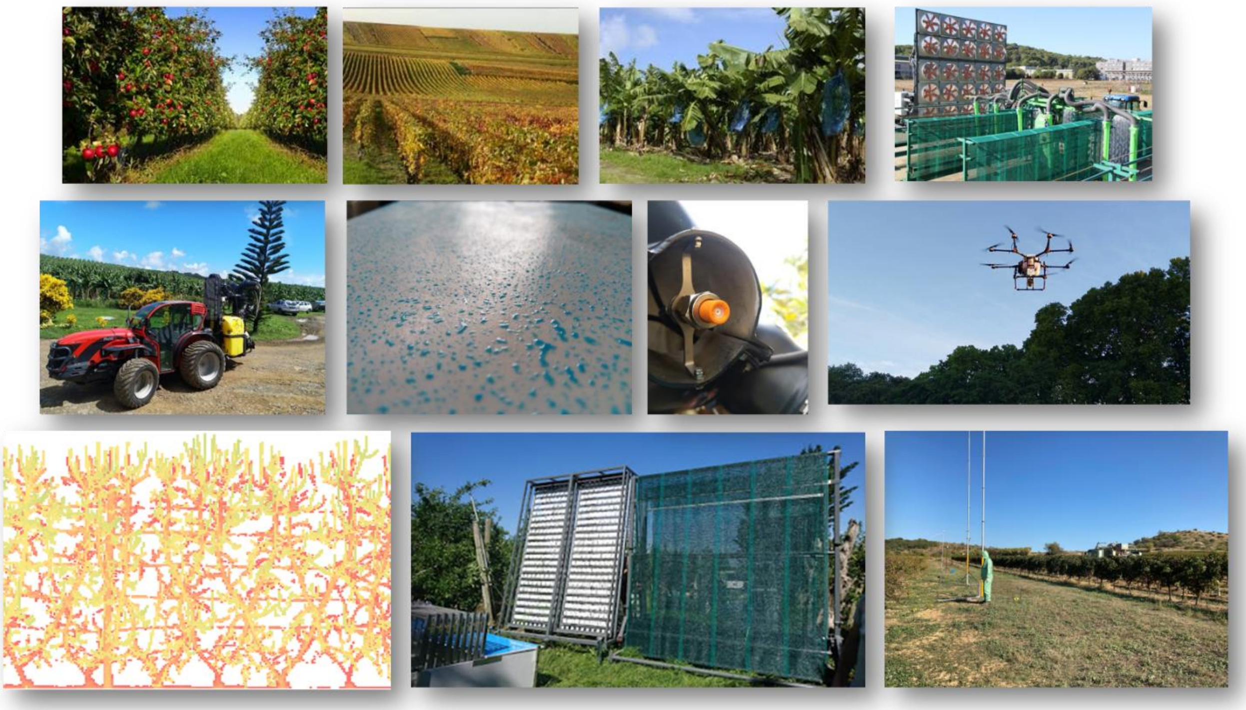
16th Workshop on Spray Application and Precision Technology in Fruit Growing
Programme and Abstracts



September 19-21, 2023 – Agropolis International

16th Workshop on Spray Application and Precision Technology in Fruit Growing

BOOK OF ABSTRACTS



Agropolis International
1000, Avenue Agropolis,
Montpellier, France
19 – 21 September 2023

Table des matières

Welcome to the workshop

This 16th Workshop on Spray Application and Precision technology in Fruit Growing offers the floor for the presentation of scientific results and for discussion of the societal context of the application of plant protection products and the use of precision technology in orchards and vineyards.

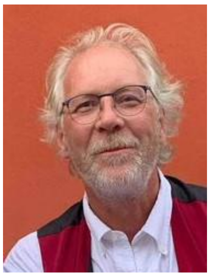
Suprofruit workshops have taken place biennially in Europe since 1991 with a primary focus on developments in spray application techniques in fruit and other three dimensional crops. The workshops offer a platform for scientists, researchers, technicians, advisors, manufacturers of spray equipment and industry from all over the world to present new ideas and developments, but also to discuss various topics in a three day workshop.

At this 16th Workshop at **Agropolis, Montpellier** in September 2023, the scope of the conference includes precision technology. Precision technology encompasses techniques/tools/knowledge to target correct interventions of the correct magnitude according to need in time and space. In fruit and other horticultural crops, individual plants and parts of plants can be treated according to their individual needs. These technologies have been playing an increasingly important part in spray application and in horticulture in general. Contributions on all aspects of precision technology including for example remote sensing, the use of UAVs, Normalized Difference Vegetation Index mapping, image analysis, machine learning, Decision Support Systems and the utilization big data and the Internet of Things, and especially where these relate to spray application, were sought. We hope you appreciate and enjoy the workshop!

Dr Marcel Wenneker
Convenor of Suprofruit workshops

Dr Jean-Paul Douzals
Local Organizer
Science Group Leader, INRAE

Welcome on behalf of the organizers



Welcome to Montpellier, a medium-size and old university city in South East France, surrounded by vines and the Mediterranean see. Since 1986, spray application techniques are studied in our laboratory (formerly Cemagref then IRSTEA, and now INRAE) for the benefit of users, manufacturers and authorities as a contribution to safe food.

The workshop is held in Agropolis International that is a non-profit association of research centers co-founded by INRAE. This association provides funding and facilities for scientific exchanges.

We hope you will enjoy your stay, discover good food and wine, exchange and discover some original research with about 80 colleagues from Europe, China, South Africa and the US. Suprofruit workshop is usually a non-formal conference and contacts with researchers, manufacturers and the industry are encouraged.

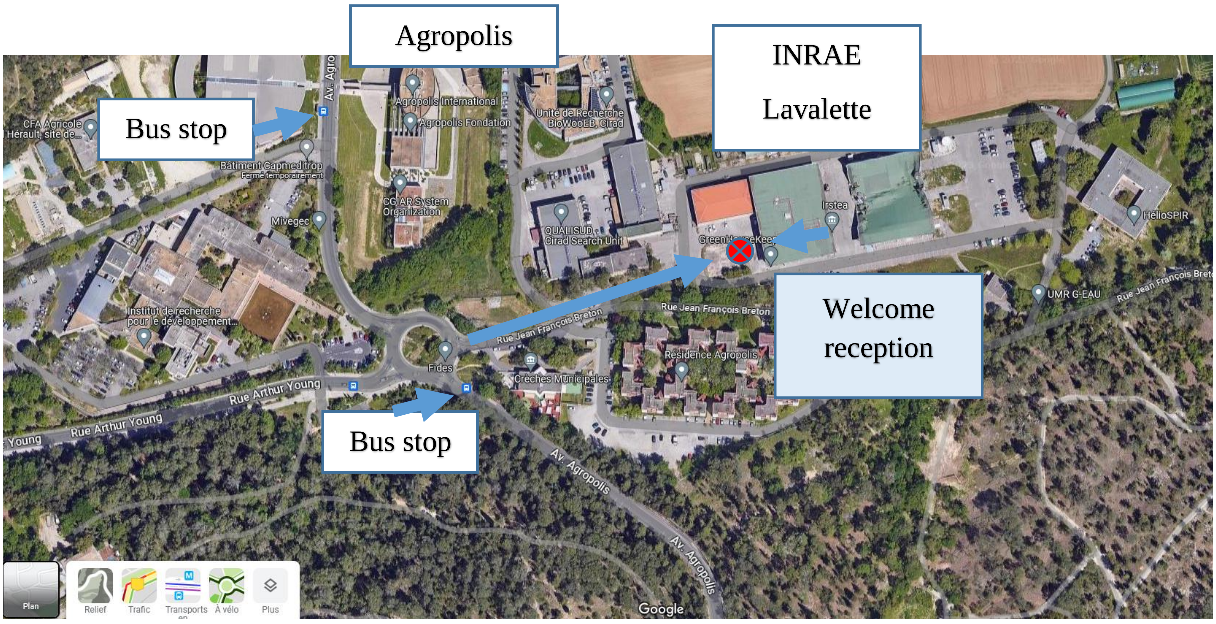
We wish you a nice stay and a fruitful workshop!

For the organizing committee, Jean – Paul Douzals, INRAE

Programme

Monday Sept 18th Welcome reception and registration

Welcome of participants from **16h – 20h** - INRAE (walking distance from Agropolis building and bus stops). Address is 100 rue Jean-François Breton, 34000 Montpellier https://goo.gl/maps/QvPj3XJmwgvzADPU7



Tuesday Sept 19th – Agropolis International

Time		name	Title
8:30		Agropolis International	Welcome coffee and registration
9:00		Welcome remarks	
9:30	Jan van de Zande		Precision spray application in fruit growing: recent and future issues
10:00	Session 1	Francisco Garcia-Ruiz	1.1 Variable Rate Application in mountain viticulture based on canopy maps generated by satellite remote sensing
10:20		Lars Berger	1.2 3D Computer Vision for Real Time Sprayer Adjustments
10:40		Erdal Ozkan	1.3 Current Status of Real-time Target-oriented Spray Application Research in Ohio
11:00		Coffee Break	
11:20	Session 2	Sebastien Codis	2.1 PERFORMANCE PULVÉ®: a labelling system for vineyard sprayers based on their performance in terms of spray quality and potential for PPP dose reduction. Review after two years of implementation
11:40		J Gideon Van Zyl	2.2 Evaluating the influence of drape netting on spray deposition and disease control in apple orchards using apple scab as a model pathogen

12:00		Vincent Philion	2.3 Row by row exclusion netting in apple orchards negatively impact spray deposition but don't prevent spray efficacy.
12:20		Lunch at Agropolis	
13:40	Session 3	Marco Grella	3.1 Effect of UASS spray application rates on vines canopy deposit
14:00	Session 3	Daniel Bondesan	3.2 Hydraulic-based fixed spray delivery system: preliminary result of apple scab management in Italy
14:20	Session 3	Pierre-Henri Dubuis	3.3 Determination of drift and exposure of bystanders and residents during treatment with a UASS in an apple orchard
14:40	Session 3	Pengchao Chen	3.4 Spray quality assessment of unmanned aerial spraying system in tropical fruit trees in southern China
15:00	Session 3	Jean-Paul Douzals	3.5 Return on Experience on the use of UASS for plant protection application on crops grown on steep slopes in France.
15:20	Session 3	Santiago Planas	3.6 Assessment of Unmanned Aerial Sprayer Systems (UASS) for drift and spray quality.
15:40		Coffee break	
16:00	Session 4	Jan van de Zande	4.1 Airborne spray drift and ground deposition spraying an orchard with standard and drift reducing techniques
16:20	Session 4	Adrien Verges	4.2 Spray drift measurements in 3D crops using several collection methods. Evaluation of different scenarios in the French context.
16:40	Session 4	Katrin Ahrens	4.3 Drift 3D, exposure of residents and bystanders during the application of plant protection products in orchards
17:00	Session 4	Kris Ruysen	4.4 Drift reducing effects on wind break screens
17:20	Session 5	Roberto Beltrán-Martí	5.1 Do hydraulic pumps of sprayers influence the performance of Beauveria bassiana (Balsamo) Vullemin as biocontrol agent?
17:40	Session 5	Nesrine Bouchekoum	5.2 Main defaults of vine and orchard sprayers observed during sprayer inspection
18:00		End of the day	

Wednesday Sept. 20th – Field trip

time	20/06/2023
8:30	Meeting at Agropolis and short walk to INRAE
9:00	Field demos on spray deposition, spray drift – INRAE https://goo.gl/maps/XhEaJZu9fHDGeMRH9
11:30	Transfer by bus Lunch and visit at Domaine royal de Jaras (Listel winery) Le Grau du Roi https://goo.gl/maps/zaTV6GsgYh6FJWEf7
15:00	visit of CTIFL Balandran field demos Bellegarde https://goo.gl/maps/KRXvAPsG3JPc3ujS8
18:30 22:00	Gala diner at Domaine de Massillan Le Crès https://goo.gl/maps/CrNLmm48pVBajQxJA Transfer by bus to Montpellier

Thursday Sept. 21st – Agropolis International

Time		Name	Title
8:10		Anne Alix	Introduction to the European Precision Application Task Force (EUPAF): remit and ongoing activities
8:40	Session 1	Patricia Chueca	1.4 Spray technologies in 3D crops grown in Southern Europe: a state-of-the-art survey
9:00		Zbigniew Czaczyk	1.5 Do the different field scenarios require properly optimized droplet characteristics?
9:20		Charles Whitfield	1.6 Blackberry Fruit Ripeness Analysis – Working Towards Application of Augmented Reality on Farms
9:40		Anice Cheraiet	1.7 LIDAR based Porosity and LAI measurement: Can we use LIDAR scanning on one side only?
10:00		Coffee Break	
10:20	Session 3	Eric Mozzanini	3.7 Cleaning performance of a pneumatic-based SSCDS designed for crop protection in modern orchard systems
10:40		Tobias Hüni	3.8 Thanks to air support: Spray effectively and efficiently from 0.5 up to 13m and saving up to 40% liquid
11:00		Peter Triloff	3.9 Target Adapted Dosing and Spray Application in 3D Crops
11:20		Gaétan Fleury	3.10 The aeroconfined© BLISS-ecospray concept, a new type of sprayer to eliminate sprayer losses at their source
11:40	Session 2	Yoan Hudebine	2.4 PerformancePulvé Arbo: comparative assessment of orchard sprayer efficiency under standardized indoor conditions
12:00		Tanja Pelzer	2.5 OptiSpray: Sprayer classification for pesticide savings based on deposition and efficacy trials in orchards and vineyards
12:20		Justine Garnodier	2.6 Influence of application material on spray deposition on strawberry in tabletop growing system
12:40		Jean-Marie Michielsen	2.7 Deposition of coarse droplets in dormant apple trees
12:45		Adel Bakache	2.8 A new tool and a rapid methodology to assess the spray application quality in vineyards and orchards
12:50		Lunch and Posters	
14:00		Grzegorz Doruchowski	2.9 Spray deposition and loss during different application scenarios performed by orchard sprayer with individually adjusted air-jets
14:20	Session 4	Nils Bjugstad	4.5 A novel and simple method for potential spray drift measurements in orchards
14:40		Cruz Garcera	4.6 Reduction of pesticides in the environment by the use of CitrusVol tool and spray drift reduction techniques during applications in citrus
15:00		Jean-Paul Douzals	4.7 ADDI Spray Drift: A spray drift model for vine sprayers
15:20		Dirk de Hoog	4.8 A novel method for drift calculations in orchards
15:40	Session 5	Sonia Grimbuhler	5.3 Operator safety in orchards and vineyards
16:00		Paolo Marucco	5.4 Indoor measurements to develop a methodology for spray mass balance assessment from air-assisted sprayers
16:20		Closing remarks and Farewell	

Organizing Committee: (among others)

Jean-Paul DOUZALS, INRAE, jean-paul.douzals@inrae.fr
Nesrine BOUCHEKOUM, INRAE, nesrine.bpuchekoum@inrae.fr
Florence VERPONT, CTIFL florence.verpont@ctifl.fr
Laurent Farine, CTIFL laurent.farine@ctifl.fr
Sebastien CODIS, IFV, sebastien.codis@vignevin.com
Elodie BROCHIER, INRAE, elodie.brochier@inrae.fr
Michèle EGEA, INRAE, michele.egea@inrae.fr

Sponsors

The organizers warmely acknowledge the company France Pulvé (Exel group) for the support. EXEL Industries is one of the world's leading manufacturers of agricultural spraying equipment, with its various brands: AGRIFAC, APACHE, BERTHOUD, CMC, EVRARD, HARDI, MATROT, NICOLAS and TECNOMA, all with a different DNA. They cover a complete range of products designed to protect and improve agricultural productivity, whether for small or large crops, vines, market gardening, fruit trees or tropical crops. Our sprayer brands are marketed through independent networks of authorized distributors, who provide sales and after-sales service for our sprayers. The Group's development on all continents also enables it to limit the risks of regional climatic contingencies on its level of activity. In 2021, the Group has decided to create France Pulvé, the aim of which is to unite the independent French brands of the EXEL Industries Group (Nicolas, Evrard, Berthoud, Tecnoma, CMC and Matrot), each with its own market positioning, under a single management structure.

Scientific Committee

	Marcel WENNEKER	Suprofruit Convenor, Wageningen University Research (WUR), The Netherlands, marcel.wenneker@wur.nl
	Paolo BALSARI (Prof.)	University of Turin, Italy, paolo.balsari@unito.it
	Jean-Paul DOUZALS	INRAE, France, jean-paul.douzals@inrae.fr
	Grzegorz DORUCHOWSKY	INHORT, Poland, grzegorz.doruchowski@inhort.pl
	Emilio GIL (Prof.)	University Polytechnic Catalonia (UPC), Spain, emilio.gil@upc.es
	Kris RUYSEN	PC Fruit, Belgium, kris.ruysen@pcfruit.be
	Peter TRILOFF	Consultant, Germany, peter.triloff@lindavino.de
	Jan Van de ZANDE	Wageningen University Research (WUR), The Netherlands, jan.vandezande@wur.nl
	Charles WHITFIELD	NIAB East Malling Research (NIAB EMR), United Kingdom, charles.whitfield@niab.com

Supporting institutions

INRAE Institut National de Recherche pour l'Agriculture et l'Environnement

INRAE is the National Research Institute for Agriculture, Food and Environment for France. It was created in 2020 and aims at developing research for a sustainable agriculture, food and feed production with respect to the environment. INRAE has about 11000 staff sprayed over 18 regional centers and Montpellier represents the second largest INRAE campus in France. UMR ITAP is a multidisciplinary research unit joint with Institut Agro Montpellier aiming at developing Information and Technologies for tomorrow's agriculture. Among other topics, the evaluation and the optimization of spray application techniques is a key research to reduce the use of pesticide and facilitate the use of bioproducts. The team, led by jean-Paul DOUZALS, is about 7 permanent staff and several contracted. www.inrae.fr

IFV Institut Français de la Vigne et du Vin
IFV (French Wine and Vine Institute) is the French technical institute of R&D for vine and wine and is governed by a board members representing all professionals of the wine industry. IFV's role is to implement applied research projects and transfer acquired technology and knowledge to the French wine sector. 150 people, including 90 engineers, offer a wide range of expertise covering all the areas needed for wine production from the vine plant to the glass of wine: vine plant selection and production, ampelography, vine diseases and protection, organic vine and wine production, agroecological viticulture, oenology, agronomic itineraries, microbiology, wine making processes, mechanisation and robotics, etc. Laboratories are officially recognized for agronomy and oenology trials or studies. Established in 18 research centers located in the main French wine producing regions, its multidisciplinary teams exploit experimental facilities (field trials, wineries, technological platforms). As a result, IFV has a role of interface between professionals and research teams, with a good innovating capacity, and transfer of research results to wine industry. The unit based in Montpellier and working on spray application is located inside INREA facility. www.ifv.fr

CTIFL Centre Technique Interprofessionnel des Fruits et Légumes
Created in 1952, our organisation, the Interprofessional Technical Centre for Fruits and Vegetables (CTIFL), is the reference in France in applied research for the fruit and vegetable sector, from production to distribution. Our main mission is to help professionals meet the challenges of sustainable production and consumer satisfaction in a constantly changing, increasingly competitive and demanding context. Our priority is to have a positive impact on the sector through our actions. Our five research centres carry out experimentation and research activities on the issues identified in the sector and provide technically and economically viable solutions. We develop and propose a range of services, professional tools and training courses as well as publications in various formats to transfer these innovative practices and provide the best possible support to the stakeholders in the sector. Recognised as a competent authority, we carry out the control and certification of fruit propagation materials. The unit based in Bergerac works on the evaluation and the optimisation of spray application in fruit production with a dedicated platform TITEC including an artificial orchard and artificial wind generator. www.ctifl.fr

UMR ECOTECH
Since 2011, INRAE and IFV are collaborating on the topic of the evaluation and the optimisation of spray application in a joint technical unit call ECOTECH. This joint technical unit, recognized by the French Ministry of Agriculture, has developed most of the semi-field size test benches (artificial vine and wind generator). In 2019, the CTIFL has join the group while developing its own testing facility for orchard sprayer. The joint research unit conducts tests for Performance Pulvé® initiative and is a recognized organization dealing with the evaluation and the optimization of spray application in bush and tree crops. https://www.vignevin.com/umt-rmt/ecotech/

SUD EXPE
Sud Expe is a regionally financed horticulture station aiming at developing and testing solutions for local growers (fruits & vegetables). Sud Expé has two main locations: Marsillargues with pome fruit and Saint Gilles with mainly stone fruits. It plays a role as a local experimental stations for CTIFL. Sud Expé is a partner of INRAE and UMR Ecotech for several projects. www.sudexpe.net

EUFRIN

EUFRIN is an informal, voluntary organization of university departments and research institutes that specialize in research, development, and extension on temperate fruit crops and which are based within countries of the European Union, Switzerland, and Eastern Europe. https://eufrin.eu

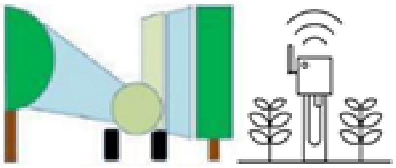
WUR

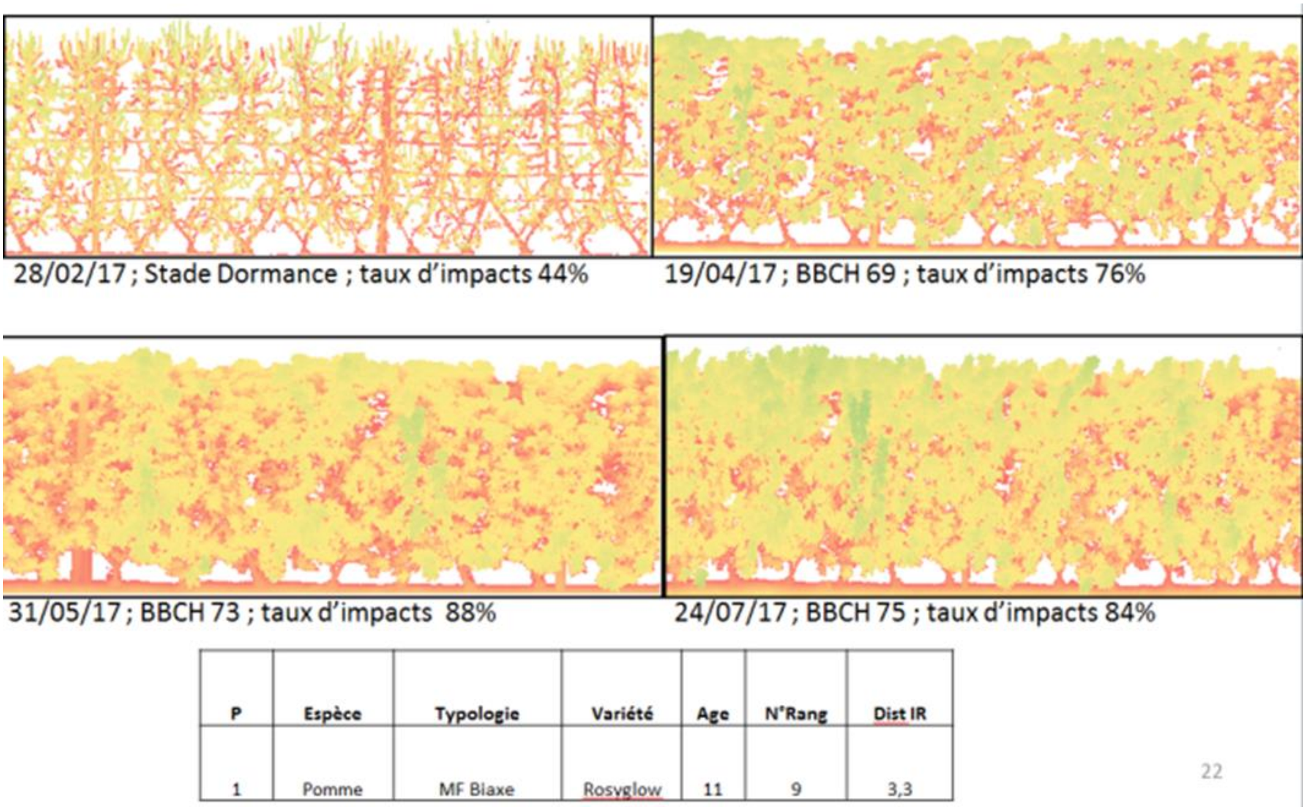
Wageningen Research is part of Wageningen University & Research (WUR), and is the only university in the Netherlands to focus specifically on the theme 'healthy food and living environment', by working closely together with governments and the business community. At Wageningen Plant Research, we combine knowledge and expertise in plant sciences. With this, we offer new perspectives for sustainable agriculture to our partners from e.g. industry, governments, research institutes and universities. Within this research area, a further subdivision, is the business unit Field & Fruit Crops performing (i) applied research and focusses on implementing fundamental research results into practical solutions, preferably into farming systems. Part are economic analyses and analyses of critical success factors. Much research is performed as co-innovation with stakeholders to maximise implementation, and Agrosystems Research, is based on agroecology, which refers to an integrated perspective on agronomic systems and land use. We do this by means of experimental design and computer modelling, on-farm testing and implementation in interaction with stakeholders. WUR has a long tradition in research about application technology of plant protection products; especially research on spray drift and drift reducing techniques, development of precision application techniques minimising spray drift and minimising the use of PPP. www.wur.nl

The National Precision Agriculture Aviation Center – Shandong University. China

"National Center for International Collaboration Research on Precision Agricultural Aviation Pesticide Spraying Technology" is the national research center approved by the Ministry of Science and Technology of China. The center focuses on aerial plant protection for typical food crops and economic crops, and jointly carry out innovation research on key technology and common issues for agricultural aviation remote sensing, precision aerial variable spraying and other related technologies and equipment with the USDA ARS Aerial Application Technology Research Unit (USDA-ARS-AATRU), the Center of Pesticide Application and Safety, the University of Queensland, Australia, and other world-class research institutions in advanced agricultural aviation application technologies in order to promote the development of precision agricultural aviation technology.

Session 1: Precision Technologies, Crop Sensing and Precision Spray Application





P	Espèce	Typologie	Variété	Age	N°Rang	Dist IR
1	Pomme	MF Biaxe	Rosyglow	11	9	3,3

1.1 Variable Rate Application in mountain viticulture based on canopy maps generated by satellite remote sensing

Francisco Garcia-Ruiz[1], Antonio Graça[2], Sofía Correia[2], Natacha Fontes[2], José Manso[2], Ana Rita Ferreira[2], Ramón Salcedo[1], Emilio Gil[1]

[1] *Department of Agri-Food Engineering and Biotechnology, Universitat Politècnica de Catalunya, Spain*
[2]*SOGRAPE Vinhos S.A., Rua 5 de Outubro, 4527, 4430-809 Avintes, Portugal*
Email address: fco.jose.garcia@upc.edu

INTRODUCTION

Plant protection processes continue to be one of the main sources of contamination in agriculture. This is especially important due to the social impact it generates, with risks of negative effects on water resources and the environment, while generating unnecessary costs for producers.

The technology of variable application (VRA) of Plant Protection Products (PPP) emerges as one of the possible solutions to achieve the challenge of reduction posed and an optimal use of them. This technology allows the quantity of product to be continuously varied, adapting it to the needs of the crop in each area of the plot (Gu et al., 2020). Crop characterization can be done with real-time sensors or based on vegetation maps generated from aerial images (drone or satellite). Previous work has already demonstrated important savings of PPP when using VRA in commercial hedge vineyards using drone and satellite imagery as a source for prescription map generation (Campos et al., 2019, Campos et al., 2021, Garcia-Ruiz et al., 2023). Mountain vineyards are characterized by important slope percentages in the terrain and a slightly different plantation scheme to overcome the terrain unevenness. Furthermore, mountain vineyards tend to have important concave and convex areas incrementing the canopy variability along the row. This makes even more important the implantation of variable rate technology to improve sustainability of pesticide application by adapting application rates to canopy characteristics. On the other hand, slope vineyards pose a challenge for satellite imagery with spatial resolution of several meters, non-regular spacing between vine rows due to different terrace-type planting systems. For this reason, the objective of this communication is to present the first results obtained in mountain vineyards generating and validating satellite based maps and variable rate application of PPP.

MATERIALS AND METHODS

The study was carried out in a commercial vineyard in Douro Region (Portugal). Four plots from this vineyard were selected for the experiments (Fig. 1). The variety planted in all plots was Touriga Nacional. Trials were carried out in three different dates during the season 2022 (May 24th, July 4th and July 20th). On each date, satellite imagery was downloaded, a three-class canopy map was generated and validated using manual sampling of canopy characteristics in the field to determine the significant differences of vegetation in every vigour class in the map.

The canopy maps were generated using a commercial nano-satellite Super Dove (Planet Labs Inc., San Francisco, CA, US). These satellites are equipped with a line scanner imaging sensor with eight spectral bands in VIS and NIR regions of the spectrum, providing high-resolution imagery (3 m spatial resolution) with an approximately daily revisit time. The images were analysed to extract the NDVI index, and were classified into three vigour levels (high, medium, and low) based on the quartile approach. This classification was considered relative for each plot to be able to observe variability in every vineyard.

To select a representative and unbiased subset of vines and conduct the field measurements (sampling vines), a multi-stage (nested) systematic uniform random (SUR) sampling design was established. A total of 79 vines were sampled and their canopy height, width and density measured in every sampling date. Different sampling locations were classified according to vigour and a statistical comparison was done. Furthermore, in May 2023, a VRA application was attempted. The optimal volume rate per vigour zone was calculated using the DSS DOSAVIÑA® (Gil et al., 2019) and variable rate prescription maps were generated and applied in the vineyard using a Waatic device (Waatic, Abrera, Spain).

RESULTS AND DISCUSSION

Results demonstrated significant differences of canopy characteristics between vigour zones in all plots assessed (Figure 1). Furthermore, canopy characteristics also varied from date to date and this was also seen in the average NDVI values per vigour area, which proved the ability of satellites to provide an estimation of canopy development during the season. The differences were more prominent from May to July, and remained similar in the two sampling dates in July. This is due to the canopy management performed in hedge vineyards where the canopy is forced to grow in a vertical shoot position, and sometimes trimmed to retain the vegetative growth.

After the first season trials, it seems that satellite imagery can be reliably used in slope vineyards to determine the spatial variability of the canopy, and further used to produce variable rate prescription maps for pesticide application. Results in terms of a potential reduction of PPP, following the Farm to Fork Strategy, expect to be promising showing a positive potential on the use of this new technology.

REFERENCES

Campos, J., Llop, J., Gallart, M., Garcia-Ruiz, F., Gras, A., Salcedo, R., and Gil, E. (2019). Development of canopy vigour maps using UAV for site-specific management during vineyard spraying process. Precis. Agric. 20:1136–1156.

Campos, J., García-Ruíz, F., and Gil, E. (2021). Assessment of Vineyard Canopy Characteristics from Vigour Maps Obtained Using UAV and Satellite Imagery. Sensors, 21(7), 2363.

Campos, J., Llop, J., Gallart, M., Garcia-Ruiz, F., Gras, A., Salcedo, R., and Gil, E. (2019). Development of canopy vigour maps using UAV for site-specific management during vineyard spraying process. Precis. Agric. 20:1136–1156.

Garcia-Ruiz, F., Campos, J., Llop-Casamada, J., and Gil, E. (2023). Assessment of map based variable rate strategies for copper reduction in hedge vineyards. Comput. Electron. Agric., 207, 107753.

Gil E., Campos, J., Ortega, P., Llop J., Gras A., Armengol E., Salcedo R., Gallart M. 2019. DOSAVIÑA: Tool to calculate the optimal volume rate and pesticide amount in vineyard spray applications based on a modified leaf wall area method. Computers and Electronics in Agriculture, Volume 160, May 2019, Pages 117-130

Gu, C., Wang, X., Wang, X., Yang, F., and Zhai, C. (2020). Research progress on variable-rate spraying technology in orchards. Appl. Eng. Agric. 36(6):927-942.

Fig. 1. Canopy vigour maps from July 4th 2022 classified in three zones (Low, Medium and High vigour in red, yellow and blue respectively) with sampling vines locations based on the SURS sampling.

1.2 3D Computer Vision for Real Time Sprayer Adjustments

L. T. Berger[1], J. Alarcón[1], P. Perales[1], E. Ukhandeeva[1]

[1]*Pulverizadores Fede S.L.U., Valencia, 46380 Cheste, SPAIN*
Email address: info@fedepulverizadores.com

INTRODUCTION

Plant protection product (PPP) savings of up to 25% in specialty crops have been demonstrated by well-adjusted spraying technology like the *Smartomizer H_3O* (Berger *et al.* 2019, Berger *et al.* 2022). Nevertheless, the *Green Deal* with its *Farm-to-Fork* strategy has set the objective of 50% reduction in use of hazardous pesticides by 2030. Hence, high-end smart spraying technology is dearly needed to address growers' environmental and productive challenges. Fede's *AIs* system (pronounced "eyes") jumps-in to fill the void. *AIs* is a comprehensive agronomic solution based on computer vision and *Artificial Intelligence* (AI) that allows to sense the canopy with 3D cameras. In the sequel, the visual inputs, with a well-balanced degree of detail and temporal resolution, provide exact information on crop dimensions, which facilitate real time sprayer adjustments to perform high precision PPP spraying and foliar fertilization.

MATERIALS AND METHODS

The *AIs* system, as indicated in Fig. 1, is fitted on a tractor and contains two stereo vision cameras per side. Mounting *AIs* on the tractor enables sprayer-independent crop statistics collection. However, collecting data with "*AIs on the Ground*" also bears significant technical challenges, *e.g.* the timing for spray nozzle actuation is dependent on information captured from another vehicle, with sprayer and tractor only loosely coupled. Further, establishing a reliable high-speed data connection between vehicles that get frequently disconnected and reconnected under harsh conditions is a challenge. *AIs* here provides a robust Ethernet solution. Moreover, the issue of keeping camera lenses clean is addressed with a pressurised air-curtain system that shields off the lenses from dust, rain, *etc*. Pressurised air is also used to cool cameras and *AIs*' edge processing unit.

