25 Years of fighting Black-Grass in Bavaria

Institut for Plant Protection

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Weed Resistance Global Symposium
Agenda

- Introduction
- Black-grass in Bavaria
- Activities to fight Black-grass
- Results from
  - field trials
  - resistance tests
  - long term trial
- Conclusion
- Overall experience
Introduction

Bavaria
Country & People

Country & People
Introduction

Agriculture in Bavaria

- About 90,000 Farms
- Arable Farms with
  - Ø 75 ha
  - Ø 2,2 farm hands
  - Ø 95,000 €/a profit
- Production value (plant & animal products)
  ~ 11,000 Mio. €/a
- Export value (agriculture & foods)
  ~ 8,500 Mio. €/a
Introduction

Field Crops in Bavaria 1960 vs. 2013

- triticale
- grain maize
- oilseed rape
- grain legumes
- hops
- vegetables
- winter barley
- silage maize
- forage grasses
- spring wheat
- sugar beet
- oats
- clover
- winter rye
- winter barley
- winter wheat
Introduction

Yield development of major field crops in Bavaria

- wheat
- barley
- corn
- oilseed rape

2005-2014
Ø t/ha

9,9
7,2
6,0
3,6
Black-grass in Bavaria

Distribution – formerly and today

Cause of dispersion:

1. Simple crop rotations

2. Contract thresher

3. Conservation tillage
Activities to fight Black-grass

Bavarian Plant Protection Service

1. **Field trial programs** for the chemical control of
   - normal black-grass in winter wheat
   - hard to control black-grass in winter wheat
   - black-grass in winter barley
   - black-grass in winter oilseed rape and maize

2. **Tests** in suspicion of herbicide resistance
   - biotest in greenhouse and climate chamber
   - genetic TSR analysis

3. **Long-term trial** with proof of
   - herbicide strategy and
   - kind of cultivation
   for effects on resistance dynamic
Results – field trials

Herbicide efficiency vs. normal black-grass in winter wheat

efficiency mean, standard deviation & trend - 125 field trials - Bavaria 1990-2014

- Isoproturon/Chlortoluron
- Fenoxaprop-P, Clodinafop
- Flupyrsulfuron
- Flufenacet
- Mesosulfuron-methyl
- Pyroxsulam

only single treatments
sometimes sequence applications

Year (n results)
Results – field trials

Black-grass efficacy – Atlantis vs. Broadway
74 field trials, winter wheat, Bavaria 2001 - 2014

Treatments and design:

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Atlantis WG/OD</th>
<th>Broadway</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.i.</td>
<td>Mesosulfuron-methyl 30 g/kg</td>
<td>Pyroxsulam 68 g/kg</td>
</tr>
<tr>
<td></td>
<td>+ Iodosulfuron-methyl 6 g/kg</td>
<td>+ Florasulam 23 g/kg</td>
</tr>
<tr>
<td>Amount</td>
<td>300 g + 0,6 l/ha adjuvant (A. WG)</td>
<td>220 g + 1,0 l/ha adjuvant</td>
</tr>
<tr>
<td></td>
<td>1,0 l/ha (A. OD)</td>
<td></td>
</tr>
<tr>
<td>Addition</td>
<td>different broadleaf herbicides</td>
<td>-</td>
</tr>
<tr>
<td>Application design</td>
<td>spring; march – beginning of april</td>
<td>small plots, 4 replications, randomised</td>
</tr>
</tbody>
</table>
Black-grass efficacy – Atlantis vs. Broadway

74 field trials, winter wheat, Bavaria 2001 - 2014

Trials | Atlantis | Broadway |
--- | --- | --- |
74 | 46 |

Results | Atlantis | Broadway |
--- | --- | --- |
127 | 55 |

Period | Atlantis | Broadway |
--- | --- | --- |
2001-14 | 2007-14 |

Total results
Results – field trials

Black-grass efficacy in case of herbicide resistance (rank 3-4)

Atlantis (300 g/ha) vs. Broadway (220 g/ha)
efficacy (%) - mean & range, 9 field trials, Bavaria 2007-2013
Results – field trials

