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Abstract

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To support decision making on the authorisation of the use of agrochemical data are needed on actual spray drift, and on drift reducing measures when spraying an agrochemical in a crop. No data are available for evaluating the effect of spray drift reducing techniques and the width of the buffer zones next to the field to meet the thresholds of these chemicals for ecotoxicological risk in the off-field zone (non-target arthropods and plants). Standard drift deposition on the off-field evaluation zone is set at 10% for boom sprayed crops at 1m distance from the last crop row. The effect of spray technique on drift deposition at the off-field evaluation zone is evaluated based on data from earlier spray drift field experiments. Spray drift was investigated for standard flat fan nozzles and low drift nozzles, both used with and without air assistance, in combination with a low boom sprayer set-up, and a Släpduk spraying system when spraying a potato crop. It is evaluated what the effect of the place of the evaluation zone is as specified at a certain distance from the last crop row. The specification of the position and the width of the off-field evaluation zone differ much in spray drift deposition value for the same spray technique. This opens the discussion on what area is to be protected or what is defined by off-field.

Preface

Studies have been carried out to show the effect (and interaction) of application technique and width of buffer zone on spray drift deposition alongside a sprayed field. These studies make it possible to assess the requirement in meeting ecotoxicological values for off-field evaluation of agrochemicals that is applied to different arable crops and fruit crops.

This study was made within the framework of the Research programme Crop Health (BO-06-010/BTB08) of the Ministry of Agriculture, Nature and Food Quality in cooperation with Bayer CropScience B.V.

Wageningen, July 2007

Summary

The Dutch government's policy (Water Pollution Act, Sustainable Crop Protection) has set goals for the reduction of the emission of pesticides into the environment. Data are needed on actual spray drift and drift reducing measures when spraying an agrochemical to support decision making on the authorisation of the use of pesticides in different crop types (Board for the authorisation of pesticides, CTB).
Data were extrapolated from performed spray drift experiments, in order to assess spray drift deposits for the distance at which the off-field threshold level to protect plants and non-target arthropods is likely to be met when spraying an agrochemical onto different crop types. Based on the active ingredient specific threshold levels are to be met, but standard drift deposition on the off-field evaluation zone is 10%. This value is based on a standard conventional application with flat fan nozzles with drift deposition evaluated at 0.5-1.5m distance from the centre of the last crop row for arable crops. Drift deposit can however differ much for the different spray techniques. The effect of spray technique on drift deposition at the off-field evaluation zone is evaluated based on data from earlier spray drift field experiments. Spray drift was investigated for standard flat fan nozzles and low drift nozzles, both used with and without air assistance, in combination with a low boom sprayer set-up, and a Släpduk spraying system when spraying a potato crop. Also results are used from experiments with drift reducing techniques in orchard spraying like conventional cross-flow fan sprayers equipped with coarse nozzle types, and shielded or tunnel sprayers. Results of these drift reducing techniques are and presented for the off-field evaluation at 3m from centre of the last tree row.
It is evaluated what the effect of the place of the evaluation zone is as specified at a certain distance from the last crop row. The specification of the position and the width of the off-field evaluation zone differ much in spray drift deposition value for the same spray technique. The use of an end nozzle to prevent over spray at edge of the field contributes much to the drift reduction close to the field edge. Drift reducing spray techniques like nozzle type, air assistance, boom height, Släpduk spray systems or tunnel sprayers for bed-grown crops differ a lot in spray deposition at the off-field evaluation zone. Drift reducing techniques are therefore also relevant in reducing off-field risk for non-target arthropods and plants as in aquatic risk assessments.

From the presented results it can be concluded that depending on the dimensions of the off-field evaluation zone, the crop type, the presence of a ditch around the field, or the specification at what zone distance from the crop edge (last crop row) or position of the last nozzle the environment is to be protected, large differences do occur in spray drift deposition. As a result of this the spray drift deposition value to be compared with the threshold value of the off-field risk for non-target arthropods and plants varies a lot. This influences the discussion on what area is to be protected or what is defined by off-field.

Samenvatting

In het Nederlandse gewasbeschermingsbeleid (Lozingenbesluit open Teelt en Veehouderij, Duurzame gewasbescherming) zijn doelen gesteld voor de reductie van gewasbeschermingsmiddelen naar het milieu. Ter onderbouwing van de uitvoering van dit beleid en voor de beoordeling in de toelating van gewasbeschermingsmiddelen (CTB) zijn data nodig over de drift depositie bij standaard en driftbeperkende toedieningstechnieken zoals gebruikt in de verschillende gewassen.
Om te onderzoeken wat de drift depositie naast het perceel is bij bespuiting van verschillende gewasssen ter bescherming van niet doelwit arthropoden en planten is een inventarisatie gemaakt van eerder uitgevoerde driftmetingen. Afhankelijk van de actieve stof in het gewasbeschermingsmiddel moeten specifieke drempelwaarden voor de maximale driftdepositie naast het perceel gehaald worden. Voor akkerbouwmatig geteelde gewassen waarbij een veldspuit gebruikt wordt voor het toedienen van gewasbeschermingsmiddelen is de standaard driftdepositie in de beoordeling van middelen voor niet doelwit organismen en planten nu gesteld op 10%. Dit is gebaseerd op de hoeveelheid drift van een standaard bespuiting met spleetdoppen op de strook 0,5-1,5 m afstand vanaf het hart van de laatste gewasrij. Omdat de drift erg afhankelijk is van de gebruikte spuitapparatuur is onderzocht wat het effect van spuittechniek op de driftdepositie op de evaluatie zone voor niet doelwit organismen en planten is. Onderzochte spuittechnieken voor de akkerbouwmatige teelten zijn onder andere driftarme spuitdoppen, luchtondersteuning, spuitboomhoogte, Släpduk spuitsysteem en een tunnelspuit voor op bedden geteelde gewassen. Ook voor de fruitteelt is gekeken naar het effect van spuittechnieken, zoals de standaard dwarsstroom spuit uitgerust met standaard en driftarme venturi spuitdoppen, een dwarsstroom spuit met reflectieschermen of een tunnelspuit op de driftdepositie op de evaluatiestrook voor niet-doelwit organismen en planten. Voor de fruitteelt ligt deze strook op 3 m vanaf de laatste bomenrij.
Onderzocht is wat het effect is van de plaats van de evaluatie zone zoals nu gespecificeerd op een bepaalde afstand vanaf het hart van de laatste gewasrij. Door de zone te specificeren vanaf de laatste gewasrij varieert de driftdepositie op de evaluatie strook voor de verschillende gewassen bij dezelfde toedieningtechniek. De driftdepositie binnen de nu gespecificeerde evaluatie strook verschilt sterk. Door het gebruik van een kantdop kan de driftdepositie dicht naast de gewasrand aanzienlijk gereduceerd worden. Drift reducerende toedieningtechnieken zoals doptype, luchtondersteuning, spuitboomhoogte, Släpduk spuitsysteem of een beddenspuit voor op bedden geteelde gewassen kunnen de drift depositie op de evaluatiestrook voor niet doelwit organismen en planten aanzienlijk beperken. Drift reducerende toedieningtechnieken zijn dus in de risicobeoordeling voor niet doelwit organismen en planten net zo belangrijk als voor de bescherming van oppervlaktewater.
De resultaten laten zien dat afhankelijk van de afmetingen van de evaluatie zone voor niet doelwit organismen en planten, de positie van de evaluatie zone vanaf de laatste gewasrij of vanaf de laatste spuitdop, het soort gewas, de aanwezigheid van een sloot rond het perceel, en de mogelijke toedieningtechnieken er grote verschillen in driftdepositie zijn. Hierdoor is de beoordeling over de bescherming van de niet doelwit organismen en planten op grond van de gestelde drempelwaarden voor en de driftdepositie afhankelijk van de gemaakte keuzes. Dit is van invloed voor de discussie over wat precies gedefinieerd wordt als te beschermen gebied voor niet doelwit organismen en planten.

