BASF EXCLUSIVE:
Keep up to herbicide resistance.
(With down-to-earth advice.)
Welcome

Welcome to the first-ever BASF webinar on managing herbicide resistance

Hosted by:

- **Shaun Haney**
  Founder of Real Agriculture

You’ll also hear from:

- **Dr. Roger Mandel**
  Technical Service Specialist, BASF Australia

- **Dr. Bob Blackshaw**
  Retired Weed Scientist,
  Formerly with Agriculture and Agri-Food Canada

- **Andrew Reid**
  Technical Service Specialist, BASF Canada
Webinar Goals

2018: Managing herbicide resistance

- Gaining a big-picture (global) perspective on resistance
- Keeping up to date on resistance in Canada
- Discovering helpful strategies to manage resistant weeds
What We’ll Be Covering

Our experts will be covering many aspects of herbicide resistance, including:

- Herbicide resistance in Australia
- Tough weeds to keep on the radar
- Integrated weed management strategies
- Diversified cropping systems to manage resistance

Don’t be shy; submit your questions via the chat box near the end of the discussion to get them answered during the Q & A session at the end.

Today’s webinar is eligible for one CCA CEU for Integrated Pest Management (IPM).
Just the Facts

- Three out of four Canadian growers say herbicide-resistant weeds are affecting their bottom line
  
- Resistance develops when the same herbicide group is used repeatedly to manage weeds in a field

- Canada has the third highest number of resistant weeds, behind the United States and Australia

An Australian Perspective on Resistance Management

Dr. Roger Mandel

- Technical Service Specialist at BASF Australia
- Adjunct Senior Lecturer at Curtin University, Australia
- 17 years of experience in the Australian university system with education and research in Weed Science and Agronomy
- Educated in Lethbridge and Calgary, Alberta
- Grew up on a wheat and Angus farm in Warner, Alberta
WISDOM

Sometimes the Only Difference Between a Budding Genius and a Blooming Idiot is Where They Choose to Take a Stand.
How many herbicide modes of action have been lost?

<table>
<thead>
<tr>
<th>#</th>
<th>Country</th>
<th>TOTAL</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
<th>D</th>
<th>G</th>
<th>K1</th>
<th>O</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>United States</td>
<td>160</td>
<td>15</td>
<td>52</td>
<td>26</td>
<td>11</td>
<td>6</td>
<td>17</td>
<td>6</td>
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<td>19</td>
</tr>
<tr>
<td>2</td>
<td>Australia</td>
<td>90</td>
<td>12</td>
<td>26</td>
<td>8</td>
<td>0</td>
<td>10</td>
<td>16</td>
<td>3</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Canada</td>
<td>67</td>
<td>4</td>
<td>25</td>
<td>13</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>6</td>
</tr>
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<td>0</td>
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<td>0</td>
<td>1</td>
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<td>7</td>
<td>19</td>
<td>4</td>
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<td>1</td>
<td>8</td>
<td>0</td>
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<tr>
<td>6</td>
<td>China</td>
<td>43</td>
<td>8</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Spain</td>
<td>38</td>
<td>2</td>
<td>8</td>
<td>18</td>
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<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>8</td>
<td>Israel</td>
<td>36</td>
<td>6</td>
<td>12</td>
<td>12</td>
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<td>2</td>
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<td>9</td>
<td>Japan</td>
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<td>21</td>
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<td>7</td>
<td>3</td>
<td>2</td>
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</tr>
<tr>
<td>10</td>
<td>Germany</td>
<td>32</td>
<td>5</td>
<td>10</td>
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<td>0</td>
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<td>1</td>
</tr>
</tbody>
</table>
### Which Resistant Weeds are Making the Most Noise? Why?

