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Wenneker, M.; Heijne, B.; van de Zande, J.C.

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# Spray drift reduction in orchard spraying in the Netherlands

M. Wenneker<sup>1</sup>, B. Heijne<sup>1</sup> and J.C. van de Zande<sup>2</sup>

<sup>1</sup> Applied Plant Research (WUR-PPO-fruit), P.O. Box 200, 6700 AE Zetten, The Netherlands

<sup>2</sup> Field Technology Innovations, Plant Research International B.V. (WUR-PRI), P.O. Box 16, 6700 AA Wageningen, The Netherlands

## Summary

The reduction of the emission of plant protection products to the environment is an important issue in the Netherlands. The Dutch government has formulated new goals on the reduction of pesticide use and emissions to the environment. Spray free and crop-free buffer zones are introduced, to minimize the risk of mainly spray drift. In the Netherlands, several methods have been developed to minimize drift in orchard spraying. Combinations of methods are entered in the certification process for the classification of low of spray techniques in the Netherlands, and are allowed for growers to be used in combination with smaller dimensioned crop-free buffer zones. This paper presents an overview of drift reducing measures in orchard spraying and officially accepted drift reducing methods in the Netherlands.

**Key words:** *Crop protection, spray drift, pesticides application, sprayers*

## Introduction

Spray application of crop protection products (PPP) causes spray drift. This is especially high in fruit growing where the spraying direction is horizontally and upwards. Drift is enhanced too by to the (high) air support that is common in orchard spraying. Spray drift causes serious problems by contaminating surface water, especially in the Netherlands. Ditches and canals are common elements in the Dutch landscape, including in the regions with apple and pear culture. In these area's orchards are often adjacent or close to waterways. Therefore, it is important to reduce spray drift of pesticides in order to minimize environmental pollution of surface water during spray application. The reduction of the emission of plant protection products (PPP) to the environment is already for a long period an important issue 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; V&W *et al.*, 2000). In the Netherlands, several methods have been developed to minimize spray drift, such as a windbreak, tunnel sprayer, or a cross-flow sprayer with reflection shields (Zande *et al.*, 2001; Heijne *et al.*, 2003).

### *Spray application in fruit culture*

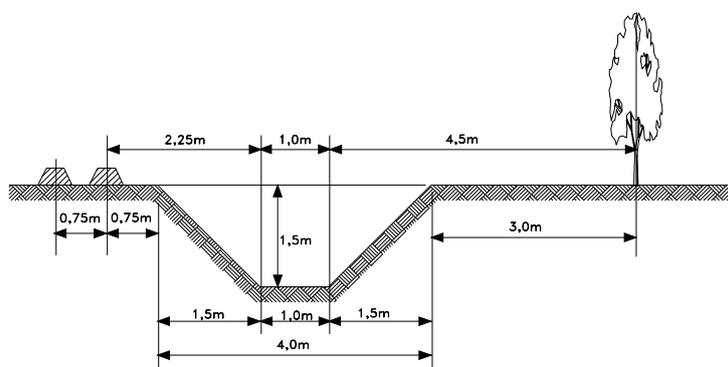
In general, applications of fungicides in the Netherlands are carried out with low volume spraying (200 – 250 l ha<sup>-1</sup>). The most often used nozzles are of the size 0050 (lilac) and 0067 (olive green), producing a Very Fine spray quality (Southcombe *et al.*, 1997). For most growers, volume of water is primarily related to economical considerations (filling and spraying time) and secondly to crop protection issues (leaf wall or canopy density). In the Netherlands the most commonly used sprayers are cross-flow sprayers. A minority of the growers uses axial fan sprayers or multi-fan spray towers.

### *Drift measurements*

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. Drift measurements are carried out according to the ISO standard (ISO 22866; 2005) adapted for the situation in the Netherlands (ground deposits, ditch, surface water next to the sprayed field) following the Dutch protocol (CIW, 2003). Spray drift is measured on ground surface on the down wind edge of an orchard. Spray drift measurements are carried out adding the fluorescent dye Brilliant Sulfo Flavine (BSF) and a non-ionic surfactant (Agral) to the spray agent. Ground deposit is measured on horizontal collection surfaces placed at ground level in a double row downwind of the sprayed swath. The collectors (synthetic cloths) are placed at several distances from the centre of the last tree row. Spray deposits are calculated and presented as percentage deposit of the applied rate per unit surface area on the different distances of the collectors. Especially important is the distance of 3.0 – 7.0 m from the last tree row, being the place where ditches (surface

water) are commonly situated (figure 1, Huijsmans *et al.*, 1997). Drift deposition on the middle of the ditch (4.5–5.5 m from the last tree row), i.e. the water surface, is especially taken into account for the authorization of pesticides.