The data collected can be directly used to act on the sprayer, *e.g.* to open and close spray nozzles as a function of detected tree dimensions. To do so, sprayers have to be "*AIs-enabled"*, which means, they need an Ethernet connection into the *Sprayer Control System* (SCS) over which to receive proprietary *AIs* commands, and they must be fitted with actuators, *i.e.* the *Nozzle Control Unit* (NCU), to open and close individual nozzles while maintaining spray pressure constant.

The baseline sprayer was a *Smartomizer H_3O* Q_i of 2000 *l*, with n = 26 identical individual switchable nozzles, *n/2* per side. The flow rate per nozzle q is calculated as in (Świechowski *et al.* 2012), *i.e.* $q = (Q \cdot R \cdot v)/(600 \cdot n)$, where Q is the *desired spray volume* in *l/ha*, R is the *interrow distance* in *m*, and *v* is the *driving velocity* in *km/h*.

Test results are obtained in a traditional orange grove, a.) configuring the sprayer in a conventional way selecting the base line *Q* with respect to the *Tree Row Volume* (Świechowski *et al.* 2012), and b.) allowing *AIs* to switch individual nozzles on and off for segments of the canopy where no foliar content is detected. Opening and closing times are logged, and the time during which the nozzles are closed is subtracted from the total time, which is identical between treatment (a) and (b). To assure no negative impact of *AIs* on

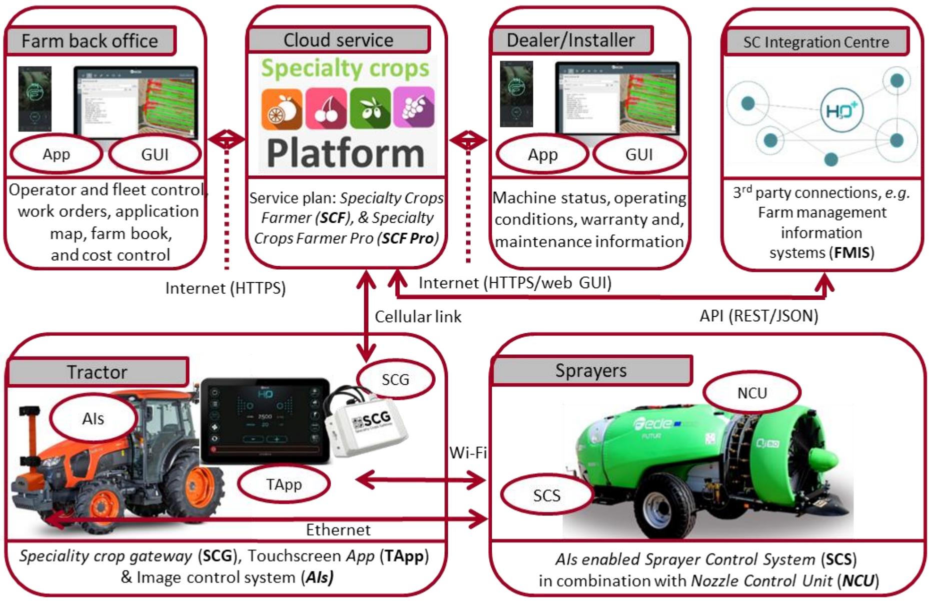


Fig. 1. Fede *AIs* system embedded into the Fede *Specialty Crops Platform* (SCP).

distribution and deposition, hydro sensible paper is distributed over the canopy, putting especial emphasis on areas close to canopy holes where *AIs* is supposed to switch nozzles.

RESULTS AND DISCUSSION

Visual inspection of the hydro sensible paper under case (a) and (b) revealed comparable spray distribution and deposition. Comparison of the total of the nozzle opening times between case (a) and (b) revealed a spray volume reduction of up to 40% when using the *AIs*. This means that with *AIs* in operation the performed treatment is *"equivalent to"* a spray volume of $Q_{baseline}$, being in fact apt to save up to 40% of *Plant Protection Product* (PPP) in the particular situation under test.

While *AIs* has been demonstrated to work well in this particular context, it should be noted that the effectively achievable savings depend on the variability of the canopy. In very heterogeneous canopies with little holes, less PPP will be saved, while in highly variable canopies with holes or even entire trees missing, savings can be very significant.

These results indicate that the latest advances in Specialty Crops sprayer developments allow growers to significantly reduce their production costs due to PPP inputs savings in line with EU objectives, and contributing to the transition to a net zero agriculture that sustainably delivers food security to the world population.

REFERENCES

Berger, L. T., Ukhandeeva, E., Andreu, F., Ribeiro, I., Carapinha, P., Ayuso Rodríguez, J.M. 2022. *Life Farm, Fresh Fruit - Effects of Operator Training and Sprayer Adjustments on Agronomic Inputs.* Aspects of Applied Biology 147, pp. 19-26.

Berger, L. T., Ortega, P. E., Gil. 2019. *Smartomizer – Proactivity and Traceability in Orchard Spray.* In: J. Cross & M. Wenneker, SuproFruit2019: 15th Workshop on Spray Application and Precision Technology in Fruit Growing, 16th-18th July 2019, p. 43-44.

Świechowski, W., Godyń, A., Hołownicki, R. Doruchowski, G. 2012. *Calibration of orchard sprayers – the parameters and methods.* SPISE 4, Lana, Italy, Julius-Kühn-Archiv.

ACKNOWLEDGEMENTS

With funding of the European Union's *LIFE Programme*, the EU's funding instrument for the environment and climate action GA 101074540 - LIFE21-ENV-ES-Life-AIs.

1.3 Current Status of Real-time Target-oriented Spray Application Research in Ohio

Javier Campos[1], Carla Román[1], Hongyoung Jeon[2], Heping Zhu[2], Erdal Ozkan[1]

[1]The Ohio State University, Wooster, OH, USA
[2]USDA-ARS Application Technology Research Unit, Wooster, OH, USA
Email address: ozkan.2@osu.edu

INTRODUCTION

Target-oriented precision spray application has been the main focus of the research conducted in Ohio over the last 20 years. Two of the most recent projects for potential improvements of this emerging technology to enhance its accuracy and viability for future advancements in orchard applications are highlighted.

MATERIALS AND METHODS

The first project discussed here is the assessment of functional activation ranges of Pulse Width Modulation (PWM) solenoid valves to control hollow cone nozzles operated at high pressures and frequencies (Campos et al., 2023). PWM valves have been used on orchard sprayers equipped with crop detection sensors to perform precision variable-rate applications in real-time. However, the current use of PWM valves is limited to modulation speeds of 10 Hz and maximum operating pressures of 8.27 bar. Twelve industrial-graded PWM valves to modulate disc-core hollow-cone nozzles (TeeJet D5-DC25, Spraying Systems Co., Wheaton, IL, USA) for variable-rate applications were evaluated at modulation frequencies between 5 and 50 Hz and duty cycles (DUCs) ranging from 10% to 100% at 13.8 bar pressure. Upstream and downstream pressure profiles were recorded and compared with the ideal pressure profiles to determine the maximum DUC ranges and modulation frequencies at which the PWM valve could work properly. If pressure profiles did not follow the ideal profiles, the valve was considered not functional for the particular DUC and frequency combination.

The second study is about performance of a real-time variable rate sprayer our research group has developed (Román et al., 2023). The sprayer utilizes a stereo vision system to control spray volumes using PWM valves based on detection of targets to spray, and sprayed an empirical rate of 80 mL per m^3 of canopy volume as shown in Figure 1.

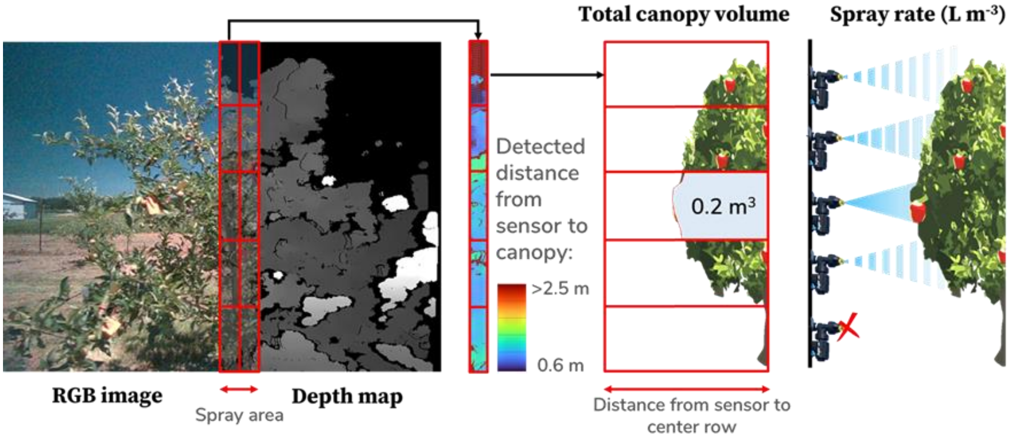


Figure 1. Canopy volume calculation and spray decision used by the sprayer.

The sprayer was tested in the field for its accuracy in applying the spray rate based on detected canopy volume while traveling from 3.2 to 8.0 km h^{-1}. Spray deposition on the canopy of different trees was assessed spraying a fluorescent tracer collected on stainless steel disks. In addition, a conventional constant rate application of 338 L ha^{-1} at a travel speed of 8.0 km h^{-1} was sprayed as a performance benchmark for variable rate application.

RESULTS AND DISCUSSION

The results obtained from testing PWM valves showed that there were noticeable differences in the modulation capabilities of the 12 PWM valves tested due to differences in their design. Only two out of 12 valves were able to manipulate the disc-core hollow-cone nozzles with DUCs ranging from 30% or 40% to 70% at the modulation frequency of 40 Hz. For example, as illustrated in Figure 2 below, for 6 of the valves tested, some valves cannot function (red zones) at certain frequencies and DUCs.

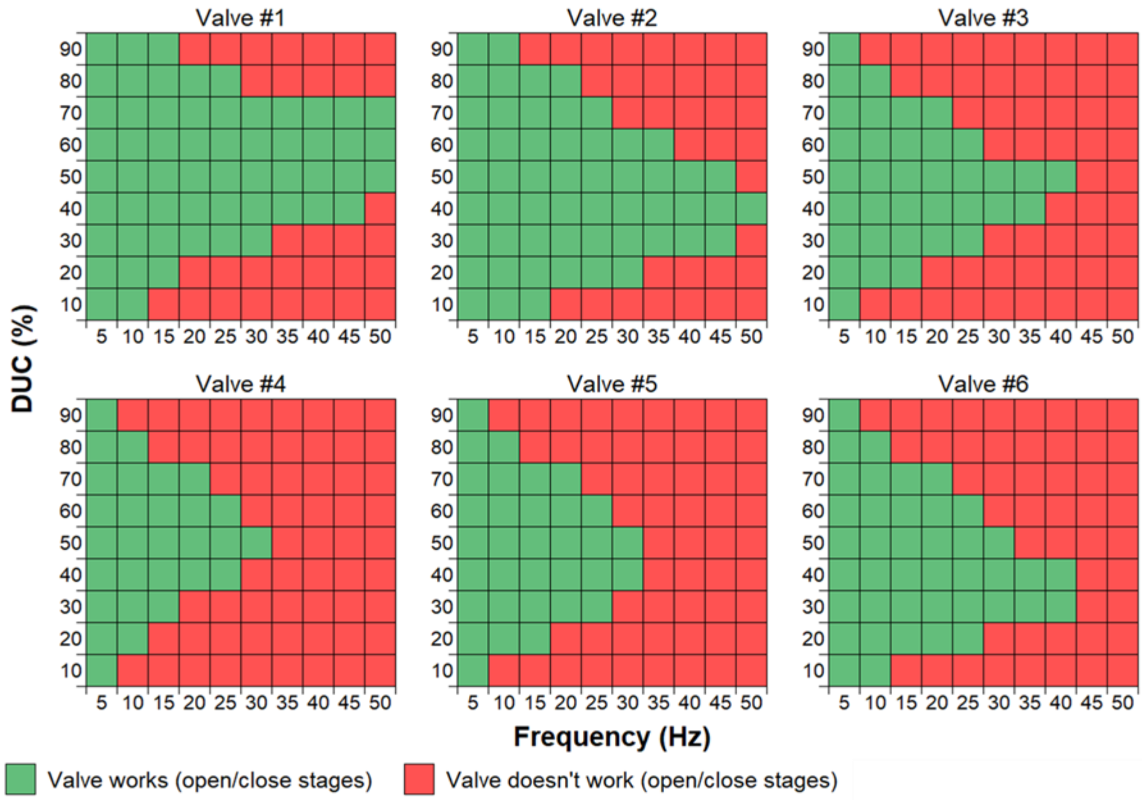


Figure 2. Performance of PWM valves tested at different operating frequencies from 5 to 50 Hz (on horizontal axis) and duty cycles (DUC) from 10 to 90% (on vertical axis).

The results from the vision-based real-time variable rate sprayer showed that the sprayer achieved the spray rates from 73 to 83 mL m^{-3} for different apple trees irrespective of their canopy size by controlling its outputs as intended. On the other hand, the conventional constant rate spray application applied 250 to 440 mL m^{-3} (Figure 3, left). This variability was attributed to the differences in canopy volumes of the trees selected for this experiment; with tree 1 and 2 being smaller than the third one.

In addition, canopy spray deposition was similar with variable-rate application regardless of travel speed and tree volume. On the contrary, the constant-rate application resulted in superior deposition on smaller trees (Figure 3, right). Accurate spray output controls of the sprayer made possible to attain the spray volumes of 65.8 to 90.3 L ha^{-1} under the test conditions. This outcome proved that this image-based prototype real-time variable-rate sprayer was capable of applying the intended amount of spray accurately in proportion to canopy volumes.

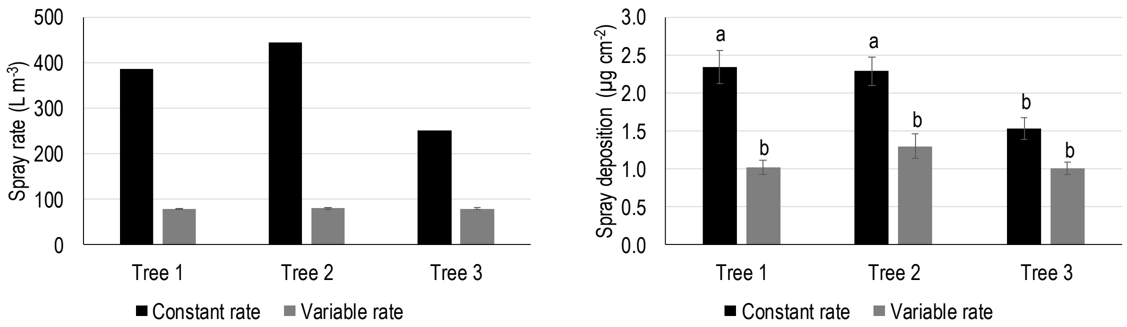


Figure 3. Evaluation of constant and variable-rate spray applications at 8.0 km h^{-1}. Actual spray rate applied at different trees (left) and spray deposition on the same trees (right).

CONCLUSIONS

The conclusions of the PWM Valve Testing Project indicated that there were differences in the modulation capability of the 12 PWM valves tested. These differences were due to the inherent design of the valves. Two out of the 12 valves were able to manipulate the hollow cone nozzles at frequencies up to 40 Hz with maximum functional DUC ranges of 40% to 70% and 30% to 70%. This indicates that the integration of these valves into variable rate precision application sprayers could potentially increase the accuracy of the system up to four times compared to the commonly used 10 Hz frequency valves. However, further investigation of flow rate modulation capability and droplet size distribution would confirm that these valves could be useful for precision spray systems.

In the second project, the stereo vision-based real-time variable-rate sprayer demonstrated effective canopy detection, enabling precise and targeted spray applications. Compared to the constant-rate spray applications, the stereo vision-based variable-rate sprayer offered more uniform application and a significant reduction in spray volume, resulting in environmental benefits. Further research will focus on validating equivalent efficacy in reduced-rate crop protection applications. The technology holds great promise for sustainable and efficient spraying of specialty crops with great potential to expand its use to other applications.

ACKNOWLEDGMENTS

This research was supported by USDA-ARS in-house project 5082-21620-001-00D.

REFERENCES

Campos, J., Zhu, H., Jeon, H., Salcedo, R., Ozkan, E., Gil, E. (2023). Assessment of PWM solenoid valves to manipulate hollow-cone nozzles with different modulation frequencies. *Applied Engineering in Agriculture 39*(2): 235-244. https://doi.org/10.13031/aea.15415

Román, C., Jeon, H., Zhu, H., Campos, J., Ozkan, E. (2023). Stereo vision controlled variable rate sprayer for specialty crops: Part II. Sprayer development and performance evaluation. *Journal of ASABE*. (*In press*). https://doi.org/10.13031/ja.15578

1.4 Spray technologies in 3D crops in Southern Europe: a state-of-the-art survey

Patricia Chueca[1], Jaime Mata[1], Marco Grella[2], Marco Resecco[2], Konstantinos P. Ferentinos[3], Giovanna Azimonti[4], Cruz Garcerá[1]

[1]*Instituto Valenciano de Investigaciones Agraria / Centro de Agroingeniería (Valencia, Spain)*
[2]*Università degli Studi di Torino / Dept. of Agricultural, Forest and Food Sciences (Turin, Italy)*
[3]*Hellenic Agricultural Organization "DIMITRA" / Dept. of Agricultural Engineering (Athens, Greece)*
[4]*International Centre for Pesticides and Health Risk Prevention (Milan, Italy)*
Email address: chueca_pat@gva.es

INTRODUCTION

Nowadays, human and environmental risk assessment of plant protection products (PPP), described by Regulation 1107/2009 (EC, 2009), is based on a combination of model/scenarios, which consider the reasonable worst case in European agricultural areas. To this extent, spray drift curves are used for the PPP registration process at EU level. These curves are based on results of drift trials conducted almost 30 years ago in Northern Europe in field crops, grapevines, pome fruits and hops (Ganzelmeier et al., 1995; Rautmann et al., 2001). To date, curves obtained for pome fruits are also used for risk assessment purposes related to other 3D crops such as citrus, olives, stone fruits, nuts, tropical fruits, etc. Noteworthy these last crops are mainly grown in the Southern European countries (SEU) characterized by environmental conditions and agronomical practices different from the northern EU countries. Therefore, to obtain reliable information concerning both PPP drift values and pesticide application management currently adopted in Southern countries in 3D crops, the European Food Safety Authority (EFSA) financed the partnering grant "PPP exposure models for 3D orchards considering spraying technologies in Southern Europe".

This report presents the results of the initial phase of the granted project aiming to increase knowledge about pesticide application management in the main European Southern 3D crops.

MATERIALS AND METHODS

At the first stage, an identification of the main crops in the three Southern European countries, Spain, Italy and Greece, was carried out. A search was conducted in national databases of each country and FAOSTAT to obtain the areas in each member state covered by the different crops considered (vineyard, olive, citrus, stone fruits, nuts, and tropical fruits). Next, specific questionnaires about PPP use practices were designed for 3 populations: 1) sprayer dealers and manufacturers, 2) inspection stations of sprayers, and 3) producers of citrus, olives, vines, stone fruits and nuts. In each country, for each population and, in the case of producers for each crop 30 surveys were carried out. Based on the answers of the surveys a dataset was built and a statistical description analysis was carried out per target population and country, and for the three countries together.

RESULTS

The analysis of the database of the agricultural land dedicated to each crop showed that more than 90% of the 3D-orchards grown in Europe are located in the South.

The results of the surveys have highlighted similarities and differences between countries and crops in terms of the main sprayer features that users value most. Results help to identify the current scenario of spray application techniques for crop protection in 3D crops to be considered for human exposure and environmental risk assessment in Southern European countries. Results showed that airblast sprayers are the main equipment used for all target crops in all countries. In general, the equipment is around 10 years old on average, with devices for the adjustment of air flow direction and speed as the most valued ones. The efficacy of applications is the most important parameter for farmers, thus driving the choice of spray application technique/technologies. Furthermore, devices to adjust the airflow constitute the main technology to control the environmental impact of PPP applications found in the sprayers in use, together with the drift reducing nozzles (Fig. 1).

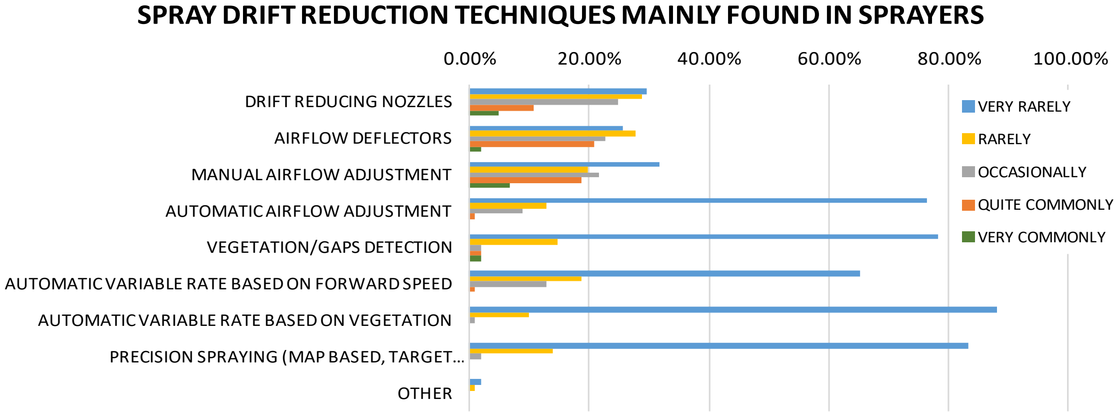


Fig. 1. Frequency of spray drift reduction techniques installed in the sprayers, based on Inspection Stations surveys in the three countries.

The comprehensive analysis of results will adequately identify the PPP spray application scenario for different crops in the Southern Europe in order to better calibrate the current models used for risk assessment, matching them to realistic situations.

ACKNOWLEGMENTS

This work has been funded by the EFSA Grant Agreement number GP/EFSA/ENCO/2020/03. Cruz Garcerá was recipient of a post-doctoral grant DOC-INIA funded by Instituto Nacional de Investigación y Tecnología Agraria y Agroalimentaria (ref. DR2015-0318).

REFERENCES

European Commission (2009) Regulation (EC) No 1107/2009 of the European parliament and of the council of 21 October 2009 concerning the placing of plant protection products on the market and repealing council directives 79/117/EEC and 91/414/EEC. Off. J. Eur. Union 309, 1–50.

Ganzelmeier, H., Rautmann, D., Spangenberg, R., Streloke, M., Herrmann, M. & Wenzelburger, H.J. (1995) Studies on the spray drift of plant protection products. Mitteilungen aus der BBA für Land-und Forstwirtschaf, 305, 111.

Rautmann, D., Streloke, M. & Winkler, R. (2001) New basic drift values in the authorisation procedure for plant protection products. Communications from Biologischen Bundesanstalt für Land- und Forstwirtschaft. In: Foster, R., Streloke, M (Eds.), Workshop on Risk Assessment and Risk Mitigation Measures in the Context of the Authorisation of Plant Protection Products, Berlin-Dahlem. 383, 133–141.

1.5 Optimization of spray atomization taking into account the current field conditions – a conception

Zbigniew Czaczyk[1], Andrew Hewitt[2], Jean-Paul Douzals[3]

[1]Poznań University of Life Sciences, Poland
[2]University of Queensland, Australia
[3]Universite de Montpellier, INRAE, Montpellier, France
Email address: zbigniew.czaczyk@up.poznan.pl

INTRODUCTION

Precision farming systems introduce intelligent possibilities for locally differentiated application of agrochemicals. Progress in the implementation of new technologies is very dynamic in the European Union thanks to subsidies, or in other parts of the world, for example in Australia. Many technologies were developed on variable rate application (VRA) techniques in fruit crops and single nozzle control using PWM systems. As a result, the choice of spray equipment and components (nozzles), and settings are getting more difficult and may be adapted to different environmental context (Fritz et al., 2016, Czaczyk et al., 2013, Hewitt, 2010). For economically and biologically effective PPP (Plant Protection product) application, atomizers with a different droplet size spectrum are offered. In order to develop precision PPP application, local ambient conditions shall be monitored (local Automatic Weather Station, or sprayer/tractor mounted AWS) and used. PPP application should be realised following PPP label recommendations and restrictions (dose rate, spraying categories). Also local wind speed and relative air humidity influence the atomization phenomena, and droplets distribution (on target - and not on target ratio) Since there are various technical equipment at the user's disposal, it is necessary to develop rules of conduct in various field conditions and to include those field conditions in sprayer control systems (Czaczyk et al., 2019). In the current situation, there is a shortage of advisory materials based on comparative experiments.

MATERIAL AND METHODS

A prototype of an active weather station, named Spray Monitor®, allows the nozzle flowrate control and was originally developed to adjust atomization settings according to field conditions (Czaczyk et al., 2019). Compared to a traditional flowmeter, the system consists of a Teejet e-Chem Saver valve, a flowmeter (up to 6.5 l/min) and a pressure gauge (up to 10 bar). Atmospheric conditions are evaluated using temperature and humidity sensors in order to evaluate and to adjust the settings according to the evaporation ratio. Alarms can be set when the flowrate exceeds the flowrate tolerances (+/–5%) or when the air and liquid temperature difference exceeds 5 K.

RESULTS AND DISCUSSION

At the moment, this device is a prototype that is under test with a various type of nozzles and atmospheric conditions, in the laboratory and in the field. This systems aims at better inform the user on local weather conditions and on the optimal settings. There is a large number of nozzles types present on the market, with a wide range of setting parameters and detailed atomization characteristics (Czaczyk et al. 2013, Czaczyk 2012, 2014).

However, most of the nozzle adjustments are generally ruled by the presence of a sensitive area, but not the local weather conditions (local wind speed or direction, temperature and relative humidity). In good weather conditions, the setting of working parameters is easy, and clear (nozzles type, flow rate, working speed) and corresponds to the information provided by nozzle manufacturers and generally obtained from lab measurements. When spraying close to a sensitive area, whatever the real weather conditions, the operator is supposed to switch the active nozzles selected for good field condition to "drift reduction type" – mostly air induction nozzles. Such a change is realized without adjustment of the working pressure and may lead to unknown atomization characteristics. In the case in fruit crop conditions, this phenomenon is potentially worse due to higher pressure with hollow cone nozzles.

On this base and using this detailed technical information, the droplets distribution can be adjusted more exactly for a professional using the optimal to "local field scenario"

CONCLUSIONS AND PERSPECTIVES

Different field scenarios and ambient conditions need an adequate optimized droplet distribution characteristics. As a result, the conditions for a precise and safe PPP application can be controlled and maintained in accordance with recommendations. Taking into account the local evaporation conditions based on RH/T ratio, the spray characteristics of used nozzles (drift reduced/air included) may guarantee a professional application of PPP.
Once validated, this system may help the calibration and selection of operating parameters of PAE. Trends in nozzles development and atomization characteristics should be elaborated in form useful for sprayer operators and advisory.

REFERENCES

Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides

Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC

Hewitt, Andrew J. (2010). Drift reduction technologies in Australia and New Zealand. 239th ACS National Meeting & Exposition, San Francisco CA, United States, 21-25 March 2010.

Czaczyk Z. 2012: Droplet size characteristics of selected nozzles for protection of spatial crops. J. Res. Appl. Agr. Eng. 57(2): 22-30.

Czaczyk Z. 2014: Drop-size classification according to requirements of pesticide labels. ISSN 1427-4337, Prog. Plant Prot. 54(1): 111-120

Czaczyk Z., A. Hewitt, C. Hoffmann, B. Fritz, T. Szulc 2013: Potential for efficiency increase of crop protection by use of optimized spraying fractions. Book of Abstr. 12th Workshop on Spray Appl. Tech. in Fruit Growing (SuproFruit 2013), 26-28 June, Valencia, Spain: 116-118.

Czaczyk, Z., Pietrzyk, J., Lodwik, D., 2019. Spray Monitor – a concept of spraying parameters optimization taking into account application conditions. Proceedings of Farm Machinery and Processes Management in Sustainable Agriculture. 109-114.

Fritz B.K., Z. Czaczyk, W.C. Hoffmann 2016: Model based decision support system of operating settings for MMAT nozzles. J. Plant Prot. Res. 56(2): 178-185.

1.6 Blackberry Fruit Ripeness Analysis – Working Towards Application of Augmented Reality on Farms

E. Charles Whitfield[1], Chollette C. Olisah[2], Ben Trewhella[3], Bo Li[4], Benjamin Winstone[2], Felicidad Fernández Fernández[1], Harriet Duncalfe[5], Melvyn L. Smith[2]

1 NIAB at East Malling, UK, Charles.Whitfield@niab.com
2 Centre for Machine Vision, Bristol Robotics Laboratory, University of the West of England, Bristol, UK.
3 Opposable Games Ltd, UK.
4 Syngenta, Jealott's Hill Research Centre, UK.
5 Berry Gardens Growers, UK.

INTRODUCTION

Correctly determining fruit ripeness by vision alone during harvesting is a concern for fruit growers. Most challenging are fruits that do not show obvious and reliable visible traits of ripeness when mature and therefore pose great difficulty to pickers. Blackberry (*Rubus fruticosus*) is an example of such a fruit which, to the human eye, is black prior, during, and post ripening (Mikulic-Petkovsek et al., 2021). During harvest, pickers need to make the decision of which berries are ripe and ready to pick within their field of view in less than three seconds by evaluating the colour appearance and the size of the drupelets. To address this challenge, a feasibility project was completed to assess the potential for the application of spectral imaging, convolutional neural network (CNN), and augmented reality to develop an aid to fruit pickers. The objectives of the project were to (i) identify key wavelengths that enhance differentiation of fruit ripeness, (ii) build a prototype spectral imaging headset, (iii) develop a machine vision algorithm for berry detection and ripeness determination, and (iv) test the potential for conveying the output to the user via an augmented reality headset.

MATERIALS AND METHODS

Hyperspectral imaging and fruit ripeness

Blackberries were collected from Clockhouse Farm, Kent, UK by professional farm pickers and NIAB technicians, one or two times per week from 23/09/2020 to 12/11/2020, a total of 16 times during the season. Fruit was collected from either polytunnels or glasshouse sites. A total of 528 blackberries at a range of ripeness stages were analysed using two hyperspectral line scanning cameras: i) VNIR 600 to 975 nm, IMEC Ltd (Gent, Belgium), and ii) SWIR 900 to 1700 nm, SPECIM SP-N17E (Oulu, Finland). The background was removed from the images and individual blackberries isolated. An average reflectance score was calculated for each blackberry.

After imaging, the chemical, physical, visual, feel, and taste properties were measured for each blackberry (Cockerton et al., 2020). The following measurements were recorded: mass, Brix, pH, visual colour score, colour uniformity, radiance, firmness, skin strength, flavour, sweetness, mouth texture, and aftertaste. The measurements were completed by a single technician, trained in taste assessments, to reduce the influence of human taste/perception preferences. Multivariate statistical analysis was used to find relationships between the reflectance spectra and ripeness and other berry metrics (Li et al., 2018).

Machine learning

A multi-input CNNvgg16 ensemble learner (MCE) was developed for classifying a blackberry fruit as ripe or unripe. This learner combines a multi-input CNNvgg16 architecture and ensemble learning. The MCE utilises a pair of 'stereo' images. Both images were monochrome spectral images but with different wavelengths, one at 700 nm and the other at 770 nm – together referred to as a 'bispectral image'.

Headset

A stereo camera mount was 3D-printed to hold two RGB camera and narrowband pass filters (at 700 and 770 nm). The mount was designed to attach onto Nreal Light augmented reality glasses. Power, control, and data storage is provided via a USB cable connected to a laptop.

RESULTS

Hyperspectral imaging

The results in Figure 1 show the spectral reflectance averaged for each blackberry ripeness classification, 0-4. Ripeness classification levels 2-3 represent optimally ripe fruit, where 0-1.5 are under-ripe and 4 is overripe. Analysis of the spectral data found that the largest differences in reflectance for under-ripe, ripe, and over-ripe berries was in the visible and near-infra red range, particularly at around 700 and 770 nm. The spectral regions were used in the bispectral imaging system and to collect image data for training the CNN.

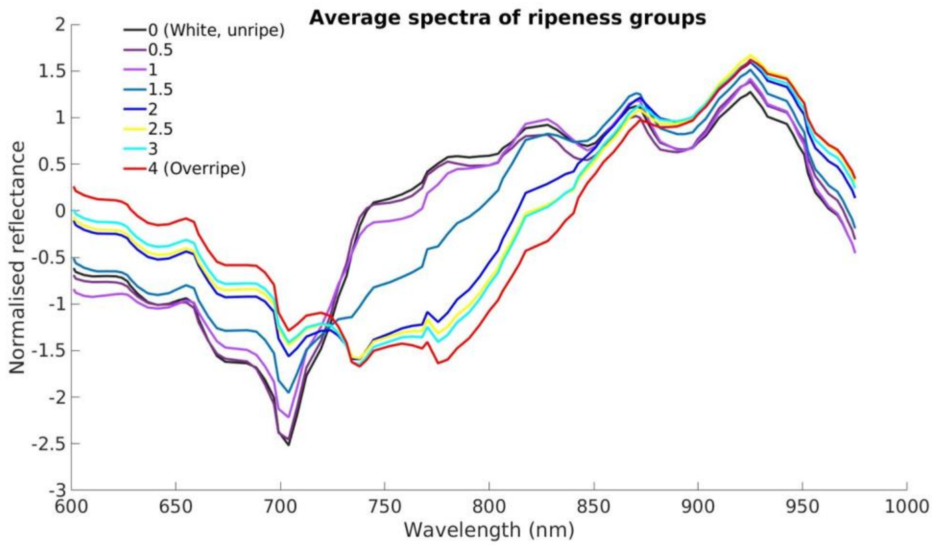


Figure 1. Averaged reflectance spectra of raw, unripe, near ripe, ripe, and overripe blackberries collected from a farm. Differences in reflectance are observable for the ripeness levels in the range of 600 to 850 nm.

