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Aspects of Applied Biology

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https://www.aab.org.uk/aspects-of-applied-biology/

Aspects of Applied Biology 71, 2004
International advances in pesticide application

Biological efficacy of a prototype segmented canopy density orchard sprayer

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Summary

Biological efficacy of a prototype segmented cross flow sprayer was tested against codling moth (*Cydia pomonella*) and apple scab caused by *Venturia inaequalis*. There was significantly more damage of codling moth in the top of the trees (8 %) than in the bottom of the apple trees (1.4 %). However, there was no interaction between the sprayer type or sprayer setting of the prototype and the position in the tree. The prototype sprayer was equally effective in the control of codling moth compared to the standard Munckhof cross flow sprayer. There was a tendency for better efficacy of the prototype segmented sprayer when three nozzles per segment were continuously open in the codling moth experiment. Also, the efficacy of the prototype segmented cross flow sprayer against apple scab was similar to that of the standard Munckhof cross flow sprayer. It is therefore concluded that the biological efficacy of the prototype segmented cross flow sprayer is as good as the standard sprayer in the Netherlands.

Key words: precision spraying, fruit growing, apple scab, codling moth, *Venturia inaequalis*, *Cydia pomonella*

Introduction

The PreciSpray research project (EU-QLK5-1999-1630) aimed to develop a precision orchard sprayer. The main property of this sprayer should be a mechanism to adjust the spray volume to the tree shape and volume. The quantity of spray liquid and as a result of that, the total quantity of pesticide used should be reduced by such a mechanism (Meron *et al*., 2003). Koch *et al*. (1998) found that a fixed nozzle distance to the canopy was preferred to obtain a homogeneous spray distribution on the leaves of a tree. Therefore, a prototype sprayer was build with segments, which move in- and outwards in the direction of the trees. The segments follow a contour line parallel to the outside of the canopy. Three nozzles are present per segment of the sprayer enabling variation in spray volume by opening and closing nozzles. The quantity of spray volume is made dependent on the canopy density. Air support is made adjustable by a valve in each outlet of the air support to enable an optimal spray distribution depending on the canopy volume.

The properties of the prototype segmented cross flow sprayer are chosen to optimise spray deposits on all positions in trees. On top of that, the settings should be flexible to adapt to individual shapes of trees. The combination of these properties should guarantee a reduced quantity of pesticide needed to adequately control pests and diseases in orchards. It is important to measure not only the quantity of pesticides used and the deposits on leaves, but also the direct effect of sprayings against pests and diseases. Therefore, experiments are done with the aim to measure the efficacy of the prototype sprayer under natural orchard conditions against apple scab, caused by *Venturia inaequalis*, and codling moth (*Cydia pomonella*).

Materials and Methods

Codling moth experiment

The codling moth experiment was carried out in a commercial orchard at Millingen, the Netherlands. The experiment comprised cultivar Elstar on M.9 rootstock planted in 1992 in a single row planting system of 3 x 1 m and an average tree height of 2.5 m. Twenty-six rows of 100 m long were used. Two replicates were behind each other in the length direction of the row and three replicates were adjacent. Hence, six replicates in total. Each plot was seven rows wide and twenty trees long. However, untreated plots were seven rows wide and ten trees long. Buffer rows were present on the outside of the field and between adjacent plots. Only tree number 6 to 11 (the middle six trees) from the middle two rows per plot were used for observations. The experiment was set-up as split plot randomised block design with three main treatments. The three main treatments were untreated (U) in six replicates, pesticides applied with a standard orchard sprayer (S) in six replicates and with the prototype segmented cross flow sprayer (P). The latter main treatment (P) was subdivided in three settings of the prototype sprayer. The prototype sprayer was operated with one nozzle per segment continuously open (P_1) in two replicates, with automatic opening and closing of nozzles (P_2) in two replicates and with three nozzles per segment continuously open (P_3) in two replicates.

