



WUR Drift Calculator user manual

Belonging to software version 2.6

Henk Jan Holterman, Jan van de Zande



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In 2003 the IMAG Drift Calculator was developed to compute downwind spray deposits onto surface water. Recently, it was renewed, improved and expanded resulting in the current WUR Drift Calculator. This calculator is a tool to quantify spray drift to surface waters and non-target areas near a sprayed field or orchard. The calculator uses statistically obtained regression curves to calculate spray deposition next to the sprayed field. These spray drift curves are derived from experimental drift data for field crops, fruit orchards and avenue tree nurseries. The calculator is intended for computation of spray drift deposits onto the surface water next to a field crop, fruit orchard or avenue tree nursery. It can also be used to compute spray drift deposits onto off-field terrestrial non-target zones, to evaluate exposure of non-target plants and arthropods (NTP, NTA) to pesticides. Drift mitigation measures such as additional buffer zones and the use of drift reducing application techniques, represented by their DRT classes (DRT50 up to DRT99), can be selected as well. For field crops, a distinction is made between applications on bare soil (including low-height emerging crops) and applications on higher or full-grown crops. For fruit orchards, dormant trees and trees in full leaf are distinguished. With avenue tree nurseries, a distinction between spindle trees, transplanted trees and high avenue trees is available.

Keywords: spray drift, arable crops, fruit crops, nursery tree, drift reducing techniques, crop-free buffer zone

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Contents

	Preface	5
	Samenvatting	7
	Summary	9
1	Introduction	11
	1.1 How to use this manual	14
2	Spray drift curves	15
	2.1 General set-up	15
	2.2 Field crops	16
	2.3 Fruit orchards	19
	2.4 Avenue tree nurseries	22
	2.5 Dealing with inconsistent drift reduction sequence	24
3	Getting started	25
	3.1 Installation of the WUR Drift Calculator	25
	3.2 Requirements	25
	3.3 Start-up	25
4	Using the WUR Drift Calculator	27
	4.1 Pictogram buttons	27
	4.2 Field crops, spray drift deposits onto surface water	28
	4.3 Field crops, spray drift deposits onto non-target evaluation zone	31
	4.4 Fruit and avenue tree crops, spray drift deposits onto surface water	33
	4.5 Fruit and tree crops, spray drift deposits onto non-target evaluation zone	35
	4.6 Computation of crop-free zone for given spray drift deposits	37
	4.7 Computation of spray drift deposits for given crop-free zone	38
	4.8 Topic-based help file	39
5	Conclusions and recommendations	40
	References	41
	Annex 1 Model constants	42

Preface

The risk of exposure to spray drift for aquatic organisms and other non-target organisms has been studied experimentally for many years. During these years the need for ready availability of the results grew stronger. The IMAG Drift Calculator was developed in 2003 as an answer to that need. However, the IMAG Drift Calculator could only be used for the evaluation of spray drift deposits on an edge-of-field ditch next to field crops.

Further developments resulted in the current WUR Drift Calculator, version 2.6, suitable for field crops and tree crops (fruit orchards and avenue tree nurseries). The exposure of non-target plants and arthropods can be evaluated as well. Various drift reducing application techniques and additional crop-free buffer zones can be selected as drift mitigation measures.

This report is the user manual belonging to the WUR Drift Calculator version 2.6. It is produced on behalf of the Dutch Ministry of Agriculture nature and Food Quality (LNV) under project number BO-43-011.01-007.

Samenvatting

Dit rapport is een gebruikershandleiding bij de WUR Drift Calculator, versie 2.6 (release code: 2.6.005/2021.01.29). De WUR Drift Calculator is een hulpmiddel om bij bespuitingen met gewasbeschermingsmiddelen de driftdepositie op oppervlaktewater en niet-doelwit gebieden te kwantificeren naast een bespoten veldgewas of boomgaard.

De driftberekeningen in de calculator zijn gebaseerd op statistische regressiecurves van gemeten driftdeposities als functie van de afstand vanaf het bespoten gewas. Deze meetgegevens van driftdepositie voor akkerbouwmatige teelten, fruitteelt en laanbomenteelt zijn in de loop van de jaren verzameld. De WUR Drift calculator heeft vier afzonderlijke units om driftdepositie te bepalen, namelijk voor (a) oppervlaktewater naast een veldgewas (neerwaartse toediening), (b) oppervlaktewater naast een boomgaard van fruit- of laanbomen (op- en zijwaartse toediening), (c) niet-doelwit planten en arthropoden in randen naast een veldgewas (neerwaartse toediening), (d) niet-doelwit planten en arthropoden in randen naast een boomgaard van fruit- of laanbomen (op- en zijwaartse toediening). Voor oppervlaktewater wordt gerekend met een standaardsloot en voor niet-doelwit planten of arthropoden evaluatiezones naast een gewas.

Er gelden voorwaarden voor de toelating van chemische gewasbeschermingsmiddelen en de toediening ervan. Dit is in wetten en regels vastgelegd, zoals in het Activiteitenbesluit Milieubeheer (MinI&W, 2021). In de Evaluation Manual van het CTGB (2020a, 2020b) is vastgelegd welke combinaties van toedieningstechnieken, teeltvrije zones en andere mitigerende maatregelen mogen worden gebruikt voor de verschillende teelten in Nederland en ook welke driftdeposities daar bij horen ten behoeve van de beoordeling van een mogelijke toelating van gewasbeschermingsmiddelen. Met de WUR Drift Calculator wordt op eenduidige manier de driftdeposities bepaald voor neerwaarts bespoten teelten (met name akkerbouwmatige teelten) en op- en zijwaarts bespoten teelten (met name fruitteelt en laanbomenteelt). Ook het effect van mitigerende maatregelen als driftreducerende toedieningstechnieken en teeltvrije bufferzones op de driftdepositie is met de calculator vast te stellen.

In het Activiteitenbesluit worden in de akkerbouw twee gewasgroepen onderscheiden bij neerwaartse toedieningen: intensief bespoten gewassen en overige gewassen. Deze gewasgroepen onderscheiden zich in de minimaal vereiste teeltvrije zone. Daarnaast wordt onderscheid gemaakt in bespuitingen op kale grond en lage gewassen (<20 cm) en hogere gewassen. Naast de standaard toedieningstechniek zijn er zes driftreducerende technieken te kiezen in de calculator. Deze driftreducerende technieken zijn representatief voor de zes driftreductieklassen (DRT-klassen) zoals beschreven in het meetprotocol voor driftreducerende spuittechnieken (MinI&W, 2017), aangeduid met DRT50, DRT75, DRT90, DRT95, DRT97.5 en DRT99. In de WUR Drift Calculator is voor neerwaarts bespoten gewassen tevens een gewaslijst opgenomen, de DTG-lijst (CTGB, 2019), waarmee eenvoudig de gewenste instellingen voor de driftberekening kunnen worden gekozen voor een gewas.

Voor op- en zijwaarts bespoten gewassen kan gekozen worden uit fruitbomen en laanbomen. Voor fruitteelt wordt onderscheid gemaakt in kale bomen (vóór 1 mei) en bomen vol in blad (vanaf 1 mei). Voor fruitboomgaarden zijn ook de DRT-klassen DRT50 t/m DRT99 vertegenwoordigd. Laanbomen worden opgesplitst in spullen, opzetters en hoge laanbomen, die de drie te onderscheiden groei- en teeltstadia aangeven. Voor laanbomen zijn niet alle DRT-klassen vertegenwoordigd; voor hoge laanbomen DRT50, DRT75 en DRT95, voor spullen en opzetters alleen DRT50 en DRT90. Voor andere klassen zijn geen spuittechnieken beschikbaar of onvoldoende meetgegevens bekend.

Naast de berekening van driftdepositie op de evaluatiezone (hetzij standaardsloot of niet-doelwit zone), zijn twee aanvullende bepalingen mogelijk met de calculator. Ten eerste kan de driftdepositie voor een willekeurige teeltvrije zone berekend worden (zodat het effect van aanvullende bufferzones bepaald kan worden). Ten tweede kan, omgekeerd, bij een gegeven of gewenste driftdepositie bepaald worden welke teeltvrije zone minimaal nodig is bij een bepaalde spuittechniek. Deze beide bepalingen maken gebruik van de eerder ingestelde gewas- en techniekinstellingen.

Summary

This user manual describes how to install and use the WUR Drift Calculator, version 2.6 (release code: 2.6.005/2021.01.29). The WUR Drift Calculator is a tool to quantify spray drift to surface waters and non-target areas near a sprayed field or orchard. The calculator uses statistically obtained regression curves to calculate spray deposition next to the sprayed field.

The spray drift curves are based on the latest experimental data for field crops, fruit orchards and avenue tree nurseries. The calculator has four separate units, to compute spray drift deposits onto (a) surface water next to a field crop, (b) surface water next to an orchard or avenue tree nursery, (c) non-target area next to a field crop, (d) non-target area next to an orchard or avenue tree nursery. The surface water belongs to a standardized ditch. The non-target area is defined separately for arthropods and plants outside the treated fields.

Since 2018, the Environmental Activity Decree of the Dutch Ministry of Infrastructure and Water Management distinguishes two categories of field crops (with downward spraying): intensively sprayed crops and other crops. These crop categories differ in the minimally required crop-free zone, defined in the Activity Decree. Two crop growth stages are distinguished: bare field and full-grown crop. The application techniques involve a reference application technique and six drift reducing application techniques that are representative for six drift reduction classes ranging from 50% up to 99% reduction of spray drift deposits onto the water surface of the standardized ditch. When a waterbody is located next to the sprayed field, the use of an end nozzle is required. In the WUR Drift Calculator an additional crop-free buffer zone can be selected as well. The Dutch crop definition list (DTG list) is added to the WUR Drift Calculator for field crops to facilitate the appropriate selection of parameters for different crops required for the drift computation.

With upward and sideways spraying, fruit trees and avenue trees can be selected. For fruit trees two growth stages can be selected: either dormant or in full leaf, dated before and after 1 May, respectively. Representative drift reducing techniques are available of drift reduction classes ranging from 50% up to 99% reduction. For avenue trees, the selection involves three stages corresponding to the layout of avenue tree nurseries: spindles, transplanted trees and high trees. A limited number of drift reducing techniques is available for avenue tree nurseries.

For all four scenario units two additional options are available: (a) to quantify the effect of a given crop-free zone on downwind spray deposits and (b) the other way around, to compute the required crop-free zone when a given level of spray drift deposits is to be reached. These two options apply to the selected crop and sprayer settings.

1 Introduction

In agriculture, the use of chemicals still is an essential way of protecting crops against all kinds of harmful plagues (weeds, pests, diseases). Nevertheless, the application of pesticides should be done with the greatest care to minimize unwanted side-effects and to protect the environment. Common application techniques involve the use of spraying equipment to transfer the chemicals to the target (usually the crop to be protected). Off-target deposits of spray drops should be minimized to protect non-target organisms outside the sprayed area. This involves both aquatic organisms in edge-of-field waterbodies and terrestrial organisms living just outside the sprayed area.

The last two decades many experiments were carried out to investigate downwind spray deposits under varying circumstances for field crops, fruit orchards and avenue tree nurseries (Van de Zande *et al.*, 2012, 2019). The experiments were analysed statistically, and the results are available as regression curves of spray deposits as a function of downwind distance.

In 2003 the IMAG Drift Calculator was introduced to compute downwind deposits of spray drift next to field crops and fruit orchards. Back then only a limited number of cases was investigated experimentally and implemented in the model. At present, a more consistent system of application techniques involving a classification of drift reducing techniques (DRT) is available. So the WUR Drift Calculator (WDC) described in this report has more flexibility and can be used in more situations. Drift reducing techniques are classified according to their potential to reduce drift deposits on the surface of the standardized ditch with respect to the reference application technique, considering full-grown crops or trees in full leaf (Van de Zande *et al.*, 2012). The protocol for classification of drift reducing spray application techniques is defined by the Ministry of Infrastructure and Water Management (MinI&W, 2017). Several classes of drift reduction are defined. For instance, DRT50 indicates an application technique that reduces deposits of spray drift by at least 50% (but less than 75%) at the water surface of the standardized ditch. Classes DRT75 through DRT99 are defined in a similar way. For a full list of accepted drift reducing techniques, see TCT (2020).

Table 1 gives an overview of the situations covered by the WUR Drift Calculator, identified by crop type (including growth stage) and application technique. The application techniques that are currently available differ for different crop types, as indicated in the table below. For each of the seven crop types (including sub-types) a separate reference application technique was identified. For non-selectable options in Table 1, currently no application techniques are available in practice or no experiments have been carried out with such spraying equipment. For each of the selectable options in Table 1 a regression curve is present for the drift deposition in relation to the distance from the sprayed crop.

Table 1 Available application techniques for various crop types in the WUR Drift Calculator¹⁾.

Crop type	Sub type	Reference technique	DRT50	DRT75	DRT90	DRT95	DRT97.5	DRT99
Field crops	bare soil	x	x	x	x	x	x	x
	full-grown	x	x	x	x	x	x	x
Fruit trees	dormant	x	x	x	x	x	x	x
	in full leaf	x	x	x	x	x	x	x
High avenue trees		x	x	x		x		
Transplanted trees		x	x		x			
Spindle trees		x	x		x			

¹⁾ Empty cells imply that no application techniques are available.

For each DRT class one actual application technique was selected as a representative, close to the lower boundary of that class, offering a conservative approach. Table 2 gives the selected application techniques for field spraying (van de Zande *et al.*, 2012; 2006; Van de Zande, 2012; Stallinga, *et al.*, 2003); all techniques involve the use of an end nozzle at the position of the last nozzle at the boom, as required by the Environmental Activity Decree (EAD) when an edge-of-field waterbody is present (MinI&W, 2021). Similarly, for spraying in fruit orchards, Table 3 shows the representative application techniques for the different application classes (Van de Zande *et al.*, 2019). Finally, Table 4 shows the application techniques for spraying of avenue trees (Van de Zande *et al.*, 2019). Currently, the EAD requires the use of at least a 75% drift reducing application technique (MinI&W, 2021).

Table 2 Selected application techniques for downward field spraying as representatives for drift reduction classes 50%, 75%, 90%, 95%, 97.5% and 99% in the Netherlands. (Van de Zande, 2012, Van de Zande, *et al.*, 2012, 2006; Stallinga, *et al.*, 2003).

Drift reduction class	Spray drift reduction technology in drift reduction class
50%	50% drift reducing nozzles
75%	75% drift reducing nozzles
90%	50% drift reducing nozzles, air-assisted boom sprayer
95%	90% drift reducing nozzles, air-assisted boom sprayer
97.5%	Hardi Twin Force air-assisted sprayer with 50% drift reducing nozzles and end-nozzle
99%	floating nozzle sprayer (e.g. Släpduk, Wingssprayer) with 50% drift reducing nozzles and end-nozzle

Table 3 Selected application techniques for orchard spraying (upward/sideways) as representatives for drift reduction classes 50%, 75%, 90%, 95%, 97.5% and 99% in the Netherlands. (Van de Zande, *et al.*, 2019).