Ripeness

Manual assessments

The relationships between the manually measured variables of the blackberries were investigated using correlation analysis. Manually determined ripeness correlated strongly with mass, colour uniformity, firmness, Brix, flavour, sweetness, mouth texture, aftertaste, and pH. The variables with the largest and most significant correlations with ripeness were: uniformity of colour, firmness, flavour, sweetness, mouth texture. Of these variables, only uniformity of colour is a visible attribute and therefore useable by the machine learning algorithm.

Machine classification

The machine classifier for ripeness was able to identify ripeness between blackberries, even between blackberries that would appear ripe to the human eye (human ripeness score of 2), which is evident in several samples. The confidence of the classification revealed the machine classifier was overly confident in its classification of ripe and unripe blackberries. This can be observed for blackberries that are very unripe with ripeness scores of 1.5 or 2, and optimally ripe with ripeness scores of 3 and 3.5. More intriguing is that for one sample the classifier correctly classified a blackberry that was unripe despite the human assessor identifying it as ripe from external appearances, but upon tasting was found to have a mouth texture of 4 (crunchy) and therefore was unripe.

DISCUSSION

Blackberry picking is a skilled task that takes weeks or months to learn to do well. Even pickers with more than one season of experience can easily make mistakes in selecting optimally ripe blackberries during harvest. If a punnet of blackberries contains fruit of mixed ripeness, overripe fruit can start to leak juice into the punnet leading to mould, whilst underripe fruit taste sour, both scenarios causing customer dissatisfaction. Losses due to incorrectly ripe fruit in punnets at the packhouse and on retailers' shelves are estimated to be 10-20% (Duncalfe, 2020 personal communication). For high-value fruit a device that could quickly and accurately determine blackberry ripeness non-destructively could reduce waste and save farms significant sums of money. Beghi et al., 2013, proposed a similar system for blueberries, using a portable optical device and microcontroller. The results from this project demonstrate the potential for spectral reflectance-based imaging, combined with machine learning, to provide a technological solution to determining blackberry ripeness accurately. An augmented reality device with bispectral cameras could guide pickers to selecting optimally ripe fruit during harvest.

REFERENCES

Beghi, R., Giovenzana, V., Spinardi, A., Guidetti, R., Bodria, L. and Oberti, R., (2013). Derivation of a blueberry ripeness index with a view to a low-cost, handheld optical sensing device for supporting harvest decisions. Transactions of the ASABE, 56(4), pp.1551-1559.

Cockerton, H., Unzueta, M.B., Johnson, A.W., Diegues, A.V. and Fernández, F.F., (2020). Pathway analysis to determine factors contributing to overall quality scores in four berry crops. Journal of Horticultural Research, 21(I), p.35.

Li, B., Cobo-Medina, M., Lecourt, J., Harrison, N., Harrison, R. J., & Cross, J. V. (2018). Application of hyperspectral imaging for nondestructive measurement of plum quality attributes. Postharvest Biology and Technology, 141, 8-15.

Mikulic-Petkovsek, M., Veberic, R., Hudina, M., Zorenc, Z., Koron, D. and Senica, M., (2021). Fruit Quality Characteristics and Biochemical Composition of Fully Ripe Blackberries Harvested at Different Times. Foods, 10(7), p.1581

1.7 LiDAR based porosity and LAI: can we use lidar scanning on one side only?

Anice Cheraiet[1], Alexis Bourguignon[1], Sébastien Codis[2], Adrien Vergès[2], Xavier Ribeyrolles[1], Xavier Delpuech[2], Maude Lewis[2], Elodie Trinquier[2], Jean-luc Lablée[1], Marc Brucker[1], Olivier Naud[1]

[1] ITAP, Univ Montpellier, INRAE, Institut Agro, Montpellier, France
[2] IFV French Vine and Wine Institute, 3430 Route de l'Espiguette, Le Grau-du-Roi, France
Email address: anice.cheraiet@inrae.fr

INTRODUCTION

Characterisation of the vineyard is a prerequisite for any precision farming approach in which the aim is to adapt cultivation operations to the characteristics of the environment and production objectives. Examples include crop protection by spraying, fertilisation, irrigation, and crop management in terms of quality and quantity. The need for regular phenotyping and in particular physical phenotyping of the crop is emerging as a necessity to further precision viticulture. From this perspective, the total leaf area (TLA, LAI when normalised by ground area) is a major candidate descriptor for site-specific management. Cheraiet et al. (2020 developed a method for automatically calculating the height of vines, their thickness and their apparent porosity as seen from the inter-row from 3D point clouds provided by a mobile 2D LiDAR sensor. Using this work as a foundation, the aim of our research is to develop generic multivariate regression models for predicting TLA from the analysis of the 3D point cloud, throughout the cropping season. The present contribution is a first step in this direction by working on the relation between LiDAR based estimation of the optical porosity of a stratum of vegetation and TLA.

MATERIALS AND METHODS

Acquisitions were made in three different plots called Aglae, Collection and Terre Blanche, at the end of bunch closure phenological stage. These plots were chosen because of their contrasting vigour. Within each plot, two segments corresponding to 1 m in length in the direction of travel and one vine plant, with contrasting vigour were identified. In each of these segments, destructive measurements of the TLA and vegetation scans were carried out using a tractor-mounted terrestrial 2D LiDAR sensor. In order to assess TLA variability, each of the 6 vegetation segments was subdivided into 12 cells (3 heights indexed A, B and C and 4 depths indexed from 1 to 4). In the middle of vegetation (B2&B3), cells were 0.4 m high and 0.15 m deep. A total of 6 scans were taken per segment, one scan of the front and back sides of the vegetation, and four scans of the front side, after successive defoliation of all the cells of a given depth on the vine plant. TLA was predicted from a leaf mass-surface relationship. A linear regression analysis was carried out to assess the performance of the IBR parameter (intercepted beam rate) in estimating TLA before any defoliation. Two linear models were built. The first was made using exclusively LiDAR data from front side scanning, while the second has been optimised using a combination of the front and back sides scanning of the vegetation segment. The number of beams that reach each cell in back-side scanning was used to provide relative weights for cells of depth strata 3 and 4 (farthest from LiDAR when scanning from front side). Instead of using IBR on the whole depth as in (Cheraiet et al. 2020), IBR was calculated for each cell, calculating incoming beams and intercepted beams on a given cell.

RESULTS AND DISCUSSION

The results of the analysis of the TLA data and the LiDAR point clouds show that for several segments (P2, P3, and P4), asymmetry is present between the two sides of the same stock (table 1).

Table 1: Mean values of the TLA and the IBR indicator observed between the two sides of a vegetation segment, and coefficients of variation including both sides.

	TLA			IBR		
	Sum (m^2)		CV (%)	Mean		CV (%)
Vegetation segment	Front	Back		Front	Back	
Terre blanche – P1	0.31	0.29	2.8	0.52	0.49	4.2
Terre blanche – P2	0.43	0.56	18.7	0.53	0.59	8.1
Collection – P3	0.69	0.48	24.7	0.84	0.62	21.3
Collection – P4	0.44	0.77	38.3	0.87	0.55	31.9
Petit Verdot – P5	1.21	1.23	0.8	0.72	0.93	17.5
Petit Verdot – P6	1.22	1.08	7.4	0.83	0.91	6.5

Considering asymmetry and higher variability of IBR for depth strata 3 and 4 due to few beams reaching these strata, the interest of developing the optimised linear model and compare it to the one side scanning model was justified. Interpretation of the results of the regression models linking TLA and IBR revealed significant differences between the two predictive models (reference with one side scanning and combination of front and back sides scanning). The TLA correlated only 23% with IBR for the one-sided regression model (Figure 2) and 71% with IBR for the regression model optimised from the combination of the two sides of the same vine segment (Figure 1). Based on this data, it appears that a single variable regression model obtained by scanning only one side of the vegetation presents risks of biased estimate of TLA. The poor ability to predict TLA from IBR in the first model can be explained by a masking phenomenon due to the vegetation present on the outer layers.

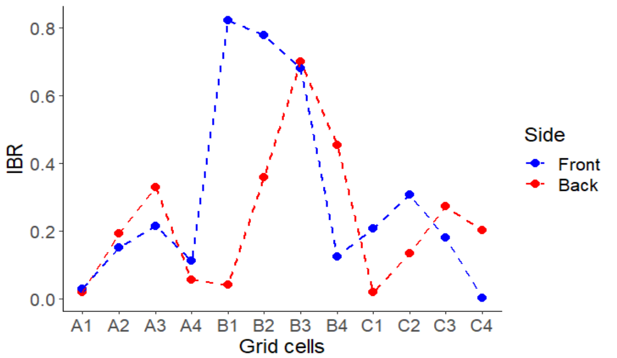


Figure 1: Comparison of IBR values between front and back side acquisitions at the resolution scale of the grid cell

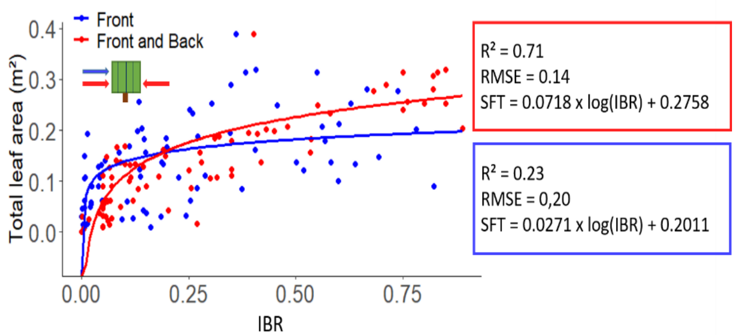


Figure 2: Relationship between the TFI index and the SFT measured on all the vegetation compartments defined by considering all the vegetation segments

Because one-side scanning is much desirable for operational reasons, future research should be devoted to multi-variable prediction models.

REFERENCES

Cheraïet, A., Naud, O., Carra, M., Codis, S., Lebeau, F., & Taylor, J. (2020). An algorithm to automate the filtering and classifying of 2D LiDAR data for site-specific estimations of canopy height and width in vineyards. Biosystems Engineering, 200, 450-465. https://doi.org/10.1016/j.biosystemseng.2020.10.016.

Session 2: Spray cover and deposition

2.1 PERFORMANCE PULVÉ®: a labelling system for vineyard sprayers based on their performance in terms of spray quality and potential for PPP dose reduction. Review after two years of implementation

Sébastien Codis[1], Adrien Vergès[1], Xavier Ribeyrolles[2], Xavier Delpuech[1], Maude Lewis[1], Anice Cheraiet[2], Elodie Trinquier[2], Christophe Auvergne[3], Olivier Naud[2]

[1]IFV, French Vine and Wine Institute, Site de INRAE B.P. 5095, F-34196 Montpellier Cedex 5, France.
[2]UMR ITAP, University of Montpellier, INRAE, Institut Agro, B.P. 5095, F-34196 Montpellier cedex 5, France.
[3]Chambre d'Agriculture de l'Hérault Maison des agriculteurs Mas de Saporta CS 10010, 34970 Lattes
Email address: sebastien.codis@vignevin.com

INTRODUCTION

PERFORMANCE PULVÉ® is a sprayer labelling system that guarantees the performance of vine sprayers through ratings on their spray application quality and their potential for reducing the use of plant protection products. Set up in 2021, PERFORMANCE PULVÉ® is a service designed for wine growers and their advisers to help them to choose their sprayer. The service also provides advice on sprayer settings to optimize protection efficiency. Sprayers ratings are used by several institutions in France to release subsidies for the renewal of the sprayer fleet. The ratings attributed to sprayers by PERFORMANCE PULVÉ® are based on the results of sprayers tests carried out on the EvaSprayViti test bench, an artificial vine that mimics different growth stages and ensures the standardization of spray tests (Codis et al., 2013).

MATERIALS AND METHODS

The project started concretely in 2013 with the development of the EvaSprayViti test bed by IFV (French Institute for Vine and Wine) and INRAE (French national research institute for agriculture). The EvaSprayViti test bench is a modular artificial vine composed of 4 rows of 10 meters used for measuring the deposition on the canopy in standardized conditions. The test bench can mimic three vegetative stages of the vine (early growth stage, middle and full growth stage), which makes it possible to assess the sprayers over the entire vegetative cycle of the vine. Between 2014 and 2018, dozens of sprayers sold on the market were tested on EvaSprayViti according to the methodology developed by IFV and INRAE. This made it possible to identify significant differences between sprayers and validate the interest of building a classification. Trials were carried out in collaboration with sprayers manufacturers and with the support of the local Chambers of Agriculture. In 2018, IFV and INRAE had gained sufficient references to define a sprayers classification method based on thresholds linked to the average deposition and its distribution inside the canopy.

Following the trials on the EvaSprayViti test bench, detailed performance ratings (A+, A, B or C) are assigned to the sprayers for each of 3 the vegetative stages (early, half and full growth stage). These ratings reflect different capacities to reduce the amount of PPP used while maintaining deposition on the vegetation at least equivalent to those produced by a reference sprayer used at full dose rate (Vergès et al., 2017). In addition, a synthetic notation, in the form of a class, gives an overall view of the sprayer's performance all around the vegetative season taking into account the detailed ratings obtained for each growth stage. 7 performance classes have been defined (from 1 to 7), class 1 being the most efficient.

In 2017, a Steering Committee was set up to collectively agree on the rules for the labelling system. This multidisciplinary committee has representatives from the Ministry of Agriculture, local Chambers of Agriculture, CIVC, AXEMA (French agricultural machinery Association), Phyteis (French Crop Protection Industry Association), INAO (National Institute of origin and quality) and Regional Councils. The committee has drawn up the governance charter that defines all the rules for classification of the sprayers. This committee made it possible to develop the labeling system in a collectively validated and supported direction, consulting all stakeholders throughout the decision-making process.

A second working group was established in 2018: the PERFORMANCE PULVÉ® Technical Commission that analyzes the application files provided by the manufacturers and the results of the trials and then makes the decision to classify the sprayer according to the rules laid down in the governance charter. The Technical Commission is made up of independent experts specialized in spraying, coming from the different wine growing regions in France. To date, the Technical Commission is composed of 8 agricultural equipment advisors from the Chambers of Agriculture and the Comité Champagne. The Technical Commission began the evaluation of the first files for sprayer evaluation in January 2020.

In 2019, the decision was made to award qualification at the level of the sprayer unit by issuing a PERFORMANCE PULVÉ® certificate. This certificate is specific to the machine unit and contains the serial number of the machine. It also includes, through the detailed sheet that accompanies it, the detailed and the synthetic ratings obtained as well as the conditions under which the ratings are awarded. The certificate specifies, among other things, the settings, and the range of inter-rows for which the qualification is delivered.

RESULTS AND DISCUSSION

In total, 21 different manufacturers have carried out sprayer tests on EvaSprayViti with at least one of their machines. To this date, 25 models of sprayers with more than 120 manufacturable variations from 16 different brands have been qualified. The PERFORMANCE PULVÉ® internet platform available since December 2020 on http://www.performancepulve.fr/ references all the qualified sprayers. The platform allows: (i) winegrowers and advisers to browse the list of referenced sprayers as well as their detailed factsheets, (ii) the manufacturers to edit the certificates for each machine unit of the referenced model, (iii) institutions that use PERFORMANCE PULVÉ® to guide subsidies may proof the certificates of the sold referenced sprayers using the serial number. To ensure the long-term success of the approach, the challenge is twofold: to continue disseminating and transferring the service to the various operators in the sector, and to have PERFORMANCE PULVÉ® recognized as a support for future investment subsidies (EAFRD).

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. 12th Workshop on Spray Application Techniques in Fruit Growing (SuproFruit) Valencia Spain June 2013

Vergès A, Codis S., Carra M., Delpuech X., Montegano P. , Ruelle B. , Savajols S. , Ribeyrolles X. (2017) Sprayer's classification in viticulture according to their performance in terms of deposition and dose rate reduction potential. 14th Workshop on Spray Application Techniques in Fruit Growing (Suprofruit) Hasselt Belgium May 2017

Vergès A., Codis S., Ruelle B., Bonicel, JF., Bastidon, D., Ribeyrolles X. Montegano P., Carra M., Delpuech X. (2018) Labellisation des pulvérisateurs viticoles selon leurs performances agro-environnementales - AFPP - colloque sur les techniques d'application de produits de protection des plantes - Lyon – 13 et 14 mars 2018

2.2 Evaluating the influence of drape netting on spray deposition and disease control in apple orchards using apple scab as a model pathogen

Johannes Gideon van Zyl[1], Philip Rebel[1], Bekker Wessels[1]

[12]ProCrop (Pty) Ltd, Stellenbosch, South Africa
Email address: gideonvz@procropsa.co.za

INTRODUCTION

Deciduous fruit growers in South Africa are adopting nets to moderate the microclimate surrounding trees to Conserve water, improve fruit colour, reduce sunburn, wind damage, and protect fruit against increasingly regular hailstorms, and through it, improve marketability for exportable stone and pome fruit. New orchards in the Western Cape and Langkloof regions of South Africa are established with permanent netting structures. However, it is costly and, in some cases, not possible to cover established orchards with permanent netting structures. Drape netting is used therefore on established orchards or orchards where permanent netting structures cannot be used. Drape netting also has the potential benefit of reducing insect damage through exclusion. However, drape netting creates a physical barrier around the tree, which can possibly complicate airflow and thus penetration onto/into the tree canopy. This in turn can have adverse effects on pest and disease control, especially in orchards that had early season fungal infections. Pest and disease control will be influenced due to reduction in spray deposition. In addition, management of ‘bitter pit’ can be negatively impacted because deposition of calcium sprays on fruit is reduced by the presence of drape netting. This study therefore investigated the influence of drape netting on deposition parameters and disease control using apple scab (*Venturia inaequalis*) as a model pathogen.

MATERIALS AND METHODS

In 2019, 2021 and 2022 separate spray trials were conducted in uniform drape netted and undraped sections of three apple orchards in the Western Cape of South Africa. a High profile ROVIC LEERS EVENFLO or NOBILI ANTIS (28000 m^3/h air volume) and/or low profile NOBILI GEO (48 000 m^3/h) axial fan sprayers were used. Spray water volume ranged from 500 to 750 L/ha depending on orchard tree row volume. Fine to very fine (61-235 µm) droplet VMD spectrum was used in all trials. Sprayer setup and speed was based on the principals of canopy adapted spraying for all trials.

10 Trees of three replicates were sprayed per application with SARDI yellow fluorescent pigment (1 ml/L) with dose adjusted per tree row volume in draped and undraped sections. After spray application, 12 leaves were randomly sampled from the inner and outer canopy at the top, middle and bottom tree positions per tree (6 sampling positions, 72 samples per tree) from three sample trees for each replicate. Digital images were taken of sampled leaf material illuminated by UV-A ≈ 365 nm light source and the following deposition parameters determined by means of digital image analyses: deposition quantity, measured as percent of total leaf area covered by pigment particles (percentage fluorescent particle coverage; %FPC); deposition uniformity, measured as the coefficient of variation (CV%) of deposition quantity between leaves; and deposition quality, measured as the interquartile coefficient of dispersion (%ICD) (van Zyl *et al*., 2013, 2014). Deposition quantity data was evaluated using FPC% benchmarks proposed by Rebel *et al.* (2020) to interpret theoretical apple scab control. Undraped sections were kept undraped throughout the growing season with apple scab incidence rated on fruit and leaves at harvest following a season long fungicide strategy with sprayers as set up in the 2021 and 2022 trail using methodology as described by McHardy (2000) and Sutton *et al*. (2000).

RESULTS AND DISCUSSION

In all trials, deposition quantity (FPC%) realised on draped and undraped apple trees were above the 1.35% FPC% recommended for theoretical scab control by Rebel *et al*. (2020). However, data did indicate significant interactions for draped and undraped sections. In 2019, deposition quantity (FPC%) on inner and outer canopy leaves, as influenced by drape netting. The presence of drape netting when using a conventional low profile axial sprayer (air volume of 48 000 m^3/h) resulted in a reduction in deposition quantity by 30% compared to without the netting; using a high profile axial fan sprayer (air volume of 28 000 m^3/h) the spray deposition reduced by 49% compared to undraped trees. In 2021, using a low profile axial fan sprayer, deposition quantity measured on drape netted trees were 25% lower on inner canopy leaves and 23% lower on outer canopy leaves compared to undraped sections. Apple scab incidence on fruit harvested was not significant ($P > 0.2074$). On drape netted fruit scab incidence was 14.18% compared to 12.72% for undraped sections. Leaf infections was also not significant ($P > 0.2732$). Higher scab incidence was found on drape netted vs undraped sections (68.3% vs 58.02%), realising a higher potential ascospore carry over for the next season. In 2022 good early season scab control was achieved, with no discernible scab infection at harvest. Deposition quantity was however negatively impacted by the presence of drape netting, with inner canopy leaf deposition reduced by 11% and 59% on the outer canopy leaves, when using a high profile axial fan sprayer.

The data concludes that drape netting does have a negative effect on spray deposition parameters and therefore has the potential to reduce fungal disease control and possibly increase the incidence of bitter pit. However, with good pest and disease control before trees are closed with nets, the advantages of netting outweigh the disadvantages as was indicated in the 2022 season.

REFERENCES

MacHardy, W. E. 2000. Action thresholds for managing apple scab with fungicides and sanitation. International Conference on Integrated Fruit Production, 2000. Acta Hortic. 525:123-132.

Rebel, P., Poblete-Echeverria, C., van Zyl, J.G., Wessels, J.P.B., Coetzer, C., McLeod, A. 2020. Determining mancozeb deposition benchmark values on apple leaves for the management of Venturia inaequalis. Plant Disease 104, pp 168-178.

Sutton, D. K., MacHardy, W. E., and Lord, W. G. 2000. Effects of shredding or treating apple leaf litter with urea on ascospore dose of Venturia inaequalis and disease buildup. Plant Dis.84:1319-1326.

van Zyl, J. G., Fourie, P. H. and Schutte, G. C. 2013. Spray deposition assessment and benchmarks for control of Alternaria brown spot on mandarin leaves with copper oxychloride, Crop Protection, 46, pp. 80–87.

van Zyl, J. G., Sieverding, E. G., Viljoen, D. J. and Fourie, P. H. 2014. Evaluation of two organosilicone adjuvants at reduced foliar spray volumes in South African citrus orchards of different canopy densities, Crop Protection. Elsevier Ltd, 64, pp. 198–206.

2.3 Row by row exclusion netting in apple orchards negatively impact spray deposition but don't affect spray efficacy

Gérald Chouinard[1], Vincent Philion[1], Francine Pelletier[1], Mikaël Larose[1]

[1]IRDA, Saint-Bruno-de-Montarville, Québec
Vincent.philion@irda.qc.ca

INTRODUCTION

Commercial apple production requires intensive spraying of pesticides and growth regulators in most areas where this fruit is grown. On top of providing hail protection, orchard netting can prevent insect and even disease damage to the crop, but sprays are nonetheless required at least for fruit thinning and fertilizers. Row by row complete exclusion netting is sometimes preferred over full block netting because of soil insect control but unless the netting is retractable, sprays need to be applied through very fine mesh to reach the target (Chouinard et al. 2019). The extent of spray filtration caused by netting was studied in an orchard in Saint-Bruno (Qc).

MATERIALS AND METHODS

Tartrazine was used as a tracer of spray deposits and the distribution was studied at the leaf scale. Different sprayer settings (forward speed, air speed, droplet size), orchard characteristics (canopy width and density), and netting mesh sizes were compared. A certified Aircheck sprayer (Triloff, 2019) was used to insure sprayer performance was not limiting deposition. The best combination was used to test if the spray interception prevented agronomical efficacy.

RESULTS AND DISCUSSION

Although netting reduced median deposits by at least 36% depending on the settings, pest control and fruit thinning remained unaffected. Unsurprisingly, for a given tractor forward speed, the combination of netting with the largest mesh size (Artes), use of small droplets (ATR 80 Lilac instead of Lechler IDK 90-01), and fan speed adapted to crop instead of full fan speed, resulted in the highest deposits (Fig. 1). High spray losses without agronomical impact underline that it may be worthwhile investigating retractable nets to insure optimal deposits and underlines doses applied in absence of nets are likely excessive.

REFERENCES

Chouinard, G., Veilleux, J., Pelletier, F., Larose, M., Philion, V., Joubert, V., et al. (2019). Impact of exclusion netting row covers on 'Honeycrisp' apple trees grown under northeastern North American conditions: Effects on photosynthesis and fruit quality. Insects. 10:214.
Triloff P. (2019). Canopy Adapted Dosing and Spray Application: Environment Protection in Crop Protection, SuproFruit Proceedings 2019, 45 - 46.

Figures

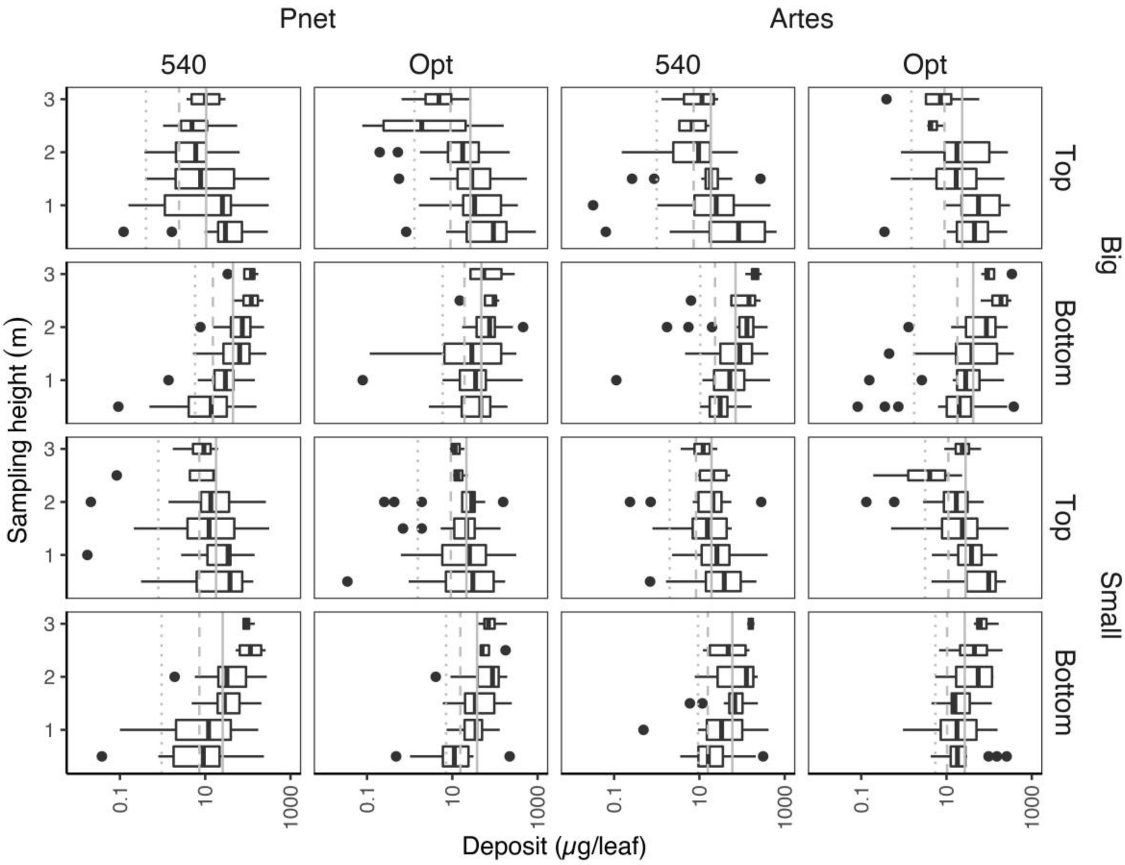


Fig. 1. Effect of netting type (Pnet vs Artes), sprayer air speed (540 RPM maximum vs Optimally adjusted), and droplet size (Big vs Small) on the tartrazine deposit observed at different heights on the Top and Bottom apple leaf surfaces.

2.4 PerformancePulvé arbo: comparative assessment of orchard sprayer efficiency under standardized indoor conditions

Yoan Hudebine[1], Florence Verpont[1], Harmony Carmagnat[1], Adrien Vergès[2], Sébastien Codis[2], Anice Cheraiet[3], Jean-Paul Douzals[3], Olivier Naud[3]

[1] CTIFL, Technical and Interprofessional Centre for Fruit and Vegetables, 28 route des Nébouts 24130 Prigonrieux, France.
[2]IFV, French Vine and Wine Institute, Site de INRAE B.P. 5095, F-34196 Montpellier Cedex 5, France.
[3]UMR ITAP, University of Montpellier, INRAE, Institut Agro, B.P. 5095, F-34196 Montpellier cedex 5, France.
Email address: yoan.hudebine@ctifl.fr

INTRODUCTION

Spray quality is a key point to optimise the use of plant protection products while maintaining the effectiveness of the crop protection. The French Plan Ecophyto2+ encourages the use of high-performance application techniques. This requires the ability to assess and classify sprayers on objectively measured indicators. The PerformancePulvé® sprayers labelling system, targeted to winegrowers, guarantees the performance of vine sprayers through an objective assessment of their sprayer's quality and potential in terms of plant protection products reduction through trials (Vergès et al., 2017). The trials are carried out on the EvaSprayViti test bench, which mimics 4 rows of vine at 3 different growth stages (Codis et al., 2013). The objective of the Performance Pulvé Arbo project (2021-2023) is to extend this approach to the fruit-growing sector. A new test bench that mimics three rows of orchard has been developed to assess performances of fruit trees sprayers in terms of deposits and drift. The characteristics of the test bench were determined according to a panel of LiDAR characterizations of more than 200 orchards located in France. To overcome climatic conditions and to be able to work all year-round, the tests are carried out indoor a platform located at CTIFL in Bergerac. This article presents the ongoing work on the performance of the deposits of the project PerformancePulvé Arbo led by the CTIFL, in partnership with IFV and INRAE.

MATERIALS AND METHODS

The test bench is made up of three rows of 10 meters long and includes two parts: The first part was a measurement section, consisted of 1 custom-designed metal support that enables the collection of spray deposits from on the artificial leaves. The second part of the test facility was a section without measurement, consisted of 16 insect proof nets (mesh size: 3.4x2.2mm, and fiber diameter: 0.3mm) mounted on either side of 8 custom-designed metal supports to simulate different levels of canopy porosity. Designed to reproduce a fruit hedge, the height, the width and the porosity are adjustable to mimic two growth stages. The early stage (until blossoming) was 3.30 m high and 1.45 m wide whereas the full growth stage was 3.80m high and 1.90 m wide. The tests were carried out with an inter-row spacing of 4.2 m, (Fig. 1).

Figure. 1. Performance Pulvé arbo test facility located in TITEC platform.

The measurement section contains branches each with 14 leaves consisting of a fibrous tarpaulin used to collect and assess the spray deposition on the canopy. The leaves are bounded by a branch made of the same material; 12 branches constitute a frame. 24 frames are present in the early stage and 36 in full vegetation. The tracer used for trials was tartrazine (E102). After spraying, the branches were collected and placed separately in boxes, (one per box) then washed with demineralized water. The individual analyses of the boxes provided the amount of tracer per unit of area for one gram of tracer sprayed per hectare (unit: ng/dm² for 1g/ha). The following table describes the configurations chosen for the tests considering the stage of vegetation and the row spacing of 4.2 m.

Table 1. Characteristics of the measurement section simulating two possible stages of vegetation.

Growth stage	Early	Full
Number of leaves / branches	1680 / 120	3024 / 216
Number of layers	2	3
Leaf Area Index (m²/m²)	1.19	2.13

Net benches are structures with insect proof nets that aim to replicate the air porosity characteristics of the canopy and limit edge effects. The dimensions are adjusted according to the measurement section. The sprayers used were Nicolas ASI Magistral and Chabas Opti-ajust, with 3 replicates for each sprayer and each step. The first step consisted in validating the number and arrangement of branches for each stage of vegetation (according to a fixed leaf area index), and the repeatability of the method. The second step aimed to study the minimum sampling to be carried out to guarantee the reliability and reproducibility of the results. The third step aimed to study the sensitivity of the method using a completely different type of sprayer.

RESULTS AND DISCUSSION

The results obtained made it possible to validate the characteristics chosen for each stage of vegetation, thanks to the consistency of the deposits with respect to previous results. The coefficients of variation depending on the stage and the sprayer were between 2.5% and 4.4%, showing very good repeatability of the method. For the Opti-adjust sprayer, the coefficients of variation according to height and thickness are respectively 20% and 10% at the early stage, 30% and 20% at the full vegetation stage. Sampling will be done over the entire height and over the 3 thicknesses. The deposits according to the width of the facility provided coefficients of variation of 3% whatever the stage. This will reduce the number of branches to be sampled by 66%. Both sides of the measurement section will be sampled to retain sufficient data for evaluation. The average deposit obtained at the early stage for the Magistral sprayer and the Opti-ajust were respectively 179 and 210 ng/dm² per 1g/ha, and 142 and 187 ng/dm² per 1 g/ha in full vegetation, i.e. a difference of 15% and 24% respectively. These figures are similar to those obtained during our trials in real orchard, during the French project PulvArbo (Verpont and Douzals, 2020).

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. In: E. Molto et al., Book of abstracts 12th Workshop Spray Application Techniques in Fruit Growing; Suprofruit 2013, IVIA, Valencia, Spain. pp. 23-25.Vergès A.,

Vergès A., Codis S., Bonicel J.F., Diouloufet G., Douzals J.P., Magnier J., Montegano P., Ribeyrolles X., Ruelle B., Carra M., Delpuech X., Savajols B. (2017). Sprayer classification in viticulture according to their performance in terms of deposition and dose rate reduction potential. In: K. Ruysen. Book of abstracts Suprofruit 2017, Hasselt, Belgium. pp. 31-32.

