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Classification of spray applications for driftability, to protect surface water

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Summary

A summary is given on field measurements of spray drift research for the past 10 years in the Netherlands. Results are presented for orchard spraying, nursery tree spraying and arable field spraying for the typical Dutch situation, related to defined distances and dimensions of the surface water. Spray drift research was setup in order to identify and quantify drift reducing technologies. Results are presented for cross-flow sprayers, tunnel sprayers, and air-assisted field sprayers. The effect of nozzle type on spray drift is highlighted both with a modelling approach as based on field drift experiments. The use of spray drift data in regulation is discussed. The effect of spray drift reducing technologies in combination with crop- and spray-free bufferzones is outlined. It is concluded that the right choice of spray technology can be used to minimise spray- and crop-free bufferzones and maintain acceptable levels of ecotoxicological risk in the surface water.

Key words: crop protection, pesticides application, deposition, spray-drift, air-assistance, sprayer, field crops, orchards, nozzle-type

Introduction

The Multi Year Crop Protection Plan (MYCPP, 1991) of the Dutch government formulates objectives for a reduction in plant protection products to be used and for an application practice for these products which is safe and more compatible with the environment. The emissions of plant protection products to soil, (surface)water and air should be reduced. A general reduction in spray drift to surface water next to the sprayed field can be achieved by improvements in spray application techniques. For the last 10 years an intensive measuring programme on spray drift has been performed. The research programme consisted of laboratory measurements, field experiments and computer modelling. A system analysis approach was developed to divide the research into processes and parts important for spray drift: the nozzle (drop sizes, spray quality, driftability), sprayer boom movement and boom height (drop trajectory), sprayer outline and additional drift reducing technology on it, the crop type (height, density, and the placement of the last nozzle to the edge of the crop), the field layout and the place of the surface water. The programme started with the quantification of the drift for the reference situation of the MYCPP and addressed whether the set 2% drift level was a true value for common agricultural practice in arable farming. A stepwise approach was chosen to lower drift with: air assistance or shielding sprayer booms on a field sprayer, a tunnel sprayer, sprayer boom height and nozzle type.

In order to apply a risk assessment the results are presented on a uniform basis and expressed as percentage of the application rate per surface area, at a distance of 2.25-3.25 m (for a potato crop) or 4.5-5.5m (for orchards) of the last crop row, being the place where the ditches are commonly situated (figure 1).

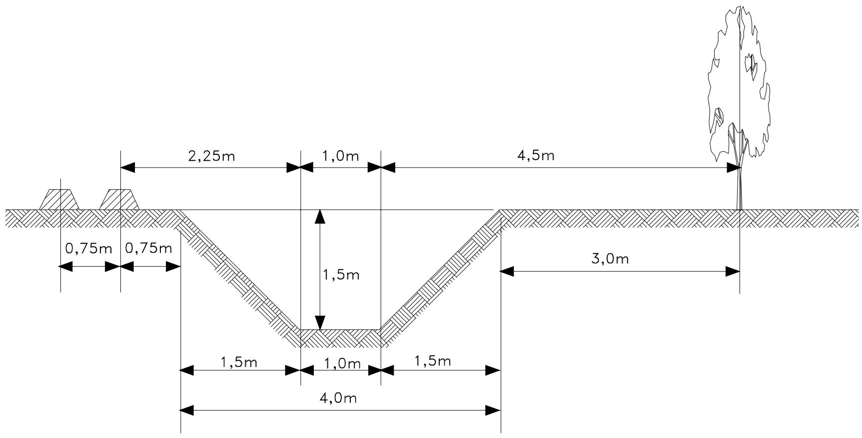

Figure 1. *Representation of the place of the ditch, embankments and water surface, and the last rows of a potato crop and a tree row in an orchard*

Different aspects will be highlighted in this paper, both for orchard spraying, nursery tree spraying as for arable field spraying. Results from the research programme are summarised in this paper. An outline is given of how the results are used in laws dealing with the authorization of pesticides and the quality of the water.

Materials and Methods

Modelling

Spray quality and driftability are two important nozzle parameters in this context. Spray quality depends on nozzle type, nozzle size and spray pressure and is of importance for crop coverage. Drop size, drop speed, and drop direction in the spray fan influences driftability. Through a combination of laboratory measurements and computer modelling a driftability classification system can be developed. With a PDPA-laser (Aerometrics; Phase Doppler Particle Analyser), spray quality and drop speed are measured. These data are used as input for the IDEFICS spray drift model (Holterman et al., 1997), calculating spray drift deposits downwind of the sprayed field. Spray drift is calculated for the zone 2.125-3.125m from the last nozzle. In most cases this is the surface water area of the ditches adjacent to a potato field.