Two pheromone traps were placed in the orchard to monitor the flight of moths. Substantial numbers of moths, 37 and 23 respectively, were caught on 12 May 2003. Applications against codling moth started 15 May 2003 and continued as long as moths were flying. Applications were made on 15 and 30 May, 16 and 30 June, 11 and 30 July and 19 August 2003. Only the last three applications were part of the experiment. The first four applications were made with indoxacarb at a rate of 170 g/ha (as Steward; 42.3 % a.i.). The experimental applications were made with granulose virus at the rate of 1.5 l/ha (as Carpovirusine containing 6.7 x 10^{12} particles per l). The dose of granulosis virus was reduced to one third in the treatment with three nozzles per segment continuously open (P_3). The total number of apples per plot and the number of apples with codling moth damage were counted at harvest. Data were collected differentiated for the east and the west side of the trees and for the top of the tree (higher than 2 m), the middle part of the tree (1 to 2 m height) and the bottom of the tree (below 1 m).

Apple scab experiment

The apple scab experiment was carried out in the experimental orchard of Applied Plant Research, Randwijk, the Netherlands. The experiment comprised four rows of ninety m long in the middle of an orchard. The first two rows consisted of cultivar Elstar and the last two rows consisted of cultivar Jonagold. Both cultivars were on M.9 rootstock and planted in 1996 in a single row planting system of 3 x 1.25 m and had an average tree height of 2.8 m. On each side two buffer rows were left unsprayed to avoid contamination by drift from neighbouring experiments. Two replicates were behind each other in the length direction of the row. There were three treatments, namely untreated (U), fungicides applied with a standard orchard sprayer (S) and fungicides applied with the prototype segmented cross flow sprayer (P). The latter sprayer was operated with automatic opening and closing of nozzles.

Ten well growing long shoots per tree and ten trees per plot were selected randomly in the two middle rows of the plots, i.e. one row of cultivar Elstar and one row of cultivar Jonagold on 4 July 2003. A tag was placed at each shoot to mark the leaves susceptible for scab. Applications were made at 7, 14, 22 and 28 July and 5 August 2003 with captan at the rate of 1.2 kg/ha (as Captosan; 80 % a.i.). The last two applications were made on 12 and 25 August 2003 with captan at the rate of 670 g/ha (as Captosan; 80 % a.i.). Scab evaluation was done by counting the total number of leaves on marked shoots newly grown after placing the tag and the number of infected leaves.

Sprayer settings

The standard treatment (S) sprayings were applied with a Munckhof cross flow sprayer mounted with two times eight Albuz ATR lila nozzles for both experiments. Two hundred l/ha was delivered at 7 bar during the experiments. The prototype segmented cross flow sprayer (P) consisted of five segments mounted with three nozzles each on one side of the sprayer only. The nozzles were of the type Hardi F8001. Nozzles switch on and off depending on tree canopy volume (Achten *et al.*, 2003) for each of the 5 segment heights of the tree. A spray volume of 600 l/ha on average was applied at a pressure of 5 bar with this sprayer. Air support was kept constant.

Results

Codling moth experiment

A Walt test was done for analyses of three-way and two-way interactions between main treatments for the codling moth experiment. There were no significant three- and two-way interactions. Subsequently, a Walt test was applied for fixed effects, followed by pair wise comparisons. There were no significant differences between sprayer treatments (Table 1). The prototype sprayer with three nozzles continuously open (P_3) had the best efficacy and together with the standard sprayer (S) they were significantly more effective than the untreated control (U).

Table 1. *Average percentage of apples damaged by codling moth* (Cydia pomonella). *Averages with no letters in common are significantly different at* $P \leq 0.05$.

	% apples damaged	
(U) untreated	7.6	a
(S) standard sprayer	3.1	bc
(P_1) prototype one nozzle open	3.9	abc
(P_2) prototype automatic opening and closing nozzles	4.5	abc
(P_3) prototype three nozzles open	1.7	c

There was significantly more damage of codling moth in the top of the trees (8.0 % of apples damaged) and the lowest damage in the bottom of the trees (1.4 % of apples damaged; $P \leq 0.001$). It is an indication that spray liquid quantity and following the contour line of the canopy in the prototype (P) sprayer is as effective as the standard sprayer (S) since there was no significant interaction between treatments and place in the tree. More codling moth damage occurred on the west side of the trees (4.2 %) than on the east side of the trees (3.2 %; $P = 0.002$). But again, there was no interaction between treatment and side of the tree.