Drift experiments are carried out in apple orchards. Commercial apple orchards in the Netherlands are normally planted in single rows (spindle trees on dwarfing root stocks). Spacings are about 3 m x 1.25 m, and crown heights of 2.25–2.75 m. The reference situation for orchard spraying is a cross-flow fan sprayer (Munckhof), equipped with Albuz lilac nozzles, used at 7 bar spray pressure producing a Very Fine spray quality. The experiments have to be carried out in early (dormant) and late growth stage (full canopy) of the trees. In the early growth stages (developing foliage), air assistance is supplied with low gear settings for the fan. In the fully developed foliage stage, experiments are carried out with high gear fan settings.



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

## Results and overview of tested methods

### *Spray drift reduction*

To minimize spray drift different technical methods or cultural practices are possible. Examples of technical methods are nozzle type, shielding and air assistance. A cultural practice is an increased crop-free zone or buffer zone. A crop-free buffer zone is in the Netherlands defined as the distance between the last tree row and the upper edge of the ditch bank. A buffer zone in general can be described as the distance between point of direct pesticide application and the nearest boundary of a sensitive area. Also planting a barrier vegetation or structure (windbreak) can offer additional protection against drift contamination of the surrounding area.

### *Single sided spraying*

Normally, in orchard spraying with axial and cross-flow fan sprayers, tree(-rows) are sprayed two-sided. Driving along all alleys, each tree is sprayed from two sides, including the last or outer tree row. Spraying from the second last alley in the direction out of the orchard causes most drift, especially down-wind. Spraying of the last tree row only from the outer alley into the orchard, and not from the second last alley in the direction out of the orchard results in one-sided spraying of the outer tree row. Drift reduction of 40%–45% was measured for the early growth stage and the fully developed foliage stage, respectively. Although it is a simple and cheap method for growers to apply, this technique should not adversely affect biological efficacy of the spray application.

### *Sensor equipped sprayers*

In orchard spraying part of the spraying liquid is not applied on the target tree, due to gaps in the leaf

canopy between the trees. Spraying of these gaps contributes significantly to the drift deposition outside the orchard. With (infrared) sensors these gaps in the tree fruit wall can be detected. Nozzles, connected to the sensors, are closed when no target is detected and opened when leaf canopy is in front of the nozzle. Spray drift reductions of 20% and 50% were achieved for nearly bare (dormant) trees and fully developed canopy, respectively. Biological efficacy against apple scab is comparable to conventional application methods. Depending on the proportion of gaps in the fruit wall, spray volume savings (and financial savings for the farmer) can be quite high. In experiments savings were on average 26% for a young orchard and 28% for an old orchard (Wenneker *et al.*, 2003). Koch & Weisser (2000) estimated that 25% - 30% in plant protection product costs can be saved by an average fruit grower using a sensor equipped sprayer.

#### *Sprayer with reflection shields*

Sprayers with reflection shields are at this moment classified as 55% drift reducing machines, when equipped with standard Albus lilac hollow cone nozzles. These results were obtained in experiments in 1992-1993 (Porskamp *et al.*, 1994a, 1994b). In 2005, experiments were performed with a modified sprayer (Wanner sprayer with reflection shields). In these trials also the effect of venturi nozzles (Lechler ID 90-015C; 300 l ha<sup>-1</sup>) in combination with reflection shields on drift deposition was evaluated. For the Wanner sprayer with reflection shields and Albus lilac nozzles, the spray drift was reduced in the area 3.0 – 7.0 m downwind of the last tree row with 69% and 58%, respectively for the early growth stage (developing foliage; before 1<sup>st</sup> of May) and the fully developed foliage stage (after 1<sup>st</sup> 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 (developing foliage; before 1<sup>st</sup> of May) and the fully developed foliage stage (after 1<sup>st</sup> of May).

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 1<sup>st</sup> of May) and the fully developed foliage stage (after 1<sup>st</sup> 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 (developing foliage; before 1<sup>st</sup> of May) and the fully developed foliage stage (after 1<sup>st</sup> of May). Additional advantage for growers is the possibility to spray two complete tree rows from one driving alley. In this way time (and money) is saved. Also, spray volume savings (and financial savings) are possible as the shields are equipped with recollection systems.

