Drift Reduction in Orchard Spraying Using a Cross Flow Sprayer Equipped with Reflection Shields (Wanner) and Air Injection Nozzles

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ABSTRACT

In a country as the Netherlands with much surface water, is important to reduce spray drift of pesticides in order to minimize environmental pollution, especially pollution of the water surface during spray application. In a series of experiments, the drift reduction to the soil surface outside an apple orchard was measured for the Wanner sprayer with reflection shields in comparison with a reference sprayer. The reference spraying machine for orchard spraying is a cross flow fan sprayer, equipped with Albuz ATR lilac nozzles (fine droplets), and a spray volume of approximately 200 $l.ha^{-1}$. Spray drift measurements were performed spraying a fluorescent tracer and quantifying spray drift deposition next to the orchard on artificial collectors.

For the Wanner sprayer with reflection shields and Albuz ATR lilac nozzles, the spray drift was reduced in the area 3.0 – 7.0 m downwind of the last tree row (equivalent to the area where the ditch is positioned) with 69% and 58%, respectively for the early growth stage (developing foliage; before 1st of May) and the fully developed foliage stage (after 1st of May). At 4.5 – 5.5 m downwind of the last tree row the spray drift deposition was reduced with 71% and 62% respectively for the early growth stage and the fully developed foliage stage.

Very high drift reduction levels were obtained with the Wanner sprayer with reflection shields and Lechler ID 90-015C (venturi) flat fan nozzles. In this situation spray drift was reduced in the area 3.0 – 7.0 m downwind of the last tree row with 95% and 94%, respectively for the early growth stage (developing foliage; before 1st of May) and the fully developed foliage stage (after 1st of May). At 4.5 – 5.5 m downwind of the last tree row the spray drift deposition was reduced with 95%, both for the early growth stage and the fully developed foliage stage.

From the experiments it is concluded that the combination of drift reducing methods consisting a sprayer with reflection shields and coarse droplets application is a very effective method to reduce spray drift in the Netherlands.

Keywords: Orchard sprayer, spray drift reduction, reflection shields, Netherlands

1. INTRODUCTION

The reduction of the emission of plant protection products (PPP) to the environment is an important issue when applying agrochemicals in fruit growing in the Netherlands. Spray free and crop free buffer zones were introduced, to minimize the risk of mainly spray drift (Water Pollution Act, Plant Protection Act). In general, applications of fungicides in fruit growing in the Netherlands are carried out with low spray volumes. The most often used nozzles are of the size 0050 (lilac) and 0067 (olive green), producing a Very Fine spray quality (Southcombe *et al*., 1997). In the Netherlands the most commonly used sprayers are cross flow fan sprayers. A minority of the fruit growers uses axial fan sprayers or multi-fan sprayers. Recently, new legislation is set into force (Anonymous, 2007), in which it is specified that fruit growers have to achieve 90% drift reduction compared to standard spray applications with a cross flow sprayer. At this moment, 7 drift mitigation measures for fruit growing are accepted by water control authorities; e.g. crop free buffer zone of 9 meters, windbreaks (hedgerows), tunnel spraying and specific coarse droplet applications. Sprayers with reflection screens were classified as 55% drift reducing machines, when equipped with standard Albuz lilac hollow cone nozzles. These results were obtained in experiments in 1992-1993 (Porskamp *et al*., 1994a, b). Apart from spray drift also other initiatives have been taken to reduce possible (environmental) problems with pesticides such as mandatory sprayer inspections, recycling of empty containers and licensing of the sprayer operator.

In this paper we discuss the results of experiments on spray drift reduction with the Wanner sprayer equipped with reflection shields, and standard Albuz ATR lilac hollow cone nozzles or Lechler venturi flat fan nozzles (ID 90-015C). Drift reduction was determined compared to the reference situation; i.e. a cross-flow fan sprayer equipped with Albuz ATR lilac nozzles (fine droplets).

