Spray drift from PPP’s
-Setting the Scene-

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Outline

– Introduction
  • Sources of PPP into water
  • What is (droplet) spray drift?
  • Importance and consequences of spray drift

– Effect of spray application technique on drift
– Other factors affecting drift
– Drift regulations in Belgium
– Conclusions
Introduction
Sources of PPP into water

• Use of plant protection products (PPP’s)
  – In Europe: $500 \times 10^6$ kg/year or 4.3 kg/ha (Candela, 2003)
    + To ensure good agricultural efficiency and quality products
    - Possible contamination of the environment – Impact on ground and surface water quality

• Main sources of PPP entry into water:
  – Point sources: related to the handling of pesticides
    • Key risky working processes: sprayer filling, sprayer cleaning and management of contaminated solutions after spraying
    • Operator awareness!
  – Diffuse sources
    • Leaching and drainflow
    • Surface runoff
    • Spray and dust drift
Introduction
What is (droplet) spray drift?

• Spray drift
  = the quantity of plant protection product that is carried out of the intended spray treatment zone by the action of air currents.

Vapour drift

• Occurs when PPP's molecules evaporate in the air
• Mainly related to the chemical's properties and/or formulation
• Can occur > 12 hours after application (Matthews, 2006)

Droplet drift

• Movement of spray droplets/particles at the time of application
• Mainly related to spray application technique
• Most important part of the total amount of spray drift

In many cases expressed as:
Percentage (%) of the (intended) applied dose in the field
Introduction
Importance and consequences of spray drift

- Drift can have serious consequences such as...
  - Damage to sensitive adjoining crops, plants and other susceptible off-target areas
  - Water contamination (EU drinking water standard: individual a.i.: 0.1 µg.L⁻¹; sum of a.i. 0.5 µg.L⁻¹)
  - Health risks for animals and humans
  - A lower dose than intended on the target field and an uneven spray distribution
  - Over-dosing if the farmer knowingly over-applies chemicals to compensate for drift losses

- Amount of spray drift
- Toxicity of PPP
- Sensitivity of plants and organisms

- (Spray) drift continues to be a major problem in applying PPP’s
  - Protecting the Flemish environment against drift – The importance of drift-reducing techniques (’03-’09)
  - An integrated approach to investigate and optimize the orchard spray application process (’09-’13)
  - Measures and innovative techniques to reduce dust drift from pesticide seed dressing during sowing (’11-’15)
Outline

– Introduction

– Effect of spray application technique on drift
  • Spray quality
  • Field crop sprayers
  • Orchard sprayers

– Other factors affecting drift

– Drift regulations in Belgium

– Conclusions
Effect of spray application technique on drift

Introduction

• Spray application factors influencing the risk of spray drift:
  – Spray quality
    • Droplet size
    • Droplet velocity and trajectory
  – Field crop sprayers
    • Spray boom height
    • Driving speed
    • Air assistance
    • Asymmetric edge nozzles
    • Shielded sprayer booms
  – Orchard sprayers
Effect of spray application technique on drift
Spray quality

• Atomisation
  – Process of producing a large number of small droplets from a liquid body
  – Most nozzles produce a spectrum of droplet sizes & velocities at a given operation condition and different spectra at different conditions

• Objective: ideal nozzle – pressure combination
  – Maximize spray efficiency (deposition, penetration,…)
  – Minimize residues & off target losses (e.g. drift)

• Spray characteristics influencing the efficiency of the pesticide application process
  – **Droplet size distribution** → spray drift
  – Droplet velocity distribution
  – Droplet trajectory, spray angle
  – Entrained air characteristics
  – Spray sheet structure
  – Structure of individual droplets

XR110015 - 275 kPa (Oxford Laser Imaging System)
Effect of spray application technique on drift
Spray quality

- Droplet size characteristics are mainly determined by:
  - Nozzle type
  - Nozzle size
  - Spray pressure

