Glyphosate-resistant kochia

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Canada
Prior to any herbicide being applied to a field

-- 1 in a million; 1 in a billion
After repeated herbicide use...
Risk of selection for resistance by herbicide group

Number of applications:

- High: ≤ 10
- Moderate: 11 - 20
- Low: > 20

Risk levels:
- High
- Moderate-high
- Moderate
- Low - moderate
- Low

Applications counts:
- Low: 4, 6, 9, 10
- Low - moderate: 7, 22
- Moderate: 3, 8
- Moderate-high: 5
- High: 1, 2

Other:
Risk of resistance by weed species

**Distribution and density:** commonly occurring weeds in a region, e.g. wild oat on the Canadian prairies
- kochia is the 3\textsuperscript{rd} most abundant weed in southern Alberta
- resistance is a numbers game

**Genetic diversity:** greater chance of having the resistant gene in the first place

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

- Annual C4 species (like corn)
- Tolerant of heat, drought, salinity
- Germinates at low soil temperatures of 2-4°C
- Emerges in early spring but additional flushes occur throughout the growing season
- Optimal emergence from 0-2 cm soil depth
- Produces 10,000-25,000 seeds per plant
- Tumbleweed seed dispersal mechanism
- Little seed dormancy
- Seed bank persistence of 1-2 years
Previous herbicide resistance in kochia

**Group 5:** confirmed in the 1970s
- triazine herbicides (atrazine, simazine)

**Group 2:** confirmed in the late 1980s
- ALS-inhibiting herbicides (17 herbicides in Canada)
- Express, Odyssey, Everest, Frontline, Simplicity
- 90% of kochia is Group 2 resistant in western Canada

**Group 4:** confirmed in the 1990s
- dicamba resistance (Montana, Nebraska, North Dakota)
24 Species of Glyphosate-Resistant Weeds

**Broadleaves**
- Hairy Fleabane
- Horseweed
- Sumatran Fleabane
- Palmer Amaranth
- Waterhemp
- Giant Ragweed
- Common Ragweed
- Wild Poinsettia
- Buckhorn Plantain
- Kochia

**Grasses**
- Crabgrass
- Jungle Rice
- Goosegrass
- Annual Ryegrass
- Rigid Ryegrass
- Johnsongrass
- Liverseed Grass
- Perennial Ryegrass
- Sourgrass
- Annual Bluegrass

http://www.weedscience.com
Glyphosate-resistant (GR) kochia confirmed in Kansas (2007), Colorado (2011), Nebraska (2011) and North Dakota (2012)
Kansas: confirmed glyphosate resistance in 2007 (Dr. Phil Stahlman, Kansas State University)
GR kochia in southern Alberta: 3 chemfallow fields (3 separate farms) in Warner-Milk River area in 2011
Greenhouse study

- three suspected Alberta populations (fields 1, 2 and 3)
- three known resistant populations from Kansas
- two known susceptible populations from Saskatchewan and Kansas

- applied glyphosate at 9 rates
  - 0, 56 (1/8X), 112 (1/4X), 225 (1/2X), 450 (1X), 900 (2X), 1350 (3X), 1800 (4X), and 2250 (5X) g active/ha
  - 450 g/ha = ½ litre product/acre of original (360 g/L) formulation
½ L/ac 360 formulation
2.5 L/ac 360 formulation
Note: Field confirmation experiment at Lethbridge, 2012 indicated a resistance factor of 6.2.
Additional glyphosate-resistant kochia sites

Fall, 2011
- collected kochia plants from 46 sites within a 20-km radius of original populations
- 7 of 46 sites were glyphosate-resistant

April, 2012
- glyphosate-resistant kochia confirmed in Turin area

Summer, 2012
- 8 more kochia populations confirmed resistant (some from Brooks-Medicine Hat area)
- 10 confirmed populations in southern Saskatchewan

Fall, 2012
- random kochia samples from 300 sites in southern Alberta

Note: All GR kochia populations were found to be Group 2 resistant but susceptible to dicamba (Group 4).
Resistance mechanism

