Effect of sprayer settings on spray distribution and drift potential when spraying dwarf apple trees

van de Zande, J.C.; Barendregt, A.; Michielsen, J.M.G.P.; Stallinga, H.

https://elibrary.asabe.org/techpapers.asp?confid=cil2002

The Society for engineering in agricultural, food, and biological systems

Paper Number: 021036
An ASAE Meeting Presentation

Effect of sprayer settings on spray distribution and drift potential when spraying dwarf apple trees

J.C. van de Zande,

Institute of Agricultural and Environmental Engineering (IMAG), PO Box 43, 6700AA Wageningen, the Netherlands. j.c.vandezande@imag.wag-ur.nl

A. Barendregt,

MSc student Wageningen Agricultural University, Dept. Agr. Eng., Mansholtlaan 10-12, Wageningen, the Netherlands

J.M.G.P. Michielsen & H. Stallinga

Institute of Agricultural and Environmental Engineering (IMAG), PO Box 43, 6700AA Wageningen, the Netherlands.

Written for presentation at the
2002 ASAE Annual International Meeting / CIGR XVth World Congress
Sponsored by ASAE and CIGR
Hyatt Regency Chicago
Chicago, Illinois, USA
July 28-July 31, 2002

Abstract. *Matching spray volume to tree sizes and shapes can reduce chemical application, thus reducing operational costs and environmental pollution. A tree-specific variable volume precision orchard sprayer, guided by foliage shape and volume map is developed. The spray and air volume will be adjusted to tree variation of the foliage shapes and volumes of the mapped trees. In preparing the spray and air volume controllers experiments were performed on a spray track with a prototype cross-flow element spraying different artificial leaf canopies. The effects of nozzle- and air-outlet distance to canopy, air volume and speed, and canopy density on spray penetration were quantified using fluorescent tracer techniques. Air speed was measured with a vane-anemometer. Results can be used as input for optimal settings towards maximum in canopy deposit and minimal spray drift of a segmented cross-flow sprayer in dwarf apple trees.*

Keywords. Sprayer settings, air flow, spray deposition, air distribution, spray distribution, orchard-sprayer, apple-trees

Introduction

In fruit crop spraying the goal is to come to an uniform spray deposition all over the leaves in the tree. Losses to the soil underneath the tree and outside of the orchard through spray drift are to be minimised. Spray distribution of orchard sprayers are measured in a vertical plane (Miralles *et al.*, 1996). However it is not clear what the relation is between a spray distribution measured stationary in a vertical plane and that in a dynamic situation, when driving through an orchard, and the spray deposition on the leaves in the tree. Schmidt & Koch (1995) concluded that the requested distribution on a patternator depends on the type of sprayer and the shape and height of the trees to be sprayed. Koch *et al.* (1998) found that with a cross-flow fan sprayer a fixed nozzle distance in combination with a uniform distribution on the vertical patternator was preferred to obtain a homogeneous spray distribution on the leaves of the tree. Siegfried *et al*. (1995) prefer however a more canopy shaped spray distribution corresponding with leaf-mass and canopy-width in the tree.

It is known that sprayer settings are important for spray distribution in tree canopy. Important parameters determined are: vertical liquid distribution (Jaeken *et al*., 2002), air settings (Moor *et al*., 2002; Svensson, 2002), sprayer speed (Zande *et al*., 2001a). Canopy structure however varies a lot, because of plantation systems, plant varieties, pruning systems and in time during the season (Jaeken *et al*., 2001).

The research described in this paper is performed within a research project (PreciSpray EU-QLK5-1999-1630) aiming to develop a Canopy Density Sprayer (CDS) using information on leaf canopy density and the structure of the trees (Zande *et al*., 2001b) to adapt spray volume and air settings. Using site-specific information of individual trees from an aerial survey (stereoscopic) enables to spray every tree as an individual and unique object using GPS. Knowledge of settings of a cross-flow sprayer on spray distribution for different heights is however very limited (Porskamp *et al*., 1993). Koch *et al.* (1998) showed the effect on spray deposition of individual spray element on different heights of a cross-flow orchard sprayer in apple trees. More detailed information is needed to come to an algorithm to automate sprayer settings depending on tree structure and canopy density.

