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Spray deposition on apple trees in the early stages of tree development: effect of sprayer type, nozzle type and air settings

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Summary

Until recently, spray deposition and distribution was assessed in full-leaf orchard trees. In the Netherlands measurements were done for single row cross-flow fan sprayers, multiple-row sprayers and a two-row tunnel sprayer. However, in the early stages of tree development significant spray losses to the environment occur. Therefore, to find optimum combinations of application parameters these should be measured for different stages of canopy development in order to maximise spray deposition in tree canopy, reduce spray drift and reduce ground deposition.

In a series of experiments, spray deposition measurements were carried out in the dormant and early stages of tree canopy development, comparing different sprayers and settings against a standard spray application. Based on the ISO-22522 protocol adaptations were made to measure spray deposition on the stem, branches and twigs of the tree. As wooden parts of the tree cannot be taken as a sample because of destruction and loss of the trees; collectors were identified, and sampling methods were developed.

Overall results of the experiments are discussed, as well as how data can be presented in terms of in-tree deposition, spray deposition on wood parts, ground deposition, and spray drift potential to the neighbouring tree rows.

Key words: orchard sprayer, spray deposition, air assistance, nozzle type, dormant growth stage.

Introduction

The evaluation of the latest data on spray drift in orchard spraying in the Netherlands, and measurements of surface water quality parameters show that the current legislation and measures are insufficient to protect the surface water. This can also have implications for the approval of pesticides in fruit growing. To meet the national and European objectives regarding surface water quality also a reduction of chemical input is required.

New strategies must be developed to retain chemicals for crop protection and a clean environment. To improve the current practice of spray application in fruit crops in the Netherlands a research programme was setup assessing spray and liquid distribution of nowadays often used single- and multiple-row orchard sprayers and spray deposition and distribution in orchard trees (Michielsen *et al*., 2019, Wenneker *et al*., 2012, 2014, 2016, 2018, Zande *et al*., 2018). Potential pathways of improvement assessed were; air amount, nozzle type and spray pressure. Results showed that all sprayer types can be setup in a better way leading to an increase on leaf canopy spray deposition of up to 50% compared to a reference sprayer (Zande *et al*., 2020). Improved spray deposition can lead to reduced use of agrochemical and therefor reduced emission to the environment while maintaining high levels of spray drift reduction and biological efficacy. From the mass balance of the spray deposition it was obvious that a gap of around 30% remained (Wenneker *et al*., 2018). As in the full leaf situation, only spray deposition at the leaves were sampled, it could be so that this was caused by not measured spray deposition at the trunk and branches of the tree; the wooden part. Also, it was not known if the best sprayer settings for the full leaf situation would also give the highest deposition on the wooden parts of the tree in the dormant situation. Therefor measurements were setup to measure spray deposition in the dormant/early leaf stages of the trees to quantify spray deposition on the trunk and the branches.

In this paper the results are presented of the spray deposition at the wood parts of the tree in the dormant/early leaf development stage of a fruit crop using single row and multiple row sprayers.

Materials and Methods

Experimental set up

Spray deposition measurements and sampling procedure were carried out based on the ISO22522 standard adapted for the dormant tree situation. As picking of leaves in the dormant/early leaf stage of the tree is not possible and taking parts of the stem and the branches as samples would destroy the tree architecture, a sampling methodology was developed. To sample the trunk a PVC pipe (length 250 cm, diam. 10 cm) was positioned in between two trees. At heights of 50cm, 80cm, 150cm and 210 cm from ground surface, collectors (Technofil TF290; 33 cm x 10 cm) were attached to Velcro stitched around the PVC pipe (Fig. 1). To mimic the branches, hollow clay pipes (DB-Schietsport, Reference: 30548; 4 cm x 1 cm diam.) were positioned at 80 cm, 150 cm and 210 cm height from ground surface in a tree. Four clay pipes were fixed to a horizontal bar at both sides of the trunk in the row direction and per height. The four pipes were positioned over nails in approximately 45^{o} angles to the front and the back (Fig. 1, 2). Spray deposition on the ground was measured from 3 rows upwind to 3 rows downwind putting collectors (Technofil TF290; 100 cm x 10 cm) underneath the trees and in between the tree rows on the grass strips. Vertical spray distribution going into the treated tree row was measured up till 3 m height using three collectors (Technofil TF290; 100 cm x 10 cm) on top of each other attached to a vertical pole in front of the treated row. Spray passing the trees and entering the next, second and the third tree row was measured downwind and upwind at collectors (Whatman no. 2; 300 cm x 2 cm) attached to vertical poles of 3 m height (resp. at 2 m, 5 m and 8 m from the treated row). Apple trees were sprayed with a solution containing the fluorescent dye Acid Yellow 250 (AY250, DC Finechemicals, CAS nr 93859-32-6; 2-5 g L^{-1}) and a non-ionic surfactant (Agral; 7,5 mL 100 L^{-1}). The spray deposition experiments were carried out in the dormant situation of the apple trees (16-19 April 2018; BBCH 53-54) in an apple orchard (cv Elstar) at WageningenUR Experimental station for Fruit Crops in Randwijk The Netherlands. Tree height was about 2.75 m, tree row spacing 3.0 m and tree spacing in the row 1.10 m. Four repetitions were made, i.e. spraying