Field measurements

The developed methodology to classify spray nozzles for driftability holds only for conventional use of nozzles. Extension of the classification of driftability of nozzle types in combination with air-assistance, shielding, etc. on field sprayers still needs field measurements of spray drift.

In a series of field experiments air-assisted spraying was compared with conventional spraying in a potato crop during the growing season. The effect of low-drift nozzles on spray drift was also quantified, as well as the effect of a no-spray buffer zone. Measurements were done on a bare soil surface and in a ditch, downwind of the crop.

Spray drift measurements were carried out by adding the fluorescent dye Brilliant Sulfo Flavine (BSF) to the spray agent and placing collectors in and outside the field. The swath-width sprayed was at least 18m. The length of the sprayed track was at least 50m. A minimum of ten replications were made in time and place along the edge of the field during the growing season. The distance of the last downwind nozzle to the edge of the field (the last crop leaves) was determined. Measurements of spray drift were always compared to a reference situation i.e. field sprayers applying a volume rate of 300 l/ha with a Medium spray quality. In case of air

assistance, nozzles were kept vertical and air velocity was set to the maximum capacity of the fan.
Ground deposit was measured on horizontal collection surfaces placed at ground level in a double row downwind of the sprayed swath. When measuring field sprayers the collectors were placed at distances 0-0.5, 1-1.5, 1.5-2, 2-3, 3-4, 4-5, 5-6, 7,5-8,5, 10-11, 15-16 m from the last downwind nozzle. Collectors used were synthetic cloths with dimensions of 0.50x0.08 and 1.00x0.08 m.
Airborne spray drift was measured at a distance of 5.5 m from the last downwind nozzle. The collection of airborne spray was done on two seperate lines with attached collectors at 0, 1, 2, 3, and 4 m height. Collectors used were spherical synthetic cleaning pads (diameter 0.08 m) (no data presented). After spraying, the dye was extracted from the collectors. The rate was measured by fluorimetry and expressed per surface area of the collector. The spray drift was expressed as percentages of the application rate of the sprayer (spray dose).
Meteorological conditions during spray drift measurements were recorded. Wind speed and temperature were recorded at 5 s interval at 0.5 and 2.0 m height, using cup anemometers and Pt100 sensors. Relative humidity was measured at 0.5 m height and wind direction at 2.0 m height.
Statistical analysis of the data was done using analysis of variance (ANOVA 5% probability).

Results

Modelling

Nozzles are classified into drift-reduction classes compared to a reference nozzle BCPC Fine/Medium (Southcombe et al., 1997) in a reference situation. Calculations are performed at a wind speed of 3 m/s, a crop height of 50 cm and a sprayer boom height of 50 cm above crop canopy. Nozzle-pressure combinations are classified accordingly. It was shown that the combination of nozzle type, nozzle size and spray pressure (Table 1) defines the spray drift (Porskamp et al., 1999).

Table 1.*Classification of nozzle-pressure combinations for spray quality and driftability. Spray quality is classified according to BCPC. Spray drift reduction is quantified with the threshold nozzle Fine/Medium (Lurmark 31-03-F110 @ 3 bar) as a reference.*

Manufacturer	Nozzle type	Pressure [bar]	Spray quality	Drift reduction class
Delavan	LF-110-01	4.5	Very Fine / Fine	-90
Lurmark	**31-03-F110**	**3.0**	**Fine / Medium**	**0**
Lechler	LU 120-06S	2.0	Medium / Coarse	50
Teejet	8008 VS	2.,5	Coarse/ Very Coarse	75
Teejet	8015 SS	2.0	Very Coarse / Extra coarse	90
Albuz	ADE3 orange	1.5	Coarse	75
Albuz	ADE3 orange	3.0	Medium	50
Albuz	ADE3 orange	5.0	Medium	25
Lechler	ID 120-02	3.0	Extra Coarse	75
Lechler	ID 120-02	5.0	Very Coarse	75
Lechler	ID 120-02	7.0	Coarse	50
Teejet	TT11004	1.5	Very Coarse	75
Teejet	TT11004	3.0	Coarse	50
Teejet	TT11004	5.0	Medium	-25
Teejet	DG11002	3.0	Medium	25
Teejet	DG11004	3.0	Coarse	50
Teejet	XR11002	3.0	Fine	-90
Teejet	XR11004	3.0	Medium	0
Teejet	XR11008	3.0	Coarse	50