<table>
<thead>
<tr>
<th><strong>Lolium rigidum</strong></th>
<th><strong>Rigid Ryegrass</strong></th>
<th><strong>Multiple Resistance: 7 Sites of Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ACCase inhibitors (A/1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ALS inhibitors (B/2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DOXP inhibitors (F4/13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microtubule inhibitors (K1/3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mitosis inhibitors (K2/23)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long chain fatty acid inhibitors (K3/15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lipid inhibitors (N/8)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Raphanus raphanistrum</strong></th>
<th><strong>Wild Radish</strong></th>
<th><strong>Multiple Resistance: 5 Sites of Action</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ALS inhibitors (B/2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inhibitors of photosynthesis at photosystem II (PS II inhibitors)(C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carotenoid biosynthesis inhibitors (F1/12)</td>
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<tr>
<td></td>
<td></td>
<td>EPSP synthase inhibitors (G/9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Synthetic auxins (O/4)</td>
</tr>
</tbody>
</table>

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**Note:** The table above lists the sites of action targeted by the weed control medications specified for each weed species. The resistance mechanisms described include ACCase inhibitors, ALS inhibitors, DOXP inhibitors, microtubule inhibitors, mitosis inhibitors, long chain fatty acid inhibitors, and lipid inhibitors. These mechanisms are integral to the growth and development of the weeds, and their resistance to these chemicals is crucial for effective weed management.
Wild Radish; Our Worst Dicot Weed
## How Widespread are Resistant Weeds?

### Grass Weeds

<table>
<thead>
<tr>
<th>Grass Weeds</th>
<th>Groups</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual ryegrass (<em>Lolium rigidum</em>)</td>
<td>A, B, C, D, L, M, Q</td>
<td>&gt;20,000 &gt;20,000 &gt;50 &gt;5000 10 &gt;500 3</td>
</tr>
<tr>
<td>Barley grass (<em>Hordeum spp.</em>)</td>
<td>A, B, L</td>
<td>&gt;200 &gt;200 &gt;100</td>
</tr>
<tr>
<td>Brome grass (<em>Bromus spp.</em>)</td>
<td>A, B, M</td>
<td>&gt;200 &gt;1000 6</td>
</tr>
<tr>
<td>Wild oat (<em>Avena spp.</em>)</td>
<td>A, B, Z</td>
<td>&gt;2000 &gt;50 &gt;200</td>
</tr>
</tbody>
</table>

### Broadleaf Weeds

<table>
<thead>
<tr>
<th>Broadleaf Weeds</th>
<th>Groups</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common sowthistle (<em>Sonchus oleraceus</em>)</td>
<td>B, I, M</td>
<td>&gt;5000 3</td>
</tr>
<tr>
<td>Indian hedge mustard (<em>Sisymbrium orientale</em>)</td>
<td>B, C, F, I</td>
<td>&gt;1000 3</td>
</tr>
<tr>
<td>Wild radish (<em>Raphanus raphannistrum</em>)</td>
<td>B, C, F, I, M</td>
<td>&gt;1000 &gt;20 &gt;50 &gt;500 3</td>
</tr>
</tbody>
</table>
Discuss how, with the loss of so many modes of action, Australian growers are now forced to resort to unconventional ways of dealing with resistant weeds?

$3.3$ billion/year

**Figure 1**: The total cost of weeds (revenue loss plus expenditure) to Australian grain growers is estimated at $3,318 million.
What Do We Do After Resistance?
Fire is Still a Viable Tool
Chaff Decking with Control Traffic
(use of hostile environments)
Mother Nature Doesn’t Play Fair

- Directional selection for flowering time leads to adaptive evolution in *Raphanus raphanistrum* (Wild radish)

*Evolutionary Applications Volume 9, Issue 4*

Michael B. Ashworth, Michael J. Walsh, Ken C. Flower, Martin M. Vila-Aiub and Stephen B. Powles
Flowering Date Selection

EARLY FLOWERING DATE SELECTION

Base Population (WARR 7)

S1 S2 S3 S4 S5

C1 C2 C3 C4 C5

UNSELECTED CONTROL GENERATIONS

LATE FLOWERING DATE SELECTION

Base Population (WARR 7)

S1 S2 S3

C1 C2 C3

UNSELECTED CONTROL GENERATIONS
Flowering Date Shifts to Early FD Selection

FD<sub>50</sub> = 59 days
Flowering Date Shifts to Early FD Selection

Cumulative Flowering (% of population) vs. Emergence to Flowering (days)

FD\textsubscript{50} = 29 days

FD\textsubscript{50} = 59 days
Flowering Date Shifts to Long FD Selection?