Drift reduction class	Spray drift reduction technology in drift reduction class
50%	sensor sprayer equipped with standard nozzles
75%	cross-flow sprayer using 75% drift reducing nozzle types, outside row sprayed one-sided
90%	cross-flow sprayer using 90% drift reducing nozzle types, outside row sprayed one-sided
95%	cross-flow sprayer using 90% drift reducing nozzle types, low air setting, outside row sprayed one-sided
97.5%	KWH 3-row sprayer equipped with 90% drift reducing nozzles
99%	KWH 3-row sprayer equipped with 90% drift reducing nozzles, with reduced variable air assistance (400 rpm PTO)

Table 4 Selected application techniques for upward/sideways spraying in avenue tree nurseries; representatives for drift reduction classes 50%, 75%, 90% and 95% in the Netherlands. (Van de Zande, *et al.*, 2019).

Drift reduction class	Spray drift reduction technology in drift reduction class ¹⁾	
	Spindles and transplanted trees	High trees
50%	conventional sprayer with 50% drift reducing nozzles	mast sprayer with 90% drift reducing nozzles
75%	n/a	mast sprayer with standard nozzles, with gap-detection sensor
90%	conventional sprayer with 95% drift reducing nozzles	n/a
95%	n/a	mast sprayer with 90% drift reducing nozzles, with gap-detection sensor

¹⁾ n/a = not available.

Spray drift deposits onto an adjacent waterbody are evaluated for a ditch with standardized geometry and location. This standard ditch was defined as the common edge-of-field ditch in the Netherlands, see Figure 1 (Huijsmans *et al.*, 1997). The water surface has a width of 1.0 m, the banks have a horizontal width of 1.5 m. The crop-free zone is defined as the distance from the centre of the last crop row (or tree row) to the field edge, which equals the onset of the first bank (MinI&W, 2017).

For non-target arthropods and plants, different (terrestrial) evaluation zones are defined. This is part of the NL-specific aspects of risk assessment, as described in the CTGB's Evaluation Manual (CTGB, 2020a). For field crops, the evaluation zone for risk assessment of non-target arthropods (NTA) is located at 0.5 – 1.5 m from the centre of the last crop row. Since this is very close to the sprayed area, often part of this zone is sprayed directly by the last few nozzles (so-called 'overspray'). For non-target plants (NTP) the evaluation zone is located at 1.5 – 2.5 m from the centre of the last crop row. In this case the risk of overspray is much less.

For fruit orchards the location of the NTA and NTP evaluation zones is equal. It is defined as a 1.0 m wide zone centred at the field edge. With the minimal agronomic crop-free zone of 3.0 m, the NTA/NTP evaluation zone is located at 2.5 – 3.5 m from the last tree row. For avenue tree nurseries the same definition applies. For spindles the crop-free zone is 1.5 m, so the NTA/NTP evaluation zone is located at 1.0 – 2.0m from the last tree row. With transplanted and high trees, the crop-free zone is 2.0 m wide, so the evaluation zone is at 1.5 – 2.5 m from the last tree row. These distances are summarized in Table 6 below.

Table 6 Location of evaluation zone for risk assessment for non-target arthropods and non-target plants in different crops.

Crop type	Protection goal	Evaluation zone [m] ¹⁾
Field crops	Non-target arthropods (NTA)	0.5 – 1.5
	Non-target plants (NTP)	1.5 – 2.5
Fruit trees	NTA/NTP	2.5 – 3.5
High avenue trees	NTA/NTP	1.5 – 2.5
Transplanted trees	NTA/NTP	1.5 – 2.5
Spindle trees	NTA/NTP	1.0 – 2.0

¹⁾ Distance from centre of last crop row or tree row.

1.1 How to use this manual

The WUR Drift Calculator (WDC) is a useful tool to compute spray drift deposits on a downwind evaluation zone. To quantify such deposits, experiments that were carried out throughout the years were combined and regression curves ('drift curves') were fitted to these data as a function of downwind distance from the sprayed crop. Chapter 2 gives an introduction to these drift curves for both conventional and drift reducing application techniques in the relevant crops. It serves as a background to the calculator itself; the calculator can be used without reading Chapter 2.

In Chapter 3 information is given on how to install the WUR Drift Calculator. Software requirements and first start-up are mentioned also.

Clearly a major part of this manual is concerned with the actual use of the drift calculator. This is described in detail in Chapter 4. The four main calculation units are described corresponding to the four basic scenarios:

- Spray drift deposits onto edge-of-field watercourses next to field crops
- Spray drift deposits onto edge-of-field watercourses next to fruit orchards and avenue tree nurseries
- Spray drift deposits onto non-target terrestrial area (plants, arthropods) next to field crops
- Spray drift deposits onto non-target terrestrial area (plants, arthropods) next to fruit orchards and avenue tree nurseries

Each of the corresponding calculation units is described separately.

Finally, conclusions follow in Chapter 5, with final remarks and future perspective.

2 Spray drift curves

2.1 General set-up

For all situations, downwind deposits of spray drift are computed in a two-phase set-up. Firstly, the deposits for the reference application technique is computed. Secondly, if a drift reducing technique is involved, the corresponding relative drift reduction is computed. In combining deposits from the reference case and the reduction factor for the drift reducing technique, downwind spray deposits can be computed for every case and every downwind distance.

Drift deposits for the reference spray application is computed by:

$$y = (A_0 e^{-A_1(x-p)} + B_0 e^{-B_1(x-p)}) / (1 + C_0 e^{-B_1(x-p)}) \quad (1)$$

where y are the deposits (usually given as percentage of the applied dose), x is the distance downwind from the centre of the last crop row or tree row, p is the position of the last nozzle relative to the last crop row. A₀ through C₀ are constants depending on crop type and crop stage. The constants A₀ through C₀ are given in Annex 1 for the reference application techniques in field crops, fruit tree orchards and avenue tree nurseries (Table 1-1).

By definition, p>0 when the last nozzle is downwind from the last crop row. In the Introduction section it was mentioned that nozzle position p can take values 0.125, 0.0 and -0.25 m. In fact, x-p is the distance from the last nozzle to the location where drift deposits are evaluated ¹. When the nozzle is downwind from the last crop row (p>0), then the nozzle is closer to the deposition area (i.e. the distance x-p has decreased) and the spray drift deposits increase. For upward and sideways spraying in fruit orchards and avenue tree nurseries, (horizontal) nozzle position is not an issue and p=0 by definition.

The numerator is the sum of two exponential functions. The denominator acts as a correction for small distances, limiting the drift values at small distances. At large distances, the denominator approaches 1 and the function approximates the sum of two exponentials as given by the numerator. In some cases the sum of two exponentials can describe the drift curve sufficiently well (without having to use the denominator part); in those cases the same equation can be used with C₀=0 (as given in Table 1-1, Annex 1).

Relative drift reduction is a function of downwind distance as well, and the following equation is used:

$$R = P_0 e^{-P_1(x-p)} + Q_0 e^{-Q_1(x-p)} + S_0 \quad (2)$$

Where R is the relative drift reduction, a value between 0 and 1. The constants P₀ through S₀ depend on crop type, crop stage and application technique. Their values are given in Table 1-2 (Annex 1). With fruit trees, a single exponential could describe the reduction factor curve sufficiently well; this is equivalent to setting Q₀ and Q₁ to zero in those cases.

The mathematical nature of Eq.(2) is such that, depending on the value of the constants, R may take values outside the range 0 through 1 for certain distances. In those cases, R is assumed to take the corresponding boundary value (0 for R<0 and 1 for R>1). Effectively, this means that drift reductions should be physically realistic (R≤1) and drift reducing techniques will never increase drift deposits compared to the reference technique (R≥0).

The following sections describe the drift curves and reduction curves for the various crop types separately.

¹ This shows that the spray drift equation actually is a function of distance between last nozzle and downwind evaluation point (x).

2.2 Field crops

As given in the previous section, drift with a reference application technique is described by Eq.(1) and the subsequent drift reduction factor is given by Eq.(2). In the full-grown crop situation, the sum of two exponentials could describe the drift curve sufficiently well; in fact achieved by setting $C_0=0$. Figure 2 shows drift curves for the reference application technique on a full-grown crop and on bare soil. The dots are averaged measured deposits; the lines represent fitted drift curves according to Eq.(1). The vertical dashed lines indicate the location of the water surface of the standard ditch for 'other' (not intensively sprayed) field crops (2.0 – 3.0 m; see Table 5). For intensively sprayed crops the water surface is located at 3.0 – 4.0 m.

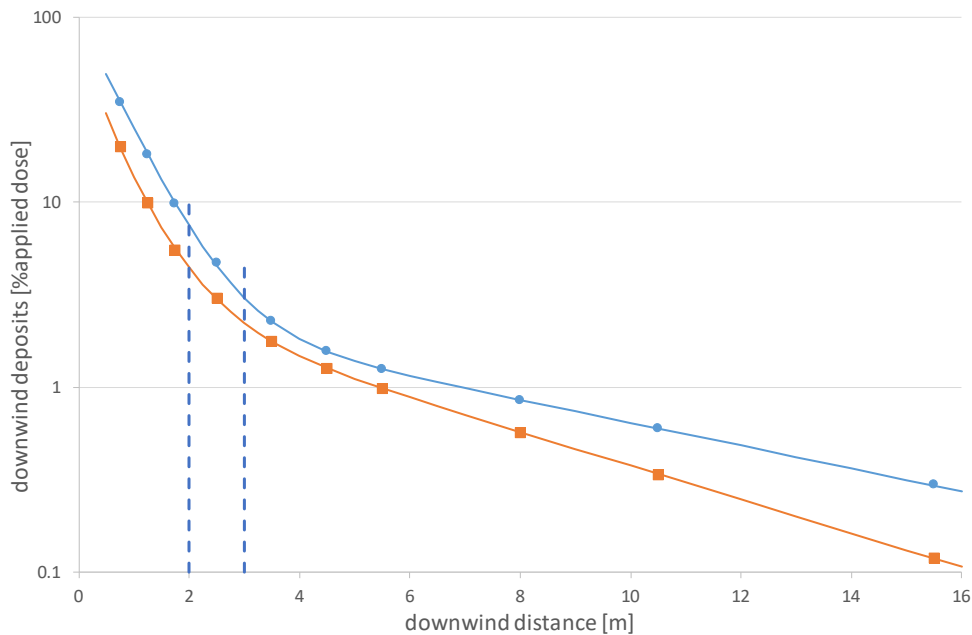


Figure 2 Downwind spray deposits as a function of distance from centre of last crop row; for field crops; reference application technique in full-grown crop and on bare soil. Last nozzle is positioned above last crop row ($p=0$). Dots: measured deposits (average); solid lines: fitted curves (Eq.(1)); dashed lines: indicate where the water surface of the standard ditch is located (for 'other', not intensively sprayed crops; Table 5).

The drift reduction equation (2) is fitted to experimental data for applications on full-grown field crops and bare soil, as shown in Figure 3. The dots indicate the measured reductions, the lines show the fitted curves. The top graph represents applications onto a full-grown crop, the bottom graph represents bare soil applications. In some situations (DRT50 and DRT90 for a full-grown crop) a single exponential could describe the reduction factor curve sufficiently well; in those cases, Q_0 and Q_1 are effectively set to zero.

It may seem odd that an application technique classified as DRT50 (or any other class), intuitively implying 50% reduction of spray drift deposits, shows a drift reduction which is not equal to 50% for many distances downwind. The DRT system is based on the assessment of spray drift reduction for a full-grown field crop on a given evaluation zone; for field crops it is defined as the zone 2 – 3 m downwind from the last nozzle (MinI&W, 2017). Typically, this corresponds to the location of the water surface of the standard ditch for 'other' crops, if the last nozzle is positioned above the centre of the last crop row (Table 5). This definition of DRT classes does not make any claims on drift reduction level at other distances; the actual drift reduction of a certain application technique can be higher or lower at distances other than the DRT evaluation distance, or with an application on bare soil. Indeed, the graphs of Figure 3 show that for instance for DRT75 the reductions fall below its 75% level for distances further downwind than about 5 m. Similarly, the reduction for DRT95 can be less than 95% further downwind than the evaluation distance of the standardized ditch. This has some peculiar

practical consequences. For instance, the performance of the DRT95 technique for a full-grown crop is worse (that is, it gives less reduction) than the DRT90 technique on distances 6 m downwind and beyond. This can be seen in Figure 3 where the lines for DRT95 and DRT90 cross. Similarly, DRT75 may give less reduction than DRT50 on specific distances.