Field experiments

MYCPP reference situation

The reference situation for the MYCPP for field crop spraying was a conventional boom sprayer spraying a potato crop during the growing season with an average windspeed of 3 m/s. Crop height was on average 0.5m above soil-surface and sprayer boom-height was 0.7m above crop height. Spray volume was 300 l/ha, spraying was done with a flat fan nozzle-type (BCPC-class Medium). From field experiments performed in the period 1991-1993 (34 repetitions) it was found that the spray-drift deposition at the soil at 2.25-3.25 m downwind of the last potato-row was 5.4% of the application rate per surface area (Porskamp et al., 1995).

Effect of spray volume and air assistance

To quantify the effect of spray volume and air assistance on spray drift, a number of drift measurements were executed in the period 1992-1994 (Porskamp et al., 1995). Spray volumes compared were 150 l/ha and 300 l/ha, resp. a Fine and a Medium spray quality (Southcombe et al., 1997). Sprayer boom height was set to 0.7m above the canopy of the potato crop. Within this volume range the spray quality (resp. 52 and 34 repetitions) did not significantly affect the drift deposition in the experiments. Spray drift deposition on the distance 2.25-3.25 m from the last potato-row was on average 5.3% for both nozzle types sprayed conventionally.
Compared to the conventional spraying (86 rep.), a field boom sprayer with air assistance (70 rep.) achieved a 50% reduction in spray drift on the soil surface at the same downwind distance.

Effect of crop free buffer zone

Increasing the distance from the crop boundary, and therefor the last nozzle to the surface water zone, by means of a non-cropped spray-free zone of 2.25m (3 potato ridges) reduced the deposition by 70% on the surface water zone (Porskamp et al., 1995).

Effect of shielding and air assistance

In a series of experiments in a flower-bulb crop (1993-1996) the drift deposition on the soil next to the sprayed field was measured (33 rep.) for an air-assisted and a shielded field-sprayer and a prototype tunnelsprayer for bed-grown crops (Porskamp et al., 1997). Sprayers were equipped with flat fan nozzles, either a XR11003 or a XR11004 sprayed at 3 bar pressure. Sprayer boom height was set to 0.5m above a crop canopy of on average 0.3m. The field experiments were performed in tulips, lilies or a flower-bulb look-alike crop, cut mustard. No effect of these crop types was found on spray drift data. Also no effect was found of the used nozzle types on spray drift. A shielded sprayer boom and air assistance reduced spray drift deposition at 2-3m distance from the last nozzle with 50%. A tunnelsprayer for bed-grown crops reduced spray drift with 90%.

Effect of nozzle type and air assistance

In 1997 field tests on spray drift have been performed to quantify the effect of a “low-drift” nozzle type and air assistance (Michielsen & van de Zande, 1998). A comparison has been made with use of a Hardi Twin sprayer using air assistance, and as a conventional sprayer without air. Nozzle types compared were a standard flat fan nozzle XR11004 sprayed at 3 bar pressure applying 300 l/ha (36 repetitions) and a TT11004 sprayed at 1.5 bar pressure applying 200 l/ha (26 repetitions) at the same driving speed. Sprayer boom height was set to 0.5m above crop canopy of a potato crop 0.5m in height. Spray drift deposit on the soil surface was reduced by the use of a TT11004 by up to 60% at a distance of 2-3 m downwind. The effect of air-assistance as performed in this test (full air, nozzles kept vertical) was the same for both the standard flat fan nozzle (XR11004) as for the anvil nozzle type (TT11004), reducing spray drift in both cases with 70% on a distance of 2-3 m downwind.

In 1998 spray drift was quantified for a series of low-drift nozzle types all applying a spray volume of 300 l/ha. With identical travelling speed, sprayer boom height (0.5 m above crop canopy) and liquid pressure (3 bar) the nozzle types: standard flat fan (XR11004), drift guard (DG11004), anvil flatfan (TT11004) and two types of injection nozzles (ID12004 and XLTD11004) were evaluated in the field (Michielsen et al., 1999). All nozzles were used in a conventional way and with the use of air assistance (Hardi Twin, full capacity - nozzles kept vertical). Canopy height of the potato crop was 0,5 m. Results show that the terminology "low drift nozzle" needs further specification. From the experiments in 1998 it became clear that within the group of low drift nozzles a ranking by level of drift reduction is possible. Compared with the XR11004 nozzle, the ranking for drift reduction on 2-3 m distance from the last nozzle was: 57% for the TT11004, 76% for the DG11004, 87% for the ID12004 and 88% for the XLTD. With air assistance this ranking was: 82% for the XR11004, 89% for the DG11004, 90% for the TT11004, 96% for the ID12004 and 96% for the XLTD. The reduction of spray drift because of the use of air assistance seems to be independent of the nozzle type, at around 70%.