The effect of sprayer settings on the stationary air distribution and dynamically the spray distribution on different targets is therefore assessed. The effect of fan capacity, air outlet dimensions, distance of spray element to target area, spray volume and driving speed are to be investigated. In this paper we describe the results of the research on fan capacity and air outlet setting on spray distribution in free air, on leaf walls of defined density and in and through an artificial apple tree (Zande et al., 2001) in the laboratory. Results are evaluated for spray deposition and drift potential to prepare for use in a Canopy Density Sprayer controller.

Materials and Methods

In the IMAG spray laboratory experiments are performed on a spray track placed in a conditioned chamber (15mx5mx4m, lwh). On the spray track (free space to the floor 2m) a prototype spray element of a CDS cross-flow fan orchard sprayer was hanged. The spray element consists of a switchable tree-nozzle element connected to a variable air-outlet of 0.50x0.06m. Direction of the nozzles is fixed to 20^o in the air flow. Individual nozzles were angled 10^o on top of each other to prevent spray fan disturbance. Nozzle type used was a Hardi ISO F8001 used at 5 bar pressure having a flow rate of 0.52 l/min. Only one nozzle was used in the experiments presented here. Fan speeds was variable and adjustable between 0 and 3000 rpm, having a maximum air flow of 7000 m^3/hr. Fan settings used in the experiments were 0, 1500 and 3000 rpm. The air-outlet was variable adjustable and used in the settings, full open, half open, ¼ open and closed. The spray element was moved on the spray track with a speed of 1 m/s.

Fig. 1. Spray element on spray track

Measurements performed were air distribution in the stationary situation to characterise the fan air-outlet combinations. Spray distribution was measured dynamically on different targets: poles on different distances to measure free flight spray distribution, leaf walls of known density, and an artificial apple tree.

Air distribution

Air distribution was measured with a vane anemometer (Lambrecht 1416 K). On distances 0, 0.25, 0.50, 0.75 and 1.00 m from the nozzle at nozzle height and 0.10, 0.20 m above and below nozzle height. A two-dimensial airflow pattern could be quantified. Measurements were repeated three times for a fan speed of 1500 rpm and 3000 rpm and the air-outlet settings: full, ½ open, and ¼ open.

The quantification of the spray deposition on the collectors was performed by means of fluorimetry. Therefore a fluorescent tracer (Brilliant Sulfo Flavine BSF, 0.5g/l) was added to the tank mix.

Free air spray distribution

Spray distribution in free air was measured on chromatography paper (1.50x0.02m) fixed to vertical poles placed at 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50m from the nozzle. Nozzle height was marked on the paper and after spraying the paper was cut into 0.10m pieces to be separately analysed on spray deposition.

Leaf walls

Spray deposition through a known leaf density was measured with leaf walls of 1.0x1.0m size. In a framework branches with artificial leaves were stuck to simulate a leaf area (LAI) of 2.14 m^2/m^2. Leaf walls were placed in single and double orientation on 0.25m distance from the nozzle alongside the path of the spray element. Double leaf walls were placed on 0.25m behind eachother. Behind these leaf walls spray distribution was measured on chromatography paper (0.60x0.02m) fixed to vertical poles placed at 0.25m from the nozzle for the double wall and 0.25,and 0.50m from the nozzle for the single leaf wall. Paper was centred around the nozzle height.

Artficial tree

In order to evaluate leaf deposition in a tree, spray deposition measurements were performed passing an artificial apple tree. The tree was reconstructed from a semi-dwarf Elstar apple tree on M9 rootstock. Stem and main branches were reconstructed from stainless steel. Shoots were established with artificial Ficus Benjamina leaves. Height of the tree was 2.2m, crown diameter was 1.5m The tree had 3000 leaves and total leaf area was 6.8 m^2. With a tree density of 3m row spacing and 1.25m tree spacing in the row leaf area index (LAI) is 1.8. Number of leaves and leaf surface area are as measured from an orchard tree. In the tree leaf samples (filter papers Whatman GF/A ø 0.055m) were placed in front of the stem and behind the stem on nozzle height, 0.23m higher, and 0.23m lower of nozzle level. Per sample point 2 filter papers were placed both in horizontal and vertical orientation. On the stem and behind the tree a chromatography paper strip was placed to measure vertical spray distribution.