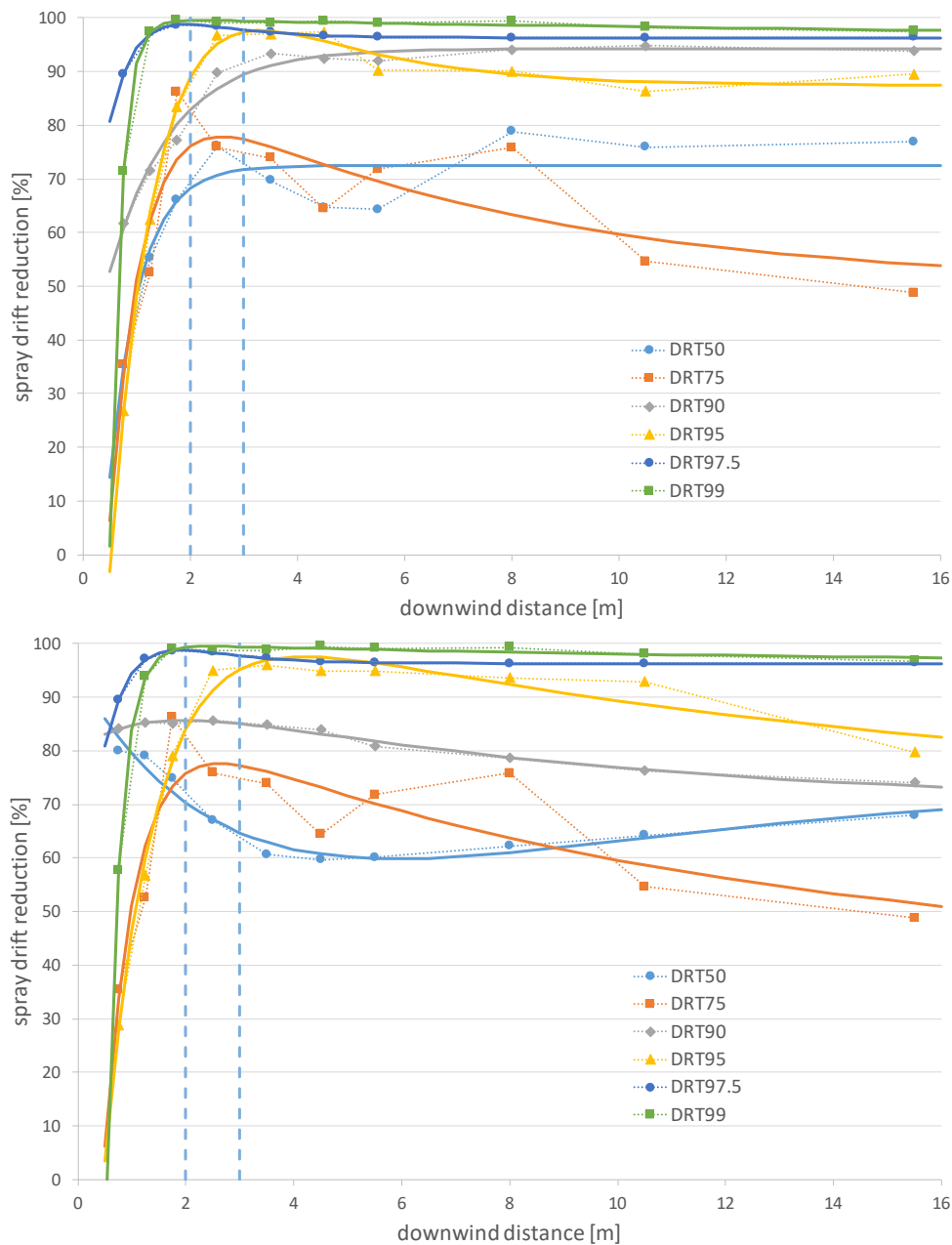


Figure 3 Reductions of spray drift deposits downwind from field crops as a function of distance from centre of last crop row, for all DRT techniques, with last nozzle position $p=0$; top: full-grown crop; bottom: bare soil. Dots: measured reductions; lines: fitted curves based on Eq.(2); dashed lines: location of evaluation zone for DRT classification (2 – 3 m; MinI&W, 2017).

The actual drift deposits for drift reducing application techniques are computed by multiplying the drift values from the reference application techniques, Eq.(1), by $1-R$, from Eq.(2). The resulting drift curves of downwind spray deposits are shown in Figure 4 for full-grown crops (top) and bare soil (bottom). Again, here you can see clearly that several lines cross and result in higher spray drift deposits than that of a lower DRT class. Particularly close to the edge of the crop ($x < 2$ m) the drift reduction is low and all drift curves get very close and may cross several other lines. This limits the mitigation possibilities of drift reducing techniques for NTA and NTP evaluations as these are evaluated on zones close to the crop.

Figure 4 shows that the shape of the curve for DRT95 is a major cause of the 'problem of crossing lines'. Partly this is caused by the selection of the representative application technique (Table 2 in the Introduction). Currently, it has not been investigated whether a different choice of the representative application technique would have led to a 'better' (non-crossing) reduction curve; see also Conclusions and Recommendations. The consequences of this problem are discussed in Section 2.5 and, for the time being, a pragmatic solution has been proposed and implemented.

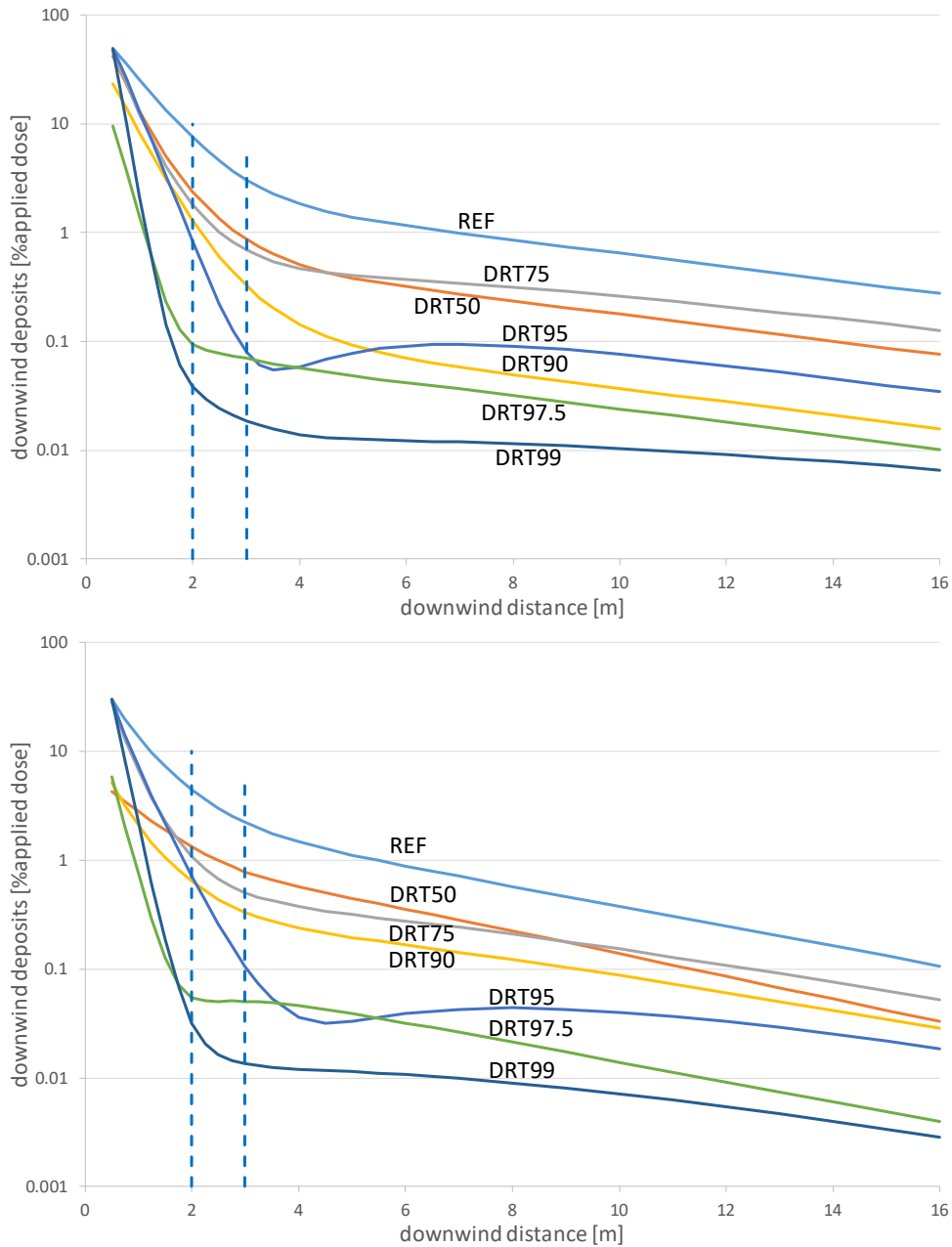


Figure 4 Downwind spray deposits as a function of distance from last crop row, for field crops, for each application technique; with last nozzle position $p=0$. Top: full-grown crop; bottom: bare soil; dashed lines: location of evaluation zone for DRT classification (2 – 3 m; MinI&W, 2017).

2.3 Fruit orchards

In fruit orchards, fungicide and insecticide sprays are applied in upward and sideway direction. The drift curve for downwind spray deposits with the reference application technique is given by Eq.(1), the same equation as used for field crops but obviously with different constants (see Table 1-1 in Annex 1). Measured deposits and fitted drift curves for the reference application technique are shown in Figure 5. Drift deposits for the reference application technique in dormant trees appear to be about 1.5 – 2.5 times higher than those for trees in full leaf. The vertical dashed lines indicate the location of the water surface of the standard ditch, when the crop-free zone is 4.5 m (see Table 5, Introduction).

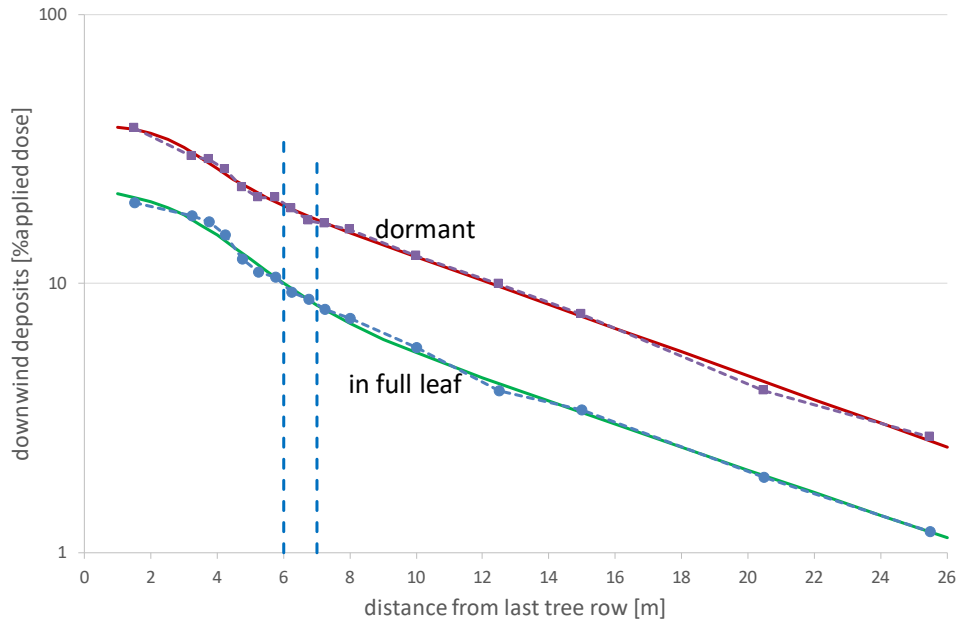


Figure 5 Downwind deposits of spray drift next to fruit trees as a function of distance from the centre of the last tree row, for the reference application technique. Dots: measured deposits; solid lines: fitted curves based on Eq.(1); dashed lines: location of water surface of the standard ditch, with a crop-free zone of 4.5 m (Table 5).

Subsequent drift reducing techniques combine the reference drift curve with an appropriate reduction curve, as given by Eq.(2). However, for fruit orchards, the equation for drift reductions can be simplified by putting Q_0 and Q_1 to zero, effectively using only a single exponential (plus constant S_0):

$$R = P_0 e^{-P_1 x} + S_0 \quad (3)$$

Constants P_0 , P_1 and S_0 are given in Table 1-2 (Annex 1). In all cases $P_0 < 0$ and both P_1 and S_0 are > 0 . This implies that R is an increasing function of distance, asymptotically approaching S_0 for large distances. The measured reductions (dots) and fitted reduction curves (lines) are shown in Figure 6 for both trees in full leaf (top) and dormant trees (bottom). With fruit orchards the evaluation zone for DRT classification is 4.5 – 5.5 m from the centre of the last tree row, implicitly assuming a crop-free zone of 3.0 m (MinI&W, 2017). This is indicated by the vertical dashed lines in Figure 6. Note that according to the EAD the water surface is located at 6.0 – 7.0 m when a DRT75 technique is used (Table 5). For trees in full leaf, the drift reduction curves are ordered nicely on top of each other: techniques with higher DRT classification indeed give higher reductions. For dormant trees, in general the drift reductions are lower than with trees in full leaf. Note that with dormant trees the DRT97.5 technique gives less drift reduction than the DRT95 technique. As before, the DRT classification is based on reductions achieved on the evaluation zone with trees in full leaf, while in other situations this reduction may not be achieved.

Multiplying the reference curve and the subsequent reduction curves gives the drift curves for all application techniques. Figure 7-top shows the resulting curves for drift deposits next to trees in full leaf, while the bottom graph shows the drift curves for dormant trees. For small distances (<2 m) and for some larger distances with dormant trees, the problem of crossing lines may occur; see also section 2.5.

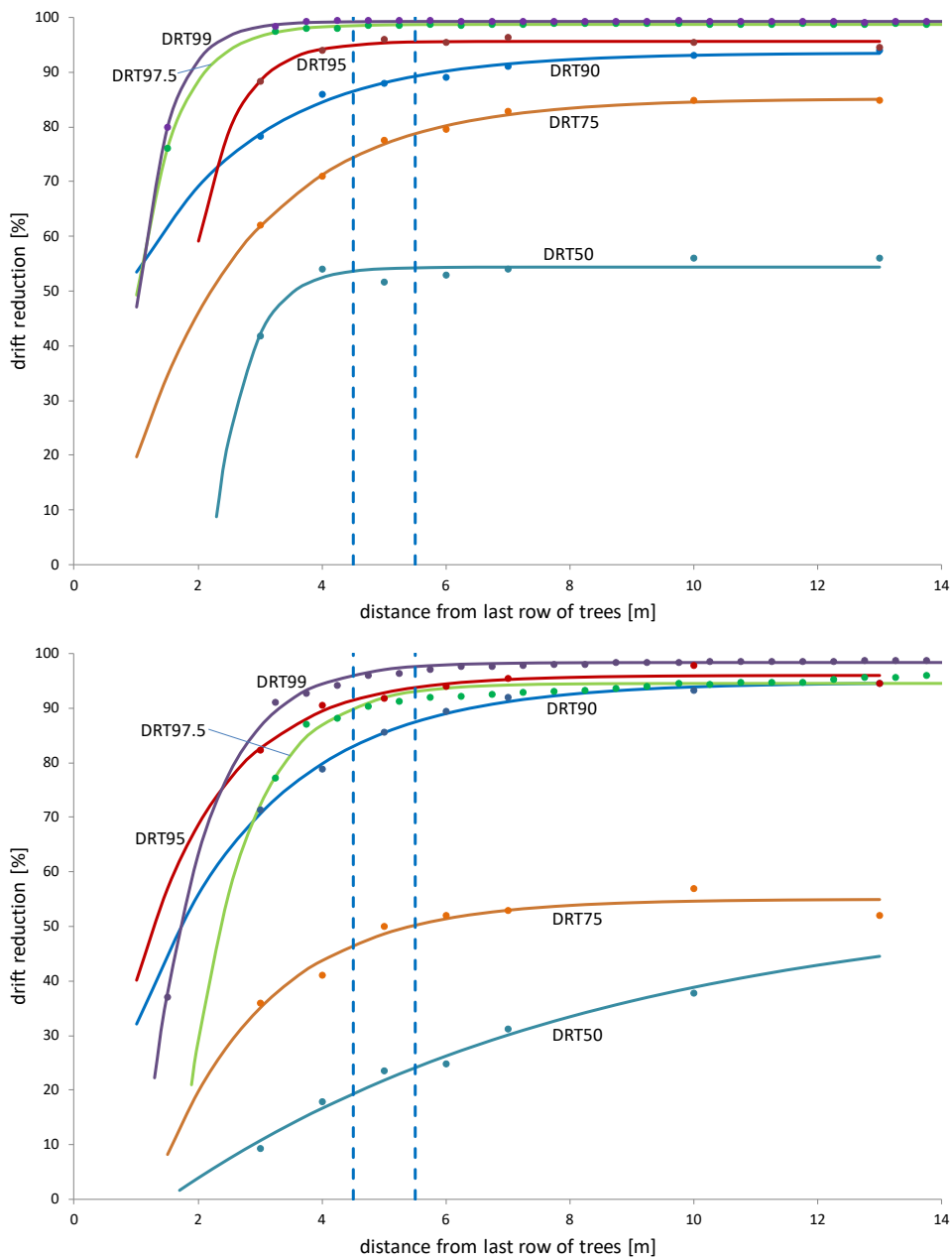


Figure 6 Reductions of spray drift deposits downwind from fruit tree orchards as a function of distance from the centre of the last tree row; for all DRT techniques; top: trees in full leaf; bottom: dormant trees. Dots: measured reductions; lines: fitted curves based on Eq.(3); dashed lines: indicate the location of the evaluation zone for DRT classification (4.5 – 5.5 m; MinI&W, 2017); this corresponds to a crop-free zone of 3.0 m.

