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A drift-calculation tool based on spray drift field measurements in field crops

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Summary

Spraying plant protection products with boom sprayers in field crops is an important tool to produce safe and sufficient food. But off-target deposits of spray drops because of spray drift should be minimised. Especially, the occurrence of spray deposits onto surface waters adjacent to or near sprayed fields should be avoided. Many field measurements were done but the effects of individual measures to reduce drift cannot simply be added to determine the effect for the whole system. Representative methods were determined from which the spray drift deposition curves could be used as a model for other methods with the same drift reduction. These Drift Reduction Technology classes of grouped spray techniques with similar drift reduction were combined in a calculation tool to be used by authorities and industry.

Key words: Spray drift, drift measurements, Brilliant Sulfo Flavine, classification spray method, field experiments, regression curve

Introduction

In agriculture, the use of Plant Protection Products (PPP) still is an essential way of protecting crops against all kinds of harmful diseases, pests and weeds. Nevertheless, the application of PPP should be done with the greatest care to minimise unwanted side-effects and to protect the environment. Common application techniques involve the use of spray equipment to transfer the chemicals to the target (usually the crop to be protected). Off-target deposits of spray deposits onto surface waters adjacent to or near sprayed fields should be avoided and is therefore an important part in the authorisation of PPP (EU, 2009; Ctgb, 2011) and surface water regulation (EU, 2000).

The common technique for PPP application onto field crops in the Netherlands is an application using a ‘conventional’ boom sprayer, operated with a spray boom at 0.5 m above the crop canopy, equipped with ‘medium spray quality’ flat fan nozzles (Southcombe *et al*., 1997). Additional drift reducing techniques consist of variation in height of the sprayer boom above the crop (Jong *et al*, 2000), different types of nozzles used (van de Zande *et al*., 2000*a*), and the use of ‘air assistance’ (i.e. using a downward air stream to guide drops towards the crop) (van de Zande *et al*., 2006) eventually also in combination with reduced boom height, low drift nozzle types and air assistance (Stallinga *et al*., 2004). The last two decades many experiments were carried out to investigate downwind spray deposits under varying circumstances. Because the contribution of a spray parameter to the drift is inconsistent, each spray application is classified according to its drift reduction and fit curves are assigned to that application method. As a consequence the spray drift from a field sprayer can only be classified as a complete specified method (specifying for example nozzle type, boom height, liquid pressure). The spray drift reduction curves for different methods are combined in the Wageningen UR Drift Calculator (WDC) so one can calculate spray drift deposits onto downwind areas in order to calculate drift to surface water and bystanders. The input parameters for the calculator mainly consist of crop type, width of crop free (buffer) zone (i.e. a measure increasing the width of ground without vegetation between the last crop row and the top of the bank of an adjacent water body), dimensions of the water body and last nozzle position.

The drift to a certain area can be calculated by spray drift models which need many assumptions and validation of the relevant parameters (Holterman *et al.*, 1997). The WDC offers a more simple approach to drift estimation, as the spray drift curves used in the tool are determined by real spray drift measurements in the field. In this way the effects of different crop types, weather conditions and spray equipment is taken into account. The large variety and choice in spray equipment makes it essential to rank the effect of these methods. For each group of methods a representative measured drift curve is determined. This curve is used as a reference to calculate drift reduction classes following ISO22369. The WDC calculates the drift deposition to the water body as a percentage of the applied dose. Apart from a choice in water body it is possible to calculate the crop free zone when a certain drift value is specified to be met and the drift when a crop free zone or distance to the water body is given. In order to apply a risk assessment the drift reduction classification is based on a uniform basis at a chosen 'evaluation range' of 2.25–3.25 m from the last row of potatoes. This evaluation range is the place where ditches are commonly situated in the Netherlands (Fig. 1).