30 m of a single tree row from both sides for the standard sprayer and two rows for the multiple row sprayers, and analysing collectors from four individual trees.

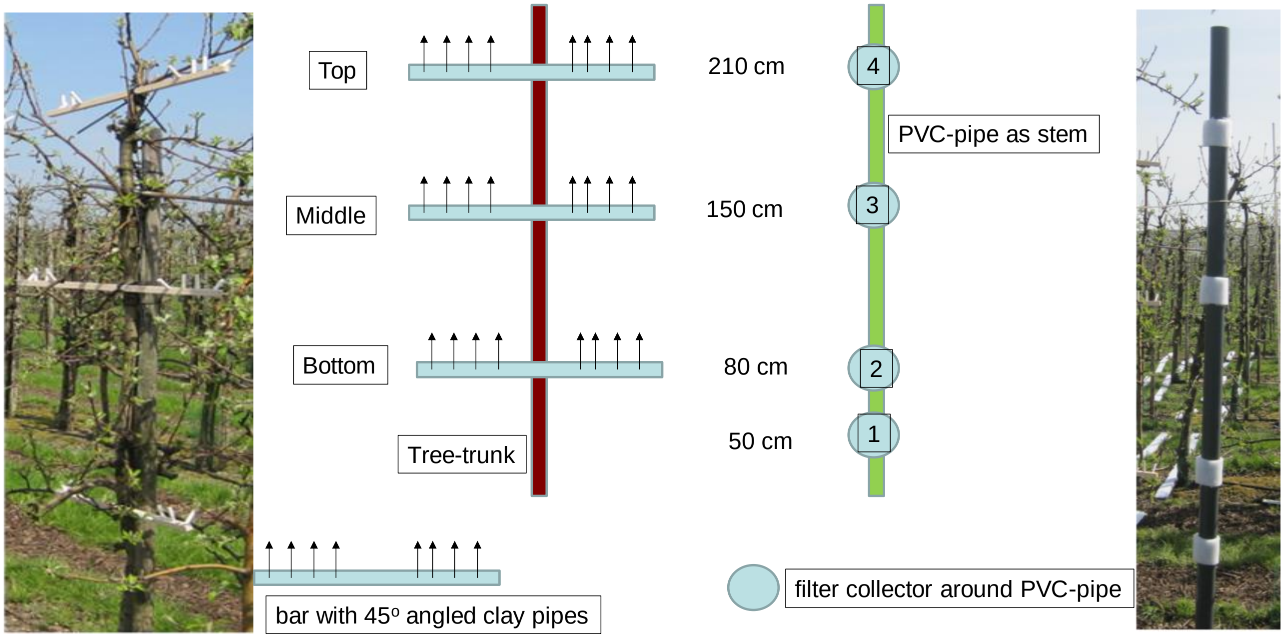

Figure 1. *Schematic layout and picture of artificial collectors to mimic tree branches at three heights (top, middle, bottom) in the tree (left) and a PVC-pipe to mimic the stem and collectors at four heights attached around it (right).*

Figure 2. *Clay pipes fixed to horizontal bar at three heights in the tree to mimic tree branches.*

Treatments

In this experiment different treatments were compared against a defined reference spray technique; the other techniques were evaluated in their standard setting for dormant trees and one of the sprayer settings having the highest spray deposition in tree crop canopy at the full leaf stage (Zande *et al*., 2018, 2020). The reference/standard technique was a conventional cross-flow fan sprayer (Munckhof); Albuz ATR lilac at 7 bar spray pressure (Very Fine spray quality; Southcombe *et al*., 1997), low gear air setting, 540 rpm PTO; 200 l/ha. Other techniques used were (Table 1) the Munckhof cross-flow fan sprayer at low air setting and 90% drift reducing nozzles (Albuz TVI 80015 at 7 bar); HSS cross flow at high and low air (resp. ATR at 7 bar and IDK9001 at 3 bar nozzles); Lochmann two row tunnel sprayer at high and low air (resp. ATR and TVI nozzles); Munckhof 2-

row cross-flow sprayer at high and low air (resp. ATR and TVI nozzles). Spray volume for the ATR were 200 L/ha, for the ID nozzles 250 L/ha and for the TVI nozzles 300 L/ha.