Effect sprayer boom height

Although not measured in the same experiments but based on the number of repetitions, it can be concluded that a decrease in sprayer boom height from 0.7m (experiments 1992-1994) to 0.5m (experiments 1997-1998) above a 0.5m crop canopy reduces spray drift with 70% on the distance 2-3m from the last nozzle when spraying a potato crop (300 l/ha). When sprayer boom height was reduced the effect of air assistance on drift reduction increased from on average 50% for the 0.7m boom height to 70% for the 0.5m boom height.

End nozzle

Overspray of plant protection products when spraying the edge of the field can be reduced by the use of an end-nozzle. An end nozzle produces a cut-off spray fan like from an off-center (OC) or UB nozzle type. Depending on the placement of the last nozzle towards the crop-edge the nozzle is placed in the last nozzle connector or 0.2m more to the outside (potatoes). An end nozzle (UB8504), in combination with a low drift nozzle (DG11004), reduced spray drift with 20% (60% with air assistance) on 2-3m distance from the last nozzle (Michielsen et al., 1999). On 1-2 m distance this effect was 50% (80% with air assistance).

Orchards

The reference situation for orchard spraying (Figure 3; top) is a cross-flow fan sprayer spraying in an orchard with leaves on the trees (LAI 1.5-2) and an average windspeed of 3 m/s. The spray-drift deposition on the soil at 4.5-5.5 m downwind of the last tree is 6.8 % of the application rate per surface area.

Compared to this reference situation a tunnel sprayer (Figure 3; middle) can achieve a reduction in spray drift on the soil surface of 85 % and a cross-flow fan sprayer with reflection shields of 55% (Huijsmans et al., 1993). Spraying trees without leaves increases spray drift 2 to 3 times compared to spraying trees with full foliage.

A wind-break on the outer-edge of the field (Figure 3; bottom) can reduce spray-drift 70-90 % on the zone 0-3 m downwind of the wind-break (Porskamp et al., 1994).

Nursery trees

In a series of experiments (1996-1997) in lane trees, a conventional sprayer equipped with flat-fan nozzles was compared with a conventional axial fan sprayer with hollow cone nozzles (Porskamp et al., 1999). The comparison (16 rep.) was made for two tree types: spindle form and transplanted alley-trees. The level of spray drift deposition next to the sprayed field did not

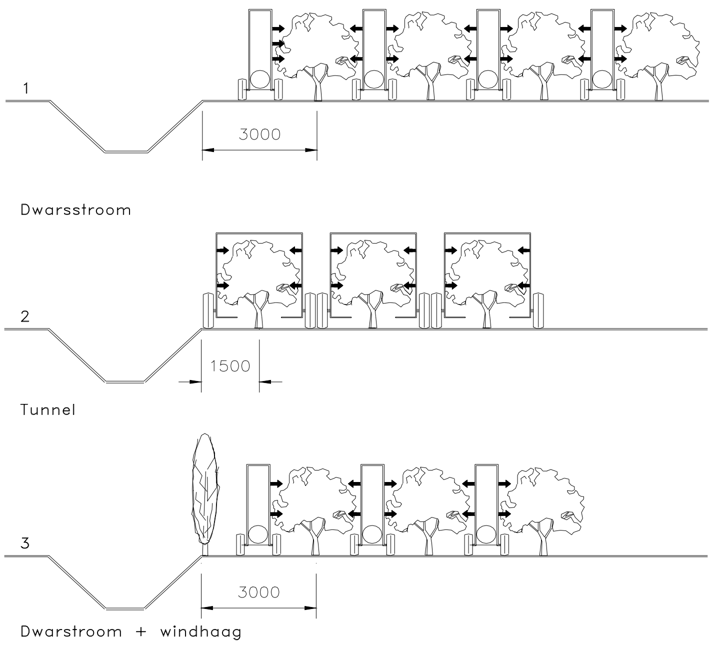

Figure 3. *Representation of used spraying systems and situations in orchard spraying.*
Top: cross-flow sprayer spraying last tree row towards the field
Middle: tunnel sprayer
Bottom: cross-flow sprayer with a hedge-row planted on the edge of the field

differ for the two nozzle types. The spray drift deposition on the soil at 3-4 m from the last tree row was, for the transplanted trees 13.6% and for the spindle trees 3.3%.