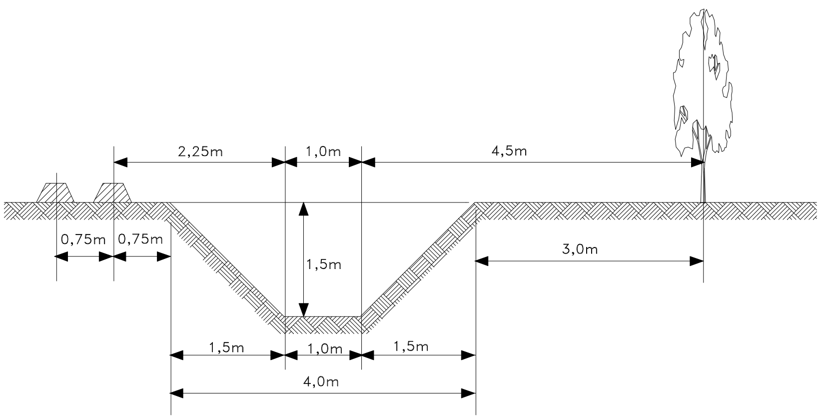

Fig. 1. Representation of the place of the ditch, embankments and water surface, and the last rows of a potato crop (Huijsmans *et al.*, 1997).

As a reference point for the drift measurements the last row of a crop is chosen. Drift originates from the position of the nozzle but in the field this is no practical measure. As a consequence an additional parameter was required to position the nozzle relative to the last crop row (this is dependent on crop type). The tool is developed to help authorities and agrochemical industry to quantify effects of Drift Reducing Technology and proposed crop free zones.

Materials and Methods

In a series of field experiments, downwind drift measurements were recorded during the growing season. In potato crops various application techniques were compared: conventional spraying, air-assisted spraying, applications using drift reducing nozzles and applications involving a no-spray buffer zone. For other crops a less extensive application scheme was carried out (often only a conventional application). Measurements were done on a bare soil surface and in a ditch, downwind of the crop following the Dutch protocol to classify drift reducing spray techniques (TCT, 2003) adapted from the ISO22866 standard. The fluorescent dye Brilliant Sulpho Flavine (BSF) was added as a tracer to the spray liquid. Drift collectors were placed inside and outside the field. The swath width sprayed was at least 18 m or 24 m (i.e. the full width of the sprayer boom). The length of the sprayed track was at least 50 m. Spray drift was measured in at least ten replications, at different places along the edge of the field and at different times during the growing season. The distance of the last downwind nozzle to the edge of the field (the outer crop leaves) and the last crop row was determined. All measurements of spray drift included a reference measurement, which involved a conventional field sprayer applying a volume rate of 300 L ha^{-1} with a medium (Southcombe *et al*., 1997) spray quality nozzle (XR11004 at 3 bar spray pressure). In the case of air assistance, nozzles sprayed vertically downward and air velocity was set to the maximum capacity of the fan.

Based on field measurements drift reduction was determined for the following spray techniques:

- air assistance on a boom sprayer (Porskamp *et al*., 1995; Michielsen *et al.,* 1999)
- nozzle types of the classes 50%, 75% and 90% reduction (Michielsen *et al*., 1999)
- low boom height with two nozzle types (De Jong *et al*., 2000; Stallinga *et al*., 2004)
- low boom height with two nozzle types and additional air assistance (De Jong *et al*., 2000; Stallinga *et al.*, 2004)
- Släpduk system with two nozzle types (van de Zande *et al*., 2005)
- air assistance system (Hardi Twin Force) with two nozzle types (van de Zande *et al.*, 2006)
- tunnel sprayer for bed grown crops (Porskamp *et al*., 1997) when spraying an arable crop, a flower bulb crop or an flower, ornamental or small fruit crop.

For the bare soil surface situation drift reduction measurements were performed with a band sprayer (van de Zande *et al*., 2000*b*), air assistance (Stallinga *et al*., 1999), and a Hardi Twin Force air assistance with two nozzle types (van de Zande et *al.*, 2006).

From these data, new drift curves were generated (van de Zande *et al*., 2011) for the reference spray technique, generally referred to as the standard drift curve when spraying a crop. The drift of low drift spray techniques can be presented as relative to the reference spray technique. Among measurements regression analysis did not show a significant effect of wind speed (within the range of 1–5 m s^{-2}) on spray drift. Therefore wind speed was not a parameter in the WDC. The total number of measurements and the average weather conditions during drift measurements are presented in Table 1 for the reference technique and the standard low drift technique (DRT50), for both potato and bare soil spraying.

