SuproFruit 2009
10th Workshop on

Spray Application Techniques in Fruit Growing

September 30-October 2, 2009
Wageningen, The Netherlands

Book of abstracts

Editors

M. Wenneker
J.C. van de Zande

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WAGENINGEN UR
For quality of life

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Hof van Wageningen, Wageningen
The Netherlands

Editors: M. Wenneker, J.C. van de Zande

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Welcome to SuproFruit 2009

Dear participants,

This ‘SuproFruit 2009 Book of Abstracts’ contains the abstracts of the papers and the posters presented at the 10th Workshop on Spray Application Techniques in Fruit Growing, held in Wageningen the Netherlands September 30 – October 2, 2009. This series of Workshops has a tradition bringing together people from research, industry and extension. The Workshops give the opportunity for presenting, discussing and exchanging information in an open atmosphere about matters dealing with all aspects of application techniques in fruit growing. The workshops started in 1992, with a first meeting gathered in Wageningen by Bart Heijne. This 10th Workshop is again in Wageningen, showing that a round table meeting has grown to a semi-conference with 40 presentations in three days, including an interesting excursion day to the fruit growing area around Wageningen.

We want to thank all authors for their interest in this conference and for writing abstracts. We also want to acknowledge the sponsors for their contribution, and the sprayer manufacturers for their involvement in the field demonstration. Plant Research International and Applied Plant Research – section Fruit are thanked for bearing the organizational risks. The scientific committee and the session chairmen are thanked for their contributions and efforts, with special thanks to Dr. Greg Doruchowski as workshop convener. The local organizers Hedy Wessels, Kees van Nes, Fred Geers, Jean-Marie Michielsen and Nina Joosten and the others of the Crop Protection group at WUR are thanked for their work to make this conference a success.

Jan van de Zande
Marcel Wenneker

Workshop co-ordinators

Sponsors

The Organising Committee gratefully acknowledges the support of:

Albuz

Dutch Ministry of Agriculture, Nature and Food Quality

Koninklijke FruitmastersGroep

KWH

Nederlandse Fruittelers Organisatie

Syngenta Global

TeeJet Technologies

Van de Munckhof

Wageningen University and Research Centre

Waterschap Rivierenland

General information

Conference organisation and venue

The 10th Workshop on Sustainable Plant Protection Techniques in Fruit Growing is held in Wageningen, the Netherlands from September 30th until October 2nd, 2009. The workshop – Suprofruit2009 – is organized by Plant Research International and Applied Plant Research of the Wageningen University and Research Centre. The workshops on Spray Application Techniques in Fruit Growing, organized since 1991, have always served as platform for open discussion between researchers, manufacturers, as well as policy-makers involved in fruit growing, crop protection, application technology and environmental issues.
The workshop covers the state of the art, novel ideas, new approaches and latest developments in technology and methods that will increase the precision in application of plant protection products and reduce the risks for consumers and the environment. The most recent advances are presented in lectures by scientists and guest speakers and in posters. One day in the programme is allocated for an excursion against the inspiring scenery of orchards in the heart of the fruit producing area in the Netherlands. As in the past, we expect a lively international meeting with contributions from many parts of the world.

Abstracts

This book contains the abstracts of keynote speakers, followed by the abstracts of oral presentations, and finally the poster abstracts.The posters are arranged in alphabetical order of first author. The organising committee does not take any responsibility for scientific or typographical errors.

Posters

Posters are on display during the congress. Authors of posters are requested to be present at their poster during the poster sessions at the times indicated in the program, in order to stimulate discussions.

Programme overview

Wednesday 30 September 2009	SuproFruit2009 - programme	
08:30 - 09:30 hrs	Registration	
Opening session Session leader Doruchowski, G.	**Guest speakers**	**Title of presentation**
09:30 - 09:35 hrs	Doruchowski, G.	Convenor – opening of workshop
09:35 - 09:55 hrs	Heer, H. de	Dutch ministry of agriculture, nature and food quality - spray technique in the authorisation process of ppp
09:55 - 10:10 hrs	Heijne, B.	Ten workshops spray application techniques in fruit growing
10:10 - 10:20 hrs	Koning, S.	Director Dutch fruit growers association (NFO) – Importance of spray technique developments for the fruit growers
10:20 - 10:35 hrs	Rousseau, J-C.	Autonomous spraying in pomefruit orchards
10:35 - 10:50 hrs	Corelli Grapadelli, L.	ISAFRUIT – Role of spray technique research in safe and environmental friendly production of fruit
10:50 - 11:10 hrs	Coffee break	
Session: ISAFRUIT Session leader Landers, A.	**Authors**	**Title of presentation**
11:10 – 11:30 hrs	Balsari, P., Doruchowski, G., Marucco, P., Tamagnone, M., Zande, J.C. van de, Wenneker, M.	Assessment of spray deposits and biological efficacy in apple orchard using a crop identification system (CIS)
11:30 – 11:50 hrs	Doruchowski, G., Swiechowski, W., Godyn, A., Holownicki, R.	Spray deposit in apple canopies as affected by low drift application strategies with environmentally dependent application system
11:50 – 12:10 hrs	Zande, J.C. van de, Meuleman, J., Wenneker, M.	Early detection of apple scab in apple leaves; development of a crop health sensor (CHS)
12:10 – 12:30 hrs	Wenneker, M., Zande, J.C. van de, Poulsen, M.	Effect of nozzle type on pesticide residues on fruits
12:30 – 14:00 hrs	Lunch and Posters	

Session: Spray drift Session leader Gil, E.	Authors	Title of presentation
14:00 – 14:20 hrs	Michielsen, J.M.G.P., Zande, J.C. van de, Wenneker, M.	Nozzle classification for drift reduction in orchard spraying; effect of nozzle type in a dormant stage orchards
14:20 – 14:40 hrs	Stallinga, H., Zande, J.C. van de, Michielsen, J.M.G.P., Lans, A.M. van der, Velde, P. van, Massink, G.	Spray drift caused by a mast sprayer adapted to high trees
14:40 – 15:00 hrs	Solanelles, F., Gregorio, E., Sanz, R., Rosell, J. R., Arnó, J., Planas, S., Escolá, A., Masip, J., Ribes-Dasi, M., Gracia, F., Camp, F.	Spray drift measurements in tree crops using a lidar system
15:00 – 15:20 hrs	Salyani, M., Miller, D., Farooq, M.	Effects of spraying parameters on drift potential of citrus air-carrier sprayers
15:20 – 15:40 hrs	Dröge, K., Nobbmann, J., Schmidt, K., Ganzelmeier, H.	Environmental friendly plant protection with innovative spraying systems – results of a four years project funded by BLE Germany
15:40 – 16:00 hrs	Wenneker, M., Zande, J.C. van de, Stallinga, H., Michielsen, J.M.G.P., Joosten, N.	Comparison of spray drift between an axial fan and a cross flow sprayer
16:00 – 16:20 hrs	Pergher, G., Petris, R.	An air-assisted tunnel sprayer for vineyards: spray recovery rate under static and dynamic conditions
16:40 – 17:10 hrs	Break and posters	

Session: Small fruits Session leader Pergher, G.	Authors	Title of presentation
17:10 - 17:30 hrs	Nuyttens, D., Braekman, P., Foqué, D.	Comparison between novel and traditional spray application techniques in strawberries
17:30 - 17:50 hrs	Bjugstad, N., Hermansen, P.	Potential operator exposure when spraying raspberries in a tunnel system

Session: Residue & Dosage Session leader Pergher, G.	Authors	Title of presentation
17:50 - 18:10 hrs	Simonse, R.	Residue and retail
18.10 - 18:30 hrs	Cross, J.	Outline report of the first meeting of the Tree Fruits Dose Adjustment Discussion Group, Wageningen, 29 September 2009
19:00 hrs	Joint dinner	

Thursday 1 October 2009	**Programme Excursion**
08.00 hrs	Departure Wageningen bus 1 and bus 2 to Fruitmasters Geldermalsen
09.00-09.30 hrs	Arrival at Fruitmasters coffee and presentation
09.30-11.00 hrs	Tour around Fruitmasters
11.00-12.00 hrs	Departure bus 1 to Wageningen
11.00-12.00 hrs	Departure bus 2 to Echteld
	Lunch will be provided in the busses
12.00-13.00 hrs	Arrival bus 1 at Wageningen For a tour and presentation at the spraying lab
12.00-13.00 hrs	Arrival bus 2 at Echteld For a tour and presentation at the fruit grower
13.00-13.30 hrs	Departure bus 1 to Echteld
13.00-13.30 hrs	Departure bus 2 to Wageningen
13.30-14.30 hrs	Arrival bus 1 Echteld For a tour with the fruit grower
13.30-14.30 hrs	Arrival bus 2 Wageningen For a tour around spraying lab
14.30-15.00 hrs	Departure and arrival bus 1 and bus 2 to PPO Randwijk
15.00-22.00 hrs	Arrival bus 1 and bus 2 and start programme PPO Randwijk, including presentations, drinks and dinner
22.00-22.30 hrs	End of the programma excursion Departure and arrival bus 1 and bus 2 at Hof van Wageningen

Friday 2 October 2009 Session: spray deposition + biological efficacy Session leader Balsari, P.	Authors	Title of presentation
8:30 - 8:50 hrs	Marucco, P., Balsari, P.	Spray application of micro encapsulated pheromones in apple orchards
8:50 - 9:10 hrs	Walklate, P.J., Cross, J., Harris, A.L., Richardson, G.M.	The variation of leaf deposit with volume application rate and the onset of saturation during tree fruit spraying with an air-assisted knapsack
9:10 - 9:30 hrs	Ioriatti, C., Angeli, G., Rizzi, C., Salgarollo, V., Calvi, P., Wohlhauser, R., Wolf, S.	Management of pesticide dosages and water volumes in relation to the vegetative development of pome fruit trees in Italian orchards
9:30 - 9:50 hrs	Loquet, B., Siham, M., Zavagli, F., Gleizer, B.	Reducing drift during spray application in orchard: efficiency of nozzles
9:50 - 10:10 hrs	Coffee break	
10:10 -10:30 hrs	Kaul, P., Gebauer, S., Moll, E., Ralfs, J-P., Dröge, K.	Adjustment of the quantity of chemicals according to the density and extension of the canopy
10:30 -10:50 hrs	Chueca, P., Garcerá, C., Pina, T., Urbaneja, A., Jacas, J., Moltó, E.	Optimization of water volume used in mineral oil applications tot control *Tetranychus urticae* in citrus
10:50 - 11:10 hrs	Fourie, P.H., Brink, J.C., Schutte, G.C., Grout, T.G.	Optimal use of spray machines in South African citrus orchards

Session: new spray technology Session leader Salyani, M.	Authors	Title of presentation
11:10 - 11:30 hrs	Landers, A.	In pursuit of the inevitable – the development of an autonomous sprayer for fruit crops
11:30 - 11:50 hrs	Tamagnone, M., Balsari, P., Marucco, P., Oggero, G.	Homogenisation of air flow generated by axial fans used on orchard sprayers
11:50 - 12:10 hrs	Gil, E., Llorens, J., Llop, J.	Variable rate technology for vineyard sprayers: challenges of electronic devices for crop characterization
12:15 - 13:15 hrs	lunch + posters	
13:15 - 13:35 hrs	Escolà, A., Arnó, J., Sanz, R., Camp, F., Masip, J., Solanelles, F., Rosell, J.R., Planas, S.	Real time foliage density estimation with a lidar sensor for precision fructiculture/horticulture applications. A methodology for field validation
13:35 - 13:55 hrs	Melese Endalew, A., Debaer, C., Rutten, N., Vercammen, J., Delele, M.A., Ramon, H., Nicolaï, B., Verboven, P.	CFD evaluation of the airflow from three types of sprayers in pear orchard trees using 3D canopy architecture
13:55 -14:15 hrs	Smit, G.R.J.	Pulstec technology – A new way of controlling liquids in agricultural spraying
14:15 - 14:30 hrs	Coffee break	

Session: environment and technique Session leader Holownicki, R.	**Authors**	**Title of presentation**
14:30 - 14:50 hrs	Balsari, P., Tamagnone, M.	Reducing noise from air-assisted sprayers
14:50 – 15:10 hrs	Roettele, M., Balsari, P., Doruchowski, G., Petersen, P.H.	Technical improvements to reduce surface water pollution with Plant Protection Products (ppp) from point sources
15:10 - 15:30 hrs	Klausen, N.E., Høy, J.J., Andersen P.G.	Test of equipment for internal rinsing of sprayers – three systems for subsequent installation
15:30 - 15:50 hrs	Kole, J.C.	Orchard sprayer inspection in the Netherlands
15:50 – 16:10 hrs	Leendertse, P.C, Visser, A., Balkhoven, H., Aalbers, P., Valstar, L.	Fruit crop and water protection in the region of the Bommelerwaard: new spraying techniques, integrated pest management and selection of pesticides
16:10 hrs	Doruchowski, G.	Convenor – closing of workshop
16:20 - 17:00 hrs	Farewell drink	

OPENING LECTURES

30/09/2009
Haakzaal

Spray technique in the authorisation process of PPP's

Heer, H. de

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The research cluster BO-Plant plant health runs from 2006 – 2010. The cluster contains all contract research commissioned by the Dutch Ministry of Agriculture that will be carried out by Wageningen UR. Research has to support the official Dutch policy as described in the document 'Towards sustainable crop protection in 2010', aiming at a considerable decrease of environmental impact of chemical plant protection products in 2010.
In the themes Water Framework Directive (WFD), Emission, and Plant Protection Products Authorization the effect of spray technique is addressed towards emission reduction and the use of emission reducing technology in the authorisation process of plant protection products (PPP's).
An overview is given on relevant Dutch and EU policy (Directive 91/414/EEC, Water Framework Directive, related to the use of application technology and the authorisation process of PPP's.

In the process of implementing the WFD, the Netherlands reached the conclusion that the requirements laid down in this Directive must be compatible with those of the Plant Protection Products (PPP's) Directive. As this is not yet the case, a project was started in NL in 2006 to develop a proposal. The Netherlands would like to share its views with the other Member States, with the intention of harmonizing the European authorisation process accordingly.
The core of the Dutch proposal is that authorisation criteria apply at two places in the water system: in smaller edge-of-field surface waters (e.g. drainage ditches) the existing criteria in the PPP Directive apply, whilst in larger water bodies (officially assigned as WFD water bodies) the standards derived according to the WFD methodology apply. The stricter of these two criteria will determine whether authorisation of the PPP is possible. Verification of the exposure concentrations in the WFD water bodies against WFD standards will take place using both models (pre-registration) and measurements (post-registration)**.**

References

LNV *(2004) Sustainable Crop Protection. Crop protection policy towards 2010. Ministry of Agriculture Nature Management and Food Quality, The Hague, 2004. 44pp. (in Dutch)*

Ten workshops spray application techniques in fruit growing

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Spray application is today an important issue both by policy makers and as a research subject. This is especially so in fruit growing. Droplets can drift high in the air by the horizontal and upward directed air support into neighbouring fields and field margins including a diversity of water courses. Deposits of pesticides, meant to control pests and diseases, are today more and more seen only, as risks to the environment and to human health. That was different thirty years ago. Of course, visionary researchers saw the phenomenon of unwanted drift and developed a full automatic, self driving tunnel sprayer called OOSEF in the 1980's (Werken, 1991). But, this was too far ahead of practice and was mostly laughed at. None-the-less, the idea and principles ware picked up again in 1990. Inspired by a car engineer, Norbert de Schaetzen, the Royal Research Station of Gorsem, in Belgium, started tests with a Joco tunnel sprayer equipped with rotary atomisers. Also, the research institute IMAG (now WUR/PRI) developed a pulled tunnel sprayer based on their OOSEF model, which was field tested in Numansdorp, The Netherlands (Heijne *et al*., 1993). Exchange of ideas and results of the first field tests with tunnel sprayers was organised in Gorsem, Belgium in 1991 between researchers from Belgium and The Netherlands. The next year, 1992, a similar meeting was organised among researchers from France, Switzerland, Belgium and the Netherlands at the former Research Station for Fruit Growing (now WUR/PPO) in Wilhelminadorp, the Netherlands. Looking back, this meeting in the Netherlands was recognised as the first Workshop Spray Techniques in Fruit Growing. Workshops followed in different countries: 2nd La Morinière, France (1993), 3rd Wädenswil, Switzerland (1994), 4th East Malling, England (1995), 5th Radziejowice, Poland (1996), 6th Leuven, Belgium (2001), 7th Cuneo, Italy (2003), 8th Barcelona, Spain (2004), 9th Alnarp, Sweden (2007) and finally back in Wageningen, the Netherlands in this 10th workshop in 2009.
During the years, the type of meetings gradually changed. In the first years testing of different types of tunnel sprayers was the main subject of discussion. Nowadays, all aspects of spray application techniques are presented. Similarly, the character changed from literally working together and setting up common testing protocols with participants on invitation only. Towards a full symposium with presentations, posters and proceedings, recognised as an important forum on spray application techniques in fruit growing not only in Europe but worldwide.

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Werken, J. van de *(1991) The development of an unmanned covered air-assisted sprayer for orchards. In: Lavers A, Herrington P, Southcombe ESE (Eds.) Air-assisted spraying in crop protection. BCPC monograph no. 46, Farnham Surrey, UK, pp. 61-68.*

Importance of spray technique developments for the fruit growers

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The Dutch Fruit Growers Association (NFO) is an association of the professional fruit growers in the Netherlands, and aims to enhance or strengthen fruit growing in the Netherlands. The NFO has 3100 members; of which 1600 are fruit growers (12000 hectares). This group represents 85% of the professional fruit growers in the Netherlands. The activities of NFO comprise of 3 main categories:

1. promotion of fruit growers' interests,
2. strengthening/enhancement of knowledge and entrepreneurship, and
3. services towards NFO members.

Key elements in the activities are crop protection and drift reduction (i.e. production, quality and environment); labor issues, promotion of fruit products, enhancement of markets and research. The NFO provides the fruit growers in several ways with technical, economic and policy information; e.g. the Fruit Growers Magazine (Fruitteelt), internet, meetings and demonstrations.

Spray drift in fruit growing is high and drift reducing measures are therefore necessary as indicated in different governmental action plans and regulations like the Water Pollution Act and the Authorization Procedure for Plant Protection Products (PPP). Spray free and crop free buffer zones were introduced, to minimize the risk of mainly spray drift (Water Pollution Act, Plant Protection Act). Recently, new legislation is set into force, in which it is specified that fruit growers have to achieve 90% drift reduction compared to standard spray applications with a cross flow sprayer. At this moment, 7 drift mitigation measures for fruit growing are accepted by water control authorities; e.g. crop free buffer zone of 9 meters, windbreaks (hedgerows), tunnel spraying and specific coarse droplet applications. The NFO actively stimulates spray technique research, and participates in the communication with water boards and the Board for the Authorisation of Plant Protection Products and Biocides (Ctgb).

In general, the acceptance of spray drift reducing methods by fruit growers will depend on economical impact (labour and investment costs), plant protection efficacy (biological efficacy) and legal aspects. Recycling, sensor equipped and shielded sprayers offer advantages regarding labour reduction (cost savings), spray volume reduction (cost savings), spray drift reduction (environment), the possibility to spray a wider range of pesticides (legislation), optimal timing for the chemicals (less dependent on weather conditions), and less exposure of operators to spray liquid. Recently, double tunnel sprayers and multi-row cross flow sprayers have been assembled, helping to reduce the labor costs, enhance optimum timing for spraying and increase fuel and spray volume savings. The development of autonomous driving (spraying) machine would also save much precious labour time. The NFO is involved in a project to evaluate the potential of developing an autonomous spray technique for apple and pear orchards.

Recently, food retailers or major European supermarkets have started demanding additional quality standards in terms of residue levels which have been standards that are much stricter than the legally binding standards set by the authorities. For fruit growers it is difficult to meet these additional standards, because especially pre-harvest sprayings are necessary to produce high quality fruit that can be kept in long storage facilities. Innovative spraying techniques could be helpful avoid overdosing, and lower residue levels on fruits.

Autonomous spraying in pomefruit orchards

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Introduction

BERTHOUD has been innovating for over 100 years to provide their customers with accurate, reliable, high-performance crop sprayers. They use cutting-edge technology to create products in compliance with international standards for integrated farming methods with respect to our environment and the quality of the crops.
The view of a leading manufacturer of application techniques in orchard, bush and grape spraying is given on the developments in spray technique and what they see as opportunities, challenges and pitfalls. The perspectives of future developments in sprayer development in fruit growing are given:

- spray drift control
- dose control
- optimal spray distribution
- sensing
- automation.
- robotising.

ISAFRUIT - Role of spray technique research in safe and environmental friendly production of fruit

Corelli Grapadelli, L.

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ISAFRUIT is a European Integrated Research Project that focuses on all aspects of fruit from its start as a seed till a consumer bites into a juicy end product. It has been awarded under Thematic Priority 5 - Food Quality and Safety of the 6th Framework Programme or RTD (Contract no. FP6-FOOD 016279-2). Approximately 200 researchers from 60 Research and Development Institutions and SMEs in 16 Countries co-operate in this 13.8 Million € project, which runs from January 2006 until the summer of 2010.
The strategic objective of ISAFRUIT is to increase fruit consumption, searching the improvement of health and well-being of Europeans and their environment, by taking a total chain approach, identifying the bottlenecks and addressing them by consumer-driven preferences. It is well documented that regular consumption of fruit and vegetables contributes to health by preventing cancer and cardiovascular diseases, although several factors can lead to insufficient fruit consumption:

1. Fruit on the market does not always meet consumer expectations.
2. Quality deterioration along the supply chain, price and availability are major problems.
3. Consumers often worry about pesticide residues in fruit and are concerned by the introduction of GMOs in the food chain.
4. Growers are in need of more sustainable production methods to meet the consumer expectations.

The long-term Mission of ISAFRUIT is to improve human health through increased consumption of fruit produced in a sustainable way. The Vision of ISAFRUIT is that better fruit quality and availability of a wider range of processed fruit products, more competitive and safer production systems and improved consciousness of consumers, lead to higher fruit consumption. Higher fruit consumption leads to increased health and wellbeing. ISAFRUIT activities (pillars) focus on:

1. Consumer driven and responsive supply chain
2. Fruit and human health
3. Improved appeal and nutritional value of processed fruit
4. Improved quality, safety and sustainability
5. Preharvest chain quality and sustainability
6. Genetics of fruit quality
7. Dissemination and transfer of knowledge
8. Project management and integration.

In the 5th Pillar: Preharvest chain quality and sustainability; the main subject is environmentally friendly fruit production through the development of sustainable orchard and fruit management techniques. These include: improved application of plant protection products, improved fertilizer application, "smart" management of renewable resources such as light and water, management of crop load, and improvement of apple quality. Within this Pillar, ISAFRUIT researchers are developing a sprayer that will ensure precise, efficient and safe pesticide applications in orchards, according to actual needs and with respect to the environment. A Crop Adapted Spray Application (CASA) was developed which consists of three sub-systems (i) a Crop Health Sensor, (ii) a Crop Identification System and (iii) an Environmentally Dependent Application System. The CASA system is presented to fruit growers in a cross-European demonstration tour visiting Denmark, Italy, Poland, The Netherlands, France and Spain.