2. MATERIALS AND METHODS

2.1 Location

The experiments were conducted in a commercial apple orchard. The orchard was of spindle shape dwarf trees (3.00 x 1.00 m spacing). The apple variety was Elstar on M.9 rootstock. Trees were planted in a single row planting system and had an average height of 2.25 – 2.50 m. Drift measurements were carried out in two seasons (early season and late season; 9 replicates per season) with several replicates per day. According to the drift protocol (CIW, 2003) a swath of at least 20 m has to be sprayed. In the trials, the outer 8 tree rows were sprayed with both the reference spraying machine and the Wanner sprayer. Normally, tree rows are sprayed two sided; i.e. a sprayer passes the trees from every driving alley. With the Wanner sprayer with reflection shields two tree rows are completely sprayed from one driving alley, because nozzles are also mounted on the opposite side of the tree in the reflection shields. So the reference sprayer made 8 tracks and the Wanner sprayer 4 tracks to spray the area of 8 rows on the downwind side of the orchard.

2.2 Equipment

Spray treatments were applied with a cross-flow sprayer (Munckhof) and a Wanner sprayer with reflection shields (figure 1a). The settings of the equipment are summarized in Table 1. The nozzle flow rate was measured directly after the applications. Travel speed was measured during the sprayings measuring time over 20 m of traveled distance.

Table 1. Overview of the operating conditions of the used sprayers during the spray drift measurements.

Sprayer:	**Munckhof cross-flow sprayer**	**Wanner sprayer with reflection shields**
Nozzle types:	Albuz lilac	Albuz lilac, Lechler ID 90-015C
Pressure (bar):	7	7
Nozzle flow rate (l min^{-1}):	0.39	0.40 (Albuz lilac) and 0.88 (Lechler ID 90-015C)
No. of nozzles:	2 x 7 (early season) 2 x 8 (late season)	2 x 7 + 2 x 3 (early season) 2 x 8 + 2 x 4 (late season)
Nozzle heights (cm):	50, 68, 87, 106, 137, 167, 202, 237.	80, 81, 114, 147, 180, 213, 246, 280, and reflection shields: 64, 124, 184, 244.
Fan setting:	Low gear (early season) High gear (late season)	1400 rpm (early and late season)
Driving speed (km h^{-1}):	6,5 – 6,6	6,8 – 6,9
Spraying volume (l ha^{-1}):	165 – 190 (Albuz lilac)	120 – 140 (Albuz lilac) 260 – 300 (Lechler ID 90-015C)

2.3 Drift Measurements

Drift measurements were carried out according to the ISO standard (ISO 22866; 2006) adapted for the situation in the Netherlands (ground deposits, ditch, and surface water next to the sprayed field) following the Dutch protocol (CIW, 2003). In a series of experiments the drift deposition on the soil surface outside an apple orchard was measured (9 replicates in early growth stages and 9 replicates in fully developed canopy). In the Netherlands, risk assessment in drift experiments for orchard spraying is carried out on an uniform basis and expressed as percentage of the application rate per surface area, at a distance of 3.0 – 7.0 m from the last tree row, being the place where ditches (surface water) are commonly situated (figure 1b). Drift deposition on the middle of the ditch (4.5 – 5.5 m from the last tree row) is especially taken into account for the authorization of pesticides (water surface area). The reference situation for orchard spraying is a cross-flow fan sprayer, equipped with Albuz lilac nozzles (fine droplets).

Drift was measured on ground surface on the down wind edge of an orchard. Spray drift measurements were carried out adding the fluorescent dye Brilliant Sulfo Flavine (BSF) and a non-ionic surfactant (Agral; 0.1%) added to the spray agent. A spray solution tank sample was taken directly before and after the application to determine the actual fluorescent concentration. Ground deposit was measured on horizontal collection surfaces (10 cm x 50 cm or 10 cm x 100 cm) placed at ground level in a double row (1 m distance) downwind of the sprayed swath. The collectors were placed at distances of 1.5m; 3.0m – 7.0m (0.5 m collectors); 7.5 – 8.5 m and 8.5 – 9.5 m from the centre of last tree row. Collectors used were synthetic cloths (Camfil CM360). Spray deposits were calculated and presented as percentage deposit of the applied rate per unit surface area (1 ha^{-1}) on the different distances of the collectors. As a comparison to the reference situation drift reduction was calculated for the zones 4.5 – 5.5 m and 3.0 – 7.0m from the last tree row, being the zones were in the Netherlands respectively middle of the ditch and surface water is located.

2.4 Statistical Analysis

The measured deposits were expressed as percentage of the application rate of the sprayer (spray dose). After transformation (Genstat angular function) the results of the deposition measurements were statistically evaluated using the Genstat statistical software. Statistical analysis of the data was done using analysis of variance (ANOVA 5% probability). Significant effects were analyzed with a LSD-test (α=0.05) for pairs.