Table 1. *Weather conditions during spray drift measurements (average and (standard deviation)) of the reference and the standard low drift spray technique in a potato crop and a bare soil surface*

Crop	Spray technique	No measurements	Temperature at 2 m height [°C]	Average wind angle# [°]	Average wind speed at 2 m height [m s^{-1}]
Potato	Reference	126	20.2 (2.8)	4.3 (25)	3.4 (1.0)
	Low drift	78	20.5 (3.1)	-3.9 (24)	3.4 (0.9)
Bare soil	Reference	24	17.1 (2.4)	2.8 (19)	3.2 (1.0)
	Low drift	22	17.8 (2.9)	-5.1 (15)	3.2 (1.4)

#perpendicular to the driving direction is 0°.

Based on this new reference curve, for various drift-reducing techniques the drift reduction was determined at a distance of 2–3 m. After that, these techniques were grouped into drift reduction classes as shown in Table 2. For each drift reduction class an appropriate technique was selected (marked with an asterisk (*) in Table 2) to calculate a spray drift deposition curve as a representative curve for that class. As this curve expresses a minimal drift reduction for that class it can be used as representative for all techniques in that class. To minimise uncertainties due to day-by-day variations, it proved useful to first compute drift reductions as a function of distance for each measurement. Averaging these reduction curves for a certain technique and combining the outcome with the new reference curve yielded representative drift curves for the various drift reduction classes.

Table 2. *Downward directed spray drift reducing technologies and the drift reduction classes*

Drift reduction classes	Spray drift reducing technology in drift reduction class
50%	50% drift reducing nozzle types *
	Air-assisted boom sprayer + nozzles drift reduction class 0
	Low-boom height (30 cm) conventional boom sprayer + nozzles drift reduction class 0
75%	75% drift reducing nozzle types *
	Band sprayer in maize + nozzles drift reduction class 0
	Släpduk sprayer + nozzles drift reduction class 0
	Hardi Twin Force air-assisted sprayer + nozzles drift reduction class 0
90%	90% drift reducing nozzle types
	Band sprayer in sugar beet + nozzles drift reduction class 0
	Low-boom height (30 cm) conventional boom sprayer + nozzles drift reduction class 50
	Air-assisted boom sprayer + nozzles drift reduction class 50 *
95%	95% drift reducing nozzle types
	Low-boom height (30 cm) air-assisted boom sprayer + nozzles drift reduction class 0
	Low-boom height (30 cm) air-assisted boom sprayer + nozzles drift reduction class 50
	Hardi Twin Force air-assisted sprayer + nozzles drift reduction class 50
	Släpduk sprayer + nozzles drift reduction class 50
	Tunnel sprayer for bed-grown crops + nozzles drift reduction class 0
	Air-assisted boom sprayer + nozzles drift reduction class 90 *

Nozzles belonging to the drift reduction class 0 are none drift reducing nozzles. The appropriate reference technique for each class is marked with an asterisk (*).

Regression curves

In general it appeared that the best function to be used for fitting of the drift curves is the sum of two exponential functions. This gives satisfactory results at some distance from the crop but near the crop values become extremely large. To get better results also near the crop a sigmoid function is used in the WDC. The regression function then becomes:

$$f(x) = \frac{A_0\, e^{xA_1} + B_0\, e^{xB_1}}{1 + C_0 e^{xB_1}} \qquad (1)$$

where *f(x)* is downwind spray deposit (in % of applied dosage), x is downwind distance (in m) from last nozzle, and A_0, A_1, B_0, B_1, C_0 are regression constants. These constants depend on crop type and application technique. Distance parameter x is related to the position of the last nozzle. The fit-function in Equation 1 is not a linear function so regression was performed by a fit-routine approximating the parameters iteratively.