FD<sub>50</sub> = 59 days
Diversity; Mother Nature Doesn’t Play Fair

Emergence to Flowering (days)

Cumulative Flowering (% of population)

FD_{50} = 29 days
FD_{50} = 59 days
FD_{50} = 114 days

13 DAYS
52 DAYS
84 DAYS

11 DAYS
14 DAYS
40
60
80
100
0
20
40
60
80
100

Emergence to Flowering (days)

BASF
We create chemistry
# Canadian Label

## Heat/Heat LQ

### Formulation

<table>
<thead>
<tr>
<th>Product</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat (PCP# 29368)</td>
<td>BASF Canada</td>
</tr>
<tr>
<td>Heat LQ (PCP# 31468)</td>
<td></td>
</tr>
</tbody>
</table>

Heat: 1 jug treats 30 - 80 acres, 1 case treats 240 - 640 acres Heat LQ: One case treats 30 - 80 acres

## Crops, Staging and Rates

<table>
<thead>
<tr>
<th>Crop</th>
<th>Stage</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (spring, winter, durum), barley, oats, canaryseed, corn (field, sweet), field peas, chickpeas</td>
<td>Pre-seed or pre-emerge</td>
<td>10.4 - 28.4 g/acre&lt;br&gt;21.5 - 59 mL/acre Heat LQ</td>
</tr>
<tr>
<td>Lentil*, soybean*</td>
<td></td>
<td>10.4 g/acre&lt;br&gt;21.5 mL/acre Heat LQ</td>
</tr>
<tr>
<td>Chalfallow</td>
<td></td>
<td>10.4 - 28.4 g/acre&lt;br&gt;21.5 - 59 mL/acre Heat LQ</td>
</tr>
<tr>
<td>Canola (all types), field pea, soybean and dry, common bean, sunflower, flax, red lentils, mustard</td>
<td>Pre-harvest</td>
<td>14.5 - 28.4 g/acre&lt;br&gt;29.5 - 59 mL/acre Heat LQ</td>
</tr>
<tr>
<td>Seedling bromegrass for seed production</td>
<td>Pre-seed or pre-emergent</td>
<td>10.4 - 28.4 g/acre&lt;br&gt;21.5 - 59 mL/acre Heat LQ</td>
</tr>
</tbody>
</table>
# Herbicide Cost and Application Rate on Major Australian Weeds

<table>
<thead>
<tr>
<th>Herbicide &amp; $/ha (bold underlined rate)</th>
<th>Cape-weed</th>
<th>Double-gee</th>
<th>Erodium</th>
<th>Marshmallow</th>
<th>Clover</th>
<th>Radish</th>
<th>Vol.-Legumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharpens (Heat LQ) - $5.00</td>
<td>10-17g</td>
<td>10-17g</td>
<td>10-17g</td>
<td>10-17g</td>
<td>10-17g</td>
<td>10-17g</td>
<td>10-17g</td>
</tr>
</tbody>
</table>
A Peek at Herbicide Resistance in Canada

Dr. Bob Blackshaw

- Retired from 33 years as a Weed Scientist with Agriculture and Agri-Food Canada
- Extensive expertise in weed resistance, integrated weed management and a diversified cropping system
- Spent a year in Australia to gain knowledge about their weed resistance issues
- Grew up on a family farm in Virden, Manitoba
Increase in Unique Resistant Weed Cases for Canada

