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International Advances in Pesticide Application

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Aspects of Applied Biology **114**, *2012*
International Advances in Pesticide Application

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Summary

A LIDAR guided orchard sprayer was developed for reducing the amount of pesticides used for farming. Deposition measurements were performed in order to measure its performance and, based on that information, improve its decision algorithm. The deposition measurements were also performed with conventional sprayers. The preliminary results do show that the CDS sprayer reacted on the volume of the tree. However, this resulted in a higher deposition compared to the conventional sprayers. Still, the deposition measurements need to be analysed in more detail. Accordingly, the decision algorithm will be further improved.

Key words: Precision agriculture, sensors, spraying, GPS, GNSS

Introduction

When an orchard is sprayed, the sprayer is switched on at the beginning of a row and switched off again at the end of the row. Furthermore, when the sprayer is switched on, the applied amount of pesticides is constant, regardless to the volume of the foliage. However, there is a growing attention on reducing the amount of pesticides used for farming. For this purpose a LIDAR (Laser Imaging Detection And Ranging) guided orchard sprayer was developed which applies Canopy Density Spraying (CDS) (Nieuwenhuizen & van de Zande, 2011). This sprayer will adjust the amount of pesticides applied to the foliage volume of the trees. A decision algorithm was developed for the LIDAR guided orchard sprayer (Boonman, 2011). However, agronomical knowledge was not included in this decision algorithm. Nevertheless, this decision algorithm works in theory and a Hokuyo laser-scanner, was mounted on a KWH cross flow sprayer for further testing. Deposition tests are performed in different tree training and pruning systems (e.g. spill and v-shaped trees) at orchards of Applied Plant Research (PPO) in Randwijk. The development of the decision algorithm for the CDS orchard sprayer is part of the EU PURE project (Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management).

Materials and Methods

Explanation of the CDS orchard sprayer and the deposition measurements

The CDS sprayer is based on a KWH D-1000 orchard sprayer and equipped with a Hokuyo URG-04LX-UG01 laser scanner. This scanner, mounted at a height of 1.5 metres, makes a 270° scan with a resolution of 0.35° and a range of 4 metres. The scans are performed with a frequency of 10 Hz. The measurements of the laser are processed and based on those processed data the spray flow is adjusted. The adjustments to the spray flow are made by switching on or off nozzles.

On the sprayer in total 72 nozzles are mounted. These nozzles are clustered in groups of four with Lechler VarioSelect pneumatic actuated nozzle bodies. These nozzle bodies are distributed along the sprayer, nine nozzle bodies on the left hand side and nine nozzle bodies on the right hand side of the sprayer. Furthermore, the nozzle bodies are divided into different sections, five on each side. The four lower sections consist of two nozzle bodies and the top section consists of one nozzle body. Likewise, the measurements of the laser scanner are split up into 10 sections which correspond to the different sections of the sprayer. Based on the measurements per section a decision is made about the number of nozzles, from 0 up to 4, that should be activated. This decision per section is applied to all the nozzle bodies present in that particular section. The laser scanner and some of the Lechler VarioSelect bodies are shown in Fig. 1.

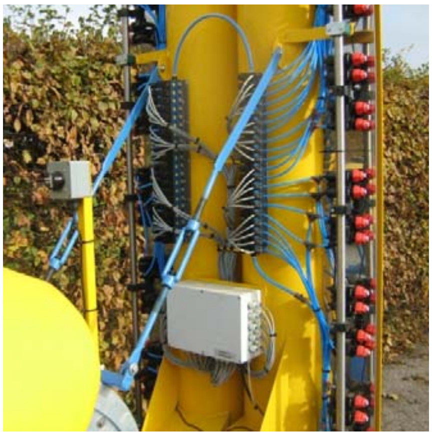

Fig. 1. The Canopy Density Spraying system is equipped with a Hokuyo URG-04LX laser scanner and with Lechler VariosSelect pneumatic actuated nozzle bodies. The sprayer used is a KWH D-1000 orchard sprayer and the nozzles are clustered in groups of four.

The adjustments to the spray flow are made with a frequency of 3.33 Hz. However, a higher adjusting frequency could be used, but then the spray cone cannot build up to its full size, which affects the spray pattern and spray distribution. For calculation of the dose, the average of the last three LIDAR measurements is used for the lower three sections and the last LIDAR measurement is used for the top two sections.

For further optimising of the decision algorithm, the performance of the current algorithm needs to be examined. For this purpose, deposition measurements are performed to examine the performance of the CDS sprayer. The deposition measurements are performed in orchards at PPO Randwijk. For the deposition measurements one tree row is sprayed from both sides, the left hand side of the tree row is sprayed with the right hand side of the sprayer and the right hand side of the tree row is sprayer with the left hand side of the sprayer.

To be able to compare the measurements of the CDS with conventional sprayers, also a Munckhof sprayer is used. Furthermore, the tree row is divided in three sections. The first third of the row is sprayed with a conventional Munchhof sprayer, the second third of the row is sprayed with a KWH D-1000 sprayer in the manual mode. In the manual mode the data of the laser scanner is not used, but at every nozzle body one nozzle is activated. So, basically the sprayer performs as a conventional sprayer. Finally, the last third of the tree row is sprayed with a CDS sprayer. A tracer liquid is used for spraying the trees, this makes it possible to measure the deposition. Furthermore, at each part sprayed by a different sprayer, three trees next to each other are chosen for picking leaves. From those trees every 10th leave is picked. The picked leaves are divided in different sections, as can be seen on Fig. 2. Furthermore, for 10 leaves per section the amount of tracer fluid was measured and for all the leaves the surface area was measured.

