Integrated Wild Oat Management

K. Neil Harker
AAFC, Lacombe, AB

Saskatoon, SK
Mar 2, 2016
Overview

• Herbicide Resistance Background
• Differential Resistance Risks:
  – Weeds & Herbicides (some higher risks than others)
• Wild Oat Resistance Management Keys
  – Crop Canopy Health
  – Diverse Cropping Systems
  – IWM

Photo: Robert Blackshaw
Where are the most GR Weeds?

- Where are the most GR Crops?
  - US, Brazil & Argentina have > 80% of world GR crop acres
  - 330 million acres in 2009
  - Worldwide, there are 112 known instances of GR Weeds

www.plosone.org
Where is the Most Kochia?

Where is GR Kochia found?

- Kansas (2007)
- South Dakota (2009)
- Nebraska (2011)
- Alberta (2012)
- Colorado (2012)
- Montana (2012)
- North Dakota (2012)
- Saskatchewan (2012)
- Oklahoma (2013)
- Manitoba (2013)
Weed Resistance is a NUMBERS “game”

<table>
<thead>
<tr>
<th>High \ Weed numbers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High density</td>
</tr>
<tr>
<td>• Broad distribution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High \ Genetic diversity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High frequency of resistance mutations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High \ Seed production:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• rapid increase in resistant biotype relative to susceptible population after herbicide application</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High \ Out-crossing (gene spread):</th>
</tr>
</thead>
<tbody>
<tr>
<td>• rigid ryegrass, kochia, ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High \ Seed Bank Turnover (low seed dormancy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• rigid ryegrass, kochia, ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High \ proportion of Herbicide Escapes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• wild oat, cleavers, kochia,</td>
</tr>
</tbody>
</table>
Risk of Selection for Resistance - Herbicide Groups

# Weed Species Resistant to Individual Herbicides (Top 15)

- atrazine: 66 species
- imazethapyr: 44 species
- tribenuron-methyl: 43 species
- imazamox: 37 species
- chlorsulfuron: 36 species
- metsulfuron-methyl: 35 species
- glyphosate: 34 species
- iodosulfuron-methyl-sodium: 33 species
- fenoxaprop-P-ethyl: 31 species
- simazine: 31 species
- paraquat: 30 species
- bensulfuron-methyl: 29 species
- thifensulfuron-methyl: 27 species
- fluazifop-P-butyl: 25 species
- pyrazosulfuron-ethyl: 25 species

©2016 WeedScience.org, Dr. Ian Heap 02/25/2016
### Most Popular Western Canada Crop Rotations

<table>
<thead>
<tr>
<th>#</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Canola</td>
<td>Wheat</td>
<td>Canola</td>
<td>Wheat</td>
</tr>
<tr>
<td>2</td>
<td>Canola</td>
<td>Wheat</td>
<td>Wheat or Barley or Peas</td>
<td>Canola</td>
</tr>
<tr>
<td>3</td>
<td>Canola</td>
<td>Canola</td>
<td>Canola</td>
<td>Canola</td>
</tr>
</tbody>
</table>
## In-crop herbicides in field crops (2006-2010)

<table>
<thead>
<tr>
<th>Site of Action</th>
<th>Wheat</th>
<th>Barley</th>
<th>Canola</th>
<th>Flax</th>
<th>Field Pea</th>
<th>Lentil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76</td>
<td>86</td>
<td></td>
<td>100</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>12</td>
<td></td>
<td>0</td>
<td>76</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>2</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(n)</td>
<td>775</td>
<td>280</td>
<td></td>
<td>49</td>
<td>129</td>
<td>49</td>
</tr>
</tbody>
</table>

Adapted from: Beckie et al. 2013 Weed Technol. 27:171-183
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<td>86</td>
<td>6</td>
<td>100</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>12</td>
<td>15</td>
<td>0</td>
<td>76</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
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<tr>
<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>42</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>0</td>
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Adapted from: Beckie et al. 2013 Weed Technol. 27:171-183
New Herbicide Modes of Action

“No new major herbicide mode of action has been introduced in a commercial herbicide active ingredient in the last 20 years.

Back to Wild Oat...