Table 1. Used application techniques in the spray deposition measurements at dormant/early growth stage of the apple trees.

Sprayer	Nozzle	Pressure [bar]	Air assistance	Forward speed [km/h]	Spray volume [L/ha]
Munckhof cross-flow	Lilac[1)]	7	High gear fan, 540 rpm PTO	6,6	200
	TVI80015		Low gear fan, 300 rpm PTO	6,6	300
HSS cross-flow	Lilac		High; 2100 rpm fan	6,5	200
	IDK9001	3	Low; 1800 rpm fan	6,8	200
Lochmann 2-row tunnel	Lilac	7	High, 540 rpm PTO	6,5	200
	TVI80015		Low, 400 rpm PTO	6,5	300
Munckhof 2-row cross-flow	Lilac		High, 540 rpm PTO	6,7	200
			Low, 400 rpm PTO	6,4	200
	TVI80015		Low, 400 rpm PTO	6,4	300

1) Reference sprayer

Figure 3. *Sprayers used for assessing spray deposition in the early leaf stage of the apple trees: Munckhof cross-flow (top left), H.S.S. cross-flow (top right), Lochmann 2-row tunnel (bottom left), Munckhof 2-row cross-flow (bottom right).*

Results

In tables 2-6 the results of the different experiments are summarized. The main results are presented for the measured spray output, the spray deposition at the stem of the trees, the branches in the tree and the ground underneath the trees, and the spray entering the next tree rows.

Low air settings of the individual sprayers show a higher spray amount entering the tree structure (Table 2). Increase in vertical spray distribution entering tree structure is highest for the Munckhof 2-row sprayer (47.5%) which is even increased using a lower level of air assistance (70%) irrespective of the nozzle type used. The Lochmann 2-row tunnel sprayer shows a high increase in vertical spray distribution towards the tree using a low level of air assistance and a 90% drift reducing nozzle type. Results show that the efficiency of delivering the spray from the nozzle and air outlets towards the tree structure varies for the different sprayer types and its settings. Delivery ranges of the sprayer output towards the tree structure range from 40% to 70% of applied spray volume.

Table 2. Vertical spray distribution (% of sprayed volume) at three height sections entering the tree after spraying early leaf stage apple trees with the different spray techniques and settings.

obj	1	2	3	4	5	6	7	8	9
sprayer	MuSt	MuSt	HSS	HSS	Loch	Loch	Mu2R	Mu2R	Mu2R
nozzle	lilac	TVI	lilac	IDK@3	lilac	TVI	lilac	lilac	TVI
air ass.	low 540	low 300	high2100	low1800	high 540	low 400	high 540	low 400	low 400
h [m]									
2-3	34.3	38.6	40.1	40.9	44.1	46.0	52.8	66.5	65.2
1-2	56.9	66.8	58.7	55.6	59.8	92.9	75.8	83.9	85.7
0-1	34.5	47.8	27.8	46.2	28.2	42.1	56.6	63.9	63.0
mean	41.9	51.0	42.2	47.6	44.1	60.3	61.8	71.4	71.3
rel to ref		22	1	14	5	44	48	71	70

Spray deposition at the stem of the tree (Table 3) shows that, except for the HSS sprayer, the lower air level results in similar or increased spray deposition spray deposition at the trunk of the tree. For both settings of the HSS cross-flow fan sprayer, both settings of the Lochmann two-row tunnel sprayer and the standard setting of the 2-row Munckhof cross-flow sprayer spray deposition at the

Table 3. Spray deposition (% of sprayed volume) at four heights at the tree stem after spraying early leaf stage apple trees with the different spray techniques and settings.

obj	1	2	3	4	5	6	7	8	9
sprayer	MuSt	MuSt	HSS	HSS	Loch	Loch	Mu2R	Mu2R	Mu2R
nozzle	lilac	TVI	lilac	IDK@3	lilac	TVI	lilac	lilac	TVI
air ass.	low 540	low 300	high2100	low1800	high 540	low 400	high 540	low 400	low 400
h [m]									
2.1	52.7	38.5	60.5	43.3	14.2	28.3	33.8	47.5	48.6
1.5	48.3	68.8	55.9	35.6	46.2	47.2	34.5	51.6	57.3
0.8	46.6	48.0	34.4	35.0	38.1	51.5	56.2	67.4	54.0
0.5	36.2	36.5	21.8	30.5	45.3	44.8	33.0	58.3	48.4
mean	46.0	47.9	43.1	36.1	35.9	42.9	39.4	56.2	52.1
rel to ref		4	-6	-22	-22	-7	-14	22	13

tree stem is lower than of the reference sprayer. Spray deposition at the tree stem varies between 36% and 56% of applied spray volume, being between 22% lower and 22% higher than of the reference sprayer (46% of applied spray volume).