SESSION ISAFRUIT

30/09/2009
Haakzaal

Assessment of spray deposits and biological efficacy in apple orchard using a Crop Identification System (CIS)

Balsari, P.[1], Doruchowski, G.[2], Marucco, P.[1], Tamagnone, M.[1], Zande, J.C. van de[3], Wenneker, M.[4]
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Introduction

An environmentally friendly orchard sprayer has been developed within the European Project ISAFRUIT (Increasing fruit consumption through a trans-disciplinary approach leading to high quality produce from environmentally safe sustainable methods). The sprayer is able to automatically adapt the application according to the characteristics of the canopy target (size and density), to the level of disease present in the canopy and to the environmental conditions (wind speed and direction). For the identification and the characterisation of the target, a Crop Identification System (CIS) based on ultrasonic sensors was developed by DEIAFA and 3B6 company (Balsari *et al.*, 2008). During 2008 season the CIS system mounted on the ISAFRUIT air-assisted sprayer prototype was tested in an apple orchard in order to assess spray deposits on leaves and fruits, ground losses and biological efficacy of treatments. Results were compared with those obtained using a conventional air-assisted sprayer. Tests were made in an apple orchard (cv. Gala) featured by a layout of 3.8 m (row distance) x 1.0 m (plant spacing) and with average tree height of 4.0 m.

Methodology of work

Spray deposition tests were made at two different growth stages: early development of fruits (BBCH 71) and shoot growth completed (BBCH 91). Tests were carried out applying an experimental mixture of water and yellow tracer (Tartrazine E102) 5% v/v. In the first round of experiments (BBCH 71 growth stage) two treatments were compared: 1) ISAFRUIT sprayer without the CIS activated and therefore applying the full rate volume (850 l/ha); 2) ISAFRUIT sprayer equipped with active CIS, applying a reduced volume rate of 435 l/ha.

In the second round (BBCH 91 growth stage) five thesis were compared: 1) ISAFRUIT sprayer without CIS activated (applied volume 850 l/ha), equipped with conventional flat fan nozzles; 2) ISAFRUIT sprayer with CIS activated (applied volume 540 l/ha), equipped with conventional flat fan nozzles; 3) ISAFRUIT sprayer without CIS activated (applied volume 850 l/ha), equipped with air induction flat fan nozzles; 4) ISAFRUIT sprayer with CIS activated (applied volume 540 l/ha), equipped with air induction flat fan nozzles; 5) conventional axial fan air-assisted sprayer equipped with hollow cone nozzles (applied volume 850 l/ha).

Leaf sampling was made following the indications of ISO 22522, for each thesis picking up 10 leaves from 7 positions in the canopy and replicating the sampling procedure on 3 trees. Ground losses were measured through rows of artificial collectors (250 x 100 mm) displaced flat on the ground in the inter row and under the trees. In the second round of tests, spray deposits on fruits were also assessed, for each thesis picking 30 apples from the higher part (h > 2.5 m) of the canopy and 30 apples from the lower part (h < 2.5 m) of the canopy.

Biological tests were conducted in the same apple orchard, starting from mid May and comparing the incidence of apple scab, powdery mildew and green apple aphids in experimental plots treated: with the ISAFRUIT sprayer equipped with the active Crop Identification System (volume applied ranging from 450 to 550 l/ha), with the ISAFRUIT sprayer without the CIS activated (volume applied 850 l/ha) and with a conventional axial fan air-assisted sprayer (volume applied 850 l/ha).

Results

Spray deposition tests pointed out that at the development of fruits growth stage (BBCH 71) the ISAFRUIT sprayer equipped with the active CIS enabled to obtain an average spray deposit on the leaves very close to that achieved switching off the sensors, even if the volume applied using CIS (435 l/ha) was nearly halved with respect to the reference thesis (850 l/ha). The use of sensors enabled to improve the spray deposition especially on the top part of the canopy and to reduce the average ground losses. With full vegetation (BBCH 91) it was confirmed that, employing the ISAFRUIT sprayer and using the conventional nozzles, CIS prototype allowed to keep an analogue average spray deposit on the leaves with respect to the full volume application rate. Use of air induction nozzles, on the other hand, resulted less efficient when CIS was activated. But all average spray deposits on leaves obtained using the ISAFRUIT sprayer (either with or without CIS activated) resulted higher than those obtained employing the conventional axial fan air-assisted sprayer. For what concerns deposition on fruits, slight differences were observed among the average spray deposits obtained in the five treatments examined.

Results of biological tests pointed out that the incidence of apple scab and of powdery mildew on leaves, observed at the end of June, were very low and resulted no statistical difference between the three spraying conditions examined. Similar results were observed for the green apple aphid. At harvest time damage on fruits due to apple scab and to powdery mildew was very low and no significant differences were observed between the treatments examined.

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Spray deposit in apple canopies as affected by low drift application strategies with Environmentally Dependent Application System

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Introduction

Use of full airflow and fine spray at the edge of orchard is usually responsible for contamination of orchard surroundings from the spray drift. The drift-reducing application strategies, including the use of coarse spray nozzles and one-sided airflow applications on the boundary of orchards give considerable drift reduction compared to traditional practice of applying fine spray nozzles and two-sided air flow application (Wenneker el al., 2005). Doruchowski et al. (2009a) developed the *Environmentally Dependent Application System* (EDAS) for automatic adjustment of both spray quality and airflow depending on wind situation and sprayer position. A unique feature of EDAS system is an on-the-go adjustment of the airflow, independently for the left and right side of the sprayer. The EDAS is a component of the *Crop Adapted Spray Application* system for precision crop protection (Doruchowski et al. 2009b), developed within the EU Project ISAFRUIT. The objective of this study was to evaluate the influence of spray quality and airflow settings on the spray deposit within the trees in the rows at the edge of orchard.

Materials and methods

Two sprayers, a standard cross-flow sprayer (Munckhof) with holow-cone nozzles ATR80-LILAC, and a prototype EDAS sprayer with an automatic nozzle selection system and adjustable airflow system, equipped with fine spray nozzles (LU-01) and coarse spray nozzles (ID-02) were used in a hedge-row type apple orchard (10-year old; cv. Honeygold). The trees were 3,5 m tall, 2 m wide and spaced 4 x 2.5 m. The spray, at liquid volume 200 l/ha, was applied on 4 rows at the edge of orchard. The application parameters for treatments with EDAS sprayer were set according to the following scheme: spray quality: (A) – fine spray on all 4 rows; (B) – coarse spray on the edge row (row 1) and fine spray on the following 3 rows; (C) – coarse spray on the edge row (row 1) and the next-to-edge row (row 2) and fine spray on the following 2 rows; air-jet setting: (1) – full air on both sides of all 4 rows; (2) – no air towards the outside of the orchard when spraying the edge row (row 1); otherwise full air; (3) - no air towards the outside of the orchard when spraying the edge row (row 1) and half air towards the outside of the orchard when spraying the next-to-edge row (row 2), otherwise full air. All the possible combinations of the spray quality (A, B and C) and the air-jet settings (1, 2, and 3) made 9 treatments of the EDAS system. The standard sprayer, as a reference, applied fine spray and full air on on both sides of all 4 tree rows. All the treatments were repeated 5 times during the fruit development period (BBCH 73-79). The deposition of BSF tracer on leaves was evaluated on seven locations within each of the three trees per row (replicates), in the three rows (row 1, 2 and 3) at the edge of orchard.

Results

The graphical interpretation of the spray deposition for treatments is shown in figure 1. In average all the treatments with the EDAS sprayer produced similar or higher deposition than that obtained with a reference standard sprayer (St-rd).

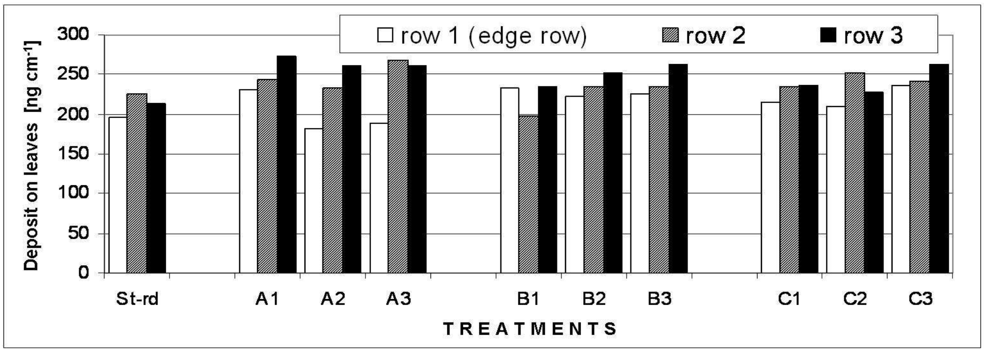

Figure 1. *Spray deposit on leaves for treatments with EDAS and standard sprayer*

The treatments according to drift-reducing scenarios as proposed by Wenneker et al. (2005), especially those including both the coarse spray quality and the eliminated or reduced airflow towards the outside of the orchard on rows 1 and 2 (B2, B3, C2 and C3) did not produce significantly lower deposition on leaves than the conventional treatments with the fine spray quality and the full air applied on both sides of all the rows (St-rd and A1). Considerably lower deposits were obtained only on row 1 for treatments A2 and A3, where the fine spray was applied with one-sided air assistance towards the inside of the orchard. Thus, for the drift-reducing treatments the average deposition in the trees can only be maintained at satisfactory level when the one-sided airflow is accompanied by coarse spray quality, like in B2, B3, C2 and C3.

The drift measurements for all the treatments used in this deposition trial are being carried out in 2009, both at dormant and the full-foliage stages. The preliminary results are to be presented at the SuproFruit Workshop.

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Early detection of apple scab in apple leaves; development of a Crop Health Sensor (CHS)

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Introduction

In the EU-FP6 ISAFRUIT project a Crop Adapted Spray Application system for precision crop protection (Doruchowski *et al*., 2009) was developed. The system ensures efficient and safe spray application in orchards according to actual needs and with respect to the environment. The system consists of three components: Crop Identification System – CIS (Balsari *et al*., 2009), Environmentally Dependent Application System – EDAS (Doruchowski *et al*., 2009), and a Crop Health Sensor – CHS. To develop the CHS, spectral analysis has been used, based on the developments in crop sensing techniques for grassland and arable crop production (Schut, 2003). Crop health status, with as an example the infection of apple scab (*Venturia inequalis*) on apple leaves, has been evaluated. This paper describes the first results of the spectral measurements done to distinguish typical reflection wavelength from healthy apple leaves and apple scab infected leaves in time after infection.

Methodology

A measuring tool developed for characterizing grass-swards has been adapted to measure picked single apple leaves placed on the floor underneath in the laboratory. The device measures with two cameras the reflection in the band-widths 400-900nm and 900-1650nm. With this device spectral analysis measurements were performed on individual apple leaves of different apple varieties (Elstar, Jonagold, Rubens, Wellant, Autento). Both young shoots and old leaves were measured on the top and underside. For the varieties Elstar and Jonagold scab and mildew infected leaves were also measured. In a second series of experiments spectral reflection of individual leaves of two cultivars (Gala, M9 rootstock), were taken to observe the change in spectrum in time. A difference was made between healthy and disease infected leaves (conidia of apple scab) evaluated on 2 hours, 4 hours, 8 hours, 24 hours, 2 days, 14 days and 28 days after infection.

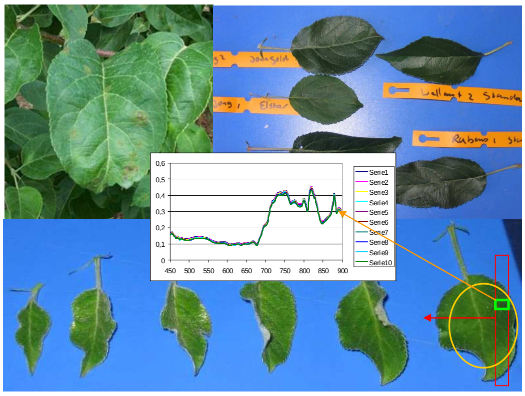

Figure 1. *Apple leaves were scanned in lines (1mm x 120mm) for spectral reflection with two cameras (400-900 nm and 900-1650nm wavelength) per mm^2 to determine areas of difference in reflection between cultivar, healthy leaf and apple scab infected leaf.*

Results

Assessment of leaves of the apple cultivars Elstar, Jonagold, Autento, Wellant and Rubens on the spectral reflectance showed that the apple varieties could be discriminated from each other based on spectral reflectance. Healthy parts of the leaves can be distinguished from diseased parts of the leaves on the mm^2 level. Assessment of the time after infection of leaves with apple scab (apple varieties Gala and M9) showed

that early detection as 2 days after infection was possible based on spectral reflectance, whereas visual detection is only possible after 10-12 days when first symptoms become visible.
The early detection of apple scab using spectral reflectance on the leaf opens new ways to develop a Crop Health Sensor (CHS) to be used for apple scab detection in the orchard and adapt the crop protection strategy as well. To translate the mm^2 information to an evaluation directly in the orchard at the leaf and tree level is still a big step to be made.

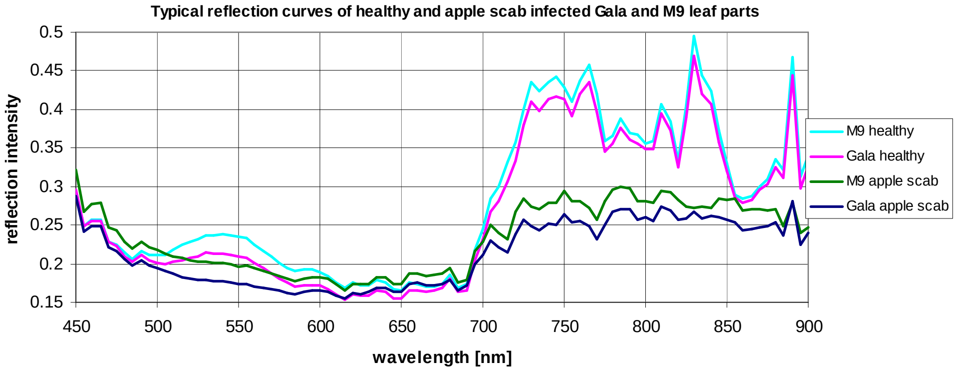

Figure 2. *Spectral reflectance curves of healthy and apple scab infected Gala and M9 apple leaves*

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Effect of nozzle type on pesticide residues on fruits

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Introduction

Pesticide residues per fruit weight unit are dependent on three processes, i.e. variation in initial spray deposit, physical decay due to weather factors and growth dilution. Variability in residues between individual samples is inevitable, partly because it is impossible to achieve an uniform spray deposition of pesticides. Application technique, crop architecture and growth stage have all been shown to affect variability in initial deposit. One of the most important factors influencing pesticide residues is the canopy structure. Many studies showed the importance of canopy structure in affecting initial deposit concentrations (e.g. Xu *et al*., 2006; Rawn *et al*., 2007); usually fruits in the top and outside regions are likely to receive more deposits than those inside the canopy. Also, in many practical situations the initial deposit is influenced by spray technology (i.e. sprayer type, sprayer settings and nozzle type). Large variability in the level of residues exists between individual sample units or composite samples. There are internationally agreed standards for monitoring pesticide residues and for assessing risks of consumer exposure. In general pesticide levels in EU fruit are below the maximum residue level (MRL) (EU Commision 2009).

In the ISAFRUIT project a sprayer is developed that minimizes spray drift by nozzle size (droplet size) selection and air support settings, and by the use of ultrasonic sensors that recognize the shape of the trees, thereby adapting spray volume to tree canopy volume, and ultimately a sensor that can recognize a disease. Altogether should minimize the use plant protection product (PPP) and therefore of residues. However, will it affect the residues in the apples as well? In practice coarse droplet applications might results in more visible residue spots on apples and pears. However, it is unknown if this also effects the residue levels of PPP's as well.

Experiments

In this paper we present and discuss the results of experiments on pesticides residues on apples, sprayed with different nozzle types. In a field trial in 2007 the effect of droplet size (nozzle type) was evaluated in a commercial orchard. The spray applications for the reference situation were performed with Albuz ATR brown hollow cone nozzles (7 bar spray pressure) and for the low-drift situation with venturi hollow cone nozzles (Albuz TVI 80-015 at 6 bar spray pressure). Spray applications were carried out in the same orchard (apple variety Jonagold), with the same spray machine (Munckhof cross flow sprayer with eight opened nozzles at each side) at a spray volume of approximately 200 l ha^{-1} for the Albuz ATR brown nozzles and 400 l ha^{-1} for the air induction nozzles, and a driving speed of 8 km h^{-1}. The orchard was divided in two experimental plots. Each plot was sprayed for the whole season with one (the same) nozzle type, according to a standard commercial spraying scheme with insecticides and fungicides, following label directions.

The canopy effect was evaluated by dividing the apple tree (spindle type) into four distinct zones: top, middle, lower outside and lower inside. Four apples were collected from five trees per nozzle type and tree zone. Selection of the trees and apples per zone was randomized out of a tree row in the middle of the experimental plot. A few days before the start of commercial harvest, single fruit samples were taken from five trees for each zone and nozzle type. The total weight of each individual apple was determined before the residue analysis.

Total residues levels (e.g. captan, bupirimate, pyraclostrobin and boscalid) per fruit and residue concentrations (mg kg^{-1}) at harvest were determined according to standard analyzing procedures and methods (GC-MS-MS and LC-MS-MS) in the laboratory, and expressed for individual fruits and mean values per nozzle type and tree zone.

Results

In general, the mean residue levels (average of 80 fruits) for the coarse and fine droplet applications did not differ significantly. However, large variations in residue levels were observed between the individual apples, either sprayed with coarse or fine droplets. These large variations were also present between fruits within the different zones. Apples from the middle or lower outside position showed the highest residue levels. The results indicated that the residue levels appeared to be independent of fruit size or weight. Figure 1 shows the results for boscalid, component of a fungicide sprayed against post-harvest or storage diseases.

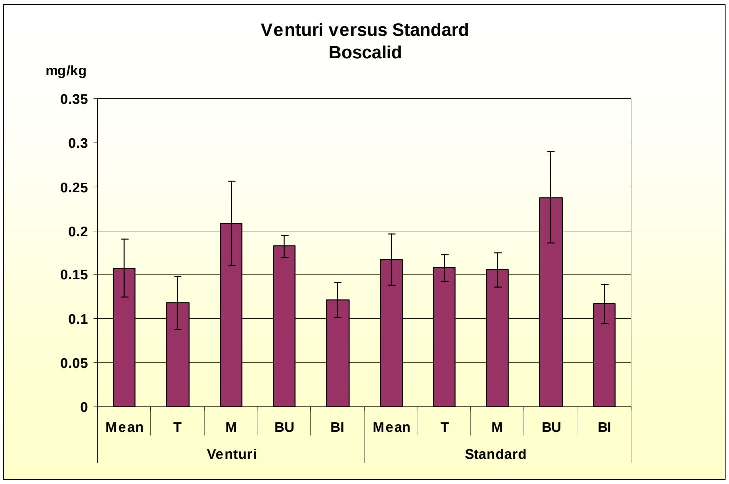

***Figure 1**: residue levels of boscalid for apples from different zones in the tree for two nozzle types. Zones: top (T), middle (M), lower outside (BU) and lower inside (BI). Mean value of 20 fruits per position. Venturi = coarse droplet application (Albuz TVI 80-15, venturi nozzle); Standard = Albuz hollow cone ATR brown nozzle.*

Compared to the standard nozzle type the residu levels for boscalid on apples of the venturi nozzle types were:

- less in the top section,
- higher in the middle section,
- less in the bottom outside section,
- equal in the bottom inside section,
- equal for the mean of the tree sections.

Conclusion

Based on the experiments it can be concluded that:

- No differences exist in average residue levels between fine and coarse droplet applications.
- Large variations exist in residue levels between individual fruits, independent of droplet size.
- Difference in maximal concentration compared to mean concentrations are between order magnitudes of 2-5 times.

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SESSION SPRAY DRIFT

30/09/2009
Haakzaal

Nozzle classification for drift reduction in orchard spraying; effect of nozzle type in a dormant stage orchards

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Introduction

In fruit growing spray drift is high, compared to arable field applications. Therefore the reduction of the emission of plant protection products is still of major importance. A project was started to develop a nozzle classification system for drift reduction in orchard spraying, following the earlier development and introduction of a nozzle classification system for drift reduction on boom sprayers (Porskamp et al., 1999). The approach and methods are, as far as possible, taken over from the existing nozzle classification system for boom sprayers. The international developments in this field (ISO, ASAE, BCPC, EU-FOCUS) are taken into account. The first, laboratory measurements were performed to identify potential threshold nozzles for discrimination of the drift reduction classes 50%, 75%, 90% and 95%, compared to a hollow cone standard nozzle (Albuz Lilac; 7 bar spray pressure). Based on the volume fraction of drops smaller than 100 micron (V_{100}), and already performed field measurements of spray drift with a venturi flat fan nozzle (Lechler ID9001; 5 bar spray pressure) in a dormant tree stage (Wenneker et al., 2004), potential drift reduction could be estimated (Zande, et al., 2008). The verification of this potential drift reduction was done by field measurements of spray drift in an orchard in a dormant and a full leaf stage, for different air settings of a standard cross-flow orchard sprayer (Munckhof). This paper describes the first results of the field drift measurements made with identified drift reduction class threshold nozzles in a dormant orchard.

Methodology

The field measurements of spray drift are made with the identified class threshold nozzles and the reference nozzle. Albuz lilac nozzles were used as reference , TeeJet DG8002 as 50%, Albuz AVI80015 as 75%, Lechler ID9001 (5 bar) as 90%, and Albuz TVI80025 as 95% reduction nozzles. All treatments were made at 7 bar spray pressure. The measurements were performed with three set-ups of the air assistance (no-air, half-air and full-air) of the reference sprayer (Munckhof cross-flow fan) in a dormant and a full leaf stage of an orchard. In this paper the results are described which were obtained with the half air setting of the cross-flow fan sprayer in the dormant orchard (before May 1st). The spray drift measurements were made by spraying the fluorescent tracer Brilliant Sulpho Flavine (BSF) in the leeward outside 20 m of an apple orchard. The measurements of spray drift deposit were made on a short cut grass strip next to the orchard to a distance up to 25 m from the last tree row. The collectors used were filter material cloths (Technofil TF-280) of 0.50 x 0.10 m in a continues line up to 15 m and of 1.00 x 0.10 m at points 20 m and 25 m. At 7.5 m distance a 10 m high measuring pole was placed with double lines of boll shaped collectors (Siebauer 00140) at 1 m interval up to 10 m height. The drift measurements were repeated 10 times.

Results

The results of the drift sediment measured in the dormant stage of the apple orchard for the drift reduction class threshold nozzles used on a cross-flow fan sprayer (Munckhof) with half air setting are presented in Figure 1.

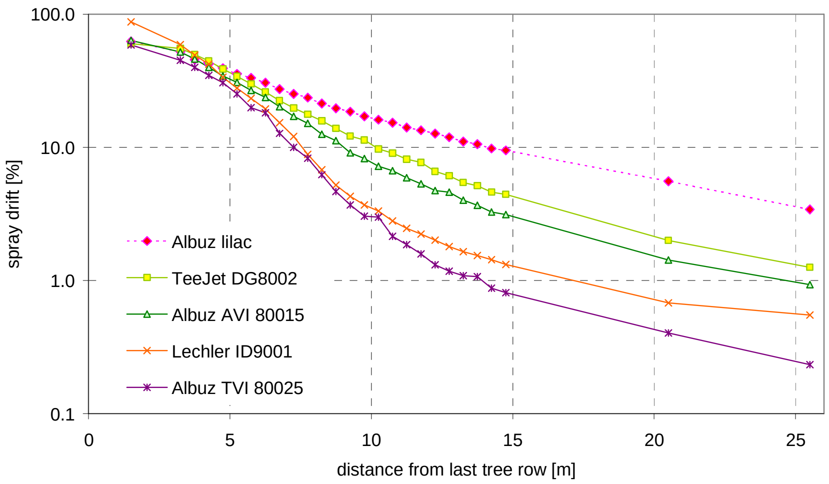

Figure 1. *Spray drift deposition on soil surface next to a dormant apple orchard when spraying with a cross-flow fan sprayer equipped with standard (lilac) and drift reduction class threshold nozzles of the classes 50% (DG), 75% (AVI), 90% (ID) and 95% (TVI)*

The expected drift reduction of the drift reduction class threshold nozzles, which was based on the volume fraction of drops smaller than 100 µm, were found in practice also. Dependent on the distance of evaluation (e.g. 10 m) a drift reduction of 40%, 60%, 80% and 85 % was found for the threshold nozzles in this specific dormant orchard with air setting half air of the cross-flow fan sprayer.