1. Introduction

The Dutch government's policy (Water Pollution Act, VW/VROM/LNV, 2000; Sustainable Crop Protection, LNV, 2004) has set goals for the reduction of the emission of pesticides into the environment. To support decision making on the authorisation of the use of agrochemical (Board for the authorisation of pesticides, CTB) data are needed on actual spray drift, and on drift reducing measures when spraying an agrochemical in a crop. Therefore, spray drift deposits of agrochemicals, authorised to be used in different crops, need to be assessed. Plant protection products are typically applied to the whole field with a field sprayer, during the growing season, when the crop is at full growth. No data are available for evaluating the effect of spray drift reducing techniques and the width of the buffer zones next to the field to meet the thresholds of these chemicals for ecotoxicological risk in the off-field zone (non-target arthropods and plants).
At this moment the drift deposition at 1 m distance from the centre of the last crop row is used to estimate the exposure to terrestrial ecosystems (non-target arthropods, non-target plants) next to a sprayed plot (LNV, 2006). In the authorization procedure a standard drift deposition of 10% is used as exposure value in the off-crop evaluation (CTB, 2006). This is based on the amount of the deposition of spray drift at 1 meter (0.5-1.5 m) from the last crop row/last nozzle when crop protection products are applied with a standard conventional spray technique (derived from Zande *et al.*, 2000).
Nowadays drift reducing spray techniques are used at the border of a field and calculations for the aquatic environment are based on the use of these techniques. Bayer CropScience B.V. inquired on the amount of drift deposition on the off-field evaluation zone next to the field when using drift reducing techniques (drift reducing nozzles and air assistance) in line with the spray drift reduction calculations for the aquatic environment. A discussion was started on the level of drift deposition at this off-field evaluation zone, the amount of drift deposition and its distribution within the zone, and the ability to reduce spray drift deposition on the zone with different drift reducing techniques. Furthermore the width and the place of the evaluation zone relative to the field edge is discussed, depending on the situation whether a natural area, a narrow uncropped area between fields or a ditch with banks on both sides are situated next to the field. Moreover the question rose what is the defined protected area. For clarity reasons in this study the distance at 1 m from the last crop row is interpreted as a zone of 1m wide at 0.5-1.5 m from the centre of the last crop row. The effect of other positions of evaluation zones depending on e.g. crop type and position of the last nozzle relative to the last crop row are evaluated, as well as the width of the evaluation zone (or protection from a point onward).

Calculations are performed to estimate the drift deposition on a band of 0.5-1.5m next to the plot for the different drift reducing techniques. To get an idea of the variation in drift deposition over this band, additional calculations are included to differentiate over sub-strips of 25 cm within this zone and in this way to view the best zone to evaluate critical loads. To limit the risk for non-target arthropods and plants, the drift deposition directly adjacent to the crop should be as low as possible. The drift deposition directly adjacent to the sprayed crop can be lowered by 'not spraying over the edge of the crop'. This can be done by using an end nozzle. The drift deposition figures can be presented using an additional estimation of the drift reducing effect of the end nozzle. Data are taken from field experiments performed by IMAG[1] in the Netherlands, sprayed with standard and low drift nozzles (150, 200 and 300 l/ha) and with the additional use of air assistance on the field sprayer, with a reduced sprayer boom height, a Släpduk spraying system and with a tunnel sprayer for bed-grown crops.

This report is merely a quantitative background to feed the discussion on how to assess off-field evaluation in The Netherlands based on:

- level of spray drift deposition on the evaluation zone
- effect of spray drift reducing technologies on level of spray drift deposition at the off-field evaluation zone
- different field situations, what is the area to be protected
- different evaluation methodologies, drift deposition calculation on a zone or from a point onward.

1 The spray research of the former IMAG is since 1-1-2006 embedded in Plant Research International B.V., within the research group Field Technology Innovations.

2. Materials and methods

In order to quantify spray drift deposits on an off-field zone when spraying agrochemicals data are taken from spray drift experiments. In these experiments a boom sprayer equipped with standard flat fan nozzles and low drift nozzles, both with and without air assistance, was used.

2.1 Field measurements

Spray drift measurements were made when spraying the downwind 18 m edge of a potato field. Drift deposits were quantified with a fluorescent tracer (Brilliant Sulfo Flavine, BSF) within the spray solution. Collectors placed on soil surface – up to 15m downwind from the last nozzle of the field sprayer – sampled fallout from the passing drift cloud.

Measurements were carried out under the 'worst case' wind direction. Hence, deviation of the wind was no more than 30 degrees from square to the driving direction that was parallel to the waterway. Spray drift experiments were in accordance with the ISO-standard for spray drift measurements (ISO22866), adapted for the typical Dutch situation, and the protocol for the certification of low-drift spray techniques according to the Water Pollution Act in the Netherlands (CIW, 2003). At least 10 replicate measurements (double sampling rows) in time and place were carried out to thereby represent the average situation for spraying a potato crop during the growing season. Spray drift deposits recovered from the collectors were averaged at the different distances and were curve-fitted for the different spray technologies.

Standard and potential drift reducing spray techniques examined and expected to be relevant for the estimation of the exposure of the terrestrial ecosystem on 1 m distance of the sprayed crop are listed in Table 1. Techniques can be used as a conventional sprayer, a sprayer with a low-boom option and with or without air assistance.

Table 1. Spray nozzles used and their specifications as used in the potato drift experiments spraying at 3 bar pressure (conventional and low boom techniques are used with and without air assistance).

Sprayer type	Nozzle type		Spray volume [l/ha]	Nozzle drift reduction class
conventional	Standard flat fan	XR11004	300	0
conventional	Pre-orifice flat fan	DG11004	300	50
conventional	Venturi flat fan	ID12002	150	75
conventional	Venturi flat fan	XLTD04-110	300	90
Low boom	Pre-orifice flat fan	DG80015	200	50
Low boom	Venturi flat fan	ID90015	200	50
Släpduk	Standard flat fan	XR110015	200	0
Släpduk	Venturi flat fan	AI110015	200	50

'Low drift' nozzles and air assistance in potatoes

Drift data are available for standard flat-fan or low-drift nozzles from field research spraying potatoes (Michielsen *et al.*, 2001). In these experiments the sprayer was equipped with nozzles representative for the spray drift reduction classes 0, 50, 75 and 90 to establish the reference fallout values against which other application techniques can be judged (Porskamp *et al.*, 1999). Spray quality definitions follow the BCPC scheme (Southcombe *et al.*, 1997). All nozzle types (Table 1) were used at a spray pressure of 3 bar to thereby apply 150 l/ha or 300 l/ha at a sprayer speed of 6 km/h. Boom height was 0.5m above a potato crop, which, itself, had a 0.5m tall canopy. Average wind speed during the experiments was 4.0 m/s at a height of 2m above bare soil surface; mean wind direction was 15° from perpendicular to the driving direction. For this study the drift data of the nozzles with a drift reduction of 50, 75 and 90 is taken into account with and without air assistance. The measured drift reduction when fitting an end-nozzle in the last nozzle body to prevent overspray at the crop edge (obligatory following the Water Pollution Act) is incorporated in the calculated spray drift deposition for the low drift nozzles.

Low boom height

Drift data are available from experiments comparing a reduced sprayer boom height in combination with two types of drift-reducing nozzles and air assistance with a standard sprayer using a reference nozzle (XR11004) (Stallinga *et al.*, 2004). In these experiments a sprayer was used capable of reducing boom height to 0.30m above crop canopy. Nozzle spacing on the sprayer boom was 0.25m. In the last nozzle body an end nozzle (IS8002) was fitted. Drift experiments were performed spraying a potato crop. Average wind speed during the experiments was 2.6 m/s at a height of 2m; mean wind direction was 11° from perpendicular to the driving direction.