![Diagram showing droplet size distribution and cumulative volume percentage]
Effect of spray application technique on drift

Spray quality

- Droplet size and velocity
  - Mainly determined by
    - Nozzle type
    - Nozzle size
    - Spray pressure

Standard meteorological conditions:
\[ T = 16°C, \ V_{3.25m} = 3 \text{ m.s}^{-1}, \ X_{H2O} = 8 \text{ g.kg}^{-1} \]
Effect of spray application technique on drift

Spray quality

- Droplet size characteristics are mainly determined by
  - Nozzle type
  - Nozzle size
  - Spray pressure

![Graph showing the effect of spray pressure on drift]
Effect of spray application technique on drift
Field crop sprayers

- **Spray boom height**
  - Most important sprayer factor related to drift
  - Operating at a boom height as close as possible to the vegetation – **without sacrificing the spray pattern** - is a good way to reduce drift

![Graph showing the effect of spray boom height on drift percentage (DRP)]

- DRP = -49.9%
- DRP = 40.1%
Effect of spray application technique on drift
Field crop sprayers

• Driving speed
  – Belgian research project: speed range (only) from 4.0 to 10.0 km h\(^{-1}\)
    • 8 km/u → 6 km/u: \(DRP = 52.9\%\)
    • 8 km/u → 4 km/u: \(DRP = 35.3\%\)
  – Less drift
  – 8 km/u → 10 km/u: no significant effect

• Literature
  • Relatively few studies, general trend: higher forward speeds → more drift
  • Miller & Smith (1997)
    o 4 → 8 km h\(^{-1}\): + 51% drift
    o 4 → 16 km h\(^{-1}\): +144% drift
    o No difference between 8 and 12 km h\(^{-1}\)
Effect of spray application technique on drift
Field crop sprayers

• Air assistance
  – What?
    • A system capable of supplying air flows (created by one or more fans) to carry and disperse sprays formed by spray nozzles towards the target
  – Possible advantages
    • Better crop deposition/penetration
    • Better efficiency – chemical savings
    • Higher capacity (higher driving speeds, more spraying hours, lower water quantities)
    • Drift reduction
  – Disadvantages
    • Price
    • Weight
    • Increased power requirements
Effect of spray application technique on drift
Field crop sprayers

- Air assistance
  - Drift results

Drift values at a distance of 5 m (%)

<table>
<thead>
<tr>
<th>Nozzle type</th>
<th>no air support</th>
<th>air support</th>
</tr>
</thead>
<tbody>
<tr>
<td>F 110 02</td>
<td>2.95</td>
<td>1.33</td>
</tr>
<tr>
<td>F 110 03</td>
<td>1.28</td>
<td>0.51</td>
</tr>
<tr>
<td>LD 110 02</td>
<td>1.32</td>
<td>0.99</td>
</tr>
<tr>
<td>LD 110 03</td>
<td>0.64</td>
<td>0.46</td>
</tr>
</tbody>
</table>

- Use of air support has the highest impact on the amount of spray drift for the finer sprays
- Besides droplet size, droplet velocity also has an effect on the amount of spray drift

*T = 16°C, V_{3.25m} = 3 m.s^{-1} and X_{H2O} = 8 g.kg^{-1}*
Effect of spray application technique on drift
Field crop sprayers

- **Asymmetric edge nozzles**
  - have an outlet orifice oriented sidewards which results in an off-centre spray pattern
  - Are used at the end of spray boom to protect sensitive areas
  - Holterman & van de Zande (1996): drift reduction from 30 to 50%

- **Shielded sprayer booms**
  - To intercept the drifting droplets and overcome the influence of wind
  - Literature
  - Disadvantages
    - Nozzles cannot be checked
    - Spray boom stability
    - Folding up the spray boom
    - Liquid dripping from the shield
    - Cost

