Effect of air distribution and spray liquid distribution of a cross-flow fan orchard sprayer on spray deposition in fruit trees

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Summary

In a 4-year ongoing research programme in the Netherlands, we focus to maximise spray deposition in pome fruit trees and minimise spray deposition underneath the trees on the ground and minimise spray drift. For a cross-flow fan orchard sprayer we therefore measured spray deposition in the tree as an effect of different air settings and nozzle types. Nozzle types chosen were the Albuz ATR lilac (as a reference) and the Albuz TVI8001, both sprayed at 7 bar spray pressure. The orchard sprayer was a Munckhof cross-flow fan sprayer with a 2.75 m high cross-flow construction on top of the axial fan, equipped with 8 nozzles on both sides. At a forward speed of 6.5 km/h the spray volume was 200 L/ha and 290 L/ha, for respectively the Albuz lilac and Albuz TVI8001 nozzles. Air settings were: High air setting - 540 rpm PTO; and Low air setting - 540 rpm, 400 rpm, and 300 rpm PTO. Liquid distributions were measured with an AAMS-Salvarani Vertical patternator with discs, and air distribution was measured with a self-constructed measuring device equipped with ultrasonic anemometers and a handheld vane-anemometer. Liquid distribution in the apple trees (cv. Elstar) was measured in the full leaf growing stage (following ISO 22522).

First results show a good correlation between air distribution and liquid distribution. Vertical liquid distribution measured on the liquid measuring device correlates also very good with the liquid distribution at different heights in the tree. However, air distribution and especially air speed of the orchard sprayer showed that decreasing air assistance increased the spray deposition in the fruit trees. Showing that air assistance is an important parameter to be taken up in the advice to fruit growers.

Key words: orchard sprayer, cross-flow fan, spray deposition, air distribution, liquid distribution, air assistance

Introduction

To improve the current practice of spray application in fruit crops a research programme was setup. Spray and liquid distribution of nowadays often used single- and multiple-row orchard sprayers were assessed, and spray deposition and distribution in orchard trees were measured (Michielsen *et al*., 2017; Wenneker *et al*., 2014, 2018). Potential pathways –for improvement are: air amount, air distribution, nozzle type and therefore liquid distribution as the spray is transported by the moving air into the tree canopy. Improved spray deposition may lead to reduced use of agrochemical and reduced emission to the environment while maintaining high levels of spray drift reduction (Wenneker *et al.*, 2005) and biological efficacy. To quantify the air and liquid distribution in a 3D space together with AAMS-Salvarani (Maldegem, Belgium) a measuring platform was developed (Zande *et al*., 2017). The setup and first results of these 3D air- and liquid distribution measurement platforms are presented. In this paper, results are presented of a single row cross-flow fan sprayer for air distribution, liquid distribution and the effect of two nozzle types and different air settings on the spray deposition for leaf canopy spraying of an apple orchard.

Materials and Methods

Spray and air distribution

The base part of the measuring device consists of a two-rail traverse system positioned parallel (x-axis) alongside the sprayer on which a measuring platform can move up- and downwards and a two-rail traverse system on which the traverse system can manually be positioned at distances up to 5 m from the centre (x) axis of the sprayer. At the traverse system, the measuring platform can move in 10 cm steps over a range of 6 m length or in a continuous way at a set speed up and down the traverse system. The stepwise mode is used for the airflow distribution measurements. The continuous speed is used for the liquid distribution measurements using an AAMS-Salvarani patternator with discs (up to 4.5 m height) which is moved up and down (x-axis) through the spray fans until measuring tubes are filled for 80%. With a double sided discs

Figure 1. 3-D liquid distribution setup (left) and air-flow distribution setup (right).

distribution also multi-row orchard sprayers can be assessed. The air distribution measurement uses three ultrasonic anemometers (Gill Windmaster) which sample air speed in 3 directions (x,y,z) at 20 Hz positioned above each other at 50 cm spacing (y-axis). The combined three ultrasonic sensors can be positioned manually from 40 cm height (lowest sensor) up to 4.5 m height (highest sensor) in 10 cm steps (z-axis). Through steering and data sampling electronics and software the three sensors are moved through the air flow in 10 cm steps sampling the air flow at each x,z-axis position for 30 sec. In this way a full scan of the air flow at one side of an orchard sprayer can be made. Measurements are repeated for the y distances 1.00 m, 1.25 m, 1.50 m, 2.00 m, 3.00 m and 4.50 m from the centre axis of the sprayer. Results can be presented as a grid (matrix) presentation showing mean vector air speed per grid cell, as interpolated speed distribution charts per y-distance, as speed vector distributions in the x, y or y, z planes.