2.5 Meteorological Conditions

Meteorological conditions (i.e. wind speed, wind direction and temperature) during the spray drift measurements were recorded. Wind speed and wind direction were measured with a hot wire anemometer (every 10 seconds), 0.5 m above tree crowns. All measurements were within the wind direction range of 90° +/- 30° of the spray track, being 0° – 18° for the early growth stage and 4° – 17° for the late growth stage. Wind speed was 2.0 – 3.4 m s^{-1} for the early growth stage and 2.4 – 3.0 m s^{-1} for the late growth stage. Temperature was 11 – 17 °C for the early growth stage and 8 – 14 °C for the late growth stage.

Figure 1a. Reference cross flow spraying machine (Munckhof) and Wanner sprayer with reflection shields.

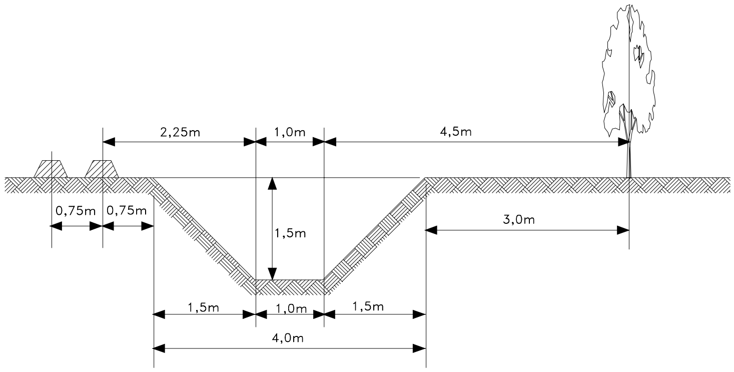

Figure 1b. Schematic presentation of the standard ditch and its dimensions in the Netherlands (after Huijsmans *et al*., 1997).

3. RESULTS

3.1 Spray drift deposition early growth stages (developing foliage)

In the early growth stage the spray drift curve of the reference situation (Munckhof Albuz lilac) showed a gradual decrease in drift deposition with increasing distance from the last tree row (figure 2). The Wanner sprayer with reflection shields and Albuz lilac nozzles gave much lower spray drift depositions. With coarse droplet applications (Lechler ID 90-015C) very low spray drift deposits were measured.

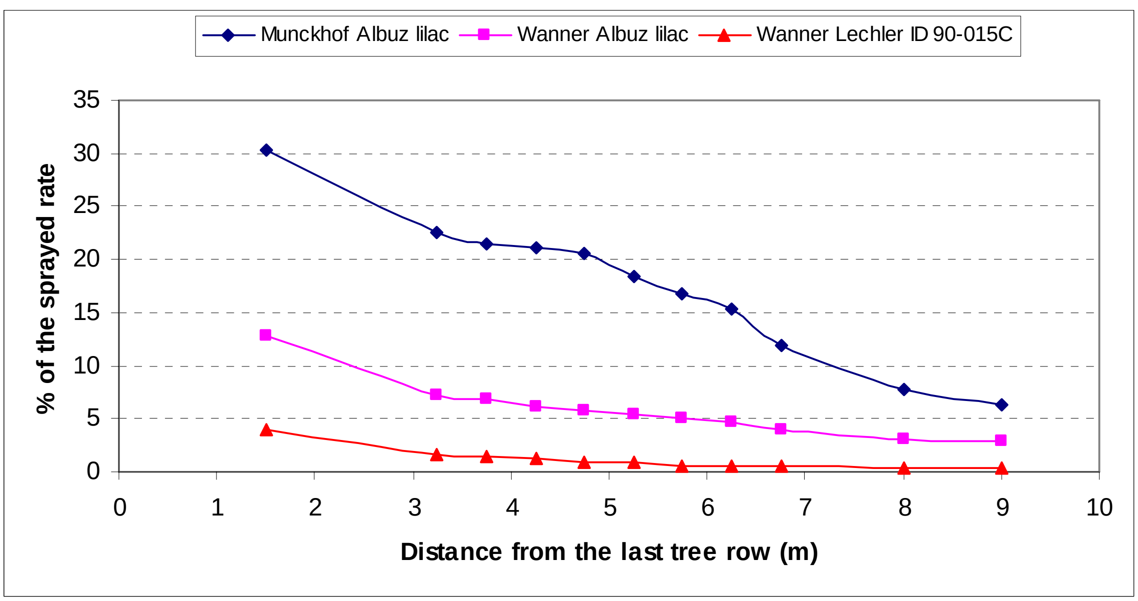

Figure 2. Spray drift deposit on the soil surface outside the orchard at several distances downwind from the last tree row, for early growth stages. Curves show mean values of 9 replicates.