Discussion

Results from reported IMAG spray drift research are summarised by Huijsmans (1997) and 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 spraying technique and period of use during the growing season. The data used in the Pesticide Act are officially published (VROM/LNV, 1998) and summarised in Table 2.

Table 2. *Spray drift values (%) for orchard spraying used from January 1st 2000 onwards in risk assessment (Dutch Pesticide Act)*

Situation	Drift [%]		Drift reduction [%]
	Stem+branches	Leaves	
Last tree row on field edge	32.5	13	
Path (3m) between last tree row and field edge	17	7	
Drift reduction methods:			
Tunnelsprayer	2.5	1	85
Windbreak on field edge	5.1	0.7	70-90

The width of spray and crop free zones are defined for in the Water Pollution Act (WVO), which comes into force from the year 2000 onwards (VWS/VROM/LNV, 1999). In the WVO, packages of drift reducing measures are described for implementation on the outer 14m of the fields by Dutch farmers. Minimal spray- and crop free bufferzones are described depending on the spray drift reducing measures used. A minimum drift reducing package for arable farming is

the use of low drift nozzles, a sprayer boom height of 0,5m and an end-nozzle, resulting in a crop free bufferzone of 1.5m. This bufferzone can be reduced to 1.0m with the additional use of air assistance on the sprayer, a tunnel sprayer or planting a catchcrop on the field boundary. A low drift nozzle is defined as a nozzle reducing drift at least 50% in comparison with the Fine/Medium threshold reference nozzle from the BCPC nozzle classification scheme (South-combe et al., 1997). The spray drift deposition level in these cases is set to the 1% level, which is in accordance with the results from field experiments in potatoes (Michielsen et al., 1999).
A historical overview of what has been achieved in common agricultural practice over the last 5 years is presented in Table 3. Up till 1995, as quantified for the MYCPP, agricultural practice resulted (sprayer boom height 0,7m) in a spray drift of 5.4% on the surface water distance 2.125-3.125m from the last nozzle when spraying potatoes. Good agricultural practice stated that sprayer boom height was 0.5m above crop canopy. In doing so, spray drift was reduced to the 2.9% level. With the new incentive of the Water Pollution Act the use of low drift nozzles and an end nozzle is obligatory on the outer 14 m of the field. In combination with a crop free zone of 1.5m spray drift is reduced then to 0.9%. The use of a venturi nozzle instead of the minimal advised low drift nozzle reduces spray drift down to a level of 0.7%. The use of air assistance reduces spray drift in all situations with 50% (sprayer boom height 0.7m) to 70% (sprayer boom height 0.7m), independent of the nozzle type used.

Table 3. *Spray drift deposition on water surface for potato growing in the Netherlands for the situations 1995, 1998 and 2000 depending on spraying technique and crop-free buffer zone*

Situation	Crop-free buffer zone [m]	Year of tests	Nozzle type	Sprayer boom height [m]	Air-assistance	Drift deposition[%] on water surface
1995	0,75	‘92-’94	4110-18	0,70	No	5,4
1995	0,75	‘92-’94	4110-18	0,70	Yes	2,7
1998	0,75	‘97+’98	XR11004	0,50	No	2,9
1998	0,75	‘97+’98	XR11004	0,50	Yes	0,6
2000	1,50	1998	DG11004 + end	0,50	No	0,9
2000	1,00	1998	DG11004 + end	0,50	Yes	0,15
2000	1.50	1998	ID12004	0.50	No	0.7
2000	1.00	1998	ID12004	0.50	Yes	0.15

The outlined spray drift reduction measures do not meet the set goals by the MYCPP (90% reduction in spray drift) and, moreover are in many cases overruled by the ecotoxicological risk values of plant protection products to be met. Going down to levels lower than 0.2% spray drift is not exceptional. As a sanction of not meeting the set MYCPP goals restrictions on availability and use of agrochemicals are implemented.
Further research on this subject is therefor needed. This holds also for the basic reason for spraying: crop protection with ensured biological efficacy. As in many cases spray drift reducing measures are not evaluated for its biological results with pesticides.
The results demonstrate that, based on spray drift research, a differentiated pesticide and water quality policy can be outlined and performed. The right choice of spray technology can be used to minimise spray- and crop free buffer zones and maintain acceptable levels of ecotoxicological risk in the surface water. Spray technology plays a key role in the environmental risk assessment for pesticides.

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