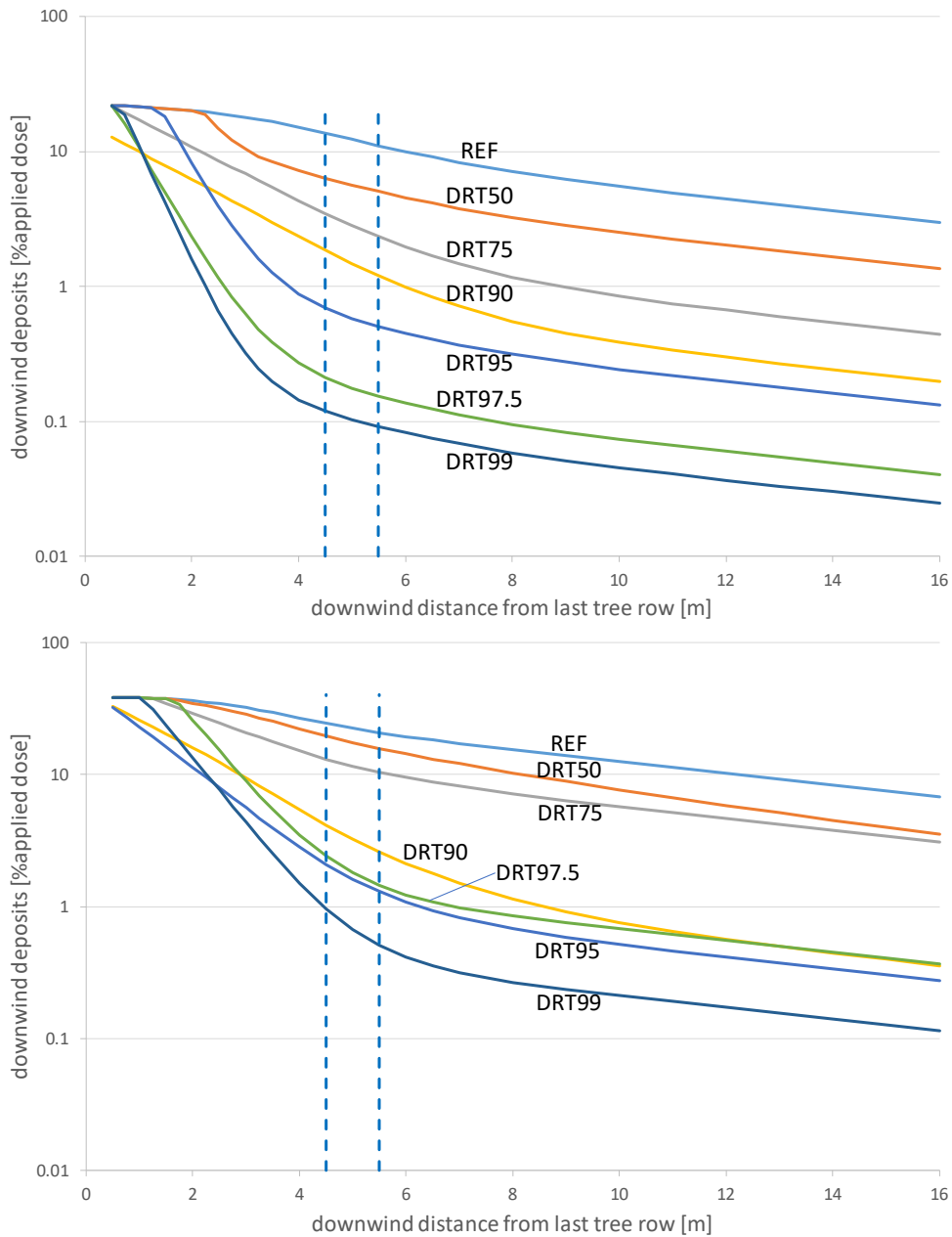


Figure 7 Downwind deposits of spray drift next to fruit trees as a function of the distance from the centre of the last tree row; for various DRT techniques; top: trees in full leaf; bottom: dormant trees; dashed lines indicate the location of evaluation zone for DRT classification (4.5 – 5.5 m; MinI&W, 2017).

2.4 Avenue tree nurseries

In general, avenue tree nurseries are distinguished into three groups based on the growth stage of the trees, which is reflected in the way the trees are planted and pruned. Young avenue trees are closely planted as 'spindles'. After some years these trees are repositioned ('transplanted') with larger intra-row and inter-row distances, allowing further development of branches. In the last stage of the avenue tree nurseries ('high avenue trees') the trees can grow much higher and the lower branches are pruned to have clear stems underneath. Spray drift measurements in these three stages resulted in different downwind deposits of spray drift, with lowest deposits in the spindles stage and highest deposits in the third stage. Figure 8 shows the spray drift results from measurements (dots) together with fitted curved (lines), based on Eq.(1). The dashed vertical lines indicate the location of the water surface of the standard ditch (6.5 – 7.5 m), taking into account the requirement of the EAD to have a crop-free zone of 5.0 m (see Table 5, Introduction).

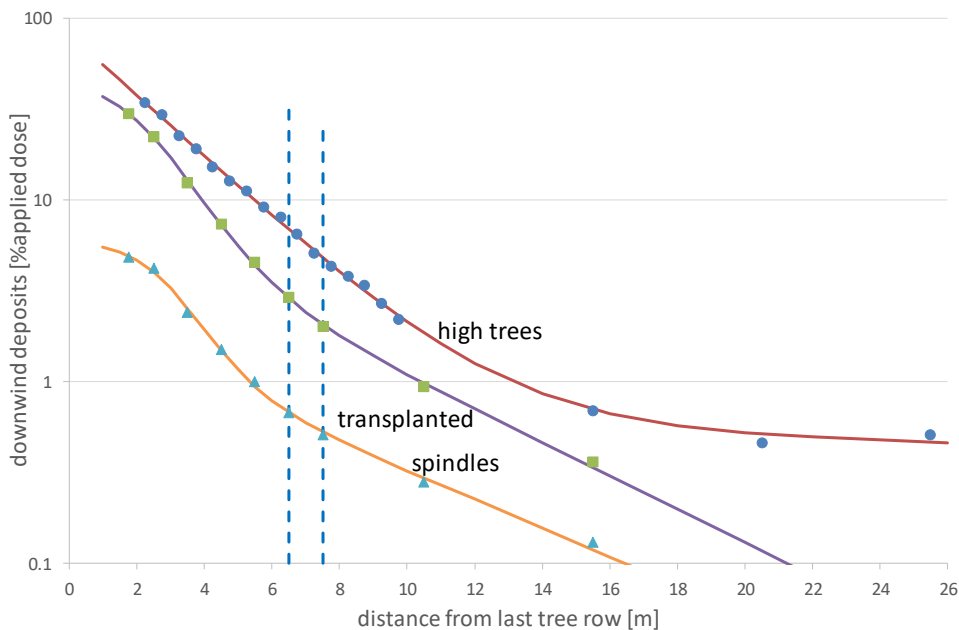


Figure 8 Downwind deposits of spray drift next to avenue tree nurseries as a function of distance from the centre of the last tree row, for the reference application technique. Dots: measured deposits; solid lines: fitted curves based on Eq.(1); dashed lines: location of the water surface of the standard ditch according to the EAD (6.5 – 7.5 m; Table 5).

For each group of avenue tree nurseries several drift reducing techniques have been evaluated. Measured drift reductions and fitted curves, using Eq.(2), are shown in Figure 9. The measurements are shown by the dots and connecting dotted lines, showing these are slightly erratic, mainly due to the limited number of experiments available. Therefore, considering the relatively large uncertainty, it makes no sense to try to fit the smooth solid lines too closely to the measured reductions and the given curves can represent actual drift reductions sufficiently well.

The top graph in Figure 9 shows that for high avenue trees the drift reduction curve of DRT75 crosses the DRT50 curve at about 7.5 m. Similar to several cases with field crops and fruit orchards, this causes a problem of crossing lines; see also Section 2.5.

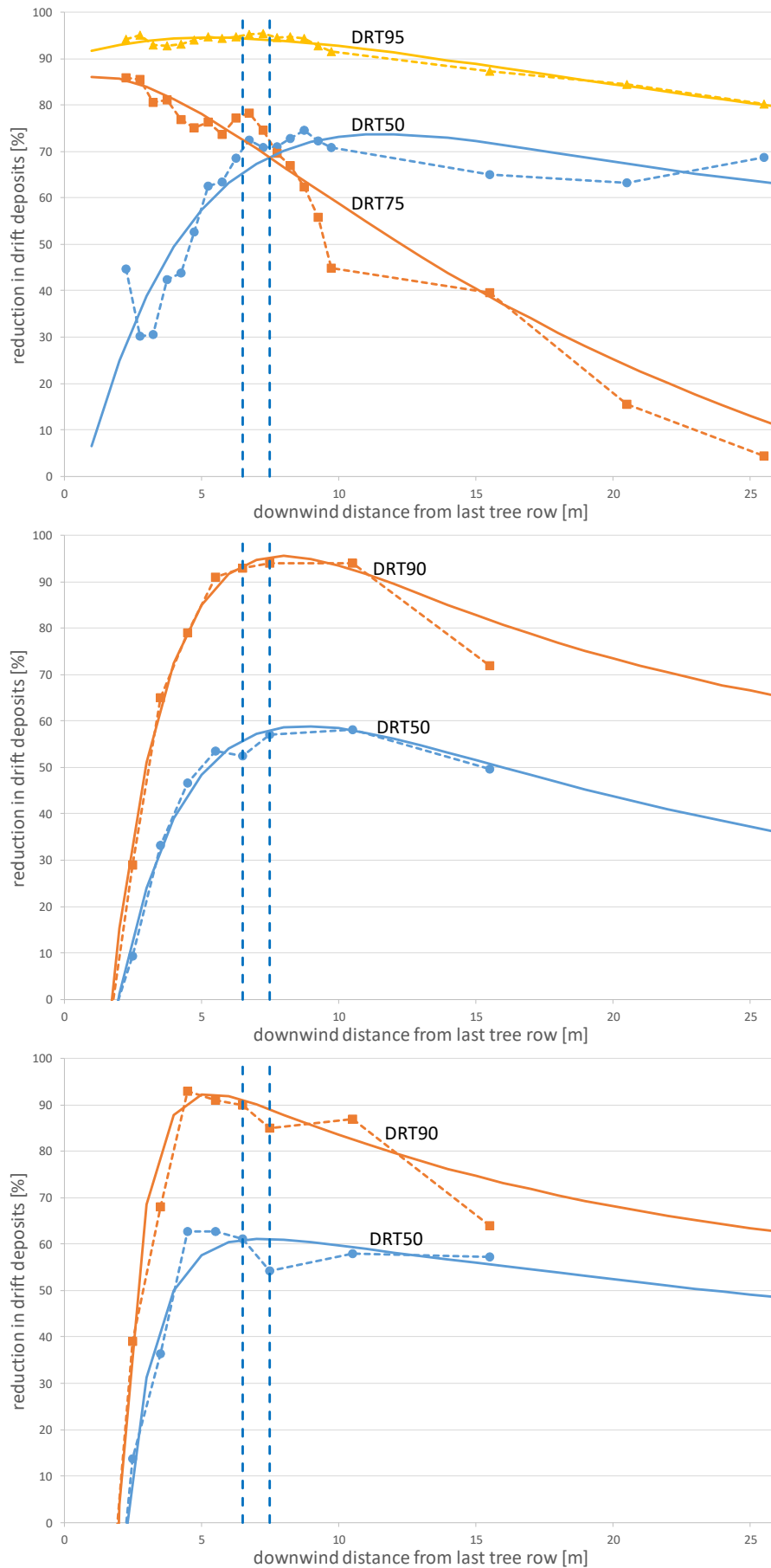


Figure 9 Reductions of spray drift deposits downwind from avenue tree nurseries as a function of distance; measured reductions (dots) and fitted curves (solid lines; Eq.(2)); top: high avenue trees; middle: transplanted trees; bottom: spindle trees; dashed lines indicate the evaluation zone for DRT classification, which for avenue trees equals the water surface of the standard ditch (6.5 – 7.5 m), with a crop-free zone of 5.0 m according to the EAD (Table 5).

2.5 Dealing with inconsistent drift reduction sequence

Ideally, drift reduction curves are expected to show a consistent behaviour: higher DRT classes should always give higher drift reductions for downwind spray deposits. In the previous sections (2.2, 2.3, 2.4) it was mentioned that drift reduction curves not always showed such expected behaviour. This may lead to unwanted situations where a higher DRT class gives less protection. This was called the 'problem of crossing lines'. Solving this problem is not an easy task, given the experimental drift curves that are available. In Chapter 5 a few possible solutions are discussed.

For the time being, the problem has been solved pragmatically in the WDC software as follows. Firstly, spray drift deposits are computed for a given scenario using the curves as they are. Secondly, drift deposits are determined for the same scenario but for all higher DRT classes. Then the highest deposits of this set of results represent the worst case and are to be used for the requested scenario as well. For instance, for a full-grown crop, intensively sprayed, the evaluation zone for surface water is at 3.0 – 4.0 m (Table 5). If the requested scenario involves a DRT95 technique, then drift deposits for DRT97.5 and DRT99 are determined as well. The graph of Figure 4 (Section 2.2) shows that the deposits for DRT97.5 at the evaluation zone are higher than those for DRT95 and DRT99, so the requested scenario (DRT95) has to use the higher deposits of DRT97.5. Note that if the initial scenario request would have been for DRT97.5, then the same spray drift deposits would have been found. This method has been implemented in the software for any possible scenario, that is, in risk assessment for surface water, NTA and NTP and at all distances. It has been applied to both field crops and fruit tree and avenue tree orchards.

