Overview of herbicide resistance issues in Europe
Alberto Collavo – Bayer AG Frankfurt am Main
Global Herbicide Resistance Challenge - May 15, 2017
Forward-Looking Statements

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Agenda

- Agricultural overview in EU
- Current status of resistance
- Reaction to resistance
- Conclusions
Agenda

• Agricultural overview in EU
  • General aspects
  • Major weeds
General aspects of EU agricultural sector

<table>
<thead>
<tr>
<th></th>
<th>EU</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>&gt;510 M</td>
<td>&gt;324 M</td>
</tr>
<tr>
<td>Area</td>
<td>432.5 M ha</td>
<td>983.3 M ha</td>
</tr>
<tr>
<td>Agricultural area</td>
<td>178.5 M ha</td>
<td>370.1 M ha</td>
</tr>
<tr>
<td>No. Farms</td>
<td>10.8 M</td>
<td>2.1 M</td>
</tr>
<tr>
<td>Average farm size</td>
<td>16.1 ha</td>
<td>175.5 ha</td>
</tr>
<tr>
<td>Share of farms smaller than 20 ha</td>
<td>86.3%</td>
<td>38.55%</td>
</tr>
<tr>
<td>Total value of agricultural production</td>
<td>€410.13 billion</td>
<td>€347.05 billion</td>
</tr>
</tbody>
</table>

Source: Eurostat, European Parliament Think Tank

- Diversified cropping system among EU countries compared to US due to geographical and historical reasons
- Differences among the EU countries in farm structure as well as yields
- Adoption of diversified agronomic practices dependent on farm size and land property
- Renting vs. owning land influences weed management
- Minimum tillage still expanding
- Cultivated as organic: 11.1 M ha (6.2%, increasing)
Utilized agricultural area

- Diversified cropping systems but crop rotations dominated by winter crops (wheat, barley and OSR) and corn in spring
- France, Germany, Poland and UK produce ~55% of EU’s cereals
- “Typical” crop rotation:
  - WW / WW / WW / OSR or Corn
- Corn: high temperature and water requirements limit growing areas
- Crop rotations with winter cereals are dominated by annual winter weed

Source: Eurostat (online data code: apro_acs_a)
Winter wheat in Europe

Winter wheat in Europe

Global Herbicide Resistance Challenge

May 15, 2017

Trnka et al., 2014. Adverse weather conditions for European wheat production will become more frequent with climate change. Nature Climate Change: 4, 637–643.

Difficult to map broadleaves due to localized distribution patterns

Weed species in cereals

<table>
<thead>
<tr>
<th>Grasses</th>
<th>Broadleaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALOMY Blackgrass</td>
<td>CONAR Field bindweed</td>
</tr>
<tr>
<td>APESV Silky bent-grass</td>
<td>GALAP Cleaver</td>
</tr>
<tr>
<td>AVEFA Wild oat</td>
<td>MATSS Chamomile spp.</td>
</tr>
<tr>
<td>BROSS Brome spp.</td>
<td>PAPRH Corn poppy</td>
</tr>
<tr>
<td>LOLSS Ryegrass spp.</td>
<td>POLSS Smartweed spp.</td>
</tr>
<tr>
<td>PHASS Canarygrass spp.</td>
<td>STEME Common chickweed</td>
</tr>
<tr>
<td>POAAN Bluegrass</td>
<td>VERSS Speedwell</td>
</tr>
<tr>
<td>SETSS Foxtail spp.</td>
<td>VIOAR Field pansy</td>
</tr>
</tbody>
</table>

Grasses

- ALOMY Blackgrass
- APESV Silky bent-grass
- AVEFA Wild oat
- BROSS Brome spp.
- LOLSS Ryegrass spp.
- PHASS Canarygrass spp.
- POAAN Bluegrass
- SETSS Foxtail spp.

Broadleaves

- CONAR Field bindweed
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Grasses

- Silky bent-grass
- Blackgrass
- Wild oat
- Brome spp.
- Ryegrass spp.
- Canarygrass spp.
- Bluegrass
- Foxtail spp.

Broadleaves

- Field bindweed
- Cleaver
- Chamomile spp.
- Corn poppy
- Smartweed spp.
- Common chickweed
- Speedwell
- Field pansy
Major crops and most important weed species

- **Cereals**
  - Wheat/Barley (36.5 M ha)
    - ALOMY, APESV, AVESS, LOLSS, PHASS
    - CENCY, GALAP, MATSS, PAPRH, SINAR, STEME, VERSS, VIOLA
  - Maize (9.3 M ha)
    - ECHCG, DIGSA, SETSS, SORHA
    - AMARE, CHEAL, POLSS, SOLNI, AMBAR (new, invasive)
- **Oilseed rape (6.4 M ha - mostly grown as winter crop)**
  - Volunteers cereals, ALOMY, APESV
- **Perennials (olive groves, citrus, vineyards – 9 M Ha)**
  - LOLSS, ERISS, MALSS
Agenda