### Shield description

<table>
<thead>
<tr>
<th>Shield description</th>
<th>Field or laboratory experiment</th>
<th>Amount of drift reduction (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Nodif” boom</td>
<td>Laboratory</td>
<td>46 to 85</td>
<td>Edwards and Ripper (1953)</td>
</tr>
<tr>
<td>Mechanical shielded boom</td>
<td>Laboratory</td>
<td>up to 70</td>
<td>Smith et al. (1982 a)</td>
</tr>
<tr>
<td>Aerofoil</td>
<td>Laboratory</td>
<td>62</td>
<td>Lake et al. (1982)</td>
</tr>
<tr>
<td>Power-aspirated winnower</td>
<td>Field</td>
<td>95</td>
<td>Ford (1984)</td>
</tr>
<tr>
<td>Gauze shroud</td>
<td>Field</td>
<td>up to 80</td>
<td>Ford (1984)</td>
</tr>
<tr>
<td>Double-foil shield</td>
<td>Field</td>
<td>67</td>
<td>Göhlich (1985)</td>
</tr>
<tr>
<td>Porous shroud</td>
<td>Field</td>
<td>85</td>
<td>Ford (1986)</td>
</tr>
<tr>
<td>“Windproof” sprayer</td>
<td>Field</td>
<td>45 to 65</td>
<td>Fehringer and Cavaletto (1990)</td>
</tr>
<tr>
<td>WindCone (Brandt Industries, Ltd.)</td>
<td>Field</td>
<td>41 to 67</td>
<td>Maybank et al. (1991)</td>
</tr>
<tr>
<td>Air-assisted spraying with bluff plate</td>
<td>Field</td>
<td>71 to 80</td>
<td>Furness (1991)</td>
</tr>
<tr>
<td>Protective cones</td>
<td>Field</td>
<td>33</td>
<td>Wolf et al. (1993)</td>
</tr>
<tr>
<td>Solid or perforated shielding + lower boom height</td>
<td>Field</td>
<td>48 to 84</td>
<td>Wolf et al., (1993)</td>
</tr>
<tr>
<td>Spray-boom shields</td>
<td>Laboratory</td>
<td>13 to 59</td>
<td>Ozkan et al. (1997)</td>
</tr>
<tr>
<td>Symmetrical triple-foil shield</td>
<td>Laboratory</td>
<td>61</td>
<td>Sidahmed et al. (2004)</td>
</tr>
<tr>
<td>Symmetrical double-foil shield</td>
<td>Laboratory</td>
<td>55</td>
<td>Sidahmed et al. (2004)</td>
</tr>
<tr>
<td>Double-foil shield</td>
<td>Laboratory</td>
<td>48</td>
<td>Sidahmed et al. (2004)</td>
</tr>
</tbody>
</table>
Effect of spray application technique on drift
Orchard sprayers

- Higher drift risk compared with field crop sprayers
  - Sideward spraying
  - Higher pressures, finer sprays
- Drift reducing application techniques
  - Sensor based spray applications (tree detection)
  - Reduction of air volume
  - One-sided spraying of the last tree row
  - Reflection screens/tunnel sprayers

Balsari et al., 2008
Outline

– Introduction
– Effect of spray application technique on drift
– Other factors affecting drift
– Drift regulations in Belgium
– Conclusions
Other factors affecting spray drift

Introduction

- Other factors influencing the risk of spray drift:
  - Natural and artificial screens
  - Buffer zones
  - Spray liquid properties
  - Meteorological conditions
  - Crop characteristics
Other factors affecting spray drift
Natural and artificial screens

• What?
  – Artificial or vegetative drift collectors placed at downwind edges of fields, adjacent to susceptible areas

• How?
  – Screens reduce spray drift by filtering the air and catching the droplets as they move in the air through or over the vegetation

• Belgian research: effect of…
  – Type of border structure: natural vs. artificial?
  – Screen characteristics (open area)?
  – Screen height?
Other factors affecting spray drift
Natural and artificial screens

• Results
  – Total drift reduction from 40 – 85% depending on screen type, height and open area