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Spray drift caused by a mast sprayer adapted to high trees

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Introduction

In high trees it is often difficult to reach the top of the tree when spraying plant protection products. Especially in crops with narrow tree rows and narrow tree spacing in the row and with dense leaf structures. Often high capacity axial fan sprayers are used to blow the fine mist of spray as far up as possible into the air, hopefully reaching the target in the top of the tree. In apple fruit growing, where dwarf trees are more common, often cross-flow fan sprayers are used to target the spray more towards the tree canopy. This concept is thought to be relevant also for high trees, like alley trees in nursery tree growing, but also relevant for other high crops with narrow row spacing and dense leaf structures. The development of a mast sprayer, a tower cross-flow sprayer for high trees (up to 6m), was systematically addressed in a stepwise approach. First step was to evaluate the spray distribution in a static and a dynamic situation (Van de Zande et al., 2007). The next step was the evaluation in the field, for biological efficacy and spray drift. In this paper it is reported what the effect of the mast sprayer is on spray drift, compared to a standard axial fan sprayer.

Methodology

The field measurements of spray drift were done comparing a reference standard sprayer used in high nursery trees and a developed prototype of a mast sprayer. The reference sprayer was a Dragone Athos axial fan sprayer, equipped with 6 hollow cone nozzles (TeeJet TXB 8003), operated at 8 bar spray pressure. With a speed of 4.2 km/h the reference sprayer applied 410-460 l/ha. The mast sprayer (van de Zande et al., 2007) was a prototype built on a Dragone Krümm axial fan sprayer, but with an extended cross-flow air duct with a height of 6 m, to be used in high nursery trees and other high and narrow row space crops. The mast sprayer was equipped with standard flat fan nozzles (TeeJet XR80015) and low-drift venturi flat fan nozzles (Lechler ID90015) of which 22-30 nozzles were used. Depending on the canopy height of the trees, both nozzle types were operated at 3 bar spray pressure. The speed of the mast sprayer during the drift experiments was around 4.0 km/h therefore applying around 540-750 l/ha (depending on row width). The effect of a 5 m spray-free buffer zone (outside 2 rows not sprayed) was also taken into account for both the sprayer setups. Measurements were performed in a nursery tree crop with a row spacing of 1.8-2.0 m. The tree size was around 6 m high with the canopy starting at around 1.6-2.0m, and tree spacing in the row of around 1 m. Tree species were plane, chestnut, lime, and maple. The leeward outside rows of the field were sprayed over a width of 20m, driving through every second path both sides were sprayed and the outside row only from the outside of the field inward. The spray drift measurements were made by spraying the fluorescent tracer Brilliant Sulpho Flavine (BSF) and measuring spray drift deposit on a bare soil surface strip next to the field to a distance up to 25 m from the last tree row. The collectors used were filter material cloths (Technofil TF-280) of 0.50 x 0.10 m in a continues line up to 10 m from the last tree row and of 1.00 x 0.10 m at points 15 m, 20 m and 25 m. At 10 m distance from the last tree row a 10 m high measuring mast was placed, with double lines of ball shaped collectors (Siebauer 00140) at 1 m interval, up to 10 m height. The drift measurements were repeated 10 times during the full leaf stage of the trees.

Results

The results of the spray drift measurements for the standard situation and the situation with a 5 m spray-free buffer zone are for the standard axial fan sprayer and the mast sprayer presented in Figure 1. The effect of standard flat fan and venturi flat fan nozzles are presented for the drift sedimentation to the soil surface next to a 6 m high nursery tree crop field.

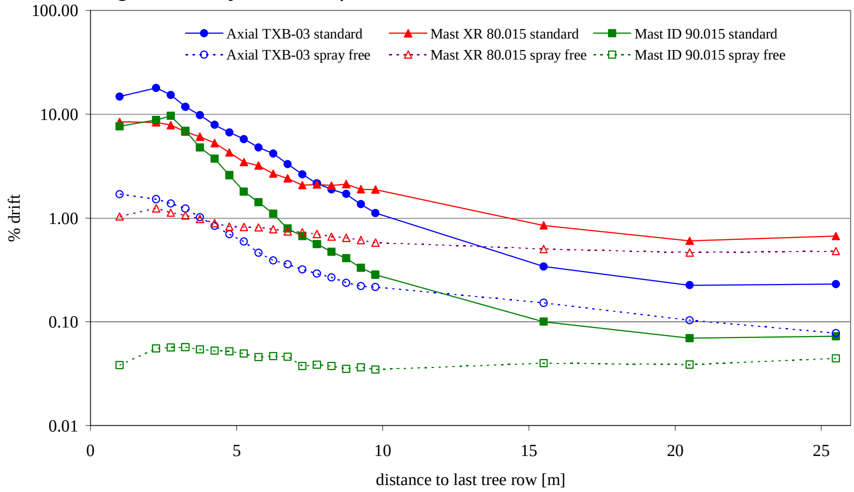

Figure 1. *Spray drift deposition on soil surface next to a nursery tree field when spraying with a standard axial fan sprayer equipped with hollow cone nozzles (TXB-03) and the mast sprayer equipped with standard flat fan (XR80015) and low-drift venturi flat fan (ID90015) nozzles in a standard situation and with a 5 m spray-free buffer zone*

The effect of a 5 m spray free buffer zone was obvious for all spray techniques; it reduced spray drift deposition at 5-9 m by 71% with mast sprayer XR110015 by 89% with axial fan sprayer TXB03 and by 96% with mast sprayer ID90015. In the standard situation the mast sprayer equipped with the standard flat fan nozzles reduced spray drift deposition at 5-9 m from the last tree row by 25% and when equipped with the venturi flat fan nozzles (ID90015) by 71%. The results showed that, despite the high output points of the spray on the mast sprayer, spraying sideways towards the trees canopy could reduce spray drift compared to that obtained when spray was blown into the air with an axial fan sprayer. However further optimization of the spray towards the tree canopy can be obtained by sensors detecting the green leaf area which is a point for further research and development.

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Spray drift measurements in tree crops using a lidar system

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Introduction

The objective of the three-year research project *OPTIDOSA* is to adjust the pesticide dosing in fruit orchards and vineyards. The spray application efficiency depends on both the quality of the spray deposit on the tree canopy and the amount of off-target spray losses. The project focuses on the improvement of the spray deposit using canopy measurement by means of optical sensors, decision support systems to improve the sprayer setup or real-time variable application systems. The project also develops methods for measurement of spray losses by means of computer models and optical sensors.

A lidar system can be used to scan a spray flow and measure the instantaneous received power from the scattered signal of a laser beam, as it goes through the spray plume. Since the late eighties lidar systems have been used to qualitatively assess the spray dispersion in aerial applications. More recently, Hiscox *et al*. (2006) attempted a quantitative approach, by means of relating the signal from a measured spray flux volume with the corresponding droplet concentration. The comparison of lidar measurements and the output of a computer spray drift model for spray application in an apple orchard was the aim of Tsai (2007), who also carried out spray drift measurements with artificial collectors. Although these previous studies made use of long-range lidar systems designed to study the atmosphere, it was decided to assess short-range lidar sensors for spray drift measurement in this study. One example of the assessment of a short-range (< 100 m) lidar used to measure spray drift can be found in Allard *et al*., 2007.

Methodology

The capability of the SICK® LMS 200 lidar sensor to spot a spray plume and to measure its concentration was assessed. Using a hand-held sprayer, the detection range of the sensor was determined to be 15 m. It was also tried to establish a relationship between the signal received and the spray concentration produced by a Teejet® XR11002 nozzle, working at 2, 4 and 6 bar at different distances and nozzle orientations. The concentration of a given volume inside the spray jet was related to the measured backscattering coming from this specific volume. Since the spray concentration was derived from the traverse spray volume distribution measured in a bench according to ISO 5682-1, some assumptions had to be made to work out the spray concentration for each of the measured zones inside the spray jet.

Afterwards, a longer-range SICK® LD-LRS 1000 sensor was used to measure the spray drifting away from an air-assisted sprayer to the atmospheric boundary layer. The sprayer was placed 30 m from the lidar sensor, so that the spray drift plume could be scanned at several distances and orientations in relation to the spray source.

Figure 1. *Spray drift measurement with the LD-LRS 1000 sensor*

First results and future work

In the relation to the laboratory measurements with the LSM 200 sensor, it was not possible to establish a good relationship between the backscattered signal and the spray concentration. This could be due, to some extent, to the inability of this kind of sensor to provide a range-resolved measure of the illuminated volume. However, statistically significant differences were found among the signal recorded for different nozzle orientations. On the other hand, the spray plume monitoring with the LD-LRS 1000 sensor, made it possible to show the spray drift motion beyond the wake of the airflow of the spray fan. However, a range resolution of the signal was not possible either. According to these results, short-range lidar systems are not adequate to measure spray drift. Therefore, the current work is focused on the use of an atmospheric lidar system. It is planned to measure the spray drift from air-assisted spray applications in tree crops and vineyards. The data will be compared with spray drift deposit and flow measurements and could also be used to assess spray drift computer models, which are also being developed in the same project.

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Effects of spraying parameters on drift potential of citrus air-carrier sprayers

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Introduction

Air-carrier sprayers are the main type of spray equipment used in Florida citrus applications (Salyani, 1997). They differ noticeably in shape, size, air system, nozzle arrangement, etc. and are normally operated at different volume rates and ground speeds, during day and night applications (Salyani, 2003). Spray drift is a matter of concern in citrus spraying and the proximity of residential areas to citrus orchards has made the drift issue more critical than ever. Earlier reports by Salyani and Cromwell (1992), Miller et al. (2003), and Salyani et al. (2007) provide some information on drift from various citrus applications. The main objective of this study was to estimate drift potential of citrus sprayers when they are operated under typical application conditions.

Methodology

The study involved five commonly used air-carrier sprayers (Salyani et al., 2007). They were equipped with various types of hydraulic nozzles or rotary atomizers, using 'air-blast' or 'air-curtain' air delivery systems in conventional and tower configurations. Spray solutions containing a fluorescent tracer were applied to 4.5 - 5.5 m tall orange trees at volume rates of 300 - 4,380 L/ha and ground speeds of 2.4 - 4.8 km/h. Drift potential of the applications was assessed by fluorometry of spray deposits collected on filters of high-volume air samplers. The samplers were positioned at two sides of the spray line above the tree canopies (7.3 m height). In another study, Miller et al. (2003) used a LIDAR instrumentation to remotely sample drift cloud generated from such applications. Spray treatments were applied in four replications. Air temperature, relative humidity, wind velocity, and wind direction were recorded during the applications. Figure 1 shows the schematic view of the test site and locations of the air samplers and meteorological instrumentation.

Results

In general, every application showed detectable spray deposits (drift potential) on the air sampler filters; however, the amounts of deposits were mostly dependent on the prevailing wind direction. For most applications, lower spray volumes showed significantly more drift potential than higher volumes. Higher ground speed appeared to have more drift potential compared to lower speed but the effect of speed was not significant. Smaller nozzles were more drift-prone than larger ones. Nozzles mounted on the upper manifold of sprayer generated more drift deposits than those mounted on the lower manifold. The effect of sprayer airflow rate was dependent on the applied volume rate. Overall, drift potential of the tested citrus sprayers appeared to be less than 8% of the applied rate.

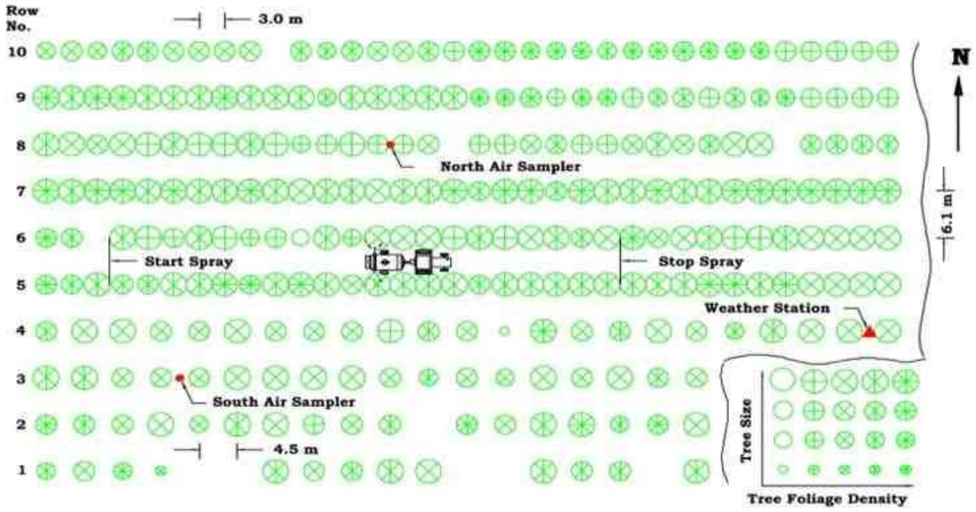

Figure 1. *Schematic view of the test site and locations of the drift samplers.*

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Environmental friendly plant protection with innovative spraying systems - Results of a four years project funded by BLE Germany

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Introduction

The project named "Maintenance of traditional fruit-growing areas in Germany by crop protection measures preserving the aquatic environment" was carried out from 2005 to 2008. It was nationally funded by the Bundesanstalt für Landwirtschaft und Ernährung (BLE). In this comprehensive project eight different sprayers for fruit production were tested concerning their environmental protecting potential and their practical use.
Four multiple row sprayers and four conventional sprayers with innovative supplementary techniques were tested in practical and scientifical tests during a three to four years period in the regions Altes Land and Lake Constance. Just the following four of eight sprayers were presented as excellent examples of innovative spraying systems:
1/2. Lipco Tunnel sprayer OSG-N1 and N2
3. Wanner sprayer with reflection shields
4. Wanner sprayer with sensor unit ECO-Reflex

The project programme included among others:
1. Drift measurements,
2. Leaf deposition trials,
3. Biological monitoring,
4. Recycling and savings potential

In order to avoid the drift of plant protection products (PPP's) to related water bodies and non- production areas it is of significant importance to choose the right spraying system. Today and in future innovative sprayers have to meet the strict demands of environmental protection.
Extensive measurements helped to identify their drift reduction potential. In addition, adapted leaf deposition trials were carried out to investigate the special technical settings of spraying systems. Measurements were accompanied by a biological monitoring and investigations in saving and recycling potentials.
The results presented here mainly refer to the drift and leaf deposition experiments that have been undertaken during the last four years.

Methodology of experiments

The different sprayers for fruit production were tested in 55 various drift settings. Measurements were carried out following the BBA (JKI) guideline 2.1 (according ISO 22866). Drift investigations were done in the early and late growth stages. The drift sediments were presented as the percentage of drift reduction related to the basic drift values in early and late growth stages.

During the project phase more than 90 leaf deposition measurements were carried out. The aim was to check the quality and quantity of PPP - deposits in the trees. Often sprayer parameters of leaf deposition measurements were adapted to the parameters of the drift trials to evaluate drift settings by PPP- allocation (e.g. 90% class: spraying without air support in five rows next to surface water). The results were presented as the percentage of the applied rate.
In addition, a biological monitoring concerning apple scab and powdery mildew was realized on each fruit farm in special orchards mostly compared to a standard sprayer, when available.
The data acquisition of saving rates was done by single trials and by the fruit growers themselves during the whole project period.

Results

The results indicate that the four sprayers can reach 95% drift reduction (compared to the basic drift values) in special settings. For example, the Lipco Tunnel sprayer OSG-N2 with a height of 3,50 m reduced drift by a minimum of 95% and a maximum of 99%. In many cases the tunnel sprayer OSG-N1 produced nearly twice the deposit of standard sprayers and ensured the biological efficacy.
The sensor unit ECO-Reflex produced by Müller Elektronik also offers the classification of 95% drift reduction, compared to the basic drift values. Spraying systems with ECO-Reflex sensors can reduce drift close to non- production areas by specific automatic turning off the nozzles in tree gaps. The use of sensors did not importantly affect the quality of deposit in the fruit trees and the biological efficacy. The leaf spray deposit often was comparable with the applied deposit of conventional sprayers.
The results of the leaf deposition measurements in Lower Saxony show that deposits of PPP's were reduced when spraying was carried out without air support as it is recommended near surface water to avoid spray drift. For this reason it seems necessary to minimize the number of rows applied without air support to avoid the biological risk in these tree rows close to surface water.
The Wanner sprayer with reflection shields reduced drift by more than 95% compared to the basic drift value. However it is recommended to choose special settings of tangential fans. Both tangential fans should have - adapted to the wind speed and direction – at least 1400 r.p.m. to guarantee high quality deposits on both sides of the fruit tree. Biological efficacy is ensured with the recommended settings.
According to the sprayer system the PPP- savings differed. Closed systems with two-sided recycling like the tunnel sprayer recycle more (up to 70%) than one -sided recycling sprayers like the Wanner sprayer with reflection shields (at an average of 10-15%). With the ECO-Reflex unit a maximum of 60% was possible, but in general savings up to 25 % are realistic.

Table 1. *Characteristics of tested spraying systems and evaluation*

characteristics				
spraying system	Lipco OSG-N1	Lipco OSG-N2	Wanner sprayer with reflection shields	Wanner sprayer +ECO-Reflex
drift reduction	+++	+++	+++	++(+)
leaf deposition	+++	+++	++	++
biological efficacy	+++	+++	+++	+++
recycling/ saving potential	+++	++(+)	+	++

standard sprayer: 0 +: good ++: very good +++: excellent

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Comparison of spray drift between an axial fan and a cross flow sprayer

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Introduction

The reduction of the emission of plant protection products (PPP) to the environment is an important issue in the Netherlands. Spray free and crop free buffer zones were introduced, to minimize the risk of mainly spray drift (Water Pollution Act, Plant Protection Act). In the Netherlands drift measurements are carried out according to the ISO standard (ISO 22866) adapted for the situation in the Netherlands (ground deposits, ditch, and surface water next to the sprayed field) following the Dutch protocol (CIW, 2003). Recently, new legislation is set into force, in which it is specified that fruit growers have to achieve 90% drift reduction compared to standard spray applications with a cross flow sprayer. At this moment, 7 drift mitigation measures for fruit growing are accepted by water control authorities; e.g. crop free buffer zone of 9 meters, windbreaks (hedgerows), tunnel spraying and specific coarse droplet applications. In the Netherlands the most commonly used sprayers are cross flow fan sprayers. Therefore, the reference spraying machine for spray drift measurements in orchard spraying (Huijsmans *et al.*, 1997) is a cross flow fan sprayer, equipped with Albuz ATR lilac hollow cone nozzles (spray pressure 7 bar generating fine droplets), and a spray volume of approximately 200 $l.ha^{-1}$. However, a substantial portion of around 25% of the growers uses axial fan sprayers. The question is whether spray drift from axial fan sprayers is equivalent to that of cross-flow fan sprayers. Also, within Europe many spray drift trials are performed, however spray drift trials with a direct comparison between the cross flow and the axial fan sprayer types are scarce. This makes it difficult to interpret results from different countries and therefore field experiments were setup.

Experiments

In this paper we present and discuss the results of experiments on spray drift with an axial fan and a cross flow fan sprayer. In a series of experiments spray drift was evaluated in the dormant and early growth stages (in the Netherlands before May 1st) and the full leaf stage (after May 1st) of an apple orchard. The spray drift into the air, and soil deposition outside an apple orchard were measured. Spray drift measurements were carried out adding the fluorescent dye Brilliant Sulfo Flavine (3 g/l BSF) and a non-ionic surfactant (Agral; 0.075%) to the spray agent. Spray deposits were calculated and presented as percentage deposit of the applied rate per unit surface area on the different distances of the collectors. The spray applications with the cross flow sprayer were performed with Albuz ATR Lilac hollow cone nozzles at 7 bar spray pressure (200 l/ha), and low-drift air induction flat fan nozzles; i.e. Lechler ID 90-01C at 5 bar spray pressure (200 l/ha). In practice, fruit growers use a spray volume of 200-250 l/ha. The axial fan sprayer was equipped with the same nozzle types and also Albuz ATR yellow nozzles (7 bar spray pressure). The latter nozzle to compensate the lower number of nozzles compared at the axial fan sprayer to the cross flow sprayer to apply 200 l/ha. During the experiments (10 repetitions in both growth stages) average wind direction was 1 – 13 degrees from cross to the tree rows and average wind speed at 3 m height was 2.1 – 3.8 m/s for the early growth stage, and 6 – 14 degrees and 2.2 – 3.7 m/s for the fully developed growth stage of the apple orchard.

Results

Spray drift deposition at an early growth stage (developing foliage)

In the early growth stages the spray drift curves of the axial fan and cross flow orchard sprayers – equipped with Albuz hollow cone nozzles showed a gradual decrease in drift deposition with increasing distance from the last tree row (figure 1). When both sprayers were equipped with low-drift air induction venturi flat fan nozzles (Lechler ID 90-01C) spraying resulted in high spray drift deposit on soil surface at short distance from the outer tree row, as coarse droplets fell down at short range from the last tree row outside the orchard. Very low spray drift deposits were measured at greater distances from the last tree row. The spray drift curves for the axial fan sprayer and cross flow sprayer showed equal patterns. Drift reductions achieved with the coarse droplet applications were comparable for the axial fan and the cross flow sprayer, being 0%, 60% and 80% at respectively 5m, 8m and 11m distance from the last tree row.

Drift into the air at a height of 1 meter was considerable higher for the cross flow sprayer with standard Albuz lilac nozzles compared to the axial fan sprayer with Albuz lilac or yellow nozzles. Mounted with drift reducing nozzles drift into the air was significantly reduced for both sprayer types.

Spray drift deposition at a fully developed foliage stage
In the full leaf situation, the drift deposition was comparable for all nozzle and sprayer combinations. At greater distance from the last tree row outside the orchard the spray drift curves for the Albuz ATR hollow cone nozzles and both sprayer types were the same; i.e. gradual decrease in drift deposition with increasing distance from the last tree row. The spray drift deposition curve for the cross flow sprayer equipped with venturi flat fan nozzles was lower than for the axial fan sprayer.
The amount of spray drift into the air was depending on the nozzle type and sprayer combination. High spray drift values were measured for the cross flow sprayer with Albuz lilac hollow cone nozzles and very low values for the axial fan sprayer with air induction flat fan nozzles.