- Current status of resistance
- Major herbicide resistant weed species and affected crops
- Trends
Herbicide resistant weed species and affected crops

Winter crops

Mainly annual winter weeds

ACCase (A/1) and ALS (B/2) inhibitors are the most affected MoAs

<table>
<thead>
<tr>
<th>Crops</th>
<th>Weed species</th>
<th>Occurrence of Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSR</td>
<td>ALOMY</td>
<td>A/1, B/2, C1/5, C2/7, K1/3, K3/15, N/8</td>
</tr>
<tr>
<td></td>
<td>LOLSS</td>
<td>A/1, B/2, C1/5, C2/7, G/9</td>
</tr>
<tr>
<td></td>
<td>APESV</td>
<td>A/1, B/2, C1/5, C2/7</td>
</tr>
<tr>
<td></td>
<td>AVEFA</td>
<td>A/1, B/2, Z/25</td>
</tr>
<tr>
<td></td>
<td>PAPRH</td>
<td>B/2, O/4</td>
</tr>
<tr>
<td></td>
<td>GALAP</td>
<td>B/2</td>
</tr>
<tr>
<td></td>
<td>MATSS</td>
<td>B/2, C1/5</td>
</tr>
<tr>
<td></td>
<td>STEME</td>
<td>B/2, C1/5</td>
</tr>
<tr>
<td></td>
<td>POLSS</td>
<td>B/2, C1/5, F3/11</td>
</tr>
</tbody>
</table>
### Herbicide resistant weed species

**Other crops**

ALS (B/2) inhibitors in corn and glyphosate (G/9) in perennial crops are the most affected MoAs

<table>
<thead>
<tr>
<th>Crop affected</th>
<th>Weed species</th>
<th>Occurrence of Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn, Soy, Sugar beet, Potato</td>
<td>AMASS</td>
<td>B/2, C1/5*, C2/7</td>
</tr>
<tr>
<td>Corn, Rice</td>
<td>ECHSS</td>
<td>B/2, C1/5*</td>
</tr>
<tr>
<td>Corn, Soy</td>
<td>SORHA</td>
<td>A/1, B/2</td>
</tr>
<tr>
<td>Corn, Sugar beet, Potato</td>
<td>CHEAL</td>
<td>C1/5*</td>
</tr>
<tr>
<td>Corn</td>
<td>POLSS</td>
<td>C1/5*</td>
</tr>
<tr>
<td>Corn</td>
<td>SOLNI</td>
<td>C1/5*</td>
</tr>
<tr>
<td>Corn</td>
<td>SETSS</td>
<td>B/2, C1/5*</td>
</tr>
<tr>
<td>Olive groves, citrus, vineyards</td>
<td>ERISS</td>
<td>G/9, C1/5*</td>
</tr>
<tr>
<td>Olive groves, vineyards</td>
<td>LOLSS</td>
<td>G/9,</td>
</tr>
</tbody>
</table>

* pre-selection with atrazine, banned in EU in 2003
### Herbicide resistance: affected area
(estimate, K ha)

<table>
<thead>
<tr>
<th>Country</th>
<th>Wheat/OSR</th>
<th>Corn</th>
<th>Rice</th>
<th>Plantations</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>1500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRANCE</td>
<td>2625</td>
<td>90</td>
<td></td>
<td>0.2</td>
</tr>
<tr>
<td>GERMANY</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nordics</td>
<td>800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLAND</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPAIN+PORTUGAL</td>
<td>1500</td>
<td>10</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>TURKEY</td>
<td>750</td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>ITALY</td>
<td>300</td>
<td></td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>BELGIUM+NETHERLANDS</td>
<td>50</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU+Turkey</td>
<td>&gt;8725</td>
<td>&gt;180</td>
<td>&gt;135</td>
<td>&gt;220</td>
</tr>
</tbody>
</table>
Crops and herbicides affected by resistance

Most affected crops are the ones with limited availability of MoAs:

- Winter cereals (ACCase and ALS inhibitors)

Or with intense use of mainly one mode of action:

- Perennials (EPSPs inhibitor)

Due to regulatory restrictions:

- Loss of MoAs controlling special weed species
- Dose rate restrictions / reductions cause difficulties in controlling tough species, promote metabolic resistance
Trends

- Minimum tillage increasing: increases species with seeds germinating from surface (ALOMY, APESV and LOLSS)
- Climate change effects:
  - blackgrass migrating to the east, ryegrass spreading over all of EU
  - corn moving to the north (even the UK!)
- Adoption of non-GM HT crops: volunteers (e.g., OSR in wheat; ALS HT traits)
- Biogas green mass production increasing (weeds don’t matter as much)
- Increasing farm size
- Increasing adoption of digital farming
Agenda

• Reaction to resistance
  • Long term cultural studies
  • Demonstration trials
  • Research and communication
  • The UK example
Which things are working?