Results

The results of more than a thousand spray drift measurements resulted in the drift reducing technologies being classified in drift reduction classes following ISO22369. For each class a nozzle, liquid pressure and method combination (end nozzle and/or air assistance) was chosen as a representative method for that class (Table 2). The typical curves obtained for the different Drift Reduction Technology classes when spraying a field crop are given in Fig. 2 for the cropped situation and in Fig. 3 for the bare soil or small crop situation. Close to the last nozzle (0–2 m) drift reduction is limited as overspray occurs of the last nozzle which depends much on the top angle of the outside nozzle. Therefore drift deposition curves can cross in this area. The shape of the drift deposition curves exist clearly of two parts. A steep declining part close to the crop edge and a constant decreasing part further away (each represented by one of the two exponentials in the fit function).

The reference techniques of the drift reduction classes are based on the evaluation in the cropped situation (spraying a potato field). This means that the spray deposition curves in the bare soil/short crop situation can have other drift reduction steps (Fig. 3). The choice for a bare soil/short crop or a cropped spray drift situation is based on crop height at application time, i.e. crop height is below or above 20 cm. Grassland follows therefore the bare soil/short crop spray drift approach.

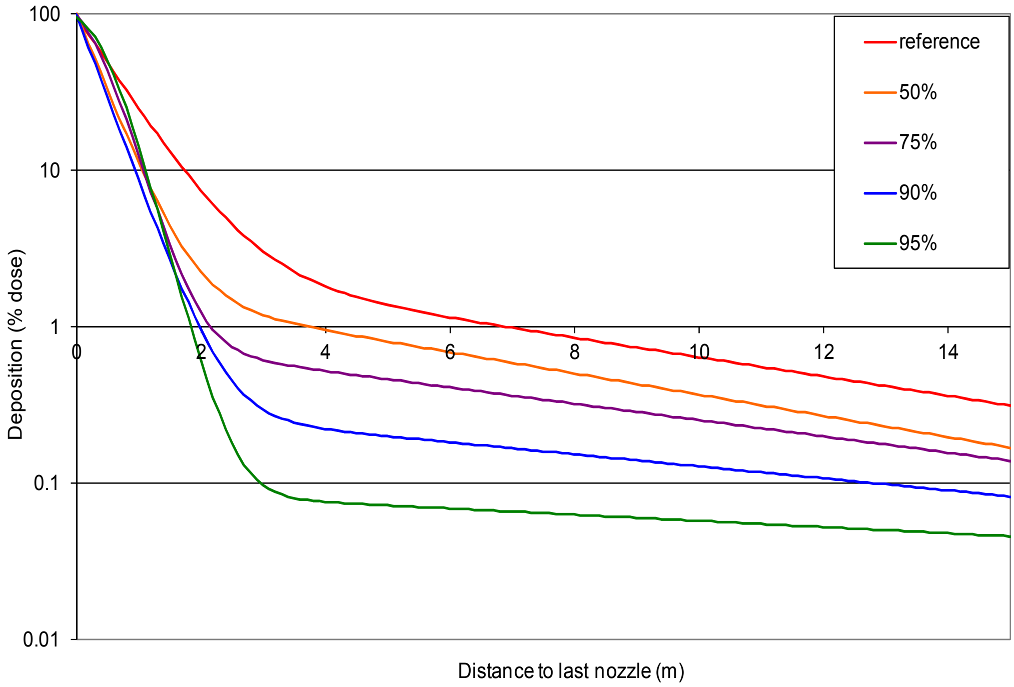

Fig. 2. Spray drift deposition curves of the reference and 50%, 75%, 90% and 95% drift reducing technology spray techniques for downward directed spray applications (boom sprayer) in a crop situation.

Based on the field layout, the many different crops in the Netherlands can be classified into intensive crops, cereal crops and other crops. Examples of intensive crops are potato, strawberry and flower bulbs, examples of cereals are barley and wheat and examples of other crops are sugar beet and maize. For each of the crop type groups a differentiation can be made in the place of the last nozzle on the spray boom in relation to the last crop row. This placement of the last nozzle defines the starting point of the drift curve for this specific crop (Fig. 4). Last nozzle to row distances for the different crop types are typically: 12.5 cm outside of the last crop row, on top of the last crop row, 25 cm inside of the last crop row and 50 cm inside the last crop row/outside edge of the crop (Table 3). This means that the spray drift calculations for the different crops can be limited to nine specific situations of crop type groups, as indicated in Table 3.