Spray passing the leaf walls and the tree is an indicator for the filtering capacity of the tree and therefore indirectly for drift potential.

Fig. 2. Leaf walls (left) and artificial tree (right) as setup in the spray chamber alongside the spray track in the IMAG spray laboratory.

A statistical analysis was executed on the results. Differences between means were assessed using analysis of variance at a 95% confidence interval with the GENSTAT software package (PAYNE, 1993).

Results

Air distribution

Measured air speeds for the high (3000 rpm) and low (1500 rpm) fan capacities and the air-outlet setting: full open, ½ open and ¼ open are presented in Figure 3. The smaller the opening the higher is the air speed coming out of the air-outlet. For both fan capacities it is also shown that with the narrower air-outlet the air speed is more uniform over the total height of the air-outlet. Average speed on the center line of the air-outlet is for the different air outlet settings presented in Figure 4. On nozzle height it is clearly shown that with both fan capacities air speed is higher for the smaller opening of the air-outlet. For the ¼ open air-outlet air speed decreases however in such a fast way that already after 0.50m from the nozzle air speed is lower than for the other settings. After 0.50m little difference exists in center line air speed for the ½ open, ¾ open and full open air outlet settings.

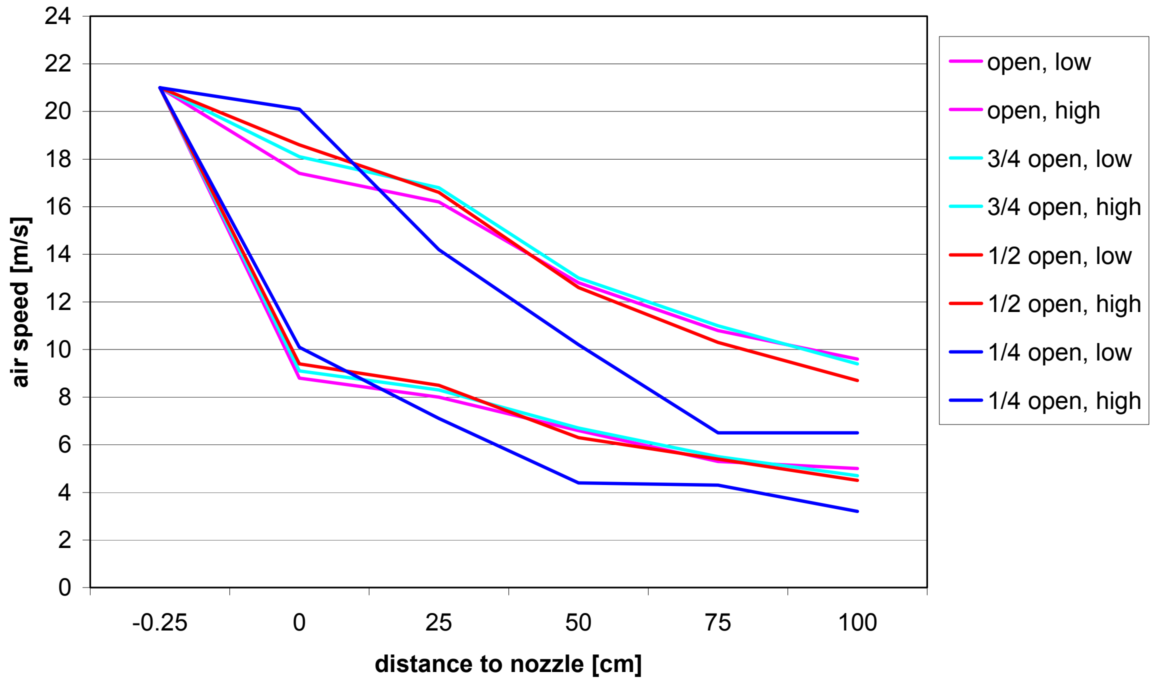

Fig. 4. Air speed at the center line of the air outlet for different settings of the air-outlet and with a high (3000 rpm) and a low (1500 rpm) fan capacity.