Spray deposition in tree canopy

Spray deposition measurements were performed in an apple orchard (Randwijk, The Netherlands) to quantify the effect of a reference cross-flow fan orchard sprayer (Munckhof 105) in a full leaf situation (June-October 2017). Apple trees (cv. Elstar) are of the spindle type spaced at 1 m in the row and at 3 m row spacing. The sprayer was equipped with standard hollow cone nozzles (Albuz ATR lilac) and a 90% drift reducing (Zande *et al*., 2008, 2012) venturi hollow cone nozzle (Albuz TVI8001) both operated at 7 bar spray pressure and a forward speed of 6.7 km/h. Eight nozzles were used on both sides of the sprayer resulting in a spray volume of respectively 200 L/ha and 290 L/ha. Air setting during the experiments was in the high (540 rpm PTO) or low settings of the fan gear box (540, 400, 300 rpm PTO). To measure the spray deposition in the apple tree a single row was sprayed with a fluorescent tracer (BSF 0.3 g/L) from both sides spraying consecutively from the left and right hand side of the sprayer (same driving direction). To sample the spray distribution the tree was divided in 7 compartments: top, middle-east, middle-west, bottom-east-outside, bottom-east-inside, bottom-west-inside and bottom-west-outside. From four trees the leaves in each compartment were counted and every tenth leaf was picked and put in a sample bag. Number of leaves per compartment were recorded and in the laboratory 10 leaves were taken from the sample and washed with a fixed amount of deionised water to recollect the tracer from the leaf surface. The surface area of the individual leaves was measured (Li-cor). Tracer amount in the solution was measured using a fluorimeter (Perkin-Elmer LS50) and expressed as µl/cm² and percentage of applied spray volume per tree compartment and for the whole tree. Specific parameters as mean, median, CV of leaf samples per compartment of 40 leaves, CV per compartment in the tree and CV between mean total deposition in the trees were calculated.

The effect of the different air settings and nozzle types on spray deposition in tree leaf canopy is presented.

Results

Spray and air distribution

The average liquid and air speed distribution at the left and right hand side of the cross-flow fan sprayer is presented in Figure 2 for the full air fan setting and the Albuz ATR lilac nozzles (7 bar). Liquid distribution over height was different for both sprayer sides. Air speed distribution was also not similar on the left and right hand side and shows a gap with reduced air speeds at 2-3 m height.

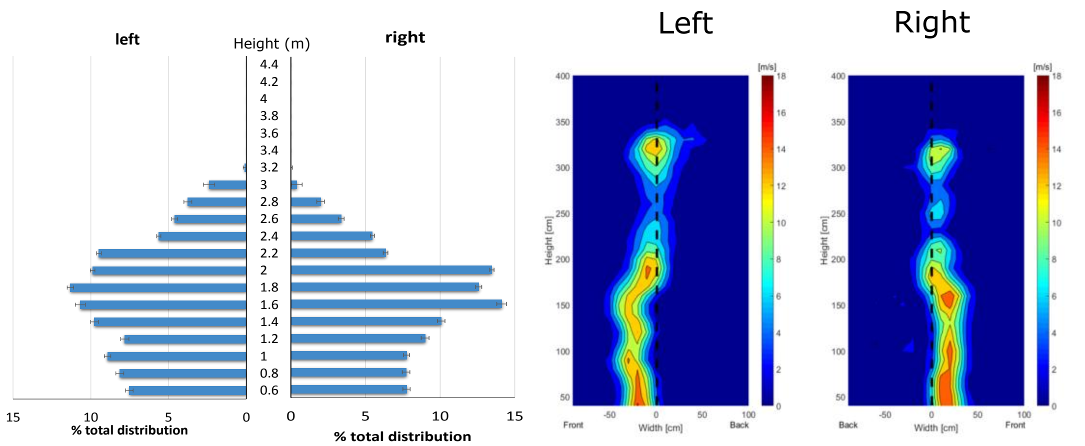

Figure 2. Liquid (left; % of total spray volume) and air speed (right; m/s) distribution over height (m) at 1.5 m distance from the centre line of the sprayer of the left and right hand side of the cross-flow fan sprayer (Munckhof ATRlilac@7 bar; full air).

The result of the liquid and air distribution (Figure 2) is the input for the measured spray deposition in tree canopy of an apple orchard as the spray plume moves over larger distances. The average liquid distribution at the left and right hand side of a cross-flow fan sprayer is presented in Figure 3 for distances up to 4.5 m from the centre axis of the sprayer. Showing that liquid distribution over height was different for both sides and the maximum liquid deposit was at higher heights at further distances from the sprayer.