3 Getting started

The WUR Drift Calculator (WDC) is an independent software application, developed and supplied by Wageningen Plant Research, business unit Agrosystems Research. Installing the software package is dealt with in the next section.

3.1 Installation of the WUR Drift Calculator

Installation is kept very simple. The installation file WDC26setup.exe unzips five files and copies them into the default folder c:\Program Files (x86)\WUR Drift Calculator or any folder the user can select instead. If not present, the folder will be created first. The folder name can be set manually just before unzipping, if necessary. The unzipped files are:

- WDC26_32.exe: the actual WUR Drift Calculator program for 32bits systems
- WDC26_64.exe: the actual WUR Drift Calculator program for 64bits systems
- WDC26manual.pdf: this manual as a PDF file
- WDC26help.chm: offline help file connected to the software
- Readme_WDC26.txt: text file with latest information and instructions.

For the software to work adequately, it is important to have all these files in the same folder. Occasionally, the online help file (.chm) may not open properly when the package is installed on a network drive. This is due to a security feature of Microsoft regarding the use of .chm files. If this problem occurs, the package may be installed on a local drive instead. Note that all the above files must be placed in the same folder.

3.2 Requirements

To run the program no additional files are needed. Installing the calculator requires about 10MB of disk space. Run-time memory consumption is about 10MB. The program is developed and tested on a 64bits system with Windows 10. Fatal run-time errors are expected if the decimal symbol is not set to a dot (.).

3.3 Start-up

The drift calculator is started from the Windows Explorer by starting the program file WDC.exe (usually by double-clicking the file). It may be convenient to create a shortcut on the desktop or in the start menu.

The opening window (Figure 10) shows the main menu:

- General info: provides a short introduction to the calculator by opening the .chm help file
- Field crops, surface water: computation of spray drift deposits onto a standardized ditch next to field crops
- Field crops, non-target: computation of spray drift deposits onto the non-target area for arthropods (NTA) or plants (NTP) next to field crops
- Fruit and trees, surface water: computation of spray drift deposits onto a standardized ditch next to fruit orchards or avenue tree nurseries
- Fruit and trees, non-target: computation of spray drift deposits onto the non-target area for arthropods (NTA) or plants (NTP) next to fruit orchards or avenue tree nurseries
- Fruit and trees, herbicides: for downward spraying underneath fruit orchards and avenue trees; not implemented yet in software version 2.6
- Exit: closes the drift calculator.

On the lower left part of the screen, an indication of the software version and release code is given. How to use the calculator is described in the next chapter.

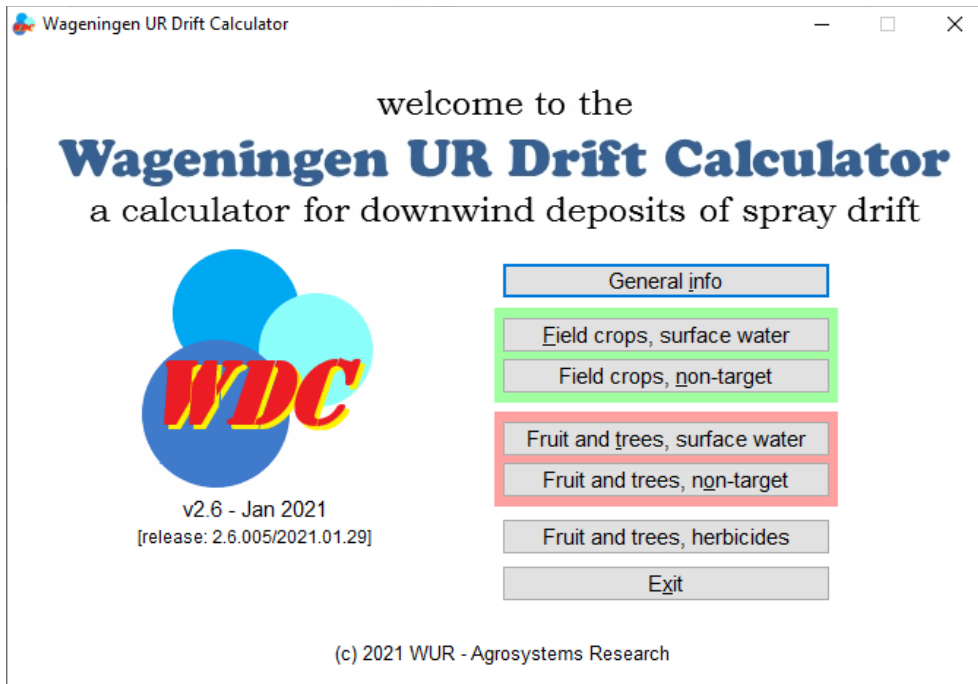


Figure 10 Opening window of the WUR Drift Calculator v2.6, showing the main menu.

4 Using the WUR Drift Calculator

The drift calculator currently has four main calculation units to compute deposits of spray drift onto:





- surface water next to field crops
- non-target ground area next to field crops
- surface water next to fruit orchards and avenue tree nurseries
- non-target ground area next to fruit orchards and avenue tree nurseries

Each unit has its own window. Various interactive processes by the user are performed by clicking 'action buttons'. These buttons are very similar for the four calculation units, and will be explained first (Section 4.1). How to use each of the computation units is explained in Sections 4.2 through 4.5. Sections 4.6 and 4.7 deal with the relation between crop-free zone and spray drift deposits.

4.1 Pictogram buttons

The calculator windows comprise small buttons for various actions. Each button has its own pictogram, which is explained in the table below. The column text reference specifies the button name that will be used in this manual to refer to one of these buttons.

Table 7 Action buttons; pictograms and explanations.

Button	Text reference	Explanation
	EXIT	closes the current window and return to previous window (usually main menu).
	HELP	opens file with relevant information on using current window or function
	CALC_CFZ	opens a window to calculate the crop-free zone, given a specified value of spray drift
	DRIFT_CFZ	opens a window to calculate the spray drift deposits, given a specified crop-free zone

EXIT button

Clicking the EXIT button closes the current window and the user returns to the previous window. Usually this is the main window (when closing one of the scenario windows). When closing a window for calculating the crop-free zone, the corresponding scenario window will return.

HELP button

The HELP button opens the help file WDC_help.chm at the page corresponding to the current window of the calculator. See Section 4.8.

CALC_CFZ button

By clicking this button, a new window opens, where the user can enter a drift value (%applied dose) and the required crop-free zone for this drift value is returned. Depending on the context (i.e. the window where the button was clicked), the crop-free zone is given for field crops, fruit or avenue trees, or for non-target ground areas, using all contextual settings of the current scenario. See Section 4.6.

DRIFT_CFZ button

By clicking this button, a new window opens, where the user can enter a crop-free zone (m) and the corresponding spray drift deposits are returned. Depending on the context (i.e. the window where the button was clicked), the spray drift deposits are computed at the surface of an edge-of-field ditch or at a non-target evaluation zone, using all contextual settings of the current scenario. See Section 4.7.

4.2 Field crops, spray drift deposits onto surface water

Figure 11 shows the window for computing spray drift deposits onto an edge-of-field watercourse next to a field crop. The window shows four boxes. On the left-hand side, in the box 'crop and application', various selections can be made regarding the crop type and sprayer type. The right-hand side shows a box with a schematic graph of the field and ditch with relevant distances and heights. The third box is at the bottom right of the window, showing computed results. A fourth box, bottom left, contains the action buttons mentioned in the previous section. In the next paragraphs the first three boxes will be dealt with in more detail.

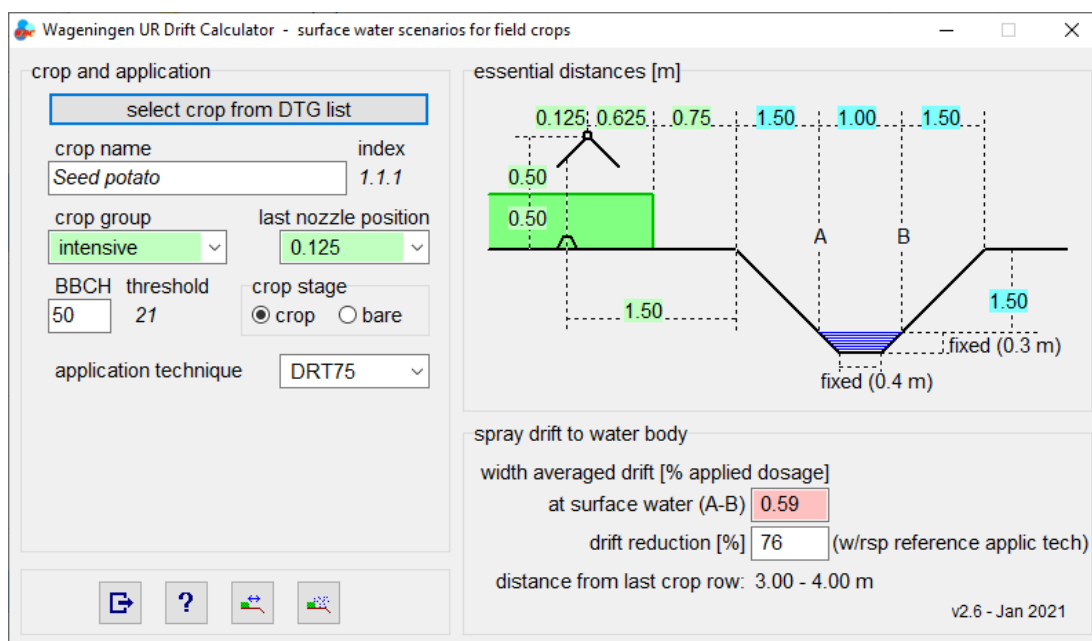


Figure 11 Window for computation of spray drift deposits onto a ditch next to a field crop, after selecting 'seed potato' from the DTG list.

Crop and application settings

In the first box (Figure 12, left) the button 'select crop from DTG list' can be used to select a field crop from the Dutch crop definition list, DTG (CTGB, 2019), and to adjust the crop's settings in this window. In this example the crop 'seed potato' has been selected, showing the crop name and the index in the DTG list. These two parameters are for informative purpose only. Seed potato belongs to the group of intensively sprayed crops, and the corresponding last nozzle position is 0.125 m. Both parameters are indicated in the box. 'Threshold' indicates the BBCH value (for growth stage) above which the crop height is more than 0.2 m; for each crop in the DTG list a threshold BBCH value has been determined (Van de Zande and Ter Horst, 2019). For a crop height <0.2 m the drift curves for 'bare soil' are used (indicated by the selection of 'bare' for crop stage), for higher crops the curves for full-grown crops are used (indicated by the selection of 'crop' for crop stage). As an arbitrary default, the BBCH for the scenario is set to 50, which is above the threshold for seed potato, so for crop stage the option 'crop' is selected automatically. The EAD prescribes the use of at least DRT75 application technique for field crops. Therefore, the option DRT75 is selected by default.

After selecting a crop from the DTG list, all relevant parameters can still be changed manually: crop group, last nozzle position, BBCH, crop stage and application technique. Since crop group and last nozzle position are closely linked to the selected DTG crop, a manual adjustment of these two parameters may have compromised the settings of the selected crop. To indicate that this may have occurred, the crop name and index are coloured red (Figure 12, right).

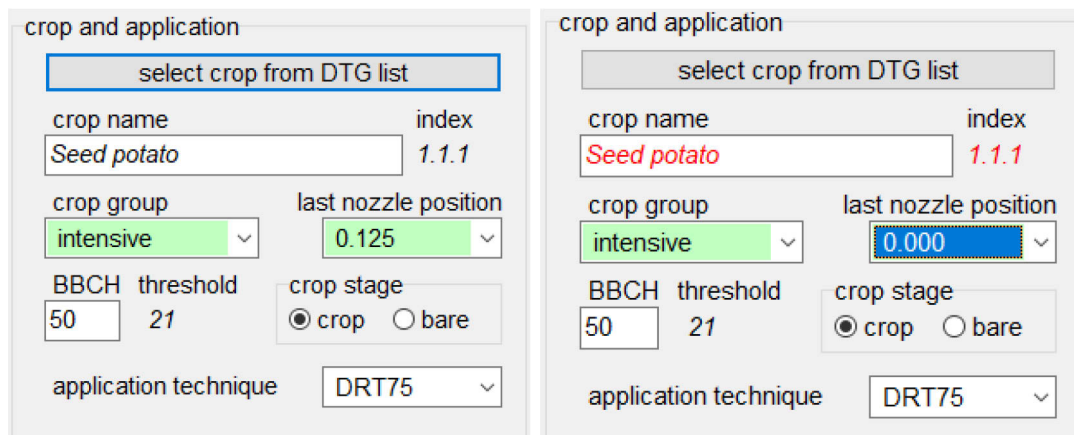


Figure 12 Box with information on the crop and the spray application. Right: after manually changing crop group or last nozzle position, the crop name and index are coloured red.

From the drop-down list for crop group, two categories can be selected: intensively sprayed crops and other crops. These crop categories differ in crop-free zone as defined by the EAD and the extension of the crop canopy with respect to the last crop row (see Table 5).

Depending on distance between crop rows, nozzle distance on the boom and width of the sprayer, in practice the last nozzle can have slightly different positions with respect to the last crop row. In the calculator three nozzle positions can be selected from a drop-down list: 0.125 m, 0.0 m and -0.25 cm. In the first case the nozzle is located 12.5 cm outside the centre of the last crop row. In the second case the last nozzle is exactly above the last row. In the third case the nozzle is 25 cm inward from the last crop row. Different crop categories and nozzle positions result in different spray drift deposits on the evaluation area.

Two crop growth stages can be selected: 'crop' (full-grown crop, indicated as 0.50 m height) or 'bare' (bare soil or emerging crop, indicated as <0.20 m height). The application technique can be selected from a drop-down list, showing the reference technique and one or more drift reducing techniques (DRTs). Only DRTs are shown that are available for the selected crop. Table 1 (Introduction) shows available application techniques for the different crops.

Using the DTG list

For field crops, the DTG list can be viewed and used for selection after clicking the button 'select crop from DTG list'. A new window opens, see Figure 13. A search string can be given to find a specific crop. Also a partial name can be used. After typing the search string, the button 'find (next)' must be clicked to activate the search process. Then the first crop in the list that matches the search string is selected. Subsequently pressing the 'find (next)' button shows further results, if present. In bold and red the selected crop and its index is shown just below the search box. Figure 14 gives an example after searching for 'beet' and repeating the search several times.