Ian Heap
Alberta – Wild Oat Control for Wheat

Altitude FX (C)
Assert +
Avadex BW
Axial
Axial iPak
Broadband
Everest +
Everest GBX
Express FX
Express Pro +
Express SG
FirstStep
Fortress
Harmony K
Harmony Max +
Harmony SG

Horizon +
Inferno Duo
Liquid Achieve SC +
Pace
Predicate
Puma +
Simplicity
Tandem
Titanium
Traxos
Traxos Two
Tundra
Varro
Velocity m3
Top 10 Herbicide Targets - Western Canada

Estimated Cost of Herbicide Products Applied ($ million)

- Redroot pigweed
- Sowthistle
- Cleavers
- Wild mustard
- Kochia
- Stinkweed
- Green foxtail
- Canada thistle
- Wild buckwheat
- Wild oat

Available: http://weedscience.ca/resources/annual-meeting-archived-files/
Group 1 (ACCase) Resistant Wild Oat Alberta

2001: 11% of fields
2007: 39% of fields
2014: > 50%

Provincial Resistance Maps
By Hugh Beckie
Seeding Depth & Weeds?

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>4 mph</th>
<th>1 cm</th>
<th>June 7 Photo</th>
<th>(April seeded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid</td>
<td>4 mph</td>
<td>4 cm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crop Health
- Rotating Varieties & Species
- continuous silage cropping

PRINCIPLE
Rotating Varieties & Species →
• ↑ Crop Health
• ↑ Productivity
• ↓ Diseases
• ↑ Crop Competition
• ↓ Weeds
Materials and Methods

Cropping sequences: 2002-2004

- Barley cv. ‘Seebe’ / ‘Seebe’ / ‘Seebe’
- Barley cv. ‘CDC Helgason’ / ‘AC Harper’ / ‘Seebe’
- ‘CDC Helgason’ / Triticale ‘Pronghorn’ / ‘Seebe’
- ‘CDC Helgason’ / Oat ‘AC Mustang’ / ‘Seebe’
- ‘Pronghorn’ / ‘AC Mustang’ / ‘Seebe’

Data: T. Kelly Turkington, AAFC, Lacombe
% Leaf Area Diseased (PLAD)  

Rotation

Seebe/Seebe/Seebe
Helgason/Harper/Seebe
Helgason/Pronghorn/Seebe
Helgason/Mustang/Seebe
Pronghorn/Mustang/Seebe

PLAD

LSD_{0.05} = 2.1
Root biomass (2004)

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Seebe/Seebe/Seebe</th>
<th>Helgason/Harper/Seebe</th>
<th>Helgason/Pronghorn/Seebe</th>
<th>Helgason/Mustang/Seebe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29.1</td>
<td>34.4</td>
<td>35.1</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>42.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD$_{0.05} = 8.2$
Cropping System Diversity

- Wheat – Canola
- Wheat – Canola – Peas
- Canola – Canola
- Wheat - Wheat
- Wheat – Lentils/Chickpeas – Wheat – Canola
- Wheat – Fallow
- Barley silage
- Barley silage - Winter Wheat – Canola
- Wheat – Alfalfa – Alfalfa – Alfalfa – Canola

Weeds fortunate enough to grow in simple, repeated cropping systems of the same life cycle will continue to have little difficulty adapting and thriving.
Cropping - Rotations & Cycles

Winter - Spring - Summer - Fall - Winter

J F M A M J J A S O N D
Cropping - Rotations & Cycles
- Summer Annual Crops

Wild Oat Adaptation

Crop Growth

J F M A M J J A S O N D
Cropping - Rotations & Cycles - Later Seeding

Wild Oat Adaptation

J F M A M J J A S O N D
Cropping - Rotations & Cycles - Earlier Seeding

Wild Oat Adaptation

J F M A M J J A S O N D
Cropping - Rotations & Cycles
- Winter Annual Crops

Wild Oat Adaptation

J F M A M J J A S O N D
Downy Brome & Winter Wheat – Weed Density

Adapted from Blackshaw, Weed Technol. 1994. 8:728-732
Wild Oat Adaptation

J F M A M J J A S O N D
Integrated Weed Management
Treatments

- Rotation – Continuous Barley vs. Bar-Can-Bar-Bar-Pea
- Varieties/Cultivars – Short versus Tall
- Seeding Rate – 1X or 2X (200 or 400 seeds/m\(^2\))
- Herbicide Rate – ¼, ½, or 1X (ACCase or ALS)