Släpduk

Drift data are available from Släpduk spraying system experiments (Zande *et al.*, 2005). The Släpduk system used a shield to float over crop canopy that maintains nozzle height over crop canopy. Average nozzle height was therefore around 0.20 m. Nozzle spacing on the sprayer boom was 0.33m. Drift experiments were performed comparing the Släpduk spraying system with a standard spray application using a reference nozzle (XR11004) spraying a potato crop. Average wind speed during the experiments was 3.4 m/s at a height of 2m; mean wind direction was 13° from perpendicular to the driving direction.

Tunnel sprayer for bed-grown crops

Spray drift data of a tunnel-sprayer developed for bed-grown crops, and in use in flower-bulb crops, were taken from Porskamp *et al.* (1997). This spray technique is equipped with standard flat fan nozzles (XR11004+UB8504); shielding around the spray process reduces spray drift.

The above mentioned drift reducing spray techniques are certified in different drift reducing classes (DDK 0, 1, 2 and 3) and are used for intensively sprayed crops in the Water Pollution Act (CIW, 2003) and are agreed to be used (TCT, 2006) in the Netherlands.

2.2 Drift deposition

Drift deposition decreases with the distance to the sprayed plot (Figure 1). From the spray drift measurements in the field the data of the conventional spraying using an XR11004 nozzle was used as a basic curve for the drift deposition. The data of the years 1995-1999 were combined and a reference spray drift curve was presented for the situation boom sprayer with boom height at 0.50 m above crop canopy equipped with standard flat fan nozzles (XR11004, drift reduction class 0). Based on the comparative drift measurements in the field, spray drift reduction curves were determined for the different drift reducing spray techniques like nozzle type, air assistance, low boom height, and special types of equipment. The spray drift reduction curves were used to calculate the spray drift deposition for these drift reducing spray techniques by calculating the fractions at various distances (zones) from the last nozzle. Typical differences in height of absolute values of spray drift deposition occurring because of field situations or weather conditions could therefore be eliminated and drift reduction capabilities of the drift reducing spray techniques could be compared on an equal basis. These calculated spray drift depositions of the drift reducing techniques were again curve fitted representing the normalized spray drift curve for the drift reducing spray technique.

To present the measured spray drift deposition on different distances from the last nozzle or the last crop row the measured quantities were curve fitted and spray drift deposition was determined as the area under the drift curve (Figure 1) for the specific zone between the zones begin point and end point.

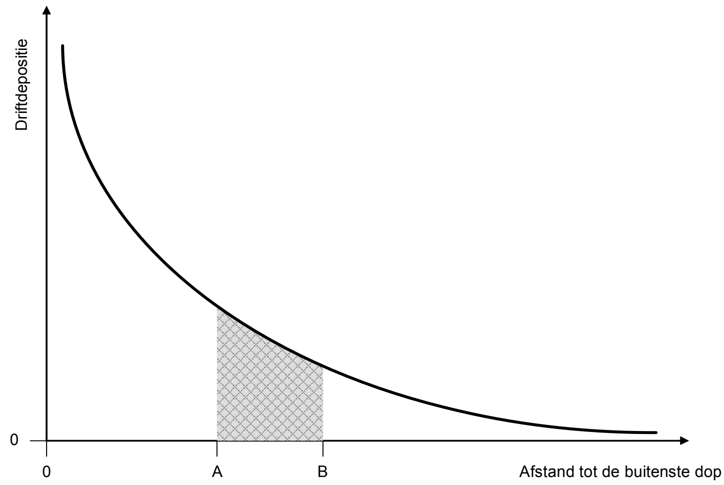

Figure 1. *Determination of the spray drift deposition at a specific evaluation zone on distance (A-B) of the last spray nozzle.*

Spray drift curves were determined for the spray techniques:

- conventional spraying using spray nozzles of the drift reduction classes 0 (standard), 50, 75 and 90
- air-assisted spraying using spray nozzles of the drift reduction classes 0 (standard), 50, 75 and 90
- spraying using the Släpduk system (two nozzle types)
- spraying with reduced sprayer boom height (two nozzle types)
- spraying with reduced sprayer boom height in combination with air assistance (two nozzle types).

From the spray drift curves of the above mentioned spray techniques the spray drift deposition at the off-crop evaluation zone of 0.50-1.50 m from the last crop row was calculated. At first instance it is assumed that the last nozzle is placed right above the last crop row, and therefore the off-crop evaluation zone is at 0.50-1.50 m from the last nozzle. To show the relevance of the width of the off-crop evaluation zone it is also calculated what the spray drift deposition is when the evaluation zone is not 1.0 m wide at 1.0 m distance from the last crop row/nozzle (zone 0.5-1.5m) but also for a zone width of 0.2 m (0.90-1.10 m) and 0.1m (0.95-1.05 m), being almost a point value at 1.0 m distance. Also it is shown how the decline of the spray drift curve with increasing distance from the last row affects the height of the spray drift deposition in zones of 0.25 m within the 1.0 m evaluation zone.

The position of the last nozzle will not always be precisely above the middle of the last crop row. The position of the last nozzle relative to the position of the last crop row is specified by the nozzle spacing and the crop row width. Typically for 1.50 m bed grown crops like flower bulbs and onions the last nozzle is right above the outside of the bed (the last crop row). For crops like potatoes, maize and cabbages which are grown with a 0.75m row spacing the last nozzle is placed 12.5 cm outside of the last crop row. For a large group of crops with row spacings of 12.5 cm like cereals, 25 cm row spacing like lettuce and carrots, 50 cm spacing like sugar beet the last nozzle is positioned 25 cm inside of the last crop row (Table 2). For all of these groups of crops other than flower bulbs it means that the off-crop evaluation zone should be shifted to the nozzle position relative to the last crop row, resulting in different spray drift deposition values for the different spray techniques. Figure 2 shows a typical situation when spraying a potato crop (Huijsmans *et al.*, 1997)

Table 2. Examples of crops divided in groups for position of the off-crop evaluation zone based on crop row distance, crop height, and position of the last nozzle compared to the last crop row (after CIW, 2003).

Crop row distance [cm]	Crop height [cm]	Crop examples	Position last nozzle compared to last crop row (cm)*)	Position off-field evaluation zone to last nozzle (cm)
0	0	Fallow fields	+ 50	100-200
0	5	Grass	+ 50	100-200
12.5	5	Spinach	+ 25	75-175
12.5	25	Conserve peas	+ 25	75-175
12.5	50	Luzern, green fertilizer crops, oil seed rape, poppy seed, caraway	+ 25	75-175
		Grass seed, winter-wheat, spring barley, rye, oat, triticale, flax	+ 25	75-175
25	25	Lettuce,	+ 25	75-175
		Beets, endive	+ 25	75-175
25	50	Ornamentals, horticulture seeds	+ 25	75-175
37.5	25	Kidney bean, marrowfat	+ 25	75-175
50	25	Carrots (light soils)	+ 25	75-175
		Witloofroots, celeriac	+ 25	75-175
50	50	Salsify,	+ 25	75-175
		Sugar-beet, cabbage, broad bean	+ 25	75-175
75	25	Strawberry	- 12.5	37.5-137.5
		Maize, chicory	- 12.5	37.5-137.5
75	50	Potatoes, leek, winter-carrots and bulb-flowers (both ridge cultures)	- 12.5	37.5-137.5
		Rosebushes, small conifers, other ornamental bushes and climbing plants	-12.5	37.5-137.5
		Bush and hedge public gardens, perennials	- 12.5	37.5-137.5
		Cauliflower, broccoli	- 12.5	37.5-137.5
75	100	Conifers	- 12.5	37.5-137.5
		Brussels sprouts, kale	- 12.5	37.5-137.5
150	25	Bed culture of lettuce, carrots	25	75-175
		Bed culture of endive	25	75-175
150	50	Bed culture of onions, bulb-flowers	0	50-150

**) + is inside and – is outside of the last row*

The effect of nozzle position was quantified and shown as drift deposits for typical spraying of the different crops (Figure 1). Spray drift deposits were subsequently adapted for the distance to the off-field zone of 1 m (0.5-1.5 m) adjacent to the sprayed field and presented.