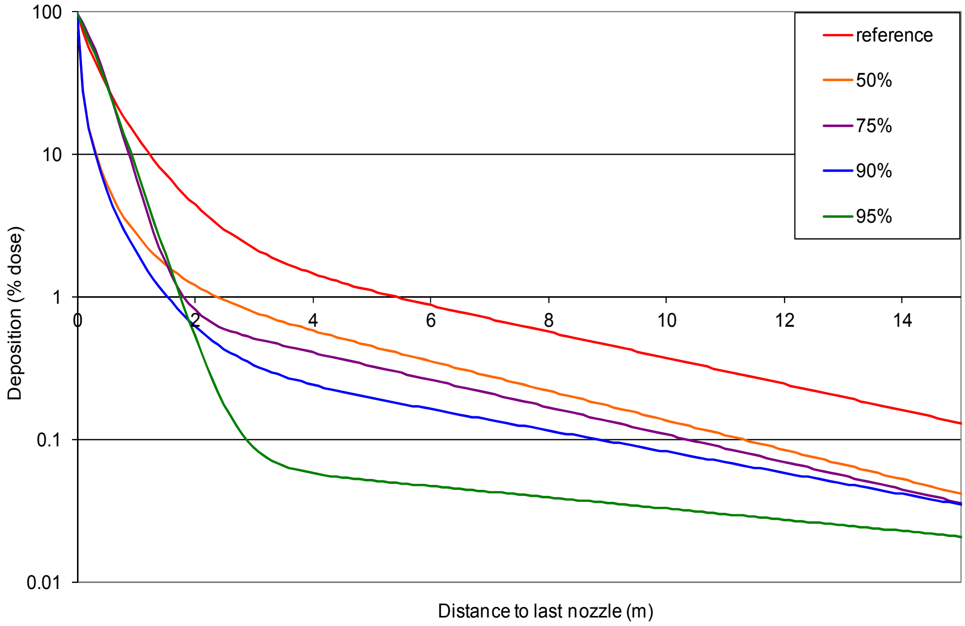

Fig. 3. Spray drift deposition curves of the standard and 50%, 75%, 90% and 95% drift reducing technology spray techniques for downward directed spray applications (boom sprayer) in a bare soil – short crop situation.

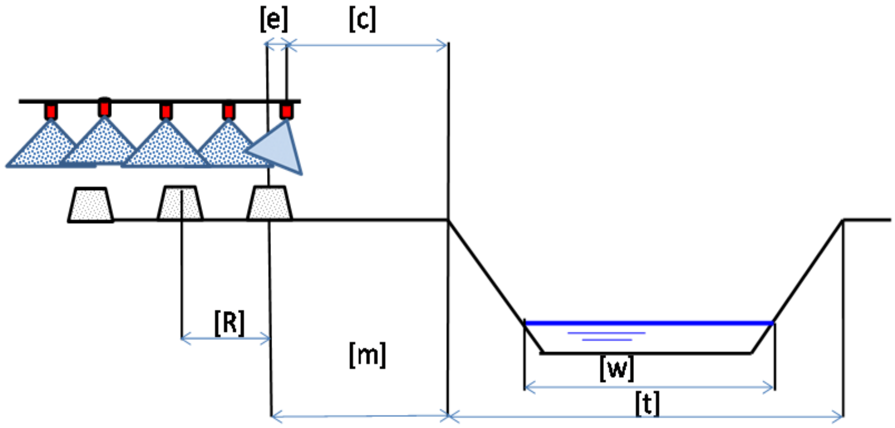

Fig. 4. Definitions of the distances used in the determination of the spray drift deposition on surface water for field (boom) sprayers. [m] is the distance between the top of the ditch bank and the centre of the last plant row (i.e. the minimal agronomic crop-free zone), [e] is the distance between the last nozzle position and the centre of the last crop row, [c] is the distance between the last nozzle and the top of the ditch bank (=m+e), [R] is the distance between the crop rows, [w] is the width of the water surface, and [t] is the width of the ditch (distance between top of the banks).