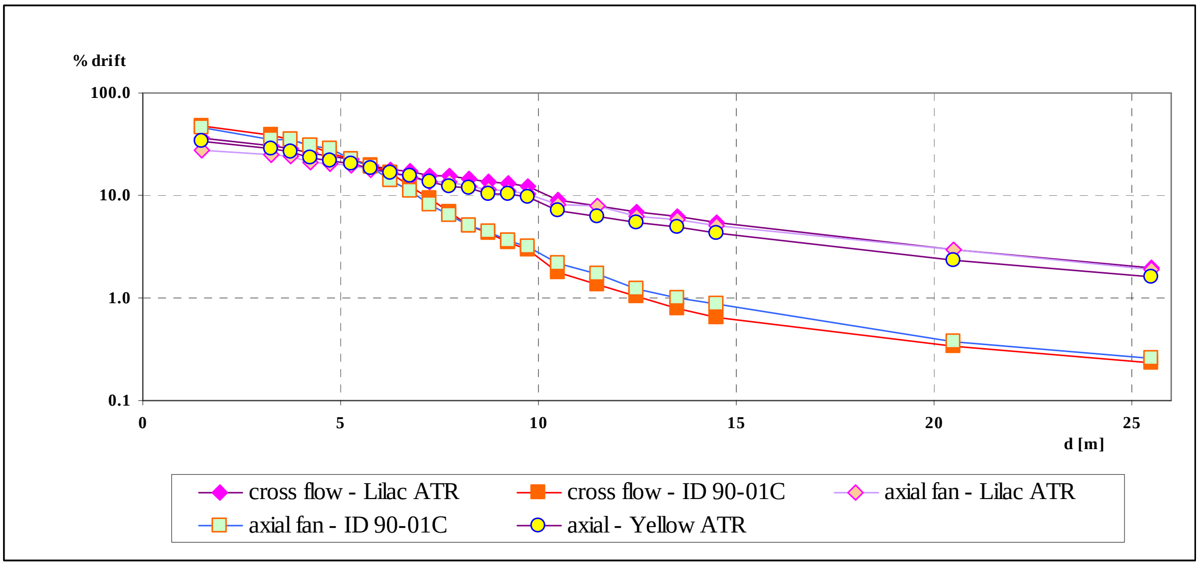

Figure 1. *Spray drift deposition on soil surface next to a dormant apple orchard, spraying with an axial fan and a cross flow sprayer equipped with hollow cone and air induction flat fan nozzle types.*

Conclusion and discussion

Based on the experiments it can be concluded that, both in the dormant or full leaf situation, the axial fan sprayer equipped with Albuz lilac or yellow hollow cone nozzles does not give higher spray drift values than the reference cross flow fan sprayer (equipped with Albuz ATR lilac nozzles). With drift reducing air induction flat fan nozzles the spray drift values for the axial fan sprayer and cross flow sprayer are equally minimized in the dormant situation. However, in the full leaf stage for the axial fan sprayer the spray drift deposition at short distance from the last tree row was lower and higher at larger distances, compared to the cross flow sprayer. These results indicate that the outcome from the nozzle classification system for fruit growing that is currently developed can be used for axial fan sprayers and cross flow sprayers (Van de Zande *et al*., 2008).

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An air-assisted tunnel sprayer for vineyards: spray recovery rate under static and dynamic conditions

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Introduction

Tunnel (recycling) sprayers have long been recognised as an important tool to reduce drift losses, and to recover most of the spray fraction which has not been retained by the canopy, thus allowing pesticide savings of 20 to 60% (Bäcker and Rühling, 1990; Siegfried and Holliger, 1996).
However, most tunnel sprayers for vineyards currently on the market are sold without any air assistance. This typically leads to insufficient spray penetration into the vine canopy and poor deposition on leaf undersides (Siegfried and Holliger, 1996; Viret et al., 2003). On the other hand, the development of an air-assisted tunnel faces the problem that any volume of air fed into the tunnel must at the same time exit it, and this may increase spray drift while decreasing the recovery rate. One solution may be to use air-droplets separators to recover the liquid portion of the spray, while discharging the excess air to the outside (Bäcker and Rühling, 1990; Panneton et al., 2005). A prototype, two-row air-assisted tunnel sprayer for vineyards, based on this principle, was developed in 2006 by the University of Udine and Agricolmeccanica s.r.l.

Methodology of work

Initial tests were performed in the laboratory and without any plants, in order to check the overall recovery efficiency of the sprayer. The recovery rate (in % of the delivered spray volume) was assessed by collecting the water flow from the pipe of the recycling system (after the separators), having previously disconnected it from the tank. Several settings were tested, including the tunnel opening (or, the horizontal distance between the walls: 0.50, 0.75 or 1.00 m), the orientation of the air-jets relative to the opposite separator panel (10°, 20° or 30°), and the air flow rate (1.46, 2.05, or 2.40 m^3/s). Additional measurements were conducted with the sprayer in motion at 6.2 km/h. Six Albuz ATR brown nozzles (Very Fine BCPC spray quality) per side were used in all these tests, delivering 0.66 l/min/nozzle at 10 bar pressure.
The sprayer was then tested in the vineyard during actual spray application. Seven tests were performed between April 3, 2007 (bud break, BBCH 01) and July 11, 2007 (full foliage, BBCH 81), using 219 to 555 l/ha spray volumes (depending on canopy development). The spray recovery rate and the LAI (Leaf Area Index) of the vineyard were assessed.

Results

Maximum recovery rate under stationary conditions in the laboratory was 95.1% or 93.5%, at 0.50 m or 0.75 m tunnel openings, respectively (air-jet angling: 20°). Different air flow rates had comparatively little effects on spray recovery.
With the sprayer in motion at 6.2 km/h, the air-jet orientation needed to be adjusted to offset the effect of the additional flow of air, entering the tunnel from the front opening. Maximum recovery was 87.4% (maximum air flow rate; tunnel opening: 0.50 m; air-jet angling: 5° and 25°, front and rear boom, respectively).
The recovery rate in the field tests was maximum at bud break (77%), but still very good during the growing season of the vines (50% to 34%, BBCH 69 and BBCH 81, respectively). This was consistent with the data from spray deposition tests (not described in this paper) showing 33% and 56% total deposition in the canopy (% of volume applied; same growth stages as above, respectively).

Figure 1 . *The prototype tunnel sprayer.*

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30/09/2009
Haakzaal

Comparison between novel and traditional spray application techniques in strawberries

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Introduction

Increasingly, Flemish greenhouse growers use spray booms instead of spray guns to apply PPPs (Goossens *et al*., 2004). In spite of important advantages, e.g. a more uniform spray liquid distribution (Nuyttens *et al*., 2004) and a reduction in operator exposure (Nuyttens *et al*., 2009), many questions remain concerning their optimal settings (Braekman & Sonck, 2007).

The main objective of this research was to investigate the effect of spray application technique on the spray deposition in strawberries grown on beds in greenhouses and in particular the effect of nozzle type, size and spray pressure and the difference between the traditional spray gun and vertical spray booms (Braekman *et al*., 2009).

Methodology of work

Six different spray application techniques were compared, all applying a spray volume of 1000 $l.ha^{-1}$. Five different flat fan nozzle types mounted on a vertical boom sprayer: extended range and low-drift ISO 110 03 nozzles at 2.5 bar (TeeJet XR 110 03, DG 110 03); extended range, air inclusion and twin air inclusion ISO 110 02 nozzles at 6.0 bar(TeeJet XR 110 02, Lechler 120 02, Albuz AVI-TWIN 02) and a spray gun equipped with a disc-core nozzle (TeeJet D 1.5) at 10.0 bar. All sprayings were performed by well experienced growers. Mineral chelates in combination filter paper collectors were used to quantitatively determine 300 spray deposition measurements at five different positions in strawberry plants (*Elsanta*, average height 0.40 m) at the crop contours as well as inside the crop canopy. Deposits measured on the crop contours gave a good appreciation of the spray liquid distribution whereas the deposits measured on the inner collectors were used to evaluate crop penetration. Factorial analysis of variance (ANOVA) was used to study the effect of the spraying technique and the collector position on spray deposition. Using a PDPA laser (Nuyttens *et al*., 2007), droplet characteristics of the different nozzle-pressure combinations were measured and linked with spray deposition measurements.

Results

Regardless of the kind of nozzle fitted on the vertical spray boom, in general, this spraying technique performed better than the traditional spray gun. Hence, the use of a vertical spray boom is a promising technique for applying plant protection products in a safe and efficient way in strawberries.

The experiments also showed the importance of a well-considered nozzle choice when using a vertical spray boom. Selection of the appropriate nozzle type significantly affected spray deposition and crop penetration (Figure 1). The highest deposits both at the contours and at the inside of the crop canopy, were achieved using air inclusion or extended range flat fan nozzles at their recommended spray pressure. The twin air inclusion flat fan nozzle gave sufficient deposits on the contours of the strawberry crop, but showed a tendency to deposit less inside the crop canopy. Furthermore, using the small-size extended range flat fan nozzles (XR 110 02) at a pressure above the recommended pressure range (6.0 bar) resulted in lower deposits, especially inside the crop canopy. Because this is still common practice with many growers, the findings of these trials are a very important tool - also valid for outdoor grown strawberries- to direct them to a more appropriate spraying technique.

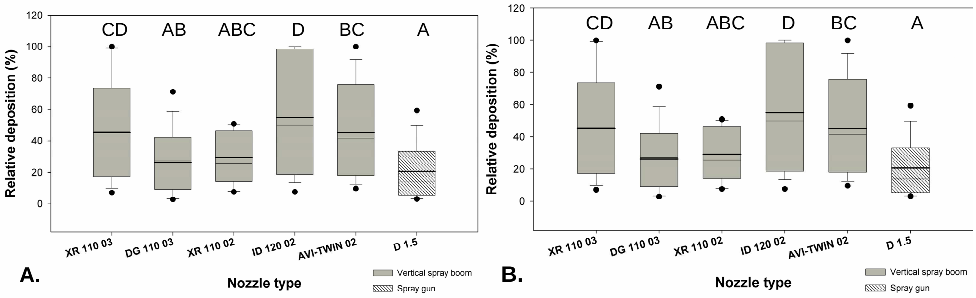

Figure 1. *Relative spray deposition (% of the maximal feasible deposition, assuming a uniform distribution of the spray liquid on the crop contours) on A. the crop contours and B. inside the crop for a vertical spray boom with different nozzle types and a spray gun (letters indicate significant differences in average spray distribution.*

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Potential operator exposure when spraying raspberries in a tunnel system

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Introduction

In order to obtain a better crop quality, higher yield and lower number of spraying applications, an increasing number of the Norwegian growers cultivate raspberries in a tunnel system instead of using the conventional open field method. Questions have been raised if there are any disadvantages when using pesticides in a tunnel system from an environmental point of view. Thus, the Norwegian Food Safety Authority founded a project in order to document if there is a difference in the potential operator exposure of pesticides influenced by a tunnel system versus an open field arrangement. Only a few previous studies have focused on operator exposure when spraying strawberry in the open field (Bjugstad and Torgrimsen, 1994; Jensen and Spliid, 2005), and none of them studies the effect of cultivating systems in raspberries.

Objectives

The main goal of this project was to examine the effect of cultivating system (open field versus tunnel) on potential operator exposure when spraying raspberries.

The total exposure is not interesting in this context, because that exposure will contain exposure also when stopping at the end, when turning, exposure depending of field shape etc., i.e. other factors than caused by the cultivating system alone. Thus, the measurement only could be carried out for single track(s) inside the tunnel and for the similar length outside in the open field. To avoid measuring failures like those explained above, the time carrying out the experiments were only 1-2 min. Pre studies showed that if the samplers were fixed inside a closed cabin for such a short time of application, the amount of exposure was negligible. Thus, in order to obtain any possible significant difference in exposure between the two application situations, the samplers had to be position outside the tractor cabin in the open area in order to be able to catch possible droplets drifting away against the operator. Analogous to the phase I and phase II drift described for drift measurements (Herbst and Ganzelmeier, 2002), we can define phase I (outside the cabin) as potential exposure detected closer to the nozzles depending only on spraying equipment and tunnel vs open field, and phase II as the total exposure measured on the operator in the cabin including the turning, stopping and other impacts of exposure in addition to the factors causing the phase I potential exposure. Because the spraying equipment, adjustment, sampler position, operator and plants were similar, the only influence on the potential exposure was the cultivation system as pointed out in the objectives.

Material and Methods

In earlier exposure measurements active as well as passive samplers have been used (Bjugstad and Torgrimsen 1996). However, the use of active samplers like filter pumps are time consuming to set up and normally need a longer exposure time than passive samplers to ensure detectable exposure values, mainly because these samplers measure the respiratory fraction. Furthermore the respiratory exposure caused by hydraulic nozzles normally is very low compared with dermal exposure measured by the passive sampling method (Bjugstad and Torgrimsen, 1994; Chester, 1993). Passive samplers have been used in a large variety of size and structure (Kramer *et al*., 2002; Miller, 1993). Among others, an advanced sampler type is used in Belgium in greenhouses consisting of three layers; an outer cotton layer, filter paper and a dense plastic foil as the inner layer (Nuyttens *et al*, 2004). The cotton layer should catch the large drops and the dense inner layer should prevent drops to contaminate from the overall below. However, such a filter is complex to attach and collect quickly in the field.
Thus, after some pre studies, a simple conventional overhead sheet, black & white copier transparency film *(3M, PP2500)* cut to a size of 10 x 10 cm^2 according to the WHO standard (WHO, 1982), proved to be a very simple and well suited passive sampler. The drifting droplets were caught by the vertically fixed sampler without any risk of run-off. Every sampler was fixed by tape strips on a similar clean transparency film with a size of approx. 12 x 12 cm^2 in order to prevent any contamination from the below exposed operator surface. All samplers, including supporting layers, were prepared in advance in order to reduce the total experimental

time. Unexposed samplers were controlled for any backup residues and proved to be clean. Normally, setting out 10 to 12 samplers, performing the spraying operation (1-2 min) and collecting the samplers took approximately 15-20 min.

***Figure 1**. Passive samplers, size 10 x 10 cm^2 fixed on a 12 x12 cm^2 layer. Dotted lines show the edges of the samplers and supporting layers. Sprayer tank pulled by the ATV for raspberry on the picture to the right. An inner tape was used to fix the bottom layer.*

Fluorescein was used as tracer in a concentration of 0.1%. Because the tracer is sensitive to sunlight, the samples were collected immediately after the exposure and put in pre numbered transparent plastic bags. The samples were stored in dark and chilly conditions until the analysis was carried out the following day.

***Table 1.** Technical factors of the used equipment.*

Equipment	Driving speed km/h	Nozzles	Pressure MPa	Flow rate l/min	Volume rate l/100 m row
ATV-Hardi Trailer	4.7	4 x orange unigreen /side	0.7	6.85 / 4 nozzles	17.5 (8.7 -one side)
Hardi mist blower	4.7	5 x ATR yellow nozzles per side	1.0	1.0/ nozzle	12.8

***Figure 2.** Spraying with ATV and trailed sprayer to the left side only. In the tunnel (left) and in the open field (right). Drift of droplets can be visually seen in the open field situation.*

Results

Table 2. *Range test of operator exposure for tunnel (trial 1) and open field (trial 2) when spraying in raspberry. Average exposures for samplers fixed around the operator are expressed as tracer in µg cm* $^{-2}$ *100 m* $^{-1}$ *row in the right column. (p<0.05)*

Crop and equipment	Rang test for tunnel (trial 1) and open field (trial 2)
	Trial
Raspberry 1 Run ATV	1 2.63E-03 A (tunnel significantly higher)
	2 8.93E-04 B
	Trial
Raspberry 2 Run ATV	1 5.74E-03 A (tunnel significantly higher)
	2 1.64E-04 B
	Trial
Raspberry 1 Run Mini Variant	2 1.51E-03 A (open field tendency to be higher)
	1 1.17E-03 A
	Trial
Raspberry 2 Run Mini Variant	1 7.66E-04 A (tunnel significantly higher)
	2 3.24E-04 B

The potential operator exposure when carrying out the spraying application was significantly higher for a tunnel system compared with the conventional open field except in one run using the Mini Variant. However, the drift of pesticide to the environment is expected to be higher for an open field system. This is due to the documented higher influence of the wind vector in an open area. Additionally, the operator exposure is more dependent of length of rows, number of turnings, the use of drift minimizing spraying equipment, wind conditions, driving speed and other operations like filling and mixing of pesticides. Normally the number of applications also will be decreased by using a tunnel system, due to less attack of fungus and other diseases. Thus, tunnel cultivation of raspberries is recommended as an important tool to improve the quality of the berries, increase the yield and reduce the total use of pesticides. Protective clothing should be used in any case.

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NOTES

SESSION RESIDUE & DOSAGE

30/09/2009
Haakzaal

Residue and retail

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The Greenery bv is a market-oriented sales company whose shares are owned by the producers who are members of the horticultural cooperative The Greenery U.A. The 1,500 producer-owned member companies market all their products via The Greenery. The Greenery B.V. is one of the leading concerns in Europe in the vegetable, fruit and mushroom sector. The main activity of The Greenery is to provide a complete range of vegetables, fruit and mushrooms to supermarket chains in Europe, North America and the Far East throughout the year.

Environmental organisations such as Natuur en Milieu (N&M), Milieudefensie (Friends of the Earth, Netherlands; www.weetwatjeeet.nl), Greenpeace – Hamburg (Germany) and consumer associations started pressure on supermarkets in campaigns with demand to supermarkets that only residue-free produce is sold. They argue that it is unacceptable to sell 'contaminated' fresh produce. However, there are internationally agreed standards for monitoring pesticide residues and for assessing risks of consumer exposure. In general pesticide levels in EU fruit are (far) below the maximum residue level (MRL) (EU Commision 2009). Therefore, it can be concluded that there has been an overreaction against fruit and vegetables for chemical residue.

Maximum residue levels (MRLs) are trading standards that represent the maximum residue that could be found if a crop protection product (CPP) is applied according to critical good agricultural practice (cGAP). Foodstuffs are monitored for MRL compliance and exceedence can have economic, social and political consequences. There is a trade-off when calculating MRLs, as low MRLs prevent misuse of CPPs and high MRLs prevent an 'unlucky' farmer exceeding the MRL by chance. The MRL ensures that no pesticide exceeds the Acute Reference Dose (ARfD) or the Acceptable Daily Intake (ADI).

Never-the-less, in recent years many major European supermarkets have taken steps to reduce the levels and/or numbers of pesticides present in fruits and vegetables they sell. Food retailers or major European supermarkets have started demanding additional quality standards in terms of residue levels which have been standards that are much stricter than the legally binding standards set by the authorities.

Examples of additional standards taken by supermarkets in 2008:

Super de Boer (NL) – Super de Boer only tolerates pesticide residues present at below 50% of the concentration allowed under EU law. Super de Boer operates its own pesticide black list which includes 12 substances currently approved for use in the EU.

LIDL (DE, NL) – In Netherlands and Germany, LIDL only tolerates pesticide residues present at below 33% of the MRL. Additionally LIDL aims to ensure that no pesticide is present in excess of the ARfD and the sum of all ARfD's <100%.

ALDI (DE, NL) – In Netherlands and Germany, ALDI only tolerates pesticide residues present at below 70% of the MRL, and in the sum <80% of the MRL's. ALDI also aims to ensure that no pesticide is present in excess of 80% of the ARfD, and that food products contain no more than 3, 4 or 5 different pesticide residues depending on their produce group.

Important is that fruit growers have to spray against storage diseases because of the very low economic threshold: all the costs of labour and storage are done; long storage is demanded for longer shelf-life (export). In order to meet the demands of consumers and retailers regarding residues on fruits, more work is needed to determine the importance of different spray application techniques and related deposition.

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Outline report of the first meeting of the Tree Fruits Dose Adjustment Discussion Group, Wageningen, 29 September 2009

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Introduction

There are several different dose expression methods and dose adjustment schemes for tree fruits and other '3 dimensional' crops in different European countries. Past experience, which culminated in an EPPO meeting of over 50 interested parties in Paris in May 2001, indicates that it is likely to be difficult to easily agree a harmonised single method and scheme. However, the problem is a very real one and is getting worse as different parties adopt increasingly entrenched positions and with approved labels taking different approaches in different countries. Further discussion is needed amongst a smaller group of key individuals to try to reach a consensus and to consider whether/how the different approaches can be harmonised and/or how the dose can be read between different schemes to facilitate harmonisation of approvals and mutual recognition.

A Tree Fruits Dose Adjustment Discussion Group has been formed, comprising approximately 30 persons including regulators, agrochemical company representatives and tree fruit spray application researchers, to discuss the problem to try to agree a way forward. The overall objective of the group is to understand the problem and determine what needs to be, and what can be practically done to unify systems of dose expression and adjustment for tree fruit spraying in Europe.

An outline report of the first meeting held on Tuesday 29 September 2009, the day before the 10th Workshop on Sustainable Plant Protection Techniques in Fruit Growing (SuproFruit2009)" will be presented.

NOTES

SESSION SPRAY DEPOSITION

AND BIOLOGICAL EFFICACY

02/10/2009
Haakzaal

Spray application of micro encapsulated pheromones in apple orchards

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Introduction

The use of pheromones in apple and peach orchards to limit the presence of leaf miners (*Cydia pomonella* and *Cydia Molesta*) by means of sexual confusion is growing steadily. This technique enables to drastically reduce the amount of insecticides applied in orchards and therefore is very helpful in meeting the environmental friendly agriculture protocols. Usually, pheromones are applied in orchards using ad hoc dispensers or traps which require constant monitoring to guarantee their correct functioning. A new micro encapsulated formulation of pheromones (Suterra® Checkmate® CM-F) was recently proposed to contrast *Cydia pomonella* in apple orchards. Micro encapsulated pheromones can be applied on the vegetation using the conventional air-assisted sprayers to release pheromones by sublimation.

Methodology of work

In order to assess the persistence of pheromone microcapsules on the vegetation after the spray application, laboratory and field tests were carried out using a fluorescent tracer. Apple plants (cv. Golden Delicious) were sprayed with a test solution of water and microcapsules of Suterra® Checkmate® CM-F which were previously treated with a fluorescent tracer to emphasize their presence. To make treatments a conventional axial fan sprayer applying a volume rate of 800 l/ha was used. Leaf samples picked up from the sprayed trees were then analysed in laboratory under UV light after different intervals of time. The number of microcapsules per unit area was measured, in order to check their persistence on the target. To avoid the degradation of the fluorescent tracer at the daylight, leaf samples picked up after the treatment were stored in refrigerator at dark and analysed every 24 hours to measure the amount of microcapsules still present.

Further trials were made in laboratory to investigate the persistence of microcapsules on the treated leaves after rain events of different duration and intensity. Rain was simulated using hollow cone disc-core type nozzles of large size (2.0 mm diameter) operated at low pressure (3 bar) and oriented upwards in order to obtain the fall of droplets by gravity on the exposed targets. Treated leaves were exposed to rain falls between 10 and 40 mm/h over periods of 30 and 60 minutes.

Results

The amount of pheromone microcapsules counted on the apple leaves immediately after treatment progressively decreased over a period of 15 days. The decreasing trend was more rapid on the leaves left on the sprayed trees in the field, due to the photo degradation of the fluorescent tracer. On the samples stored at dark in the refrigerator, about 20% of the amount of microcapsules originally deposited on the target was still present 15 days after the application.

Concerning the persistence of pheromone microcapsules on leaves exposed to rain, experimental data pointed out that even after rain events quite severe, simulating the rain fall occurring during summer storms (30-40 mm/h), the amount of microcapsules still present on the leaves reached about 50% of the original deposit (Figure 1).

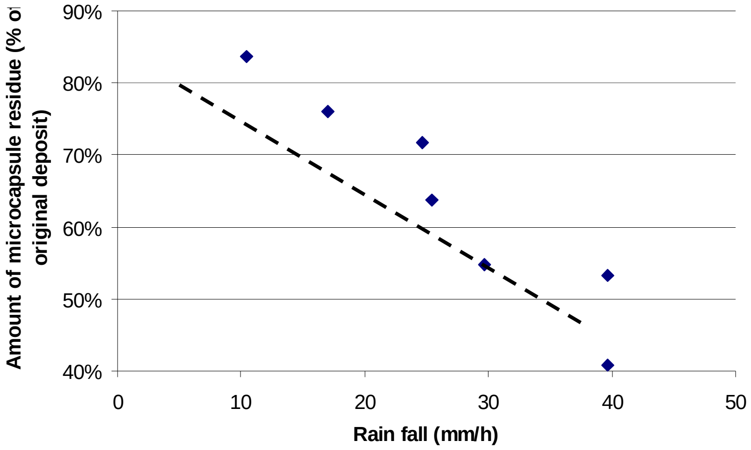

Figure 1. *Persistence of pheromone microcapsules on apple leaves exposed for 60 minutes to rain events of different intensities.*

The variation of leaf deposit with volume application rate and the onset of saturation during tree fruit spraying with an air-assisted knapsack

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Introduction

The characteristic variability of the volume application rate at which leaf deposit begins to saturate is a source of uncertainty that influences efficacy evaluation of plant protection products (PPP) when they are registered for fruit spraying. This paper describes the field measurements and the results from a simple data fitting model (Barabási & Stanley 1995) which is used to extract key parameters that may be used to describe the characteristic variability. It is possible that the outcome of this research will lead to an improvement in current regulatory practices for setting the maximum dose-rate and water volume rate recommendations on the labels of PPP.