To meet specified threshold-values for agrochemicals to be evaluated an example is given how defined distances to the off-field critical edge point were predicted from the curve-fitted curves for the spray drift deposition values of 5%, 2.5% and 1.0%, being 50%, 75% and 90% lower in spray drift deposition at the off-crop evaluation zone. These distances are expressed as off-field buffer zone distance relative to the last crop row.

In case a ditch is around a field the Water Pollution Act specifies a minimal crop-free buffer zone to protect the aquatic environment. In this case the off-field evaluation zone is now specified at a minimal distance away from the centre of the last crop row as stated by the required crop-free buffer zone. As these crop-free buffer zones are crop specific and the last nozzle position varies with crop row spacing this influences the spray drift deposition on the off-field evaluation zone. Spray drift deposition for standard and drift reducing techniques are given for these situations.

3. Results

3.1 Drift deposition at 1 meter distance

The drift deposition at 1 m distance can be used to estimate the exposure of terrestrial ecosystems next to the plot. The Board for the Authorization of Pesticides (CTB) uses 10 % drift deposition at this moment. This is now based on the drift deposition on the zone 0,5-1,5 m from the last nozzle for the situation conventional field sprayer; equipped with standard flat fan nozzles (XR11004, spray drift reduction class 0) operating at a spray boom height of 0.50 m above crop canopy.

Spray drift deposits on the off-field evaluation zone for terrestrial plants and non-target arthropods at 0.50-1.50 m from the crop edge (for flower bulbs distance from the last nozzle) have been determined by using the available results of the spray drift field experiments for the conventional field-crop boom sprayer equipped with standard flat fan nozzles (XR11004) and three types of drift reducing nozzle types (drift reduction classes 50, 75, and 90) (Table 3). Spray drift deposition is presented for conventional spraying and for air-assisted spraying.

Table 3. Spray drift deposits (as % of dose applied to treated area) on the off-field evaluation zone for plants and non-target arthropods (0.5-1.5 m from the crop edge / last nozzle) when spraying flower bulbs y conventional or air-assisted methods.

Sprayer type	Nozzle type	Nozzle spray drift reduction class	Spray drift (% dose)	
			conventional	full air
conventional	XR11004	0	9.9	7.9
conventional	DG11004	50	7.1	5.7
conventional	ID12002	75	7.1	6.9
conventional	XLTD04-110	90	9.7	9.4

Large differences in spray drift deposits can occur on the off-field evaluation zone for plants and non-target arthropods. The differences in spray drift deposits show that spray techniques are of a major importance in reducing spray drift deposition and reducing the risk of agrochemical to the terrestrial environment close to the crop edge.

It is clear that the drift reducing effect of the drift reducing nozzle types and the drift reducing nozzles in combination with air assistance on the 0.5-1.5 meter zone is limited compared to the standard nozzle (XR11004, no air assistance, 9,9 % spray drift deposition). This can be explained by the fact that part of the spray drift is produced by spraying over the crop edge directly onto the now used evaluation zone.

3.2 Distribution of spray drift deposit within the evaluation zone

When the presented spray drift deposition figures (Table 3) are differentiated into smaller areas over the now used evaluation zone of 1 m, e.g. in parts of 25 cm, it becomes clear that there are big differences in drift deposition over the evaluation area, depending on the technique (Table 4). The differences originate from the different shapes of the drift curves, the steepness close to the crop-edge, as in the field a full dose (100%) is applied.

Table 4. Spray drift deposition differentiated to four parts within the off-crop evaluation zone of 0.5-1.5 m from the last crop row/last nozzle.

Drift reduction class	Nozzle type	Air assistance	Subdivision of the off-crop evaluation zone 0.5-1.5 m			
			0.5-0.75	0.75-1.0	1.0-1.25	1.25-1.50
0	XR11004	No	10.5	10.3	10.0	8.6
0	XR11004	full	10.4	8.7	7.3	5.4
50	DG11004	No	9.3	7.8	6.5	4.8
50	DG11004	full	6.6	6.1	5.7	4.3
75	ID12002	No	9.2	7.9	6.7	4.5
75	ID12002	full	9.8	7.7	6.0	3.9
90	XLTD04	No	12.9	10.7	8.9	6.3
90	XLTD04	full	13.7	10.5	8.1	5.2

In Table 5 the total spray drift deposition on the off-crop evaluation zone is set to 100% and the spray deposition at the parts of the zone are presented as relative percentage of spray drift deposition compared to the average spray drift deposit on the zone 0.5-1.5m with a length of 1 m (Table 5). The relative distribution of spray drift deposition over the off-crop evaluation zone of 1 meter length (%) differs between 146% close to the crop (0.5-0.75) and 55% further away from the crop (1,25-1,50 m).

Table 5. Relative distribution of spray drift deposition as percentages of the total drift deposition (%) over the off-crop evaluation zone at 0.50-1.50m.

Drift reduction class	Nozzle type	Air assistance	Subdivision of the off-crop evaluation zone 0.5-1.5 m			
			0.5-0.75	0.75-1.0	1.0-1.25	1.25-1.50
0	XR11004	No	107	104	102	88
0	XR11004	full	131	109	92	68
50	DG11004	No	131	110	92	67
50	DG11004	full	115	108	100	76
75	ID12002	No	130	111	95	63
75	ID12002	full	143	112	88	57
90	XLTD04	No	133	111	92	65
90	XLTD04	full	146	112	87	55

It can be discussed that when you want to protect the off-crop environment at a certain threshold level you should accept that within the evaluation zone differences of this magnitude (55%-145% of threshold value) are acceptable or that it is better to specify the threshold value on a more point like way.

3.3 Effect width of evaluation zone in off-crop evaluation

At this moment the drift deposition at 1 meter distance from the last row/last nozzle is used to estimate the exposure of the terrestrial ecosystem next to the treated field. Standard the Board for the Authorization of Pesticides (CTB) uses 10% drift deposition. This is based on the drift deposition at 0.5-1.5 m from the last nozzle for the situation field sprayer with standard nozzle XR11004.

For the amount of spray drift deposition for a conventional boom sprayer equipped with standard flat fan nozzles (XR11004) and drift reducing techniques (nozzle types of drift reduction classes 50, 75 and 90 used conventional and in combination with air assistance) an evaluation is made on effect of the evaluation zone width when evaluating the 'spray drift deposition at 1m from the crop last row' (Table 6). A distinction is made in evaluating spray drift deposition on a zone width of 1 meter (0.5-1.5 m), of 20 cm (0.90-1.10m) and of 10 cm (0.95-1.05 m), all at 1 m distance from the last crop row at the centre.

Table 6. Spray drift deposition onto the off-crop evaluation zone at 1 m from the last crop row evaluated at an evaluation zone width of 1 m (0.5-1.5 m), of 20 cm (0.90-1.10m) and of 10 cm (0.95-1.05 m).