Source: Dr. Ian Heap, WeedScience.org, 2016
The Rising Incidence of HR Weeds in Western Canada

<table>
<thead>
<tr>
<th>Year Range</th>
<th>M ha / M ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001 - 2003 surveys</td>
<td>4.4 / 10.9</td>
</tr>
<tr>
<td>2007 - 2009 surveys</td>
<td>9.9 / 24.4</td>
</tr>
<tr>
<td>2014 - 2017 surveys</td>
<td>15.4 / 38.0</td>
</tr>
</tbody>
</table>
Risk of Resistance by Weed Species

- **Distribution and density:** commonly occurring weeds in a region, e.g. wild oat on the Canadian prairies
  - resistance is a numbers game

- **Genetic diversity:** greater chance of having the resistant gene in the first place, e.g. kochia resistant to Group 2, 4, 9 herbicides

- **High seed production:** increase in resistant biotype relative to susceptible population after herbicide application
  - kochia produces 10,000 to 25,000 seeds per plant
Canadian Prairie Weeds

Top 10 (Relative Abundance Rank)

1. Green foxtail
2. Wild oat
3. Wild buckwheat
4. Canada thistle
5. Lamb’s quarters
6. Chickweed
7. Stinkweed
8. Redroot pigweed
9. Cleavers
10. Kochia
Saskatchewan Field Resistance Survey – 2014-2015 Results

Wild oat
- Group 1 – 59%
- Group 2 – 32%
- Group 1+2 – 25%

Green foxtail
- Group 1 – 17%
- Group 2 – 15%
- Group 1+2 – 2%
Saskatchewan Field Resistance Survey – 2014-2015 Results

Group 2 resistance

- Cleavers – 20%
- Wild mustard – 25%
- Shepherd’s purse – 23%
- Chickweed – 20%
- Stinkweed – 14%
- Redroot pigweed – 10%
Glyphosate Resistance

- Kochia is the only documented weed on the prairies
- Predictive modelling for glyphosate resistance on the prairies: kochia, wild oat, green foxtail, cleavers
- Glyphosate-resistant Russian thistle in the USA
Managing Resistance

- Herbicide rotation and mixtures (different mode of action)
- Herbicide layering
  - Pre-plant or pre-emergent soil-active herbicide followed by a post-emergent in-crop herbicide with a different MOA
  - Common practice in US Corn Belt to manage glyphosate-resistant weeds
  - Delay/prevent further resistance development
Soil-Active Herbicides in Conservation Tillage

- Many differences compared to soil-incorporated Avadex and Treflan in previous years
- Weed seed remains on or near the soil surface
- Herbicide presence in the 0-3 cm soil zone is sufficient to control germinating weeds
- Greater herbicide concentration when present in 0-3 vs 0-10 cm zone
- Need to be in reduced till system (<30% soil disturbance) for previous 3 years to grow out weed seed at deeper depths
All soil herbicides require adequate soil moisture to be dissolved in the soil solution and subsequently taken up by plants.

Surface soil moisture usually greater in reduced till systems (snow trapping).

Cooler soil temperatures with conservation tillage reduce risk of volatilization losses.

Granular formulations are not tied up by stubble and are less susceptible to photodegradation/volatilization losses.
Recent Soil-Active Herbicides

- In addition to Avadex and Trifluralin, there are other soil-active herbicides
  - Authority
  - Focus
  - Heat LQ
  - Valterra
Multiple Herbicide Economics

- Glyphosate-resistant horseweed study in USA
- Added a second MOA herbicide as soil-applied herbicide or as mixture with in-crop glyphosate in corn-soybean rotation
- Used field data and modelled for a further 20 years
- Year 1: negative $12/acre
- Year 2: slightly negative to break even
- Year 3-20: positive $24-55/acre
Two-pass Weed Control in Corn - Ontario

Weed Control (%)