#### *Coarse droplet application*

In the Netherlands growers are using low spray volumes (200 – 250 l ha<sup>-1</sup>), mainly due to economic considerations, and use fine spray quality nozzles (e.g. Albus lilac and Teejet olive green). However, these nozzle types generate in general finer droplet spectra. It is assumed that droplets smaller than 100 µm are very prone to drift. The drift reducing effect of coarse spray quality nozzles in orchard spraying is generally accepted. From the experiments it was clear that the air induction nozzle reduces soil deposition in a considerable way. However, in all situations the level of drift reduction of coarse droplets was strongly related to the measuring points outside the orchard. The ballistic behaviour of bigger droplets resulted in an off crop soil deposit peak close to the orchard, which is however, in many cases within the field margins of the orchard. The drift reducing effect is therefore small or absent near the orchard boundaries, as found by Heijne *et al.* (2002).

In 2002 – 2003 series of experiments were performed with coarse spray quality nozzles, i.e. the air induction (flat fan) nozzle Lechler 90-01C (5 bar), compared to the (hollow cone) Albus lilac nozzle (7 bar). Applications were made with a spray volume of approximately 200 l ha<sup>-1</sup>. Effect of air assistance (fan speed, air velocity) and one-sided spraying of the outer tree row on spray drift was determined.

Spraying with coarse droplets resulted in high soil deposit outside the orchard at short distance from the last tree row. The bigger droplets produced by the air induction nozzles behave in a ballistic way, once the air support drops below a critical value. One-sided spraying with coarse droplets resulted in very low drift deposits. In the early growth stages (dormant trees, or developing canopy) the drift reducing effect of coarse droplet application was absent, due to the high soil deposit at short distance from the last tree row. However, one-sided spraying and switching off air assistance resulted in more than 80% drift reduction in the dormant situation.

With fully developed canopies a drift reducing effect of coarse droplets was found of 55%, due to the filtering capacity of the trees. Again, this effect was enhanced by lowering the level of air assistance (78% drift reduction) and by one-sided spraying of the last tree row (88% drift reduction). Combining both methods resulted in a drift reduction of 96% at 4.5 – 5.5 m from the last tree row. From the experiments it is concluded that the combination of drift reducing methods consisting of coarse droplets, one-sided spraying of the last tree row and adjustment of air assistance is an effective method to reduce spray drift in the Netherlands. Based on these experiments new research is started to develop a nozzle classification system based on driftability and a drift model, comparable to the system that is available for arable farming (Porskamp *et al.*, 1999; Zande *et al.*, 2000).

#### *Windbreaks*

In the Netherlands windbreaks (mainly Alder trees, *Alnus glutinosa* and *A. cordata*) are commonly grown to protect orchards against wind damage and to improve micro-climate. Barrier vegetation like windbreaks and hedgerows can however also reduce spray drift, and offer therefore additional protection against drift contamination of the surrounding area. Natural windbreaks of broad-leaved trees can also reduce the risk of surface water contamination caused by spray drift during orchard spraying. Point of concern is the growth stage of the barrier vegetation at moment of spraying. Data show that the risks of drift contamination are very high during the early stages of the growing season for dormant trees. Alder trees remain dormant for a relatively long period. First orchard spray applications are already carried out in this stage. Windbreak species as *Acer*, *Crataegus*, *Sambucus* and *Carpinus* will develop much earlier than Alder, and give a better drift reduction in the early season (Wenneker *et al.*, 2005).

From the experiments it was concluded that the risk of drift contamination is high during the early developmental stages of the growing season. The 70% drift reduction at early season as determined in initial experiments (Porskamp *et al.*, 1994c), appears to be valid only for windbreaks with a certain degree of developed leaves. At full leaf stage 80% – 90% drift reduction by the windbreak was measured. The use of evergreen windbreaks or windbreak species that develop in early season can reduce the risk of drift contamination considerably. Also, the combination of drift reducing methods, such as one-sided spraying of the last tree row and a windbreak is an effective method to reduce spray drift in the Netherlands in early season.

#### *Riparian vegetation*

Some of the smaller ditches in the Netherlands have natural high vegetation. Reed (*Phragmites* spp.) can dominate this vegetation. The vegetation acts as a filter for airborne droplets but also gives impedance to air flow. The height of the vegetation can be over 2.5 m. Measurements revealed that drift is reduced between 50% - 90% at the position in the middle of the ditch. The drift reduction was variable during the winter season, when both reed and apple trees are leafless (Heijne *et al.*, 2003). Bare reed canes will reduce wind speed, but have limited droplet filtration or entrapment capacity. However, in contrast to windbreaks, riparian vegetation (reeds) is not accepted as a drift reducing measure. Because pesticide residues in riparian vegetation have the potential to be washed off with precipitation or to affect wildlife. As reeds also grow at a distance of 3.0 – 7.0 m from the last tree row, being the place where ditches (surface water) are commonly situated, all spray drift deposit in this area should be avoided.