Drift reduction class	Nozzle type	AIR assistance	Drift deposition [%] at		
			0.5-1.5 m	0.9-1.1 m	0.95-1.05 m
0	XR11004	No	9.9	10.2	10.2
0	XR11004	Full air	7.9	7.9	7.9
50	DG11004	No	7.1	7.1	7.1
50	DG11004	Full air	5.7	5.9	5.9
75	ID12002	No	7.1	7.3	7.3
75	ID12002	Full air	6.9	6.8	6.8
90	XLTD04	No	9.7	9.8	9.8
90	XLTD04	Full air	9.4	9.2	9.2

Depending on the spray technique the drift deposition on the evaluation zone widths of 10 and 20 cm is (a little) higher or lower than the drift deposition on the evaluation zone of 1 m. This is due to the shape of the drift curve, the steepness. In general it seems that with the techniques in combination with air assistance the drift deposition on the 10 and 20 cm zone widths equals or is higher than the drift deposition on the 1 meter zone width. Using conventional spray techniques, the spray drift deposition on the 1 meter zone width seems to be lower than the drift deposition on the 10 and 20 cm wide evaluation zones. Although differences between the evaluation zone widths at the 1 m point are relatively small (less than 5%) the protection level of 10% at 1m distance is not met for the standard situation (XR11004) when evaluating off-field risk for terrestrial plants and arthropods as a cut-off point at 1m, as shown by the 20cm and 10cm zone width deposition (10.2%). On average, a zone of 1m wide at 1m distance from the last crop row meets the specified threshold value of 10% (actually calculated as 9.9%) for the standard spray technique (XR11004) very well, showing that the mid point is around 10% (10.2%). One has to take into account however that the evaluation zone as a whole does not have the same protection level as is shown also in Table 5.

3.4 Effect of end nozzle

The drift reducing effect of the drift reducing spray techniques on the off-crop evaluation zone is limited. This is due to the position of the evaluation zone close to the target area and spraying over the edge of the crop, whereas in the field on the crop a full dose (100%) is applied. Using an end nozzle, which cuts off the width of the spray fan at the outside of the field, the drift deposition on the evaluation zone at 0.5-1.5m from the last nozzle of the crop row can be reduced significantly. Comparable measurements (Michielsen *et al.*, 2001) of a 50% drift reducing nozzle with and without an end nozzle (UB8504) limited the drift deposition on the zone 0.5-1.5m with ca. 30%. In combination with air assistance the drift reduction due to using the end nozzle was even higher, ca. 60% (Table 7).

Table 7. Effect of end nozzle (UB8504) combined with drift reducing nozzles (DG11004; drift reduction class 50) and air assistance on the drift deposition next to the edge of the crop at 0.5-1.5m from the last nozzle.

Potatoes field sprayer		Air assistance	Drift deposition [%] at 0.5-1.5 m
drift reduction class	nozzle type		
50	DG11004	No	7.1
50	DG11004	Full air	5.7
50	DG11004+UB8504	No	4.8
50	DG11004+UB8504	Full air	2.0

Taking into account the measured effects of the end nozzle (UB8504) and a drift reducing end nozzle (off-centre venturi flat fan IS8004) the reductions by using the end nozzle on the zone directly next to the crop are determined (Figure 2) for the situations conventional spraying and air-assisted spraying.

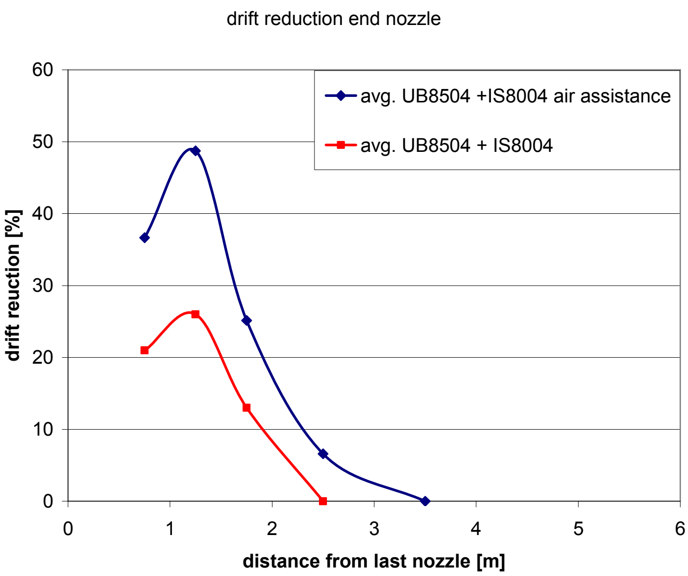

Figure 2. Drift reduction by using an end nozzle (average of UB8504 and IS8004) and an end nozzle in combination with air assistance on a boom sprayer.

This (Figure 2) shows the relevance of using an end nozzle to protect off-field plant and non-target arthropods in the areas close to the crop edge. An end nozzle decreases the drift in the band up to 2 meter distance of the last nozzle. In combination with air assistance the decrease is relevant up to 3 m from the last nozzle. With these reductions new drift deposition values can be calculated on variable zones within the evaluation zones. By using curve-fitting the drift deposition values have been determined (Table 8) for drift reducing techniques (nozzle types and air assistance) in combination with an end nozzle in the last nozzle position on the zones 0.5-1.5m, 0.9-1.1m and 0.95-1.05m from the last nozzle (last crop row).

Table 8. Calculated drift deposition on different widths of off-field evaluation zones next to the crop for nozzle types from the drift reduction classes 50, 75 and 90 in combination with an end nozzle used on a conventional or on an air-assisted boom sprayer.

Drift reduction class	Nozzle type	Air assistance	Drift deposition [%]		
			0.5-1.5 m	0.9-1.1 m	0.95-1.05 m
50	DG11004+kd	No	5.5	5.4	5.4
50	DG11004+kd	Full air	3.3	3.3	3.3
75	ID12002+kd	No	5.5	5.6	5.6
75	ID12002+kd	Full air	4.1	3.8	3.8
90	XLTD04+kd	No	7.5	7.5	7.5
90	XLTD04+kd	Full air	5.6	5.2	5.2

The drift deposition can be decreased in a significant way by using an end nozzle (compare Table 3 and 8). Differences between the widths of the off-field evaluation zones is limited, except for the nozzle type of the drift reduction class 90 in combination with air assistance where the difference between the 1m evaluation zone width and the 20cm and 10 cm zone width is 7% difference.

3.5 Ecotoxicological threshold values and buffer zone width

Required buffer zones are calculated for the conventional application method and drift reducing nozzles and techniques (air assistance, low boom height and Släpduk), for defined reductions in spray drift deposition of 50%, 75%, and 90% compared to the used 10% spray drift deposition in the authorization procedure on the now used off-field evaluation zone at 0.5-1.5 m from the last crop row/last nozzle. The specified ecotoxicological threshold values for these reduction levels are 5.0%, 2.5%, and 1.0% spray drift deposition on the non-target now used evaluation zone. These threshold levels can be met for the different drift reducing spray techniques and with additional widths of buffer zones. (, and can be compared to those specified by the Water Pollution Act.) A buffer zone is in this case defined as the distance between the last crop row and the starting point of a 1m length zone which meets the specified threshold value. Using this terminology the width of the buffer zone in the evaluation procedure at this moment used in the authorization procedure is at 0.50m (off-field evaluation point on 1m with a 1m wide evaluation zone at 0.5-1.5m). For the conventional boom sprayer applications results are presented in Table 9, and in Table 10 for air-assisted boom sprayer applications.

Table 9. Distance from last crop row [m] needed to meet the specific threshold value of 5.0%, 2.5%, and 1.0% spray drift on the off-field evaluation zone (1.0 m wide) for plants and non-target arthropods as a consequence of conventional spraying.