![Graph showing drift reduction](image)

- Natural screen:
  - Typical drift profile
  - Constant drift reduction

- Artificial screen:
  - The closer to the screen, the higher the drift reduction
  - Possible deposition ‘peaks’ behind the screen
Other factors affecting spray drift
Buffer zones

- **What?**
  - “A buffer zone is an area in which direct application of the agricultural chemical is prohibited; this area is specified in distance between the closest point of direct chemical application and the nearest boundary of a site to be protected.”
  - mandatory buffer zones are increasingly being incorporated into product labels in many countries like Belgium, The Netherlands, United Kingdom, Germany, etc.

- **Drift reduction**

<table>
<thead>
<tr>
<th>Bufferzone (m)</th>
<th>Total drift reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>± 30%</td>
</tr>
<tr>
<td>2</td>
<td>± 50%</td>
</tr>
<tr>
<td>5</td>
<td>± 65%</td>
</tr>
<tr>
<td>10</td>
<td>± 80%</td>
</tr>
</tbody>
</table>
Other factors affecting spray drift

Meteorological conditions

- Reference spraying: 32 experiments at a wide range of climatological conditions
  - Validated non-linear statistical drift prediction equation

\[
\text{drift}\% = (\text{drift} \_ \text{dist})^{-1.05} \times (13.00 + 0.50 V_{3.25m} + 0.40 \times T - 1.74 \times X_{H_2O})
\]

\[R^2 = 0.84\]

- Effect of climatological conditions on drift for the reference spraying

\[T = 16°C\]
\[V_{3.25m} = 3 \text{ m.s}^{-1}\]
\[X_{H_2O} = 8 \text{ g.kg}^{-1}\]

- Drift distance
- Wind speed
- Absolute humidity

\(\text{(abs.) humidity} \downarrow \leftrightarrow \text{Drift} \uparrow\)

\(\text{Temperature} \uparrow \leftrightarrow \text{Drift} \uparrow\)

\(\text{Wind speed} \uparrow \leftrightarrow \text{Drift} \uparrow\)
Other factors affecting spray drift

Crop characteristics

- Field drift measurements
  - Grassland
  - Uncultivated
  - Potatoes
  - Wheat

Crop height $\uparrow \Rightarrow$ drift $\uparrow$

at a constant boom height of 0.50 m above the crop

grassland < potatoes < wheat
uncultivated > grassland

$T = 16^\circ C$, $V = 3 \text{ m.s}^{-1}$, $\chi_{\text{H2O}} = 8 \text{ g.kg}^{-1}$

$\text{DRP} = -19\%$

$\text{DRP} = -49\%$
Outline

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Drift regulation in Belgium

• EU Framework directive on sustainable use of pesticides – EU Water Framework Directive

Goal is to reduce the risks for the human health and the environment caused by the use of pesticides

- Promotion of mitigation structures to reduce environmental contamination from pesticides

- Limitation of risks due to spray drift

- Adoption of buffer zones

- Classification of sprayers according to drift risks

- The last 10 years, some countries already introduced legislative drift reducing measures (Germany, The Netherlands, Belgium, UK,...)
Drift regulations in Belgium

- Belgium
  - Introduced in 2005 (www.phytoweb.fgov.be)
  - Buffer zone = unsprayed zone along a watercourse
  - Bufferzone width
    - is mentioned on product label (7 possibilities)
    - based on the toxicity of the product
    - can be reduced using a drift reducing application technique

