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Improvement of spray deposition in orchard spraying using a multiple row tunnel sprayer

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Summary

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. Latest developments showed great perspectives for multiple row orchard sprayers. This is predominantly because they require less time to spray an area, and therefore timeliness is higher and anticipation to weather conditions and disease development is better. Therefore, the efficiency of multiple row orchard sprayers is higher than conventional ones for pest and disease control, and reduces costs for the farmer. It is assumed that spray deposition is improved when spraying with multiple row sprayers and dose can therefore be reduced accordingly, without reducing biological efficacy. Further research therefore is necessary to assess spray deposition in the tree canopy. The objective is to find the optimum combination of application parameters for different stages of fruit tree canopy development to reduce spray drift while improving spray deposition. In a series of trials, spray deposition measurements were carried out following the ISO-22522 protocol. Results are presented of experiments comparing a multiple row orchard tunnel sprayer (Lochmann) with a conventional cross-flow fan sprayer (Munckhof).

Key words: Orchard sprayer, spray drift reduction, spray deposition, air assistance, nozzle type

Introduction

New strategies have to be developed to retain chemicals for crop protection and a clean environment. Latest developments showed great perspectives for multiple row orchard sprayers. Because of increased work capacity the use of these types of sprayers has increased enormously in the Netherlands in the recent years. It is proven that multiple row sprayers reduce spray drift significantly (Wenneker *et al*., 2012, 2014). This is due to the spraying system that sprays tree rows from both sides at the same time, in contrast to standard orchard sprayers that spray the tree row only from one side. It is assumed that spray deposits are improved when spraying with multiple row sprayers. Therefore, doses of agrochemical can be reduced, without reducing biological efficacy, implicitly reducing emission to the environment while maintaining high levels of spray drift reduction. Further research therefore is necessary to assess spray deposition in the tree canopy (Wenneker *et al*., 2016).

To improve the current practice of spray application in fruit crops a research programme is setup assessing spray and liquid distribution of nowadays often used orchard sprayers and its spray deposition and distribution in orchard trees. Potential pathways of improvement identified are: air amount, air distribution, nozzle type and therefore liquid distribution as the spray is transported by the moving air into the tree canopy.

The objective is to find the optimum combination of application parameters for different stages of fruit tree canopy development to reduce spray drift while improving spray deposition. In a series of trials, spray deposition measurements were carried out following the ISO-22522 protocol. In the experiments multiple row orchard sprayers of several manufacturers (Munckhof, KWH, Lochmann) were compared to conventional cross-flow fan sprayers (Munckhof, Hol Spraying Systems). Different levels of air assistance and nozzle types are included in the experimental set up. In this paper results of the spray deposition measurements of the Lochmann multiple row tunnel sprayer are presented.

Materials and Methods

Experimental set up

Spray deposition measurements and sampling procedure were carried out following the ISO22522 standard, adapted for the orchard layout, equipment used and research questions, picking leaves from the different tree compartments and measuring ground spray deposition. Apple trees were sprayed with a solution containing the fluorescent dye Brilliant Sulpho Flavine (BSF; 0,5–1 g L^{-1}) and a non-ionic surfactant (Agral; 7,5 mL 100 L^{-1}). Spray volume was around 200 L ha^{-1} for the ATR Lilac nozzles to 300 L ha^{-1} for the TVI8001 nozzles used on both spray techniques. The spray deposition experiments were carried out in the full leaf situation of the apple trees (19, 21 July 2016; BBCH 75–76) 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 leaves samples from four individual trees. Leaf samples were taken by counting all leaves in seven tree sections (P1-P7; Fig. 2): Top (P7), Mid West (P5), Mid East (P6), Bottom Outside West (P1), Bottom Inside West (P2), Bottom Inside East (P3), Bottom Outside East (P4), and putting every 10^{th} leaf in a bag. The picked leaves were analysed in the laboratory for spray deposition of the sprayed fluorescent tracer BSF. The leaf surface areas were determined, and the spray deposition was calculated. Spray deposition on ground surface was measured underneath the tree rows and in the paths in between the tree rows. Ground collectors were laid out on both sides from the treated tree row up to 4.5 m in the upwind direction and to 7.5 m in the downwind direction. Collectors used for determining the ground deposition are Technofil (TF270) sized 100 cm × 10 cm and attached to PVC ground plates of the same size with velcro. Vertical poles of 3 m height were positioned at both sides of the treated tree row and in front of the next tree row and the second downwind row for the standard cross-flow fan sprayer (see Fig. 3).