Sprayer type	Nozzle type	Nozzle spray drift reduction class	Distance from centre of last crop row [m] at ecotoxicological threshold level		
			5.0%	2.5%	1.0%
Conventional	XR11004	0	1.45	2.35	4.00
Conventional	DG11004+ end nozzle	50	0.60	1.20	1.80
Conventional	ID12002+ end nozzle	75	0.60	1.05	1.45
Conventional	XLTD04-110+ end nozzle	90	0.85	1.25	1.65
Low boom	DG80015+ end nozzle	50	0.35	0.60	1.05
Low boom	ID90015+ end nozzle	50	0.45	0.65	0.90
Släpduk	XR110015	0	0.40	0.65	1.00
Släpduk	AI110015	50	0.35	0.50	0.75
Tunnel	XR11004 + UB8504	0	<0.25	<0.25	<0.25

For the conventional application technique using standard flat fan nozzles (XR11004) the distance from the centre of the last crop row to meet the specific threshold values increases from 0.5 m for the standard evaluation value (10%) to 1.45m for the 5.0% level, 2.35m for the 2.5% level and 4.0m for the 1.0% level. For the minimal nozzle requirement (drift reduction class 50 and an end-nozzle), which use is based on the Water Pollution Act obligatory on the outside 14 m of the field, the minimal distance to the centre of last crop row, should be at least 0.60m wide for the 5.0% threshold value (10cm wider than for the standard evaluation situation but with 50% less spray drift deposition), 1.2m for the 2.5% threshold level and 1.8m for the 1.0% threshold value. The low boom sprayer equipped with the DG80015 pre-orifice nozzle type and the ID90015 venturi nozzle type meets the 5.0% threshold value within 0.5m, the standard evaluation distance but with 50% reduction in spray drift deposition. The Släpduk sprayer equipped with either nozzle types of the drift reduction classes 0 and 50 can meet the off-field threshold values of 5.0% within the 0.50m. The Släpduk sprayer equipped with a nozzle of the drift reduction class 50 can meet the 2.5% threshold value also at a buffer zone distance of 0.5m, reducing spray drift deposition with 75% at the standard off-field evaluation zone. The tunnel sprayer for bed-grown crops can meet all three threshold levels within a distance of 0.25m from the last nozzle.

Required distance from the centre of the last crop row to meet the specific threshold values are also calculated for the air-assisted application method and drift reducing nozzles and techniques (low boom height) on the now used off-field evaluation zone for plants and non-target arthropods (Table 10).

Table 10. Distance from the centre of the last crop row [m] needed to meet the specific threshold value of 5.0%, 2.5%, and 1,0% spray drift on the off-field evaluation zone (1.0 m wide) for plants and non-target arthropods as a consequence of air-assisted spraying.

Sprayer type	Nozzle type	Nozzle spray drift reduction class	Distance from the centre of the last crop row [m] at ecotoxicological threshold level		
			5.0%	2.5%	1.0%
Conventional	XR11004	0	0.95	1.40	1.85
Conventional	DG11004+ end nozzle	50	<0.20	0.85	1.45
Conventional	ID12002+ end nozzle	75	0.35	0.80	1.30
Conventional	XLTD04-110+ end nozzle	90	0.60	0.95	1.35
Low boom	DG80015+ end nozzle	50	<0.20	0.40	0.75
Low boom	ID90015+ end nozzle	50	<0.20	0.25	0.55

For the air-assisted application technique using standard flat fan nozzles (XR11004) the distance to the centre of the last crop row increases from 0.5 m for the standard evaluation value (10%) to 0.95m for the 5.0% level, 1.40m for the 2.5% level and 1.85m for the 1.0% level. Air-assisted spraying in combination with nozzle types of the drift reduction class 50, 75 and 90 need distances to the last crop row of respectively 0.5m to meet the threshold value of 5.0%, reducing spray drift deposition with 50% and more on the standard off-field evaluation zone. The low boom spraying in combination with nozzle types of the drift reduction class 50 can meet the specified threshold levels of 5.0% and 2.5% spray drift deposition for the off-field evaluation at distances from the centre of the last crop row /last nozzle less than 0.50m, reducing spray drift deposition therefore with more than 75% on the standard off-field evaluation zone.

3.6 Crop type and spray technique differentiation in off-field evaluation

For the evaluation of critical ecotoxicological threshold values at the off-field evaluation zone a differentiation can be made in a crop situation alongside waterways and in the open field. In the open field the off-field evaluation zone is now defined as the zone at 0.5-1.5m from the last crop row. When a waterway is next to the field, based on the Water Pollution Act, obligatory crop-free buffer zones have to be taken into account to prevent spray drift entering surface water (Figure 2). The width of these crop-free buffer zones is defined based on crop type and the intensity and number of spray applications (CIW, 2003).

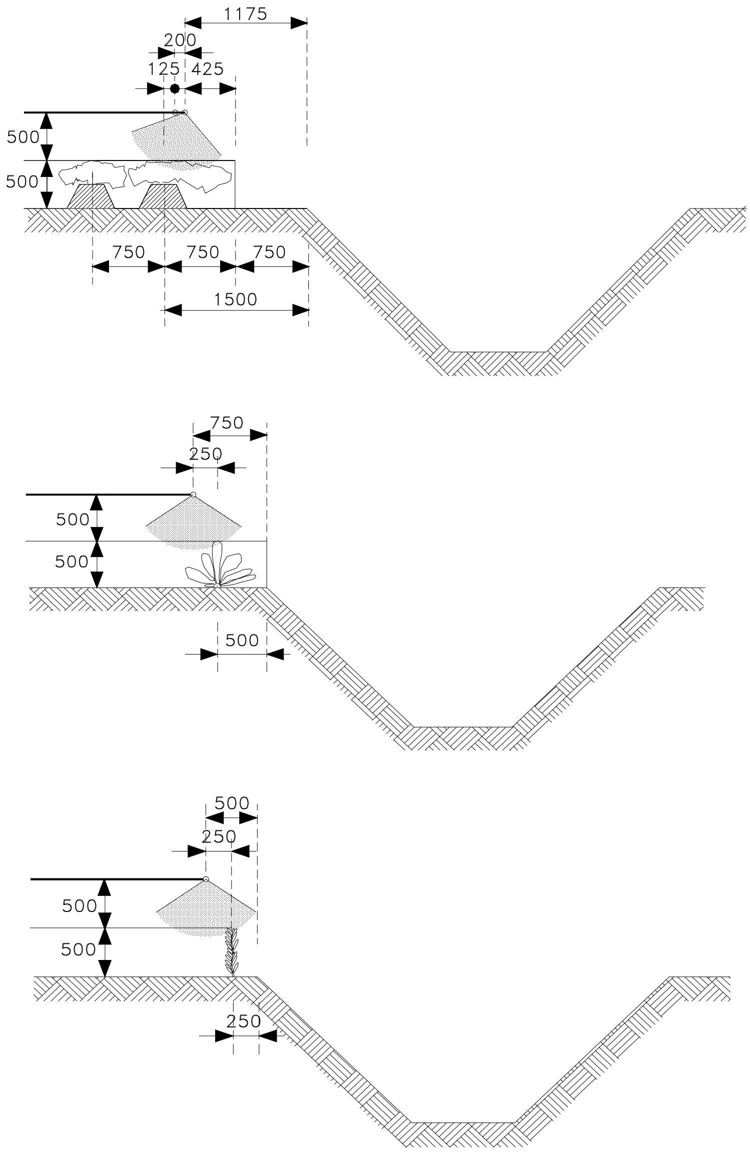

Figure 2. *Schematic presentation of the situation spraying a potato crop (top); crop free buffer zone 1.5 m, last nozzle position 0.125 m outside the last crop row, nozzle distance to crop edge 0.625 m, to edge of ditch 1.375 m. A sugar beet crop (middle); crop free buffer zone 0.5m, last nozzle position 0.25 m inside the last crop row, nozzle distance to crop edge 0.75 m, to edge of ditch 0.75 m and a cereal crop (bottom): crop free buffer zone 0.25 m, position of the last nozzle position 0.25 m inside the last crop row, nozzle distance to crop edge 0.5 m, to edge of ditch 0.5 m. Boom height is 0.5 m above a crop, which is 0.5 m tall. (Adapted from Huijsmans et al., 1997).*

Crops with high spray intensity, like potatoes, onions and flower bulbs, have a wider crop-free buffer zone than cereals and sugar beet (Table 11). When a crop-free buffer zone is in force the protected area for off-field evaluation is on a distance further away from the last crop row as specified by the width of the crop-free buffer zone and spray drift deposition is to be calculated for this area further away. The adapted position of the off-field evaluation zones based on this crop-free buffer zone criteria are presented in Table 11.