In the WDC these curves are implemented and used to calculate the spray drift deposition next to the sprayed field. In Fig. 5 a screen dump is shown. In the window crop type the crops intensive, cereals and other can be selected, where intensive is short for "intensively sprayed crops" in Table 3. In the window modified nozzle position the positions -12.5, 0.0 and 25 cm of the last nozzle relative to the last crop row can be selected. In the window reduction curve a selection from reference, and spray Drift Reduction Technology classes 50%, 70% 90% and 95% can be made. In the window water body the water bodies ditch old (the nowadays used standard Dutch ditch; Huijsmans *et al*., 1997) and ditch new (90-percentile exposure ditch in future PPP Dutch authorisation procedure; van de Zande *et al*., 2011) can be selected. Above the selection windows buttons selecting curves measured in a cropped situation or on bare fields are located. In this way for each crop type and field dimension drift curves are available.

Table 3. *Specific crop type groups defined by crop-free buffer zone and last nozzle position for downward directed sprayed crops*

Crop type group	Crop-free buffer zone (m) [m]	Distance nozzle/row (cm)* [e]	Distance nozzle / edge of the ditch (m) [c=m+e]
Cereals	0.25	25	0.50
	0.25	50	0.75
Other crops	0.50	-12.5	0.375
	0.50	0	0.50
	0.50	25	0.75
	0.50	50	1.00
Intensively sprayed crops	0.75	-12.5	0.675
	0.75	0	0.75
	0.75	25	1.00

*A positive value of [e] means that the last nozzle is positioned inside the last plant row; a negative value means that the last nozzle is positioned outside the last plant row.

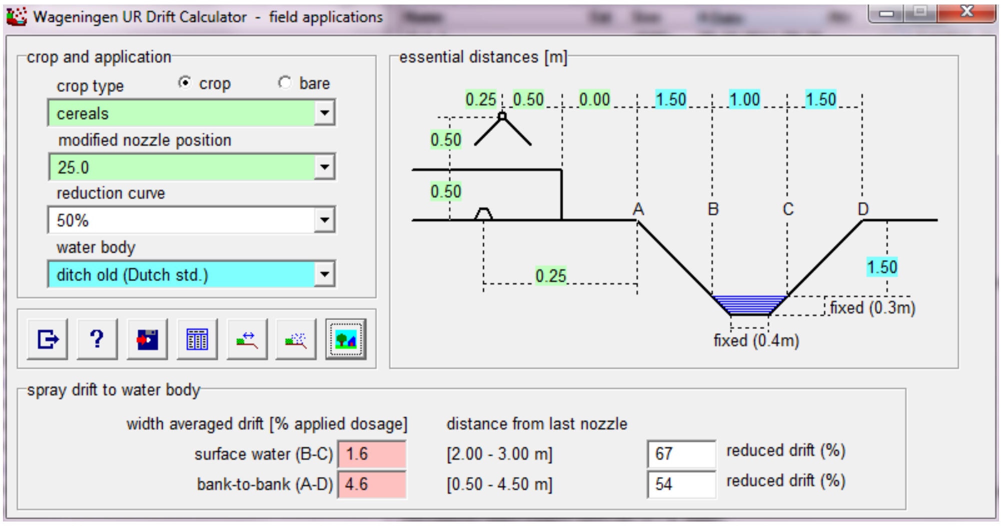

Fig. 5. Screen dump of the WDC. At the top-left the selection windows are located. The top right displays schematically the dimensions of the application method. The bottom part is reserved for drift figures at the standard evaluation range. With buttons at the right side below the selection windows additional information about the spray drift can be obtained.

Discussion

The aim of the research on spray drift is to realise good crop protection with minimal environmental burden. Choosing an optimal spray application technique is the obvious next step. To classify applications accordingly, it is essential to define a reference situation for comparison. In this study the reference method was a potato crop with a conventional boom sprayer applying a spray with a medium sized drop distribution with a 300 L ha^{-1} applied dose and boom height at 0.50 m above the crop canopy. The presentation of spray drift data in a uniform way can be the basis for the exchange of data and the harmonisation of methodologies to classify Drift Reducing Technology (Huijsmans & van de Zande, 2011).

From measurements it was found that the effects of measures to reduce drift cannot simply be added. For example drift reduction with an application involving reduced boom height, air assistance and reduced-drift nozzles does not match the sum of reductions by each of these measures separately.