Spray deposition at the branches at the early growth stage of the tree (Table 4) shows to be 38% of applied spray volume for the reference sprayer. Higher spray deposition at the branches does only occur for the Lochmann 2-row tunnel sprayer (both settings) and the Munckhof 2-row cross-flow sprayer using ATR lilac nozzles and low air assistance level (400 rpm PTO). Increases in spray deposition are within the range of 3% to 17% for the Lochmann and 10% for the Munckhof 2-row sprayer. Lowest deposition on the branches is for the HSS cross-flow sprayer using ID9001 nozzles at 3 bar spray pressure and low level of air assistance (1800 rpm fan), being 12% of applied spray volume and 69% lower than of the reference sprayer.

Table 4. Spray deposition (% of sprayed volume) at the tree branches at three heights in the tree structure after spraying early leaf stage apple trees with the different spray techniques and settings.

obj	1	2	3	4	5	6	7	8	9
sprayer	MuSt	MuSt	HSS	HSS	Loch	Loch	Mu2R	Mu2R	Mu2R
nozzle	lilac	TVI	lilac	IDK@3	lilac	TVI	lilac	lilac	TVI
air ass.	low 540	low 300	high2100	low1800	high 540	low 400	high 540	low 400	low 400
h [m]									
2.1	53.0	28.8	36.2	13.6	47.5	34.2	26.9	33.7	30.8
1.5	31.4	48.5	40.5	11.5	56.0	40.5	47.6	48.6	38.5
0.8	30.9	33.2	30.8	11.0	31.5	43.9	34.7	44.4	36.0
mean	38.4	36.9	35.8	12.0	45.0	39.5	36.4	42.3	35.1
rel to ref		-4	-7	-69	17	3	-5	10	-9

Spray deposition at ground surface (Table 5) shows a difference in spray deposition underneath the tree rows and in between the tree rows at the grass strips. The spray deposition underneath the tree rows is the highest being 46% for the refence spray technique and varies between 21% for the Lochman 2-row tunnel sprayer using ATR nozzles and 75% for the HSS sprayer using IDK nozzles and low air. Spray deposition at the grass strips is 36% for the reference sprayer and varies between 20% and 77% for the same sprayers. Spray deposition at ground surface is for all spray techniques

Table 5. Spray deposition (% of sprayed volume) at ground surface underneath the trees (row) and at the grass strips in between the tree rows (path) after spraying early leaf stage apple trees with the different spray techniques and settings.

obj	1	2	3	4	5	6	7	8	9
sprayer	MuSt	MuSt	HSS	HSS	Loch	Loch	Mu2R	Mu2R	Mu2R
nozzle	lilac	TVI	lilac	IDK@3	lilac	TVI	lilac	lilac	TVI
air ass.	low 540	low 300	high2100	low1800	high 540	low 400	high 540	low 400	low 400
h [m]									
row	45.6	60.2	35.1	74.8	20.7	46.8	50.1	52.5	74.3
path	35.6	60.9	20.8	77.3	19.5	31.4	34.8	41.0	37.4
mean	40.6	60.6	28.0	76.1	20.1	39.1	42.4	46.7	55.9
rel to ref		49	-31	88	-50	-4	5	15	38

using drift reducing nozzles and lower air assistance higher than of the standard setting of the sprayer. Compared to the reference sprayer average spray deposition at ground surface can be 88% higher (HSS sprayer using IDK nozzles and low air) and 50% lower (Lochmann standard).

Spray deposition on vertical poles of the spray flux entering the next, second and third row from the treated row (Table 6) shows that all spray techniques reduced spray drift potential except the H.S.S. in standard setting (25% higher than standard). Spray techniques using drift reducing nozzle types and low levels of air assistance all gave lower values spray drift potential than of the reference sprayer. Potential drift reduction evaluated in this way ranged from 74% (H.S.S.) up to 99% (Lochmann).