The button 'clear selection' obviously clears the selection. The first action button closes the window to return to the previous screen. If a crop was selected, its settings are copied into the scenario window (Figure 11). If no selection is available, the user is asked to confirm to return to the previous screen.

A crop can be selected also directly from the list, by searching it manually using the scroll bar on the right.

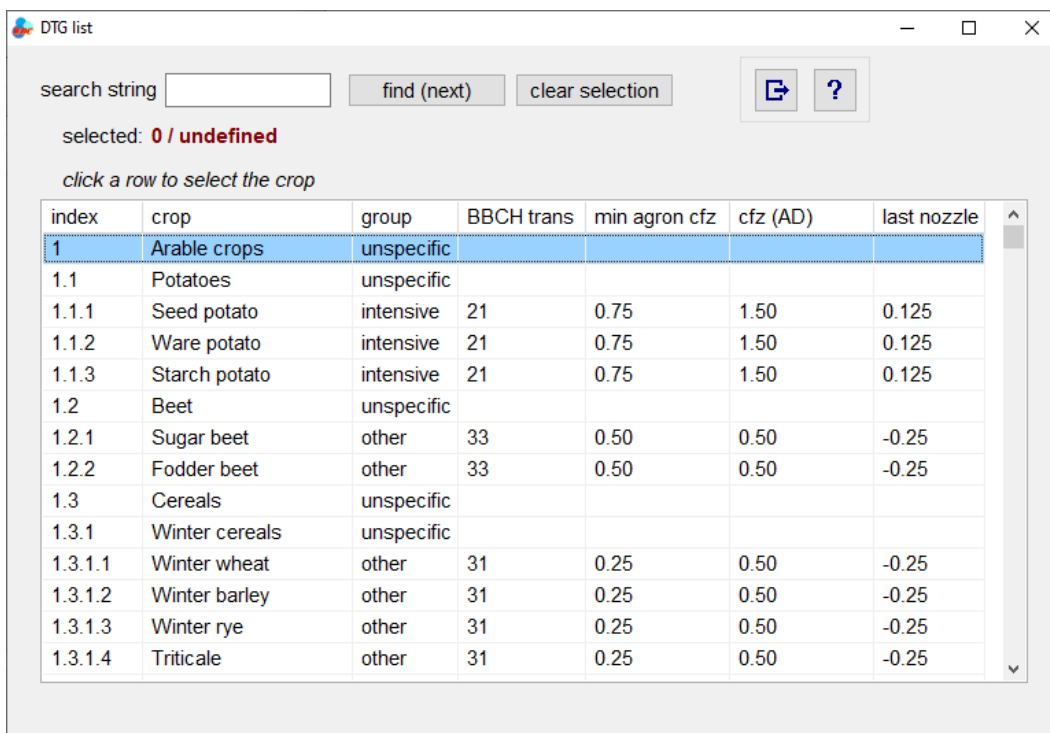


Figure 13 Window showing the built-in DTG list of field crops.

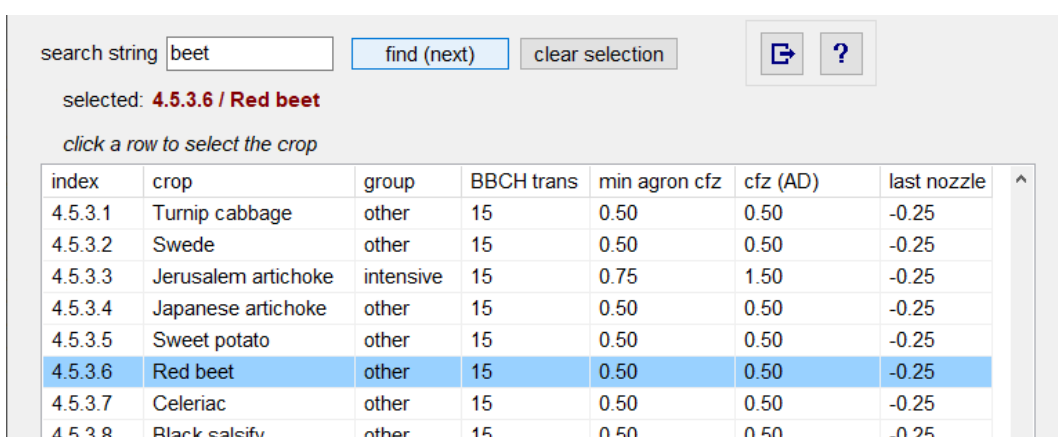


Figure 14 Example using the search option to find a specific crop.

Field and ditch layout

The second box of Figure 11 gives a schematic view of the field layout (Figure 15). Distances and heights are shown as well. Values in small green boxes correspond to crop settings; these may change according to the settings of crop and sprayer as described above. Small blue boxes refer to the geometry of the ditch. In the current version of the WUR Drift Calculator only the Dutch standardized ditch is available, so the geometry of the ditch does not change. Moving the mouse over a small box gives a hint on what the box refers to.

Depending on the position of the last nozzle and whether the crop stage is 'crop' or 'bare', the layout could be changed accordingly, see Figure 16. The nozzle position is marked yellow when it is left of the crop row. In general, when a distance equals 0 the appropriate text box is marked yellow as well.

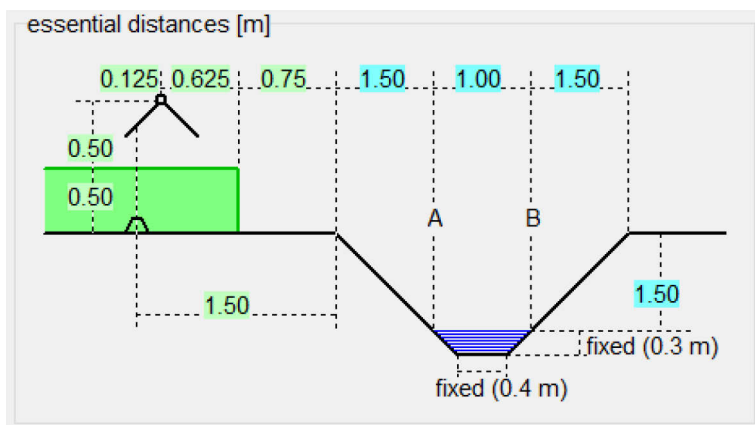


Figure 15 Schematic layout of field crop and ditch, showing distances and heights.

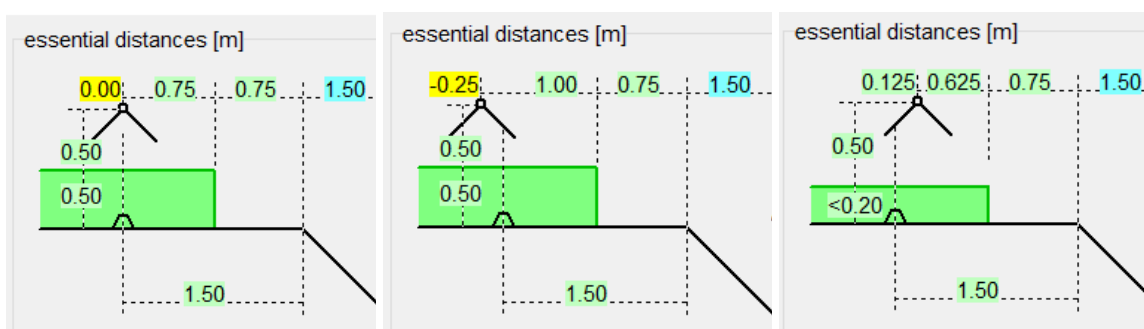


Figure 16 Layout modifications according to the requested situation.

Drift results

The third box gives computed values of average deposits of spray drift onto the water surface (A-B); see Figure 17. These deposits are presented in the red cell as a percentage of the applied dosage. The average drift reduction percentage is given compared to the drift that would be obtained when the reference application technique would have been used. The actual location of the evaluation zone is shown below that.

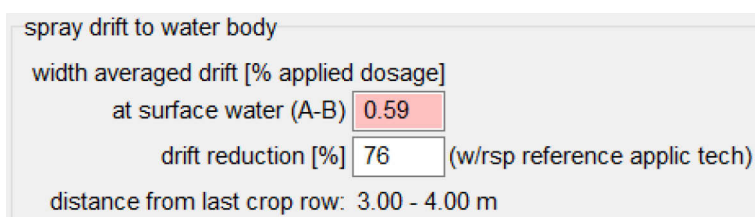


Figure 17 Box showing results of spray drift deposits onto the water surface of the standard ditch, as a percentage of the applied dose (red text box). Below that, the drift reduction with respect to the reference application technique is given. The distance from last crop row is given as well.

4.3 Field crops, spray drift deposits onto non-target evaluation zone

For non-target arthropods (NTA) and non-target plants (NTP) next to a field crop, the window is shown in Figure 18. The layout is very similar to that of the previous section. The actual layout of the boxes is slightly different, though, and will be presented below. For field crops the NTA evaluation zone is located at 0.5 – 1.5 m from the centre of the last crop row. The NTP evaluation zone is defined at 1.5 – 2.5 m from the centre of the last crop row.

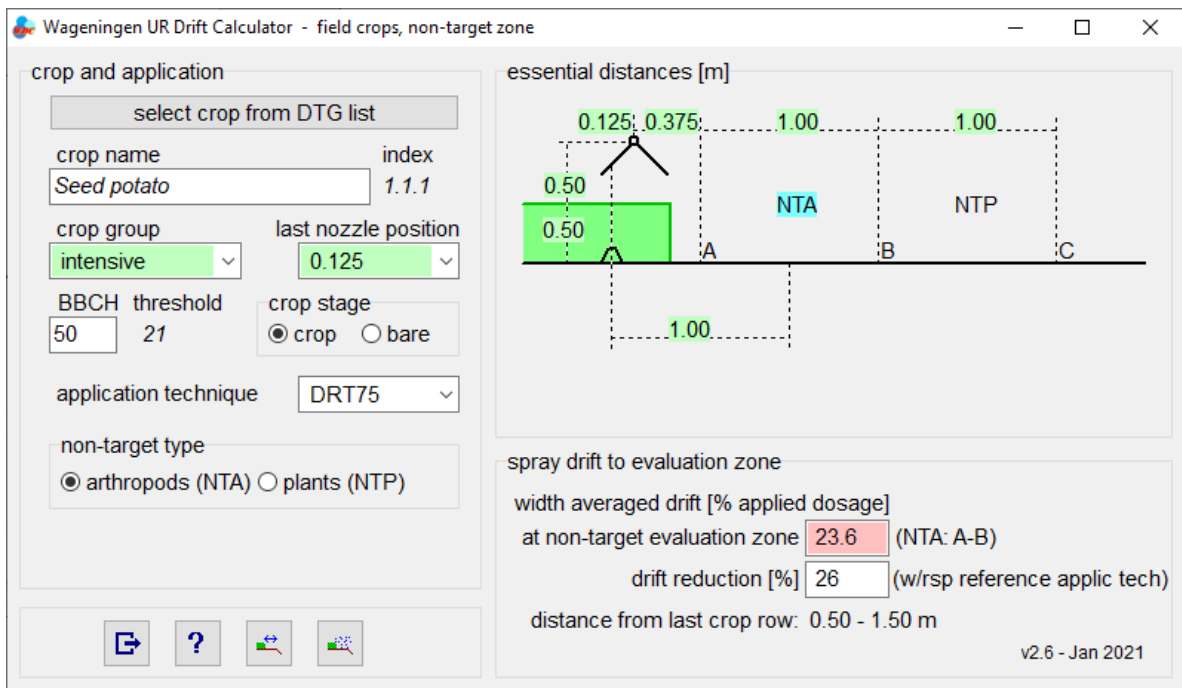


Figure 18 Window for computation of spray drift deposits onto the non-target evaluation zones next to a field crop.

Crop and application settings

The box for 'crop and application' is almost equal to that for drift evaluation onto an edge-of-field ditch (Section 4.2). There is one additional option: the box to select the non-target type, NTA or NTP, since these evaluation zones are different for field crops (CTGB, 2020a). The selected type is coloured blue in the graphical layout (box 2) on the right.

Field layout

The second box gives a schematic view of the field layout for non-target evaluation (Figure 19). Distances and heights are shown as well. Values in small green boxes correspond to crop settings; some of these may change according to the settings of crop stage. The range AB defines the NTA evaluation zone, the range BC defines the NTP evaluation zone. Which evaluation zone has been selected is shown by the blue background of NTA or NTP. Moving the mouse over a small box gives a hint on what the box refers to. Note that the location of the evaluation zones is the same for intensively sprayed crops and other crops. The layout of the nozzle and crop height may change according to the selections made in box 1 (similar to Figure 16).

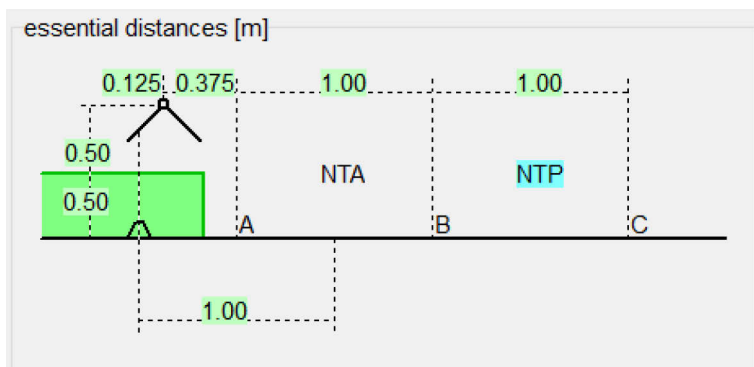


Figure 19 Schematic layout of field crop and non-target evaluation zones, showing distances and heights.

Drift results

The third box at the bottom-right of the window gives the average deposits of spray drift onto the non-target evaluation zone (NTA or NTP); see Figure 20. These deposits are presented in the red cell as a percentage of the applied dosage. Further, the average drift reduction percentage is given compared to the drift that would be obtained when the reference application technique would have been used. Below is the actual location of the evaluation zone, for instance in this case the NTP zone was selected, which is located at 1.5 – 2.5 m from the centre of the last crop row, corresponding to the case shown in Figure 19.

spray drift to evaluation zone	
width averaged drift [% applied dosage]	
at non-target evaluation zone	2.5 (NTP: B-C)
drift reduction [%]	73 (w/rsp reference applic tech)
distance from last crop row:	1.50 - 2.50 m

Figure 20 The computation results of average downwind deposits of spray drift on the selected non-target evaluation zone. Below that, the drift reduction with respect to the reference application technique is given. The distance from last crop row is given as well.