Verpont F., Douzals JP. (2020). « PulvArbo, la pulvérisation en arboriculture fruitière : un levier pour réduire les intrants ». ONEMA Ecophyto Project report, pp. 125.

2.5 OptiSpray: Preliminary results on sprayer classification for pesticide savings based on deposition and efficacy trials in orchards and vineyards

Katrin Ahrens[1], Christian Göppinger[2], Michael Glaser[3], Tanja Pelzer[1]

[1]Julius Kühn Institute (JKI) – Federal Research Centre for Cultivated Plants, Institute for Application Techniques in Plant Protection, Braunschweig, Germany
[2]Center for Agricultural Technology Augustenberg (LTZ), Rheinstetten, Germany.
[3]Center for Agricultural Technology Augustenberg (LTZ), Karlsruhe, Germany.
Email address: katrin.ahrens@julius-kuehn.de

INTRODUCTION

National and international policies like the EU Commission's European Green Deal are pursuing a reduction of chemical plant protection products (PPP) by up to 50% until 2030 (EC - European Commission, 2020). The use of efficient sprayers offers the potential to save PPP in orchards and vineyards by improved target area application. The reduction of PPP dependent on sprayer performance offers economic and ecological incentives. For the evaluation of different sprayers regarding deposition efficacy and efficiency, comparable and reproducible measurement results are required. Continuous research efforts in France resulted in the establishment of an artificial vineyard test system and a sprayer classification for agro-environmental performance assessments (Codis et al., 2013; Naud et al., 2014). Current research and development is conducted in France to establish a similar system in orchards. Meanwhile the joint research project 'OptiSpray' aims to establish a system for sprayer performance assessments in orchards and vineyards for Germany. Research institutes, sprayer manufacturers, and government agencies cooperate to accomplish this. A classification of sprayers regarding reduced amounts of PPP as part of the risk assessment for the approval of PPP in Germany is one of the major objectives of this project. This is supposed to accompany the already existing classification on drift.

MATERIALS AND METHODS

Extensive deposition trials on test benches in artificial vineyards and apple orchards are supported by deposition trials in natural orchards and vineyards at three locations each. This is for functional validation and optimization of the artificial test benches. Trials are conducted to verify whether sprayers with an above-average deposition efficiency can be used with reduced application rates and thus ensure a comparable biological effect. In addition, common pathogens and pests are monitored for three years.

The artificial orchard and vineyard consist of several rows of steel frames covered with nets representing a dense leaf wall. Within these rows, a test bench with artificial leaves (rectangular polypropylene cards) is implemented. Uniform parameters for carrying out and evaluating spray deposition are defined to make reproducible measurements possible. The artificial orchards and vineyards were sprayed on both sides with a fluorescent tracer (Pyranine 120%, Lanxess GmbH) dissolved in water. Collectors were removed, stored, and analysed according to the developed specifications in the course of the project. In a first step, all collectors that represent the deposition on the foliage were analysed. Now in the next development steps of this project, only a part of the collectors on the foliage wall will be selected due to high labour intensity and the fact that enough information about the deposit is gained by these leaves.

Two sprayers have been identified as reference sprayer for each cultivation type. The axial blower P 32/1000-140 (Wanner Maschinen GmbH, Wangen, Germany) serves as the reference sprayer in orchards while a radial blower DGR56/300-70 PE is used in vineyards. The results of the sprayers are compared with those of sprayers with supposedly better technology. For orchards, an axial blower with a blower case to simulate a cross flow distribution PA32/1000-150 PE and for vineyards a comparably structured DA24/300-70 PE were chosen to be evaluated. One aim of the future works within the project is to test other types of equipment as well (e.g. tangential blower, axial blower with dual fan, etc.). For each sprayer, two variants are investigated regarding application rates (full and reduced application rate), each with the same tracer or active substance concentration. An assessment of the performance in PPP savings will be made based on the measurements of deposition and effectiveness of different systems and should result in a sprayer classification.

RESULTS AND DISCUSSION

The measurements are accompanied by the Julius Kühn Institute (JKI). In cooperation with the regulatory authorities of PPPs and in terms of the future need to save on PPPs the methods and the results are supposed to be taken into account for the future regulation of PPPs.

Currently, efficacy trials in orchards and vineyards are tested according to the hypothesis that savings potentials can be derived from the measurements of application efficiency, and thus a reduction of the application rate according to a factor calculated from the application rates is possible without having to accept significant reductions in efficacy.

Initial findings show that the deposition in the artificial test benches follow a similar pattern compared to the deposition in the fruit trees, although this was not evident at all locations. For example, at one location, the reference sprayer with the full application rate showed similar depositions as the supposedly better sprayer with a reduced application rate in different areas of the tree. Generally, it is a challenge to synchronize the activities of all locations so that the data can be presented and evaluated in a comparable way.

Finally, a system for the evaluation of sprayers for orchards and vineyards with regard to application efficiency is to be developed on the basis of the above mentioned assumptions. Accompanying advancements will be the simplification of the sampling scheme in the artificial measurement modules and further implementation of technological systems with the goal of process automation for direct data generation.

ACKNOWLEDGMENTS

The project is supported by funds of the German Government's Special Purpose Fund held at Landwirtschaftliche Rentenbank.

REFERENCES

EC – European Commission, 2020: A European Green Deal. URL: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en, accessed: 25.05.2023.

Codis, S., Bonicel, J.-F., Diouloufet, G., Douzals, J.-P., Hébrard, O., Montegano, P., Ruelle, B., Ribeyrolles, X., and Vergès, A. (2013). EvaSprayViti: a new tool for sprayer's agro-environmental performance assessment. 12th Workshop on Spray Application Techniques in Fruit Growing - SuproFruit 2013, 26-28 June 2013, Book of Abstracts ISBN: 978-84-9048-077-9, *Valencia (Spain), 23-25.*

Naud, O., Vergès, A., Hébrard, O., Codis, S., Douzals, J-P., and Ruelle, B. (2014). Ref: C0661 Comparative assessment of agro-environmental performance of vineyard sprayers using a physical full scale model of a vineyard row. Proceedings International Conference of Agricultural Engineering, Zurich (Switzerland), 6-10 July 2014 DOI: 10.13140/2.1.3509.4402.

2.6 Influence of application material on spray deposition on strawberry in tabletop growing system

Justine Garnodier[1], Florence Verpont[2], Camille Allemann[1], Harmony Carmagnat[2], Yoan Hudebine[2]

[1] *CTIFL, 751 chemin de Balandran, 30127 Bellegarde*
[2] *CTIFL, 28 Rte des Nébouts, 24130 Prigonrieux*
Email address: justine.garnodier@ctifl.fr

INTRODUCTION

Strawberry is an important crop in France with 3300 ha of commercial production per year (Agreste, 2022). In 2018, pest management required in average 8.8 treatments in soilless production system compared to 6.4 in in-soil system (Agreste, 2020). In soilless system, 50% of treatments is fungicide used mainly to control powdery mildew infestation. The other treatments include insecticides for arthropod pests like aphids and mites. Movento® (Spirotetramat) is the main aphid insecticide used currently for strawberry protection. This active ingredient will no longer be authorized by 2025. As the number of applications of each active ingredient is limited per season, the loss of spirotetramat means growers need to balance and optimize the utilization of other available insecticides for the target pests to increase their effectiveness throughout the season, e.g. against aphids. The quality of spray application is a key factor to maximize the efficiency. A wide diversity of spray application machinery is available to use in soilless production system. According to a survey carried out by the CTIFL in 2021, the air assisted sprayer Autran & Mab® was the main equipment used by soil less strawberry growers. Other types of equipment, such as vertical boom sprayer or gun sprayers were also used widely but their spraying quality is highly variable (Nuyttens et al., 2004). The objective of the present study was to compare spray deposition on different parts of plants between vertical boom sprayer and reference practice (air assisted sprayer).

MATERIALS AND METHODS

The study was carried out in glasshouses at the technical center CTIFL de Balandran located in the south of France. The strawberry cultivar Gariguette (INRAE) was cultivated in tabletop growing system. Plantation took place in week 3, 2022 with density of 10 plants/m. The experimental design was a complete randomised block design with four blocks. The main treatment factor was sprayer equipment, and spray deposition measurements were taken before flowering and at the end of harvest periods.

Fig.1: Vertical boom sprayer

Two types of sprayers adapted to greenhouse conditions were tested, the air-assisted sprayer and the vertical boom sprayer (Fig. 1). The configuration of each sprayer (nozzle number, nozzle orientation, and boom height) was individually adjusted according to the vegetation characteristics (Tab. 1). This adjustment aimed to maximize the matching of the whole vegetation and minimize losses of sprays under or above the plant level.

Tab.1: Spray application parameters for field trials

Application period	Sprayer	Application rate (L ha_1)	Forward speed (km h_1)	Flow rate (L min_1)
Before flowering	Vertical boom sprayer	502,9	3,28	0,914
	Air assisted sprayer	493,4	3,20	0,875
End of harvest	Vertical boom sprayer	832,0	2,08	0,940
	Air assisted sprayer	747,4	3,00	1,243

In each modality, 12 plants were chosen randomly, on each plant, 8 artificial collectors (plastic, 4*5cm) were placed to evaluate spray deposition. These collectors were distributed over four zones: The top of the plant, the heart of the plant, on a leaf outer of the gutter and on a leaf inner of the gutter, with two collectors per zone (upper and lower leaf surface). The 12 plants were distributed on 4 replicates (3 plants/ replicates) and 96 artificial collectors were used by modality.

We used the Yellow Tartrazine (E-102 yellow) colorant as a tracer with a concentration of 5g/l. Spectrophotometric technique was applied to measure the deposit on unitary target in the laboratory. Each artificial target was washed with distilled water and optical absorbance of the washing mixture was measured with a spectrophotometer. Factorial analysis of variance (ANOVA) was used to determine the effect of the spraying technique and the collector position (zone and side) on the quantity of deposition. Before statistical analysis, the assumptions of ANOVA were checked.

RESULTS AND DISCUSSION

The results of spray deposition are summarized in Table 2. A detailed analysis of the spray deposition showed that the average deposition value was 1,5 times higher on the upper sides of the plants than on the lower sides. This difference in spray deposition between the two sides was bigger for the vertical boom sprayer with 4,4 times more deposits on the upper side compared to the down one.The air assisted sprayer provided the maximum spray deposition on the vegetation. The average deposition with the air assisted sprayer was 19,3% higher than with the vertical boom sprayer. For the before flowering measurement, the deposition delivered by the two equipment was significantly different for the downside on the outside zone. Higher deposit on the lower face was obtained with the air assisted sprayer than with the vertical boom sprayer. For the upper face, there are no significant differences.

Differences in spray deposition between the two equipment was bigger at the end of the harvest than at the before flowering period. This difference could be explained by a large increase in the leaf area index at the end of the harvest which may reduce the spray penetration. On the lower leaf side, the deposits were higher when using the air assisted sprayer on both the outside leaf (3,11 times higher) and the inside leaf (1,9 times more). On the upper side, no significant differences were observed between the two sprayers. Although, there were 53% more deposits at the top of the plant with the air assisted sprayer compared to the vertical boom sprayer, the variance in the mean deposition was such that no significant difference was identified.

Table 2. Results of spray deposition ((ng/dm²)/g of tracer/ha) per zone and per side for each material tested

	Face	Zone	Vertical boom sprayer	Air assisted sprayer	P. value
Before flowering	Lower	Heart	2,175 ± 0,89	4,252 ± 2,48	NS (> 0,05)
		Outside	1,142 ± 0,30	12,487 ± 8,89	0,0434
		Top	2,955 ± 2,01	6,801 ± 5,31	NS (> 0,05)
		Inside	1,503 ± 1,78	1,486 ± 0,80	NS (> 0,05)
	Upper	Heart	7,413 ± 4,31	8,120 ± 3,85	NS (> 0,05)
		Outside	16,514 ± 3,43	9,746 ± 7,21	NS (> 0,05)
		Top	12,279 ± 3,60	9,388 ± 6,14	NS (> 0,05)
		Inside	8,492 ± 1,07	7,371 ± 2,84	NS (> 0,05)
End of harvest	Lower	Heart	1,381 ± 1,09	2,211 ± 0,56	NS (> 0,05)
		Outside	1,384 ± 0,73	4,373 ± 0,99	0,00289
		Top	4,292 ± 3,59	6,458 ± 6,26	NS (> 0,05)
		Inside	1,179 ± 0,35	2,260 ± 0,73	0,0381
	Upper	Heart	4,984 ± 3,03	5,595 ± 1,51	NS (> 0,05)
		Outside	9,624 ± 2,12	6,193 ± 3,38	NS (> 0,05)
		Top	9,084 ± 3,24	13,984 ± 2,62	NS* (0,0567)
		Inside	2,892 ± 0,90	3,381 ± 2,15	NS (> 0,05)

Our results suggest a consistent effect of the sprayer type on deposition (quantity and homogeneity. The choice of the sprayer is an important factor to be considered to enhance the quality of application and increase the efficiency of treatments especially for contact pesticides.

REFERENCES

Agreste Conjoncture Fruit, (2022). Infos rapides - Une récolte 2022 plus tardive et en légère hausse. N°2022-091

Agreste (2020). Chiffres et données – Pratiques phytosanitaires en production légumière en 2018 IFT et nombre de traitements. SEPTEMBRE 2020 N°7.

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

2.8 A new tool and a rapid methodology to assess the spray application quality in vineyards and orchards

Marine Louargant[1], Adel Bakache[2], Alexandre Davy[3]

[1]*Centre Technique Interprofessionnel des Fruits et Légumes* - marine.louargant@ctifl.fr
[2]*Chambre d'agriculture de la Gironde* - a.bakache@gironde.chambagri.fr
[3]*Institut Français de la Vigne et du Vin* - alexandre.davy@vignevin.com

INTRODUCTION

The available number of chemical solutions has significantly decreased in recent years, leaving wine and orchard growers with less and less solutions to protect the fruit against various diseases. Within this context, the spray application quality has become a major factor in the success of crop protection. However, growers have limited resources to assess the performance of their equipment. The main goal of the paper is to present a tool and an associated methodology that allows technical advisors together with vine and orchards growers to assess the spray application quality under real operating conditions.

MATERIALS AND METHODS

The developed methodology is a qualitative one, aimed at assessing deposits directly on the upper and lower sides of the leaves. It is based on:

1-A fluorescent tracer dye: unlike most fluorescent dyes, which lose their ability to fluoresce in the dry state (e.g. BSF, fluororescein...), the selected dye is perfectly visible when subjected to UV light.

2- A box equipped with UV lighting system and an image acquisition system: the purpose of the box is to enable image acquisition in various lighting conditions. It also serves as a support for the lighting system and the camera (phone, industrial camera).

3- An image processing algorithm (cf. Figure 1) is based on the colorimetric characteristics of the leaves and the fluorescent tracer dye, as well as the characteristic leaf shape. Step 1 consists in calculating an Excess Red (ExR) index combining the three channel R, G, B from image. The background is removed from the image in step 2 by applying Otsu thresholding (Otsu, 1979). At the same time, the threads are located and removed from the image by applying a Hough Transform for line detection to the ExR images (step 3). Both images are then used as a mask on the image's blue channel in step 4. Thresholding is then applied from the blue channel to extract dye impacts (step 5). Indicators are then calculated, such as leaf area, tracer dye covered areas, droplets number, etc. (steps 6 and 7). These indicators are calculated for the whole leaf and by zone (step 6).

Field tests have been carried out according to ISO22522:2007 on a vine estate

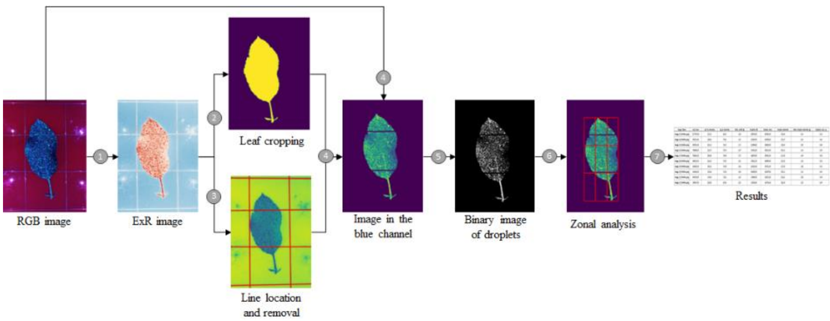


Fig.1: Main image processing steps for droplet detection and analysis

RESULTS AND DISCUSSION

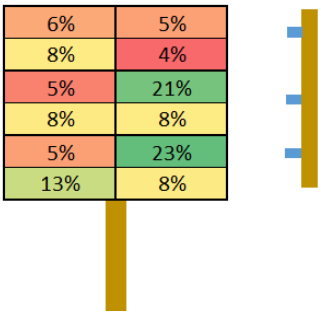


Fig2. Coverage measured in different compartments of a vine row

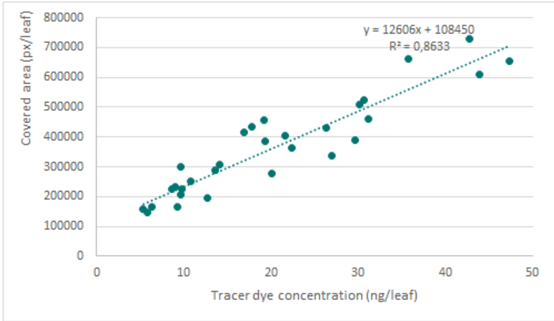


Fig. 3 Comparison of qualitative (from image analysis) and quantitative measurements

Figure 2 shows the results obtained with a Berthoud sprayer (Winnair - 6 km/h) equipped with brown ATR 80° nozzles (8 bar) with a 20 leaves sampling per zone. The used method allowed to identify the areas which have received more or less deposits, allowing the assessment of the of spray application quality in the field and, improve the settings of the device. In our example, the side directly treated received significantly more deposits.

To evaluate the qualitative method of spray quality assessment using image analysis, the results of image processing were compared with the amount of deposit on each leaf. A tracer dye solution was sprayed onto 30 leaves. These leaves were analysed using the presented tool, and the amount of dye was determined by spectrometry (Codis, 2013). The calculated droplet areas showed a strong correlation (R^2 = 0.86) with the amount of deposition.

CONCLUSION

The proposed tool showed its ability to detect heterogeneity in the row compartments to adapt sprayer settings. Furthermore, the image analysis results are encouraging regarding the possibility of measuring spray quality, both qualitatively and quantitatively.

ACKNOWLEDGMENTS.

Florence Verpont, Harmony Carmagnat, Yoan Hudebine, Clément Turbillier and Yannick Sire for their contribution.

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.ISO 22522:2007 - Matériel de protection des cultures — Mesurage au champ de la répartition de la pulvérisation pour arbres et arbustes fruitiers

Hough, P. V. C. (1962). Method and means for recognizing complex patterns. Vol. U.S. Patent Office N°3069654.

Otsu, N. (1979). A Threshold Selection Method from Gray-Level Histograms. IEEE Transactions on Systems, Man, and Cybernetics 9, 62-66

2.9 Spray deposition and loss during different application scenarios performed by orchard sprayer with individually adjusted air-jets

Grzegorz Doruchowski[1], Waldemar Świechowski[1], Andrzej Bartosik[1], Ryszard Hołownicki[1], Artur Godyń[1]

[1]The National Institute of Horticultural Research, Dept of Agriengineering - Skierniewice, Ploand
Email address:grzegorz.doruchowski@inhort.pl

INTRODUCTION

An excessive speed and volume of the unevenly distributed airflow produced by axial fans of the most commonly used orchard sprayers is responsible for poor spray deposition on the target, ground loss and drift (Garcera et al., 2022). In order to avoid this problem the airflow should be adjusted adequately to the situation, i.e. canopy development, weather conditions (wind speed and direction), proximity to the edge of orchard or to sensitive areas (e.g. surface water, residential areas). Different on-the-go controlled airflow adjustment systems have been tested, including a laterally moving air deflector plate mounted inside the axial fan outlet to change the horizontal air output (Salyani et al., 2007), adjustable side louvres on the axial fan outlets to regulate portion of airflow discharged towards the target (Landers, 2009), or a leaf shutter at the radial fan inlet limiting the air intake and an adjustable air guide at the fan outlet to vary the air flow independently to both sides of the sprayer (Doruchowski et al. 2012). In this study a double tower sprayer with two independent, hydraulically driven axial fans was tested during different air stream discharge scenarios in order to evaluate the influence of the airflow setting on spray deposition in the apple tree canopies, spray loss on the ground and spray drift in the event of crosswind interference.

MATERIALS AND METHODS

The orchard sprayer (AGROLA, PL) with two one-sided, oppositely facing tower fans, independently driven by adjustable hydraulic motors was fitted with hollow-cone nozzles TR80-02 (8 on each tower). It was tested in apple orchard (2,9 m tall trees of Gala/M9, spaced 3,5x1 m) while applying BF7G fluorescent tracer based spray liquid at the volume rate 400 L ha^{-1} and driving speed 7,5 km h^{-1}, according to three scenarios of the airflow output settings to the LEFT and RIGHT side of the sprayer (L/R): S – symmetrical: 100% / 100%; C – compensating crosswind: 30% / 100%; O – one-sided: 0% / 100%. The full air output (100%) was 7,2 m^3 h^{-1}. The performance of application scenarios was evaluated in terms of spray deposition on the tree canopies, ground loss to and drift. The spray collectors (laid out as in Fig. 1) for deposition and ground loss were in 3 lines and for drift in 10 lines (reps in space). Application for each scenario was repeated 3 times.

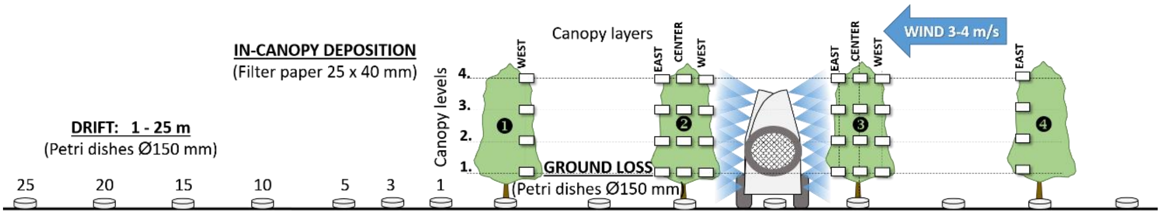


Fig. 1. The layout of samples for in-canopy deposition, ground loss and drift evaluation.

RESULTS AND CONCLUSIONS

The results of spray deposition, ground loss and drift measurements are graphically presented on Fig. 2, 3 and 4 respectively as % of applied dose (means followed by the same letter are not significantly different according to Duncan's multiple range test: P<0,05). By the asymmetrical airflow setting C (30% / 100%), with one-sided reduced airflow, the mean spray deposit in the canopies was not in general reduced, and in none of the vertical canopy layers it was significantly lower than the lowest deposit for symmetrical setting S (100% / 100%) considered as a reference application technique. The C application scenario allowed for reduction of spray loss to the ground by 25% and drift by 50% compared to S setting.

Thus, application scenario with the reduced airflow in the direction of crosswind can maintain the satisfactory spray penetration in the tree canopies while mitigating the environmental impact by reduced spray loss and CO_2 emission.

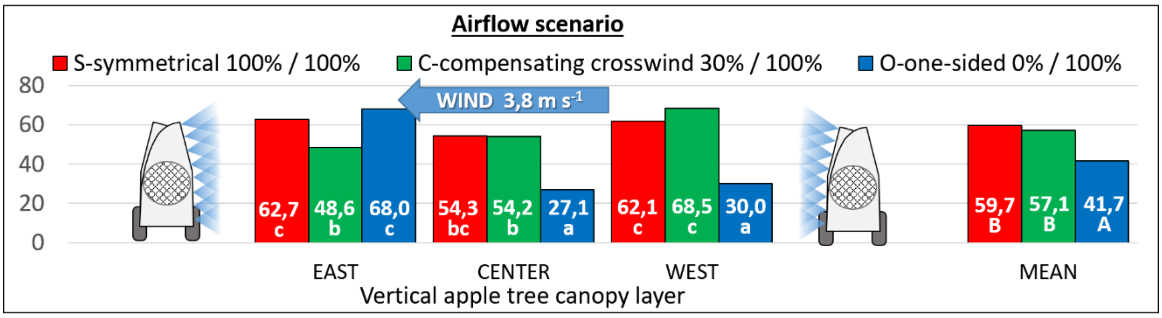


Fig. 2. In-canopy deposition of spray applied according to different airflow scenarios

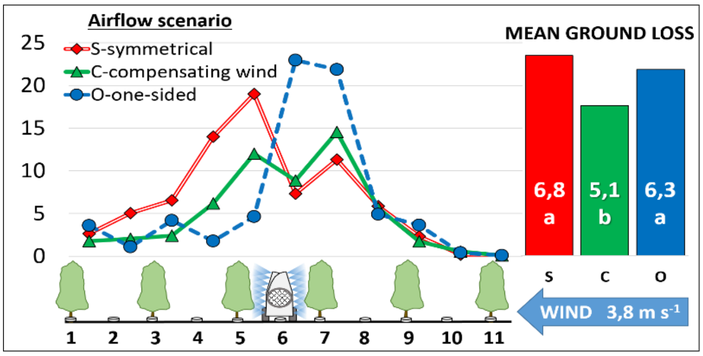


Fig. 3. Ground loss of spray for airflow scenarios

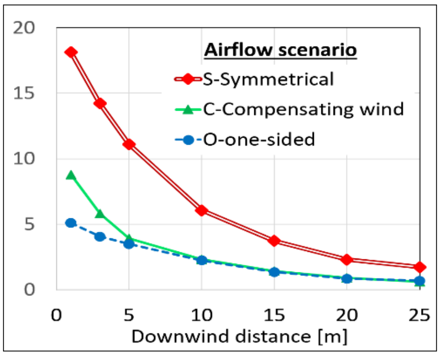


Fig. 4. Drift for airflow scenaios

REFERENCES

Doruchowski, G., Balsari, P., Marucco, P., Zande, J van de & Wenneker, M. (2012). Crop Adapted Spray Application (CASA) - Precise and safe plant protection in fruit growing. Aspects of Applied Biology, 114, 129-136.

Garcera, C.. Moltó, E., Izquierdo, H., Balsari, P., Marucco, P., Grella, M., Gioelli, F. & Chueca, P. (2022). Effect of the Airblast Settings on the Vertical Spray Profile: Imple-mentation on an On-Line Decision Aid for Citrus Treatments. Agronomy 2022, 12, 1462.

Landers, A.J. (2009). The Development of a Precision Canopy Sprayer for Orchards and Vineyards. Proc. FRUTIC CHILE 2009 – 8th Fruit, Nut and Vegetable Production Engineering Symposium, Concepcion, Chile, 5-9 January 2009, 485-493.

Salyani, M., Pai, N. & Sweeb, R.D. (2007). On-the-go changing of sprayer airflow based on tree foliage density. Proc. SuProFruit 2007 – 9th Workshop on Spray Application Techniques in Fruit Growing, Alnarp, Sweden, 12-14 September 2007, 63-64.

Session 3: Spray atomization, air support, new technologies (incl. drones) for spray application

3.1 Effect of UASS spray application rates on vines canopy deposit

Marco Grella[1], Alessandro Biglia[1], Paolo Marucco[1], Paolo Balsari[1], Fabrizio Gioelli[1], Paolo Gay[1]

[1]Department of Agricultural, Forest and Food Sciences (DiSAFA), University of Turin (UniTO), Largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy
Email address: marco.grella@unito.it

INTRODUCTION

Aerial spray applications are usually carried out broadcast using uncrewed aerial spray systems (UASSs) irrespective of the crop type. Biglia et al. (2022) demonstrated that UASS band applications, when used to only target the vines canopy, can increase the canopy deposit, and concurrently reduce off-target losses. The authors also showed that, even applying similar spray rate, canopy deposits were higher when using an airblast sprayer. In this context, different spray application rates deserve to be tested to support a credible UASS use for vineyards crop protection. This work presents the results of field tests where the effect of UASS spray application rates on vines canopy deposit and coverage was studied. The performances of an airblast sprayer were used as reference.

MATERIALS AND METHODS

Field tests were carried out at two growth stages (early and late) in a commercial trellised vineyard. The UASS used for spray applications was a DJI Matrice 600 Pro (DJI, China) equipped with a customised sprayer system and a RTK antenna. The UASS flight mode was set to automatically fly above the vines canopy the vine row (2.7 m AGL) and align the two active hollow-cone nozzles (Abbà s.n.c., Italy) with the vine rows (Biglia et al., 2022). The combination of both fly mode and nozzle narrow-spray pattern (30°) allowed to achieve a canopy-targeted band-application. To vary the spray application rate, only the nozzle size was changed while keeping constant the fly speed (1.5 m s^{-1}) and spray pressure (0.3 MPa). Therefore, at both growth stages, 53, 71, 107 and 133 L ha^{-1} of test solution (water and E-102 tartrazine) was applied with ISO 015, 02, 03 and 04 nozzle sizes, respectively. Finally, the airblast sprayer Dragone TAV was monitored during the farmer routinely pesticide spray application, and its performances were compared with those of UASS. The farmer applied 143 and 283 L ha^{-1} at early and late growth stage, respectively.

The UASS spray deposit and coverage were measured by applying the ISO22522:2007 methodology. At each sampling position, semi-disc filters and water sensitive papers (WSPs) were affixed to the leaves to collect the spray. Technical replicates were carried out and tests were repeated three times. The airblast sprayer applications were monitored following the same procedure as for the UASS, but just using WSPs. As detailed in Biglia et al. (2022), to determine coverage (% of covered surface) and canopy spray deposit (µL cm^{-2}), image and spectrophotometric analysis were applied to WSPs samplers and to the filters, respectively. Two-way ANOVA and Tukey post-hoc test for multiple comparison were performed to evaluate significant differences among growth stages, spray application rates and significant interactions among factors ($p < 0.05$).

RESULTS AND DISCUSSION

The canopy deposit (µL cm^{-2}) did not statistical differ between early and late growth stages [$F(1, 7) = 0.157$, $p = 0.692$] while significantly increased by increasing the applied spray rates [$F(3, 7) = 9.350$, $p = 4.304E-6$] (Fig. 1). No significant interactions among the tested factors were observed. Increasing the spray application rates by 151% (from 53 to 133 L ha^{-1} using the 015 and 04 nozzle sizes, respectively), the deposit increased proportionally up to 161%. On the contrary, the standardized amount of applied tartrazine in (g cm^{-2}) did not statistical differ between the spray application rates [$F(1, 3) = 0.594$, $p = 0.619$] (Fig. 1). Also, no significant effect of growth stage and interaction between factors were observed. These results underline that when using the UASS, the strategy to concentrate the spray mixture to compensate for the poor spray rates (e.g. small pump/s) and spray autonomy (e.g. limited payload) allows to comply with the mandatory pesticide label dosage without affecting the amount of active ingredient deposited on the target, irrespective of spray application rates.

Concerning target spray coverage, results were consistent with those for the canopy deposit, where linear increase was detected from 015 (2.5%) to 04 (4.7%) nozzle sizes showing an increment of 86%. Nevertheless, also in the best case (nozzle 04 size) the average spray coverage measured operating the UASS was lower than 5%, resulting too low to potentially guarantee the biological efficacy. Indeed, the best UASS spray coverage was 82% lower than those obtained using the airblast sprayer (4.6 *vs* 26.4%).

REFERENCES

Biglia, A., Grella, M., Bloise, N., Comba, L., Mozzanini, E., Sopegno, A., Pittarello, M., Dicembrini, E., Eloi Alcatrão, L., Guglieri, G., Balsari, P., Ricauda Aimonino, D. and Gay, P. (2022). UAV-spray application in vineyards: Flight modes and spray system adjustment effects on canopy deposit, coverage, and off-target losses. Science of the Total Environment, 845, 157292. DOI: 10.1016/j.scitotenv.2022.157292

Figures

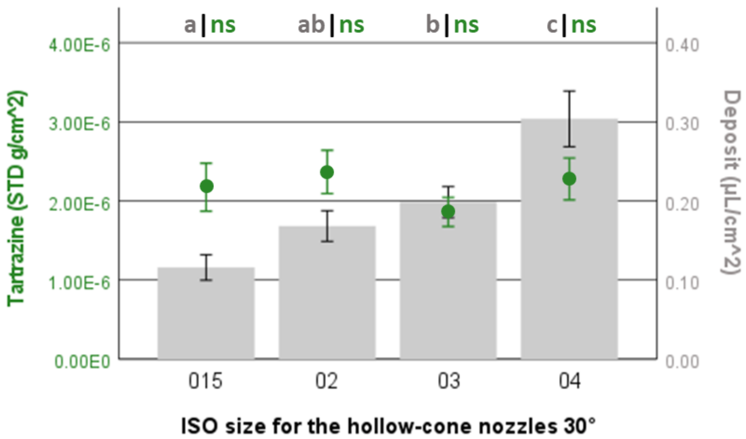


Fig. 1. Dual axis graph representing with green dots the standardized values (100 L ha^{-1} spray application rate) for the Tartrazine E102 amount (g cm^{-2}) and with the grey bars the deposit (µL cm^{-2}) achieved applying different spray application rates according to the nozzle sizes. Different letters denoted significant differences as well as “ns” denoted any differences between nozzle sizes ($p < 0.05$).

Acknowledgements

The research activities were carried out within the founded NODES project “PNRR – M4C2, Avviso: 3277 del 30.12.2021, Progetto NODES 0000036”.