Spray distribution

Spray distribution in free air

The spray distribution in the free air for the high fan capacity (3000 rpm) is shown for the different air-outlet settings in figure 5.

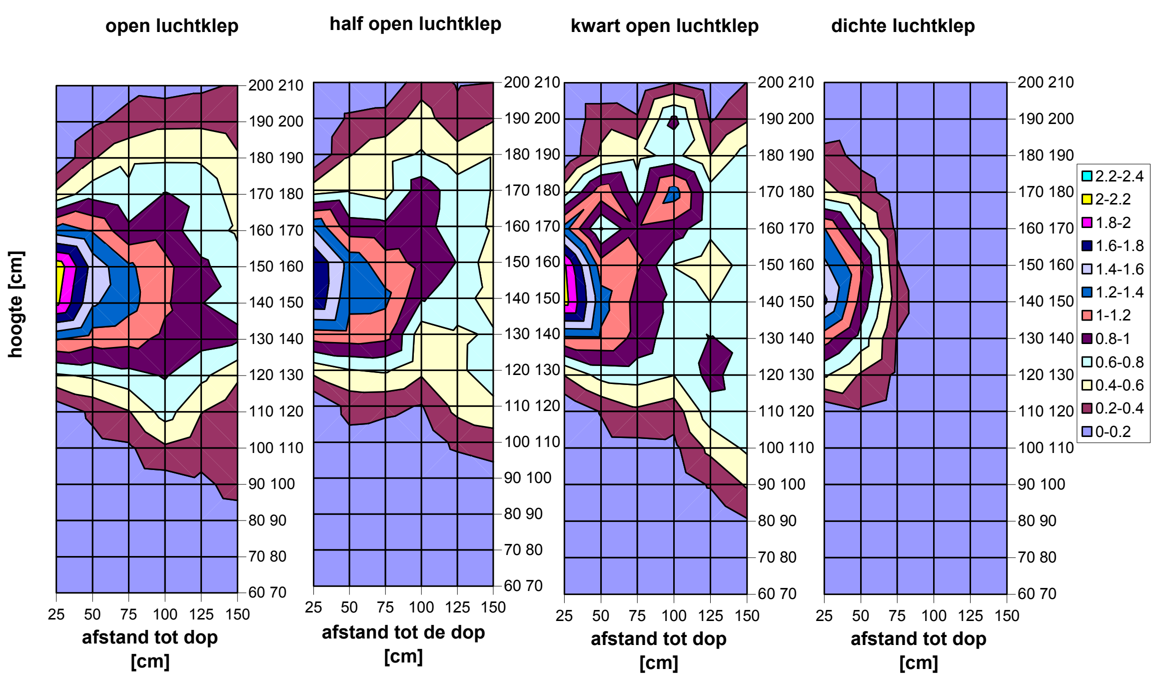

Fig. 5. Effect of air-outlet settings on the spray distribution ($\mu l/cm^2$) in the free air. Presented from right to left for the full open, ½ open, ¼ open and closed air-outlet setting. Nozzle position is at left side on 1.50m height.

Averaged spray deposition in front of the spray element (0.60m height) on different distances is for the high and low fan capacity are presented in Figures 6 and 7 respectively.