The air distribution, at the right hand side of the Munckhof cross-flow fan sprayer (Figure 4) showed a gap in the air speed profile at 2.0-2.5 m height which widened at larger distances from the sprayer. The gap rose to higher heights up to 2.5-3.0 m at 3 m distance and 3.5 m at 4.5 m distance from the centre-axis of the sprayer.

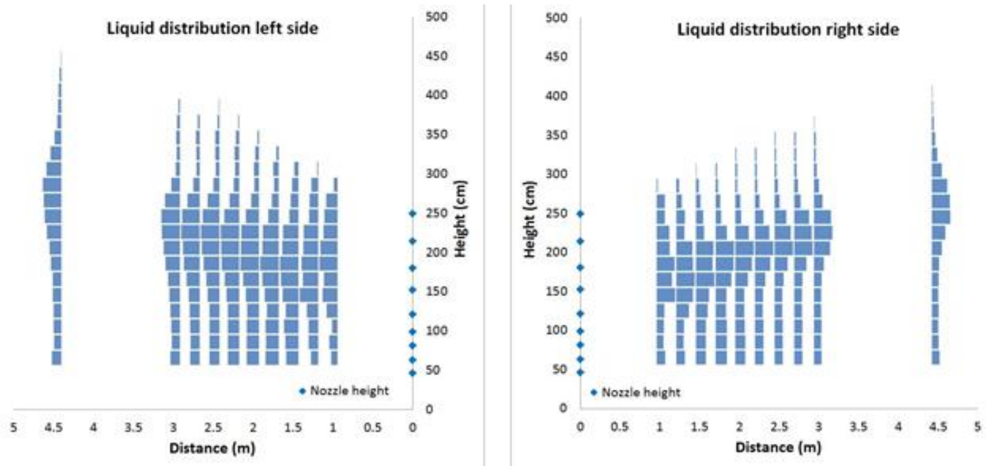

Figure 3. Liquid distribution in the x,z plane of the left and right hand side of a cross-flow fan sprayer.

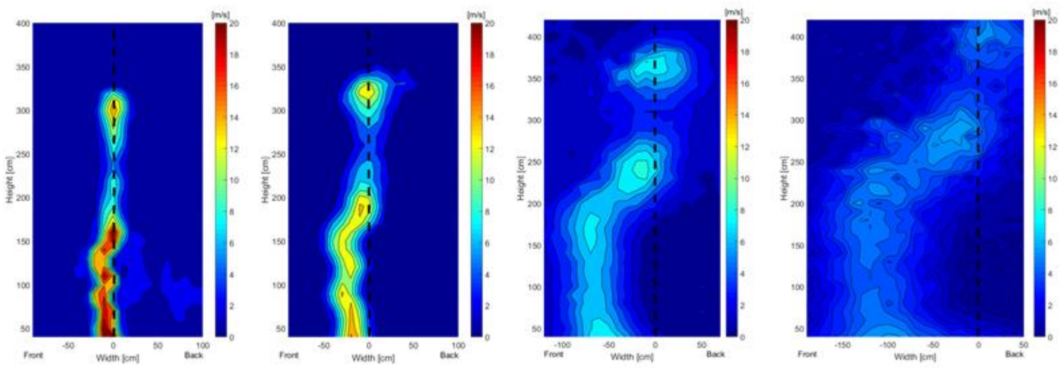

Figure 4. Air distribution (m/s) in x,z plane at 1.0 m, 1.5 m, 3.0 m and 4.5 m from the centre axis (x,z plane) of a cross-flow fan orchard sprayer (right hand side).

Spray deposition in tree canopy

As an example of the spray deposition in the apple tree, the results of July 4th 2017 (Figure 5) measurements are given for the Munckhof ATR lilac (7 bar) at full air setting. This is presented as the average spray deposition per compartment of the four sampled trees (10 leaves per compartment). Spray deposition was between 0.37 µL/cm^2 in the top of the tree and 0.17 µL/cm^2 in the bottom-inside compartment of the tree. Average spray deposition for all compartments of the four trees was 0.25 µL/cm^2 with a coefficient of variation (CV) between the four trees of 17%. Variation in spray deposition between the compartments of the four trees varied between 13% in the middle-west part of the tree and 49% in the bottom outside part of the tree. Within a compartment a large variation was observed between spray deposition at individual leaves CV for the 40 leaves per compartment picked was from 41% in the bottom outside compartment to 68% in the bottom inside compartment of the tree. Spray deposition in the top of the tree was between 0.04 and 0.76 µL/cm^2, which is a 20-fold difference. On average only 20-30% of applied spray volume was traced back on the leaves in the tree canopy.

