Fungicides and disease control strategies

Huub Schepers

Fungicides to control diseases

- Fungicides are chemical or biological compounds used to kill or inhibit fungi or fungal spores.
- Fungicide characteristics
  - Action mode
  - Effectiveness
  - Resistance management
- Adjuvants
- ICM strategies
Mode of action *P. infestans* fungicides

- Dimethomorph
- Fenamidine, Faroxadine, Cyazofamid
- Folpet, Metalaxyl
- Spinosyns
- Plumatic
- Azoxystrobin
- Metalaxyl, mancozeb
- Prohexadione, Carbendazim
- Nebulaxyl
- Propanocarb

*The precise biochemical mode of action has not been fully characterized.*
Contact – local-systemic fungicides

Fungicides

Biological efficacy

- **Protectant**: has to be present on (or in) the leaf/stem surface before spore germination/penetration
- **Curative (kick-back)**: is active during the immediate post infection period, but before symptoms appear
- **Eradicant**: fungus is killed/inhibited when sprayed on lesions (incl. anti-sporulant)

Mobility in plant

- **Contact**: are on the surface of the potato plant
- **Local-systemic**: limited to translaminar movement and hardly any translocation from leaf to leaf and stem to foliage
- **Systemic**: translocation upwards (and downwards) in the plant
Fungicides

**CONTACT**
- mancozeb, fluazinam
- cyazofamid, mandipropamid, ametoctradin

**WAX LAYER**
- cymoxanil, fluopicolide, dimethomorph

**TRANS LAMINAR**
- propamocarb, metalaxyl-M

**SYSTEMIC**
- fluopicolide, dimethomorph

**ANTI SPOREULANT**
- cyazofamid, fluazinam, amisulbrom

**SPORICIDE**
Spray strategy

- The protection conferred by a spray decreases as its active substances degrade over time and as new unsprayed leaves grow. Spray timing and interval therefore depend on the characteristics of the fungicide, the growth of the crop, weather conditions and disease pressure.
Protectant & curative efficacy

Spray strategy

- Spray preventively!!!!
  - When symptoms are already visible, fungicides are less effective
- Product choice depends on:
  - Conducive environment
  - Identity of the disease present
- Spray frequency depends on:
  - Conducive environment
  - Efficacy and characteristics of fungicides: higher frequency of weaker fungicides and lower frequency of stronger fungicides
## Vegetables: Efficacy of fungicides

<table>
<thead>
<tr>
<th>Fungicide group</th>
<th>Protectant</th>
<th>Powdery mildew</th>
<th>Downy mildew-LB</th>
<th>Anthracnose</th>
<th>Alternaria</th>
<th>Botrytis</th>
<th>Sclerotinia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protectant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propineb</td>
<td>multisite (M)</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Copper</td>
<td>multisite (M)</td>
<td>+</td>
<td>&lt;(+)&gt;</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorothalonil</td>
<td>multisite (M)</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Manebe</td>
<td>multisite (M)</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Mancozeb</td>
<td>multisite (M)</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Captan</td>
<td>multisite (M)</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Eurotine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cymoxanil</td>
<td>PRAC 27</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Protectant + curative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benomyl</td>
<td>MBC (B1)</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>(+)&gt;</td>
<td></td>
</tr>
<tr>
<td>Carbendazim</td>
<td>MBC (B1)</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>(+)&gt;</td>
<td></td>
</tr>
<tr>
<td>Hexaconazole</td>
<td>DMI (G1)</td>
<td>+</td>
<td>&lt;(+)&gt;</td>
<td>&lt;(+)&gt;</td>
<td>&lt;(+)&gt;</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Propiconazole</td>
<td>DMI (G1)</td>
<td>+</td>
<td>&lt;(+)&gt;</td>
<td>&lt;(+)&gt;</td>
<td>&lt;(+)&gt;</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Azoxystrobin</td>
<td>strobilurine (C3)</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>(+)</td>
<td>+</td>
</tr>
<tr>
<td>Trifloxystrobin</td>
<td>strobilurine (C3)</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>(+)&gt;</td>
<td>-</td>
</tr>
<tr>
<td>Iprodion</td>
<td>dicarboximide (E3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>&lt;(+)&gt;</td>
<td>++</td>
</tr>
<tr>
<td>Fusethyl-Al</td>
<td>PRAC 33</td>
<td>-</td>
<td>(+)&gt;</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Metalaxyl+mancozeb</td>
<td>multisite + phenylamide (A1)</td>
<td>+</td>
<td>++(+)&gt;</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- not effective; + reasonable effect; ++ good effect; +++ very good effect