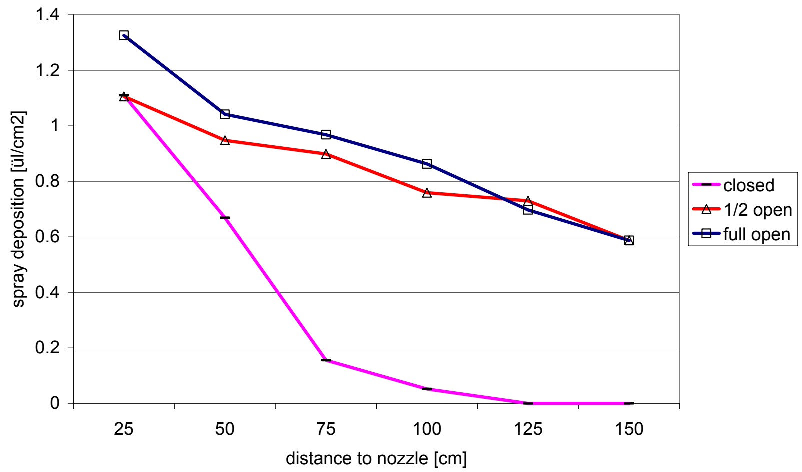

Fig. 6. Averaged spray deposition ($\mu l/cm^2$) in front of the spray element for the high fan capacity and the air-outlet settings full open, ½ open, and closed.

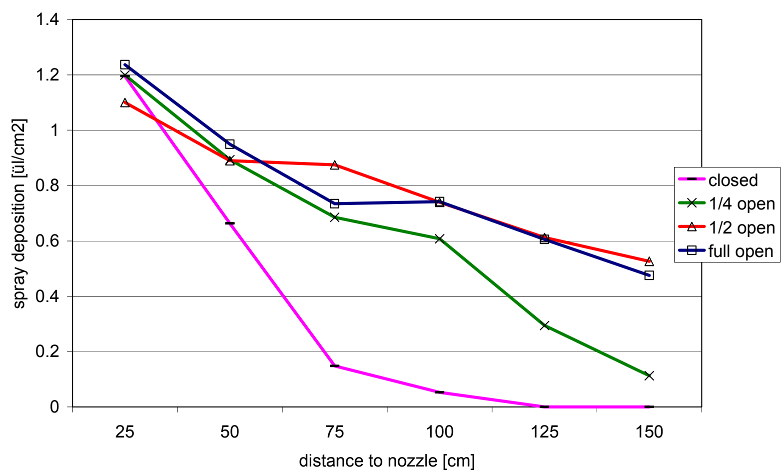

Fig. 7. Averaged spray deposition ($\mu l/cm^2$) in front of the spray element for the low fan capacity and the air-outlet settings full open, ½ open, ¼ open and closed.

From both figures 6 and 7 it is obvious what the effect of air assistance is in spray transport and deposition. For the high fan capacity (Fig. 6) spray deposition is for the full open air-outlet setting higher than for the ½ open setting for a distance up to 1.0m from the nozzle ($\alpha<0.05$). For the low fan capacity (Fig. 7) no difference exists between spray deposition for the full open and ½ open air-outlet setting. The ¼ open setting is lower for distances further than 0.50m from the nozzle ($\alpha<0.05$). The level of spray deposition of the high and low fan capacities do not differ for the full open and ½ open air-outlet setting.

Leaf walls and artificial tree

The spray deposition passing through the artificial leaf wall and the tree are presented in tables 1 and 2 for the high and low fan capacities, respectively. Also is presented spray deposition on the tree stem within the tree. This, to compare with the deposition behind the leaf walls that are on the same distance from the nozzle.

Table 1. Spray deposition (µl/cm^2) behind 1 and 2 artificial leaf walls, inside an artificial tree on stem and behind the tree for different settings of the air-outlet and a high fan capacity

Air-outlet	Place			
	1 leaf wall	2 leaf walls	Stem in tree	Behind tree
closed	0.000	0.000	0.164	0.000
½ open	0.201	0.044	0.113	0.012
Full open	0.370	0.124	0.158	0.046

Sed: air-outlet = 0.027, place = 0.035, air-outlet*place = 0.061

Table 2. Spray deposition (µl/cm^2) behind 1 and 2 artificial leaf walls, inside an artificial tree on stem and behind the tree for different settings of the air-outlet and a low fan capacity