Table 11. Crops grouped by similar width of the crop-free buffer zone and its position of the off-field evaluation zone to the last nozzle in the standard evaluation situation and in the situation with wide crop-free buffer zones based on the Water Pollution Act (adapted from CIW, 2003).

Crop examples	Position last nozzle compared to last crop row (cm)	Crop free buffer zone [cm]	Position off-crop evaluation zone to last nozzle (cm)	Position off-crop evaluation zone to last nozzle based on crop-free buffer zone (cm)
Fallow fields	+ 50	50	100-200	*
Grass	+ 50	25	100-200	*
Spinach	+ 25	50	75-175	*
Conserve peas	+ 25	50	75-175	*
Luzern, green fertilizer crops, oil seed rape, poppy seed,	+ 25	50	75-175	*
caraway	+ 25	25	75-175	*
Grass seed, winter-wheat, spring barley, rye, oat, triticale, flax				
Lettuce,	+ 25	150	75-175	150-250
beets, endive	+ 25	50	75-175	*
ornamentals, horticulture seeds	+ 25	50	75-175	*
Kidney bean, marrowfat	+ 25	50	75-175	*
carrots (light soils)	+ 25	150	75-175	150-250
Witloofroots, celeriac	+ 25	50	75-175	*
Salsify,	+ 25	150	75-175	150-250
sugar-beet, cabbage, broad bean	+ 25	50	75-175	*
Strawberry	- 12.5	150	37.5-137.5	
Corn, chicory	- 12.5	50	37.5-137.5	
Potatoes, leek, winter-carrots and bulb-flowers (both	- 12.5	150	37.5-137.5	150-250
ridge cultures)	-12.5	150	37.5-137.5	150-250
Rosebushes, small conifers, other ornamental bushes and climbing plants	- 12.5	150	37.5-137.5	150-250
Bush and hedge public gardens, perennials	- 12.5	50	37.5-137.5	*
Cauliflower, broccoli				
Conifers	- 12.5	150	37.5-137.5	150-250
Brussels sprouts, kale	- 12.5	50	37.5-137.5	*
Bed culture of lettuce, carrots	25	150	75-175	*
Bed culture of endive	25	50	75-175	*
Bed culture of onions, bulb-flowers	0	150	50-150	150-250

For the standard off-field evaluation zone and for the crop-free buffer zone adapted off-field evaluation zones the spray drift is calculated for the standard (XR11004) and the obligatory used drift reducing spray technique, which specifies a nozzle minimal in the drift reducing class 50, a maximum sprayer boom height above crop height of 0.5 m and the use of an end nozzle to prevent overspray (DG11004+end nozzle). Also for other certified drift reducing spray techniques the spray drift deposition at the different crop type depending evaluation zones are presented for conventional application techniques in Table 12 and for air assisted application techniques in Table 13.

Table 12. Spray drift deposition (% of applied dose) for different conventional spray techniques at different off-field evaluation zone distances (1m wide) depending on crop type, spray intensity and position of the field.

Sprayer type	Nozzle type	Nozzle spray drift reduction class	Spray drift deposition [%] at distance from last nozzle				
			37.5-137.5	50-150	75-175	100-200	150-250
Conventional	XR11004	0	10.2	9.9	8.8	7.5	4.7
Conventional	DG11004	50	7.9	7.1	5.5	4.0	1.7
Conventional	DG11004+ end nozzle	50	6.2	5.5	4.2	3.1	1.5
Conventional	ID12002	75	7.9	7.1	5.2	3.4	1.0
Conventional	ID12002+ end nozzle	75	6.2	5.5	4.0	2.6	0.9
Conventional	XLTD04-110	90	10.9	9.7	7.3	5.0	1.6
Conventional	XLTD04-110+ end nozzle	90	8.5	7.5	5.6	3.9	1.4
Low boom	DG80015+ end nozzle	50	4.4	3.1	1.6	1.0	0.9
Low boom	ID90015+ end nozzle	50	6.4	3.9	1.5	0.7	0.3
Släpduk	XR110015	0	4.7	3.4	1.7	0.9	0.6
Släpduk	AI110015	50	4.1	2.5	0.9	0.3	0.03
Tunnel	XR11004 + UB8504	0	0.26	0.26	0.26	0.25	0.21

For the conventional application technique using standard flat fan nozzles (XR11004) the spray drift deposition on the off-field evaluation zone is for crop types like maize and potatoes 10.2% (37.5-17.5m evaluation distance), for crops as flower bulbs 9.9% (0.50-1.50m evaluation distance), for crops as cereals 8.8% (0.75-1.75m evaluation distance), and for fallow land applications 7.5% (1.0-2.0m evaluation distance). Differentiation of the defined off-field evaluation zone, at 0.5-1.5m from the last crop row, means that spray drift deposition varies. For a potato crop the criteria of 10% is too low as it should be 10.2% and for the for the other crop types it is too high, or can be lowered to the specified values in Table 12. In case of surface water around the field the evaluation zone the minimal required drift reducing spray technique is to be used (DG11004+end nozzle). For this application technique the spray drift deposition on the evaluation zones minimal at crop-free buffer zone distance is for crop types like maize 6.2%
(37.5-17.5m evaluation distance), for crops as flower bulbs 5.5% (0.50-1.50m evaluation distance), for crops as cereals 4.2% (0.75-1.75m evaluation distance), and for fallow land applications 3.1% (1.0-2.0m evaluation distance). For potatoes, onions, flower bulbs the minimal crop-free buffer zone is 1.5m and the off-field evaluation zone is than replaced from 0.5-1.5m to 1.5-2.5m from the last crop row. The spray drift deposition for the obligatory minimal drift reducing technique is 1.5% at 1.5-2.5m from the last crop row.

Table 12. Spray drift deposition (% of applied dose) for different air assisted spray techniques at different off-field evaluation zone distances (1m wide) depending on crop type, spray intensity and position of the field.