3.2 Hydraulic-based fixed spray delivery system: preliminary result of apple scab management in Italy

Daniel Bondesan[1], Marco Grella[2], Claudio Rizzi[1], Eric Mozzanini[2], Paolo Balsari[2], Gino Angeli[1], Claudio Ioriatti[1]

[1] *Fondazione Edmund Mach, Via Edmund Mach 1, 38010 San Michele all'Adige (TN), Italy*
[2] *Department of Agricultural, Forest and Food Sciences (DiSAFA), University of Turin (UNITO), Largo Paolo Braccini, 2, 10095 Grugliasco (TO), Italy*
E-mail address:daniel.bondesan@fmach.it

INTRODUCTION

Due to steep slopes and fragmented plots in hilly and mountainous areas, the spray application for crop protection is challenging. Currently, valuable alternatives to the conventional pesticide application equipment, like ground-based airblast sprayers, are under evaluation both in apple orchards and vineyards. Amongst them, fixed spray delivery systems (FSDS) have shown potential to guaranteeing adequate spray deposition on the target and biological efficacy while reducing spray drift phenomena (Mozzanini et al., 2023, Ballion and Verpont, 2023). Based on this premises, two FSDS prototypes were tested in apple orchard to evaluate their performances for apple scab management.

MATERIALS AND METHODS

Two apple orchards (cv. 'Golden delicious'), featured by different canopy shape, size, and density according to the pedestrian and not-pedestrian training systems, were used for experimental purposes. Each orchard was divided in three plots to obtain an untreated control, a grower control applied using an axial fan sprayer (Steiner A300) with ATR nozzles operated at 12 bar, and a treated plot applied by using FSDS. According to the training system, FSDS were equipped with specific emitters, namely VibroNet and StripNet models (Netafim Ltd. company) for the pedestrian and not-pedestrian, respectively. In all the treated plots the same spray program (from May 10th to September 10th) and pesticides dosage (indicated by labels) were used. Biological efficacy evaluation was carried out on June 21st (after fruit thinning treatment) and on September 27th (before harvest) according to the EPPO standards guidelines. During the season, spray deposition in every treated parcel was also evaluated using the sampling strategy standardized by the ISO22522:2007 and applying dye tracer (Tartrazine E102) as spray mixture. One-way ANOVA and Tukey post-hoc test for multiple comparison were performed to evaluate significant differences among the treatments ($p < 0.05$).

RESULTS AND DISCUSSION

The spray deposit resulted lower for the FSDS compared to the grower control one, -77% (4.37 vs. 1.00 µL cm^{-2}) and -37% (2.29 vs. 1.49 µL cm^{-2}) for the VibroNet and StripNet, respectively. Even if the deposition for the FSDS was much lower, the results in Figure 1 underline the FSDS capability to guarantee the biological efficacy of treatments against apple scab anyway. Indeed, the biological efficacy obtained by using FSDS did not differ from that obtained by using conventional airblast sprayers for the two FSDS tested. Also, the biological efficacy was maintained for all plant parts considered. The comprehensive results interpretation suggested that FSDS-emitter type plays a key role while spraying a specific training system and further studies are needed to further investigate better solutions (emitter type and their layouts) to increase the canopy deposit thus potentially further improve the FSDS spray application efficiency. These outcomes provide the basis to identify the more suitable combination between emitter and apple orchard training system to promote apple scab and other diseases management with a FSDS.

Noteworthy, additional trials demonstrated that FSDS is suitable not only for crop protection purposes but also for chemical fruit thinning, a crucial orchard management operation. The comparison of FSDS with an airblast sprayer (grower control) highlighted that VibroNet and StripNet emitters performed +26% and -34% of fruit thinning, respectively. However, while compared to the untreated control, all the FSDS showed a 39% of fruit reduction (177 *vs.* 108 fruits per plant) as well as the airblast sprayer showed a fruit reduction of 56% (177 *vs.* 78 fruits per plant).

REFERENCES

Ballion, S. and Verpont, F. (2023). Fixed spraying system PulVéFix: a future way to apply plant protection products in apple orchards? XXXI International Horticultural Congress (IHC2022): International Symposium on Innovative Perennial Crops Management. Acta Hort. 1366 (11).

Mozzanini, E., Grella, M., Marucco, P., Balsari, P., Gioelli, F. (2023). Characterization of irrigator emitter to be used as solid set canopy delivery system: which is best for which role in the vineyard? Pest. Manag. Sci. 79 (2), 584-597. https://doi.org/10.1002/ps.7228

Figures

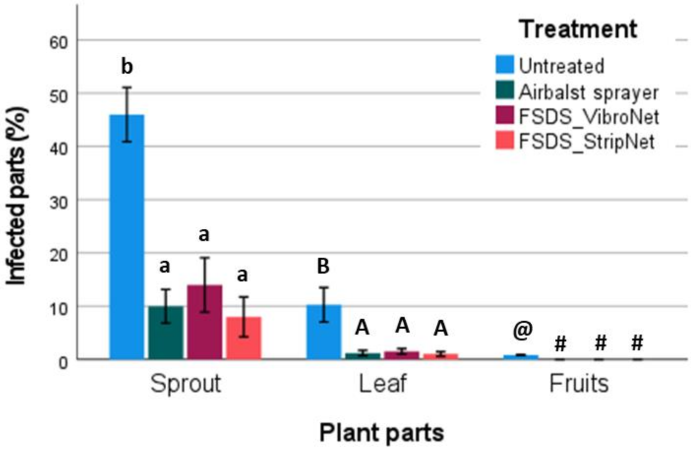


Fig. 2. Average values of infected parts (%) are shown for the different plant parts and split for the treatments. Different lowercase, capital letters and symbols indicate significant differences among treatments within each plant part ($p < 0.05$).

Acknowledgements

The authors would like to thank Mr. S. Ballerini and Mr. A. Puggioni for their support. This research was partially funded by Netafim Ltd. company (Tel Aviv, Israel).

3.3 Determination of drift and exposure of bystanders and residents during treatment with an UAV in an apple orchard

Pierre-Henri Dubuis[1], Michel Droz[1], Aurélie Melgar[1], Ursina A. Zürcher[2], Jürg A. Zarn[2], Katia Gindro[1], Sebastian L.B. König[2]

[1]Agroscope, Swiss Federal Agricultural Research Station in Changins, 1260 Nyon, Switzerland
[2] Federal Food Safety and Veterinary Office (FSVO), Risk Assessment Division, 3003 Bern, Switzerland
Email address: pierre-henri.dubuis@agroscope.admin.ch

INTRODUCTION

In Switzerland, the use of unmanned aerial vehicle (UAV) to spray plant protection product is allowed since 2019 (Anken and Waldburger, 2020) and unmanned aerial spraying systems (UASS) are mainly used in steep vineyard as alternative to helicopter or backpack sprayer. Although new to Europe, UASS are widely used in Asia. A report published in 2021 by the Organization for Economic Cooperation and Development, emphasises that spray drift and exposure of residents and bystanders caused by spraying drones have been little studied. This lack of data results in regulatory concerns with respect to the environment and human safety. The objective of this study was to quantify environmental, resident and bystander exposure following the application of a plant protection product to an apple orchard using a commercial UASS under field conditions.

MATERIALS AND METHODS

Field trials were conducted with a DJI agras T30 UASS in April and October 2022 on a commercial apple orchard in Switzerland. The fluorescent tracer Helios 500 SC (Syngenta Crop Protection, Basel) was used to quantify the drift and exposure. Ground deposits (drift data) were collected using Petri dishes at different downwind distances up to 50 m. Aerial drift was collected up to 6 m using polypropylene strings. Direct exposure to spray drift of residents and bystanders was quantified using twenty display mannequins (adults and children) dressed with coveralls and located at three downwind distances of the sprayed area. For inhalation exposure determination fifteen mannequins were equipped with personal air sampling pumps. The data analysis methods are described in details in Dubuis et al (2023)

RESULTS AND DISCUSSION

Ground sedimentation drift decrease rapidly as distance from the treated area increases. At a given distance, UASS drift is lower than that of a reference ground sprayer. The aerial drift is highest close to the ground and decreases with height. This profile is different from the one of an airblast sprayer. The dermal exposure decrease with distance and the exposition of the legs is higher than the one of the arms, torso and face. In most of the case, exposure from UASS is lower than the one of an airblast sprayer. To sum up, drift and exposure decrease with height and/or distance from the treated area. Existing European and American risk assessment models for ground and aerial applications cover the results of field trials with UASS presented here.

REFERENCES

Anken, T. and Waldburger C. (2020). Working quality, drift potential and homologation of praying drones in Switzerland. In, edited by Umwelt und Tier, M. Gandorfer et al. Digitalisierung für Mensch, Lecture Notes in Informatics (LNI), Gesellschaft für Informatik, Bonn 2020, 25-30

Dubuis, P.-H., Droz, M., Melgar, A., Zürcher U. A., Zarn J. A., Gindro, K. and König S. L. B. (2023). Environmental, bystander and resident exposure from orchard applications using an agricultural *unmanned aerial spraying system. Science of the Total Environment 881* [*http://dx.doi.org/10.1016/j.scitotenv.2023.163371*](http://dx.doi.org/10.1016/j.scitotenv.2023.163371)

OECD (2021). Report on the State of the Knowledge – Literature Review on Unmanned Aerial Spray Systems in Agriculture.

Figures

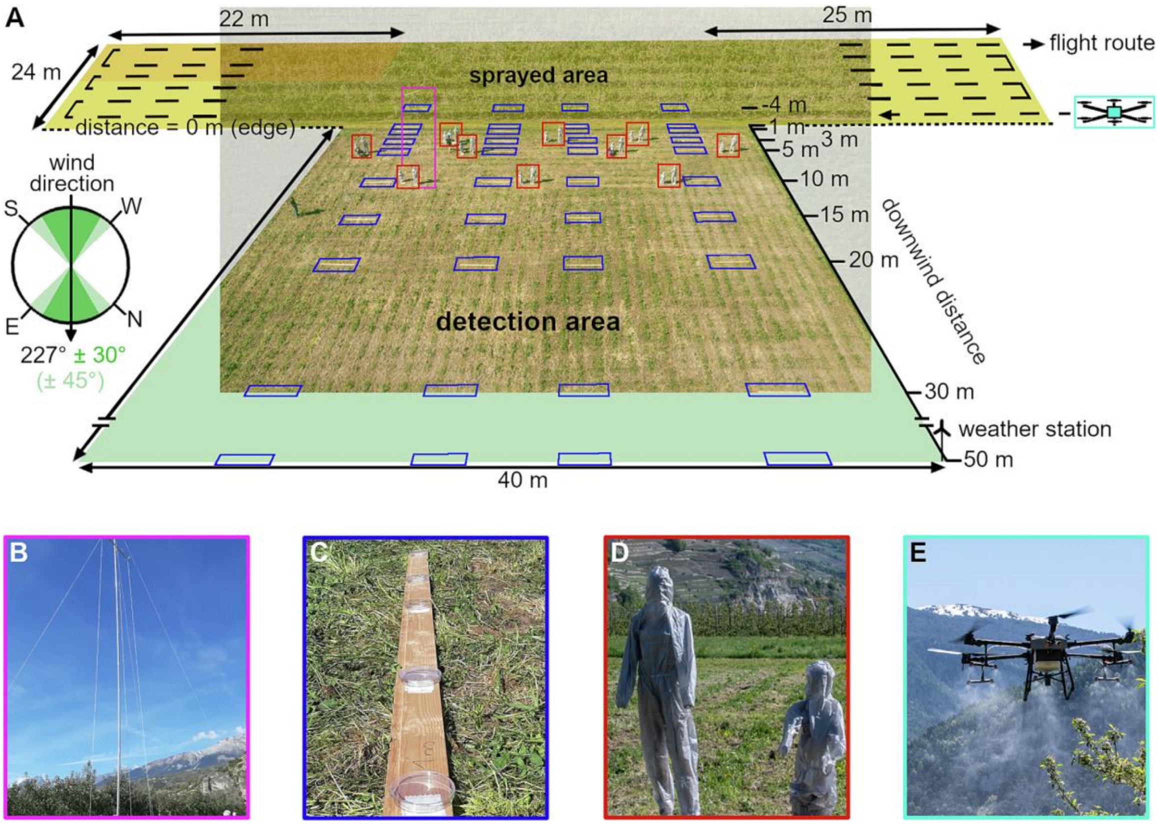


Fig.1. Trial layout. A. Schematic view of the experimental design. B. Drift sampling tower. C. Petri dishes used to collect ground deposit spray drift. D. Mannequins representing adult or child bystanders and residents directly exposed to spray drift via the dermal and the inhalative route. E. DJI Agras T30 used for spraying.

3.4 Field evaluation of spray quality of unmanned aerial spray systems in mango orchards

Pengchao Chen[1,2], Juan Wang[3], Yubin Lan[1,2]

[1]National Center for International Collaboration Research on Precision Agricultural Aviation Pesticides Spraying Technology, South China Agricultural University, Guangzhou, China
[2] College of Electronic Engineering and Artificial Intelligence, South China Agricultural University, Guangzhou, China
[3]College of Mechanical and Electrical Engineering, Hainan University, Haikou, China
Email address: pengchao.chen@scau.edu.cn

INTRODUCTION

Unmanned aerial spraying system (UASS) has been validated as a spraying tool for plant protection products (Chen P. et al., 2022; Chen H et al., 2021). Field observations show that the rotor downwash wind field easily forms vortices in the canopy of flexible crops such as rice but this effect is less obvious in the case of high-density and non-flexible crops such as cotton and fruit trees. The fruit trees in some areas are dense or too tall, such as bananas and betel nuts; some fruit trees are planted in mountainous and hilly areas, and it is difficult for ground machinery to function in the above scenarios. (Chen P et al., 2022). UASS is still the spraying choice machine for mountain or 3D fruit trees. Therefore, it is necessary to explore the application technology of UASS in 3D fruit trees.

Mango is a widely grown tropical fruit. After refined planting, grafting, and pruning, the tree's height is kept between two and three meters. In this study, mango trees widely planted in tropical areas of China were selected as the research object, and three mango tree varieties with different phenotypic structures were selected for the study. Using a T40 UASS equipped with a centrifugal spraying system as a spraying tool, the study evaluated the spray quality of UASS in differentiated canopy structures.

MATERIALS AND METHODS

The experiment was carried out in the Danzhou (109.505284 E, 19.516913 N), Hainan Province, China. Three mango varieties were selected in the test base as the test objects. The varieties of fruit trees were Pan No.1 (No. 410), Pan No.5 (No. 412), and Sugar (No. 418), with specific heights and crown diameters and the age of the trees was 7.5 years. Use Phantom 4 RTK (Shenzhen DJI Sciences and Technologies Ltd.) to obtain 3D point cloud information of the fruit tree canopy. Deposits on Water Sensitive Papers were samples at three different canopy levels (bottom, middle and top) and were analyzed in terms of percentage of coverage and deposit number per cm².

The T40 agricultural unmanned aerial vehicle (Shenzhen DJI Sciences and Technologies Ltd, Shenzhen, China) was used as the test model for this experiment. Compared with previous models, this model adopts a coaxial dual-rotor structure, that is, a total of 8 rotors are installed above and below 4 inclined arms. The spray system includes 2 impeller pumps, 2 centrifugal atomizing nozzles and anti-drip centrifugal valves, etc. The particle size range of the centrifugal atomizing nozzle is 50-300 μm, and the maximum flow rate of the impeller pump is 6 L/min. In this study, the flying speed was 3m/s, the height was 5m (from the ground), and the spraying flow rate was 65.7-68.1 L/ha.

RESULTS AND DISCUSSION

Results showed significant differences in the distribution of plant protection UAVs among mango tree canopies. However, this difference changes with the size of the canopy structure of the fruit trees. We analyze the differences in the results based on the observations at the test site, which may be affected by the tree structure of the canopy. As illustred in Figure 1, the coverage on smaller trees (418 plant canopy) showed lower gradient than in the case of taller trees in this study is better than that at the middle and upper layers.

The research results of spray quality show that there are still some limitations in applying UASS, a new type of spraying equipment, in spraying densely planted fruit trees such as mango trees. First, there are differences in the vertical plane of the canopy space. Without considering the influence of operating parameters, the spraying liquid volume we set at 65.7-68.1L/ha can achieve full coverage of spraying on small fruit trees.

REFERENCES

Chen, P., Douzals, J. P., Lan, Y., Cotteux, E., Delpuech, X., Pouxviel, G., & Zhan, Y. (2022). Characteristics of unmanned aerial spraying systems and related spray drift: A review. Frontiers in plant science, 13, 870956.

Chen, H., Lan, Y., Fritz, B. K., Hoffmann, W. C., & Liu, S. (2021). Review of agricultural spraying technologies for plant protection using unmanned aerial vehicle (UAV). International Journal of Agricultural and Biological Engineering, 14(1), 38-49.

Li, J., Shi, Y., Lan, Y., & Guo, S. (2019). Vertical distribution and vortex structure of rotor wind field under the influence of rice canopy. Computers and Electronics in Agriculture, 159, 140-146.

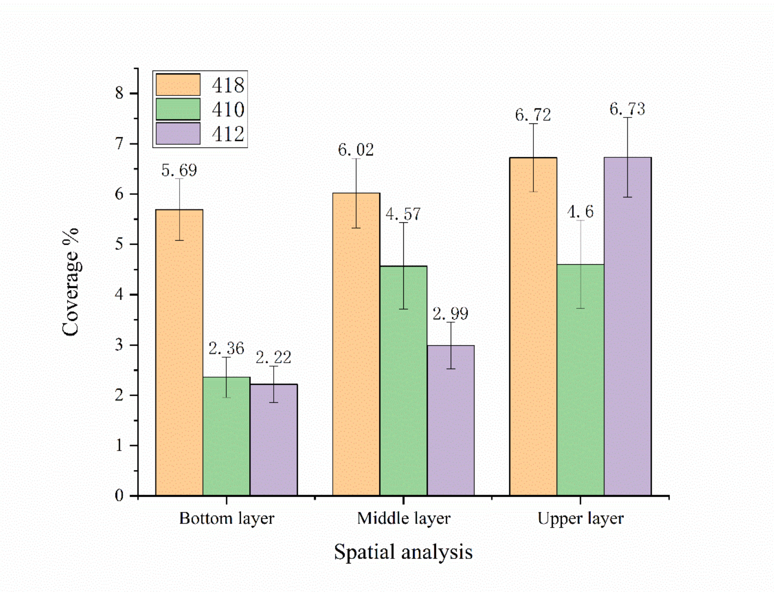


Fig. 1 Spatial distribution of droplet coverage in mango tree canopy

3.5 Evaluation of UASS for plant protection application on crops grown on steep slopes in France

Jean-Paul Douzals[1], Xavier Delpuech[2], Guilhem Pouxviel[1]

[1] *INRAE UMR ITAP, Université de Montpellier, France*
[2] *Institut français de la Vigne et du Vin, Montpellier, France*

Email : jean-paul.douzals@inrae.fr

INTRODUCTION

The application of plant protection products with aerial means is banned in the European Union unless national derogation is requested. Unmanned Aerial Spraying Systems (UASS) represent a highly potential interest in certain conditions, such as steep slope situations, to reduce accidents and operator exposure. In 2020, the French government asked for a 2 years derogation of the ban of aerial spraying in order for research and technical institutes to conduct field tests in vineyards, apple orchards and banana plantations that are mostly represented in steep slopes.

MATERIALS AND METHODS

Altogether, 64 individual tests were conducted in different locations in the main land and overseas, in order to characterize UASS performance in terms of canopy deposition, biological efficacy and/or spray drift. Deposition on crop, spray drift and resident exposure were determined either in steep slope fields or on the flat testing facility of IFV INRAE in Montpellier (Table 1).

Table 1. List of experiments with UASS.

Crop/Vol rate terrain	***Operator/Institute***	***Drone***	***Deposition***	***Biological efficacy***	***Spray drift***	***Operator exposure***
Vine/140 L /ha Slope	CYMDRONE	DJI Agras MG 1P	1/Dye			
Vine/140 L/ha Slope	Ch Agr. Ardeche	DJI Agras MG 1P		12/fungicides		
Vine/140 L/ha Slope	Ch Agr. Alsace	Aero41 AGv2		2/fungicides		
Vine/140 L/ha Slope	ANADIAG	Aero41 AGv2				1 /cyflufenamid
Artificial Vine 70 L/Ha/ Flat	IFV-INRAE	DJI T16	13/dye tracer/flat			
Vine 70 L/ha/Flat	IFV – INRAE	DJI T16 DJI Agras MG 1P Aero41 AGv2	25/dye tracer/slope		18/dye/3 nozzles/3 heights/2 travels	3/dye tracer/flat
Apple 150 L/ha/Flat	CTIFL	ACT6	4/dye tracer		2/dye tracer/2 nozzles	2/dye tracer/2 nozzles
Banana 20 L/ha Slope	IT2 – INRAE	DJI Agras MG 1P	1/dye tracer		3/dye tracer/3 nozzles/residents	2/dye tracer
Total		**4**	**44**	**14**	**23**	**8**

RESULTS AND DISCUSSION

Influence of operating parameters on crop deposition

Several operating parameters (droplet size, flying height, flying route strategy) were tested on the flat experimental platform of INRAE in Montpellier. Different crop compartments were defined and analysed (Figure 1). A vertical gradient was observed but the global deposition was mostly dependent on the type of nozzle and the flight height.

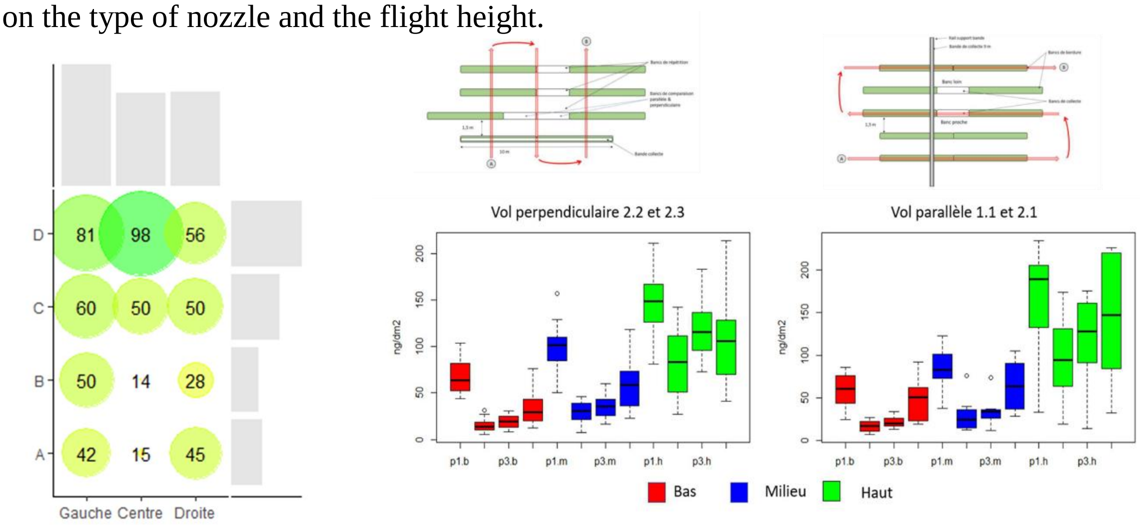


Fig. 1. deposition profile on the artificial vineyard (left) and effect of the UASS trajectory.

Spray drift

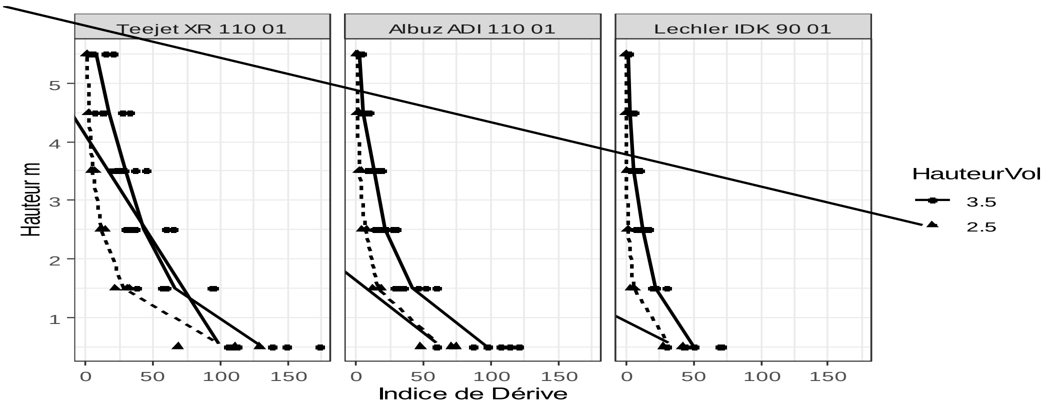


Fig. 2. Airborne spray drift profile of UASS equipped with Teejet XR 110 01, Albuz ADI 110 01 or Lechler IDK 90 01 and flight height (2.5 or 3.5m).

Experiments using the artificial wind generator (Figure 2) showed the combined effect of the droplet size and the flight height on the potential spray drift. Experiments conducted in banana crop in steep slope situation highlighted technical limitations of UASS due to the control of obstacles, the terrain following option. As a result, spray drift from UASS was higher than for a manual application with a knapsack sprayer. The return of experience on the necessarily adaptation of existing experimental methodologies to UASS, as well as steep slopes, will be discussed through the relevance of the different protocols and the identification of specific issues. A critical analysis of all the results was also achieved by the French Agency for Food and Environment Safety in (ANSES, 2022) order to identify missing data or information and other weak points to be satisfied priory to the formal authorization of UASS in France.

3.6 Assessment of Unmanned Aerial Sprayer Systems (UASS) for drift and spray quality

Santiago Planas de Martí[1], Ramón Piñeiro Rodríguez[2], Manuel Pérez Ruiz[3], Luis Asín Jones[4], Elena Alonso-Prados[5]

[1]Agrotecnio CERCA Center – University of Lleida – Lleida; [2]Colegio Oficial de Ingeneros Agrónomos de Centro y Canarias – Madrid:; [3]Universidad de Sevilla – Sevilla; [4]FRUITCENTRE - IRTA – Lleida; [5]INIA-CSIC - Madrid
Email address: santiago.planas@udl.cat

INTRODUCTION

UASS, also designated by drone for crop protection, have potential advantages associated with their capacity to spray non-operable areas to ground equipment or restricted spaces as the buffer zones established for conventional aerial treatments. Drones could also be valuable in treatments of isolated small plots (field crops or orchards) and to control pests in fruit orchards by specific techniques such as mating disruption or insecticide bait. Another remarkable field is precision crop protection in patch-selective treatments linked to detection and risk and prescription maps.

According to that, it is remarkable that the European rules are being adapted to this new scenario through the project of Regulation on the Sustainable Use of Plant Protection Products (EC, 2022), where the UASS are first considered (art. 20 and 21).

This paper reports part of the Spanish Project PHYTODRON www.gophytodron.es in which several marketed UASS have been assessed for horizontal transverse spray deposition, drift, losses to the soil, operator and residents exposure, spray quality, residues on fruits and efficacy to control fruit flies in citrus and olives using bait insecticide.

MATERIALS AND METHODS

The experiments were carried out in 2022 in Andalucia (olive), Castilla-León (olive and vine) and Catalunya (olive and vine). They include six drift trials (ISO 22866:2005) (Figure 1) and five evaluations of ground losses and on-target deposition (ISO 22522:2007). In all situations, tartrazine has been used as a tracer. Samples have been taken from artificial collectors or leaves and analysed by spectrophotometric technique. All trials include the comparison of UASS performance against the ground sprayers commonly used in the orchards where the tests have been carried out (air assisted with vertical booms in grapes or atomizer axial fan in grapes and olive trees).

RESULTS AND DISCUSSION

Aerial drift. Except for medium/high cross-wind conditions, the drone drift is slightly more minor than the drift produced by the ground equipment.
Sedimenting drift. The drone seems very sensitive to the crosswind and increases substantially the drift regarding the reference ground sprayer. Moreover, in low wind conditions, the drift is similar for both aerial and terrestrial equipment.
On-target depositions. The total spray recovered tends to be lower for drone applications, mainly in the early stages in vineyards and the variability is greater for drones than ground sprayers. Drones have always more difficulty penetrating canopies horizontally in vine full-stage and olive trees and, as expected, have a pronounced trend to focus the depositions on the upper canopy level.

Losses to the soil. The results are irregular and dependent on the canopy architecture, the height and trajectory of the flight and the orientation of the nozzles.

Drone treatments on 3D crops are feasible when appropriate weather conditions, particularly wind (still). However, they have important limitations in general treatments of adult full-stage trees. Therefore, it is worth considering the drone for especially treatments at initial stages and specific uses in which uniformity is not a requirement (semiochemicals, insecticide bait). In any case, additional experimental work is needed to define the limits and settings appropriate to each scenario.

Fig. 1. Aerial and sedimenting drift test in a vineyard in wintertime.

REFERENCES

ISO 22866:2005. Methods for field measurement of spray drift.

ISO 22522:2007. Field measurement of spray distribution in tree and bush crops.

PHYTODRON project has involved several Spanish research institutes, organizations and chemical industries. The project has been financed by the European Agricultural Fund for Rural Development and the Spanish Ministry of Agriculture.

3.7 Cleaning performance of a pneumatic-based SSCDS designed for crop protection in modern orchard systems

Eric Mozzanini[1], Gwen-Alyn Hoheisel[2], Marco Grella[1], Dattatray G. Bhalekar[2], Paolo Balsari[1], Fabrizio Gioelli[1], Lav R. Khot[2]

[1] *Department of Agricultural, Forest and Food Sciences (DiSAFA), University of Turin (UNITO), Largo Paolo Braccini, 2, 10095 Grugliasco (TO), Italy*
[2]*Center for Precision and Automated Agricultural Systems, Washington State University, Prosser, WA 99350, USA*
E-mail address: eric.mozzanini@unito.it

INTRODUCTION

Fixed spray delivery system (FSDS) offers several potential advantages over the conventional pesticide application equipment (PAE) in modern orchard and vineyard production systems. A FSDS consists of three main components: (i) a spray delivery system – an emitter network placed in the crop canopy where emitters are permanently plumbed to reservoirs and a main pipeline installed along the crop row, (ii) a pumping station – tank and a pump, to fill the system with spray mixture, and (iii) a cleaning system – a device that is used to deliver the spray mixture and to clean the spray delivery system. A pneumatic spray delivery (PSD)-based solid set canopy delivery system (SSCDS), a FSDS variant, has been optimized in the United States (Sinha et al., 2020) for spray applications. In the PSD-based SSCDS, an air compressor is used to push fluid through the spray lines for both the liquid delivery (through the emitters) and cleaning of all the components in the spray delivery system. The increasing interest in PSD-based SSCDS highlights the need to evaluate the system compliance to the actual ISO mandatory regulation. Also considering the Sustainable Use of Pesticides Directive (SUD) requirements, it is critical to ensure the humane and environmental safety of such PAE. Therefore, this study evaluated PSD-based SSCDS, first in laboratory and then in field condition, towards its cleaning performances following the ISO 22368-1:(2004) standard methodology.

MATERIALS AND METHODS

A small-scale PSD-SSCDS was assembled in a laboratory using two pumping stations, an air compressor, and a spray delivery system of 5 m length. One pumping station was used to fill the PSD-SSCDS with a mixture of water and fluorescent tracer (Pyranine 10G, Keystone Inc., IL, USA) at 500 ppm (hereafter called mixture). The second pumping station was used to fill the PSD-SSCDS with water. Two (235 and 700 ml) volumetric capacities of reservoirs were evaluated with two emitters (number 2 and 12, Jain Irrigation Inc., Fresno, CA, USA). The following cleaning trials were evaluated: air injection for 30 s (standard timing) to check the actual cleaning performance, air injection for 300 s (extended timing) to check if timing and cleaning performance are proportional, and one rinse using water after 30 s air injection (rinse stage), to check if water will improve the cleaning performance. A stepwise procedure was used for the residue sample collection. Those steps include: (i) blank collection: filling and spraying with water; (ii) mixture collection: filling and spraying with mixture; (iii) residue sample collection: filling and spraying with water. For the trial that included a rinse stage, it was performed between steps (ii) and (iii). All liquid delivered was collected and tracer concentration was quantified using a fluorometer (Model: 10AU, Turner design, San Jose, CA, USA).

After laboratory trials and evaluation of the most effective cleaning techniques, the same step-wise procedure was used to evaluate the cleaning performance of a PSD-based SSCDS layout in a vineyard. Trials were performed with 1% suspension of copper oxychloride as spray mixture and copper concentration per each sample was quantified through atomic-absorption-spectrometry. Both laboratory and field datasets were used to calculate the spray mixture concentration reduction (%). For the first experiment, a three-way ANOVA model was run with the volumetric capacity of reservoir, emitter number installed, and the cleaning technique as fixed factors. Tukey post-hoc test for multiple comparison was performed to evaluate significant interaction among the factors ($p < 0.05$).

RESULTS AND DISCUSSION

ANOVA results showed that only the cleaning technique [$F_{(2, 276)}$ = 162.129, p < 0.001] and volume of reservoir [$F_{(1, 276)}$ = 4.537, p = 0.034] as a fixed factors significantly affect the tracer residue levels (mg l^{-1}). No significant interactions among the tested factors were observed. Laboratory trials suggested that the rinse stage duly cleaned the spray delivery system (Fig. 1). With respect to the mixture in the tank, this cleaning technique achieved a tracer concentration reduction > 99.67 %. The use of air (standard or extended) was able to achieve residue reduction up to 94.78 %. Field trial data is being analysed and it can potentially demonstrate that PSD-based SSCDS be cleaned effectively using one of the three cleaning techniques to realize ISO standard compliance system. The results will also help in further development and commercialization of the PSD-SSCDS.

REFERENCES

ISO 22368-1:(2004), n.d. ISO 22368-1:(2004). Crop protection equipment — Test methods for the evaluation of cleaning systems — Part 1: Internal cleaning of complete sprayers. ISO (International Organization for Standardization).