4.4 Fruit and avenue tree crops, spray drift deposits onto surface water

Figure 21 shows the window for computing spray drift deposits onto an edge-of-field watercourse next to a fruit tree orchard. The window shows the same type of boxes as in the window for field crops in the previous sections. On the left-hand side, in the box 'crop and application', various selections can be made regarding the crop type and stage and sprayer settings. The right-hand side shows a box with a schematic graph of the field and ditch and relevant distances and heights. The third box at the bottom right of the window shows computed drift results. The fourth box, bottom left, contains the action buttons as before. In the next paragraphs the first three boxes will be dealt with in more detail.

crop and application	
tree type	<input checked="" type="radio"/> fruit trees <input type="radio"/> avenue trees, high <input type="radio"/> avenue trees, transplanted <input type="radio"/> avenue trees, spindle
fruit trees, growth stage	<input checked="" type="radio"/> in full leaf <input type="radio"/> dormant
application technique	DRT75
crop free zone [m]	4.5

essential distances [m]

spray drift to water body

width averaged drift [% applied dosage]	
at surface water (A-B)	1.7
drift reduction [%]	81 (w/rsp reference applic tech)
distance from last tree row:	6.00 - 7.00 m

v2.6 - Jan 2021

Figure 21 Window for computation of spray drift deposits onto a ditch next to a fruit orchard or avenue tree nursery.

Crop and application settings

In the first selection box, fruit trees or avenue trees can be selected. This includes the nursery systems for high avenue trees, transplanted trees and spindles. Additionally, for fruit trees a distinction is made between dormant trees and trees in full leaf, corresponding to applications before and after 1 May, respectively. Typically, with trees in full leaf the downwind drift deposits are significantly lower due to the interception of the initial spray cloud by the canopy. For avenue trees no distinction is made for canopy stage. The selected growth stage for fruit trees is reflected in the graphical layout as well, see Figure 22.

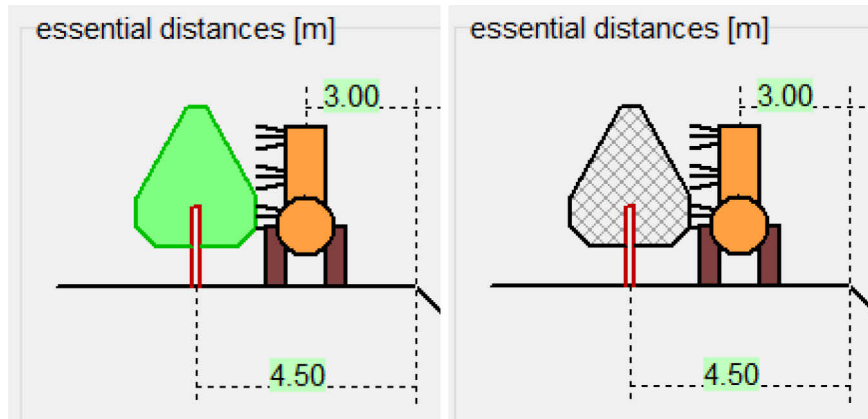


Figure 22 Layout modifications for fruit trees in full leaf (left) and dormant trees (right).

The application technique can be selected from a drop-down list, showing the reference technique and one or more drift reducing techniques (DRTs). Only DRTs are shown that are available for the selected crop (Table 1, Introduction). For fruit trees all drift reducing techniques are available (DRT50 through DRT99). For avenue trees the number of available application techniques is less. According to the EAD, at least a DRT75 technique is required and therefore is selected by default. For transplanted trees and spindles no DRT75 technique is available, so the next higher class (DRT90) is selected by default. Other application techniques (including lower DRT classes) are still available for manual selection.

With each tree type one or more crop-free zones can be selected. The default values correspond to the requirements of the EAD (Table 5). Table 8 shows the crop-free zones that can be selected from the drop-down box for the different tree types, together with the corresponding location of the water surface of the standard ditch.

Table 8 Crop types and corresponding geometry.

Crop type	Crop-free zone [m] ¹	Evaluation zone, from last tree row [m]
fruit trees	3.0 ^A	4.5 – 5.5
	4.5 ^B	6.0 – 7.0
avenue trees: high, transplanted	2.0 ^A	3.5 – 4.5
	5.0 ^B	6.5 – 7.5
avenue trees: spindles	1.5 ^A	3.0 – 4.0
	2.0	3.5 – 4.5
	5.0 ^B	6.5 – 7.5

¹ Superscript A indicates the minimal agronomic crop-free zone, which is equal to the row distance between rows of trees, by definition; superscript B indicates the requirements by the EAD.

Field and ditch layout

The second box gives a schematic view of the layout at the edge of the orchard (Figure 23). Distances and heights are shown as well. The small green boxes indicate crop-free zone and the corresponding position of the sprayer; these may change according to the settings of tree type and crop-free zone as

described above. The small blue boxes refer to the geometry of the ditch. In the current version of the WUR Drift Calculator only the Dutch standardized ditch is available, so the geometry of the ditch does not change. Moving the mouse over a small box gives a hint on what the box refers to.

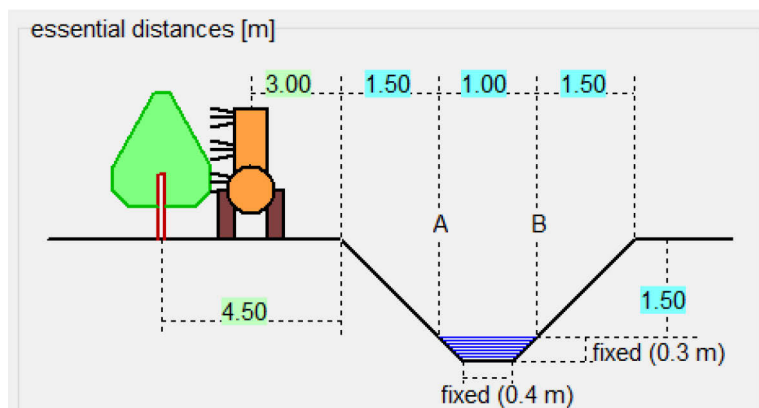


Figure 23 Schematic layout of tree crop and ditch, showing distances and heights.

Drift results

The third box at the bottom of the window gives computed values of average deposits of spray drift onto the water surface (A-B); see Figure 24. This box is almost equal to that for field crops, except for the word 'tree' instead of 'crop' on the bottom row with the distance.

spray drift to water body	
width averaged drift [% applied dosage]	
at surface water (A-B)	1.7
drift reduction [%]	81 (w/rsp reference applic tech)
distance from last tree row:	6.00 - 7.00 m

Figure 24 Box showing results of spray drift deposits onto the water surface of the standard ditch, as a percentage of the applied dose (red text box). Below that, the drift reduction with respect to the reference application technique is given. The distance from last tree row is given as well.

4.5 Fruit and tree crops, spray drift deposits onto non-target evaluation zone

For non-target arthropods (NTA) and non-target plants (NTP) next to a fruit orchard or avenue tree nursery, the window is shown in Figure 25. Like before, the layout is structured in four boxes. The actual layout of the boxes is adjusted to this particular case and will be presented below. For fruit orchards and avenue tree nurseries there is no difference between the location of the NTA and NTP evaluation zones. This evaluation zone is defined as a 1 m zone centred around the downwind distance equal to the inter-row distance of the tree rows (see Introduction). Consequently, for fruit orchards the NTA/NTP zone is located at 2.5 – 3.5 m downwind from the centre of the last tree row, while for avenue tree nurseries (high and transplanted trees) the NTA/NTP zone is at 1.5 – 2.5 m downwind from the centre of the last tree row. For spindles (1.5 m inter-row distance), the NTA/NTP zone is located at 1.0 – 2.0 m downwind.

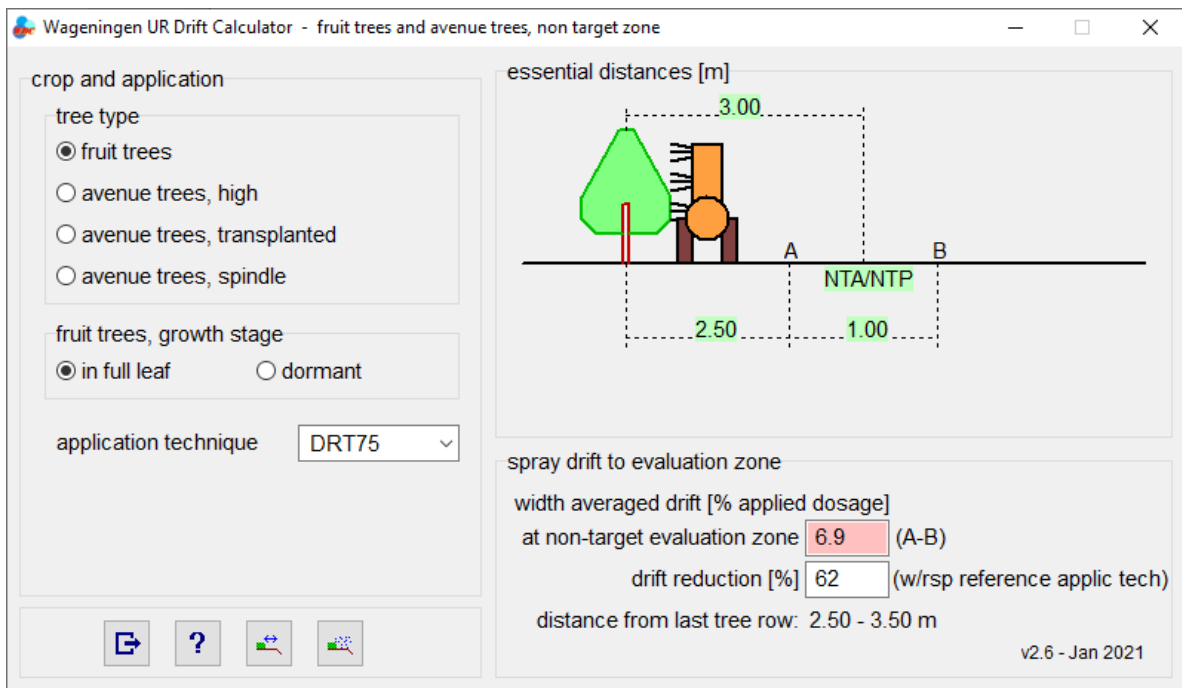


Figure 25 Window for computation of spray drift deposits onto the non-target evaluation zone next to a fruit orchard or avenue tree nursery.

Crop and application settings

The box for 'crop and application' is almost equal to that for risk assessment for drift deposits onto surface water (Section 4.4). The only difference is that no selection of NTA or NTP is required, since the NTA/NTP risk evaluation is based on the same evaluation zone (CTGB, 2020a).

Field layout

The second box gives a schematic view of the field layout for the non-target evaluation. Relevant distances of the evaluation zone with respect to the last tree row are shown. The evaluation zone (A-B) always has length 1.0 m. Its location depends on the fruit or tree crop selected. Moving the mouse over a small box gives a hint on what the box refers to.

For fruit orchards, the layout changes slightly when the dormant stage is selected, similar to Figure 22.

Drift results

The third box at the bottom-right of the window gives the average deposits of spray drift onto the non-target evaluation zone (which is the same for NTA and NTP); see Figure 26. These deposits are presented in the red cell as a percentage of the applied dosage. Again, the drift reduction percentage compared to the drift deposits for the reference application technique is given as well. The bottom line gives the location of the evaluation zone.

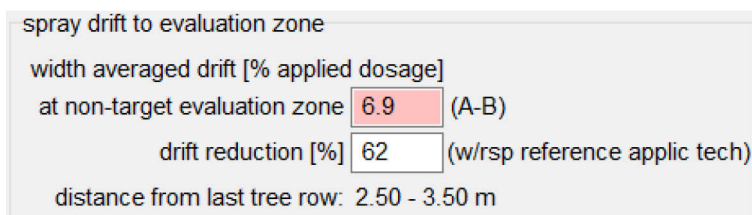


Figure 26 The computation results of average downwind deposits of spray drift on the selected non-target evaluation zone. Below that, the drift reduction with respect to the reference application technique is given. The distance from centre of last tree row is given as well.

4.6 Computation of crop-free zone for given spray drift deposits

Each of the four calculation units has four action buttons (Section 4.1). The third action button involves the calculation of the required crop-free zone, given a certain acceptable drift level. After clicking the action button, a new window opens (Figure 27). The edit box with the width averaged drift is pre-set to 1.0% but can be changed by the user. By clicking the button 'calculate zone' the required crop-free zone is calculated and shown in the blue box. Next to the blue box the crop-free zone rounded to the next multiple of 0.25 m is given. Note that for field crops the crop-free zone refers to the distance from the last crop row, while for tree crops it refers to the last row of trees. The texts in italic in the window of Figure 27 may change accordingly.

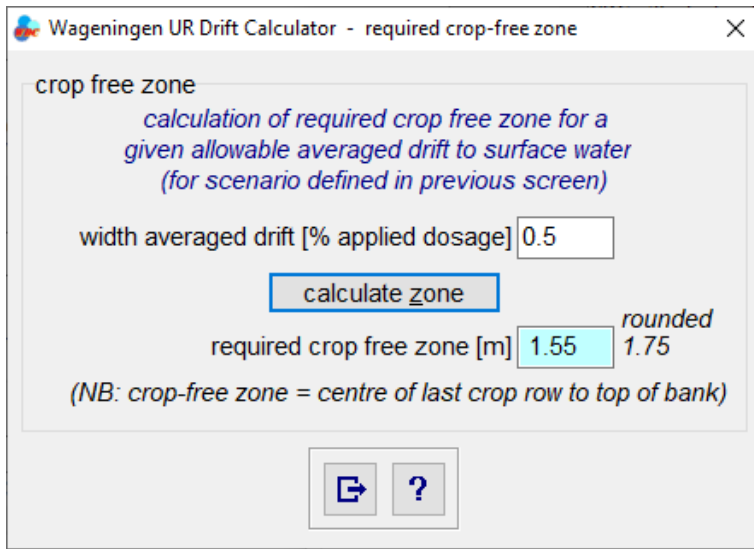


Figure 27 Window for computation of crop-free zone for a given value of spray drift deposits. The drift percentage (0.5%) is inserted manually and the corresponding crop-free zone is computed, including the higher multiple of 0.25 m.

If the given value for drift deposits is relatively low, a very large crop-free zone may be needed. For convenience, the higher cut-off value for crop-free distances is set to about 25 m. In those cases the blue box shows a value like '>24.5' instead. The exact cut-off value depends on the actual location of the evaluation zone with respect to the crop-free zone and therefore it may vary slightly around 25 m.