Table 6. Spray drift potential, being the vertical spray distribution (% of sprayed volume) entering the next (2 m), the second (5 m) and the third (8 m) tree row after spraying early leaf stage apple trees with the different spray techniques and settings.

obj	1	2	3	4	5	6	7	8	9
sprayer	MuSt	MuSt	HSS	HSS	Loch	Loch	Mu2R	Mu2R	Mu2R
nozzle	lilac	TVI	lilac	IDK@3	lilac	TVI	lilac	lilac	TVI
air ass.	low 540	low 300	high2100	low1800	high 540	low 400	high 540	low 400	low 400
row [m]									
-5	0.0	0.0	0.0	0.0	7.6	0.1	0.0	0.1	0.0
-2	17.1	5.0	0.0	0.0	8.0	0.2	0.0	0.1	0.0
2	12.4	0.3	17.9	8.7	5.9	0.1	3.6	4.9	2.8
5	7.8	0.1	13.3	0.4	0.1	0.0	1.2	2.4	0.3
8	0.0	0.0	7.7	0.3	0.2	0.0	0.4	1.0	0.2
Mean 2m	14.8	2.6	9.0	4.3	6.9	0.2	1.8	2.5	1.4
Mean 5m	3.9	0.1	6.7	0.2	3.8	0.1	0.6	1.2	0.2
Mean 2-8	6.2	0.9	7.8	1.6	3.6	0.1	0.9	1.6	0.6
rel to ref		-85	25	-74	-41	-99	-85	-75	-90

Discussion

Measuring spray deposition in dormant or early growth stages is difficult as no leaves can be picked to sample in tree deposition. Taking samples from the branches and the stem of the tree cannot be done as this destroys the tree. The sampling methodology developed shows to work properly for the measurements on the stem of the tree. The sampling of the branches by means of the clay pipes we used is promising but needs to be refined. Some doubts about spray deposition results do occur especially with the experiments of the H.S.S. sprayer. It is however uncertain whether these doubtful results do occur because of the sampling methodology or because of uncontrollable sprayer performance during the tests. More research is needed to come to a robust methodology of spray deposition measurement in the dormant and early development stages of trees. These experiments showed that spray deposition varied significantly, depending on nozzle type and spray quality, fan setting and sprayer type. Further research is needed to adjusted sprayer configurations for a further improvement of spray deposition at the wooden parts in the dormant and early growth stages of the fruit trees for multiple and single row orchard sprayers.

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References

ISO22522, 2006. Crop protection equipment — Field measurement of spray distribution in tree and bush crops. International Standardisation Organisation, Geneva, 2006.

Michielsen JMGP, Stallinga H, De Hoog D, Dalfsen van P, Wenneker M, Zande van de JC, 2019. Spray deposition of a cross-flow fan orchard sprayer with low air and low spray pressure settings. In: **J. Cross & M. Wenneker** (eds): *Suprofruit2019 – Book of Abstracts. 15th Workshop on Spray Application and Precision Technology in Fruit Growing, July 16-18, 2019, NIAB EMR, East Malling, UK. 2019*. pp. 47-48

Southcombe E S E, Miller P C H, Ganzelmeier H, van de Zande J C, Miralles A, Hewitt A J. 1997. The international (BCPC) spray classification system including a drift potential factor. *Proceedings of the Brighton Crop Protection Conference - Weeds, 1997*, pp. 371–380. November 1997, Brighton, UK.

Wenneker M, Nieuwenhuizen A T, Zande J C van de, Balsari P, Doruchowski G, Marucco P. 2012. Advanced drift reduction in orchard spraying. *Aspects of Applied Biology* **114**, *International Advances in Pesticide Application 2012*, pp. 421-428.

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

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

Wenneker M, Zande van de JC, Michielsen JMPG, Stallinga H, Dalfsen van P, Velde van P, 2018. Improvement of spray deposition in orchard spraying using a multiple row tunnel sprayer. *Aspects of Applied Biology* **137**, *International Advances in Pesticide Application 2018*, pp.101-108.

Zande van de JC, Michielsen JMGP, Stallinga H, Dalfsen van P, Wenneker M, 2018. Effect of air distribution and spray liquid distribution of a cross-flow fan orchard sprayer on spray deposition in fruit trees. **In: P. Balsari & H.J. Wehmann,** SPISE 7; 7th European Workshop on Standardized Procedure for the Inspection of Sprayers in Europe, Athens, Greece, September 26-28, 2018. *Berichte aus dem Julius Kühn-Institut* **196,** Braunschweig, 2018. p.186-192

Zande van de JC, Wenneker M, Michielsen JMPG, Stallinga H, Dalfsen van P, Snoussi M, De Hoog D, 2020. Improved spray deposition in full-leaf orchard spraying by sprayer type, nozzle type and air setting. *Aspects of Applied Biology* **143**, *International Advances in Pesticide Application 2020*, pp.