January 2015

## Agrochemicals used at the farms visited (Ghana 2015)

<table>
<thead>
<tr>
<th>Product name</th>
<th>active ingredient(s)</th>
<th>Type</th>
<th>Mobility</th>
<th>Distributed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Cop</td>
<td>sulphur (50%) + copper sulphate (8,4%)</td>
<td>F, B, M</td>
<td>C</td>
<td>Chemico Ltd</td>
</tr>
<tr>
<td>Sulfa 80WDG</td>
<td>sulphur (80%)</td>
<td>F, M</td>
<td>C</td>
<td>Agrimat Limited</td>
</tr>
<tr>
<td>Topin-M 70% PM</td>
<td>methylthiophenate (70%)</td>
<td>F</td>
<td>LS</td>
<td>Annoh &amp; Sons Agrochem/Kumark</td>
</tr>
<tr>
<td>Sidalco Defender</td>
<td>copper oxychloride (143 g/l)</td>
<td>F</td>
<td>C</td>
<td>Sidalco Ltd</td>
</tr>
<tr>
<td>Champion WP</td>
<td>cupric hydroxide (77%)</td>
<td>F</td>
<td>C</td>
<td>Nufarm SA</td>
</tr>
<tr>
<td>Mancozan B0</td>
<td>mancozeb (88%)</td>
<td>F</td>
<td>C</td>
<td>Louis Dreyfus Commodities Ghana</td>
</tr>
<tr>
<td>Fokozeb</td>
<td>mancozeb (80%)</td>
<td>F</td>
<td>C</td>
<td>Thomas Fosu Enterprise</td>
</tr>
<tr>
<td>Dizrozeb B0- WP</td>
<td>mancozeb (80%)</td>
<td>F</td>
<td>C</td>
<td>Dizengoff Ghana Ltd</td>
</tr>
<tr>
<td>Kilaze B0 WP</td>
<td>mancozeb (80%)</td>
<td>F</td>
<td>C</td>
<td>Shenzhen Baicheng Chemical Industry CD Ltd</td>
</tr>
</tbody>
</table>

Type: F=fungicide, B=bactericide, M=miticide
Mobility: C=contact; LS=local systemic; S=systemic
Resistance management fungicides

- Multi-site mode of action: no resistance risk
  - Propineb, mancozeb, chlorothalonil
- Specific-site mode of action: resistance risk present
  - Strobilurines: azoxystrobin, pyraclostrobin etc.: maximum of 1/3 of total sprays
  - Acylalanines: mefenoxam/metalaxyl 2 sprays/season

<table>
<thead>
<tr>
<th>Fungicide Class</th>
<th>Fungicide Risk</th>
<th>Combined Risk</th>
<th>Agronomic Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzimidazoles (e.g. dimethrinazol)</td>
<td>high = 6</td>
<td>12</td>
<td>high = 1 medium = 0.5 low = 0.25</td>
</tr>
<tr>
<td></td>
<td>medium = 4</td>
<td>8</td>
<td>high = 1 medium = 0.5 low = 0.25</td>
</tr>
<tr>
<td></td>
<td>low = 3</td>
<td>2</td>
<td>high = 1 medium = 0.5 low = 0.25</td>
</tr>
<tr>
<td>Strobilurines (e.g. azoxystrobin)</td>
<td>1, 0.5</td>
<td>2</td>
<td>1, 0.5</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>1, 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1, 0.5</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Combined resistance risk diagram based on inherent fungicide risk, inherent pathogens risk, and agronomic risk (* only most important classes and groups mentioned) (according to Kock, 2001)
Development of resistance

“Shifting” multistep resistance

Disruptive, discrete resistance

Fig. 2. Metalaxyl sensitivity among isolates of *P. infestans* from Vietnam sampled in 2002-03. S = sensitive, I = intermediate and R = resistant as described in Materials and methods. North = isolates from eight provinces in the north of Vietnam, while South = isolates sampled from the Lam Dong province in the south of Vietnam.
Adjuvants

- An adjuvant is a substance without significant pesticide properties which enhances the efficacy of a pesticide, when added to that pesticide.
- Adjuvants can modify the physical, chemical or biological properties of the active ingredient when used in the spray solution.