When the CDS sprayer is used, the data of the canopy (laser), the position (GPS) and the speed (wheel sensor) together with the pressure and for every nozzle if it's on or off is stored at a

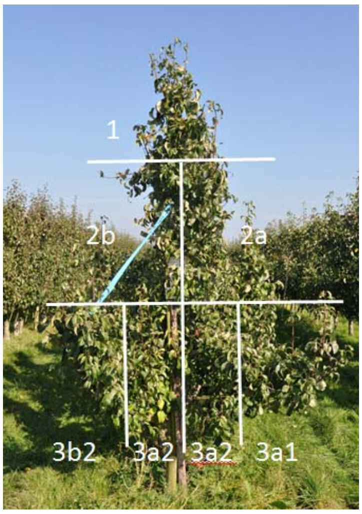

Fig. 2. A conference pear tree, with the different tree sections overlaid. The numbers in the picture correspond to: 1: top, 2a: mid east, 2b: mid west, 3a1: bottom out east, 3b1, bottom out west, 3a2: bottom in east, 3b2: bottom in west.

frequency of 10 Hz. So, there is a lot of data available. This data is used as a input for virtual testing of the adjustments made to the decision algorithm. Furthermore, field tests will be performed at the spring of 2012.

Results

Preliminary results of the deposition measurements

From the recorded CDS sprayer data can be concluded that the sprayer reacted on the volume of the tree. However, the applied amount of spray volume is much higher than the standard KWH sprayer. The spray flow of the CDS and the KWH sprayer is shown in Fig. 3.

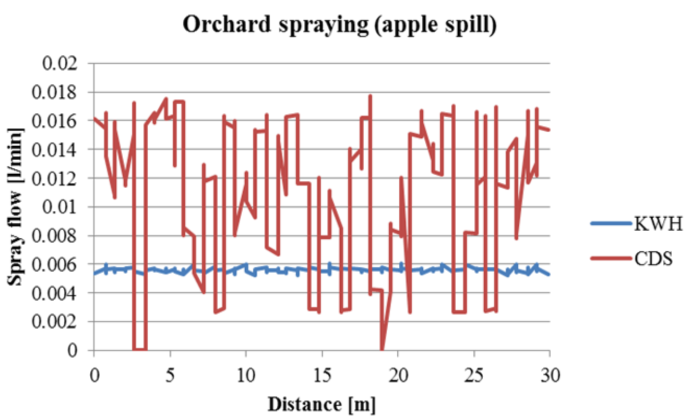

Fig. 3. The spray flow in l min^{-1} for the KWH and the CDS sprayer. Due to small variations in speed and pressure is the spray flow of the KWH not completely a flat line, but the spray flow is rather constant. Furthermore, the spray flow of the CDS sprayer is much less stable, because it does react on the volume of the tree.

Furthermore, the first analyses of the deposition measurements show that the Munckhof and the KWH have similar kind of deposition. In contrast, the CDS sprayer resulted in higher deposition, as shown in Table 1. This higher deposition matches to the higher volume rate that is currently applied by the dose algorithm.

Table 1. *Results of the deposition measurements in pear spill trees. The average of the deposition and of the leaf surface and the standard deviation are presented per section and for the total tree. For every sprayer three trees are analysed*

Sprayer	Munckhof		KWH		CDS	
	Leaf surface	Deposition	Leaf surface	Deposition	Leaf surface	Deposition
Tree section	[cm^2]	[$\mu L\ cm^{-2}$]	[cm^2]	[$\mu L\ cm^{-2}$]	[cm^2]	[$\mu L\ cm^{-2}$]
Top	30.28 (13.40)	0.42 (0.29)	31.55 (15.58)	0.89 (0.55)	35.98 (12.12)	1.10 (0.64)
Mid east	36.49 (14.28)	0.28 (0.20)	30.93 (13.34)	0.25 (0.16)	30.20 (13.07)	0.99 (0.86)
Mid west	29.62 (13.53)	0.48 (0.26)	36.42 (11.84)	0.17 (0.10)	29.72 (13.53)	1.10 (0.75)
Bottom out east	31.45 (11.89)	0.32 (0.18)	31.97 (15.18)	0.28 (0.24)	30.39 (16.93)	0.92 (0.67)
Bottom out west	29.75 (13.84)	0.40 (0.28)	28.32 (13.98)	0.35 (0.26)	29.70 (10.95)	1.22 (0.68)
Bottom in east	31.44 (13.55)	0.21 (0.14)	38.14 (16.66)	0.11 (0.12)	30.04 (14.97)	0.51 (0.52)
Bottom in west	30.66 (14.97)	0.20 (0.13)	34.92 (18.08)	0.09 (0.08)	33.25 (12.26)	0.35 (0.31)
Total	31.13 (13.56)	0.33 (0.24)	33.33 (15.19)	0.30 (0.36)	31.40 (13.57)	0.88 (0.71)

Discussion

First of all, these are preliminary results. The deposition measurements need to be analysed in more detail. Furthermore, from the recorded data, there will be examined if, based on the number of measurements per section and the ratio between the number of measurements between the upper and lower section, automatically a distinction can be made between different pruning systems. Also, there will be examined if, based on the measurements of the laser scanner, an estimate of the foliage density can be made, following the advice of Walklate *et al*. (2002).

In addition, the decision algorithm need to be adjusted in such a way that the sprayer is able to apply different doses, so it can be used with different kind of PPP. Furthermore, the sprayer need to be able to spray in low drift areas, where low drift nozzles are obligated (e.g. within 14 m of surface water (VW *et al*., 2000)). Also, different combinations of nozzle types will be examined (e.g. four different nozzles for a bigger variety of spray flows, or two normal and two low drift nozzles etcetera). In the end, only the type of nozzles present and the base dose should be entered by the user, before he can use the CDS sprayer.

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