3.2 Spray Drift Deposition Fully Developed Foliage Stage

The spray drift deposition in the full leaves situation was for the reference sprayer approximately three times lower (figure 3), as compared to the early growth stages (figure 2). The difference in spray drift deposition between the reference sprayer and the Wanner sprayer with reflection shields and Albuz lilac nozzles was smalles than in the early growth stages. Again, very low drift depositions were measured with the coarse droplet application (Lechler ID 90-015C) and shielded spraying.

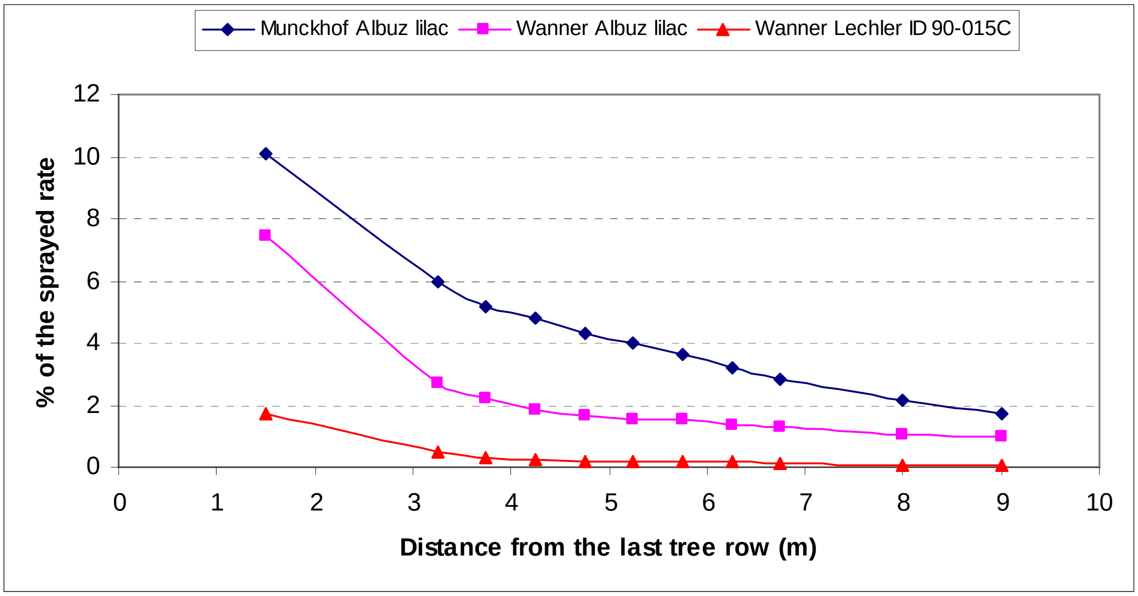

Figure 3. Spray drift deposit on the soil surface outside the orchard at several distances from the last tree row, for full leaf stages. Curves show mean values of 9 replicates.

3.3 Spray Drift Depositions for the Reference Situations

For the reference spray technique; Munckhof cross-flow fan sprayer and Albuz lilac nozzles, the average spray drift deposition on the soil at 3.0 – 7.0 m downwind of the last tree was 18.6% and 4.3% of the application rate per surface area, respectively for the early growth stage (developing foliage; before 1st of May) and the fully developed foliage stage (after 1st of May). At 4.5 – 5.5 m downwind of the last tree row the average spray drift deposition was 19.5% and 4.2%, respectively for the early growth stage (developing foliage; before 1st of May) and the fully developed foliage stage (after 1st of May). From these figures the spray drift reduction for the Wanner sprayer were calculated. The presented reductions were statistically different.