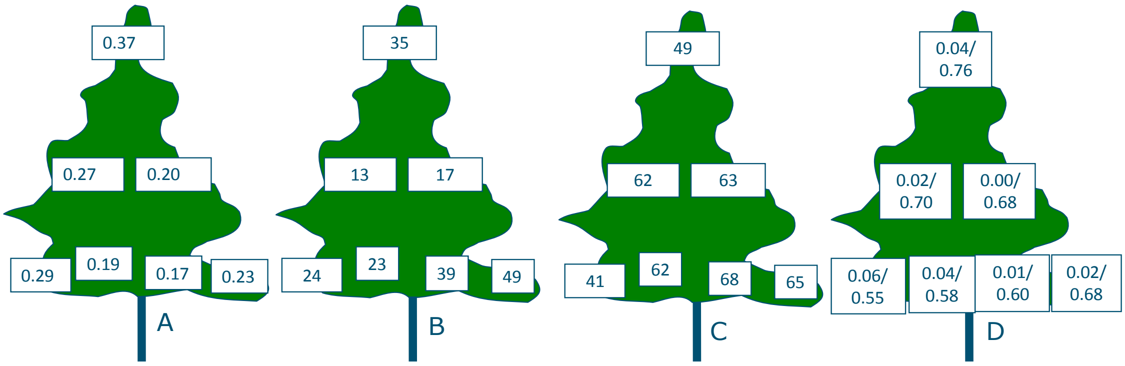

Figure 5. Spray deposition (µL/cm2) of a cross-flow fan sprayer (Munckhof with ATR lilac nozzles at 7 bar; full air) in full leaf apple tree (4 July 2017); distribution in compartments (A), coefficient of variation per compartment of 4 trees (B), coefficient of variation inside a compartment (C) and min/max deposition per compartment of 4 trees (D).

Total spray deposition in the tree

Effect of air settings

The correlation between air amount of the air settings of the Munckhof cross-flow fan sprayer and the spray deposition in the total tree leaf canopy of an apple orchard is presented in Figure 6. Total spray deposition in tree canopy was similar or increased with lower air settings of the Munckhof cross-flow fan sprayer. This was observed for the 90% drift reducing venturi type nozzle (TVI8001) as well as for the standard hollow cone nozzle (ATR Lilac). Maximum increase in spray deposition of the ATR Lilac hollow cone nozzle was 34% and for the 90% drift reducing venturi hollow cone nozzle was 46% both at Low gear setting of the Munckhof cross-flow fan sprayer and with 300 rpm PTO.

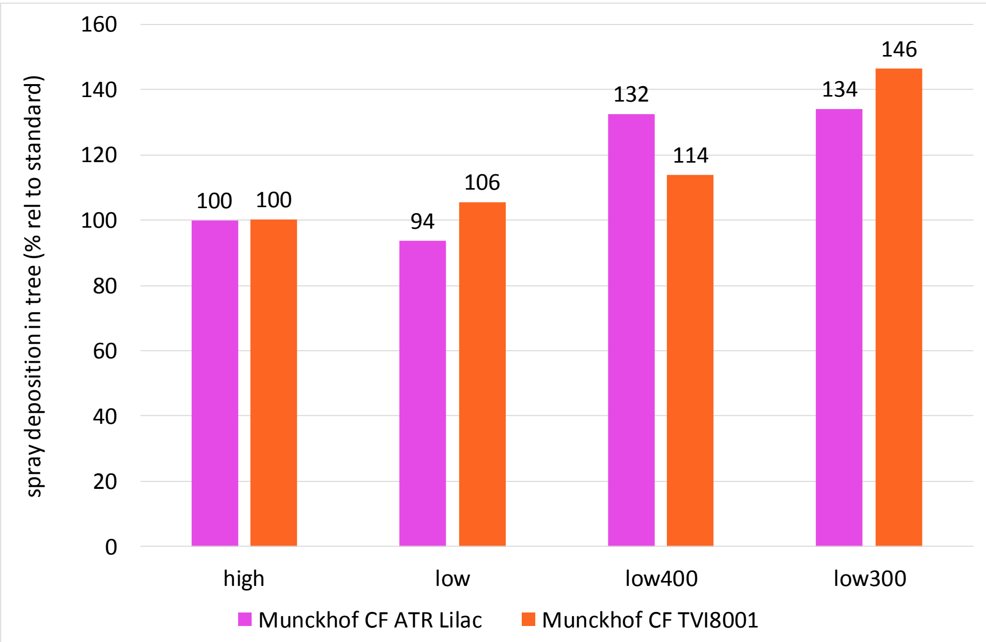

Figure 6. Effect of air settings of the Munckhof cross-flow (CF) fan orchard sprayer on total spray deposition in leaf canopy (% relative to deposition of standard setting).