Sprayer type	Nozzle type	Nozzle spray drift reduction class	Spray drift deposition [%] at distance from last nozzle				
			37.5-137.5	50-150	75-175	100-200	150-250
Conventional	XR11004	0	8.8	7.9	6.2	4.5	1.9
Conventional	DG11004	50	6.1	5.7	4.6	3.4	1.2
Conventional	DG11004+ end nozzle	50	3.7	3.3	2.6	2.0	0.9
Conventional	ID12002	75	7.9	6.9	4.8	3.1	0.9
Conventional	ID12002+ end nozzle	75	4.9	4.1	2.7	1.7	0.7
Conventional	XLTD04-110	90	10.9	9.4	6.5	4.1	0.9
Conventional	XLTD04-110+ end nozzle	90	6.8	5.6	3.7	2.3	0.6
Low boom	DG80015+ end nozzle	50	2.4	1.8	1.0	0.6	0.3
Low boom	ID90015+ end nozzle	50	1.5	1.0	0.5	0.3	0.1

For the air-assisted application technique using standard flat fan nozzles (XR11004) the spray drift deposition on the off-field evaluation zone is for crop types like maize and potatoes 8.8% (37.5-17.5m evaluation distance), for crops as flower bulbs 7.9% (0.50-1.50m evaluation distance), for crops as cereals 6.2% (0.75-1.75m evaluation distance), and for fallow land applications 4.5% (1.0-2.0m evaluation distance). For all crop types the evaluation criteria of 10% is too high, or can be lowered to the specified values in Table 12. In case of surface water around the field the evaluation zone of the minimal required drift reducing spray technique is to be used (DG11004+end nozzle). For this application technique the spray drift deposition on the evaluation zone is minimal at a crop-free buffer zone distance, and is for crop types like maize 3.7% (37.5-17.5m evaluation distance), for crops as flower bulbs 3.3% (0.50-1.50m evaluation distance), for crops as cereals 2.6% (0.75-1.75m evaluation distance), and for fallow land applications 2.0% (1.0-2.0m evaluation distance). For potatoes, onions, flower bulbs the minimal crop-free buffer zone is 1.0m when air assistance is used and the off-field evaluation zone is than replaced from 0.5-1.5m to 1.0-2.0m from the last crop row. The spray drift deposition for the obligatory minimal drift reducing technique used in intensively sprayed crops is 2.0% at 1.0-2.0m from the last crop row.

It is obvious that the definition of an evaluation zone specified as on 1m distance from the last crop row, evaluating the spray drift deposition on a zone width of 1 m, means that large differences do occur in actual spray drift deposition specified by crop type and spray technique. The placement of the last nozzle compared to the last crop row is essential information and can be used to differentiate the off-field evaluation threshold value of crop protection products for different groups of crop types.

4. Discussion

4.1 Arable crops

Drift data presented in this study are based on field measurements in potatoes. The application of the agrochemical in other crop types, with possible crop-specific nozzle relationships to the field edge, may affect spray drift in the field. These effects are topic of present research.

Results presented in this report are state-of-the-art for the spray drift research in the Netherlands. The data will however be subject to change because of new developments in spray technology and ongoing research.

Reducing spray drift deposits on the off-field area can be achieved with changes in spray technique. Lowering sprayer boom height (De Jong *et al.*, 2000; Stallinga *et al.*, 2004a), using extra coarse sprays (Michielsen *et al.*, 2001), shielding the sprayer boom (Porskamp *et al.*, 1997), use of air assistance (Van de Zande *et al.*, 2006), or special application techniques like tunnel sprayer for bed-grown crops (Porskamp *et al.*, 1997), band spraying (Zande *et al.*, 2000) and Släpduk spraying (Zande *et al.*, 2005), or combinations of these options all make this goal possible.
Drift reduction of the drift reducing techniques on the off-field evaluation zone close to the crop is limited. This is due to spraying over the edge of the crop. Using an end nozzle the drift deposition on the band of 0.5-1.5m from the last nozzle or edge of the crop can be decreased (Michielsen *et al.*, 2001) with ca. 30%. In combination with air assistance the drift reduction due to using the end nozzle was even higher (ca 60%). These figures show the relevance of using an end nozzle to protect off-field plant and non-target arthropods in the areas close to the crop edge.

From the presented results it can be concluded that depending on the dimensions of the off-field evaluation zone, the crop type, the presence of a ditch around the field, or the specification at what zone distance from the crop edge (last crop row) or position of the last nozzle the environment is to be protected, large differences do occur in spray drift deposition. As a result of this the spray drift deposition value to be compared with the threshold value of the off-field risk for non-target arthropods and plants varies a lot. This influences the discussion on what area is to be protected or what is defined by off-field.

4.2 Fruit crops

Similar relations as specified in this report so far can also be dealt with in fruit growing. From the early nineties onward spray drift measurements have been performed in order to quantify spray drift reduction in orchard spraying (Porskamp *et al.*, 1994a, 1994b) and are summarised by Van de Zande *et al.* (2001). From these studies and more recent measurements by Wenneker *et al.* (2003, 2005, 2006) the spray drift deposition on the off-field evaluation zone for fruit growing can be obtained. As specified (CTB, 2006) the off-field evaluation zone for orchard spraying is at 3m from the last tree row. In Table 13 the spray drift deposition values at 2.5-3.5m are presented for orchard spraying with the standard application technique, cross-flow sprayer equipped with Albuz Lilac nozzle type (7 bar spray pressure), air flow set to the maximum for the full leaf situation and half for the dormant situation, both for the full leaf (after May 1st) and the dormant (before May 1st) situation.

Table 13. Spray drift deposition (% of applied dose) for different spray techniques used in orchard spraying in the full leaf and dormant situation at the off-field evaluation zone at 3m from the last tree row (2.5-3.5m).

Spray technique	Nozzle type	Spray drift deposition [%]	
		full leaf	dormant
Cross-flow - reference	Albuz lilac	14.7	36.8
Cross-flow + reflection shield	Albuz lilac	6.4	16.6
Tunnel	Albuz lilac	2.3	5.6
Cross-flow + one-sided spraying outside row	Albuz ATR brown/ ConeJet TXA800067VK	6.2	23.2
Cross-flow + crop detection sensor	ConeJet TXA800067VK	8.6	33.3
Cross-flow + venturi nozzle+ one-sided spraying outside row	Lechler ID9001 5 bar	3.1	10.6
Wanner Cross-flow + reflection shield	Albuz lilac	6.6	11.8
Wanner Cross-flow + reflection shield	Lechler ID90015	1.2	2.6

For the reference situation, Cross-flow – Albuz lilac, the spray drift deposition on the evaluation zone at 3m distance from the last crop row is 14.7% in the full leaf situation and 36.8% in the dormant situation. Depending on the spray drift technique this can be lowered to respectively 1.2% and 2.6% for the Wanner cross-flow sprayer with reflection shields equipped with venturi flat fan nozzles (Lechler ID90015 sprayed at 7 bar pressure).

5. Conclusions

In applying crop protection products in different crop types the use of drift reducing nozzle types and air assistance on a (boom) sprayer can reduce spray drift when applying agrochemical. Also in orchard spraying spray drift reducing techniques are available. When spraying crop protection products ecotoxicological threshold values for the off-field area are to be met to protect plants and non-target arthropods. Depending on the crop type and the used spray technique different endpoint values must be used to meet these goals when the evaluation zone is specified at a certain distance from the last crop row. The specification of the position and the width of the off-field evaluation zone differ much in spray drift deposition value for the same spray technique. The use of an end nozzle to prevent over spray at the edge of the field contributes much to the drift reduction close to the field edge. Drift reducing spray techniques like nozzle type, air assistance, boom height, Släpduk spray systems or tunnel sprayers for bed-grown crops differ a lot in spray deposition at the off-field evaluation zone. Drift reducing techniques are therefore also relevant in reducing off-field risk for non-target arthropods and plants as in aquatic risk assessments.

From the presented results it can be concluded that depending on the dimensions of the off-field evaluation zone, the crop type, the presence of a ditch around the field, or the specification at what zone distance from the crop edge (last crop row) or position of the last nozzle the environment is to be protected, large differences do occur in spray drift deposition. As a result of this the spray drift deposition value to be compared with the threshold value of the off-field risk for non-target arthropods and plants varies a lot. This influences the discussion on what area is to be protected or what is defined by off-field.

Results presented in this report are state-of-the-art for the spray drift research in the Netherlands. The data will however be subject to change because of new developments in spray technology and ongoing further research. Combining the different measures for spray drift reduction can lead to a promising set-up of a low-drift spray technology for applying crop protection products with a minimal crop-free buffer zone. Further research on the development of new spray techniques is needed and a field evaluation will be necessary before introduction.

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