Sinha, R., Ranjan, R., Khot, L., Hoheisel, G., Grieshop, M., 2020. Comparison of within canopy deposition for a solid set canopy delivery system (SSCDS) and an axial–fan airblast sprayer in a vineyard. Crop Protection 132, 105124. https://doi.org/10.1016/j.cropro.2020.105124

Figures

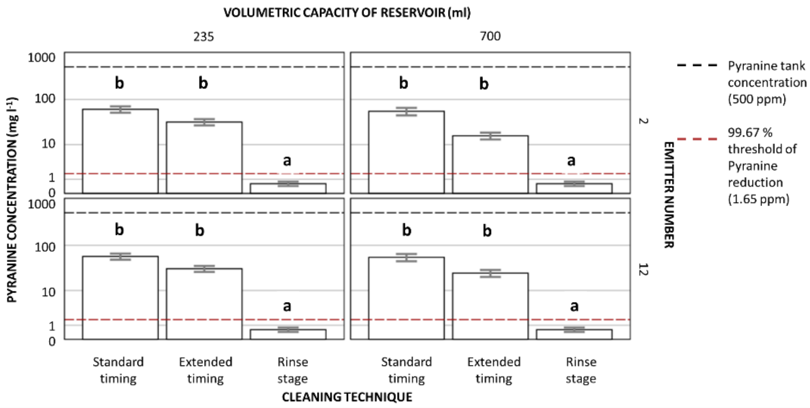


Fig. 1. Tracer concentration (in logarithmic scale) as a residue per treatment during laboratory trial. For optimal cleaning, ISO 16119-4:(2014) requires a 99.67% residue reduction (red dash) from the original concentration (black dash). Different letters denote significant differences among cleaning techniques within each reservoir capacity and emitter number (p < 0.05).

3.8 Thanks to air support: Spray effectively and efficiently from 0.5 up to 13m and saving up to 40% liquid

Tobias Hüni[1]

[1]Birchmeier Sprühtechnik AG
Email address: tobias.hueni@birchmeier.com

INTRODUCTION

In the past, we produced mist blowers for plant protection. Because of several disadvantages (Figure 1) with that unit, we stopped the production and developed a new spraying technology. The AS 1200 rechargeable spray blower: spraying in an air stream with pressure-controlled fluid supply (in combination with e.g. battery operated backpack sprayer REC 15). The patented AS 1200 (battery operated backpack sprayer with a wind machine) is now used worldwide by professional users in green industry, pest control, disinfection, construction etc. The system (AS 1200 and e.g. REC 15) weights less than 10 kg (empty).

MATERIALS AND METHODS

The stream of air generated by the blower is elongated and flows in a straight direction, so that the droplets are blown in the intended direction when they are released (Figure 2). This means that more of the solution lands on the plant itself compared to previous techniques. Spraying takes place in a defined manner: the pressure of the solution, the nozzle for spraying (various nozzles for each application) and the airflow speed are optimally matched (Figure 3). This results in even distribution and foliage penetration or surface wetting (Figure 2).

The controlled airflow significantly reduces drift – a big plus especially when treating hedges, surfaces, fruit trees, vines and shrubs that often border other residential areas or farmland.

Less loss of solution not only means lower costs – it also helps to protect the environment as fewer chemicals are used. The rechargeable sprayers and blowers are also suitable for applying biological agents (including nematodes or microorganisms).

The AS 1200 spraying system can be used for a variety of applications and achieves optimum results whether users need to spray a specific area with pin-point accuracy or treat flat areas dense foliage or hedges. The users questioned stressed the good penetration and wetting of the upper and lower sides of leaves. The adjustable spray pressure, the five levels for wind speed (plus turbo) and the choice of differently sized nozzles or special nozzles for mosquito control or disinfection applications allow each user to adapt the device to their particular application. Maximum wind speed achievable with AS 1200 is 65 m/s and up to 1200 m3/h air volume.

RESULTS AND DISCUSSION

Users are on the lookout for products which save time, allow them to treat more effectively, produce no annoying exhaust gases and create less noise. The majority of users also consider saving solution or more effective spraying as a very important advantage. Depending on the application, savings of up to 40% can be achieved. Such savings are possible because there is less wastage.

The users surveyed also mentioned that they save a great deal of time when working. Users reports time saving from 20% or even more depending on application with the AS 1200 than with conventional sprayers.

The modern rechargeable devices are environmentally friendly as they produce little noise (below 83 dB (A)) and no harmful exhaust gases.

The CAS rechargeable battery system is another environmentally friendly feature. CAS battery packs are now used in more than 300 devices from a range of manufacturers that are members of the

CAS alliance. This compatibility is not only sustainable – it also saves users money as the batteries can be used in a number of different devices.

REFERENCES

Several testimonials of users:
https://www.birchmeier.com/epaper/index.html?catalog=as_1200_testimonials_en&lang=en

Figures

Figure 1. Undefined spray pattern (loss of spray liquid)

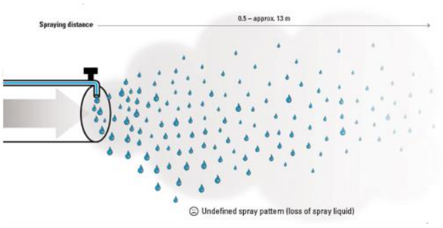


Figure 2. Defined spray pattern (no loss of spray liquid) and result on leaf with UV tracer

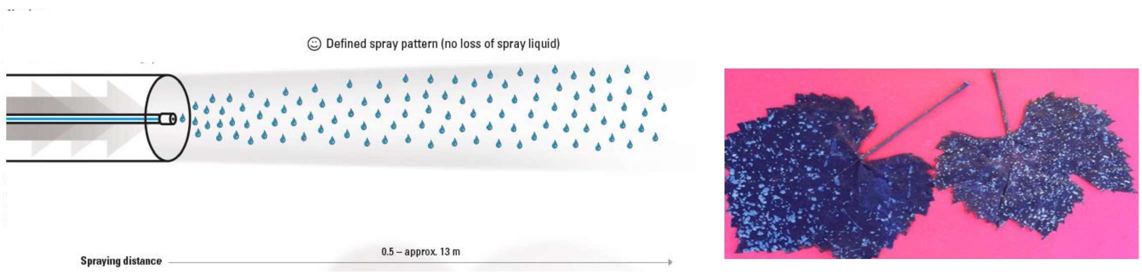
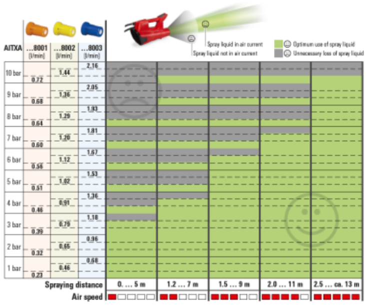


Figure 3. Control of parameters (e.g. anti drift hollow cone nozzle)



3.9 Target adapted dosing and spray application in 3D Crops in relation with the official German system

Peter Triloff

Marktgemeinschaft Bodenseeobst eG (MABO), Friedrichshafen, Germany
Email: peter.triloff@lindavino.de

INTRODUCTION

In the past four decades, considerable efforts have been made worldwide to minimize the side effects of pesticide application in 3D crops by reducing spray drift. Far ahead of any other approach this has been achieved by big droplets in order to let those that did not deposit at the target, settle on the orchard floor instead of drifting outside the treated area by the air flow of the fan and natural wind. Based on long term experiences from various fruit growing regions, other important means for reducing spray drift in 3D crops are less widespread.

Far less frequently cross flow fan types with a high potential to reduce spray drift already by construction are used in practice. Unfortunately, the vast majority of those have high angles and hence a high upward range of the air flow, typical for fan types with a radial air discharge, which diminishes their potentials for improved spray deposition and drift reduction as the angle of the airflow increases.

Regardless of the fan type, in the vast majority of spray applications in practice, fan speed is still set to the nominal PTO speed or excessive values relative to the target width. This results in avoidable spray drift and missed opportunities for improved deposition by adapting the airflow to the target width.

Additionally, low and mostly fixed forward speeds - in Germany officially still limited to max. 6 km h^{-1} - without adaptation to canopy width, further reduce spray deposition and generate avoidable spray drift due to excessive reach of the air flow.

Further on dosing rules significantly impact pesticide use with the Leaf Wall Area model being the only one that unnecessarily increases pesticide dose rates as row distance decreases, especially in slim targets of high density plantings. Interestingly, these high-density plantings have historically shown no dose-related attacks from pests and diseases.

Beyond spray drift reduction the potentials for technically minimizing pesticide consumption remained untapped. This begins with registration, where trials are mostly based on worst-case scenarios utilizing excessive water volumes, poor application technique, inadequate air distribution, excessive air flow and low forward speeds of 5 - 6 km h^{-1}, all of which demand higher dose rates to compensate avoidable losses.

Optimizing all these factors that reduce the amount of pesticide deposited at the target relative to the amount released by the nozzles and generate avoidable spray drift, should significantly increase pesticide deposition rate that reversely could be used to reduce pesticide dose rates in relation to canopy characteristics without compromising biological efficacy. This optimization also results in various secondary benefits as the reduction of spray drift, fuel consumption, noise emission, the risk for phytotoxicity and number of vat fillings per spray trip with the correlated risks for the operator and accidents on roads and avoids visible deposits. The method as a whole reduces costs for crop protection already without considering a reduced pesticide use (Triloff, 2011, 2019).

MATERIALS AND METHODS

Since fruit growers at Lake Constance used low water volumes, reduced dose rates, low fan speed and higher forward speed for about 30 years, the two main components have been optimized for a professional exploitation of these potentials. The **AirCheck®**-system (https://www.aircheck.eu/service/geeignete-spruehgeraete-persoenliche-daten/) for finding the best suited fan type for a farm specific set of orchards to which air and liquid vertical distributions are adjusted, provides the hardware for maximized spray deposition and low spray drift. For its canopy adapted operation, the **AirCheck**® Optimized Spraying (AOS43) dosing model (Triloff, 2019) as the software adapts water volume, dose rate, forward speed and fan speed to the target. For testing the biological efficacy of the complete system, a three-year trial on professional organic and integrated fruit farms at Lake Constance has been conducted.

On each of the max. 7 participating fruit farms one orchard with an apple variety sensitive to apple scab (*Venturia inaequalis*, Cke., Winter) has ben split into one untreated and two plots for the "AOS"-system and the "official" dosing and spray application. Trial plots have been sprayed with **AirCheck**®-certificated cross flow fan types, in the "AOS" plot with a mixed set of 2 x 2 flat fan air induction nozzles "Lechler IDK 90 01 C" at the two top most nozzle positions and "Albuz ATR purple" hollow cone nozzles at any other position, while in the "Official" plot a full set of "Lechler IDK 90 01 C" was used. In the AOS plot the "AOS43" model was used with the reference dose rate per hectare set to 2,0 meter canopy height, resulting in forward speeds of up to 12 km h^{-1} and fan speeds down to 300 PTO. In the "official" plot water volume and dose rate have been obtained by the German "ha^{-1} meter canopy height" rule at low forward speeds (from approx. 6 to 8 km h^{-1}) and high fan speeds (from approx. 480 to 540 PTO).

The trial period lasted over the entire ascospore release period. Both treated plots have received identical numbers of sprays with the second plot sprayed approx. 30 min after the first due to refilling. Sprays have been scheduled by the MABO crop protection advisory service operated by the author, based on simulations for apple scab (RIMpro) and leaf growth related residual activity of protectant fungicides. In the early secondary season, scab lesions have been counted for each leaf on 200/50 shoots per treated/untreated plot.

RESULTS AND DISCUSSION

From the totally 14 usable trial years, 80% of the AOS plots in both organic and integrated fruit farms showed a lower amount of lesions than the "official" plots despite a 53% average reduction of dose rates applied per ha and treatment. From the results can be concluded that all the measures listed above, combined to improve spray deposition and avoid the generation of spray drift despite the use of small droplets, compensate the reductions in dose rates and in trials resulted in a relative spray drift reduction rate of 84% and a potential of beyond 90% (Triloff, 2011). The AOS dosing and spray application system therefore is suitable to meet the EU goal of a reduction of pesticide use in fruit trees by approximately 50% until 2030.

The first obstacle however are pesticide registrations based on worst cases or counterproductive methods for dosing, spray application and drift reduction instead of demanding for the state of the art, resulting in excessive dose rates. The second is a huge lack of suitable equipment and training of operators in practice. Present spray application technique in registration for pesticides in 3D crops not only prevents the reduction of pesticide use in tree fruit to reach the EU goal, it also increases the risk of new molecules not being registered and registered ones being withdrawn, due to excessive side effects on non target organisms, operators and bystanders. This aggravates an already threatening destabilisation of crop protection in tree fruit due to a continuous but partly avoidable loss of molecules.

REFERENCES

Triloff, P. (2019). Canopy Adapted Dosing and Spray Application: Environment Protection in Crop Protection. Book of Abstracts of SuproFruit 2019 - the 15th Workshop on Spray Application and Precision Technology in Fruit Growing, East Malling, July 16 - 18, 2019, 45 – 46. (https://edepot.wur.nl/494871)

Triloff, P. (2011). Verlustreduzierter Pflanzenschutz im Baumobstbau - Abdriftminimie-rung und Effizienzsteigerung durch baumformabhängige Dosierung und Luftführung. Dissertation, Institut für Agrartechnik, Universität Hohenheim, Stuttgart, 2011, 351p.

2.7 Deposition of coarse droplets in dormant apple trees

J.M.P.G. Michielsen, D. de Hoog, A.T. Nieuwenhuizen, M. Wenneker

Wageningen University and Research (WUR) – P.O. Box 16 – 6700 AA Wageningen, The Netherlands.
Email address: jean-marie.michielsen@wur.nl

INTRODUCTION

It is proven that multiple-row sprayers reduce spray drift significantly (Wenneker et al., 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. More recently, spray drift experiments showed that spraying an apple orchard at the full leaf stage (BBCH 90/92) with a Lochmann two-row tunnel orchard sprayer fitted with 90% drift reducing nozzles (Albuz TVI8001; 7 bar spray pressure, DRN90) spray drift was clearly lower than of the reference sprayer. Spray drift reduction at 4.5-5.5 m distance from the last tree row was 99.4% in comparison with the reference spray application. Recently, this combination was classified as a spray Drift Reducing Technique (DRT) in the 99% drift reduction class in the Netherlands. It is assumed that spray depositions are improved when spraying with multiple row sprayers and dose can therefore be reduced accordingly, without reducing biological efficacy. When spraying the trees in dormant situation, the air assistance is lower. Fruit growers are concerned that these settings, i.e. low air and coarse droplets, will result in a less good coverage of spray deposits on the branches and developing foliage. The objective is to find the optimum combination of application parameters for different stages of canopy development to improving spray deposition.

MATERIALS AND METHODS

In the experiments a multiple-row orchard sprayer of the manufacturer Lochmann, was compared to a conventional cross-flow fan sprayer (Munckhof) by measuring the air velocity pattern and the deposition on branches in dormant tree situation. The spray deposition measurements were performed in an 'Elstar' apple orchard (Randwijk, The Netherlands). The reference sprayer was equipped with a hollow cone nozzle (Albuz TVI 8001), operated at 7 bar spray pressure and a forward speed of 6.7 km/h.

The air velocity is measured by a 3D ultrasonic anemometer in a 10-10 cm grid on 1.5 m distance from the centre of the sprayer. Spray deposition measurements and sampling procedure were carried out based on the ISO22522 standard adapted for the dormant tree situation. As picking of leaves in the dormant/early leaf stage of the tree is not possible and taking parts of the stem and the branches as samples would destroy the tree architecture, a sampling methodology was developed. To mimic the branches, hollow clay pipes (4 cm x 1 cm diam.) were positioned at 80 cm, 150 cm and 210 cm height from ground surface in a tree. Four clay pipes were fixed to a horizontal bar at both sides of the trunk in the row direction and per height. Spray deposition on the ground was measured from 3 rows upwind to 3 rows downwind putting collectors (Technofil TF290; 100 cm x 10 cm) underneath the trees and in between the tree rows on the grass strips.

RESULTS AND DISCUSSION

Air velocity patterns from a standard cross flow sprayer and from tunnel sprayer are presented in Figure 1. The standard sprayer pattern shows high air velocities of up to 20 m/s in the lower areas, designed to apply air assistance in full canopy situations. The tunnel sprayer shows air velocities of up to 10 m/s, and more evenly distributed along the height of the canopy. The measurements provided insights in how to adjust the air assistance of the sprayers. Adjustment of the air assistance is crucial in reaching accurate depositions on the branches and developing foliage.

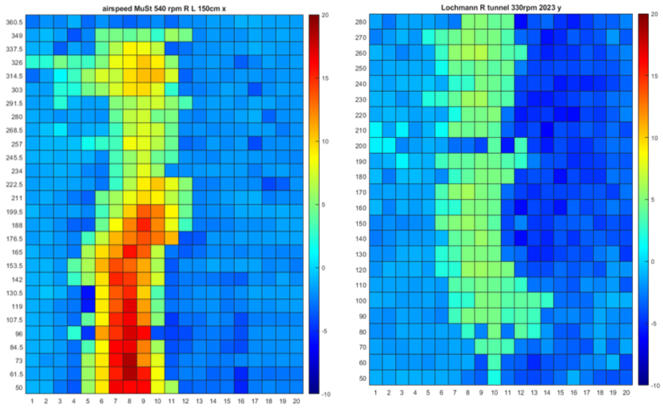


Fig. 1. Airspeed pattern for the standard Munckhof cross flow sprayer (left) and the Lochmann tunnel sprayer (right).

The spray deposition is expressed as the percentage of applied volume. The Lochmann tunnel sprayer gives a higher deposition in the lower part of the trees. In the upper half of the tree the deposition of both sprayers is similar (fig. 2-left). The use of the clay collectors gave a similar deposition pattern as the vertical collectors. The emission is also expressed as percentage of applied volume. The standard sprayer gives an equal pattern on the surface, whereas the Lochmann tunnel sprayer gives a higher deposition under the trees (fig. 2-right).

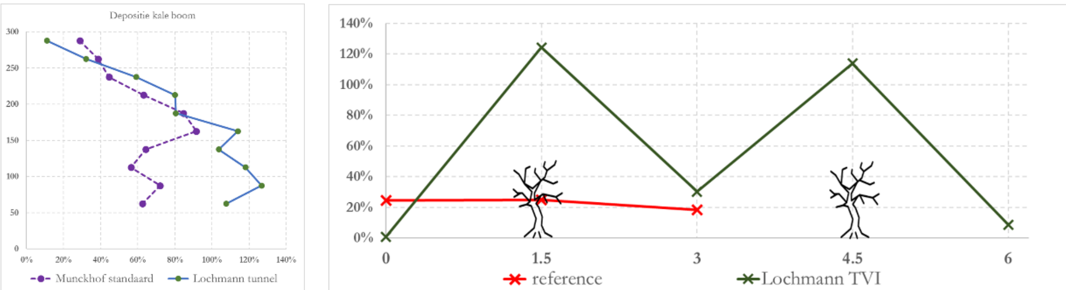


Fig. 2. Spray drift deposition in the apple tree (left), and ground deposition (right) for the standard Munckhof cross flow sprayer and the Lochmann tunnel sprayer.

Acknowledgements

Innovatieve emissieloze toedieningstechnieken 4.0 received funding under grant agreement LWV19035 and Projectcode: BO-67-001-020 Topsector TKI. Partners: Wageningen University & Research, Nederlandse Fruittelers Organisatie, BO Akkerbouw, Fruitconsult, Corteva, Syngenta, Munckhof Fruit Tech Innovators, Van der Linden, Kruse Ootmarsum, Agrifac Machinery, Rometron, Hardi-Homburg, Kverneland Group.

REFERENCES

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.

3.10 The aero-confined BLISS-Ecospray concept, a new typology of downpipes sprayer to avoid spray mix losses at the source

Gaétan Fleury [b, *], Vincent De Rudnicki [a], Yves Matton [b]

a- expert advice BLISS ecospray, Retired from INRAE, Montpellier, France, vincentdr@bliss-ecospray.com

b- Bliss Ecospray. Email: contact@bliss-ecospray.com

INTRODUCTION

The presence of plant health products in the environment and its consequences emerged in the public debate (Bedos & al, 2020). To avoid the losses of product from the sprayer and therefore drift, why do not eliminate at the source the losses by confining really and physically the sprays.

Bliss Ecospray team has developed, from the initial INRAE project, a new typology concept called "Aeroconfined©" face-to-face downpipes BLISS Ecospray. This new technology patented (*W2019/122221A1)* aims at eliminating product losses at their source, the sprayer, which is the first origin of aerial and sedimentary drift.

MATERIALS AND METHODS

BLISS is based on downpipe design that can confine spray jets within a laminar air shield tube, named "**aero-containment** ©". These laminar flows generated by BLISS downpipes are a directional air blade tube at a velocity of more than 200 km/h, which creates a barrier and thus reduces drastically spray drift.

For that, the solution used for BLISS uses the physical principles of the COANDA effect to create the laminar air blade tube and containment *(Dong-Won Lee & all.2007)*

Artificial test bench

We have cloned the INRAE distribution test bench by making some improvements (Fig 1). We built also a bench to quantify soil and air losses directly from the sprayer.

Field experiment

We use Water sensitive papers (WSP) on the upper and lower sides of the leaves, in 9 different compartments of the vine as showed on Fig. 1, top, middle and bottom, one on a grape vine twice in the row and we place 2 WSP on each adjacent row to visualize lateral air losses. 3 WSP are placed on the ground and on the vine rootstock. (Fig. 2)

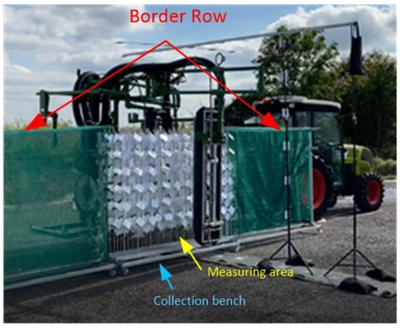


Figure 3: BLISS artificial bench

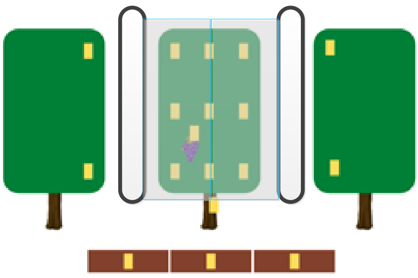


Figure 4: WSP positions on the row and adjacent row. Cross sectional view

RESULTS AND DISCUSSION

Soil & air losses

e measurements on the artificial leaves of the bench show the absence of impacts on the collectors of the air loss bank (not measurable by spectrometer).

On the vineyard plot, very low soil losses are only concentrated under the vine and then become almost zero at 50cm from the center of the row. As well as the air losses being almost zero, this exceeds the 3m buffer zone requirement defined in the introduction.

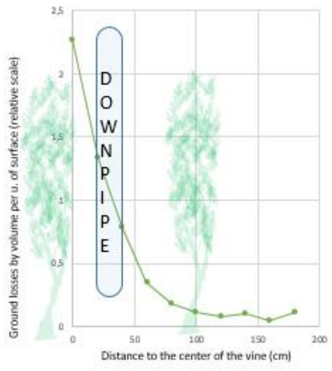


Figure 5: Soil & air losses curve

Field efficiency

One of the result in vineyard plot show the efficiency of protection compared to a sample of other devices.

Table 1: Field efficiency

ESTIMATED EFFICIENCY	TOP SIDE	BOTTOM SIDE	GRAPES	AVERAGE
BLISS 09/2022 *	97%	83%	92%	90,7%
AVERAGE TESTS CA **	99%	75%	79%	84,3%

Extract from the report of the Chamber of Agriculture of 89 (2022)
** Turbulence nozzle hollow cone), ALBUZ ATI 80-005 Lilac 80°, Operating pressure: 5.8bar, V/Ha applied: 183 litters/ha, Forward speed: 5.5km/h, Processed width: 1.00m rows, 3 nozzles/ face downpipe*
*** Results obtained in full vegetation (mid-June to end of August) for a sample of 31 pneumatic devices face by face in the row over the period 2013-2022.*

Discussion

As shown on the results on bench and plot, the BLISS Ecospray downpipes typology, thanks to the "**aero-containment** ©", is able to prevent losses of drops outside the treatment area and thus remove the source of product drift that a pneumatic face to face sprayer did not compete as well as other typologies on different tests conducted.

Therefore, BLISS downpipes improves the application quality in terms of the amount of deposit and its distribution in all vine compartments, ensuring total and safe treatment.

REFERENCES

[1] Bedos C& all. (2020). ; Application des produits phytopharmaceutiques et protection des riverains : synthèse des connaissances pour définir les distances de sécurité Rapport du groupe de travail inrae-Anses-Acta. DOI: 10.15454/8w26-5w57

[2] Dong-Won Lee & all. (2007). A study on the air knife flow with COANDA effect, Journal of Mechanical Science and zechnology21 (2007) 2214-2220

Session 4: Spray Drift

4.1 Airborne spray drift and ground deposition spraying an orchard with standard and drift reducing techniques

J.C. van de Zande, M. Wenneker

Wageningen University and Research (WUR) – P.O. Box 16 – 6700 AA Wageningen, The Netherlands.
Email address: jan.vandezande@wur.nl, marcel.wenneker@wur.nl

INTRODUCTION

In the Netherlands spray drift experiments for orchard spraying are carried out on a uniform basis comparing a reference spray application technique and a yet to be classified drift reducing technique (DRT). As spray drift measurements are done both as ground deposition next to the orchard and as airborne drift at one distance from the last treated tree row of the orchard, these data can be evaluated for the level of drift deposition and similarity of drift reduction. These comparisons can be relevant in exposure assessments for bystander and resident risk and of non-target plants or arthropods.

MATERIALS AND METHODS

Spray drift measurements were carried out according to the ISO standard (ISO 22866; 2005) adapted for the situation in the Netherlands (ground deposits, ditch, surface water next to the sprayed field) following the Dutch protocol (TCT, 2003, 2017). The outside 24 m (8 rows) of an apple orchard were sprayed with a solution containing the fluorescent dye Brilliant Sulpho Flavine (Chroma 1F 561, BSF) and a non-ionic surfactant (Agral) to the spray agent. Spray drift deposition was measured using collectors (synthetic cloths of 0,05 m^2/0,1 m^2) which were placed at several distances up to 25 m from the centre of the last tree row on ground surface on the downwind edge of the orchard. At 7.5 m distance from the last tree row, collectors (Siebauer) were fit to vertical lines up to 10 m height to collect airborne spray drift. The spray drift was measured by quantifying the BSF deposition using liquid fluorescence spectroscopy of the ground and airborne collectors.

The reference technique for orchard spraying was a cross-flow fan sprayer (Munckhof), equipped with Albuz ATR lilac nozzles, which at 7 bar spray pressure produced a Very Fine spray quality (ISO25358). The experiments were carried out in the full leaf growth stages of the trees (BBCH 56-92) and carried out with 540 rpm PTO and high gear fan settings. Drift Reducing Techniques (H.S.S., KWH, Lochmann, Munckhof) and nozzles can be grouped in drift reduction classes compared to the reference (ISO22369-1). Entries in the drift reducing classes in the Netherlands for orchard spraying (based on spray drift deposition at 4.5-5.5 m from the last tree row in the full leaf situation) are determined and based on comparative field measurements. In total 22 spray drift measurements were compared for these analyses, performed in the period 2008-2020; representing 3 DRT75, 5 DRT90, 4 DRT95, 4 DRT97.5 and 6 DRT99 techniques.

RESULTS AND DISCUSSION

Of the evaluated 22 spray drift measurements, spray drift reduction ranged from 76.8% to 99.5% and was on average 93.9%. Mean spray drift deposition at 4.5-5.5 m from the last tree row was 9.4% for the standard spray technique and 0.57% for the DRTs. Mean airborne spray drift over 0-10 m height at 7.5 m distance from the last tree row was 5.5% for the standard technique and 0.45% for the DRTs (Table 1).

Table 1. Mean spray drift deposition (% sprayed volume) at ground surface and airborne spray drift at different evaluation zones for a standard spray technique and drift reducing techniques (DRTs) and mean drift reduction (%) for the DRTs spraying an orchard at full leaf stage.

	Drift deposition ground [%]			Airborne drift [%] at 7.5m		
	4.5-5.5m	7-8m	0-10m	0-1m	0-2m	0-10m
standard	9.4	5.2	5.6	7.9	8.5	5.5
DRT	0.57	0.27	0.30	0.49	0.55	0.45
Drift reduction (%)	93.9	94.3	94.2	93.8	93.5	91.9

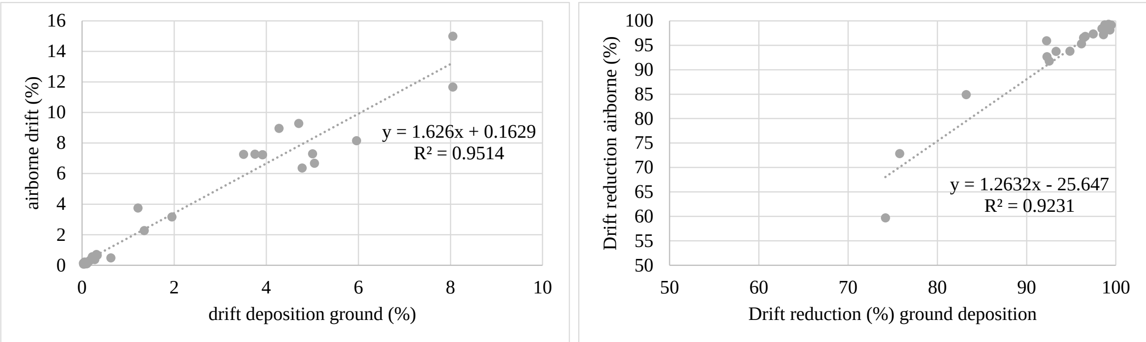


Fig. 1. Spray drift deposition (% sprayed volume; left) for the standard and drift reducing techniques and drift reduction (%; right) for the DRTs at ground surface at 7-8 m and airborne spray drift at 0-2 m height at 7.5 m spraying an orchard at full leaf stage.

Spray drift deposition at 7-8 m, coinciding with the position of the airborne drift pole (7.5 m), is for the standard technique and DRTs respectively 5.2% and 0.27%. Airborne drift at 0-2 m height is 8.5% for the standard technique and 0.55% for the DRTs. This shows that at the same distance (7.5 m from the last tree row) airborne spray drift is higher than ground deposition (Fig. 1). Mean airborne drift over 0-10 m height was for the standard technique 7% higher and for the DRTs 64% higher than ground deposition at 7.5 m distance. Two different height ranges were used which represent bystander and resident exposure of children and adults during risk analysis; for the standard technique airborne drift was 53% and 65% higher for 0-1 m and 0-2 m height respectively. For the DRTs airborne drift at 0-1 m and 0-2 m height was 81% and 102% (two times) higher than drift deposition at ground surface at the same distance.

Mean spray drift reduction of the DRTs at the ground surface for the distances 4.5-5.5 m, 7-8 m and 5-10 m were 93.9%, 94.3% and 94.2% respectively. At 7.5 m distance from the last tree row spray drift reduction at the airborne heights of 0-10 m, 0-2 m and 0-1 m were 91.9%, 93.9 % and 93.8% respectively. This shows that the spray drift reduction classes evaluated either at different ground surface zones or at airborne heights are of a similar level. For 14 of the 22 individual spray drift measurements the drift reduction classes remain similar for airborne and ground drift reduction at 7.5 m from the last tree row, for 6 DRT techniques airborne drift class is lower than ground drift class, and for two measurements the airborne drift class is higher (Fig. 1).

4.2 Spray drift measurements in 3D crops using several collection methods. Evaluation of different spraying scenarios in the French context.

Adrien Vergès[1], Florence Verpont[2], Jean-Paul Douzals[3], Yoan Hudebine[2], Sebastien Codis[1], Elodie Trinquier[1], Olivier Naud[3]

[1]IFV, [2]CTIFL, [3]INRAE, Email address:adrien.verges@vignevin.com

INTRODUCTION

In Europe, the assessment of PPP for their registration takes into account the risks of bystander exposure to spray drift by including safety distances. As a result, a significant proportion of agricultural land can no longer receive PPP treatments, which has a significant economic impact. To determine the width of safety distances, the risk assessments are made according to EFSA guidance (2014) that considers a drift reduction of maximum 50%. In this context, several European projects have studied the performance of various means of reducing drift (OBO Netherlands, PROPULPPP Belgium). The question is whether there are any means to reduce these distances without degrading, or even improving, the protection of bystanders and residents against the risks of exposure to PPP.

For this purpose, in the French context, several measurements of drift levels observed in different phytosanitary treatment scenarios, including different spray application techniques and physical barriers for drift mitigation (hedges and nets), have been carried out. The methodology used for drift measurement was based on simultaneous measurement of sedimentary drift, airborne drift and dermal exposure. This methodology was developed in consultation with ANSES (French risk assessment agency) and described in IAPA 2022 (Verpont et al., 2022).

MATERIALS AND METHODS

Sulfo-Rhodamine B was used as tracer. Sedimentary drift was measured using 5 lines of Petri dishes 14cm in diameter set at 2, 3, 5, 10 and 20m from the last sprayed row. Airborne drift was measured using horizontal wires of 2mm diameter and 7m long. Wires were arranged every 50 cm high up to 6 and 12m high respectively for vineyard and orchard trials. The collection device was set at 5m from the last sprayed row. Dermal exposure was measured using cotton long sleeved tee-shirt worn by manikins as collectors. 1 and 3 manikins per distance (3, 5, 10 and 20m) were set respectively for vineyards and orchards.

Wind conditions complied with the requirements of the standard ISO 22 866 : 2006.

Orchard tests were made in field conditions, on an adult apple orchard (4 m high, mid or full stage vegetation, row spacing 4 m). Vineyard tests were made in artificial conditions using the “EoleDrift” test bed, including artificial vegetation and a wind generator. The tests were carried out using vegetation that mimicked an early growth (BBCH 53). The row spacing was 2.5 m.

For viticulture tests, some tests scenarios included a 2.5 m high laurel (*Laurus nobilis*) hedge using potted plants located at 2m from the last sprayed row. For orchard tests, some tests scenarios included a 4 m high net (Alt’dérive net) positioned 4m from the last row and deployed over the entire 60-metre length of the orchard.

Table 1: Spraying scenarios description.