Methodology of work

Single tree plots within different orchards of pome and stone fruit were sprayed with a tracer tank mixture (water + sodium flourescein at a concentration of 0.5 g/l + the wetter Activator 90 at 0.01% concentration) using a Birchmeier B245 s motorised air-assisted knapsack sprayer. The sprayer was set-up to give a liquid flow rate of 11.3 ml/s and a Very Fine spray quality. The effects of inter-plot contamination was minimised by arranging the treatments in ascending order of spray volume along the row. Each plot consisted of one tree with a single guard tree separating it from the next plot. Different spray volumes were applied by spraying trees for different durations. To quantify spray deposit two bulk samples of 25 leaves were taken from each tree with sampling at random. The washing from these leaves were analysed using a fluorimeter (excitation 490 nm; emission 515 nm). The leaf area of each sample was quantified by weighing the leaves and applying the area/weight ratio calibration coefficient determined with a photometric leaf area analyser. Exposure and sampling of each plot was replicated. Further details of these experiments are given by Cross (2008). LiDAR recording of the tree plots were made using the methodology described by Walklate et al. (2002) to sample each row of tree containing the single tree plots. Specialised software (LidarAssistant5, 2008) was used to extract sub-samples of tree structure parameters representing each single tree plot scanned from the avenues on either side of the tree-row.

Results

Bulk leaf deposit measurements are plotted against the spray volume application rate (Fig 1) for three different crop structures defined by parameters listed in (Table 1). These results are selected from the preliminary experiments, performed on 10/09/2008 and 29/09/2008, and span the extreme characteristics of the full dataset for ten different orchard structures. For Conference pear and Braeburn/Gala apple trees the leaf-film exponent of the data fitting model (represented by the slope of log/log transformed data plotted in Fig 1) is not significantly different to normal expectation (1.0). However, the leaf-film exponent for Victoria plum (0.52) is significantly lower than normal expectation; suggesting that the mechanism for describing liquid losses from leaves is different to that for pear and apple. The saturation levels of leaf deposit span a range of nearly one order of magnitude with Braeburn/Gala apple giving the highest value and Conference pear giving the lowest value. The trees in both these orchards reaching saturation conditions around 700 l/ha and in contrast with this the plum trees do not show any sign of saturation with volume application rate as high as 7000 l/ha.

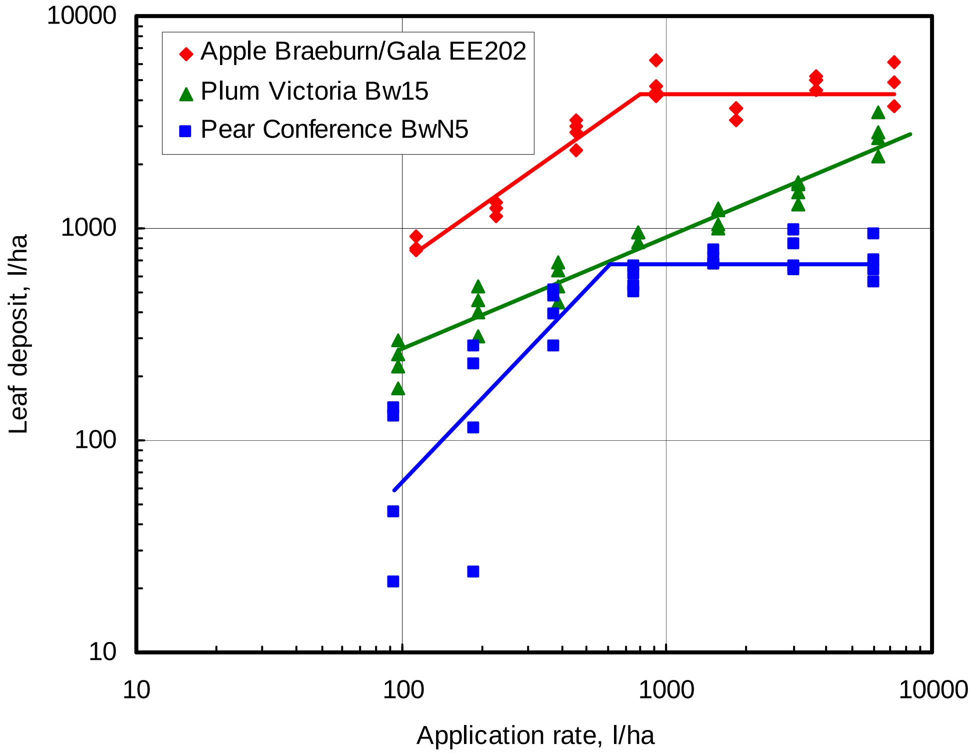

Figure 1. *The variation of spray deposit (bulk leaf samples) with volume application rate.*

Table 1. *Summary of tree-row parameters calculated from scanning LiDAR output.*

Orchard identification	Spacing m	Width m	Height m	Area Density m	TRV m	Area Index
Apple EE202	4.00	0.32	2.00	0.53	0.16	0.09
Plum Bw15	4.57	1.68	3.69	1.16	1.36	1.56
Pear BwN5	3.96	0.93	2.78	2.04	0.65	1.32

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Management of pesticide dosages and water volumes in relation to the vegetative development of pome fruit trees in Italian orchards

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Introduction

The Italian pome fruit production takes place in a highly variable pedo - climatic environment (plains, hills) and is characterized by a high number of distinct varieties. The fruit growers thus operate in a wide range of orchards by size and volume of tree leaf canopy which make it difficult for them to choose the right water volumes and the right dose of products in line with these varied conditions.

The system currently in use in Italy by which farmers calculate the dose of agrochemicals to be applied to their fruit crops does not allow them to determine the truly required quantities of products and water volumes adapted to the size and volume of the tree crowns. In order to contribute to resolving this situation experiments were carried out to examine the adaptability of the CAS method (Crop Adapted Spraying), i.e. calculation of the pesticide dosage in relation to the development stage of the leaf canopy.

Methodology of work

The experiment was designed to test the biological efficacy of the agrochemical products when applied with a dose and a water volume adapted to the volume of the tree crowns determined for each consecutive spray operation. The on farm experiments were carried out in various parts of Italy over four consecutive years.

In all orchards, the following crop parameters were measured for three consecutive growth stages: the height and the average width of the tree canopy and the distance between the rows. The leaf area indices were estimated using the crop volume – leaf area correlation formula.

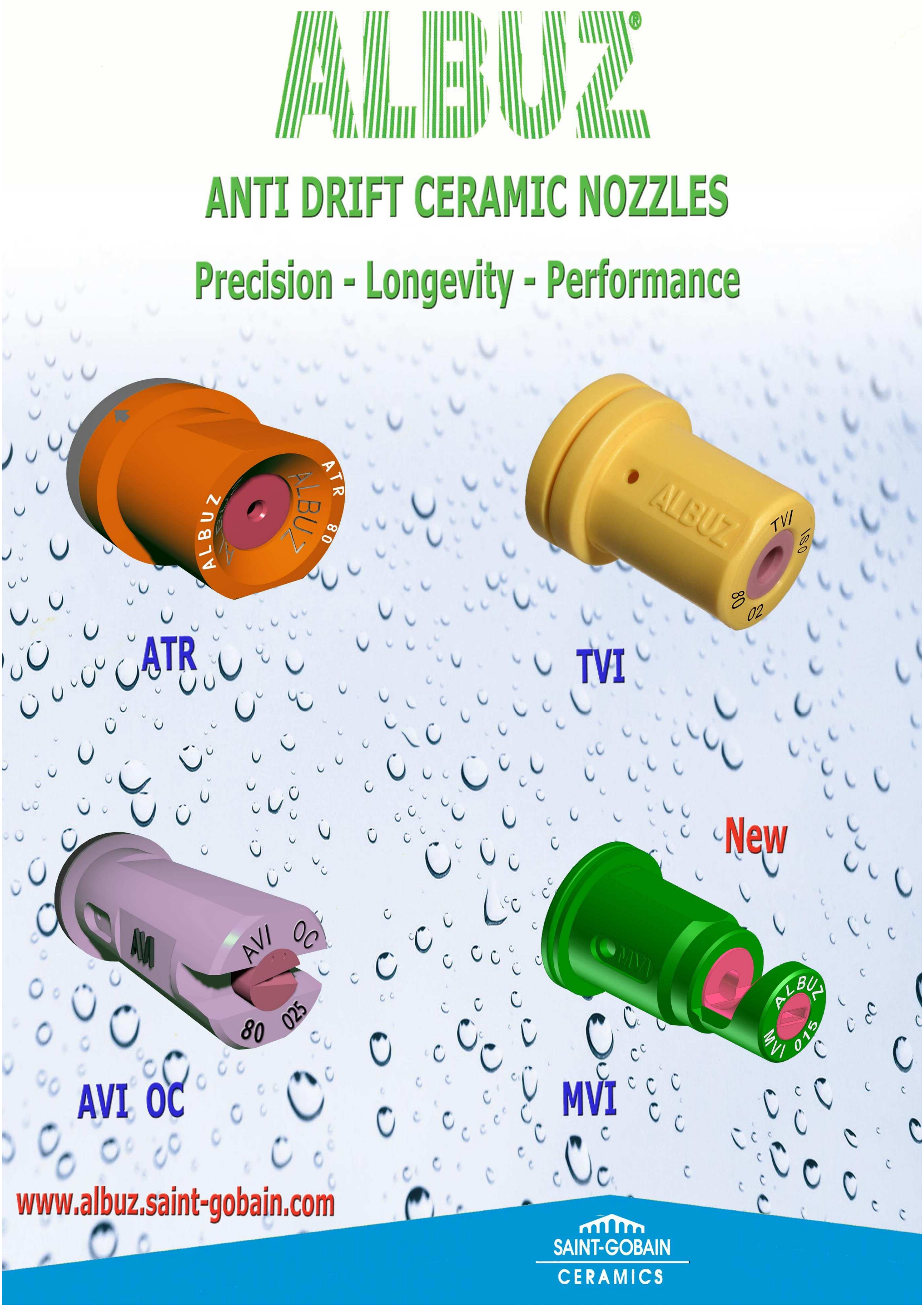
Fungicide and insecticide treatments were carried out against various diseases and pests in commercial apple orchards using commercially available products. In one plot the doses corresponded to those normally applied by the farm as a standard procedure following the instructions on the labels. In the other plot the doses were calculated according to the present crop volume as determined by the method CAS. In both plots the same products were applied at the same time. Deposit levels and distribution patterns were checked at two to three distinct crop stages using a tracer.

Based on earlier measurements the full doses of the products as given on the labels corresponded to a basic crop volume of 12'000 m^3 per hectare. At three consecutive growth stages measurements of the spray operation were made by using a fluorescent tracer to check on the quality of the spray distribution and the quantity of the spray deposition per unit leaf area. The biological efficacy of the products was evaluated in regard to powdery mildew, scab, aphids and codling moth.

Results

Results obtained showed that in Italian orchards a water volume of 1500 L/ha with the dose of the products as stated on the labels is adapted to a standard tree crown volume of 12'000 m^3/ ha. In comparison to the so far used standard dose the CAS method allowed to reduce the dose of the products by 10% - 20% for orchards which had a tree crown volume less than 12'000 m^3/ha. For orchards with tree crown volumes more than 12'000 m^3/ha the experiments showed that the doses according to the CAS method and those used according to the standard method did not differ significantly. Both methods of dosage, standard and CAS, always lead to a satisfactory biological efficacy of the products.

The results obtained are in line with the requirements set up by the European community for a sustainable use of agrochemicals and a targeted reduction of their doses per hectare. Spraying according to the CAS method requires a sprayer that is correctly calibrated and adjusted to the size of the fruit trees so as to achieve a good biological efficacy in a reliable manner. Further experiments will help to determine with even greater precision the standard tree crown volume to be referred to. This in turn will help to further reduce the impact of the agrochemicals on the environment.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Reducing drift during spray application in orchard: efficiency of nozzles

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Introduction

Because of environmental concerns, drift reducing nozzles for orchard applications have been developed. They are now commercially available. However, for French orchards, information is scarce for:
1- the spray mix distribution on the canopy and
2- the efficacy level of treatments applied with drift reducing nozzles.
To answer growers' questions, trials have been conducted from 2006 to 2008 by the CTIFL and regional research stations (West and South West).

Methodology of work

In the first trial, efficacy of pest and diseases management was assessed during the complete production season of an apple orchard. All treatments were conducted with two types of nozzles: ATR (Albuz) standard hollow-cone and TVI (Albuz) drift reducing venturi hollow-cone nozzles. Efficacy was assessed for: apple scab, aphids, and codling moth in commercial apple orchards applying standard rates of Plant Protection Products (PPP). Spraying volume, spray pressure and nozzles sizes has been adjusted according to each orchard production practices areas.
In the second trial, the deposition rate of the two nozzles types was assessed on apple tree leaves. A tracer solution (tartrazin) was sprayed in the orchard. Leave samples were collected from different levels in the canopy in order to determine the spray liquid distribution (Loquet B. et al., 2008).
During the two years of experimentation, two nozzles types were used on different sprayers being: axial fan sprayer (Chabas, Berthoud, and Nicolas) and vertical spray distribution sprayer (BAB).

Results

1. Biological efficacy was measured during the two years of trials and in the 5 different areas in France.
The results show that, in most cases, the efficacy of the treatments achieved with drift-reducing nozzles is equivalent to the one with standard nozzles (apple scab and codling moth are the most important troubles in the study's orchards). Spray applications following the orchard's protection program kept the fruit production safe from pest and disease attack.

2. Spray distribution measurements show that, both in 2006 and 2007, spray deposits are high when drift-reducing nozzles are used (Compte-rendu d'activité de la station La Morinière). Spray mix deposition with the TVI nozzles was nearly twice as high than sprayed with the ATR nozzles.
Figure 1 presents the spray distributions obtained with an axial fan sprayer in the 2007 trial (La Morinière). The spraying volume was: 400 l/ha, at 10 bar spray pressure for both ATR and TVI nozzles.

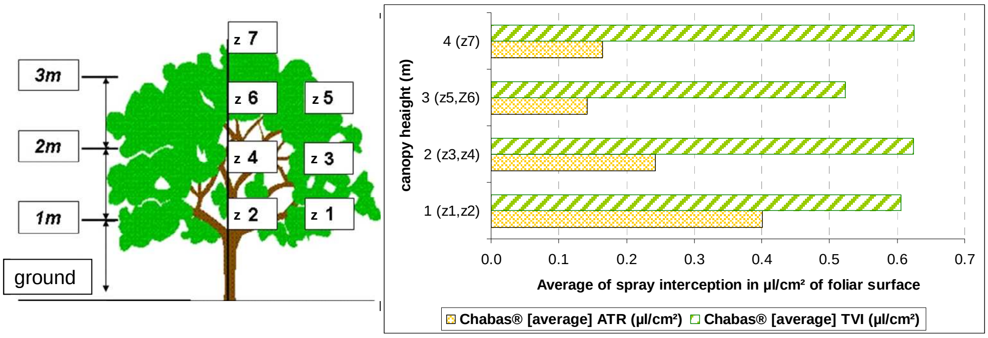

Figure 1. *Spray distributions obtained with an axial fan sprayer in the 2007 trial (tartrazin tracer) using a standard and a drift reducing nozzle type.*

Spray deposits are always higher with TVI nozzle (drift reducing nozzle), whatever the canopy level. These results can be explained by the spray quality, drop size and drift reducing level.

Conclusion

During the three years of experimentation, results proved that an orchard protection program using drift reducing nozzles is as effective as the one with "standard" equipment. Spray distribution quantification underline these observations. It is still important to continue checking the biological efficacy level of the protection achieved with different types of equipment in order to test their impact on pest and disease control.

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Adjustment of the quantity of chemicals according to the density and extension of the canopy

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Introduction

The distribution of depositions of plant protection products (PPP) on the leaves of apple trees depends on the transport of droplets within the air stream into the canopy. About 250 trials were carried out over the last five years to deduce the most important influencing parameters on the deposition. A model was developed which describes the relation between these parameters. It was determined that the density of leaves, the depth of penetration within the canopy, the VMD, the air speed of the sprayer and the kind of air stream (from divergent to convergent) have the strongest influence on the deposition. The model is based on the multiple regression analysis. An equation was found to calculate the deposition in dependence on the mentioned parameters (Kaul et. al., 2007). The description of similar models can also be found in literature (Farooq et al., 2004; Walklate et al., 2003; Svensson, 2001).

An important aim of the application of PPP is to produce an evenly distributed deposition. In this paper the main goal is to present knowledge, based on the model, about the adjustment of the quantity of chemicals for the application to get the same levels of deposition on the leaves, independent of the circumstances during spraying. The outcome of this is the reduction in use of PPP over the growing season.

Approach to calculate the reduction of PPP

The calculation of the reduction of chemicals could be based on the fact that the biological effect is achieved under the most difficult conditions for the application (Triloff et al, 2005). If the circumstances are advantageous, a reduction in PPP can be realised. Therefore, it is necessary to define the most difficult conditions independent of place and time. But it is difficult to compare the trees of orchards in different regions. Subjective effects cannot be avoided.

The proposal in this paper is to calculate the possible reduction of chemicals related to the amount which moves through the canopy. This amount is additional with regard to the application from both sides (figure 1). Consequently, it can be used to calculate the possible reduction in quantity without the risk of a deposition which is too low in certain parts of the canopy.

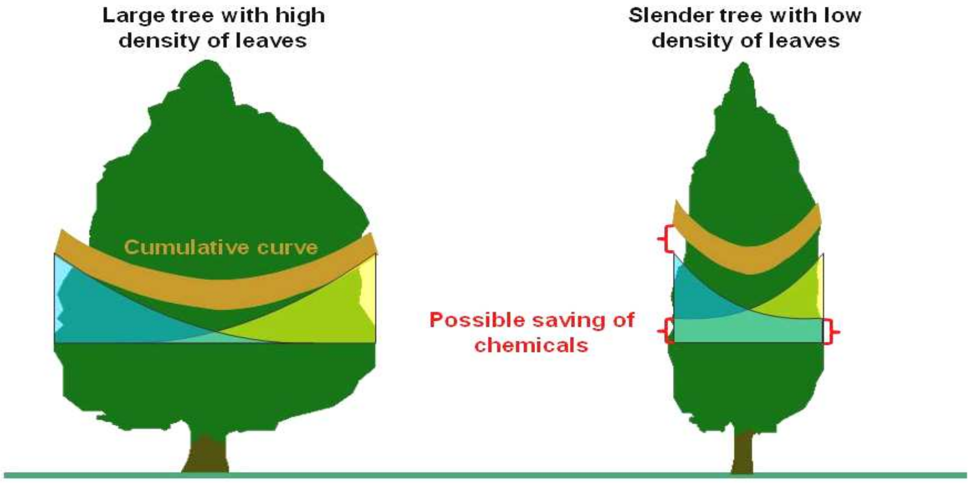


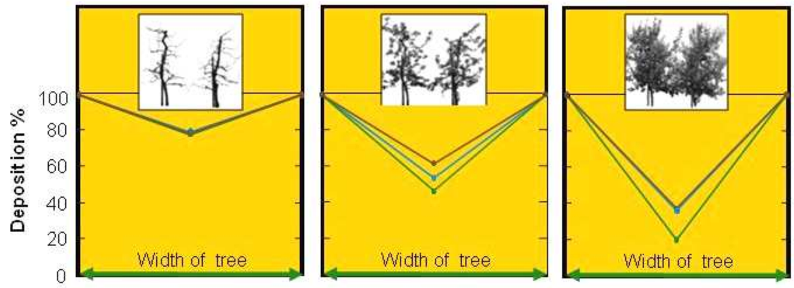
Figure 1. *Basic assumption for the saving of chemicals*

It is difficult to describe the density of a canopy accurately. However, this is one of the most important factors.

The leaf density differs from the top to the bottom of the tree as well as around the trunk and also with regard to the gaps between the trees standing next to each other. The suggested method is to take data for the density of canopy from a gallery of photos of different kinds of apple trees which are taken during the growing season. These data as well as the depth of penetration within the canopy, the VMD, the air speed of the sprayer and the kind of air stream (from divergent to convergent) are employed to develop the mathematical regression model. The picture gallery can be developed further to give a sprayer- and tree-specific as well as a hands-on recommendation to adjust the applied quantity of chemicals.

Results

A formula for the model is given to calculate the amount of deposition in front of, inside and behind the canopy. An approach to calculate the possible reduction of plant protection products is based on the calculated and needless deposition of chemicals behind the canopy (figure 2).



Density of leaves, maximum	%	30	80	100
Density of leaves, near the trunk	%	20	65	95
Density of leaves, average	%	5	30	60
Air speed	m/s	15	15	15
MVD	µm	200	200	100
Angle of highest nozzle	grad	22	22	22
Width of tree	m	0,8	1	1,2
In per cent of normal dose	%	70...73	82...89	96...102

Figure 2. *Example of the reduction of applied chemicals during the growing season*

Figure 2 depicts an example for the reduction of used chemicals during the growing season and its variability. The minimum of used chemicals is about 70 % of the recommended dose without any reduction of the deposition on leaves. First trials showing the biological effect were carried out in 2008 and are continued in 2009.

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Optimization of water volume used in mineral oil applications to control *Tetranychus urticae* in citrus

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Introduction

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is an important pest, affecting lemon (*Citrus limon* (L.) Burm f.) and mandarin (*Citrus reticulata* Blanco) (Geraniales: Rutaceae) orchards in Spain, as well as other citrus around the world. *T. urticae* adults suck the cell contents, causing chlorotic spots on the upper side of leaves. At the end of summer, *T. urticae* causes a characteristic fruit scarring and consequently depreciates the fruit (Martínez-Ferrer *et al*., 2006).
Petroleum-derived spray oils (PDSOs) have recently shown to have a high potential to control *T. urticae* under laboratory conditions. In laboratory conditions, mortalities between 90-100 % have been reported on all stages (eggs, protonymphs and adults) at concentrations between 1.5 – 2% that caused oil deposits of 15 - 30 µg cm^{-2} (Same authors, under publication). However, this pest usually grows on the under side of the leaves and is protected with its web. No information is available about the efficacy of PDSO on *T. urticae* under these conditions.
The primary cause of mortality produced by PDSOs on arthropods is anoxia. In mites, PDSOs act directly by blocking the stigmata causing suffocation (Taverner, 2002; Kallianpur, 2002). In order to guarantee the efficacy of PDSO treatments it is necessary to produce good coverage on leaves. Applied water volume is highly related with coverage. For this reason, this study is aimed at studying the influence of water volume on coverage on citrus leaves and on control of *T. urticae* when treating with a commercial mineral oil under semi-field conditions.