3.4 Spray Drift Reduction

3.4.1 Dormant Situation or Early Growth Season

For the Wanner sprayer using reflection shields and Albuz lilac nozzles spray drift was reduced in the area 3.0 – 7.0 m downwind of the last tree row with 69%. At 4.5 – 5.5 m downwind of the last tree the spray drift deposition was reduced with 71%. For the Wanner sprayer with reflection shields in combination with Lechler ID 90-015C (venturi) flat fan nozzles the spray drift was reduced with 95%, for both in the area 3.0 – 7.0 m and 4.5 – 5.5 m downwind of the last tree (figure 4).

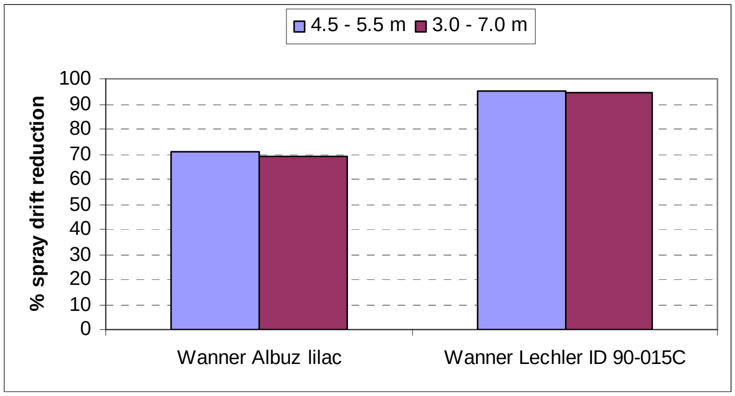

Figure 4. Spray drift reduction at 4.5-5.5m and 3.0-7.0m from the last tree row in early growth stages for the Wanner shielded sprayer equipped with Albuz lilac hollow cone nozzles or Lechler 90-015C venturi flat fan nozzles.

3.4.2 Full Leaves Situation or Late Season

For the Wanner sprayer using reflection shields and Albuz lilac nozzles spray drift was reduced in the area 3.0 – 7.0 m downwind of the last tree with 58%. At 4.5 – 5.5 m downwind of the last tree row the spray drift deposition was reduced with 62%. For the Wanner sprayer with reflection shields in combination with Lechler ID 90-015C (venturi) flat fan nozzles the spray drift was reduced in the area 3.0 – 7.0 m downwind of the last tree row with 94%. At 4.5 – 5.5 m downwind of the last tree the spray drift deposition was reduced with 95% (figure 5).

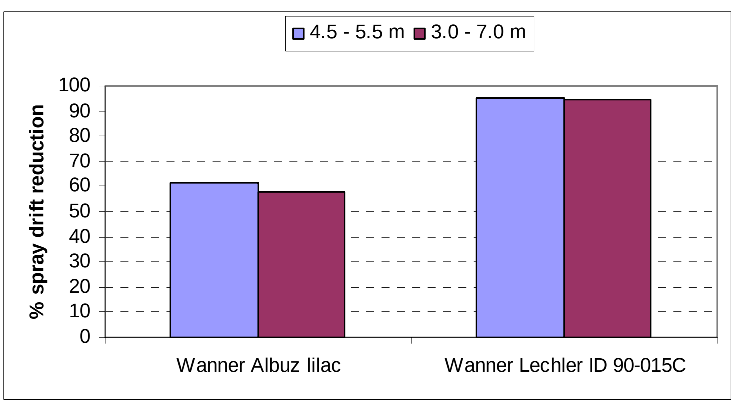

Figure 5. Spray drift reduction at 4.5-5.5m and 3.0-7.0m from the last tree row in full growth stages.

4. DISCUSSION

Spray drift from pesticide applications is a major concern in the Netherlands, especially spray drift into water courses. Fruit growing in the Netherlands is characterized by the presence of many waterways near orchards. In this perspective, spray drift reduction has been a key issue in the past decades (Zande *et al*., 2001). So far, several drift reducing measures have been accepted by water boards and the Board for the Authorisation of Plant Protection Products and Biocides (Ctgb), e.g. presence of a windbreak (70–90% drift reduction), the use of a tunnel sprayer (85% reduction). Also, a cross-flow sprayer with reflection shields and (standard) Albuz lilac nozzles has been classified as a 55% drift reducing measure. Due to improvements and modifications of the sprayer and reflection shields, as well as the availability of drift reducing nozzles, new trials were carried out in order to determine the drift reducing possibilities.