Scenario number	Sprayer type	Technology	Nozzle	Volume rate L/ha	Physical barrier
Viticulture 0 - **reference**	Arch	Pneumatic		70	None
Viticulture 1	Arch	Air assisted	Flat fan air induction	90	None
Viticulture 2	Multirow	Air assisted	Flat fan air induction	90	None
Viticulture 3	Arch	Air assisted	Flat fan air induction	90	Hedge
Viticulture 4	Multirow	Air assisted	Flat fan air induction	90	Hedge
Viticulture 5	Tunnel	Air assisted	Flat fan air induction	60	None
Orchard 0 - **reference**	Axial	Air assisted	Hollow cone	400	None
Orchard 1	Axial	Air assisted	Hollow cone	400	Anti drift Net
Orchard 2	Axial	Air assisted	Flat fan air induction	400	None
Orchard 3	Axial	Air assisted	Flat fan air induction	400	Anti drift Net
Orchard 4	Targeting flow	Pneumatic		250	None
Orchard 5	Targeting flow	Pneumatic		250	Anti drift Net
Orchard 6	Axial	Air assisted only towards the orchard on the last row	Flat fan air induction	400	None

RESULTS AND DISCUSSION

Drift reduction rates from the reference scenario for each scenario of spraying and each drift collection method are represented in Fig. 1 & 2 below respectively dedicated to vineyard and orchard contexts. For sedimentary drift and dermal exposure, average deposition from 3 to 20 m from the last sprayed row was considered. For airborne drift, deposits over the entire height of the collection plan were considered.

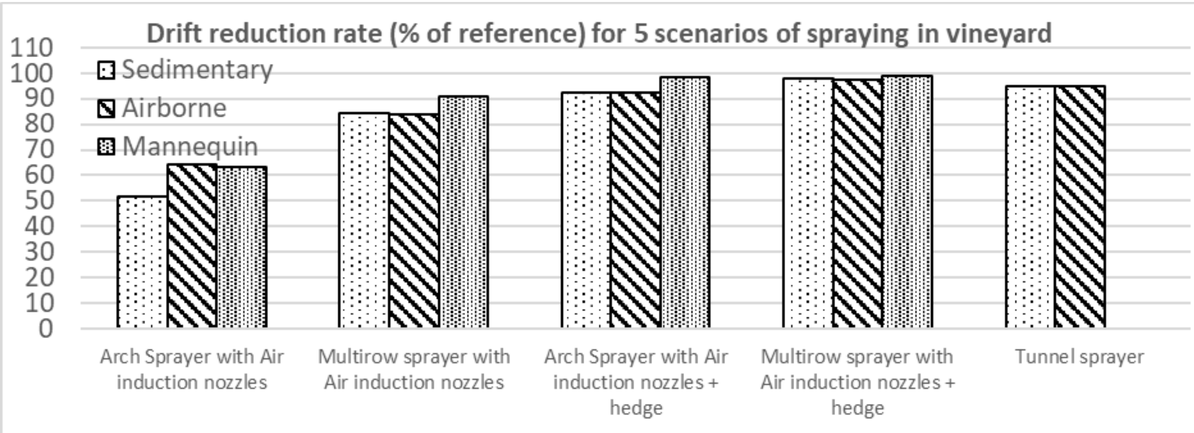


Fig. 1. Drift reduction rates from baseline calculated for 5 scenarios of spraying in the viticulture context and 3 collection methods.

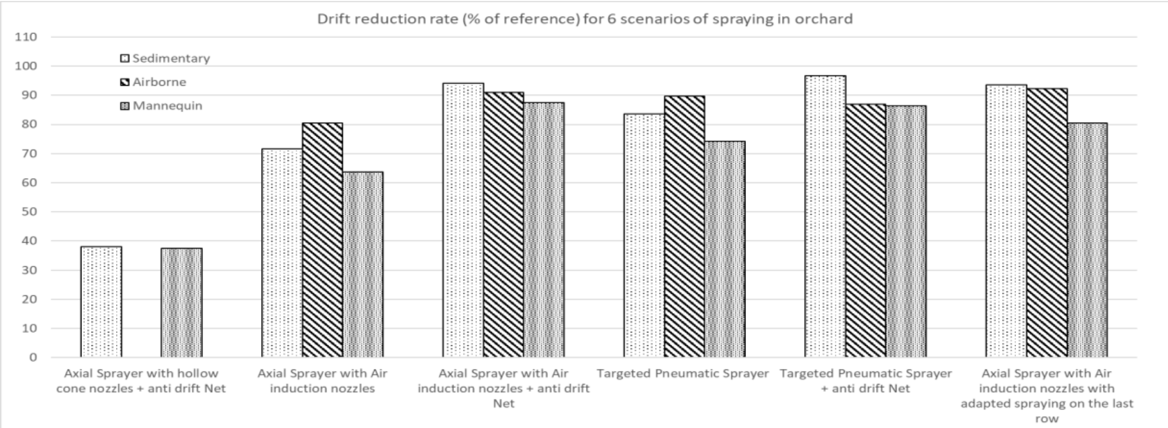


Fig 2. Drift reduction rates from baseline calculated for 6 scenarios of spraying in the orchard context and 3 collection methods.

This work confirms that there are spraying techniques that significantly reduce spray drift compared to the most common practices. Several scenarios make it possible to obtain drift reductions significantly higher than 50% which is the only reduction rate considered by EFSA guidance (2014).

Independent from the spraying scenario, a strong correlation between the three drift collection methods has been observed. This opens up the prospect of further work aimed at simplifying measurement protocols.

REFERENCES

Verpont, F., Hudebine, Y., Perriot, B., Verges, A., Douzals, JP., Bedos, C., Grimbuhler, S., Sellam, M. How to conciliate application of plant protection products and protection of bystanders - CAPRIV: a French collaborative project. International advances in pesticides application, Aspects of applied biology 147, 2022.

4.3 Drift 3D, exposure of residents and bystanders during the application of plant protection products in orchards

Katrin Ahrens[1], Markus Röver[2], Jens Karl Wegener[1]

[1]Julius Kühn Institute (JKI) – Federal Research Centre for Cultivated Plants, Institute for Application Techniques in Plant Protection, Braunschweig, Germany
[2]Federal Office of Consumer Protection and Food Safety, Braunschweig, Germany.
Email address: katrin.ahrens@julius-kuehn.de

INTRODUCTION

Since 2014, the assessment of the exposure of uninvolved persons (bystanders, residents, etc.) caused by spray drift during the application of plant protection products (PPP) has been carried out according to an internationally agreed model of EFSA (EFSA, 2014). The model for high crops (including orchards) is based on data on mannequins from the 1980s (Lloyd et al. 1987). From today's perspective, the application technique is partially not up to date any longer. Furthermore, data for different distances from the area treated and the reduction of exposure through the use of drift-reducing techniques were not comprised in these early studies. Thus, for high crop applications, neither different distances nor drift-reducing techniques can be taken into account as risk mitigation measures during the assessment of exposure risks for residents and bystanders for the authorisation of plant protection products (PPP).

In 2016, the Federal Office of Consumer Protection and Food Safety (BVL), together with the Julius Kühn Institute (JKI) and the German Federal Institute for Risk Assessment (BfR), initiated a multi-year project to address existing data gaps on the drift in PPP applications in high crops. Trials were conducted without and with drift-reducing technique. In addition, distances of 3 m, 5 m, and 10 m from the treatment area at early and late crop stages in orchards were considered. The goal of the project was to improve the predictive power and robustness of existing exposure assessment models through an extensive series of experiments. In addition, based on an expanded exposure modeling data set, new risk mitigation options were developed, including distance requirements and drift reduction techniques.

MATERIALS AND METHODS

To determine the exposure data, a method was developed following ISO 22866:2005 on drift measurement to determine the dermal and inhalation exposure of residents and bystanders with a dye surrogate. In preliminary tests, mannequins dressed in various textiles and equipped with aerosol collection pumps were placed on the measurement field and sprayed with a water-pyranine solution. It turned out that the cotton-based dosimeters used were unsuitable. The blank values were too high and the detection limit did not meet the requirements. In further tests, Tyvek® as a single-use protective coverall proved to be a suitable dosimeter material. Even on large surfaces, the dye on this material caused by spray drift can be extracted efficiently with relatively small amounts of water as a solvent. Based on these findings, the mannequins were dressed in Tyvek® coveralls to measure potential exposure.

Between September 2021 and October 2022, six test series with eight drift measurements each were carried out with a KA32/1000 orchard sprayer from Wanner (Wanner Maschinen GmbH, Wangen, Germany). A total of 18 mannequins in two sizes (adults and children, resp. 1.90 m and 1 m high) were used in the experimental setup. Three of each size were placed on a measuring field at a distance of 3 m, 5 m, and 10 m from an orchard. Zero-line is at a half-row distance from the center of the outermost tree-row (1.75 m) of the orchard. The mannequins were dressed in prepared Tyvek® coveralls and equipped with aerosol collection pumps to measure potential dermal and inhalation exposure at neck height, approx. 1.70 m and 0.80 m. At the same time, petri dishes were placed on the plot for sediment measurement at 3 m, 5 m, and 10 m. The experiments were carried out with and without drift-reducing technique (75 % drift-reduction) at different crop stages (early and late growing stage). A total of 48 drift measurements took place in orchards. The experiments provided 864 exposure data/3D drift data sets of mannequins exposed. Data for the individual parts of the body are available. In addition, 1440 data points were obtained on ground sediments, and field recovery was measured.

RESULTS AND DISCUSSION

The exposure data show that the use of drift-reducing technique leads to the expected reduction in exposure of the mannequins also in the case of 3D drift.

In terms of the 75th and 95th percentiles of the measured results, the results of the adult mannequin at 5 m without drift mitigation technique confirmed older values from the EFSA Guidance (2014).

The child mannequins showed somewhat higher exposure than expected in terms of body surface area. The body surface of the child mannequins corresponds to about 35% of the adult mannequins, but the average dermal exposure corresponds to about 50% of adult mannequins. For future studies, a generic correction factor is proposed, which can be considered very robust due to the large number of data points generated. These results will allow experiments to be conducted without child mannequins in future field studies.

The drift data obtained were submitted for publication and sent to EFSA for further development of exposure models.

ACKNOWLEDGEMENTS

The project "Exposure of residents and bystanders during application of plant protection products in high crops (3D drift measurements)" was funded by a grant from the Federal Office of Consumer Protection and Food Safety (BVL).

REFERENCES

EFSA (European Food Safety Authority). (2014). Guidance on the assessment of exposure of operators, workers, residents and bystanders in risk assessment for plant protection products. EFSA Journal 2014. 12(10):3874, 55 S., https://doi.org/10.2903/j.efsa.2014.3874

Lloyd G.A., Bell G.J., Samuels S.W., Cross J.V., Berry A.M. (1987). Orchard sprayers: Comparative operator exposure and spray drift study. Agricultural Science Service, Agricultural Development and Advisory Service, Ministry of Agriculture, Fisheries and Food.

4.4 Drift reducing effects of wind break screens.

Kris Ruysen[1], Nathalie Broers[1], Dany Bylemans[1, 2]

[1]Research Center for Fruit (pcfruit npo), Fruittuinweg 1, 3800 Sint-Truiden, Belgium,
[2]Department of Biosystems, KULeuven, Decroylaan 42, 3001 Heverlee, Belgium
Email: pcfruit@pcfruit.be

INTRODUCTION

Spray drift, which occurs during spray applications of pesticides, is defined as the spray liquid ending up downwind next to the treated field, often referred to as the non-target area. There, pesticide deposits can cause damage to the environment, especially when there is a risk of the spray liquid entering surface water. In addition to environmental problems, illegal pesticides residues will be noticed in neighbouring crops. A typical example occurs when a field with an organic production is located next to a field with a conventional crop. Passive measures such as windbreaks and living hedges are often used to avoid unintended residues.

Drift levels can reach up to 20% in orchards (Duga *et al.*, 2014*;* 2015) and depend on sprayer type and settings, tree architecture and phenological stage, and wind direction (more than wind speed).

Windbreaks and living hedges are recognized in Belgium as drift-reducing measures provided that they are as high as the crop to be treated. Closed hail nets are also qualified as a drift-reducing measure. Hail nets and hedges have been the subject of various studies in the past (Ucar and Hall, 2001; Wenneker and Van de Zande, 2008; Lazarro *et al.*, 2018). Nevertheless, there is a lot of variation in the results of deposited pesticide levels. This is mainly explained by the phenology of the crop to be treated and of the living hedge at time of application, and the variable weather conditions during the different tests throughout the season. In this study, we want to research the effect of windbreaks around orchards using a small indoor setup and find out how drift deposition depends on the nozzle type used excluding the effect of weather conditions. We tested a new potential tracer, Ferulic acid, which is easy and fast to detect.

MATERIALS AND METHODS

The experimental design allowed determining the difference in soil deposition without windbreak screen and with the screen at 2 different distances. A tracer Ferulic acid (Sigma-Aldrich, product no. 128 708) dissolved in demineralized water at a concentration of 500 ppm was used. The spray device used is a battery spray blower Birchmeier (AS 1200 AC1 spray blower) air assisted hand-held device and was operated at 6 bar, a pre-movement speed of 0.4 m/s and air assistance speed level 3.

A conventional (Albuz ATR 80 Brown) and a drift reducing nozzle (TVI 80 01 Orange) nozzles were used and mounted at 85cm above floor level. The windscreen was a Howitec (Quadro 190 ME, a 190g/m² HDPE windbreak with meshes of 1.6 x 1.3 mm) and was placed at 1.5m or at 4.0m from the nozzle outlet. Collectors (petri dishes 86mm diameter) were placed on the soil in front of and behind the screen every 0.5m in the direction of the blower nozzle. A series of samples was set up for no screen, the screen at 1.5m and the screen at 4.0m. Work was done with 2 nozzles and in 3 repetitions in an indoor set up. Immediately after the trial, petri dishes were washed with 5 ml of demineralized water. Samples were analysed with a spectrophotometer (Thermo Scientific Multiscan GO) at a wavelength of 318 nm. Using a calibration series (1.25, 2.5, 5, 10, 20, 40 and 50 ppm), the concentration and finally the spray deposition were calculated. The level of quantification was shown to be 2.5 ppm.

RESULTS AND DISCUSSION

The results without screen (Fig 1) show remarkable differences between TVI and ATR nozzles. With the TVI nozzle, we find the most deposition between 2 to 5.5 m distance. The large droplets of this nozzle situate themselves well in the airflow and are carried at least 2 metres. With the ATR nozzle, the largest deposition occurs close to the nozzle, which was described earlier (Dekeyser *et al., 2014)* The deposition decreases as a function of distance from the spray blower. Even at the last collector deposition was found. This excessive effect close to the nozzle is probably due to an imbalance between liquid velocity and air velocity in combination with the design of the spray blower. During the test, we observed an uncontrolled swirling mist. The ATR nozzle with fine spray quality does not seem suitable for this type of sprayer. The results (Fig2) show the deposition the TVI nozzle in the 3 situations: no screen, with screen at 1.5m distance and at 4.0 m distance. The difference between no screen and with screen at 1.5 m is clear. We see a shift of deposition towards the screen with a peak at 3 m from the spray blower (1.5 m from screen). The screen at 4 m shows a limited effect behind the screen as a lot of deposition already happens in front of the screen. The results (Fig3) show the deposition of the ATR nozzle in the 3 situations: The difference between no screen and with screen is low as there is less deposition behind the screen. The effect of the screen is slightly higher at 1.5m than at 4.0m. Wind screens as a barrier between crops is a solution to reduce drift. It should be taken into account that there is a risk of increased deposition at short distance (1 to 2 m) behind the screen. It is better to place the screen at min 3 m in front of the non-target area to be protected.

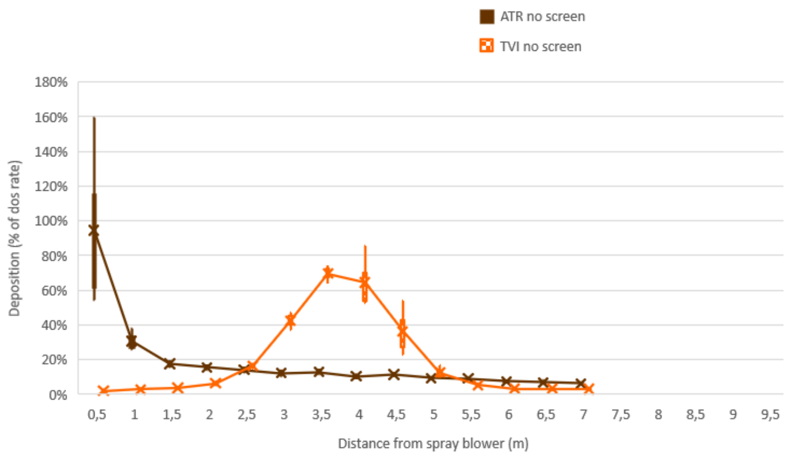


Fig. 1: Deposition no screen for a single TVI and ATR nozzle at 0.85 m height.

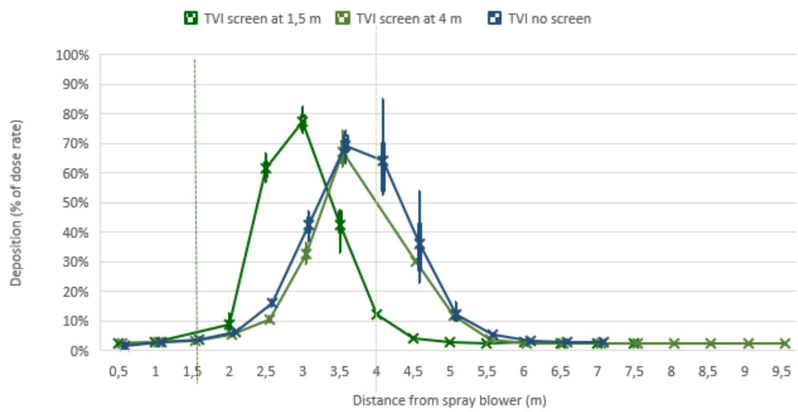


Fig. 2: Deposition for a single TVI nozzle at 0.85 m height with at 1,5 m, resp. 4.0 m and no screen. Vertical dashed lines indicate the position of the screen.

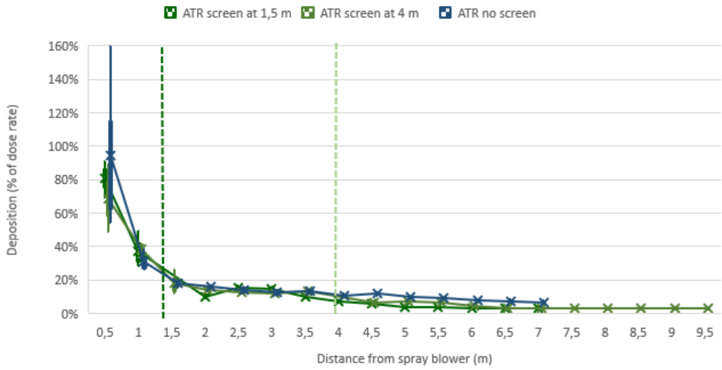


Fig. 3: Deposition for a single ATR nozzle at 0.85 m heigh with at 1,5 m, resp. 4.0 m and no screen. Vertical dashed lines indicate the position of the screen.

REFERENCES

Dekeyser, D., Foqué, D., Duga, A. T., Verboven, P., Hendrickx, N., & Nuyttens, D. (2014). Spray deposition assessment using different application techniques in artificial orchard trees. Crop Protection, 64, 187-197.

Doruchowski, G., Świechowski, W., Hołownicki, R., & Godyń, A. (year). Reduction of spray drift by hail net over apple orchard. In 15th Workshop on Spray Application and Precision Technology in Fruit Growing Programme and Abstracts (p. 87).

Duga, A. T., Defraeye, T. H. I. J. S., Nicolai, B. A. R. T., Dekeyser, D., Nuyttens, D., Bylemans, D., & Verboven, P. (2014). Training system dependent optimization of air assistance and nozzle type for orchard spraying by CFD modeling. Aspects of Applied Biology, 122(453), e458.

Duga, A., Ruysen, K., Dekeyser, D., Nuyttens, D., Bylemans, D., Nicolaï, B., & Verboven, P. (2015). CFD based analysis of the effect of wind in orchard spraying. Chemical Engineering Transactions, 44, 289-294.

Lazzaro, L., Otto, S., & Zanin, G. (2008). Role of hedgerows in intercepting spray drift: Evaluation and modelling of the effects. Agriculture, ecosystems & environment, 123(4), 317-327.

Ucar, T., & Hall, F. R. (2001). Windbreaks as a pesticide drift mitigation strategy: a review. Pest Management Science: formerly Pesticide Science, 57(8), 663-675.

Van de Zande, J. C., Michielsen, J. M. G. P., Stallinga, H., Wenneker, M., & Heijne, B. (2004). Hedgerow filtration and barrier vegetation. In Proceedings of the International Conference on Pesticide Application for Drift Management, 27-29 October, 2004, Waikoloa, Hawaii (pp. 163-181).

Wenneker, M., & Van de Zande, J. C. (2008). Spray drift reducing effects of natural windbreaks in orchard spraying. Aspects of Applied Biology, 84, 25.

4.5 A novel and simple method for potential spray drift measurements in orchards

Nils Bjugstad

Norwegian University of Life Sciences, Faculty of Science and Technology nils.bjugstad@nmbu.no

INTRODUCTION

There are several methods in order to quantify drift, e.g. using passive or active samplers (Arvidsson, 1997), or measuring the sedimentation or airborne drift (Grella et al., 2017; (ISO 22866, 2005), however the methods are often complicated to use, take long time resulting in meteorological variations and demand a high need of labour efforts.

The level of the drift depends mainly on two phases (Herbst & Ganzelmeier, 2000). Phase 1 is generated in a zone close to the sprayer and depends mainly on the sprayer settings and in particular the air flux from the fan, tractor speed and tree configuration, while phase 2 measures the drift further away involving more variables and thus results in higher measuring errors.

The testbench method, (Grella et al., 2017) is a quick method used at calm wind conditions, measuring the sedimentation drift without any influence of the tree structure. The later described method is also used at calm wind conditions measuring the airborne drift in the orchard including trees. A similar methodology has been used in strawberry drift measurements with good results (Bjugstad & Hermansen, 2009).

The objectives of this research were;

1. Develop a simple and quick method to measure potential airborne drift within the orchard (phase 1) depending mainly on sprayer settings.
2. Examine technical parameters that may reduce the potential drift before blossoming (BBCH 60) of the fruit trees.

MATERIALS AND METHODS

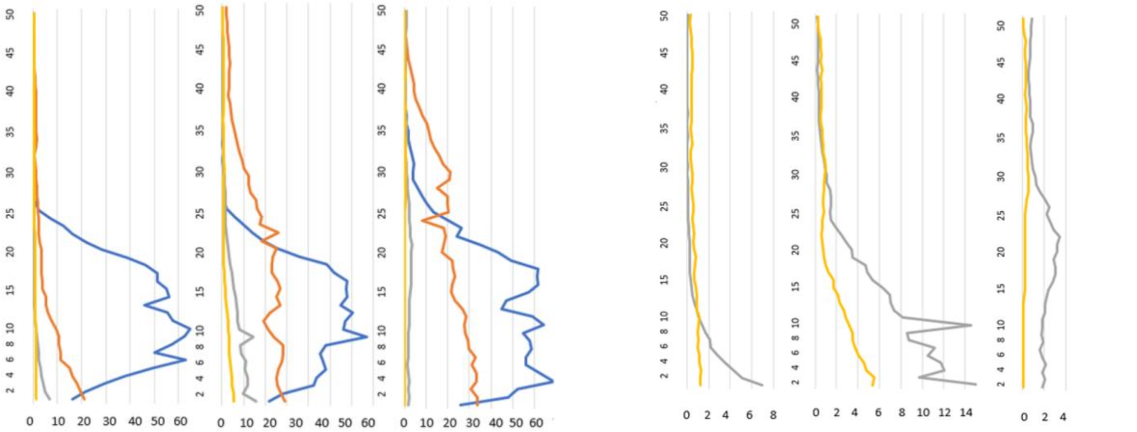
Orchard. The experiments were conducted in an apple orchard, row spacing 4.0 m, tree height approx. 2.4 m, spraying at BBCH 60, open structure with little mass of leaves. The orchard was located in Telemark in Norway (59.38865831943624, 9.227864681501979).

Equipment. A Wanner K1500 trailer mist blower sprayer was used, equipped with a vertical tower of two vertical sections, where only the lower section with six nozzles was open and spraying applied only to one side. As nozzles were used Albuz ATI 60 01 at 10 bars and 0.73 l/min. The air fan was run at the lowest gear and three replicates were conducted. The trial settings were 6.0 / 350, 6.2 / 450 and 8.1/ 350 km/h / rpm of PTO in order to examine the effect on air flux retardation and backwards bending of the spray plume and level of drift mitigation. The weather conditions were frequently noted.

Drift sampling. The passive samplers were horizontally fixed cotton threads, diameter 2 mm, length 1 m, fixed to wooden frames every 0.10 m in a vertical height from 0.2 to 5.0 m in order to measure airborne drift. One frame was set in front of the row to be sprayed in order to measure the deposit and the drift frames in the first, second, fourth and sixth interrow. The real spraying application for each run took less than 1 min, which made it easier to ensure equal and calm wind conditions. As tracer, there was used a fluorescent dye, 0.01% Fluorescein LT. Directly after spraying, the threads for every height level were collected in numbered plastic bags and put in a chilly and dark box for later analysis. The dye was analysed by a fluorimeter (10-AU-005-CE Turner) and spray volume calculated as ul per thread taken into account differences in spray volume applied.

Fig. 1: From left; Wanner K1500 sprayer spraying fluorescent tracer, frame for deposit measurements in front of the row to be applied, and then samplers at 6, 10, and 14 m from first row.

RESULTS AND DISCUSSION



6 km/h-PTO 350 6.2 km/h-PTO 450 8.1 km/h-PTO 350 6 km/h-PTO 350 6.2 km/h-PTO 450 8.1 km/h-PTO 350

Low resolution to include size of deposit High resolution to examine drift

Fig. 2: Deposit and potential drift, y-axis: vertical height 0.2 – 5.0 m, x-axis: ul spray volume per thread. Blue-deposit. Distance from first row; red-6, grey-10, yellow-14 m.

The results show almost equal deposit for all the experiments, blue line. The drift was strongly reduced by reduced speed on the fan (grey line). The drift at 14 m distance (yellow line) was lowest for the 350 rpm on the fan combined with highest forward speed.

REFERENCES

Arvidsson, T., Berström, L., Kreuger, J. (1997) Spray Drift as Influenced by Meteorological and Technical Factors, r. thesis. SLU Ultuna.

Bjugstad, N., Hermansen, P. (2009) Field Measurements of Spray Drift in Strawberry. Agricultural Engineering International: the CIGR Ejournal. Manuscript PM 1048. Vol. XI. 2009. https://cigrjournal.org/index.php/Ejounral/article/view/1048/1221

Grella, M.; Gallart, M.; Marucco, P.; Balsari, P.; Gil, E., (2017). Ground deposition and airborne spray drift assessment in Vineyard and orchards. Sustainability (Basel, Switzerland), 2017, Vol.9 (5), p.728

Herbst, A., Ganzelmeier, H. 2000. Classification of sprayers according to drift risk – a German approach, Aspects of Applied Biology 57, Pesticide application: 35-40

ISO 22866:2005(E): Equipment for Crop Protection – Methods for Field Measurements of Spray Drift. International Organization for Standardization, Geneva, Switzerland, pp. 1–17 (2005).

4.6 Reduction of pesticides in the environment by the use of CitrusVol tool and spray drift reduction techniques during applications in citrus

Patricia Chueca, Cruz Garcerá

Instituto Valenciano de Investigaciones Agrarias, Moncada (Valencia, Spain)
Email address: chueca_pat@gva.es

INTRODUCTION

The main objective of spraying of plant protection products (PPP) is to deposit an optimal amount of PPP on the plant susceptible to be attacked by a pest or disease in order to control it. However, during the application there are losses to the environment, that can have harmful effects on nearby residents, bystanders, fauna and flora (Gil and Sinfort, 2005). With the aim of optimizing the applications of PPP in citrus, the Agroengineering Center of IVIA developed CitrusVol, a tool based on scientific research that adjusts the spray volume rate of airblast sprayers treatments to the characteristics of the vegetation/orchard (based on the canopy volume, tree x row spacing, leaf density and pruning level), target organism, and the PPP applied (Garcerá et al., 2017). Another key aspect to optimize applications is the calibration and proper adjustment of the sprayers, adapting the spray profile to the target vegetation, and the use of easy-to-use technologies to prevent and reduce drift, such as low drift nozzles, air deflectors. The objective of this study was to determine ground losses and spray drift during citrus PPP applications, and to evaluate the effect of the optimization of the application, based on the spray volume rate optimization, adjustment of equipment configuration, and use of low drift nozzles.

MATERIALS AND METHODS

A trial simulating real spray applications with an axial-fan airblast sprayer, but not targeted against any pest, was carried out in a commercial citrus orchard (row x tree spacing: 5.5 x 3.5 m; ellipsoidal trees with 0-50 cm gaps). The factor was the “treatment”, with 2 variants:

- Conventional: treatment carried out according to the guidelines of the farm technician, without any regulation of the nozzle manifold to control the applied volume or to adjust the spray cloud to the vegetation. Conventional nozzles (Albuz ATR) were used.
- Optimized: application of the volume rate recommended by the CitrusVol tool, together with the use of low drift nozzles (Albuz TVI) and the adjustment of the nozzle manifold and the fan deflectors so that the spray cloud was adjusted to the vegetation shape. The case study to select the spray volume with CitrusVol was:
    - Pest group: Diaspidid scales, as a model of internal pests.
    - PPP: Abamectin, as a model of contact PPP.
    - The characteristics of the orchard vegetation, measured before each repetition.

In both treatments, forward speed was 1.6 km/h, working pressure 1 MPa, and airflow rate ≈70000 m^3/h. There were 4 repetitions/treatment.

For the assessment of drift, applications consisted in one-tree side spraying in two middle-rows, operating both sides of the sprayer (single pass). Collectors to sample the spray reaching the air, up to 9 m high, and the soil were located inside the sprayed area in the next path and two beyond to the treatment path, respectively. The active ingredient lambda-cyhalothrin was used to trace the spray (19.5 mg a.i./L).

RESULTS AND DISCUSSION

The volume rate recommended by CitrusVol was 48% lower in average than that used in the conventional treatment (2200 L/ha vs 4000 L/ha). The optimized treatment highly reduced both the airborne drift and the ground losses, with an average reduction of 81% of airborne drift and 86% of ground losses (Fig. 1), thus highlighting the joined effect of volume rate reduction, use of low drift nozzles, and spray cloud adjustment.

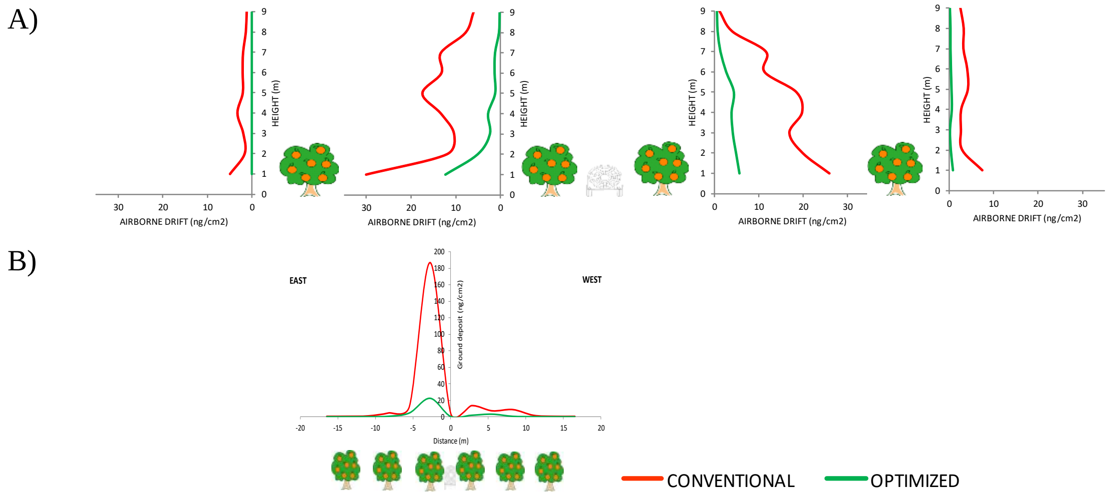


Fig. 1. Lateral view of the profile of A) airborne drift and B) ground losses (ng lambda-cyhalothrin/cm^2) through the citrus orchard (average of the four repetitions)

Considering together airborne drift and ground losses, total losses accounted for 27% of the PPP applied in the conventional treatment, while this number decreased until 5% in the optimized treatment, which is 81% lower.

As a consequence, the use of this tool and techniques generates direct savings in the use of PPP in the same percentage as the volume rate reduction due to the PPP dosage is expressed as a concentration. It also generates indirect savings in fuel consumption and time of tractor and operator work due to the lower down times to refill the sprayer tank. PPP emissions and CO_2 emissions are also reduced. Therefore, a sustainable application of PPP is achieved from the economical, social and environmental point of view.

ACKNOWLEGMENTS

This work has been funded by the LIFE PERFECT project “Pesticide Reduction using Friendly and Environmentally Controlled Technologies” (ref. LIFE17/ENV/ES/000205), through the financial instrument LIFE cofunded by Fondo Europeo de Desarrollo Rural (FEDER). Cruz Garcerá was recipient of a post-doctoral grant DOC-INIA funded by Instituto Nacional de Investigación y Tecnología Agraria y Agroalimentaria (ref. DR2015-0318).

REFERENCES

Garcerá, C., Fonte, A., Moltó, E., Chueca, P. (2017) Sustainable use of pesticide applications in citrus: A support tool for volume rate adjustment. Int. J. Environ. Res. Public Health 14, 715.