Materials and Methods

Trials were carried out on mandarin (*Citrus clementina* Hort. ex Y. Tan. cv Nules / Citrange Carrizo) seedlings sprayed under a controlled environment. Four treatments at 100, 75, 50 and 25 ml per tree were tested, representing from run-off point (100 ml per tree) to 75% reduction of this volume. Sunspray Ultrafine® (Sun Oil Co., Antwerp, Belgium; nC21, 92% unsulfonated residue, 11.84 cSt (40 ºC)) at 1.5 % v/v concentration was used along the experiments. Control trees sprayed with water were also considered in the biological part of the experiment.
The mandarin seedling trees were 2.5 years old, had around 1.3 m height and an average canopy of 38x31x44 cm (diameter 1 x diameter 2 x height). In the biological experiment, trees were infested with 5 female mites collected one by one from infested lemons, then carefully placed with a brush over different selected leaves. Infested trees were maintained in a greenhouse under controlled conditions (T: 28±4ºC; RH: 65±10%; Photoperiod: 16:8). When the trees presented enough symptoms of infection, the treatments were applied. Six replicates, of one tree each replicate, were performed for each treatment.
The laboratory was equipped with a system to simulate spray applications in field conditions. A nozzle spraying in a horizontal direction connected to an automatically controlled displacement system was used (Figure 1). In order to apply different water volumes, different spray parameters were set up (Table 3). In all cases pressure was 6 bar. The distance between the nozzle and the seedling tree was calculated taking into account the spray angle produced by the nozzle at the working pressure, in order to ensure that the spray cone cloud fully covered the seedling canopy. Seedling trees were sprayed twice, once per each side, and always in the outward direction of the equipment.

Table 1. *Spray parameters used for each volume applied*

WATER VOLUME (ml/seedling)	CONE NOZZLE	NOZZLE- SEEDLING TREE DISTANCE (cm)	SPEED (m/h)
25	D3-DC35	45	2592
50	D4-DC35	30	1980
75			1308
100			996

Figure 1. *Spraying of infested seedling with the simulate spray system.*

To evaluate the efficacy of the treatments, ten infested leaves of each seedling were marked at the beginning of the experiments. Live individuals found on each leaf were counted before the application and after 1 day (C1), 3 days (C2), 6 days (C3) and 12 days (C4). Efficacies were calculated using the Henderson-Tilton formula (Henderson and Tilton, 1955).
Spray coverage of the seedling trees was measured as percentage coverage observed on water sensitive paper (WSP) (Spraying Systems Co., Wheaton, IL). This coverage was defined as the area changed from yellow to blue due to contact with the spray. Spray cards were clipped in three heights of the crown (high, medium, low). In each height, WSP were placed on top and the bottom of two leaves. After spraying and when leaves were dry, WSP were removed and photographed with a digital camera. These pictures were analyzed using conventional software package (Matrox Inspector, version 2.2, Matrox, Dorval, QC, Canada) calculating the covered blue pixels of the WSP area (19.76 cm^2).

Results

In the applications from 25 to 75 ml/seedling coverage increased as water volume increased. Treatments at 75 to 100 ml/seedling produced similar coverage (Figure 2). The highest observed efficacies were attained in both treatments at 75 and 100 ml/seedling for all days of efficacy evaluation. Lower efficacies were observed in treatments at 25 and 50 ml/seedling (Figure 3). Therefore, the water volume was optimized at 75 ml/seedling, obtaining similar efficacy than 100 ml/seedling but saving a 25 % of water volume.
Results suggest that adequate coverage on WSP in field applications should be around 65-75 %. However, more experiments are needed in order to provide a more accurate recommendation.

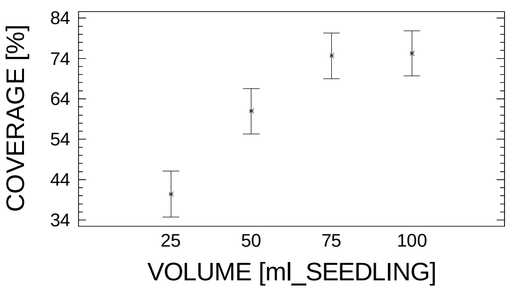

Figure 2. *LSD Intervals for % Coverage*

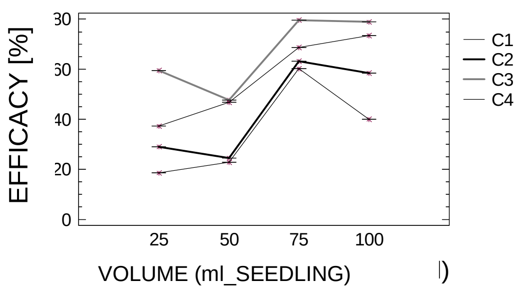

Figure 3. *Interaction plot of efficacy between the water volume and the counted day of the* T. urticae *population*

Acknowledgements

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Optimal use of spray machines in South African citrus orchards

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Introduction

At present, full cover fungicide/insecticide spray application to citrus trees in South Africa involves applications of 10 000 to 16 000 L/ha. However, mature citrus trees are reported to hold sprays to a maximum of 2 300 L/ha only (Cunningham and Harden, 1998). As much as 85% of the excessive spray volume is therefore lost to endo- and exodrift, which results not only in considerable environmental pollution of soils and air, but also increased run-off, reduced spray cover and therewith reduced spray efficacy (Furness *et al*, 2006; Fourie *et al*, 2009). Scope for improvement of the current spray application in southern Africa certainly exists as the use of novel spray applicators allowed a reduction in spray volumes to below 6 000 L/ha in Australia (Furness *et al*, 2006). A spray assessment protocol using fluorometry, photomicrography and digital image analyses was used to study the optimisation of spray application in citrus orchards.

Materials and methods

Orchard spray trials have been conducted with conventional and novel tractor-mounted or -drawn sprayers at a range of calibration settings (mostly adjustments to nozzle selection and tractor speed), which effected spray volumes with SARDI Yellow Fluorescent Pigment (100 mL/hL; Furness *et al*, 2006) ranging from 200 L/ha to 12 000 L/ha. Leaves were randomly collected from the inner and outer canopy at bottom, mid and top tree positions. Quantitative and qualitative spray deposition on upper and lower surfaces of these leaves was determined by means of a deposition assessment protocol using fluorometry, digital macro-photography and image analysis. The quantitative deposition assessment indicated the amount of pigment retained, while qualitative assessment indicated the quality of pigment distribution on leaves. The variation (%RSD) in the mean quantitative deposition per leaf values was indicative of general spray uniformity between leaves. Spray efficiency was expressed as the mean quantitative deposition per leaf value per 1000 L of spray volume.

Results and Discussion

From the results obtained to date, it was clear that the highest quantitative deposition per leaf values at the lowest variation between leaves was generally obtained with higher spray volumes. However, it was obvious that the dispersion quality of pigment deposition on individual leaves declined with increasing spray volumes due to more run-off, which might also have a detrimental effect on biological efficacy (modified from Fourie *et al*, 2009). In sparse canopies, a novel multi-fan tower sprayer, BSF-Multiwing, performed more efficiently and spray deposition was more uniform at similar or faster tractor speeds than with the conventional oscillating boom mist blower (Volcano). Remarkably, spray efficiency with this sprayer at 4 km/h was 365% better than with the Volcano at 1.5 km/h, while uniformity was also improved (average 31.8% RSD). Sprays at lower volumes per hectare and/or faster tractor speed can result in massive savings in chemical, water, fuel and labour cost, and/or substantially improved time efficiency. Additionally, the BSF-Multiwing operated at 10 bar pump pressure compared with the 20 bar of the Volcano, and was substantially more power efficient as it used only 23 kW of tractor power. This would amount to a considerable fuel saving (as much as 50%) as a smaller tractor with less power usage can be used to spray with this machine.

In more dense canopies, spray uniformity was generally poorer especially on inner canopy leaves. Canopy management through pruning practices should therefore aim to reduce canopy density to improve spray penetration. This is especially pertinent in cases where lower spray volumes and/or faster tractor speeds are used for spray application. Nonetheless, it was clear from the results that optimised application could result in improved and more efficient application. For example, two oscillating boom mist blowers, Ultima and Bateleur, deposited similar quantities of pigment at similar uniformity levels at faster tractor speeds (2.3 *vs.* 1.5 km/h) and lower spray volumes, therefore at markedly improved efficiency. Low (Cima at 1000 to 3000

L/ha) and ultra-low volume (ESS Electrostatic Sprayer at 207 to 490 L/ha) application resulted in relatively poor uniformity and spray penetration.

This research is ongoing and is complimented by research on optimal use of spray adjuvants in citrus orchards.

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SESSION NEW SPRAY TECHNOLOGY

02/10/2009
Haakzaal

In pursuit of the inevitable – the development of an autonomous sprayer for fruit crops

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Introduction

Spraying is, at the best of times, a task which needs to be done but is preferable for someone else to do it! It is potentially dangerous to operators and bystanders alike and requires constant attention to detail if mistakes are to be minimized. Autonomous vehicles have long been used in dangerous situations such as mines, quarries and the other land-based industries and now much discussion is occurring about the use of robotics in commercial horticulture. In the USA fruit growers face concerns about a well-trained and motivated labour force, particularly in the light of recent immigration controls. Lack of good labour and a potentially dangerous work situation, combined with modern engineering techniques leads agricultural engineers to the development of an autonomous sprayer. Stentz et al, (2002) developed a system for tractor automation in a Florida orange grove. Several features of the system were validated, including accurate path tracking, the detection of obstacles, and self-monitoring to determine when human intervention is required. This project is currently being developed by the author and others to include an autonomous tractor and automatic canopy sprayers for spraying orange trees, Landers (2009a).

The path of development

Spraying an ever changing target requires a sprayer which can sense changes in canopy growth and adjust both air and liquid flow accordingly. Ultrasonic sensors have been used for many years, and results in field trials, Landers (2009b) shows when using such sensors to monitor absence, presence or height of a tree in modern apple orchards can result in a reduction in pesticide use of 0 -19%, depending upon season, growth stage, trellis design and variety. Using such techniques to monitor crop health and identification has been the challenge facing the European research team, crop adapted spray application (CASA), Doruchowski et al, (2009).

Adjusting airflow and direction on fruit sprayers by various methods such as limiting air intake or air output via physical means or controlling fan speed has lead to better deposition with considerably less drift, Balsari et al (2005).

Adjusting liquid volume has proven to be quite acceptable, with results showing an average reduction in pesticide use of at least 34% over three seasons of field trials in VSP trellis on vinifera using the program Dosavina, (Landers and Gil 2009). Dosavina takes into account the sprayer and the crop canopy, developing on the well proven technique of tree row volume as used on apple trees in orchards.

Location of the sprayer within the vineyard and forward speed is accomplished via a Global Positioning System (GPS).

Monitoring an autonomous sprayer requires many sensors and controllers, not only to monitor the three factors affecting application rate: forward speed, pressure and flow rate but also all the safety features needed in case of marginal to critical failure of the components within the field. Current research at Cornell University is to design such an autonomous sprayer, festooned with an array of at least 22 sensors.

Much technology transfer can occur from such a large-scale project, for example, smaller canopy detectors can be used for the grape industry. Recording precision application with monitors will assist all the fruit industry and aid compliance with GLOBALGAP, traceability and farm management.

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Homogenisation of air flow generated by axial fans used on orchard sprayers

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Introduction

In Italian orchards, most of pesticide applications are carried out using air-assisted sprayers equipped with axial fans and fitted with nozzles mounted on semi-circular booms around the air outlet. These types of equipment are very flexible, as they allow to operate also in orchards covered with hail nets, but they are featured by an uneven vertical air flow profile, due to the fact that the distance between the air outlet and the tree canopy is different at the different vegetation heights. As in most of Italian orchards the average tree height is between 3.5 and 4 m, it is necessary to provide a sufficient air flow also at that height. Aims of the research were therefore to define the most homogeneous air flow distribution to maximise spray deposition on the target and to investigate technical solutions in order to optimise the repartition along the vertical plane of the air flow generated by a conventional axial fan sprayer. The prior target group of this research was constituted by sprayer manufacturers, but also advisers and fruit growers were concerned.

Methodology

With the aim to find the optimal air velocities on the target enabling to maximise the spray deposition, laboratory and field tests were made using a Nobili Oktopus 45-1000T air-assisted sprayer equipped with a 450 mm diameter radial fan and multiple and adjustable air spouts. Air measurements at heights between 0.5 and 4.0 m were carried out at 25 cm steps using a sonic anemometer placed at 2.0 m from the centre of the sprayer (therefore at 1.2 m from air spouts). To obtain six different average values of the air velocity, ranging from 3.7 to 23.0 m/s, different fan revolution speeds and different sizes of the air inlet were used. Field tests were then carried out in two different peach orchards, with different tree sizes, where combinations of six air velocities and four sprayer forward speeds (from 4 to 13 km/h) were used. Spray deposition was evaluated applying a water solution of Yellow Tartrazine E102 (5% v/v). Ten samples of at least five leaves were collected from two canopy zones: external and internal. The results obtained using the Oktopus sprayer were used as a reference to homogenise the air flow generated by a conventional 900 mm diameter axial fan mounted on a Nobili Geo 90S sprayer. In this sprayer model, the semicircular fan outlet, which runs along the upper fan contour, is composed by two adjacent sections: the first one, in rear position, includes the nozzles and small air deflectors; the second one, in front position, is free of nozzles. To improve the distribution of the air flow along the vertical plan, the lower part of this latter fan outlet section was partially closed and small air deflectors were added in the higher open part. Spray tests in the field were then carried out to compare spray deposition on the leaves obtained using the axial fan sprayer with the standard air flow and with the optimised one.

Results

The experiments carried out using the Oktopus sprayer showed that in the orchard with small trees (average height 2.8 m, LAI=0.9 at BBCH 91 growth stage) the optimal air velocity, which corresponded to the highest average spray deposit on the target, ranged between 6 and 10 m/s, while on the taller trees (average height 4.0 m, LAI=1.6 at BBCH 91 growth stage) the optimal air velocity on the target was around 15 m/s.
Thanks to the changes made in the fan outlet it was possible to homogenise the air flow, measured in the vertical plane, generated by the conventional axial fan sprayer (Fig. 1). The average spray deposit obtained with the modified fan configuration was higher by 14% compared to that with the standard axial fan. The spray distribution within the canopies was considerably improved.

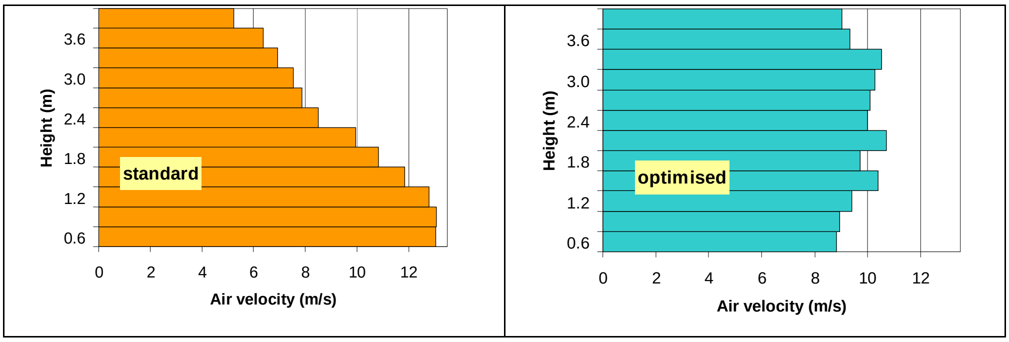

Figure 1. *Air velocity measured at different heights, at 2 m distance from the centre of the Nobili Geo 90S sprayer: standard fan configuration (left) and optimised configuration (right).*

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Variable rate technology for vineyard sprayers: challenges of electronic devices for crop characterization

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Introduction

Crop-adapted dosing of agrochemicals, i.e. dose adjustment has been widely discussed in many publications (Balsari *et al*, 2008). In all cases the main goal has been to adapt the total amount of plant protection products (PPP) to crop characteristics, but difficulties encountered in selecting the most suitable crop parameter and also the high variability on crop characteristics determinations , have always been great an obstacle obtaining general solutions adapted to all conditions and crops.

Assuming that the adequate amount of PPP depends on canopy characteristics (LAI, TRV, VRV, UCR…) and promoting the use of these parameters instead of dose expression related to ground surface ($l \cdot ha^{-1}$), the problem occurs with the selection and accuracy of the most suitable method characterizing the crop. The wide development of new technologies and electronics, together with the cheaper investment, has stimulated to different research groups to install a wide range of measuring equipment on their sprayers (ultrasonic sensors, LIDAR, optic sensors, GPS…) in order to investigate the possibilities to achieve an accurate deposit on the target (leaves) and with a minimum value of losses (drift, run off…).

Different problems and mistakes can be observed during the field test when using some of these electronic tools (Zaman *et al*, 2007). This work shows the benefits and problems observed when two different methods, ultrasonic sensors and LIDAR (Light Detection and Radar) were used for PPP spray application in vineyard.

Methodology

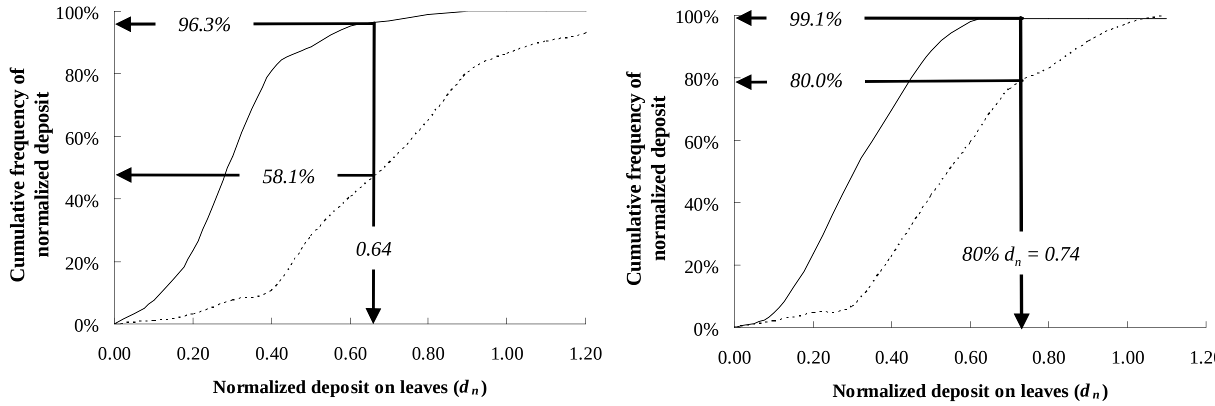
The measurement system and the electronic process unit were mounted on an air-blast orchard sprayer (Hardi LE-600 BK/2 with a centrifugal fan 400 mm in diameter). The sprayer was equipped with six individual and adjustable spouts (three on each side of the machine) in which up to five nozzles could be arranged. A mast was fitted on its left side to hold three ultrasonic sensors. A solenoid high frequency electro valve was placed before each of the three spouts linked to each ultrasonic sensor. The three sensors and electro valves were connected to the central control unit placed on the rear top of the sprayer. Software based on LabVIEW (National Instruments Corporation, Austin, USA) was developed for the purpose and was used to convert the crop width measurements from each sensor into flow rate at every nozzle set. The prototype was also implemented with a LIDAR with the aim to draw a crop map according the spatial variation on the row.

Results

Interesting results have been obtained for all varieties and crop stages in terms of total amount of saving of applied volume (table 1). At the same time proportional application improved the normalized deposit values on leaves and generated the highest number of samples over the intended threshold (figure 1). However some problems or difficulties have been encountered with the use and data interpretation of the electronic devices. The specific characteristics of ultrasonic sensors (its range or measure), its relative position on the sprayer, the difficulties to maintain the right and constant position of the tractor in the center of the row, and the influence of the pressure variations in the final droplet spectrum, are aspects for further development and improvement. As an example, figure 2 shows the theoretical and practical range of distances measured with the ultrasonic sensors.

Table 1. *Percentage of savings (variable/conventional) for different varieties and crop stages*

Variety and crop stage*		Application rate (l·ha^{-1})		Total saving (%)
		Conventional	Variable	
Merlot	85	266	141	47.0
Cabernet Sauvignon	75	299	179	40.1
	85	373	111	70.2
Tempranillo	75	299	127	57.5
	85	373	86	76.9



Var. *Tempranillo*; Crop stage: *75*; LAI: *1.24*

Var. *Cabernet Sauvignon*; Crop stage: *75*; LAI: *1.08*

Figure 1. *Cumulative frequency of normalized deposit on total leaf samples and percentage of samples below 80% of theoretical normalized deposit. Results for conventional application (—) and proportional according to sensor measurements (------)*

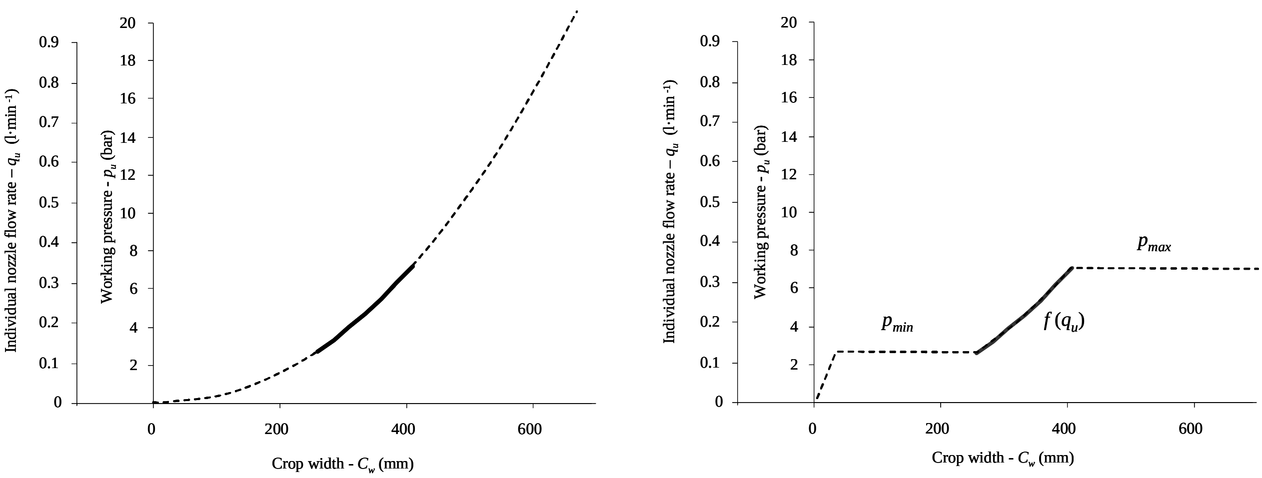


Figure 2. *Theoretical (left) and practical (right) ranges of actuation of the prototype. Measures under 250 mm will be treated as Cw = 250 mm; measures over 400 mm will be treated as Cw = 400 mm*

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Real time foliage density estimation with a lidar sensor for precision fructiculture/horticulture applications. A methodology for field validation

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Introduction

Many studies have been done correlating ground based lidar sensor measurements with well-defined and verified methods in fruit orchards. Lidar sensors provide vertical scans of the canopy to estimate tree height, width, canopy volume, foliar area, foliage density and many other geometric parameters. Most techniques need multiple vertical scans to obtain statistically significant information about individual trees or the whole orchard. However, this information is neither obtained nor used in real time (Walklate *et al.*, 2002; Sanz *et al.*, 2005). Some work has recently been done analysing and processing lidar information in real time to start implementing variable rate spray technologies (VRT) in applications in fruit growing. Wei and Salyani (2005) used single vertical scans to estimate foliage density of canopies. Palacín *et al.* (2007) used several vertical scans to estimate the foliar surface in real time. Escolà *et al.* (2007) used single vertical scans to estimate cross-sectional areas and canopy volume for spray dosing of plant protection products (PPP) and Salyani *et al.* (2007) used the algorithm of Wei and Salyani (2005) to adjust the airflow rate of a sprayer according to foliage density.

In this paper, a methodology is described to assess the foliar area from single vertical lidar scans and to estimate area density using the measured canopy volume.