Apple scab experiment

There was practically no scab found on susceptible leaves grown after the shoots were tagged in untreated plots. However, a lot of scab developed during harvest period, four weeks after the last experimental fungicide application. Those apple scab infection data were counted on 25 September 2003. Standard analysis of variance showed that there was an interaction between cultivar and treatment (Table 2). The average percentage of leaves with scab in the prototype sprayer (P) was lowest for cultivar Jonagold. In contrast, the lowest percentage of leaves with scab was found with the standard sprayer (S) for cultivar Elstar.

Table 2. *Average percentage of leaves with lesions of apple scab* (Venturia inaequalis) *for the two apple cultivars Elstar and Jonagold. Averages with no letters in common are significantly different at* $P \leq 0.05$.

	Elstar	Jonagold
(U) Untreated	9.8 a	34.3 a
(S) Standard sprayer	3.9 a	11.4 b
(P) Prototype sprayer	4.4 a	6.2 b

The efficacy of the standard (S) and the prototype (P) sprayer were not significant different from one another, but were significantly different from the untreated (U) for cultivar Jonagold. The efficacy of the sprayers was less for cultivar Jonagold than for cultivar Elstar.

Discussion

The codling moth experiment started at the moment of the flight of the second generation. The results of the experiment confirm nicely that moths deposit their eggs mainly in the upper and outside part of apple trees (Wilboz, 1959). This is especially true for the second generation of the codling moth. The results also confirm that granulosis virus is effective against relative high populations of codling moth (Helsen *et al*., 1992). There was a tendency for better efficacy of the prototype segmented sprayer when three nozzles per segment were continuously open while spraying the same amount of virus particles as concentration was 1/3 of standard. This might indicate that a higher spray volume is more effective against codling moth than a low volume application. That there were no differences between settings of the prototype over different heights of the trees indicates that there might be opportunities to adjust sprayer delivery based on tree canopy density information from a geographic information system (GIS) data set (Hetzroni *et al*., 2003).

Normally, apple scab experiments should start at the beginning of the season when ascospores are released. We only started the apple scab experiment in July for practical reasons. We then evaluated sprayers on their efficacy against apple scab conidia (MacHardy, 1996). There was practically no scab on new grown leaves during the experimental period even in untreated plots. This can easily be explained by the extreme dry summer, uncommon for the Netherlands. However, weather conditions became more favourable for development of scab after we stopped the experimental fungicide applications because of harvesting. A lot of apple scab developed in all plots. The spread of conidiospores of apple scab is rather limited (Wiesmann, 1932). Wiesmann (1935) concluded in a following study, that conidia build up disease largely within the tree canopy in which they are produced. Therefore, it can be argued that the scab epidemic following the treatments originated from the individual plots and not from neighbouring plots or the surrounding orchard. The scab infection counted on 25 September 2003 is therefore reflecting the original scab infection present during the experimental applications. The demonstrated differences can be interpreted as a magnification by population growth of the original differences in the plots, which were too low to be countable (Holb *et al*., 2003).

The results of the experiments demonstrate that the biological efficacy of the prototype segmented cross flow sprayer is as good as the standard sprayer. The biological efficacy results might be substantiated by measurements on spray deposits on leaves. Measurements of spray deposits are done in 2003 (Zande *et al*., 2003) with the same sprayers and settings and will be published more extensively soon.

A substantial reduction of pesticides used in orchards is foreseen by using the segmented cross flow sprayer (Zande *et al.*, 2001). This expectation is based on a combination of properties of the segmented cross flow sprayer together with the use of GIS. The main property of the sprayer to reach this goal is the possibility to apply more accurately and automatically a deposit on the required place in trees. Individual segments of the sprayer move in- and outwards for that purpose. On top of that, depositing the required quantity of pesticide in the right place is achieved by adapting the spray volume and air settings of the sprayer. The history of infection from the earlier generations, initial inoculum densities, or the history of the total parcel could be stored in the GIS data set. Based on this GIS information, it would be possible then to further reduce the quantity of pesticide used per application.

Acknowledgements

We thank the fruit grower, Mr. R.J.A. Smolders for making available his orchard for the codling moth experiments. We also thank Mr. R.A. Anbergen, Mr. J. Simonse, J.M. Michielsen and P. van Velde for assistance. The European Union (project QLK5-1999-1630) and the Ministry of Agriculture, Nature and Food Quality sponsored the project.

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