The measured air speed at the air outlet of the Munckhof cross-flow fan sprayer at different settings ranged from 25.5 m/s for the standard High gear full air setting at 540 rpm PTO to 13.4 m/s for the Low gear air setting at 300 rpm PTO. The reduced air settings of the sprayer resulted in a relation between air outlet speed and total spray deposition in the tree leaf canopy of an apple orchard in the full leaf stage (Figure 7). Reducing air outlet speed with 1 m/s increased spray deposition in leaf canopy with 3.5 %. This relation was similar for both nozzle types used in the experiments; the Very Fine hollow cone nozzle (Albuz ATR Lilac) and the 90% drift reducing venturi hollow cone nozzle (Albuz TVI8001) both operated at 7 bar spray pressure (Figure 7).

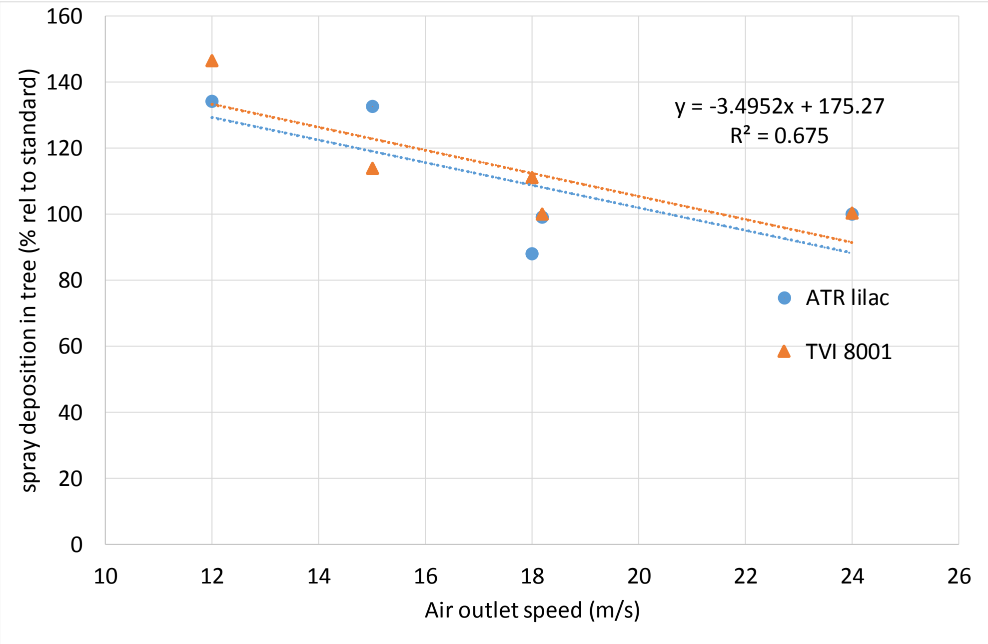

Figure 7. Relation between air outlet speed (m/s) of the Munckhof cross-flow fan sprayer and the spray deposition in tree leaf canopy relative to the deposition of the standard setting (540 rpm PTO High fan setting – 25.5 m/s air outlet speed)

Conclusion

Characterizing the air distribution and the liquid distribution is necessary to get more insight in the spray deposition process when spraying a fruit orchard. It appears that air and liquid distribution at different heights and distances from a cross-flow fan sprayer is not similar at the left and right hand side. Gaps in the air speed profile can be recorded only when small enough measuring grids are used, for example at a 10 cm square grid sampling, whereas these gaps are hardly detected at close distance of the air outlet. The spray deposition in tree leaf canopy is for a 90% drift reducing nozzle type (Albuz TVI8001) similar or higher as for a standard hollow-cone nozzle (Albuz ATR Lilac). Spray deposition in the tree leaf canopy increased with reduced air settings of the cross-flow fan sprayer. Lowering the air outlet speed from the standard Full leaf setting (High fan gear, 540 rpm PTO) to a low air setting (Low fan gear, 300 rpm PTO) increased spray deposition in the tree leaf canopy. Increase was 34% for the standard cross-flow fan nozzle (ATR Lilac) and 46% for the 90% drift reducing venturi hollow cone nozzle (Albuz TVI8001) both operated at 7 bar spray pressure. The relation of reduced air outlet speed of the cross-flow fan sprayer and increased spray deposition in the leaf tree canopy is for both nozzle types similar. Air settings and distribution seems to be more important for spray deposition in the tree leaf canopy than nozzle type.

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