Air-outlet	Place			
	1 leaf wall	2 leaf walls	Stem in tree	Behind tree
closed	0.000	0.000	0.023	0.000
¼ open	0.049	0.018	0.020	0.014
½ open	0.065	0.012	0.022	0.006
Full open	0.081	0.012	0.031	0.006

Sed: air-outlet = 0.008, place = 0.009, air-outlet*place = 0.018

For both fan capacities it is shown that there is a close resemblance between the spray deposition behind the 2 leaf walls and on the stem inside the tree. Spray deposition behind the tree is lower than behind the 2 leaf walls and inside the tree deposition. The back side of the tree still acts as an filter for the spray. It is obvious that no air assistance gives poor penetration as even no spray passes the 1 leaf wall. However, the spray deposition on the stem inside the tree is remarkable and must be related to the variation in tree canopy structure compared to the more homogenous distributed leaves in the leaf walls.

In general spray deposition decreases with narrowing the air-outlet, except with the ¼ open high fan capacity setting that has highest values for the 2 leaf walls and behind the tree.

In tree deposition

Spray deposition on the horizontal and vertical placed collectors are averaged and presented for the front-side and the back side of the tree stem in tables 3 and 4 for respectively for the high and the low fan capacity. For the different air-outlet settings also the ratio in vertical/horizontal collector deposition is presented. As most leaves have a horizontal orientation a vertical/horizontal ratio of 1 or lower would be of benefit for a better spray deposition in a real tree situation.

Table 3. Spray deposition ($\mu l/cm^2$) and vertical/horizontal deposition ratio on collectors in the front-side and the back-side of the tree for different air-outlet settings and a high fan capacity

Air-outlet	Front-side ($\mu l/cm^2$)	v/h	Back-side ($\mu l/cm^2$)	v/h
closed	0,0805	0,7550	0,0000	0,0000
½ open	0,0242	1,4233	0,0401	0,3233
Full open	0,0748	1,7283	0,0520	1,8133

From both table 3 and 4 it is shown that the closed air-outlet setting has the highest deposition in the front-side of the tree. No spray penetrates to the backside of the tree behind the stem. For the high fan capacity the ½ open air-outlet gives a lower spray deposition in the front-side of the tree. In the backside of the tree spray deposition is as high as of the full open air-outlet setting. However vertical/horizontal deposition ratio in the backside is drastically changed to most deposition on horizontal collection surfaces.

Table 4. Spray deposition ($\mu l/cm^2$) and vertical/horizontal deposition ratio on collectors in the front-side and the back-side of the tree for different air-outlet settings and a low fan capacity

Air-outlet	Front-side (µl/cm2)	v/h	Back-side (µl/cm2)	v/h
closed	0,1429	0,8030	0,0000	0,0000
¼ open	0,0888	0,6185	0,0373	0,7992
½ open	0,0909	0,9253	0,0284	1,9736
Full open	0,1083	0,8977	0,0575	1,0040

No difference in spray deposition in the front-side is found for the air-outlet settings with the low fan capacity. Vertical/horizontal deposition ratio does not differ either. On the backside of the tree spray deposition is highest for the full open air-outlet and lowest for the half-open setting. In this case the vertical/horizontal deposition ratio is changed for the ½ open setting to more in favour of the vertical collector surfaces. The ¼ open air-outlet setting has a spray deposition level between ½ open and full open.

Discussion

As found by Moor et al (2002), Jaeken et al (2002) and Svensson et al (2002) this study also shows that fan capacity and air outlet shape are of importance to characterise the air assistance of an orchard sprayer. It is however also shown that minimal changes in air-outlet dimensions can alter the air flow to a great extend. The used methodology of measuring air speed in a stationary situation cannot be used in a dynamic situation as reaction time of vane-anemometers is to slow. High frequency measuring equipment like ultrasonic or hot wire anemometers are then needed. A need for the dynamic measurements of air flow with different driving speeds and air settings is still needed, as well in as outside a canopy.