- Roundup EP: 66%
- Roundup LP: 88%
- Roundup Twice: 94%
- PRE Residual + Roundup LP: 97%
Two-pass Weed Control in Corn - Ontario

Net Returns ($/ac)

- Weedy: 549
- Roundup EP: 1017
- Roundup LP: 1041
- Roundup Twice: 1072
- PRE Residual + Roundup LP: 1067
Two-pass Weed Control

1. Protects the full yield potential of the crop
   a. Early-season weed control – Start clean, stay clean

2. Timing of the POST application is not as critical, which may be delayed due to:
   a. Frequent rain events
   b. Windy weather
   c. Machinery breakdowns
   d. Large number of acres to cover in a short period

3. Reduces selection pressure for herbicide resistant weeds
   a. Reduced weed density at POST application timing
Integrated Weed Management Systems

- Diverse crop rotations
  - cereals, oilseeds, pulses, forages, winter annuals, perennials
- Higher crop seeding rates
- Silage and forage crops
- Strategic tillage
- Green manure and cover crops
- Harvest weed seed management

A Systems Approach to Managing Resistant Weeds

Andrew Reid

- Technical Service Specialist at BASF Canada
- Works with marketing and research teams on long-term herbicide projects
- Master’s degree in Weed Science and a Bachelor of Science in Agronomy at the University of Guelph
- 5 years of focused efforts toward the agronomics surrounding crop protection products
How Can We Manage Weed Resistance?

- Managing resistance is always easier before it occurs
  - Good planning
  - Good agronomic practices
  - Integration of several different techniques
  - Cleanliness is key! (minimize movement of seeds)

Source: Univar Connectivity, CropWeb
Source: Encyclopedia Britannica
Source: Western Producer
Resistance Management: A Systems Approach

- Resistance management requires every tool you have to effectively manage the problem

- Herbicides are an extremely important tool to use, even after resistance occurs
  - Several different strategies you can use to maximize effectiveness:
    - Tank-mix multiple modes of action
    - Rotate crops and herbicides frequently
    - Minimize usage of high-risk herbicides (i.e. Groups 1, 2)
Alternate or Tank Mix?

![Graph showing frequency of resistant individuals over generations for Herbicide A or B used alone versus Herbicide A and B rotated. The graph suggests that tank-mixing of Herbicide A and B can delay the development of resistance compared to using each herbicide alone.](image)
Multiple Modes of Action

- Multiple Modes of Effective Action

- For a tank mix to be truly MMOEA, at least two active ingredients **must** have activity on the target weed

- Group 14 herbicides have a good fit for a lot of problem broadleaf weeds
Spring vs. Fall Applications

- Fall applications can provide some residual weed control
  - Benefit of improving weed control the next year
  - Less flexibility in terms of crop rotation choices

- Spring applications provide burndown/residual activity
  - Burndown of emerged weeds
  - Time available for application can be difficult some years
Systems Approach

- Utilizing multiple passes of MMOEA is part of an effective strategy to manage herbicide resistance
  - IPM: “many little hammers”

- Even if you do not get perfect control with the first pass, utilizing a second pass with a different mode of action reduces the selection pressure
  - Basis of the PeasPlus, SoybeansPlus and CornPlus program
  - More residual chemistries appearing on the market
Glyphosate vs. Heat LQ + Glyphosate

Glyphosate alone

Heat® LQ + glyphosate
Systems Approach – Soybean Example

Heat LQ + Zidua™ SC f/b Engenia®

Heat LQ + Zidua SC f/b Viper® ADV
Questions and Answers
Conclusion

Thank you for attending this BASF exclusive webinar. Tell us what you thought by filling out a brief exit survey question.

For more tips on herbicide resistance and how to manage it, visit agsolutions.ca/herbicideresistance.

Questions? Talk to your BASF Sales Representative or call AgSolutions® Customer Care at 1-877-371-BASF (2273).
We create chemistry