. Seed of nine Alberta GR kochia populations were sent to Dr. Phil Westra at Colorado State University

. Target site mutation was ruled out

. Gene amplification is possible mechanism
  - 3 to 10 extra gene copies of EPSPS were found in all Canadian and USA populations

. Reduced translocation still to be examined
### Herbicide treatment % Control

<table>
<thead>
<tr>
<th>Herbicide treatment</th>
<th>% Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate (450 g)</td>
<td>35</td>
</tr>
<tr>
<td>Cadet (fluthiacet) (4 g)</td>
<td>55</td>
</tr>
<tr>
<td>Partner (bromoxynil) (355 g)</td>
<td>60</td>
</tr>
<tr>
<td>Butril M (bromoxynil/MCPA) (560 g)</td>
<td>65</td>
</tr>
<tr>
<td>2,4-D ester (560 g)</td>
<td>65</td>
</tr>
<tr>
<td>Benchmark [florasulam (5 g) + bromoxynil (285 g)]</td>
<td>70</td>
</tr>
<tr>
<td>2,4-D ester (560 g) + Chateau (flumioxazin) (70 g)</td>
<td>70</td>
</tr>
<tr>
<td>Cleanstart (carfentrazone) (18 g)</td>
<td>75</td>
</tr>
<tr>
<td>Banvel (dicamba) (140 g)</td>
<td>75</td>
</tr>
</tbody>
</table>

*Glyphosate at 450 g/ha was included in all treatments.

**Kochia was 5 cm tall and 6 cm in diameter when sprayed; density of 30 plants/m2; non-crop situation.
## Herbicides to control Group 2 and Group 9 resistant kochia – Lethbridge, 2012

<table>
<thead>
<tr>
<th>Herbicide treatment</th>
<th>% Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attain, Prestige products (fluroxypyr) (100 g)</td>
<td>85</td>
</tr>
<tr>
<td>Fluroxypyr (100 g) + florasulam (5 g)</td>
<td>85</td>
</tr>
<tr>
<td>Fluroxypyr (100 g) + Express (tribenuron) (7.5 g)</td>
<td>85</td>
</tr>
<tr>
<td>Infinity (prasulfotole/bromoxynil) (200 g)</td>
<td>85</td>
</tr>
<tr>
<td>Fluroxypyr (100 g) + 2,4-D ester (400 g)</td>
<td>90</td>
</tr>
<tr>
<td>Fluroxypyr (100 g) + bromoxynil (380 g)</td>
<td>90</td>
</tr>
<tr>
<td>Gramoxone (paraquat) (395 g)</td>
<td>90</td>
</tr>
<tr>
<td>Banvel (dicamba) (210 g)</td>
<td>90</td>
</tr>
<tr>
<td>Optica Trio (MCPA/dichlorprop/mecoprop-P) (1480 g)</td>
<td>90</td>
</tr>
<tr>
<td>Cleanstart (9 g) + Authority (sulfentrazone) (53 g)</td>
<td>95</td>
</tr>
<tr>
<td>Distinct (dicamba/diflufenzopyr) (100 g)</td>
<td>95</td>
</tr>
<tr>
<td>Banvel (dicamba) (300 g)</td>
<td>98</td>
</tr>
</tbody>
</table>
Herbicide groups

Group 4: dicamba, fluroxypyr, MCPA/dichloroprop/mecoprop-P

Group 6: bromoxynil

Group 9: glyphosate

Group 14: carfentrazone, flumioxazin, fluthiacet, saflufenacil, sulfentrazone

Group 19: diflufenzopyr

Group 22: paraquat

Group 27: prasulfutole

www.weedscience.org – listing of weed resistance around the world
Objectives:
(1) tool for producers to assess their risk of glyphosate resistance on a field-by-field basis;
(2) raise awareness for proactive resistance management in western Canada
Grower/farm advisor answers 10 questions related to crop production system, tillage system, and glyphosate usage (each question with four possible answers)
Tool indicates relative risk of glyphosate resistance based on the 10 responses