Adjuvants can have an effect on:

- Spreading and uptake on/in plant
- Sticking to leaves
- Foam formation
- pH & Hardness
- Droplet size (drift)
- Deposition
Adjuvants (Indonesia)

Adjuvants (Myanmar-Vietnam)
Run-off tomato

Powdery mildew

- Susceptible crops
- Symptoms
- Life cycle
- ICM strategy
### Susceptible crops

- Cucumbers, endive, lettuce, melons, potato, pumpkin, squash (*Erysiphe chichoracearum*)
- Broccoli, Brussels sprouts, cauliflower, radicchio, radishes, turnips (*E. cruciferarum*)
- Tomatoes (*E. lycopersici*)
- Peas (*E. pisi*)
- Carrots, parsley, parsnips (*E. heraclei*)
- Beets (*E. polygoni*)
- Artichoke, eggplant, peppers, tomatoes (*Leveillula taurica*)
- Beans, cucurbits, okra (*Sphaerotheca fuliginea*)

### Powdery mildew

- Cucumber
- Sweet pepper
Life cycle powdery mildew

- Fungus requires living plant tissue to grow
- Year-round availability of hosts/weeds is important
- Resting spores may be formed that overwinter in plant debris
- Fungus grows as thin layer on surface of plant parts
- Spores are dispersed by wind
- Spores can germinate and infect in absence of free water!!!
Powdery mildew: ICM strategy

- Use resistant varieties when available
- Plant in sunny areas (UV light kills spores)
- Avoid applying excess fertilizer
- Overhead irrigation reduces powdery mildew but might promote other diseases
- Apply fungicides: preferably preventive
  - sulphur, triazoles (DMI), strobirulines (QoI)

Downy mildew & late blight

- Susceptible crops
- Symptoms
- Life cycle
- ICM strategy
Downy mildew: susceptible crops

- Cucurbits: cucumber, pumpkin, melons, squash (*Pseudoperonospora cubensis*)

- Solanaceae: eggplant, tomato, pepper, potato (*Phytophthora spp.*)

Symptoms: downy mildew
Symptoms: late blight

Phytophthora infestans – tomato/potato
Peronospora destructor - onion

Life cycle downy mildew & late blight

- Fungus requires living plant tissue to grow
- Year-round availability of hosts/weeds is important
- Resting spores may be formed that overwinter in plant debris and soil
- Fungus grows in leaves, fruits, stems
- Spores are produced at underside leaves and are distributed by wind and water splashes
- Spores can only germinate and infect when leaves are wet for several hours!!!
**Downy mildew & late blight: ICM strategy**

- Use resistant varieties when available
- Plant in sunny areas
- Good drainage and air circulation
- Avoid applying excess fertilizer
- Overhead irrigation can promote downy mildew by lengthening the leaf wetness period!
- Remove affected crop residues and rotate crops
- Apply fungicides: preferably preventive
  - chlorothalonil, mancozeb, metalaxyl, cymoxanil, fosetyl-Al

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**Anthracnose (Colletotrichum spp.)**

- Susceptible crops
- Symptoms
- Life cycle
- ICM strategy
Anthracnose; susceptible crops

- Cucurbits: cucumber, pumpkin, melon
- Sweet pepper, hot pepper
- Beans
- Tomatoes
Anthracnose (*Colletotrichum* spp.)

**Life cycle Anthracnose**

- Fungus can survive in seed
- Can survive in a range of host plants, crop residues and affected fruits
- Spores are distributed from affected to healthy plant parts during warm and wet weather
- Longer leaf wetness periods will lead to a higher infection rate, symptoms can appear after 5 days already
Anthracnose: ICM strategy

- Good drainage and air circulation
- Avoid applying excess fertilizer
- Overhead irrigation can promote Anthracnose by lengthening the leaf wetness period!
- Use healthy seed or planting material
- Remove affected crop residues and rotate crops
- Insect damage will provide easier entry for Anthracnose spores
- Apply fungicides: preferably preventive
  - chlorothalonil, triazoles (DMI), strobilurines (QoI)

Alternaria spp.

- Susceptible crops
  - Cabbage (*Alternaria brassicicola, A. brassicae*)
  - Potato, Tomato (*Alternaria solani, A. alternata*)
  - Carrot (*Alternaria dauci, A. radicina*)
  - Pepper (*Alternaria tenuis, A. alternata*)
- Symptoms
- Life cycle
- ICM strategy
Alternaria: symptoms

Cabbage

Potato-tomato

Carrot

Figure 3. Development and symptoms of diseases caused by Alternaria.
Life cycle Alternaria

- Conidia (spores) or mycelium overwinters in infected plant debris, on seeds, tubers etc.
- Conidia (spores) are dispersed by the wind or rain splashes
- Conidia (spores) need free moisture to infect
- Vigorous plants are less susceptible for infection
- Plants under stress are more susceptible
- Higher temperatures and change from wet to dry conditions is ideal for Alternaria

Alternaria: ICM strategy

- Use disease-free seed or seed that has been treated with a fungicide
- Use resistant cultivars
- Rotate host and non-host crops
- Remove plant debris and weeds
- Grow vigorous plants and prevent stress
- Apply fungicides: preferably preventive
  - mancozeb, copper, triazoles (DMI), strobilurines (QoIs)
Thank you for your attention