Programm vs. hard to control Black-grass

<table>
<thead>
<tr>
<th>#</th>
<th>Herbicide</th>
<th>dose (l/kg \cdot ha^{-1})</th>
<th>a.i.</th>
<th>HRAC</th>
<th>time</th>
<th>TI</th>
<th>HRAC type</th>
<th>treatment type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Herold SC / Atlantis WG + Adj.</td>
<td>0.5 / 0.5 + 1,0</td>
<td>Flufenacet + Diflufenican + Mesosulfuron + Iodosulfuron</td>
<td>K3 + F1 + B</td>
<td>E-post / S-post</td>
<td>1,83</td>
<td>B+ double</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Herbaflex + Arelon Top / Atlantis WG + Adj.</td>
<td>2.0 + 1.0 / 0.5 + 1.0</td>
<td>Bellflubutamid + Isoproturon + Mesosulfuron + Iodosulfuron</td>
<td>F1 + C2 + B</td>
<td>E-post / S-post</td>
<td>2,33</td>
<td>B+ double</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Herold SC + Atlantis WG + Adj.</td>
<td>0.5 + 0.3 + 0.6</td>
<td>Flufenacet + Diflufenican + Mesosulfuron + Iodosulfuron</td>
<td>K3 + F1 + B</td>
<td>A-post</td>
<td>1,67</td>
<td>B+ single</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Herold SC + Atlantis WG + Adj. + AS</td>
<td>0.5 + 0.3 + 0.6 + 10,0</td>
<td>Flufenacet + Diflufenican + Mesosulfuron + Iodosulfuron</td>
<td>K3 + F1 + B</td>
<td>A-post</td>
<td>1,67</td>
<td>B+ single</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Atlantis WG + Adj. + Hoestar Super</td>
<td>0.5 + 1,0 + 0,15</td>
<td>Mesosulfuron + Iodosulfuron + Amidosulfuron</td>
<td>B</td>
<td>S-post</td>
<td>2,00</td>
<td>B single</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Atlantis WG + Adj. + Hoestar Super</td>
<td>0.4 + 0,8 + 0,15</td>
<td>Mesosulfuron + Iodosulfuron + Amidosulfuron</td>
<td>B</td>
<td>S-post</td>
<td>1,83</td>
<td>B single</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Atlantis WG + Adj. + Hoestar Super</td>
<td>0.3 + 0,6 + 0,15</td>
<td>Mesosulfuron + Iodosulfuron + Amidosulfuron</td>
<td>B</td>
<td>S-post</td>
<td>1,67</td>
<td>B single</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Atlantis WG + Adj. + Hoestar Super + AS</td>
<td>0,3 + 0,6 + 0,15 + 10,0</td>
<td>Mesosulfuron + Iodosulfuron + Amidosulfuron + AS</td>
<td>B</td>
<td>S-post</td>
<td>1,67</td>
<td>B single</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Atlantis WG + Adj. + Hoestar Super + Mero</td>
<td>0,3 + 0,6 + 0,15 + 1,0</td>
<td>Mesosulfuron + Iodosulfuron + Amidosulfuron + Mero</td>
<td>B</td>
<td>S-post</td>
<td>1,67</td>
<td>B single</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Atlantis WG + Adj. + Hoestar Super + Mero / Atlantis WG + Adj. + Hoestar Super + Mero</td>
<td>0,25 + 0,5 + 0,075 + 1,0 / 0,25 + 0,5 + 0,075 + 1,0</td>
<td>Mesosulfuron + Iodosulfuron + Amidosulfuron + Mero</td>
<td>B</td>
<td>S-post / S-post</td>
<td>2,00</td>
<td>B double</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Herold SC + Traxos + Mero / Atlantis WG + Adj.</td>
<td>0,5 + 1,0 +1,0 / 0,3 + 0,6</td>
<td>Flufenacet + Diflufenican + Clodinafop + Mero</td>
<td>K3 + F1 + A + B</td>
<td>A-post / S-post</td>
<td>2,33</td>
<td>B+ double</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Malibu + Lexus / Atlantis WG + Adj.</td>
<td>2,5 + 0,02 / 0,3 + 0,6</td>
<td>Flufenacet + Pendimethalin + Flupyrsulfuron + Mesosulfuron + Iodosulfuron</td>
<td>K3 + K1 + B</td>
<td>E-post / S-post</td>
<td>2,29</td>
<td>B+ double</td>
<td></td>
</tr>
</tbody>
</table>

Legend: E-post = early post emergence, A-post = post emergence autumn, S-post = post emergence spring; Adj. = herbicide adjuvant; AS = ammonium sulfate; Mero = common liquid oil spray adjuvant; TI = treatment index = sum of full herbicide doses
Results – field trials

Programm vs. hard to control Black-grass

Efficacy (%) of different treatments
2 locations, 8 trials, Bavaria 2010-2013
Results – field trials

Programm vs. hard to control Black-grass

**Efficacy (%) according to Black-grass density**
2 locations, 8 trials, Bavaria 2010-2013
Results – field trials

Programm vs. hard to control Black-grass

Efficacy (%) according to herbicide resistance
2 locations, 8 trials, Bavaria 2010-2013
Results – field trials