- Treatments applied to same plots year after year – cumulative treatment effects
Year 5
Wild Oat BM – Maturity – ¼ X Rate – 2005 (3-site means after 5 years)

LSD (0.05) = 614
Combining Optimal Factor Synergy - Wild oat biomass **Reduction**

<table>
<thead>
<tr>
<th># Factors</th>
<th>Description</th>
<th>(x)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1x to 2x</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Short to Tall</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cont to Rot</td>
<td>2.7</td>
<td>2-3</td>
</tr>
<tr>
<td>2</td>
<td>1x-Short to 2x-Tall</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1x-Cont to 2x-Rot</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Short-Cont to Tall-Rot</td>
<td>7.3</td>
<td>6-8</td>
</tr>
<tr>
<td>3</td>
<td>1x-Short-Cont to 2x-Tall-Rot</td>
<td>18.7</td>
<td>19</td>
</tr>
</tbody>
</table>

Is a B-C-B-P-B rotation really diverse?

What would be better?
Materials and Methods

• Supplement natural wild oat infestation in fall and spring of the 1st year
• Combine optimal cultural wild oat management tactics with truly diverse rotations (not just summer-annuals) under no-till regime
• 14 Treatments
  – 100% herbicide, Chem Fallow and Alfalfa checks
• All plots receive a full rate of dicot herbicides
• 4 x 15 m plots in RCBD with 4 replications
• 8 locations
Lacombe, AB (AAFC)
- K. Neil Harker
- John O’Donovan
- Kelly Turkington

Lethbridge, AB (AAFC)
- Bob Blackshaw
- Newton Lupwayi
- Elwin Smith

Saskatoon, SK (U of S)
- Steve Shirtliffe
- Chris Willenborg

Winnipeg, MB (U of M)
- Rob Gulden

New Liskeard, ON (U of G)
- John Rowsell

Normandin, QC (AAFC)
- Denis Pageau

8 Sites

Prince Edward Island
British Columbia
Yukon
Territory
Northwest Territories
Nunavut
Alberta
Manitoba
Quebec
Ontario
Newfoundland
New Brunswick
Nova Scotia
Prince Edward Island
Labrador

Lethbridge, AB (AAFC)
- Linda Hall

Scott, SK (AAFC)
- Eric Johnson
Data Collection

- Crop stand density - Spring
- Crop biomass - Summer
- Crop yield
- Wild oat density counts - Spring
- Wild oat biomass - Summer
- Wild oat seed bank determination
# Treatments – I

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Checks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola-Wheat</td>
<td>C 100H</td>
<td>W 100H</td>
<td>C 100H</td>
<td>W 100H</td>
</tr>
<tr>
<td>Chem Fallow</td>
<td>C 50H</td>
<td>CF 100H</td>
<td>2xFR 0H</td>
<td>CF 100H</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>C 50H</td>
<td>Alf 0H</td>
<td>Alf 0H</td>
<td>Alf 0H</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer Annuals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola-Barley</td>
<td>C 50H</td>
<td>2xB 0H</td>
<td>C 100H</td>
<td>2xB 0H</td>
</tr>
<tr>
<td>Canola-Barley</td>
<td>C 50H</td>
<td>2xB 50H</td>
<td>C 100H</td>
<td>2xB 50H</td>
</tr>
<tr>
<td>Can-Bar-Pea-Wht</td>
<td>C 50H</td>
<td>2xB 0H</td>
<td>P 100H</td>
<td>2xW 0H</td>
</tr>
<tr>
<td>Can-Bar-Pea-Wht</td>
<td>C 50H</td>
<td>2xB 50H</td>
<td>P 100H</td>
<td>2xW 50H</td>
</tr>
</tbody>
</table>

0, 50, & 100% Herbicide rates are for wild oat herbicides only, dicot herbicide rates were 100%
## Treatments – II