<table>
<thead>
<tr>
<th>Bufferzone on the label (field crop sprayers)</th>
<th>2 m</th>
<th>5 m</th>
<th>10 m</th>
<th>20 m</th>
<th>30 m</th>
<th>40 m</th>
<th>200 m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard technique</strong></td>
<td>50%</td>
<td>75%</td>
<td>90%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>2 m</td>
<td>5 m</td>
<td>10 m</td>
<td>20 m</td>
<td>30 m</td>
<td>40 m</td>
<td>200 m</td>
</tr>
<tr>
<td><strong>50%</strong></td>
<td>1 m</td>
<td>2 m</td>
<td>5 m</td>
<td>10 m</td>
<td>20 m</td>
<td>30 m</td>
<td>40 m</td>
</tr>
<tr>
<td><strong>75%</strong></td>
<td>1 m</td>
<td>2 m</td>
<td>2 m</td>
<td>5 m</td>
<td>10 m</td>
<td>20 m</td>
<td>30 m</td>
</tr>
<tr>
<td><strong>90%</strong></td>
<td>1 m</td>
<td>1 m</td>
<td>1 m</td>
<td>1 m</td>
<td>5 m</td>
<td>10 m</td>
<td>20 m</td>
</tr>
</tbody>
</table>

Effective bufferzone width
Drift regulations in Belgium

- Belgium – Field crop sprayers
  - Drift reduction class (only) based on
    - Nozzle type
    - Nozzle size
    - Type of sprayer (standard spray boom, air support, shielded spray boom,…)
  - Driving speed, boom height, spray pressure,… are not brought into account
    - Idea: simple and understandable classification system
  - Reference system: standard spray boom, ISO 03 FF nozzles, 3.0 bar
**Drift regulations in Belgium**

- Belgium – Orchard sprayers
  - 5 drift reduction classes (0, 50, 75, 90 and 99%)
  - Drift reduction class based on 5 factors
    - Nozzle type
    - Nozzle size
    - Sprayer type (axial fan, cross flow sprayer (with/without sensors), tunnel sprayer)
    - Presence of a hedge/screen/hail nets
    - Leaf stage (with/without)
  - Distance to the waterbody is calculated from the last treated tree row

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<table>
<thead>
<tr>
<th>Mark</th>
<th>Type</th>
<th>Doogmaat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luchtmeerdoppen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrotop</td>
<td>TD</td>
<td>ISO 1055 - 15</td>
</tr>
<tr>
<td>Alber</td>
<td>AX</td>
<td>ISO 1055 - 15</td>
</tr>
<tr>
<td>Albi</td>
<td>AV</td>
<td>gat en gaten</td>
</tr>
<tr>
<td>Hubel</td>
<td>DI</td>
<td>ISO 1055 - 15</td>
</tr>
<tr>
<td>Lachter</td>
<td>ID</td>
<td>ISO 1055 - 15</td>
</tr>
<tr>
<td>Bezijn</td>
<td>AI</td>
<td>ISO 1055 - 15</td>
</tr>
<tr>
<td>Lommink</td>
<td>IDK</td>
<td>ISO 1055 - 15</td>
</tr>
<tr>
<td>Lage druk driftbestendige doppen</td>
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<td></td>
</tr>
<tr>
<td>Albi</td>
<td>AD</td>
<td>ISO 1100 - 05 - 15</td>
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<tr>
<td>Albi</td>
<td>AD</td>
<td>rood en gaten</td>
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<td>Hubel</td>
<td>DLD</td>
<td>ISO 035 - 15</td>
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<td>Lachter</td>
<td>IDK</td>
<td>rood en gaten</td>
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<td>DI</td>
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Complete list: [www.phytoweb.fgov.be](http://www.phytoweb.fgov.be)
Outline

– Introduction
– Drift assessment methods
– Effect of spray application technique on drift
  • Introduction
  • Spray quality
  • Sprayer factors
– Other factors affecting drift
– Drift regulations in Europe
– Conclusions
Conclusions

• Spray drift is a complex phenomena with a lot of influencing factors
• A lot of research information is available on how to reduce drift but there is still a need…
  o to bring these results into practice
  o to harmonize drift classification schemes and buffer zone regulations
Thanks to:

• Research partners
  • Department of Crop Protection, Ghent University
  • MeBioS, Department Biosystems, KULeuven
  • PCFruit
  • IWT-Vlaanderen for financial support
• Thank your for your attention!

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