Programm vs. hard to control Black-grass

Efficacy (%) according to Atlantis application
2 locations, 8 trials, Bavaria 2010-2013

![Box plot showing efficacy of Atlantis application at different dose rates.](image)
Results – field trials

Programm vs. hard to control Black-grass

Efficacy (%) according to combination of modes of action (HRAC)
2 locations, 8 trials, Bavaria 2010-2013
Results – field trials

Programm vs. hard to control Black-grass

**Efficacy (%) according to amount of herbicide**
2 locations, 8 trials, Bavaria 2010-2013

![Graph showing efficacy of herbicide application based on treatment index.](image-url)
Results – resistance tests

Methodology:

Seed samples from suspect fields by advisers

Seed preparation and plant nursery in labor and climate chamber

<table>
<thead>
<tr>
<th>Efficacy limit value (%)</th>
<th>S</th>
<th>88</th>
<th>79</th>
<th>61</th>
<th>43</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance Code</td>
<td>S</td>
<td>r</td>
<td>R</td>
<td>R*</td>
<td>R**</td>
<td>R***</td>
</tr>
<tr>
<td>(Clark &amp; Moss)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance numeric class</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Treatment:
- 2-3 Doses/herbicide
- 6-8 repetitions
- 4 MOA
- 12 Herbicides/a.i.

Detection:
plant fresh mass
Results – resistance tests

Black-grass resistance development in Bavaria
Origins/biotypes with medium - heavy resistance

year

0 500 1000 1500 2000 2500 3000 3500
cases (origins/biotypes x herbicide)
Results – resistance tests

Black-grass resistance development
407 Tests, Bavaria 2004 - 2014
Resistance according to mode of actio (HRAC Class)

HRAC:
- K3
- C2
- B
- A

number origins/biotypes

year

Results – resistance tests

Black-grass herbicide resistance – intensity and distribution
greenhouse biotest, 400 biotypes, Bavaria 2004 - 2014

Ranks of resistance
(Clarke & Moss)
- 0-1 sensitiv – low sensitiv
- 2-3 low – medium resistant
- 4-5 strong – heavy resistant
## Results – long term trial

### Overview

**Herbicide program**

<table>
<thead>
<tr>
<th>ALS-Inhibitor only „ALS“</th>
<th>MOA rotation „BMP“</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCase-Inhibitor only „ACCase“</td>
<td>Production Standard „Praxis“</td>
</tr>
</tbody>
</table>

winter wheat single-crop farming since 2011

Survey of:
- Black-grass density
- Herbicide efficacy
- Resistance

- Mulch-till „chisel“
- Conventional-till „plow“
# Results – long term trial

Black-grass resistance on the beginning in 2011

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Cadou SC</th>
<th>IPU</th>
<th>CTU</th>
<th>Lexus</th>
<th>AtlantisOD</th>
<th>Attribut</th>
<th>Broadway</th>
<th>RalonSuper</th>
<th>Topik100</th>
<th>Axial50</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.i.</td>
<td>Flufenacet</td>
<td>Isoproturon</td>
<td>Chlortoluron</td>
<td>Flupyrsulfuron</td>
<td>Mesosulfuron + Iodosulfuron</td>
<td>Propoxycarbazone</td>
<td>Pyroxsulam + Florasulam</td>
<td>Fenoxaprop-P</td>
<td>Clodinafop</td>
<td>Pinoxaden</td>
</tr>
<tr>
<td>HRAC group</td>
<td>K3</td>
<td>C2</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance level (0-5)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
Results – long term trial

Shift in resistance according to kind of soil cultivation
Resistance class difference 2011 : 2014
## Results – long term trial

### Resistance shifting according to cultivation and herbicide program

<table>
<thead>
<tr>
<th>Cultivation</th>
<th>Herbicide program</th>
<th>Resistance class (0-5) for herbicides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cadou SC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year 2011 - start</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Year 2014</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>chisel</strong></td>
<td>BMP</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Praxis</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>ALS</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>ACCase</td>
<td>0</td>
</tr>
<tr>
<td><strong>plow</strong></td>
<td>BMP</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Praxis</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>ALS</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>ACCase</td>
<td>0</td>
</tr>
</tbody>
</table>
Conclusion

Resistance dynamic as a 3-Phase-Model

Phase 1:
Shifting resistance on the level of biotypes

Phase 2:
Selection of resistant biotypes on the level of the population

Phase 3:
Population change to high and uniform nTSR and TSR
Overall experience

„Fighting Black-grass is a asymmetric war“

Science and guidance recommend resistance management strategy

Farmers planting mostly cash crops, using often the same herbicides and believe on chemistry

Black-grass use any chance for higher density and resistance
„Only a dead Black-grass is a good Black-grass“*