Treatments

In this spray deposition experiment a standard cross-flow fan orchard sprayer and a multiple-row tunnel orchard sprayer were compared. The two-row tunnel sprayer was used with standard (Very Fine spray quality; Southcombe *et al*., 1997) and Venturi (Coarse spray quality) hollow cone nozzles at two air settings; standard and reduced:

Fig. 1. Spray deposition measurements of Lochmann two-row tunnel orchard sprayer; ground deposition and spray volume in sprayer driving path (left), next path ground deposition and spray drift potential (centre), in tree deposition (right).

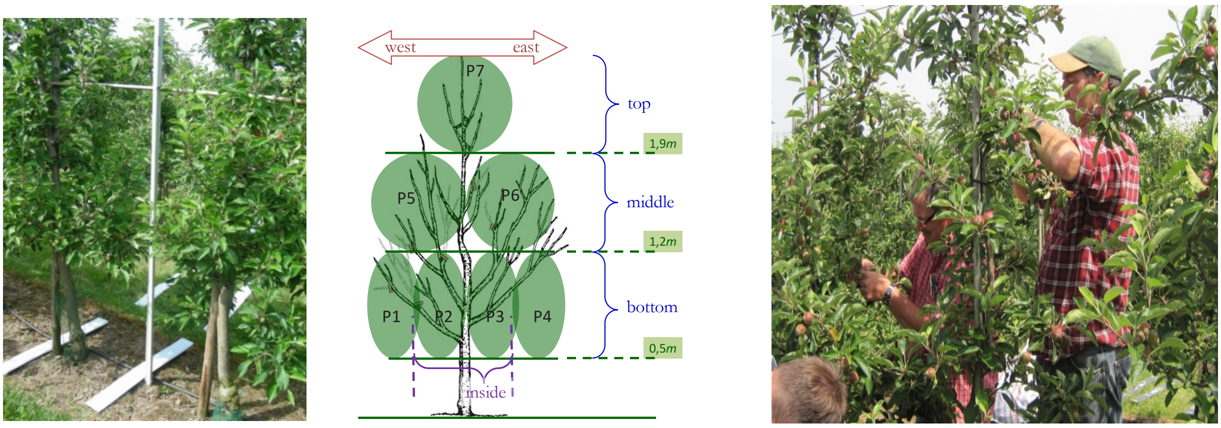

Fig. 2. Spray deposition measurement on collectors on the ground (left) and spray volume or drift potential (vertical collectors), in the tree as leaf picking (right) following the sampling scheme (centre).