Materials and methods

The trial was performed in a *Pyrus communis* L. cv. 'Conference' orchard with a LMS-200 (Sick AG, Waldkirch, Germany) lidar sensor. First step assessing the foliar area of a single scan was to exactly determine the leaves that intercept the laser beam. A nightshot camcorder was used to see laser spots (905 nm) on leaves in total dark conditions. Second step was to collect the spotted leaves and the rest behind them in the cross section. This was achieved by using a RUGBY 55 (Leica Geosystems AG, Heerbrugg, Switzerland) rotary laser pointer used for levelling. This device creates a visible red line that has to be placed in a manner to perfectly overlap the vertical laser spot line seen by means of the camcorder. After this procedure, leaves contained in the vertical scan are clearly visible and can be easily collected. Ten vertical scans were performed and leaves were collected and stored from 2 different heights. The result of the sampling was 10 lower and 9 upper samples. Several variables were calculated from lidar data for each single scan. The statistical analysis consisted in applying a linear multivariate regression model with stepwise selection. Two models were built, one for the total amount of 19 samples (partial scans) and another for the 10 full vertical scans.

Results and conclusion

In the partial scans analysis, foliar area was statistically significant correlated with canopy height and canopy half-cross-section (R^2 = 0.771). According to the full scans model, foliar area was significantly correlated with the same variables (R^2 = 0.862). Thus, the results of this work show that it is possible to estimate foliar surface from lidar measurements in real time. At the same time foliage density can be determined as the ratio between foliar surface and canopy volume. This finding encourages the research and implementation of VRT in precision fructiculture/horticulture. The information is important in dose adjustment but many other applications have to be considered related to canopy characterization.

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CFD evaluation of the airflow from three types of sprayers in pear orchard trees using 3D canopy architecture

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Introduction

Proper selection, adjustment and operation of orchard sprayers depending on canopy size, leaf area density, and row distance can maximize on-target deposition of spray and minimize losses (Marucco et al., 2008). Especially the airflow from these sprayers has been considered a major factor affecting spray uniformity. The design of, in particular, cross flow sprayers (e.g. the number and size of fans) determines the vertical distribution and uniformity of the air velocity which has a direct influence on spray pattern, transport and deposition as well as drift (Pergher and Gubiani, 1995). Excessive airflow rates increase drift losses in apple orchards (Cross et al. 1997) and in vineyards and smaller trees (Balsari and Marucco, 2004); in smaller trees they reduce deposition due to canopy compression (Pergher, 2005). Generally, the airflow from orchard sprayers should be sufficient to carry the droplets onto the target and move the foliage to improve deposition in the inside of the canopy and on the underside of leaves (Pergher and Petris, 2008). Marucco et al. (2008) reported that the most uniform coverage of pesticide on peach orchards was achieved when operating axial fan air-assisted sprayer at a forward speed of 7 km h^{-1}, air velocity of 14 m s^{-1} and spray volumes of 400 l ha^{-1}. The aim of this study was to evaluate the airflow from three air-assisted orchard sprayers (single fan radial flow, two-fan and four-fan cross flow) within pear canopy using 3D architecture of the canopy with computational fluid dynamics (CFD). A CFD model developed and validated by Endalew et al. (2009a, 2009b) was implemented for this study.

Materials and methodology

3D canopy architectures of pear trees generated using the measurement and representation method of Endalew et al. (2007) were incorporated into a CFD model to simulate the effects of the solid parts of pear trees. A detailed porous sub-domain was created around each branch to model the effect of the leaves and other small parts using source-sink terms in the momentum and turbulence equations (Endalew et al. (2009a, 2009b). Three sprayers were considered in this work; a single fan radial sprayer (Hardy Condor V), a two- and four-fan cross flow sprayers (BAB BAMPS Duoprop and AirJet Quatt). Three different pear trees were put along a simulation domain of 6 m length (four times the inter plant spacing), 3.5 m width (twice the inter row spacing), and 9 m height (three times the average height of the trees). Appropriate boundary conditions were set based on the field and weather conditions of the experiment in an experimental orchard (pcfruit, Sint Truiden, Belgium). The airflow was modeled using the Reynolds-averaged Navier-Stokes (RANS) equations and the k-ε turbulence model in a commercial CFD code of ANSYS-CFX (ANSYS, Inc., Canonsburg, PA, USA). The air velocity from the sprayers at the sprayer air outlet, before and after (behind) the first row of trees at 1.28 m and 2.68 m from the sprayer centre, respectively, were measured using ultra sonic anemometer (Metek GmbH, Elmshorn, Germany) in Spring 2008 when the trees were all leafless and in Summer 2008 when all the trees were fully leafed. During all the measurements the sprayers were driven at a forward speed of 7.1 km h^{-1}. A weather station about 50 m from the measurement position was recording wind velocity, air temperature and relative humidity at 10 m height from the ground during all the experiment time.

Results and discussion

The vertical velocity profiles obtained directly behind the first row of trees at 2.68 m from the sprayer centre is shown in Figure 1. The CFD results compared well with the measurements representing the effects of both the leafless and fully leafed trees. The maximum absolute errors were all less than 23.4 % and 23.8 % for the results behind the leafless and fully leafed trees, respectively. For all the sprayers, a reduction in the air velocity was observed at mid height of the canopy due to the increased density of the canopy. The magnitude of the reduction was less for the radial sprayer than for the other two sprayers. For this sprayer type, the velocity was already relatively low, in comparison with the others that have jets with a velocity of more than 10 m s^{-1} after the leafless trees. The resistance force due to foliage follows a quadratic relationship with velocity and is linear with the tree width, thus a stronger reduction effect is expected for the high velocity sprayers. The air velocity near the ground and at the top of the trees tends to increase when foliage is present. This is a direct result of the foliar resistance; more air tends to flow though the open spaces under the tree, on the top sparse part of the tree and in between the different trees. The model will be used to optimize sprayer design and operation as a function of crop and environmental conditions for efficient protection with minimal environmental contamination.

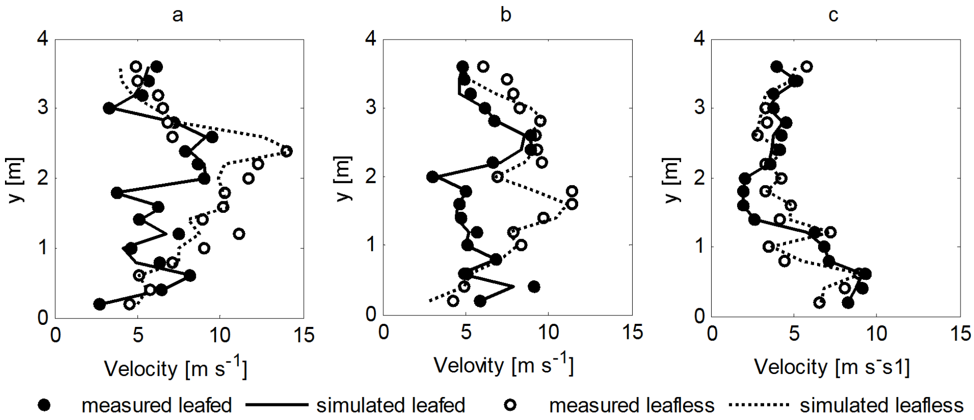

Figure 1. *Vertical velocity profile of the air jet behind the tree for (a) Two-fan cross flow (b) Four-fan cross flow and (c) Radial flow sprayer.*

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Pulstec technology – A new way of controlling liquids in agricultural spraying

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Introduction

Agricultural sprayers use pressureregulation as a way to increase or decrease the quantity of liquid that is being applied to crops. This method has some disadvantages, like 1) a limited applicationrate, and 2) a pressurerelated dropletspectrum. These disadvantages have been the start for the design of a system enabling separate control of dropletsize and quantity, named Pulstec Technology.The name refers to the fact that nozzles can be controlled individually and can either operate in normal continuous spraymode and in pulstec mode as well. In pulstec mode nozzles can be operated from 1 to 20 Hz. and up to an astonishing pressure of 150 bars.This offers some interesting possibilities, i.e. Changing the dropletsize of the nozzles at the same applicationrate and vice versa, curative spraying (in combination with suitable detectors), and application of pesticides directly to the roots. Not to forget the application of liquid fertilizers just by injecting them into the soil in a controlled way on just the right spot.

The Abstracts goal

The goal of the abstract is to awaken the creativity of the people present, and make them start thinking of possible new applications in the various crops they are dealing with. In Holland, Agri Technics Projects is involved in various researchprograms that will be executed by dept. of WUR. Prototypes have been assembled injecting fertilizer and plans to install Pulstec technology on fieldsprayers are being studied. Supported by interesting videoregistrations of prototypes in action, I will challenge the audiance to take the pictures back home and create research programs. Pulstec components are solid and reliable. They can be assembled to simple handheld singlenozzle instruments as a start, and being extended to a multinozzle system controlling up to 200 hi-powered nozzles operating at 150 bars.

Figure 1. *Injecting pesticides or fertilizer directly into the rootzone at 125 bars and in Pulstec mode*

NOTES

NOTES

SESSION ENVIRONMENT AND TECHNIQUE

02/10/2009
Haakzaal

Reducing noise from air-assisted sprayers

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Introduction

During air-assisted pesticide application to arboreal crops, the operator not only is exposed to the spray mixtures but also to the noise generated by sprayers. As decentralisation of the farms and consequently operators exposure to the noise has increased in the past few years, it is important to implement adequate prevention means to reduce the noise generated by air-assisted sprayers. A set of specific tests was carried out on axial fan sprayers in order to assess the technical and operative solutions enabling to limit the noise produced by these equipment.

Methodology of work

Three different axial fans fitted with 7 vanes, featured by different diameters (600, 700 and 800 mm) were tested. For each fan type, two rotation speeds (corresponding to the two fan gears) and three vane angles (25°, 30° and 35°) were considered in the trials. A ir flow rate measurements according to ISO 9898 test methodology were carried out combining the two fan gears and the three vane angles with three PTO rotation speeds: 450, 500 and 540 rev/min. The effects on the air flow rate due to the presence or absence of nozzles inside the air outlet as well as the presence of the flow straightener were also investigated. For all types of fan and all combinations of the tested operating parameters, power consumption was assessed by a torque meter (APIcom TR10/C) positioned on the shaft connected to the fan overdrive. Noise assessments were made following the test methodology described in the International Standards EN 1553, ISO 11201 and ISO 3744. During the tests, a tractor featured by a low noise emission (78.4 dB(A) measured at driver seat) was employed. Sound pressures at driver seat as well as the whole acoustic power emitted by the fans were measured by sound level meters.

Results

Maximum fan noise was 123 dB(A) which strictly related to the fan rotation speed (Fig. 1). The presence of nozzles within the air outlet played a negligible role in terms of noise (±0.3 dB(A)).

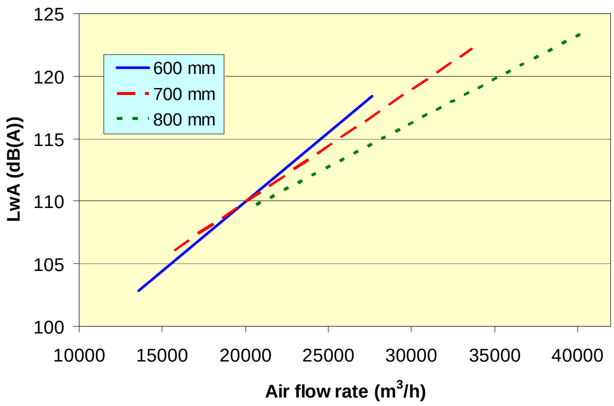

Figure 1. *Acoustic power registered according to the fan size and air flow rate.*

Experimental data indicated that, working with the same air flow rate, higher fan diameters (800 mm) enabled to reduce the noise (-4 dB(A)) and to limit the power consumption (-8 kW). The use of the flow straightener increased the noise on average by 3dB(A) independent of the air flow rate. Experimental data showed that the noise produced by conventional axial fans used on orchard sprayers is high. For the models actually available on the market it is possible to reduce the noise adopting larger fans at lower revolution speed. In future it is expected to consider also the noise aspect during the design phase of fans.

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Technical improvements to reduce surface water pollution with Plant Protection Products (PPP) from point sources

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Introduction

Plant protection products (PPP) are applied to protect the crops against weeds, diseases and pests. During the application process an unwanted side effect can be losses of PPPs to surface water. Point sources are the main entry routes of PPPs in surface water. Key risk areas identified are the cleaning, filling of the sprayer and the management of contaminated washing water (remnant management). The European TOPPS* project- developed Best Management Practices (BMPs) in order to avoid point sources. The most important factor is the correct behavior of the operator but also the improvement of equipment and infrastructure are key factors to mitigate the risk of water contamination.

Methodology of work

The TOPPS project was executed in 15 EU member states. Six pilot areas in different countries were selected to conduct farmer surveys and audits in order to understand awareness, current practices, and how current equipment and infrastructure would comply with the BMPs (see up-scaling report: www.TOPPS-life.org).

Results

a) Filling location and infrastructure
More than 80 % of the operators fill their sprayers on their farmyard mainly on hard surfaces. Only few farms have possibilities to collect spills and overflows on their filling place. BMPs recommend filling and cleaning in the field if no precautionary measures are installed on the farm
b) Filling correct amount of water in the tank.
Farmers (85%) measure the amount of water they fill in the spray tank with the scale attached to the tank. Only 17% of the sprayers tested showed a precision of + /- 1%. (Balsari, 2007) May be as result of low precision of the filling scales 14 - 43% of farmers said they add a reserve of additional water (5 to 10%) to ensure that the spray liquid is sufficient. The risk of having additional left over spray could be reduced by more precise filling techniques like flow meters.
c) Induction hoppers
Induction hoppers reduces the risk of spilling concentrated PPP. Orchard and vineyard sprayers were hardly equipped with induction hoppers while field sprayers were equipped in 30 - 86%. Induction hoppers were mostly equipped with rinsing nozzles to clean empty PPP packages.
d) Residual spray volume
Analysis of ENTAM sprayer tests showed that the best sprayers achieve a 50% lower residual volume than the standard demands (Debear, 2008). Point source risk mitigation means to reduce the residual volumes to a minimum.

e) Inside rinsing
Inside rinsing of the sprayer is necessary in the field to ensure lowest possible amount of contaminated liquid (if any) is carried back to the farm. This requires a fresh water tank to carry clean water for rinsing the sprayer in the field. 15 - 91 % of the sprayers were equipped with a rinse water tank. Current recommend rinsing procedures (tree step dilution) are time consuming and do not always achieve sufficient dilution. Continuous cleaning procedures tested in TOPPS require an additional pump, but achieve better dilution with less water in shorter time. If low enough dilution rates are achieved (1%), in France, the remaining solution in the sprayer is allowed to be left in the field. This is an efficient risk mitigation procedure.
Currently inside cleaning nozzles are not widely available in sprayers.

f) Outside cleaning
PPP deposits on the outside of sprayers especially for air assisted vineyard / orchard sprayers can be significant (Balsari, 2006). An attached high pressure lance used for outside cleaning in the field achieved best cleaning results. Currently very few sprayers are equipped with outside cleaning devices.

g) Conclusion
The potential of not yet realized risk mitigation by equipment and infrastructure can be huge. Realizing this potential will require a close cooperation between PPP - and equipment manufacturers. A consistent strategy for water protection needs stronger focus on risk mitigation optimized equipment and infrastructure.
Most important factor is the correct behaviour of the operator. This requires clear guidance (BMPs) and all available advice capacity for focussed quality advice.

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TOPPS [T**raining the **O**perators to prevent **P**ollution from **P**oint **S**ources] is a 3-year, multi-stakeholder project that began 1st November 2005 and ended 30th October 2008.*
TOPPS is aimed at identifying Best Management Practices and disseminating them through advice, training and demonstrations on a large co-ordinated scale in Europe with the intention of reducing losses of plant protection products to water. The TOPPS project was supported by the EU – Commission through the Life program and ECPA (European Crop Protection Association)

Test of equipment for internal rinsing of sprayers - Three systems for subsequent installation

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Introduction

Cleaning and filling of sprayers is an important issue in many countries at the moment. In Denmark a new legislation concerning cleaning and filling of sprayers puts up demands on where sprayers are washed and pesticides are filled, also demands are made on equipment such as induction hopper, rinse tank and inside rinsing nozzle. This work concentrates on investigating if the tested equipment is able to dilute the remnant residue fifty times, meaning down to 2% of the original tank concentration.

Methodology of work

The rinse equipment was tested on older lift mounted Hardi sprayers; 12 m. boom and tank size at 800 - 1000 l. The equipment comprises rinse tank and inside tank rinsing nozzle**.** The tested equipment was manufactured by Hardi, AAMS and Kyndestoft. The equipment from Hardi uses the sprayers' own pump to suck in the rinse water; here the method of triple rinsing was used. The equipment from AAMS and Kyndestoft are delivered with a 12 volt pump, therefore the method of continuously rinsing were used. Sodium Fluorescein was used as tracer. All valves were activated to ensure contamination of the entire liquid system. During the rinsing and diluting procedure samples of the spray liquid were taken every half minute at the outermost nozzle. After rinsing, samples were taken in the valve for pressure agitation, pressure equalization valve, the pressure filter and the self-cleaning filter. Concentration and volume of the remnant residue in the sump were also measured. With each type of equipment three repetitions were made.

Results

All three systems managed to dilute the residual remnant in the tank down less than 2 % and even down less than 1 % of original tank concentration. In some hoses and filters the concentration was up to 2.9 % (minor volume) when using contentiously rinsing. Using triple rinsing all samples were less than 2 %. The amount of used water varies from 50 to 100 litres because of the two different methods and the performance of the pumps. Using the triple rinsing method took approx. eleven minutes in total and valves had to be operated from the ground. Continuously rinsing is the quickest method, taking less than six minutes. Valves can be operated from the tractor cabin while driving forward during spraying. The results can be transmitted to most sprayers up to 1500 l, both field sprayers and mist blowers.

The following three figures show how the remnant residue in the sump gradually is diluted testing each equipment. The concentration was measured every half minute at the outermost nozzle. The degree of dilution was compared to the original tank concentration set at 100 %. The graphs show an average of the three repetitions.

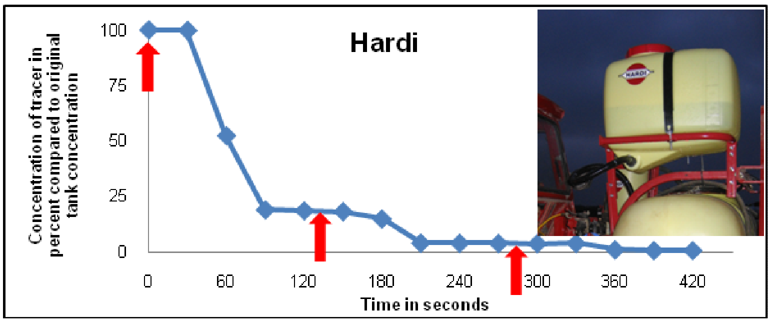

Figure 1. *Hardi. Triple rinse method. At the red arrows 1/3 of the rinse water was added via the inside rinse nozzle and sprayed out. Total use of water was 100 litres. After eleven minutes in total, the concentration was less than 1 %.*

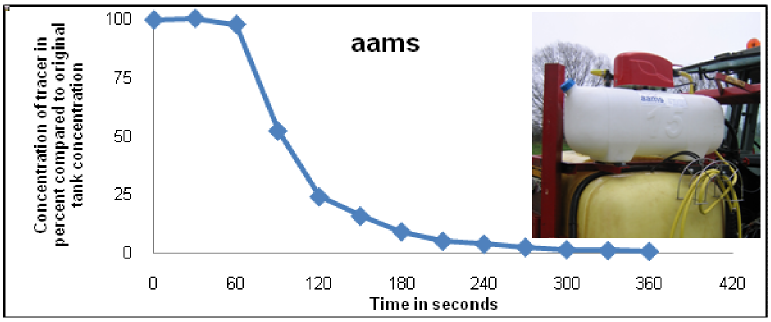

Figure 2. *AAMS. Continuously rinsing. The pump delivered 9 litres pr. minute via the inside rinse nozzle, using about 50 litres to reach 1 %, taking five and a half minutes.*

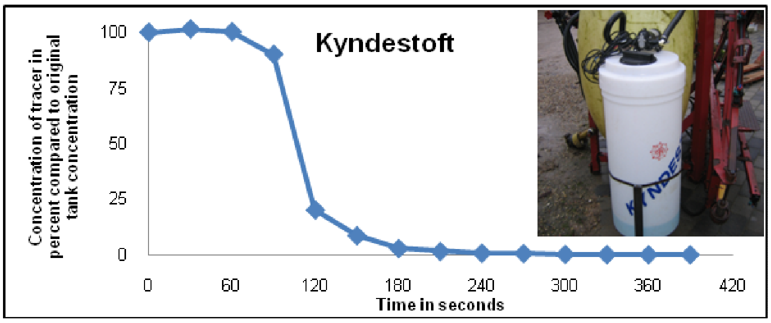

Figure 3. *Kyndestoft. Continuously rinsing. The pump delivered 13 litres pr. minute via the inside rinse nozzle, using round 50 litres to reach 1 %, taking four minutes.*

Orchard sprayer inspection in the Netherlands

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History

In the middle of the 1970s and early 1980s, several initiatives were proposed for testing sprayers in the Netherlands. These initiatives came from buyers of agricultural products, suppliers of chemicals, sprayer dealers and manufacturers, and the extension service from the Dutch Ministry of Agriculture. The objectives of these inspections were to improving the distribution of the chemicals over the crops and to decrease pesticide spillage caused by a bad distribution and leakages. These initiatives should lead to advantages for the farmer (saving on costs of chemicals and better crop quality), the environment (less input of chemicals and less point-source pollutions), and the consumers (safer food).

In 1988 the Foundation for Quality Control of Agricultural Machinery (SKL) was founded with the purpose to develop a standard for testing the equipment. In that year, the first official workshops for testing field crop sprayers were established and the first inspectors were certified. The inspections were on a voluntary basis but stimulated by buyers of agricultural products. During this period 10 - 20% of all farmers participated in the inspection scheme.

In the beginning of the 1990s, initiatives were started with the inspection of air-assisted sprayers in orchards. A working group was formed to develop adequate testing standards for testing these sprayers. A lot of effort was put in developing a good measuring method for testing the vertical distribution of spray droplets. A vertical test bench was developed and after some tests, the limits for an adequate judging of the vertical distribution were determined. The inspection consisted of measuring the sprayer vertical distribution by a vertical lamella test-bench, measuring the output of the nozzles, checking the manometers, testing of the agitation capacity, visual check on leakages, etc. In 1995 the first testing stations were established. Initially, the tests were voluntary and stimulated by the fruit buyers. The number of workshops grew from 4 in 1995 to 12 in 2002. In 2002 the testing of air-assisted sprayers in bush and tree crops became obligatory.

Present situation

Since 2002, all sprayers had to be tested at 2-year and 3-year intervals, in the periods of 2002-2006 and since 2006, respectively. The number of testing stations has grown to a network of 15 workshops in 2009. They are spread over the most important fruit-growing areas. Some workshops have a mobile testing station that could be used for testing the sprayers in other areas. All fruit growers have access to a sprayer testing station within a reasonable distance. In the period of 2006-2009, the average number of tested sprayers was 600 per year. On average, more than 60% of the sprayers needed repairs before approval. Most occurring problems were: worn nozzles, leakages, dripping, and defective manometers. Although the number of repairs stays on the same level, the seriousness of the defects has decreased since the introduction of the inspections. Therefore, the goal of the inspection scheme, i.e., improving the quality of the sprayers and increasing the awareness of the growers to the condition of their sprayers has been met. But periodical inspection is still needed to stay at this level. Almost 100% of the growers participate in the testing scheme, forced by intensive control of official bodies and the requirements from the Global-GAP certification scheme of agricultural products.