On the other hand, if the given drift value is relatively high, there may not be a need for a crop-free zone. In that case the value shown in the blue box is '<0'. Additionally, a message window pops up notifying that no crop-free zone is required. That is, even in the unlikely situation that the last crop row or tree row is planted exactly at the top of the bank, the occurring drift is lower than the value entered in the white box. The message box must be closed to continue.

To return to the main calculation unit, the crop-free zone calculation unit (Figure 27) must be closed first using the appropriate action button.

4.7 Computation of spray drift deposits for given crop-free zone

In section 4.6 the crop-free zone was calculated, given a value of drift deposits at the evaluation zone. The fourth action button (Section 4.1) on the main calculation units does the other way round: given a certain crop-free zone, the corresponding deposits of spray drift are computed. By clicking this action button, a new window pops up; Figure 28. The texts on the window varies slightly according to whether the evaluation zone is a downwind ditch (Figure 28-left) or a NTA/NTP zone (Figure 28-right), and whether it involves a field crop or a tree orchard (fruit and avenue trees). The crop-free zone is pre-set to the value from the current scenario, but it can be adjusted by the user. After clicking the button 'compute drift for given crop-free zone', the deposits of spray drift onto the water surface or evaluation zone are computed and shown in the blue text box near the bottom.

By setting the crop-free zone, this distance from the last crop row to the evaluation zone may change as well and is indicated in the second white entry box. The width of the evaluation zone is shown in the third white entry box. Its value is pre-set to 1.00 m, corresponding to both the water surface width of a standardized ditch and the NTA/NTP evaluation zone width.

These latter two entry boxes can be used to define an evaluation zone at a different location and/or with a different width. This applies to both surface waters and terrestrial zones. By clicking the large button below these entry boxes, the corresponding crop-free zone is adjusted in the first entry box and the deposits of spray drift are computed and shown in the blue box near the bottom. However, when the crop-free zone turns out to be <0 m, a warning message pops up telling this is an unlikely situation. In fact, it implies that the last crop or tree row is planted on the bank of the ditch, which of course is unrealistic.

Like before, windows that pop up must be closed to continue with previous windows.

The use of this option also allows the determination of spray drift deposits for biological cultivation, where other crop-free zones and reduction goals apply than for conventional growing systems according to the EAD.

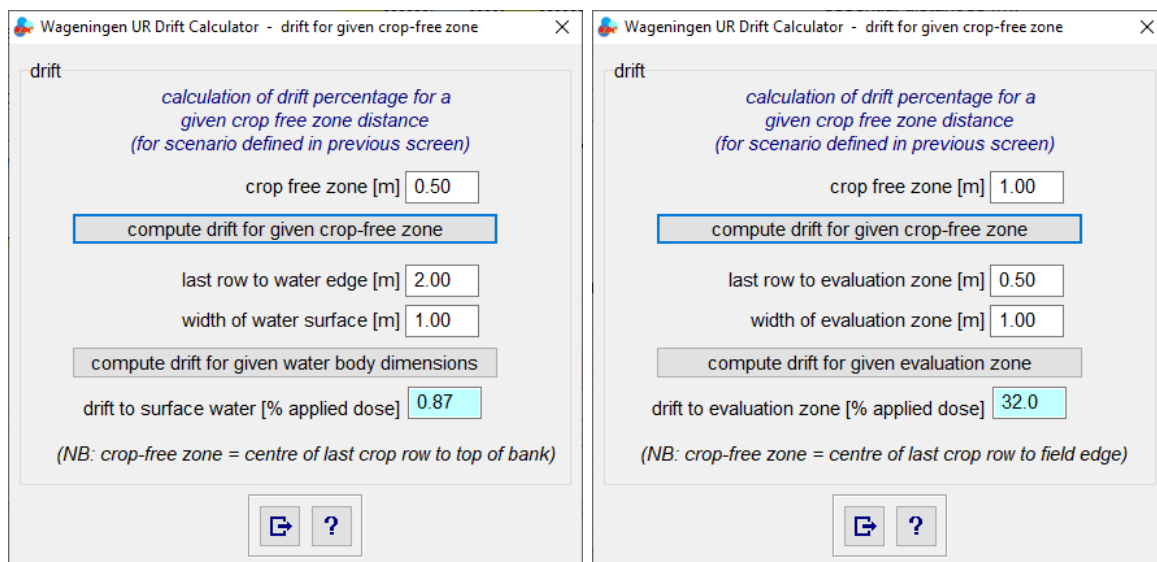


Figure 28 Window for computation of spray drift deposits onto a ditch for a given crop-free zone; the width of the water surface can be adjusted. Left: window for deposits on surface water; right: window for NTA/NTP evaluation.

4.8 Topic-based help file

In most windows an action button showing a question mark is available. When clicking this action button, the online help file opens. Note that the WUR Drift Calculator and its help file must be located in the same folder. Otherwise the help file will not be found by the software.

When clicking the help button on the entry window (Figure 10), the main window of the online help file opens in a new window (Figure 29). On the left-hand side a list of contents and index menu is available. On the right-hand side, the main entry page shows some version info. When the help button is clicked from any other window, the help file returns site-specific assistance for that window.

Unfortunately, Microsoft has changed their usage policy of .chm help files for security reasons. This means that when the WUR Drift Calculator is installed on a network drive the help file may not show any of its contents. In that case it is recommended to install the WUR Drift Calculator locally (on a local disc of your pc).

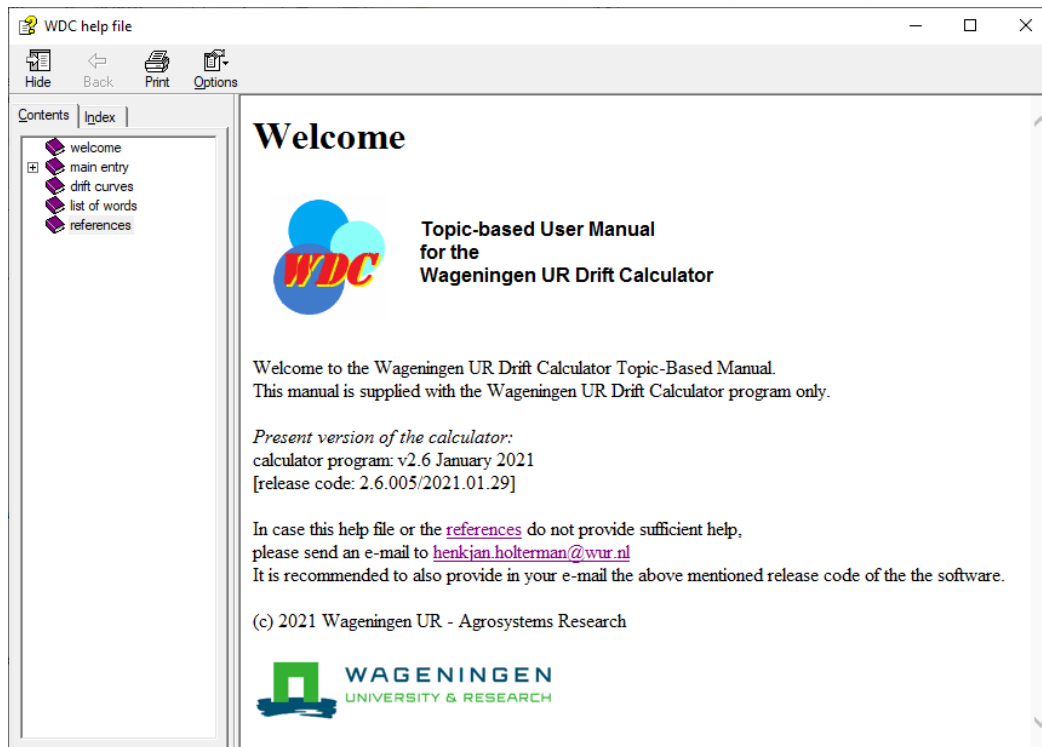


Figure 29 Main window of the topic-based help file.

5 Conclusions and recommendations

This manual describes how to use the WUR Drift Calculator version 2.6. In this version the deposition curves for downwind spray deposits are based on the knowledge from drift experiments. With drift curves that are based on experimental results, the direct link from the calculated results to practice is assured.

The options described in Section 4.6 and 4.7 offer possibilities to determine spray drift deposits for other crop-free zones and other evaluation zones. Although the WUR Drift Calculator was not developed to include its use for organic farming, the mentioned calculation options allow for using it for the application of biological agents as well.

The fifth button on the opening screen of the software involves downward applications in fruit orchards and avenue tree nurseries. This option has not been implemented yet and is one of the potential improvements for the next version of the WUR Drift Calculator.

The shape of some drift reduction curves, particularly for field crops, causes problems regarding the 'logical' structure of the DRT system. This 'problem of crossing lines' is partly caused by the selection of representative application techniques. For now, the pragmatic method described in Section 2.5 offers a conservative solution. Possibly a selection of other representative techniques, if reduction curves are available, could help reduce this problem, but it might give rise to a (new) problem with representativeness. Another possibility could be to use the statistical bandwidth of fitted drift curves and define a set of curves with minimal or no crossings. Alternatively, a more generic approach using deterministic spray drift models could be followed. It is recommended to investigate the feasibility of such options in the near future to make the system more robust.

Generally, at close range (typically <2 m from the last crop row) spray drift reductions are low, mainly due to overspray. Additionally, here also the 'problem of crossing lines' may occur. In this case the problem is more fundamental and probably cannot be solved by selecting another representative technique. Currently, the pragmatic and conservative solution of Section 2.5 applies to close range as well.

Future perspectives could make use of spray drift models to further differentiate possibilities. For instance, taking account of a continuous crop growth stage of fruit trees may add more realism to the results. Similarly, taking environmental conditions into account could make the results more realistic as well. Finally, a probabilistic approach could serve a higher tier risk assessment involving countrywide risk assessment.

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Annex 1 Model constants

The geometry of the standardized ditch is shown in Figure 1-1. The water surface has width 1.0 m, both banks have horizontal width 1.5 m and the banks have a slope of 45°. Consequently, the bank-to-bank width is 4.0 m.

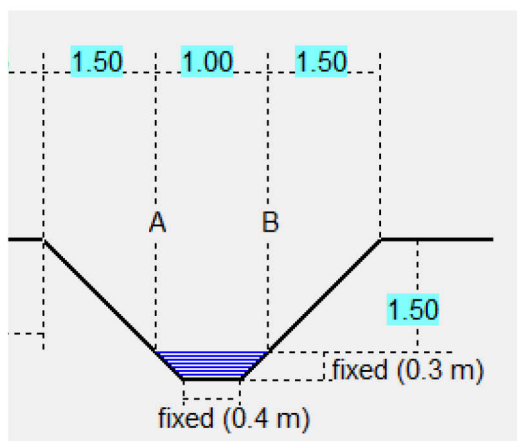


Figure 1-1 Geometry of the standardized ditch.

The constants for computing spray drift deposits, Eq.(1) in Chapter 2, for reference application techniques in field crops, fruit orchards and avenue tree nurseries are shown in Table 1-1. Using these constants, the resulting spray deposits are given in % of applied spray dose.

Table 1-1 Parameters for spray drift curves for reference application techniques in field crops, fruit orchards and avenue tree nurseries.

Crop	Crop stage	A ₀	A ₁	B ₀	B ₁	C ₀
		[%]	[m ⁻¹]	[%]	[m ⁻¹]	[-]
Field crop	Full-grown crop	2.663	0.1421	95.139	1.4261	0
	Bare soil	3.084	0.2103	37.333	1.4019	-0.596
Fruit tree orchard	In full leaf	14.218	0.0973	315.617	0.7419	13.846
	Dormant	34.723	0.1017	1161.670	1.1522	29.884
Avenue tree nursery	High trees	0.607	0.0107	81.215	0.3932	0
	Transplanted trees	8.817	0.2109	322.454	0.9490	6.649
	Spindle trees	1.991	0.1821	158.128	1.1742	26.764

Drift reducing techniques are implied by multiplying the reference drift values by 1-R where R is the relative drift reduction given by Eq.(2) in Chapter 2. The constants in the latter equation are given in Table 1-2 for all situations.

Table 1-2 Parameters for reduction curves for all crop types and crop stages; available drift reducing techniques.

Crop	Crop stage	Tech	P ₀	P ₁	Q ₀	Q ₁	S ₀
			[-]	[m ⁻¹]	[-]	[m ⁻¹]	[-]
Field crop	Full-grown	DRT50	-1.3985	1.7538	0	0	0.7248
		DRT75	-1.9356	1.6192	0.4597	0.1555	0.5
		DRT90	-0.6398	0.8603	0	0	0.9426
		DRT95	-2.6983	1.0621	0.8606	0.4686	0.8744
		DRT97.5	-0.9101	1.8252	0.3406	0.9762	0.9628
		DRT99	-11.8024	4.9727	0.0976	0.0164	0.9011
	Bare soil	DRT50	-0.8600	0.1701	1.0619	0.3050	0.7381
		DRT75	-1.9284	1.6932	0.5126	0.0961	0.4
		DRT90	-0.1352	0.8068	0.2345	0.1226	0.7
		DRT95	-1.8104	1.0855	0.4005	0.0728	0.7
		DRT97.5	-1.1121	1.6669	0.5665	1.0866	0.9629
		DRT99	-7.7005	3.8698	0.0510	0.0497	0.95
Fruit tree orchard	In full leaf	DRT50	-32.630	1.8555	0	0	0.5446
		DRT75	-1.0972	0.5159	0	0	0.8526
		DRT90	-0.6587	0.4972	0	0	0.9346
		DRT95	-9.3978	1.6237	0	0	0.9558
		DRT97.5	-2.3635	1.5664	0	0	0.9866
		DRT99	-3.7940	1.9866	0	0	0.9918
	Dormant	DRT50	-0.6819	0.1434	0	0	0.5516
		DRT75	-1.0972	0.5703	0	0	0.5492
		DRT90	-1.0122	0.4783	0	0	0.9481
		DRT95	-1.1430	0.7156	0	0	0.9600
		DRT97.5	-5.6791	1.0757	0	0	0.9460
		DRT99	-3.1614	1.0955	0	0	0.9833
Avenue tree nursery	High trees	DRT50	-1.5876	0.2169	0.8731	0.0854	0.5412
		DRT75	-0.2985	0.3216	1.4969	0.0451	-0.3537
		DRT95	-0.1980	0.1914	0.5930	0.0269	0.5035
	Transplanted trees	DRT50	-1.7771	0.3728	0.8096	0.0460	0.1160
		DRT90	-2.7792	0.4350	0.9444	0.0684	0.4947
	Spindle trees	DRT50	-4.3700	0.8477	0.6140	0.0150	0.0694
		DRT90	-9.3217	1.1092	0.6181	0.0636	0.5086

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