#### *Artificial netting*

Windbreaks of trees have some disadvantages like reduction of cropping space and maintenance costs. An alternative might be a wind-screen made out of nylon netting around the orchard. In a series of experiments with a cross-flow sprayer and a nylon netting screen (60% closed) a significant drift reduction was observed. It was concluded that artificial netting of at least 2.5 m height results in a drift reduction of 60%, both for the dormant and fully developed canopy.

#### *A crop-free zone*

Increasing the distance from the last tree row to the surface water zone by means of a crop-free zone will reduce spray deposition on the surface water. Minimal crop-free buffer zones depend on the spray drift reducing methods that are used. Combinations are entered in the certification process for low drift classification of spray techniques (CIW, 2003) in the Netherlands, and allowed be to used with smaller

dimensioned crop-free buffer zones.

## Discussion

Results of spray drift research from PRI (former IMAG) and PPO are incorporated in Dutch legislation. In the Surface Water Pollution Act and the Pesticide Act criteria for drift deposit on surface water are used, depending on the spraying technique and period of use during the growing season. The data used in the Pesticide Act are summarized in table 1. The Board for the Authorisation of Pesticides (CTB) performs a risk assessment, in which of the environmental toxicity of pesticides is assessed. The basic spray drift values for orchard spraying are 17% for the early growth stage (dormant or developing foliage; before 1<sup>st</sup> of May), and 7% for the fully developed foliage stage (full leaves; after 1<sup>st</sup> of May). A standard 3 m buffer zone is taken into account (= driving alley of the sprayer), defining water surface at 4.5 – 5.5 m from the last tree row. This assessment determines possible restrictions for application of pesticides (label).

**Table 1. Drift reducing methods in the Netherlands as accepted by CTB**

Drift reducing method	Drift reduction (%)		Drift figure (%)*	
	Dormant	Full leaves	Dormant	Full leaves
> Tunnel sprayers	85	85	2.5	1.0
> Windbreaks, in combination with	59	90	7.0	0.7
> Sensor equipped sprayers	20	50	13.6	3.4
> Single-sided spraying of the last tree row; i.e. spraying the outside tree row only from the field margin inwards	43	43	9.7	4.0
> Artificial netting of at least 2.5 m	60	60	6.8	2.8
> Cross-flow sprayers with reflection shields	55	55	7.7	3.2
> A crop free zone of 6 m	61	61	6.7	2.7
> Venturi spraying nozzle single-sided spraying of the last tree row	86	88	2.4	0.8

\*: calculated from the basic drift values of 17% and 7%, for the dormant and full leaves situation, respectively.

The width of spray and crop free zones are defined in the Water Pollution Act, which came into force in 2000. However, measurements performed by water control organizations revealed that concentration of PPP in surface water still exceeds maximum tolerable levels. In the new proposal of the Water Pollution Act, a 9 m crop free zone will be the standard when spraying with 'standard' equipment; i.e. cross flow sprayer equipped with Fine spraying quality nozzles (e.g. Albus lilac). The crop free zone can be reduced if a drift reducing method is applied (table 1). At this moment the following methods are accepted to reduce the 9 m crop free zone:

- Tunnelsprayer and 3 m crop free zone
- Windbreak and 3 m crop free zone
- Sprayer with reflection shields in combination with emission screen and 3 m crop free zone
- Sprayer with reflection shields and 4.5 m crop free zone
- Organic fruit culture and 3 m crop free zone
- Venturi nozzle and one-sided spraying of last tree row and 3 m crop free zone

As described above, several drift reducing measures have been accepted by water quality control organizations and the Board for the Authorization of Pesticides (CTB). Legal acceptance of some measurements as pressure, level of air assistance and one-sided spraying of the outer tree row depend to the extent that authorized bodies can inspect and control its implementation in practice.

The acceptance of drift reducing methods by fruit growers will depend on economical impact (labour and investment costs), plant protection efficacy (biological efficacy) and legal aspects. Some of the drift reduction methods have marked disadvantages for the fruit grower, such as high investment costs (tunnel sprayer) or the loss of cropping space (windbreak).

For fruit growers it is important to know if new drift reducing techniques are a risk regarding disease built-up or inoculum source. The drift reducing method should not adversely affect biological efficacy of the spray application (Cross *et al.*, 2002; Knewitz *et al.*, 2002). Deposit studies can be used to explain or

understand the results of biological efficacy trials. However, the biological experiment itself gives the final proof. Also, it is important to test drift reducing methods under marginally or sub-optimal conditions in order to determine its robustness. This will increase the acceptance of the method for introduction in practice by the fruit grower.

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