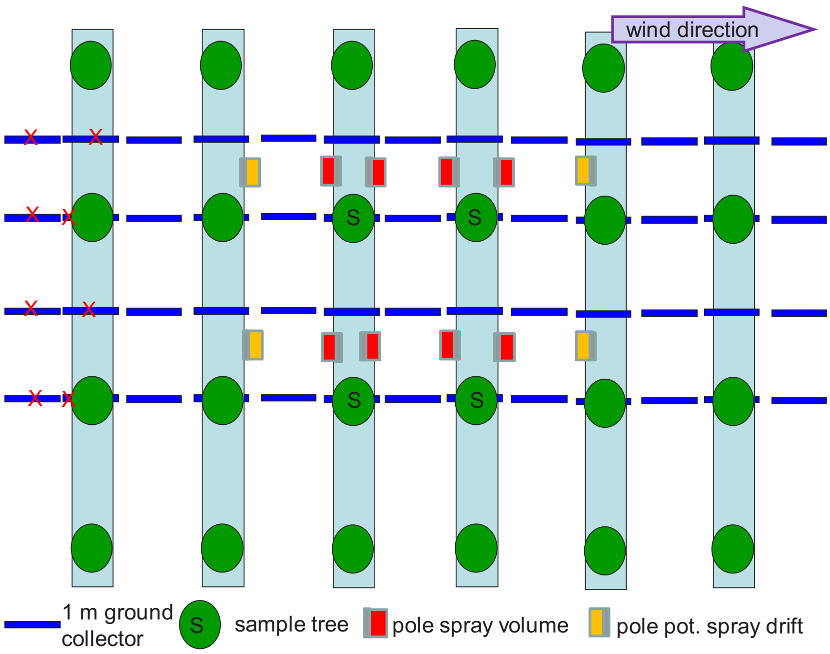

Fig. 3. Schematic overview of collector positions, treated tree rows and sampled trees for spray deposition measurements for a multiple row spray application.

Reference sprayer (Munckhof):

1. Conventional cross-flow fan sprayer (Munckhof); Albuz ATR lilac at 7 bar spray pressure (Very Fine spray quality); 200 L ha^{-1}. [Stand-ATR].

Multiple row tunnel orchard sprayer (Lochmann; Fig. 1):

2. Lochmann equipped with Albuz ATR Lilac nozzles; 190 L ha^{-1}. [LO-ATR].
3. Lochmann equipped with Albuz TVI 8001 nozzles; 290 L ha^{-1}. [LO-TVI].

Also, for the Lochmann multiple row orchard sprayer the spray pressure was 7 bar. Both sprayers used eight nozzles per tree height with the highest nozzle at 2.50 m height. Forward speed for all sprayers was 6.7 km h^{-1}. Air settings for the reference sprayer (Munckhof) were a high gear box setting of the fan and 540 rpm of the PTO. The multiple row tunnel sprayer was tested at standard and reduced fan settings of 540 and 400 rpm of the PTO. Average air speeds in the centre of the tunnel in between both sides air slots over 0.5–3.0 m height was 3.2 m s^{-1} and 2.4 m s^{-1} for the Lochmann multiple row sprayer at respectively 540 and 400 rpm of the PTO.

Results

On average spray deposition in the whole tree is for the Lochmann multiple row orchard sprayer similar or higher than for the standard Munckhof cross-flow fan sprayer (Table 1). Especially the spray deposition of the Venturi nozzle types (TVI8001) is higher, this is however also biased because of the higher spray volume than of the used ATR Lilac nozzles (resp. 300 and 200 L ha^{-1}). Low air setting (400 rpm PTO) increases spray deposition for both nozzle types (ATR Lilac and TVI8001) in the top of the tree (P7). The combination of the low air setting (400 rpm PTO) and the Venturi type nozzle (TVI8001) increases spray deposition in all the tree sections (P1–P7) compared to the standard high air setting (540 rpm PTO).

Table 1. *Spray deposition (*µL cm^{-2}*) in different tree sections after spraying with the Munckhof conventional cross-flow fan sprayer with ATR nozzles (Stand ATR) at 540 rpm of the PTO, and the Lochmann multiple row tunnel sprayer equipped with Albuz ATR Lilac nozzles and TVI nozzles tested at fan settings of 400 and 540 rpm of the PTO (LO ATR 400; LO ATR 540; LO TVI 400; LO TVI 540)*

	Spray deposition in tree sections [µL cm^{-2}]							
	MEAN P1–P7	P1	P2	P3	P4	P5	P6	P7
Stand ATR	0.29	0.23	0.20	0.24	0.34	0.31	0.37	0.32
LO ATR 540	0.30	0.22	0.17	0.24	0.37	0.40	0.33	0.36
LO ATR 400	0.31	0.28	0.14	0.22	0.35	0.39	0.38	0.43
LO TVI 540	0.51	0.65	0.40	0.33	0.65	0.57	0.54	0.43
LO TVI 400	0.60	0.72	0.46	0.49	0.73	0.67	0.62	0.51