Failure	% of all tested machines (period 2002 – 2008)
Flow rate nozzles exceed standard	26%
Dripping nozzles after the spray has collapsed	23%
Pressure gauge: inaccurate, scale not correct	15%
Problems pump	10%
Dirty/bad filters	8%

Table 1. *Failures of inspected sprayers*

The tests are done by certified workshops and supervised by SKL as independent organisation. These workshops have the testing equipment and certified test operators. The tests are done following the testing standards which are legally based. This testing standard is in line with the EN-13790(2) with additional obligation for testing the vertical distribution. The testing equipment are checked on accuracy and condition annually by SKL. SKL also checks the quality of inspected sprayers by random samples of already inspected sprayers. It has developed a web based system where the workshop can create test reports and the data of all tests are gathered in a central database.

Future

With the coming of the European Directive for a sustainable use of pesticides and the harmonisation of EN-13790, some system changes will be needed in the Netherlands. The legal structure has to change, the obligation for testing will be for nearly all types of application equipment (now only for field crop sprayers and air-assisted sprayers for bush and tree crops) and there will be some minor changes in the testing standards. Important for a EU wide uniform testing scheme for orchard sprayers is the extension of the standard EN-13790 (2) with clear requirements for the vertical distribution and equipment needed for measuring this vertical distribution. For mutual recognition of performed tests in different member states, it is necessary to implement EN-13790 correctly and also ensure uniform quality for all performed tests. There has to be a uniform quality management system in all member states to properly monitor elements such as training of test operators, quality of workshops and performed tests, registration of performed tests, etc. The Spise Working Group could be a good platform to set up initiatives in this direction.

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Fruit crop and water protection in the region of the Bommelerwaard: new spraying techniques, integrated pest management and selection of pesticides

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Introduction

Surface water in the region of the Bommelerwaard is used for drinking water by DZH (Dune Water Company South Holland). The quality of this water is seriously hampered by the presence of several pesticides (Visser & van der Wal 2007). Different stakeholders in the region have started a regional project to improve the crop protection methods of the growers in the area. Most important sections of agriculture in the area are greenhouse farmers growing flowers, dairy farmers growing maize and grass, and fruit farmers growing apples and pears (Vlaar & Leendertse 2007). A number of crop protection methods that reduce the impact of pesticides on surface water on the one hand and protect the orchards against pests on the other hand have been introduced successfully in the orchards.

Methodology of work

A study group of fifteen fruit growers has started to work together from 2001 onwards. With financial support of the Water Company and technical support of CLM, Fruitconsult and DLV Plant the fruit growers have tested and introduced a number of techniques on their farms (Table 1). Four techniques are related to spraying (nr 1-4), three techniques are related to pesticides (nr 5-7) and one technique is based on a warning system (8).

Table 1. *Techniques used by growers to reduce the environmental impact of pesticides*

Orchards	**Environmental impact (surface water)**	**Applicability by growers**	**Profits for grower**
1. Tunnel spray system	+	+	0
2. Wanner spray system	++	+	+ (long term)
3. Venturi nozzles	+	+	0
4. Nozzle tester	+	+	0
5. Pesticides with low environmental impact	++	++	+
6. Solution of calcium hydroxide against tree cancer	++	+	0
7. Biological conservation	+	+	+
8. Warning system brown spot	++	0	+

The Tunnel and Wanner spraying systems reduce the emission of pesticides to air and water and reduce the amount of pesticide needed. The Venturi nozzles reduce emission to water. The nozzle tester measures the flow from individual nozzles. This flow is compared with a standard nozzle. A flow smaller than standard (hampered nozzle) might reduce the effect of a pesticide application. A flow larger than standard (worn nozzle) can cause damage to the fruit. The environmental yardstick for pesticides is used by the farmers to choose the most environmental friendly pesticide (www.milieumeetlat.nl/index.en, Reus & Leendertse 2000). Calcium hydroxide is sprayed over the orchard by using the water supply systems in the orchards in order to replace the use of carbendazim to control tree cancer. A biological treatment is tested in the conservation of the fruit. Finally a warning system for the black fungus disease has been tested. From 2005 onwards the growers register their pesticide use. This use and the emission to water has been used to estimate the yearly environmental impact on water organisms by means of the environmental yardstick.

[1] Centre for Agriculture and Environment, [2] Fruitconsult [3] DLV Plant [4] Dune Water Company South Holland

Results

The implementation of a number of measures has led to a reduction of kg of pesticides used and to 75% reduction of the environmental impact on water organisms between 2005 and 2008 (Table 2). The costs per year varied.

Table 2. *Active substance, environmental impact and costs of applied pesticides between 2005 and 2008. Average of 12 pear growers.*

		2005	2006	2007	2008
Applied active substance	kg/ha till 1st of September	29	25	23	26
Applied active substance (fungicides)	kg/ha	34	30	32	21
Environmental impact on water organisms by fungicides	points/ha till 1st of September	16.406	10.439	10.642	3.882*
Environmental impact on water organisms by Thiram	points/ha till 1st of September	15.086	9.672	9.673	2.560*
Costs fungicides	euro/ha till 1st of September	422	408	393	492**

* 2008 calculation by 2% drift due to new low emission techniques, other years 3%

** 2008 calculation for whole year

The nozzle test gave fruit growers a renewed insight in techniques and nozzles they use by applying pesticides in their orchards (Figure 1). Nine fruit growers with different type of spraying machines tested 227 nozzles. About 50% of the nozzles had a flow that deviates 10% of the standard. Some fruit growers detected nozzles that were completely blocked. After the test the nozzles were cleaned or replaced. The nozzle test is an inexpensive technique to check the workability of nozzles for an effective application of pesticides. This reduces the environmental impact of pesticides.

Figure 1. *Nozzle test*

Conclusions

1. Eight measures varying from spraying techniques with reduced emission, selection of pesticides with a low environmental impact to biological treatment in fruit conservation have been successfully introduced in the Bommelerwaard.

2. The introduction of these methods has led to 75% reduction in environmental impact on water organisms.

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POSTERS

Haakzaal

Droplegs - spraying closer to the target: better deposition, increased biological efficacy

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Introduction

Spraying insecticides and fungicides in field vegetables with conventional booms often results in mediocre and sometimes even poor biological efficacy in the control of pests and diseases. The lion's share of the applied product is deposited on the upper surface of leaves and predominantly in the upper half of the crop. Plant tissue in the lower part of the crop and the ground facing sides of leaves and fruit usually receive little or no spray coverage at all. Those pests which sit preferentially on the lower side of the leaves and those fungal diseases which benefit from the more humid microclimate in the lower part of the plant are difficult to control by standard top down boom spraying. As a result of unsatisfactory pest or disease control farmers are tempted to spray more frequently which rarely solves the problem.

Droplegs, a device with nozzles at the lower end that travels between plant rows, was used already during the Second World War in potatoes. The company Benest experimented with droplegs in collaboration with Scottish Institutions in potato fields in the 1990's. Later the company Micron Sprayers Ltd. took over the droplegs designed and tested by Benest but was not in a position to further develop the technique. At the beginning of the 21st century the Horticultural Research Station at Waedenswil Switzerland began with a series of field trials in various vegetable crops. The results in potatoes and bush-beans were encouraging but it was felt that the British dropleg was too heavy and had several drawbacks. The Federal Research Station at Waedenswil then contacted a local manufacturer and repair workshop for spray equipment (F. Kuhn, Dintikon, Switzerland) and an improved light weight dropleg was built and tested subsequently.

Methodology of work

A conventional small plot sprayer of the Research Station at Wädenswil and various commercial boom sprayers operated by cooperating farmers in Switzerland were fitted with droplegs 70 to 100 cm long depending on the crop to be sprayed. For top down spraying usually flat fan air injector nozzles (Lechler, Teejet) were used where as the droplegs were initially fitted with Delavan hollow cone nozzles spraying upwards, later these were replaced by twin-spray-caps holding deflector nozzles spraying sidewise and upwards (Lechler, Agrotop, Hypro). The caliber of the nozzles was always chosen so as to spray 50% to 60% of the total spray volume by the droplegs and 50% to 40% by the air injector nozzles. Spray volumes ranged from 250 l/ha up to 800 l/ha depending on crop type and growth stage of the crop. For crops with waxy leaves such as cabbages, onions and leek the adjuvant Breakthru S240 was used for conventional farming and Heliosol (Omya Agro Services Switzerland) on organically producing farms. Care was taken to limit spray volumes so as to avoid any run-off spraying. In selected experiments the distribution and deposition of the spray was studied with the aid of a fluorescent tracer (Helios 500 SC, Syngenta Crop Protection AG).

Results

In bush-beans several field experiments in Switzerland and Germany with droplegs have shown that the biological efficacy of the commercially used fungicides against Sclerotinia and Botrytis was considerably increased as compared to conventional boom spraying particularly so under high disease pressure. Tracer studies in Switzerland, Germany and Italy confirmed that with the dropleg technique much higher amounts of product can be deposited on the lower part of the plants than by conventional boom spraying. Likewise in various Brassicae species as well as in onions the biological efficacy against white fly (*Aleyrodes proletella*), thrips (*Thrips tabaci*) and fungal diseases (*Alternaria sp., Peronospora destructor*) was markedly increased. In Brussels sprouts droplegs combined with top down spraying and the adjuvant Breakthru S240 increased the share of buttons with high quality and thus the total commercially marketable yield. On farm trial work with droplegs indicated that the number of sprays in Brussels sprout can be reduced by about 20% and the dose of the fungicides and insecticides applied can be adapted to the growing crop. Droplegs usually help to better distribute the spray broth over the entire plant and to reach target areas difficult to spray by conventional boom spraying (underside of leaves, lower parts of the plant). Droplegs are built as a flexible device and are attached to the boom in such a way as to allow an easy sidewise movement. As a result damages to crops were never observed. A selection of results is presented in the poster on display. For more results the reader is referred to the list of references below. Droplegs, so far, have not been tested in soybeans, cotton, cut flowers, and tree nurseries just to mention a few more crops planted in rows, but the technology is very likely to be useful in these crops as well. Precise interrow herbicide application is yet another area where droplegs could serve as a useful tool.

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Environmental friendly plant protection with innovative spraying systems
Results of a four years project funded by BLE Germany

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Introduction

In order to avoid the drift of plant protection products (PPP's) to related water bodies and non- production areas it is of significant importance to choose the right spraying system. Today and in future innovative sprayers have to meet the strict demands of environmental protection.

The project named "Maintenance of traditional fruit-growing areas in Germany by crop protection measures preserving the aquatic environment" had the aim to develop and promote new innovative sprayers. It was carried out from 2005 to 2008 and nationally funded by the Bundesanstalt für Landwirtschaft und Ernährung (BLE). In this comprehensive project four multiple row sprayers and four conventional sprayers with innovative supplementary techniques were tested in practical and scientifical tests during a three to four years period in the regions Altes Land and Lake Constance. The following four of eight sprayers were presented as excellent examples of innovative spraying systems in consideration of their drift reduction potential, leaf deposition, biological efficacy and PPP- saving potentials:

1. Lipco Tunnel sprayer OSG-N1
2. Lipco Tunnel sprayer OSG-N2
3. Wanner sprayer with reflection shields
4. Wanner sprayer with sensor unit ECO-Reflex

Results

The results indicate that the four sprayers can reach 95% drift reduction (compared to the basic drift values) in special settings. For example, the Lipco Tunnel sprayer OSG-N2 with a height of 3,50 m reduced drift by a minimum of 95% and a maximum of 99%. In many cases the Tunnel sprayer OSG-N1 produced nearly twice the deposit of standard sprayers and ensured the biological efficacy.

The sensor unit ECO-Reflex produced by Müller Elektronik also offers the classification of 95% drift reduction, compared to the basic drift values. The use of sensors did not importantly affect the quality of deposit in the fruit trees and the biological efficacy. The leaf spray deposit often was comparable with the applied deposit of sprayers without sensors.

The Wanner sprayer with reflection shields reduced drift by more than 95% compared to the basic drift value. However it is recommended to choose special settings of the tangential fans. Both tangential fans should have - adapted to the wind speed and direction – at least 1400 r.p.m. to guarantee high quality deposits on both sides of the fruit tree. The biological efficacy is ensured with the recommended settings.

According to the sprayer system the PPP- savings differed. Closed systems with two-sided recycling like the tunnel sprayer recycled more (up to 70%) than one -sided recycling sprayers like the Wanner sprayer with reflection shields (at an average of 10-15%). With the ECO-Reflex unit a maximum of 60% was possible, but in general savings up to 25 % are realistic.

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Farming with Future

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In 2003 the Dutch Government chose a new approach for the implementation of sustainable crop protection by taking the initiative to a National Agreement on Crop Protection. This agreement between stakeholders from agribusiness, governmental and non-governmental organisations set goals for the reduction of environmental effects of pesticides as a shared responsibility of the stakeholders.

The project Farming with Future started in 2004 to work on the implementation of sustainable crop protection at the regional level. Farming with Future uses a network approach. Networks in the project consist of different stakeholders from the agricultural sector (farmers, research, advisory services, suppliers, water board, etc.). Thanks to the National Agreement, there is a common interest and responsibility for sustainability of crop protection, which makes cooperation in the network possible. Within the network new technologies and strategies from research are tested on participating farms and evaluated on effectiveness and feasibility. The technologies and strategies that are supported by stakeholders in the network are disseminated to the agricultural sector in cooperation with these stakeholders. Constraints that are faced by the network of stakeholders are selected as new topics for the research agenda and communicated with policy makers. The network approach has realised a change from *one way knowledge transfer* to *knowledge circulation* by active participation of stakeholders in the process of development and dissemination of sustainable crop protection. The network approach also enables the formation of new coalitions of stakeholders that work together on specific bottlenecks in the sustainability of crop protection.

The challenge for research institutes and policy makers is to use this approach to reach a higher level of implementation of new developed strategies and technologies for sustainable development and to solve problems that can only be solved by cooperation of different stakeholders.

Method for a stochastic simulation of spray drift values as basis for a probabilistic and spatially explicit exposure assessment of surface waters

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Introduction

In current deterministic exposure assessment the spray drift deposition of plant protection products is either calculated using the regression formula of the 90 percentile JKI drift values (Rautmann et al. 1999) or according to FOCUS (2002).

In this work we propose a novel approach for modelling spray drift deposition distributions for any distances up to 75m (arable crops) and 150m (high crops) to be used in spatially explicit probabilistic exposure assessments of surface waters. In a Monte-Carlo Simulation these drift deposition distributions can then be randomly combined with other distributions of independent parameters (wind direction, filtering rate of vegetation, etc).

The polynomial functions are based on the analysis of drift measurement datasets of Ganzelmeier et al. (1995) and Rautmann et al. (1999). The approach follows the idea of trial-by-trial analysis of drift measurement datasets applied within the EUFRAM project for arable crops but only for a single distance (EUFRAM 2006). In a probabilistic assessment a trial wise analysis is more appropriate. It allows considering the variation of application conditions between trials such as air temperature, wind speed, wind direction, nozzle, vehicle speed, rel. humidity.

Materials and methods

For each crop type the individual drift measurement datasets of Ganzelmeier et al. (1995) and Rautmann et al. (1999) are analysed on a trial-by-trial basis. In a first step the means of the deposition rates per trial are computed and distributions of the trial means and the single measurements are compared (Table 1).

The trial means follow a lognormal distribution. For each of the trials and a measurement distance *x* the logarithm of the trial means is computed. For each measurement distance *x* the logarithmised trial means can be plotted as normal distribution, which again can be described with a mean and a standard deviation. By using a non linear regression (PROC NLIN; SAS Institute 2002) the following functions (1) and (2) are explored (Figure 1). They describe the mean and the standard deviation of a deposition value in dependency of a spatial distance *y*.

(1) $m\_lndrift(y) = a \cdot \ln(y)^2 + b \cdot \ln(y) + c$

(2) $s\_lndrift(y) = a \cdot \ln(y)^2 + b \cdot ln(y) + c$

m_lndrift(y)	Mean of the logarithm of a deposition value at distance y
s_lndrift(y)	Standard deviation of the logarithm of a deposition value at distance *y*
y	Spatial distance of a water body segment to the application field in wind direction WR_j
a,b,c	empirical parameter of the polynomial function (2. order)

According to the spatial distance y of a water body segment to the application field a logarithmised mean *m_lndrift(y)* and the logarithmised standard deviation *s_lndrift(y)* are explored. Then putting *m_lndrift(y) und s_lndrift(y)* in a function for random normal distributions (RAND; ditto) a logarithmised deposition value is computed (see equation 3).

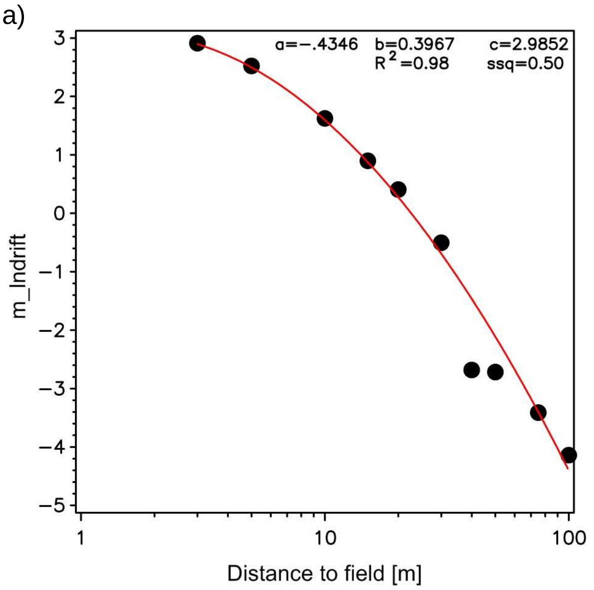
(3) *lndrift(y)* = rand(norm;*m_lndrift(y); s_lndrift(y))*

The modelled spray drift deposition value follows equation (4):

(4) *drift = exp(lndrift(y))*

In a Monte-Carlo Simulation we compute for each water body segment and wind direction a distribution of deposition values by multiple application of equation (3). Spatial distance y and wind direction WR_j stem from GIS analyses.

a)



b)

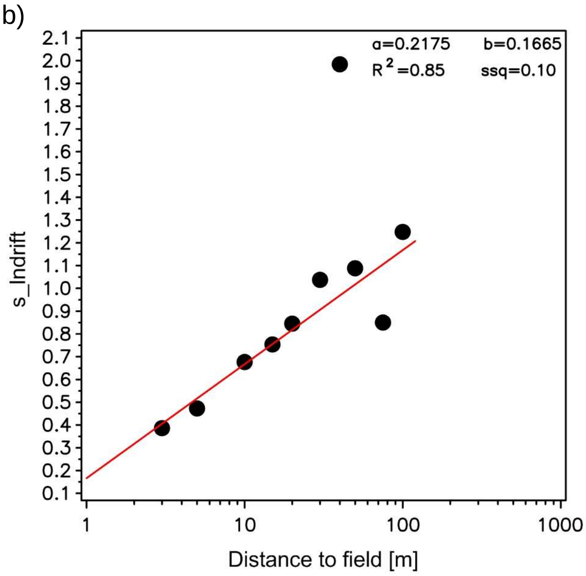


Figure 1: *Orchard early stage: Regression line to the mean of the logarithmic trial means (a) and the logarithmic standard deviation (b) of at measurement distance x*

Results

The model was tested for orchards against the trial means for the available measurement distanced by simulation of equation (5) (n=100 000). The output distribution of the simulation is compared to the distribution of the trial means and the distribution of the measurement value.

Table 1 *Comparison of the 90th percentile of the drift measurement data in orchards:* ***1st*** *row: Analysis of individual measurements (Ganzelmeier et al. 1995, Rautmann et al. 1999);* ***2nd*** *row: Analysis of the trial means;* ***3rd*** *row: Simulation of spray drift deposition according to the proposed approach*

Distance (m)	3	5	10	15	20	30	50	75
	N=351	*N=453*	*N=453*	*N=448*	*N=413*	*N=413*	*N=253*	*N=100*
Individual results	27.33	23.48	10.63	5.996	3.744	1.740	0.268	0.098
	N=38	N=40	N=40	N=40	N=40	N=40	N=24	N=10
Mean results	26.46	20.01	9.655	4.943	3.311	1.666	0.261	0.109
Calculated values N=100000	30.44	23.54	11.59	6.31	3.75	1.60	0.45	0.46

All drift values in % of the application rate

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Sharing best practices in Europe with ENDURE Information Centre

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The ENDURE Information Centre is developed as a part of the EU funded program named ENDURE (European Network for the DUrable Exploitation of crop protection strategies). The ENDURE IC is a dynamic web-application which disseminates information on best practices, IPM measures and non-chemical alternatives in crop protection. ENDURE IC is a central point of reference for extending expert knowledge, recommendations and advice for extension services, advisers, farmers and researchers. Users can search using a combination of crop and pest or disease/region and as a result receive information on IPM measures. All the available IPM measures are tested in the field, cost effective and practical to implement. The aim is to present a quality selection to ENDURE IC users, and enable them to easily search for information which usually is only available in national languages or gives information about very regional practices. Such practices could have the potential for adoption in different regions or reflect very valuable potential for disease or pest control. All the information is scientifically sound and the different levels of their practicability are indicated.

Currently documents are available mainly on potato and wheat. In the coming months the website will be launched and new documents will about crop protection in pome fruit, mais, field vegetables and grapes will be added. ENDURE IC will not offer a complete database of all integrated measures, but offers a European quality selection (European Best Practices) with information validated by experts.

The identification of the needs of advisers and their suggestions are very important for the development of ENDURE IC. Therefore a first prototype has been tested by advisers during national and international tests and feedback sessions. To maintain the connection between advisors and the research network in Endure the Endure Network of Advisors is established.

Autonomous spraying in pomefruit orchards

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Introduction

Crop protection with traditional spray equipment costs much time. Most of the time is spent on 'driving around' in the orchard, as every tree row must be sprayed separately. If tree spraying could be done with an autonomous driving machine this would save much precious labour time. A further integration of such an autonomous driving system could potentially also be integrated with current developments in the field of sensor spraying. With sensor spraying switching on and off of spray nozzle can be managed based on awareness of leaf canopy. Spray volume can be adapted based on canopy density and switching Fine/Coarse nozzles and amount of air assistance based on the position relative to vulnerable areas like ditches and housing.

In the Netherlands a project is initiated to evaluate the potential of developing an autonomous spray technique for apple and pear orchards. First an inventory was made of the growers' ideas on requirements for such an autonomous system. Raised points were:

- Usable in existing cultivation and growing systems in the fruit sector
- Integration with a mowing function is positive
- All spray application can be done, also herbicide spraying
- Limited weight to minimise damage to grass paths and headlands
- Sufficient capacity to spray a minimum of 1 ha per hour
- Easy connectivity of spray information to GPS based information of the orchard
- Integration of different systems provides the potential of 'tracking and tracing' in standard cropping systems in the fruit sector.

Results

With growers study groups discussions were held resulting in four options for developments of autonomous systems: track system like in greenhouses; autonomous tractor and sprayer combination; autonomous tunnel sprayer and autonomous multi-row sprayer. From further discussions and based on cost and labour time evaluations for three typical orchard lay-out regions in the Netherlands: Zeeland, Betuwe and IJsselmeerpolders it was concluded that an tractor + sprayer combination was the best option. Also the growers feelings of an tractor + sprayer combination moving autonomously through the orchard is more easily accepted than an new design robot like tunnel or multi-row system. At the moment preparations are made to interest sprayer manufacturers and get funding for further development of a fully autonomous tractor + sprayer combination in apple and pear orchards.

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