From the results shown it can be concluded that air speeds can be lowered in order to maximise spray deposition in canopy and reduce spray passing through canopy creating a a potential drift risk. The amount of spray passing through a tree canopy expressed as percentage of applied volume rate can be below 1 % for different settings. Especially the low fan speed with all three air-outlet settings fit into this demand. When within this group of settings also spray deposition in tree canopy (front-side of the stem) is maximised the full open air-outlet setting gives the best result. From the effect of the air-outlet settings both on spray passing through different canopy structures and densities and spray deposition in tree canopy shown it can be concluded that for every fan capacity setting a full range of range air-outlet settings exist to control spray flow depending on canopy structure and density. The data set gathered is the basis for the development of a control algorithm to be used in a CDS sprayer. Further measurements on the effect of sprayer speed and nozzle distance and nozzle flow rate are still to be done.

Acknowledgements

This research was sponsored by the Ministry of Agriculture, Nature Management and Fisheries and the EU Project PRECISPRAY (QLK5-1999-1630).

References

Jaeken, P., 2001. Dose calculation in fruit crops. *Parasitica* **57**(1-2-3)

Jaeken, P., J. Vercammen, A. de Moor & J. Langenakens, 2002. Impact of vertical liquid distribution profiles of orchard sprayers on within-tree deposit gradients. International advances in pesticide application. Aspects of Applied Biology 66: 267-275

Koch, H., P. Weisser, H. Funke & H. Knewitz, 1998. Untersuchungen zur Verteilungscharakteristik einzelner Düsen bei Applikation von Pflanzenschutzmitteln mit Gebläsesprühgeräten. *Nachrichtenblad Deutsche Pflanzenschutzdienst, **50**: 30-36.*

Miralles, A., N. Goretta, L. Dusserre-Bresson, F. Sevila, P.C.H. Miller, P. Walklate, R.P. Van Zuydam, H.A.J. Porskamp, H. Ganzelmeier, S. Rietz, G. Ade, P. Balsari, D. Vannucci & S. Planas, 1996. Results of a European programme to compare methods used to test orchard sprayers. Bulletin OEPP/EPPO Bulletin **26**: 59-68.

Moor, A. de, & J. Langenakens, 2002. Dynamic air velocity measurements of air-assisted sprayers in relation to static measurements. International advances in pesticide application. Aspects of Applied Biology 66:309-322

Payne et al., 1993. Genstat 5 Release 3 Reference Manual. Oxford: Clarendon Press.

Porskamp, H.A.J., Michielsen, J.M.G.P., Hujsmans, J.F.M., 1993. Emission reducing spray techniques in fruit growing. Spray deposition and spray drift. Institute of Agricultural and Environmental Engineering, IMAG-DLO report 94-19. 45p..

Schmidt, K. & H. Koch, 1995. Einstellung von Sprühgeräten und Verteilung von Pflanzenschutzmittelbelägen in Obstanlagen. *Nachrichtenblad Deutsche Pflanzenschutzdienst, **47**:161-165.*

Siegfried, W.,E. Hollinger & U. Raisigl, 1995. Eine neue Methode zur Bestimmung der Brühe und Präparatmengen im Obstbau. *Schweizerische Zeitschrift für Obst-und Weinbau, 131, **6**: 144-147*.

Svensson, S.A., 2001. Converging Air Jets in Orchard Spraying – influence on deposition, air velocities and forces on trees. PhD Thesis Swedish Agricultural University, Uppsala, Sweden.

Zande, J.C. van de, H.A.J. Porskamp & J.M.G.P. Michielsen, 2001. Effect of the spray distribution set-up of a cross-flow fan orchard sprayer on the spray deposition in a flat surface and in a tree. *Parasitica* **57**(1-2-3): 87-97

Zande, J.C. van de, M. Meron, E. Shimborsky, S. Meir, H. Koch, B. Heijne, 2001. the PriciSpray project. VIth Workshop on spray application techniques in fruit growing, Leuven Belgium, January 2001.Abstracts.