- **Improved cultivation tools**, with machinery manufacturers involved in redesigning drilling equipment with minimal soil disturbance
- **Delayed drilling** combined with stale seedbeds to reduce early-germinating weeds cohorts
- **Diversity in crop rotation/cultivation** to keep winter grasses off balance
- **Cover crops** to:
  - improve soil structure and drainage to allow flexible drilling dates on heavy land
  - give spring crops a head-start over weeds
- **Increasing crop competitiveness** by:
  - choosing more competitive variety
  - enhancing herbicide performance
  - reducing grasses tillering, heading & seed production
Field demonstration trials
Working to convince farmers to change their practices

• Platform studies ("matrix trials")

• Demonstrate integration of chemical & cultural control techniques
  • Pre-drill cultivation method
  • Use of stale seedbeds
  • Delayed drilling
  • Crop density effects
  • Choice of varieties
  • Pre-harvest weed seed control
Research and communications

• General observations about farmers:
  • React to resistance more than working to prevent it
  • More willing to change herbicides before changing behavior

• Research:
  • Surveys and Modelling
  • More focus on metabolic resistance

• Communications:
  • Implement communication/training, alignment with consultants
  • Knowledge transfer:
    • Local platform/matrix studies
    • New media: Twitter, YouTube more important as outreach tool
Factors preventing adoption of Cultural Control Strategies

UK ALOMY example

- Growers always concerned about inability to drill a crop in the autumn
  - So do not like to delay drilling
- Heavy UK soils are “problematic” for spring drilling
  - So less willing to try spring cropping
- Not all growers have appropriate cultivation / drilling equipment
  - So can’t meet need for different equipment for different situations
- Growers on rented land unable to take reduced income from a modified rotation (e.g. spring cropping)
  - So carry on with their standard cropping pattern with only winter crops (mainly cereals)
- Large farms tend to “block farm” rather than treating each field individually
  - So unable to adapt and adopt appropriate cultural strategies to reduce populations

…. BUT all the above changes are implemented when there is no other option!
Solutions to manage resistant populations
UK ALOMY example

Background – in many areas:
• ACCase has been “lost”
• ALS is being compromised

Ultra-High Efficacy UK Herbicide Program:
• Glyphosate (540 g) - 1 or 2 appl., up to 5
• Flufenacet (240 g) + DFF (120g) +/- prosulfocarb (4000g) or pendimethalin (1200g) OR Triallate (2250 g)
• Flufenacet (120 or 240 g) +/- DFF OR pendimethalin
• Mesosulfuron (12-15 g) + iodosulfuron (2.4-5 g)
• Glyphosate (1080 g)

An unsustainable cost of approx. 240 € / ha

combined with stale seedbeds, winter / summer crop rotation, occasional tillage

In some cases glyphosate crop destruct!
Solutions to manage resistant populations
UK ALOMY example

Background – in many areas:
- Introduction of more cultural methods
- Less chemical input

Integrated UK Herbicide Program:
- Glyphosate (540 g) - 1 or 2 appl., up to 5
- Flufenacet (240 g) + DFF (120 g) +/- prosulfocarb (4000 g) or pendimethalin (1200 g)
- Triallate (2250 g)
- Flufenacet (120 g or 240 g) +/- DFF or pendimethalin
- Mesosulfuron (12-15 g) + iodosulfuron (2.4-5 g)
- Glyphosate (1080g)

Studies show economic return for sustainable practices
Agenda

• Conclusions
  • Learning from the situation in Europe
Learning from the situation in Europe

It is all about managing the population

- Irrespective of resistance status!
- And managing the soil seed bank

Even the most difficult infestations can be overcome... in a cost-effective manner

...But need to be flexible to meet the needs of individual fields

Use of **appropriate** cultivation & drilling equipment

- **Rotational plowing** to bury seed can help in some situations
- **Minimal cultivation & minimal disturbance drills** can reduce “in crop” ALOMY emergence

Delay autumn drilling date

- **Stale seedbeds** can be more effective when drilling can be delayed
- **Flexibility to switch to spring cropping** if required

Spring cropping

- **Spring barley** in the north remains the most competitive spring crop for ALOMY control

Cover Crops

- **Facilitate entry into spring cropping** on heavy soils & maintain soil structure in minimal disturbance systems
Resistance management in the near future

**Grasses will remain the major problem in cereals/OSR:**
- Resistance to ALS due to adoption of HT-trait crops especially in eastern countries
- Diffusion of resistance in maize

**Most problematic areas:**
- Northern France, Belgium, Germany: ALOMY
- Poland, Czech Republic: APESV and ALOMY
  - Due to the short rotations (limit diversity)
- Russia and Ukraine due to intensive wheat culture, huge farms
  - In a simplified system resistance evolution is easier

**Potential solutions:**
- Learnings from UK: benefits are derived from diversified weed management tools integrated into cropping systems
- Digital farming tools optimize weed control
- Education is an important aspect and cannot be underestimated
Thank you!

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