When normalised for the applied spray volume (Table 2) it becomes obvious that average spray deposition in the tree was for the Lochmann tunnel sprayer higher than of the standard cross-flow fan sprayer. Equipped with ATR Lilac nozzles and high air setting (540 rpm PTO) average increase in spray deposition for the Lochmann tunnel sprayer was 13%. For the low air setting increase in average spray deposition was 18%. The use of Venturi type nozzles resulted in increased average spray deposition of 23% in combination with the high air setting (540 rpm PTO) and for the low air setting (400 rpm) it increased with 45%. It must however be said that total spray deposition in the tree recovered is only between 14% to 21% on average, which is very low. Spray deposition in the bottom part of the tree (P1–P4) differs between the standard and the two-row tunnel sprayer. For the standard cross-flow fan sprayer there is little difference between the spray deposition on the outside sections (P1, P4) and the internal sections (P2, P3).

Table 2. *Spray deposition (% of sprayed volume) in different tree sections after spraying with the Munckhof conventional cross-flow fan sprayer with ATR nozzles (Stand ATR) at 540 rpm of the PTO, and the Lochmann multiple row tunnel sprayer equipped with Albuz ATR Lilac nozzles and TVI nozzles tested at fan settings of 400 and 540 rpm of the PTO (LO ATR 400; LO ATR 540; LO TVI 400; LO TVI 540)*

Object	MEAN P1–P7		Rel to stand (%)	Spray deposition in tree sections [% sprayed volume] P1	P2	P3	P4	P5	P6	P7
Stand ATR	14.2	a	100	11.5	9.7	11.8	16.9	15.2	18.4	15.9
LO ATR 540	16.1	b	113	11.6	9.3	12.8	20.0	21.4	17.7	19.6
LO ATR 400	16.7	c	118	14.8	7.5	11.9	18.7	20.7	20.2	23.0
LO TVI 540	17.5	cd	123	22.3	13.7	11.2	22.3	19.6	18.5	14.7
LO TVI 400	20.5	d	145	24.6	15.6	16.8	25.0	23.0	21.2	17.3

Different letters in a column means significant differences (α<0.1).

For the tunnel sprayer, these differences are larger especially for the Venturi type nozzles. On the other hand, spray deposition on the internal sections (P2, P3) for the Venturi nozzle type and the lower fan speed (400 rpm PTO) is of the same level as at the outside sections of the standard cross-flow fan sprayer. In the middle tree section (P5, P6) spray deposition of the tunnel sprayer is for all sections similar or higher than of the standard cross-flow fan sprayer. In the top section of the tree (P7) the spray deposition of the tunnel sprayer equipped with ATR nozzles is for both air settings higher than of the cross-flow fan sprayer and the tunnel sprayer with Venturi type nozzles. For the tunnel sprayer with the Venturi nozzle types the high air setting results in a little lower spray deposition in the top of the tree (P7) and the lower air level in a little higher spray deposition than the reference sprayer.

Spray deposition at ground surface

Spray deposition on ground surface underneath the trees and the paths in between the trees is for the standard cross-flow fan sprayer and the 2-row tunnel sprayer with Albuz ATR Lilac nozzles