The lack of predictability for the contribution of an application method to the drift deposit makes it hard to build a generic model between application methods and spray drift. It is essential to determine each application method as a whole which then can be classified into a reduction class. Research at Wageningen developed a method to do this and assigned representative drift curves to each Drift Reduction Technology class. The WDC can then be used to explore the drift to other areas than the evaluation range and be used for a stepwise approach for evaluating combinations of DRT classes and width of crop-free (buffer) zones in the authorisation procedure (van de Zande *et al*., 2011).

Apart from the effect of different crop types, differences in measured spray drift can also be attributed to different weather conditions (wind speed and direction) and sprayer boom movements. Further research is needed to quantify the contribution of these parameters to spray drift.

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References

CIW. 2003. Beoordelingsmethodiek emissiereducerende maatregelen Lozingenbesluit open teelt en veehouderij. *Commissie Integraal Waterbeheer, Ministerie van Verkeer en Waterstaat, Werkgroep 4 Water en Milieu*, Den Haag. 82 pp.

Ctgb. 2011. *Evaluation manual for the authorisation of plant protection products and biocides, Version 1*. Available at www.ctgb.nl.

EU. 2000. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. *Official Journal of the European Communities* **L327**:1–72.

EU. 2009. Regulation 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. *Official Journal of the European Communities* **L309**:1–50.

Holterman H J, van de Zande J C, Porskamp H A J, Huijsmans J F M. 1997. Modelling spray drift from boom sprayers. *Computers and Electronics in Agriculture* **19**:1–22.

Huijsmans J F M, Zande J C van de. 2011. Workshop harmonisation of drift and drift reducing methodologies for evaluation and authorization of plant protection products, Wageningen, the Netherlands, 1–2 December 2010. *WUR-PRI Report 390*, Wageningen: Wageningen UR, Plant Research International.

Huijsmans J F M, Porskamp H A J, Zande J C van de. 1997. Spray drift (reduction) in crop protection application technology; *Instituut voor Milieu- en Agritechniek (IMAG), IMAG Report 97-04*,Wageningen, the Netherlands. 41 pp (in Dutch, with summary in English).

ISO-22369. 2006. *Crop protection equipment – Drift classification of spraying equipment. Part 1. Classes*. Geneva: International Standardisation Organisation.

ISO 22866. 2006. *Equipment for crop protection – Methods for the field measurement of spray drift*. Geneva: International Standardisation Organisation.

Jong A de, Michielsen J M G P, Stallinga H, van de Zande J C. 2000. Effect of sprayer boom height on spray drift. *Mededelingen Faculteit Landbouwwetenschappen, Universiteit van Gent 65/2b:919 Wageningen UR, Plant Research International* 930.

Southcombe E S E, Miller P C H, Ganzelmeier H, van de Zande J C, Miralles A, Hewitt A J. 1997. The international (BCPC) spray classification system including a drift potential factor. *Proceedings of the Brighton Crop Protection Conference - Weeds, November 1997*, pp. 371−380.
Stallinga H, Zande J C van de, Michielsen J M G P, Velde P van. 2004. Fine nozzles can be used and reduce spray drift; when used at low boom height and smaller nozzle spacing. *Aspects of Applied Biology* **71**, *International Advances in Pesticide Application*, pp. 141–148.
Zande J C van de, Porskamp H A J, Michielsen J M G P, Holterman H J, Huijsmans J F M. 2000. Classification of spray applications for driftability, to protect surface water. *Aspects of Applied Biology* **57**, *Advances in Pesticide Application*, pp. 57–65.
Zande J C van de, Stallinga H, Michielsen J M P G, Velde P van. 2006. Spray drift reduction of the Hardi Twin Force air-assisted boom sprayer (Driftreductie door Hardi Twin Force luchtondersteuning). *Plant Research International, WUR-PRI Report 124*, Wageningen. 20 pp.
Zande J C van de, Holterman H J, Huijsmans J F M. 2011. Spray drift for the assessment of exposure of aquatic organisms to plant protection products in the Netherlands. Part 1: Field crops and downward spraying. *WUR-PRI Report 419*. Wageningen UR: Plant Research International.