Gil, Y., Sinfort, C. (2005) Emission of pesticides to the air during sprayer application: A bibliographic review. Atmospheric Environment, 39, 5183–5193.

4.7 ADDI Spray Drift: A spray drift model for vine sprayers

Meriem Djouhri[1], Carole Bedos[2], Benjamin Loubet[2], Cecile Dages[3], Marc Voltz[3], Jean-Paul Douzals[4]

[1] *Wageningen University & Research, The Netherlands*
[2] *INRAE UMR ECOSYS, Université de Paris Saclay, France*
[3] *INRAE UMR LISAH, Université de Montpellier, France*
[4] *INRAE UMR ITAP, Université de Montpellier, France*
Email: jean-paul.douzals@inrae.fr

INTRODUCTION

Spray drift is an important topic concerning environment and health. Spray drift can be measured in vineyards (Herbst et al., 2023) or in semi-field conditions (Grella et al., 2021), but these experiments present a laborious task and are subjected to the weather conditions. In parallel, many attempts were taken on either empirical or mechanistic modelling (Djouhri et al., 2023) with the purpose of identifying and quantifying the effect of the key parameters on off-target deposition on the ground, in the air or on bystanders. On one hand, empirical models are based on deposition measurements but these have a limited capacity to extrapolated results from untested settings. On the other hand, mechanistic models offer sensitivity to parameters such as droplet size, atmospheric conditions, wind speed and direction (transport phase) but these still show limitation in the consideration of the emission phase: droplets velocity and direction, droplet evaporation, droplet interception, etc.

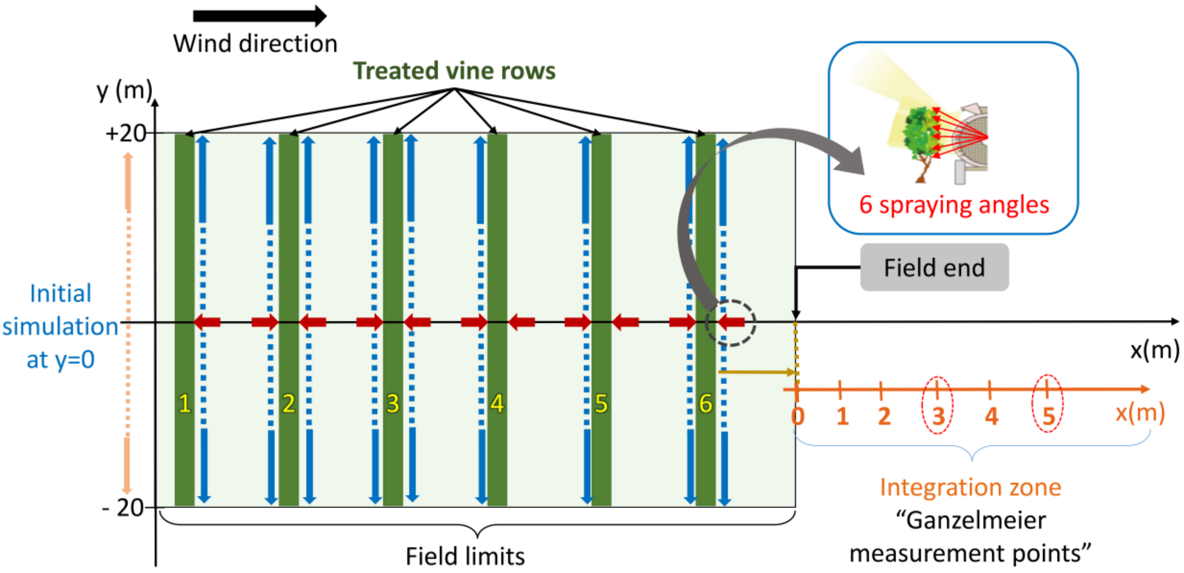


Fig. 1. Field scenario considered for modelling.

MATERIALS AND METHODS

The ADDI-Spray Drift model was developed to predict sedimentation and airborne spray drift at different distances from a vineyard. Based on a collaboration between three INRAE laboratories, this model also predicts infield soil deposition and canopy interception. The ADDI-Spray Drift is a 3D model, based on a random walk approach where inputs correspond to droplet and air emission profiles, but also taking into account droplet evaporation, atmospheric stability status, interactions between canopy and atmospheric turbulences, ground deposition and canopy interception.

Those parameters were evaluated for different sprayer locations (e.g.in the middle of the field or close to field boundary) as well as in terms of interaction between them (Fig. 1). Several spraying techniques were compared, such as pneumatic arch, axial fan or face-to-face vertical booms under different atmospheric conditions and active substance concentration.

RESULTS AND DISCUSSION

Many results were obtained from the different scenarios and some of them can be related to existing data. For this purpose, the Ganzelmeier et al. (1995) sedimentary spray drift data obtained in vineyard conditions were used for comparison with the modelling of an airblast sprayer. The prediction of sedimentary spray drift reduction along with the downwind distance was found satisfactory with less than 1% deviation at medium-range distances, and a maximum deviation reached 2.56% at shorter distances (Djouhri et al., 2023). According to the sensitivity analysis, the model appeared much more sensitive to spraying conditions, especially droplet ejection velocities that are not often easy to measure in practice.

REFERENCES

Herbst A., Glaser M., Bartsch K.-U. (2023) Spray drift from application of plant protection products with drones in vineyards [Abdrift bei der Anwendung von Pflanzenschutzmitteln mit Drohnen im Weinbau]. Journal fur Kulturpflanzen, 75 (5-6), pp. 151 - 157, DOI: 10.5073/JfK.2023.05-06.04

Grella M., Marucco P., Manzone M., Gallo R., Mazzetto F., Balsari P. (2021) Indoor test bench measurements of potential spray drift generated by multi-row sprayers. 2021 IEEE International Workshop on Metrology for Agriculture and Forestry, MetroAgriFor 2021 - Proceedings, pp. 356 - 361, DOI: 10.1109/MetroAgriFor52389.2021.9628652

Djouhri M., Loubet B., Bedos C., Dages C., Douzals J.-P., Voltz M. (2023) ADDI-Spraydrift: A comprehensive model of pesticide spray drift with an assessment in vineyards. Biosystems Engineering, 231, pp. 57 - 77, DOI: 10.1016/j.biosystemseng.2023.05.008

Ganzelmeier, H., Rautmann D., Spangenberg, R., Streloke, M., Herrmann, M., Wenzelburger, H.J., and Walter. H.F. (1995) Studies on the Spray Drift of Plant Protection Products: Results of a Test Program Carried out Througout the Federal Republic of Germany, 110p.

4.8 A novel method of calculating drift in orchards

Dirk de Hoog, Paul Goedhart, Jan van de Zande, Jan Huijsmans, Marcel Wenneker, Jean-Marie Michielsen, Hein Stallinga, Mostafa Snoussi

Wageningen Plant Research, Wageningen University and Research
Email address:dirk.dehoog@wur.nl

INTRODUCTION

In order to achieve current environmental demands it is important for orchard sprayers to reduce their drift to the environment. To determine the drift reduction of an orchard sprayer, field measurements are performed according the applicable protocols (ISO 22866, 2005; ISO 22369, 2006; TCT, 2017). These protocols clearly describe how a field measurement is to be performed but they do leave room for interpretation in how calculations are to be performed after the actual field measurement. We are making better use of the full set of measured values by doing a curve fit on a larger data set instead of just the presumed location of the ditch and the average is calculated in a more elaborate way using a Meta Analysis, which takes into account the standard error of the calculated drift reductions.

MATERIALS AND METHODS

Drift deposition curve fit

In the past, only the evaluation zone (4.5-5.5 m from the centre of the outermost row of trees, Huijsmans et al., 1997) was considered for the drift deposition calculation. In the new method, first a curve fit is done on all of the values of the continuous part of the measurement line (3-15 m from the outer tree row). Deposition data for Test machines are generally well described by a single exponential curve, while a double exponential curve is required to obtain a satisfactory fit for Reference machines. The following equations represent the single $P_T(x)$ and double $P_R(x)$ exponential curves:

$$P_T(x) = \beta \exp(-\delta\, x) \qquad [1]$$

$$P_R(x) = \beta_1 \exp(-\delta_1\, x) + \beta_2 \exp(-\delta_2\, x) \qquad [2]$$

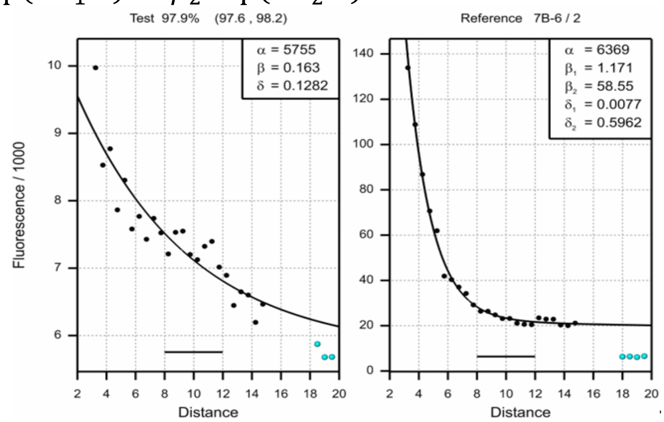


Figure 6. An example curve fit for a candidate (test, left) sprayer and the reference sprayer (right). The curve fit is done on the raw fluorometric data from the lab. In each figure, the estimated parameters of the exponential curve are given in the upper right corner, the test device corresponds to equation [1] and the reference device to equation [2]. The black dots represent the measured cloth corrected fluorescence of the collectors. The blue dots are the collector corrected fluorescence of demineralized water belonging to the measurement series, the distance at which they are shown is fictional, the corresponding distance according to the exponential model is actually infinity. The black horizontal line between 8 and 12 m. is the

estimated asymptote to which the exponential curve runs, this corresponds to the alpha parameter.

To obtain the percentage drift deposition P_i, the fluorescence F_i is calculated based on for a calibration constant K, a water flush volume V, the concentration of the fluorescent liquid in the spraying tank C and the area A_i of the cloth. The estimated drift reductions and their standard errors, for both the Test and Reference machine are then used to calculate the reduction percentage for each row along with a 95% confidence interval. This interval is obtained by application of the so-called delta method on the logit scale; the interval on the logit scale is then back-transformed to the percentage scale.

Meta analysis

The estimated reduction factors X for each duplicated row in multiple experiments, and their associated standard errors, are subjected to a meta-analysis in order to obtain a single estimate of the reduction factor of a Test machine. In the meta-analysis individual estimates are weighted by their standard errors such that more precise individual estimates have a larger weight than less precise estimates. The meta-analysis is performed on the logit scale because normality is better guaranteed on the logit scale than on the percentage scale, especially when reduction percentages are close to 100%. The estimated constant of the meta-model and the accompanying 95% confidence interval are back-transformed to the percentage scale to give the final result of the statistical analysis.

RESULTS AND DISCUSSION

The new components that were added to the way of calculating drift deposition and reduction from orchard sprayers give a more substantiated result. More of the collectors that are used during measurements are also being used in the calculation, which makes the outcome better represent the field measurements. Furthermore, the reliability of the results is evaluated using the 95% confidence interval, in the meta-analysis, this confidence interval is taken into account by giving the values with a smaller interval a higher weight in the calculation. So far, this analysis has been applied for the drift evaluation of 8 different DRT's over 2021 and 2022, which are now on the Dutch list of permitted DRT's (drift reducing technology ,TCT, 2023).

REFERENCES

Huijsmans, J.F.M., H.A.J. Porskamp & J.C. van de Zande, 1997. Drift(beperking) bij de toediening van gewasbeschermingsmiddelen. Evaluatie van de drift van spuitvloeistof bij bespuitingen in de fruitteelt, de volveldsteelten en de boomteelt (stand van zaken december 1996). IMAG-DLO

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. Meetprotocol vaststellen driftreductie spuittechnieken [versie 1 juli 2017]. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

TCT, 2023. Lijst met indeling van spuittechnieken in Driftreducerende Techniek-klassen (DRT-klassen) (DRT lijst). Versie 22 mei 2023. [https://www.helpdeskwater.nl/onderwerpen/emissiebeheer/agrarisch/open-teelt/driftreducerende/]

Session 5: environmental and operator safety

5.1 Do hydraulic pumps of sprayers influence the performance of *Beauveria bassiana* (Balsamo) Vullemin as biocontrol agent?

Roberto Beltrán-Martí[1], Cruz Garcerá[1], Jaime Cuquerella[1], Laura Catalá[1], Hector Izquierdo[1], Inma Garrido-Jurado[2], Patricia Chueca[1]

[1]Instituto Valenciano de Investigaciones Agrarias. Ctra. CV-315 km. 10,5. 46113 Moncada, Valencia (Spain)
[2]Department of Agronomy, Maria de Maetzu Excellence Unit DAUCO, ETSIAM, University of Cordoba, Campus de Rabanales, Building C4 Celestino Mutis, 14071 Cordoba (Spain)
E-mail: chueca_pat@gva.es

INTRODUCTION

Entomopathogenic fungi (EPF) have a great potential as biocontrol agents for crop pests but face challenges in field application for increasing their efficiency. One of the challenges is the equipment used to distribute them. Normally, traditional spray equipment designed for chemical pesticides are used but they can harm the microorganisms (Bateman et al., 1999). Limited research has studied spray equipment and its settings for EPF application. Factors like spray nozzle distance, nozzle type, and liquid pressure affect EPF distribution (Gouli et al., 2011; Hemalatha et al., 2017). Further research is needed to improve EPF delivery. This study aims to evaluate if two common pumps of hydraulic sprayers, diaphragm and piston pump, affect the viability of *B. bassiana* conidia and their infectivity against *Ceratitis capitata* (Wied.) (Diptera: Tephritidae) adults.

MATERIAL AND METHODS

Two assays were carried out, one for each hydraulic spray pump (diaphragm and piston). Each assay was conducted using a commercial product based on *B. bassiana* strain GHA at a concentration of 1.25 g L^{-1}. The diaphragm pump (ANNOVI REVERBERI AR 713, Modena, Italy) has a max flow of 76.1 L/min and can work at 550 rev/min, and at a maximum pressure of 4 MPa. The piston pump (COMET YA 65, Reggio, Italy) has 3 pistons, a max flow of 55 L/min, and can work at 650 rev/min, and at a maximum pressure of 5 MPa. To determine the effect of the pump on conidia, samples of the mixture were taken when it had passed 0 (negative control), 1, 10 and 30 times through the pump. To control the number of passes of the mixture through the pump a closed system using two connected spray tanks with a shut-off valve between them was designed. The viability of conidia present in the different mixture samples was assessed through the percentage of conidial germination. The infectivity of conidia was evaluated by spraying *C. capitata* adult flies with the different samples of mixture and assessing the percentage of mortality for 8 days. Also, the percentage of fungal outgrowth developed in death flies was measured to corroborate that the mortality was due to fungal infection. The temperature of the mixture was monitored during the assay. The experiments were replicated five times. The viability and infectivity data were analysed using a logistic regression and temperature was analysed using a simple regression (Statgraphics software). In all analysis the confidence level was 95%.

RESULTS

The germination percentage of *B. bassiana* conidia was above 88% in all cases, although it was significantly reduced with increasing passes for both pumps (diaphragm pump: $p<0.001$; $\chi^2=16.64$; pistons pump: $p<0.001$; $\chi^2= 15.08$). Regarding the conidial infectivity, no significant differences were observed in the percentages of mortality and external fungal growth of flies sprayed with conidia that had passed through the pump, with respect to those sprayed with conidia that had not passed through ($p>0.05$) (Table 1). The temperature of the mixture increased significantly with the number of passes in the two pumps (*p*>0.05), the increase being more noticeable when the diaphragm pump was used. However, in any case the temperature reached 30ºC.

Table 1. Mortality and fungal outgrowth of *C. capitata* adults sprayed with *B. bassiana* conidia that had pass through the hydraulic pumps. In the last row, the p-value and the χ^2 obtained in the logistic regression for each pump and parameter is presented.

Number of passages	**Diaphragm pump**		**Piston pump**	
	Mortality (mean ± SE) %	**Fungal outgrowth (mean ± SE) %**	**Mortality (mean ± SE) %**	**Fungal outgrowth (mean ± SE) %**
0	66.78 ± 8.85	75.92 ± 3.17	61.6 ± 9.78	56.73 ± 11.66
1	69.5± 8.99	67.23 ± 1.75	62.73 ± 7.34	62.06 ± 10.25
10	75.5 ± 6.08	74.04 ± 3.23	66.07 ± 8.63	55.67 ± 9.25
30	73.11 ± 5.33	66.63 ± 3.54	68.17 ± 8.68	62.78 ± 9.19
Logistic regression	*p*= 0.1981	*p*= 0.1999	*p*= 0.0957	*p*= 0.7763
χ^2	1.66	1.64	2.78	0.08

DISCUSSION

Even there was a reduction in conidial germination of *B. bassiana* for both pumps, reduction was that low that biopesticide's efficacy did not diminish. The loss in germination percentage could be due to the mechanical damage that can be caused by the shear effect exerted on the mixture when it is pumped, which Fife et al. (2007) demonstrated for entomopathogenic nematodes. The optimal temperature range for conidial germination and hyphal growth was determined to be between 20 and 30°C (Jayaprakash & Saranraj, 2017), and in this study the temperature did not reach 30ºC in any case. In view of these results, both hydraulic pumps tested seem to be an adequate element in the hydraulic sprayers for the application of *B. bassiana* conidia, however, to guarantee its optimal application it is recommended to control the temperature of the mixture, ensuring it remains below 30°C.

REFERENCES

Bateman, R. (1999). Delivery systems and protocols for biopesticides. In Biopesticides: use and delivery, Humana Press, 509-528.

Fife, J. P., Ozkan, H. E., Derksen, R. C., & Grewal, P. S. (2007). Effects of pumping on entomopathogenic nematodes and temperature increase within a spray system. Applied Engineering in Agriculture, 23(4), 405-412.

Gouli, V., Kassa, A., Skinner, M., & Parker, B. L. (2011). Fungal conidia distribution on chrysanthemum: varying spray parameters. Archives of Phytopathology and Plant Protection, 44(6), 567-574.

Hemalatha, S., Ramaraju, K., & Jeyarani, S. (2017). Influence of ultraviolet light protectants on the persistence of the entomopathogenic fungus Beauveria bassiana. Journal of Biopesticides, 10(2), 130-134.

Jayaprakash, A., & Saranraj, P. (2017). Agrobeneficial entomopathogenic fungi—Beauveria bassiana. IAJMR, 3(2), 1051-1087.

5.2 Inspection of sprayers from the fruit growing sector

Bouchekoum, N.; Douzals, J. P, Grimbuhler, S.

INRAE UMR ITAP, Univsersité de Montpellier (France);
Email: *nesrine.bouchekoum@inrae.fr*

INTRODUCTION

France is the second-largest wine producer and the fifth largest producer of fruits and vegetables in Europe (Eurostat, 2023). The agricultural sector is currently undergoing an agro-ecological transition, aiming to balance economic performance and environmental protection. The success of this sector relies heavily on the efficient utilization of various factors, including plant protection equipment. The Néopulvé project focuses on improving the performance and use of sprayers for sustainable agriculture and the reduction of pesticide use by developing training material for farmers based on the sprayer inspection data (Bouchekoum et al., 2023).

MATERIALS ET METHODS

Since January 01/01/2009, about 340,000 sprayers have been inspected based on the mandatory sprayer inspection database representing 236 000 individual sprayers currently in use. Each sprayer is identified (i.e. manufacturer, model, options), and also related to a cropping system or to a sprayer architecture (boom sprayer or booms for herbicide application, vineyard, orchard, fixed and semi-mobile sprayers). The type and likelihood of sprayer defaults were combined with the age and kind of sprayer technology. To a list of 259 potential defaults was defined in the inspection: a) defaults not requiring a reinspection, b) default requiring a partial reinspection and c) default requiring a complete reinspection (Table 1).

RESULTS AND DISCUSSION

The database contains approximately 62,000 orchard and vine sprayers from different technologies such as pneumatic sprayers, mistblowers, self-propelled side-by-side sprayers, and air-assisted sprayers. Approximately 24% of the inspected orchard and vineyard sprayers could only be approved after repair and most of these sprayers age range between 10 and 20 years old.

Out of the 86,000 sprayer inspections conducted on both orchard and vineyard sprayers, 5,052 orchard sprayers and 14,682 vineyard sprayers were found to be partially or totally non-compliant.

The main defaults were also studied according to the age of the sprayer, and showing in some cases an increase of defaults with the age, or sometimes, defaults appearing on new machines as well. The project aims at quantifying the impacts of these main defaults on spray dosage, spray distribution on crops, but also from the environmental, health and safety side. This is realized with the assistance of a group of experts using simulations and experiments. The final goal is to design a training course that addresses these impacts not only for the fruit growing sector but also for other cropping systems in France.

Table1: Example of defaults observed for sprayers use in viticulture.

Default without reinspection	**Defaults with partial reinspection**	**Defaults with full reinspection**
Filters (49%)	Pressure indicator accuracy (10%)	Fan clutch (2%)
Pb tank level indicator (43%)	Absence of mixing device (7%)	Absence/damage PTO shaft protection (2%)
Absence of cleaning /rinsing (33%)	Pressure level between nozzle holders (6%)	Dirty sprayer (0.2%)
Absence of induction bowl (29%)	Global nozzle wear (5%)	Major leaks (0.1%)
Lights/road compliance (28%)	Absence tank level indicator (3%)	Non-functioning sprayer (0.1%)
Absence of compensation control (27%)	Absence anti-dripping (2%)	

ACKNOWLEDGEMENTS

Authors would like to thank OTC Pulve for the data and collaboration.

REFERENCES

Eurostats 2023. https://ec.europa.eu/eurostat/fr/web/agriculture/data

Bouchekoum, N., Douzals, JP. Grimbuhler, S. (2023) Development of a training course on sprayer calibration and settings based on sprayer inspection database in France. SPISE Workshop, Den Haag, The Netherlands, May 2-4 2023.

5.3 NewPom Project: Worker exposure to pesticides in apple orchards

Sonia Grimbuhler[1], François Laurent[2]

[1]*INRAE ITAP, Univ. Montpellier, INREA, Institut Agro, Montpellier, France*
[2]*INRAE, UMR Toxalim,Chemin de Tournefeuille, 31027 Toulouse cedex,*
Email address: sonia.grimbuhler@inrae.fr,

INTRODUCTION

Apple orchard workers are exposed to pesticides during spray liquid preparation, treatment and equipment cleaning, as well as during re-entry phases and activities in treated plots, such as manual thinning, or opening and closing nets and harvesting (Cock et al., 1998; Fenske et al., 2003; Sankaran et al., 2015; Bureau et al., 2022). Several factors, such as weather conditions, type of activities, work intensity, and the way a task is carried out influence this exposure. Dermal exposure, the main route of exposure for workers, can last for several days after treatment (Wolf et al., 1975; Sankaran et al., 2015). After pesticide treatment, a re-entry period of 6 h to 48 h (depending on pesticide toxicity) must be observed before entering a treated plot (Arrêté 14.02.23). However, after these time limits, workers are still exposed to pesticides. The NEWPOM project aims to gain a better understanding of apple orchard workers' skin exposure to pesticides during re-entry tasks, in order to co-construct prevention messages and recommendations to reduce workers' exposure.

MATERIALS AND METHODS

After informed consent, 30 workers from the Tarn-et-Garonne region (France) volunteered to participate in the project. Their physical constraints were characterized by physiological measurements and postures analysis obtained through an ergonomic assessment. Analysis of workers' postures during manual thinning, opening and closing nets and harvesting helps to explain the differences in exposure between workers. Their exposure was determined for the three re-entry tasks: manual thinning, opening and closing nets and harvesting. Potential worker dermal exposure was characterized for different body zones. The protective gear worn by workers was divided into 7 body parts (right and left arms, torso, back, right and left legs, head) and gloves at the end of the activity. Actual dermal exposure was determined from cotton undergarments supplied to workers. The undergarments were cut into 6 body parts (right and left arms, torso, back, right and left legs), and hands and face were cleaned with 2 separate wipes (Ramos et al., 2010).

At the same time and in the same plots, leaves and apples were sampled to determine the amounts of plant protection products deposited onto the vegetation (Choi, 2023). On these samples, the dislodgeable foliar residues (DFR) of captan and its degradation product, THPI (tetrahydrophalimide) were measured. On some samples, non-targeted screening approaches for pesticide residues were used.

Dermal skin pesticide levels were correlated with leaves and apples levels using Pearson correlation coefficient. Determinants of dermal pesticide levels were studied using linear regressions, with exposure as dependent variable, the independent variables consisting of demographic, behavioural, technical and organizational factors.

RESULTS AND DISCUSSION

A dozen pesticides were identified in leaves and fruits harvested in August 2017, including captan and dithianon (with concentrations of 3.9 and 56 ng/cm², respectively). Concentrations found on vegetation were 3 times higher during thinning than during harvesting. Potential dermal exposure (PDE) to hands after a day's thinning, without gloves, averaged 0.016 mg/kg body weight/days when applying the DFRfruit model. If the DFRleaf model was used, the mean PDE was 25 times higher (0.4

mg/kg pc/d). In this case, exposure of apple orchard workers without PPE would be 8 times higher than the acceptable operator exposure level (AOEL) for captan (0.25 mg/kg pc/d).

Residue concentrations on skin, underwear and work clothes showed that all body parts are exposed to pesticides. The most contaminated areas of the body were the forearms (7 µg/cm²), followed by the arms and torso (0.2 µg/cm²). Surprisingly, left hands were 3 times more contaminated than right hands (48.5 and 17.5 µg/d, respectively). The face is also contaminated, albeit to a lesser extent (3 µg/d). Regarding the different work phases, workers are more exposed during thinning than harvesting, in relation with a higher vegetation contamination.

Estimates of exposure and contamination show that clothing ensures good protection from pesticides risk, but does not offer total protection, as exposure is only reduced by 90-95%. However, during hot spells, PPE are often opened or even removed increasing workers exposure through indirect contact with vegetation well above AOELs.

To conclude, although largely underestimated, apple orchard worker exposure to pesticides can exceed the AOELs. There is, therefore, an urgent need to raise awareness about pesticide risks among these workers, wrongly considered as the least exposed in orchard farms.

REFERENCES

Bureau, M., Béziat, B., Duporté, G., et a., (2022). Pesticide exposure of workers in apple growing in *France. International Archives of Occupational and Environmental Health, 95:811–823*

Choi, H. (2023. Transfer factor calculated using dermal exposure and dislodgeable foliar residue and exposure assessment for reentry worker after pesticide application in cucumber field. Applied Biological Chemistry, 66(1):9p.

Cock, J.D., Heederik, D., Kromhout H., et al. (1998). Exposure to captan in fruit growing. Am Ind Hyg Assoc J, 59, 158-165.

Fenske, R., Curl, C., Kissel, J. (2003). The effect of the 14-day agricultural restricted entry interval on azinphosmethyl exposures in a group of apple thinners in Washington state. Regul Toxicol Pharmacol., 38, 91–97.

Legifrance, (2023). Order of February 14, 2023 on measures to protect people when using certain phytopharmaceutical products and amending the order of May 4, 2017 on the marketing and use of phytopharmaceutical products and their adjuvants referred to in Article L. 253-1 of the Rural and Maritime Fishing Code, JORF n°0068 du 21/03/2023

Ramos., L.M., Querejeta G.A., Flores P., et al. (2010). Potential Dermal Exposure in greenhouses for manual sprayers: Analysis of the mix/load, application and re-entry stages. Stoten, 408, 4062-4068.

Sankaran, G., Chen, L., Chen, Z.S., et al. (2015).The importance of hand exposures to absorbed dosage of hand harvesters. J Toxicol Environ Health, Part A , 78, 1369-1383.

Wolfe, H.R, Armstrong, J.F, Staiff, D.C, et al., (1975). Exposure of apple thinners to parathion residues. Arch Environ Contam Toxicol., 3(3):257-67.

5.4 Indoor measurements to develop a methodology for spray mass balance assessment from air-assisted sprayers

Paolo Marucco [1], Paolo Balsari [1], Sebastien Codis[2], Fabrizio Gioelli[1], Marco Grella [1], Olivier Naud [3], Marco Resecco[1], Elodie Trinquier [2], Adrien Verges[2]

[1]Department of Agricultural, Forest and Food Sciences (DiSAFA), University of Turin (UniTO), Largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy
[2] French Institute of Vine and Wine (IFV) - 361, rue JF. Breton, BP. 5095 - 34196 Montpellier, France
[3] INRAE UMR ITAP, 361, rue JF. Breton, BP. 5095 - 34196 Montpellier, France
Email address: paolo.marucco@unito.it

INTRODUCTION

To know the allocation of the spray deposition (between target and losses in the atmosphere and to the ground) when applied on 3D crops, according to the sprayer type and configuration, as well as to the target size and density, it is useful in order: i) to assess the efficiency of treatment and, ii) to select the proper adjustment to optimise the spray distribution (Balsari et al., 2005). This evaluation, for providing comparable results, should be preferably made under controlled conditions both in terms of environmental parameters (e.g. temperature, humidity, wind speed and direction, etc.) and of target characteristics (e.g. canopy height, width, number of leaf layers, etc.). In connection with the activities made during the Life PERFECT project (www.perfectproject.eu), one specific research was carried out by DISAFA-UNITO (Italy) together with IFV-INRAE (France). The aim was to compare the spray mass balance measured indoor with different settings of a conventional axial fan air-assisted sprayer - previously used in the field for the PERFECT project experiments - to apply artificial vineyard rows, adequately sized, to mimic different growth stages.

MATERIALS AND METHODS

The tests were carried out indoor in a testing hall (length 40 m x width 30 m, x height 5 m) at DISAFA-UNITO premises (Grugliasco, Italy). A specific metal structure designed to hold filter clothes (20 x 10 cm, Camfil) used as artificial collectors, to sample the off-target losses to the air, around and over the treated rows was used together with EvaSprayViti, the artificial vine developed in France by IFV and INRAE. The EvaSprayViti test bench is a modular artificial vine composed of 4 rows 10 meters long, used for measuring the deposition and its distribution within the canopy. The test bench is adjustable and can be set to reproduce three vegetative stages of the vine (i.e. early growth stage, middle and full growth stage). The results of sprayer tests carried out with EvaSprayViti are used in the sprayer quality labeling system (www/performancepulve.fr) set up since 2021 in France (Codis et al; 2023). The test bench is made of a metal frame holding vertical sticks provided with clips for hanging pieces of white PVC (10 x 10 cm) which mimic real vine leaves (Fig. 1). Further artificial filter clothes collectors aree placed on the ground between the two vertical elements of the structure holding the filter clothes besides the rows, so to collect spray ground losses. This way a complete spray mass balance can be assessed, determining the average spray deposits on the target, on the ground and in the atmosphere besides and over the treated rows, and referring the sum of the measured deposits to the amount of effectively sprayed mixture. All trials were conducted with a Dragone Gamma 600 axial fan sprayer equipped with conventional or air induction hollow cone nozzles (Albuz ATR 80 lilac or Albuz TVI 8001, respectively) combined with different fan and air deflectors settings (1 - high fan gear, air deflectors not well adjusted, and 2 - low fan gear air, deflectors oriented to match the canopy height, respectively). Tests were carried out simulating two different growth stages (early and late), by adequately sizing the artificial rows. The right number of nozzles to cover the canopy profile was activated accordingly. Working at forward speeds between 5.0 and 5.8 km/h and at working pressures between 0.7 and 1.1 MPa, operating with an inter-row distance of 2.5 m, the volume application rates ranged from 160 to 320 L ha^{-1}.

A water solution of yellow tracer Tartrazine E102 (10 g L^{-1}) was used in the experiments. After spraying, artificial leaves and the filter clothes were collected and then washed with a known amount of deionised water in laboratory. The resulting washings were analysed with a spectrophotometer set at 427 nm wavelength (peak of absorption of the dye) as well as those from the samples of the applied original spray mixture taken from the tank. Relying on the absorbance values obtained, deposits of the original spray mixture on both the artificial rows (leaves + sticks) and on the filter clothes placed around, over and under the rows were determined and afterwards expressed in µL cm^{-2}. The sum of the average deposits obtained in all the sampling positions was compared with the liquid sprayer output referred to one cm of sprayer advancing, so to estimate the spray recovery rate of the collectors' system. This sum was also used as reference to establish the allocation of the spray applied between the target, the ground and the atmosphere surrounding the rows.

Results are still under elaboration, but a first summary will be ready to be presented during the Suprofruit 2023 Workshop.

REFERENCES

Balsari, P., Marucco P., Tamagnone M. (2005). A system to assess the mass balance of spray applied to tree crops. Transactions of the ASAE 2005 Vol.48 No.5 pp.1689-1694. DOI : 10.13031/2013.19997.

Codis S., Vergès A., Ribeyrolles X., Delpuech X., Lewis M., Cheraiet A., Trinquier E., Auvergne C., Naud O. (2023). PERFORMANCE PULVÉ®: a labelling system for vineyard sprayers based on their performance in terms of spray quality and potential for PPP dose reduction. Review after two years of implementation.

Vergès A., Codis S., Carra M., Delpuech X., Montegano P., Ruelle B., Savajols S., Ribeyrolles X. (2017). Sprayer's classification in viticulture according to their performance in terms of deposition and dose rate reduction potential. 14th Workshop on Spray Application Techniques in Fruit Growing (Suprofruit) Hasselt Belgium May 2017.

Figures

Fig. 1. General overview of experimental layout: artificial rows provided with small plastic collectors to mimic vine leaves and metal structure realised to surround the treated rows holding filter clothes collectors besides and over the applied rows.

Acknowledgements

The research activities were carried out within the funded Life PERFECT project (LIFE17 ENV/ES/000205).

Suprofruit 2023 – Book of abstracts
Editors:
Jean - Paul Douzals
Marcel Wenneker

DOI : https://doi.org/10.17180/JYS4-6D44