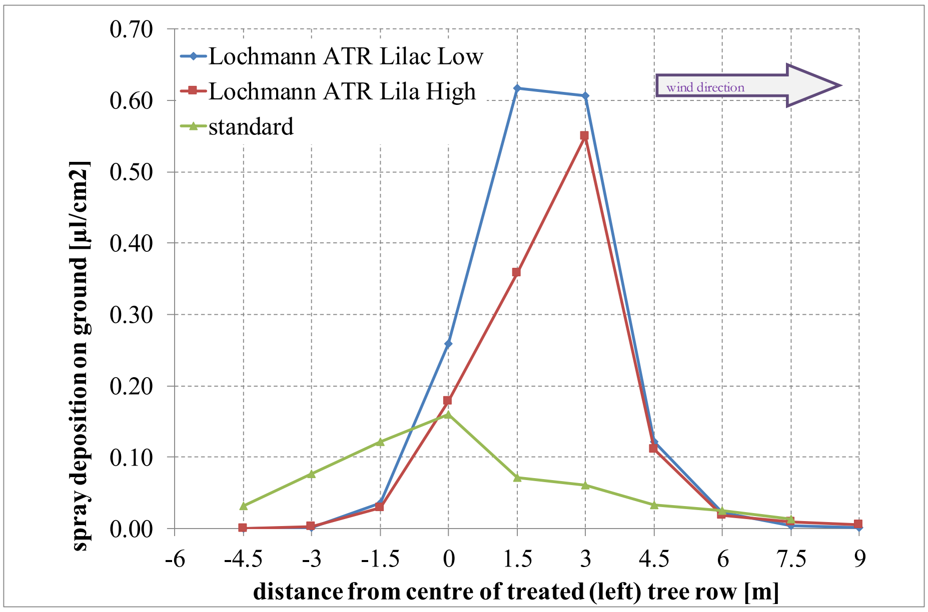

Fig. 4. Spray deposition on ground surface (µL cm²) underneath the tree rows and at the paths in betweethe tree rows at different distances (m) from the center of (left) treated tree row for the standard and the two-row Lochmann tunnel sprayer. Wind direction is from west to east.

and high and low air setting presented in Fig. 4. Treated tree rows are at 0 and 3 m for the tunnel sprayer and at 0 m for the cross-flow fan sprayer. Ground deposition is for both air settings of the tunnel sprayer highest underneath the downwind sprayed tree row, whereas for the low air setting also a high spray deposition is found in the driving path of the sprayer (1.5 m). At distances 4.5 m upwind and 6 m downwind of the driving path no spray deposition is measured. For the cross-flow fan sprayer the ground deposition is highest underneath the treated tree row (0 m).

Results presented in Fig. 4 are from a single application action in the orchard spraying a single tree row from both sides with the standard cross-flow fan sprayer and two rows with the two-row tunnel sprayer. Ground deposition when treating the whole orchard can be estimated based on the single pass spray deposition measurement and overlaying the effect of consecutive tree rows treated. Results for the standard cross-flow fan sprayer and the two-row tunnel sprayer are presented in Fig. 5.

Spray deposition on the ground surface in the orchard is for the standard cross-flow fan sprayer around 30% of applied spray volume (Fig. 5). There is little difference between the spray deposition underneath the tree rows (32%) and in the paths between the tree rows (26%). For the 2-row Lochmann tunnel sprayer spray deposition in half of the paths is around 7% for both air settings. In the other paths spray deposition is 20% for the high air setting and 33% for the low air setting.