The experiments revealed that the drift reduction figures for the Wanner sprayer with reflection shields and standard ATR hollow cone nozzles are comparable with the data as presented by Huijsmans *et al*. (1997) for a cross flow sprayer with reflection shields. These figures were based on research of Porskamp *et al*. (1994a, b). Both experiments resulted in approximately 55% - 65% drift reduction in the full leaf situation. However, Porskamp did not perform experiments in the early growth stages. In the experiments, as described in this paper, in the early growth stages or dormant trees approximately 70% drift reduction can be realized with standard ATR hollow cone nozzles and a reflection shield. Apparently, shielding is more effective in the early growth stages than in full leaves stages.

Very high drift reduction levels were obtained with the Wanner sprayer with reflection shields and Lechler ID 90-015C (venturi) flat fan nozzles. In this situation, spray drift reduction was approximately 95%, both for the early growth stage (developing foliage; before 1st of May) and the fully developed foliage stage (after 1st of May). Based on the new data, a cross flow sprayer equipped with reflection shields and ID 90-015C nozzles has been classified by the water authorities (CIW, 2003) and Board for the Authorisation of Plant Protection Products and Biocides (Ctgb) as a 95% spray drift reducing method.

The use of specific drift reducing nozzles is already an accepted method in the Netherlands. However, it should be combined with one sided spraying of the outer tree row, because the level of drift reduction of coarse droplets is strongly related to the measuring points. The ballistic behavior of bigger droplets results in an off crop soil deposit peak. This peak will be very close to the orchard and in many cases within the field margins of the orchard. The drift reducing effect is therefore small or absent near the orchard boundaries (Heijne *et al*., 2002; Wenneker *et al*., 2005). The use of shielded sprayers will overcome the problem of high depositions near the orchard boundaries.

Additional advantage for fruit growers, when using a sprayer with reflection screens, is the possibility to spray two complete tree rows from one driving alley (because nozzles are also mounted on the reflection shields). In this way, time and money is saved as only half of the numbers of tracks have to be traveled. Also, spray volume savings (and financial savings) are possible as the shields are equipped with recollection systems.

In general, the acceptance of spray drift reducing methods by fruit growers will depend on economical impact (labour and investment costs), plant protection efficacy (biological efficacy) and legal aspects. Recycling, sensor equipped and shielded sprayers offer advantages regarding labour reduction (cost savings), spray volume reduction (cost savings), spray drift reduction (environment), the possibility to spray a wider range of pesticides (legislation), optimal timing for the chemicals (less dependent on weather conditions), and less exposure of operators to spray liquid (Doruchowski & Holownicki, 2000; Wenneker *et al.*, 2003). However, the number of tunnel sprayers and sprayers with reflection shields working in the Netherlands is still low; although these sprayers are already for more than 15 years available. Mainly due to the fact that tree size, tree spacing and training systems (apples and pears) are very variable in the Netherlands. For that reason a second (standard) cross flow or axial fan sprayer would be needed in order to spray all orchards of the farm. Hence, fruit growers do not easily decide to buy a tunnel sprayer or a sprayer with reflection shields. Recently, double tunnel sprayers and multi-row cross flow sprayers have been assembled. However, for a broad implementation, new orchard training systems or more uniform orchards are necessary.

5. CONCLUSIONS

The Wanner sprayer with reflection shields and Albuz ATR lilac hollow cone nozzles, reduced spray drift deposition in the area 4.5 – 5.5 m downwind of the last tree row, equivalent to the area where the surface water in the ditch is positioned, with 71% and 62% respectively for the early growth stage (developing foliage; before 1st of May) and the fully developed foliage stage (after 1st of May). When the sprayer is equipped with Lechler ID 90-015C venturi flat fan nozzles spray drift was reduced with 95%, both for the early growth stage and the fully developed foliage stage.

The combination of drift reducing methods, such as a cross-flow fan sprayer in combination with the use of reflection shields and coarse droplet application, results in high spray drift reduction in orchard spraying. Both in the early growth stage as in the fully developed canopy 95% drift reduction were obtained.

6. ACKNOWLEDGEMENTS

The authors wish to thank the fruit grower Mr. P. Cruijsen for making his orchard and equipment available for the drift measurements. We also thank Mr. R. Anbergen, Mrs. N. Joosten and Ms K. Kiesi for technical assistance and laboratory analyses.

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