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early-Cut Silage &amp; Winter Annuals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can-ES-Pea-WT</td>
<td>C 50H</td>
<td>2xES 0H</td>
<td>P 100H</td>
<td>2xWT 0H</td>
</tr>
<tr>
<td>Can-FR-Pea-WT</td>
<td>C 50H</td>
<td>2xFR 0H</td>
<td>P 100H</td>
<td>2xWT 0H</td>
</tr>
<tr>
<td>Can-ES-ES-WW</td>
<td>C 50H</td>
<td>2xES 0H</td>
<td>2xES 0H</td>
<td>2xWW 0H</td>
</tr>
<tr>
<td>Can-ES-ES-Wht</td>
<td>C 50H</td>
<td>2xES 0H</td>
<td>2xES 0H</td>
<td>2xW 0H</td>
</tr>
<tr>
<td>Can-ES-WW-WT</td>
<td>C 50H</td>
<td>2xES 0H</td>
<td>2xWW 0H</td>
<td>2xWT 0H</td>
</tr>
<tr>
<td>Can-ES-WW-ES</td>
<td>C 50H</td>
<td>2xES 0H</td>
<td>2xWW 0H</td>
<td>2xES 0H</td>
</tr>
<tr>
<td>Can-ES-WT-ES</td>
<td>C 50H</td>
<td>2xES 0H</td>
<td>2xWT 0H</td>
<td>2xES 0H</td>
</tr>
</tbody>
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0, 50, & 100% Herbicide rates are for wild oat herbicides only, dicot herbicide rates were 100%
Wild Oats Cut with Silage
Cutting Alfalfa
Wild Oat Emergence (2014) – 8 Sites

Blue bars are significantly greater than the bottom 100% herbicide treatment (P < 0.05)
Wild Oat Biomass (2014) – 4 Sites

Blue bars are significantly greater than the bottom 100% herbicide treatment (P < 0.05)
### Canola Yield (2014) – 7 Sites

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Grain Yield (kg ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>C 50H</td>
<td>2839</td>
</tr>
<tr>
<td>2011</td>
<td>C 50H</td>
<td>3042</td>
</tr>
<tr>
<td>2012</td>
<td>C 50H</td>
<td>3017</td>
</tr>
<tr>
<td>2013</td>
<td>C 50H</td>
<td>2916</td>
</tr>
<tr>
<td>2014</td>
<td>C 50H</td>
<td>2872</td>
</tr>
</tbody>
</table>

**Blue bars** are significantly greater than the bottom 100% herbicide treatment ($P < 0.05$)
Blue bars are significantly greater than the bottom 100% herbicide treatment (P < 0.05)
Conclusions - I

• Combining 2x seeding rates of early-cut barley silage with 2x seeding rates of winter cereals and excluding wild oat herbicides for 3 of 5 yr often led to similar wild oat density, above-ground wild oat biomass, wild oat seed density in the soil and canola yield as a repeated canola-wheat rotation under a full wild oat herbicide rate regime.

• Wild oat was similarly well-managed after three years of perennial alfalfa without wild oat herbicides.
Conclusions - II

• Forgoing wild oat herbicides in only two of five years from exclusively summer annual crop rotations resulted in higher wild oat density, biomass and seed banks.

• Management systems that effectively combine diverse and optimal cultural practices against weeds, and limit herbicide use, reduce selection pressure for weed resistance to herbicides and prolong the utility of threatened herbicide tools.

Harker et al. 2016. Weed Sci. 64:170-180
Summary - I

• Some herbicides are being over-used
• Weed Resistance to herbicides continues to increase at a rapid pace
• Many popular wild oat herbicides are already less useful than a few years ago
• Few or no new herbicide mode of actions are being registered
Summary - II

• **Low Diversity Rotations are Dominant**

• HR Canola → a Resistance Reprieve, but less cropping system diversity → more problems...

• The most-profitable crops drive a lack of rotational diversity

• So far, Weed Resistance has not driven much greater IWM adoption – that could change!
Reducing Herbicide Resistance

“The only sustainable solution is for government or end-users of commodities to set herbicide-use reduction targets in our major field crops similar to European Union member states, and include financial incentives or penalties in agricultural programs to support this policy.”

Beckie & Hall. 2014. Crop Protect. 66:40-45