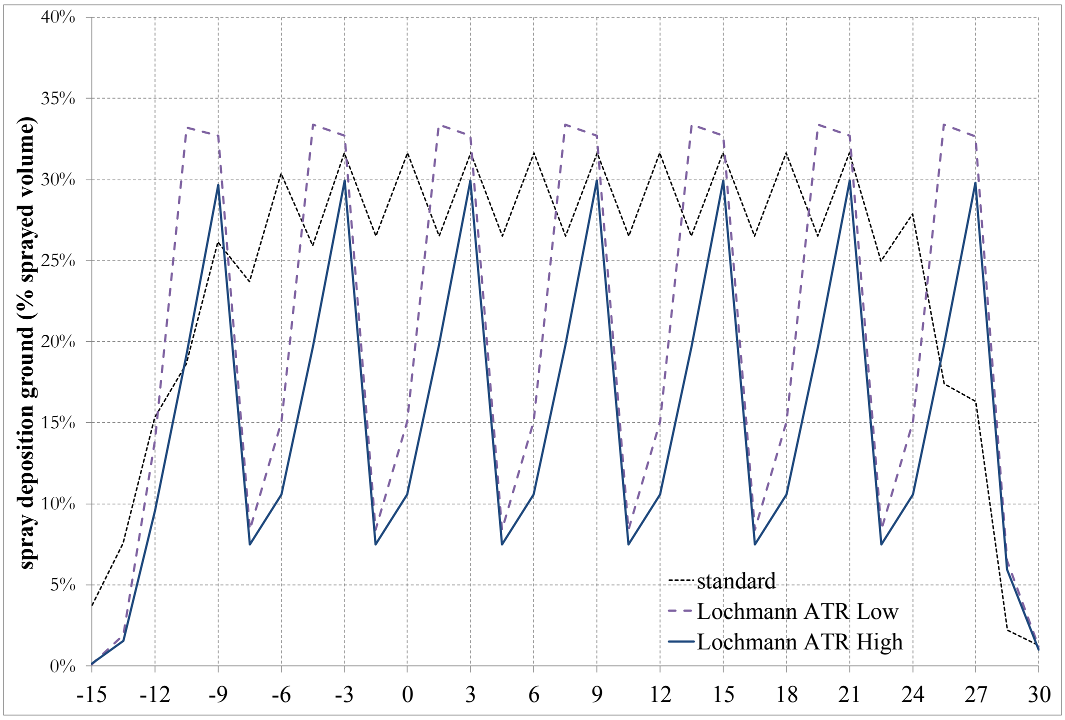

Fig. 5. Spray deposition on ground surface (% of sprayed volume) underneath the tree rows and at the paths in between the tree rows at different distances (m) from the center of the tree row sprayed with the standard and the left row of the two-row Lochmann tunnel sprayer with air assistance settings.

For 2-row tunnel sprayer with high air setting the spray deposition underneath half of the tree rows is 30% of applied spray volume and for the low air setting in half the paths is 33%. Underneath the other tree-rows spray deposition is 11% for the high air setting and 15% for the low air setting. Overall average ground deposition of the standard sprayer is 30% and for the Lochmann two-row tunnel sprayer is 20% (17% and 22% for resp. the high and low air setting).

Measured sprayer output in the tunnel towards the tree was only 31% and 34% of applied spray volume for resp. the high and the low air setting. Measured spray drift potential, being the spray collected entering the next tree row outside the tunnel over 3 m height, was 0.1–0.3% for the upwind direction and 0.3–1.0% for the downwind tree row for resp. the low and the air setting of the tunnel sprayer using the ATR Lilac nozzle types. For the standard cross-flow fan sprayer measured spray volume entering the treated row was 50%. Upwind and downwind potential spray drift deposition was 9% for the next tree row and 3% for entering the second tree row. So clearly spray drift potential for the Lochmann two-row tunnel sprayer is for the Albuz ATR Lilac nozzle types and different air settings much lower than of the standard cross-flow fan sprayer.

Discussion

The main results of the presented research are:

The two-row tunnel sprayer increases spray deposition in the tree compared to the standard cross-flow fan sprayer:

- Coarse spray quality Venturi type nozzles used in the tunnel sprayer increase spray deposition in tree canopy compared to standard Very Fine hollow cone nozzle type
- Low air settings of the tunnel sprayer increase spray deposition in the tree canopy, especially with the Coarse spray quality Venturi type nozzles
- Ground deposition of the tunnel sprayer is lower than of the cross-flow fan sprayer. Large differences do however occur between the ground area underneath the tree and the paths in between the tree;
- A tunnel sprayer shows high potential in reducing spray drift, measured as spray entering the next tree-rows outside the tunnel.

Points of interest still to address in further research is the mass balance of the measured spray deposition. It seems that we miss large portions of the sprayed volume. One of the missing routes however is the recycling part of the collected spray inside the tunnels. From earlier research, it was shown that recycling could easily be in the range of 30–60% (average 45%; Huijsmans *et al*., 1993). In tree spray deposition quantification, we also miss the deposit on stems and branches, the wooden parts, and the fruits. A rough estimation of surface area from pictures in the dormant situation of the trees indicates that the wood part of the tree could in the order of 30% of the projection surface. This part could therefore also be substantial in our mass balance.

Interesting too is the potential of further reduction in air assistance and its relation with spray deposition in tree canopy and ground deposition. Results are promising in developing more efficient application technologies for fruit crops.

Acknowledgements

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