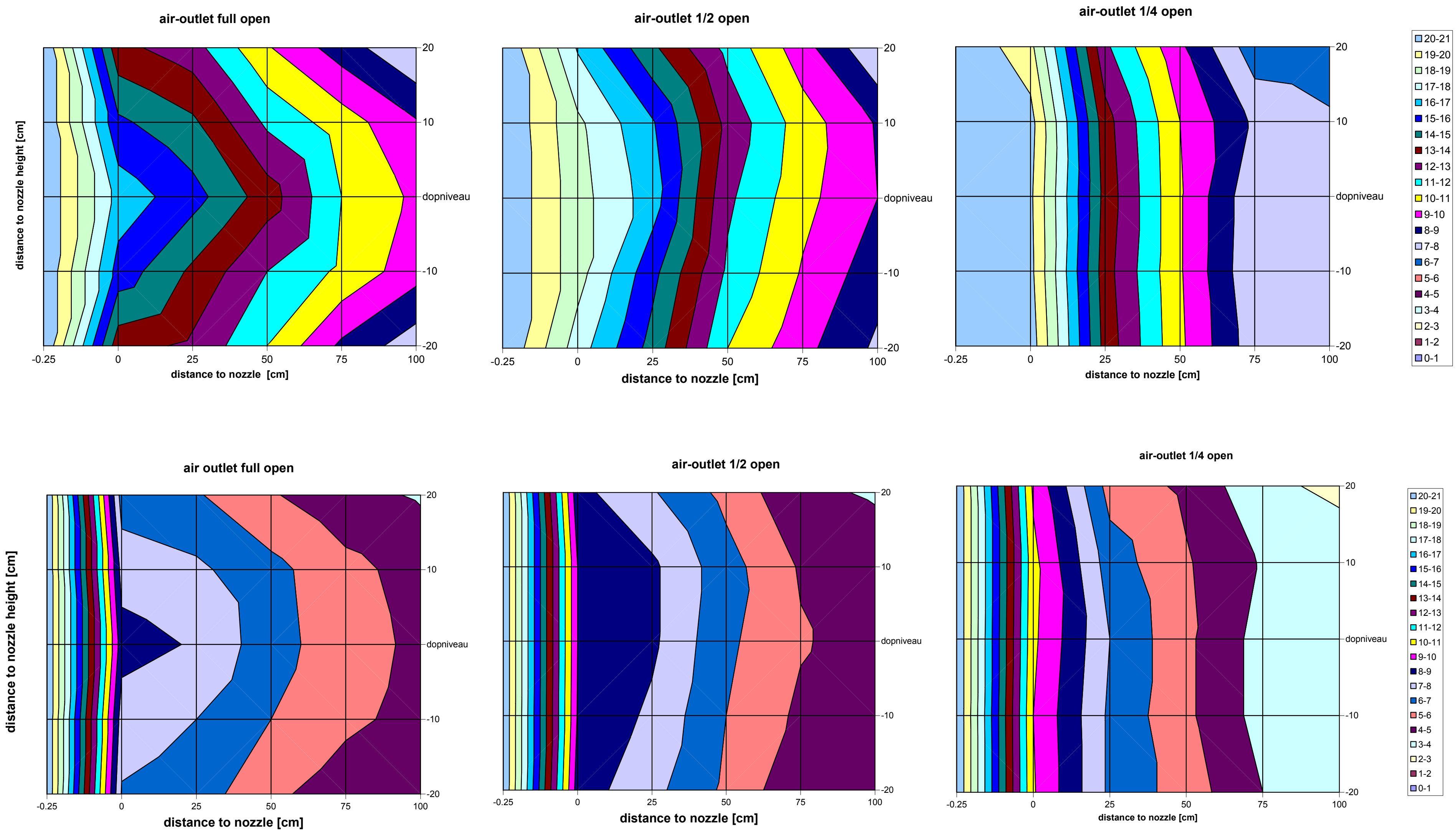

Figure 3. Air distribution (m/s) for the high fan capacity with full open, ½ open and ¼ open air-outlet (top) and for the low fan capacity with full open, ½ open and ¼ open air outlet (bottom)