Tested a suspected glyphosate resistant population collected in WA in 2015
- Survived 32 oz/ac Roundup PowerMax with no visible injury in chemical fallow
- Later controlled with 2 pints 2,4-D
Glyphosate Resistance

Greenhouse testing showed about 4x resistance to glyphosate relative to susceptible control.
Glyphosate Resistance

Field trials showed 2x to 8x resistance to glyphosate

Lind

Pullman
Lind, 4 weeks after spraying

Untreated Check (0 oz/ac)

Glyphosate Susceptible (normal)

Glyphosate Resistant
Lind, 4 weeks after spraying

16 oz/ac Gly Star Original

Glyphosate Susceptible (normal)  Glyphosate Resistant
Lind, 4 weeks after spraying

32 oz/ac

Glyphosate Susceptible (normal)  Glyphosate Resistant
Lind, 4 weeks after spraying

64oz/ac

Glyphosate Susceptible (normal)  

Glyphosate Resistant
Lind, 4 weeks after spraying

128 oz/ac

Glyphosate Susceptible (normal)  Glyphosate Resistant
Pullman, 4 weeks after spraying

Untreated Check (0 oz/ac)

Glyphosate Susceptible (normal)  Glyphosate Resistant
Pullman, 4 weeks after spraying

16 oz/ac Gly Star Original

Glyphosate Susceptible (normal)  Glyphosate Resistant
Pullman, 4 weeks after spraying

32 oz/ac

Glyphosate Susceptible (normal)  Glyphosate Resistant
Pullman, 4 weeks after spraying

64oz/ac

Glyphosate Susceptible (normal)  Glyphosate Resistant
Pullman, 4 weeks after spraying

128 oz/ac

Glyphosate Susceptible (normal)

Glyphosate Resistant
Glyphosate Resistance

- Resistant to at least 32oz/ac at both locations
- Much more resistant at Lind
  - but so were susceptible plants
  - due to higher temperatures and moisture stress at Lind
Glyphosate Resistance

- Higher temperatures and more stressful conditions made all plants more tolerant of glyphosate, but especially so for resistant plants
- This has been found for several weed species around the world
Glyphosate Resistance

- Resistance was only found at 1 location in WA. Is that really a big deal?
- Maybe
- Historical and current examples suggest resistance could spread very quickly.
# Chlorsulfuron Resistance

![DuPont Glean XP Herbicide](image)

**DuPont™ Glean® XP**

**Herbicide**

**Dry flowable**

*For Use on Wheat, Barley, Oat and Triticale*

**Active Ingredient**

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>By Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorsulfuron</td>
<td></td>
</tr>
<tr>
<td>2-Chloro-N-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)aminocarbonyl]benzenesulfonamide</td>
<td>75%</td>
</tr>
</tbody>
</table>
Chlorsulfuron Resistance

- Chlorsulfuron (Glean) introduced in mid 1980’s, initially provided excellent control of Russian-thistle

- First reports of resistance in 1987 from Horse Heaven Hills

- By 1992, 80% of Russian-thistle in Washington cropland was resistant to chlorsulfuron

Glyphosate-resistant Kochia

- Four populations in Kansas in 2007; South Dakota 2009; Nebraska 2011

- By 2012, GR kochia was common from the Texas Panhandle into the prairie provinces of Canada
>12.5 million acres infested
In 2015, glyphosate resistant Russian-thistle was also found in chemical fallow in:
  - Montana (2 fields),
  - Oregon (3 fields)

This suggests that resistance may be emerging independently at many locations across the region, although this is not known with certainty.
Glyphosate Resistance:
How fast could it spread?

- Worst-case scenario: glyphosate resistant Russian-thistle could become prevalent across WA in 5 to 10 years

- We are in the early stages of resistance development, and it is still possible that it can be prevented – or at least delayed – with good management
Resistance Management

- Rotate herbicide modes of action
  - get away from glyphosate as much as possible
- Tank mix
  - avoid glyphosate alone – include 2 + modes of action, particularly in more difficult situations
- Make good applications
  - use proper rates and timing
  - use surfactants, water conditioner
  - use adequate carrier volume
  - calibrate equipment
  - slow down
  - etc.
Questions?
THOUGHTS ON USING A SENSOR SPRAYER IN FALLOW
Thoughts on Using a Sensor Sprayer in Fallow

• Visualizing Spot Treatments
• The First Pass
  – Products and approach
• The Second and Third Passes
  – The ‘Spot Treatment’
• Each sensor makes a decision over a very small area (4-12” depending on boom height).
• Datalogger records ‘percent on’ for one second.
• At 3.5 mph, the sensors travel 4.4 ft.
Weed Spatial Distribution – The First Pass

% Spray Reduction: 46%

Nozzle Percent On

- 0.00
- 0.01 - 20.00
- 20.01 - 40.00
- 40.01 - 60.00
- 60.01 - 80.00
- 80.01 - 100.00

100 ft
Weed Spatial Distribution – The Second Pass?

% Spray Reduction: 95%  85%  85%

Nozzle Percent On

- 0.00
- 0.01 - 20.00
- 20.01 - 40.00
- 40.01 - 60.00
- 60.01 - 80.00
- 80.01 - 100.00

100 ft
What happens if this gets missed?
Spot Treatments – Check the Label *Carefully*

**Paraquat**

![Mixing Instructions for Small Quantities for Spot Spraying](image)

**Dicamba (Drexel)**

![TABLE 2. APPLICATION RATES OF THIS PRODUCT TO CONTROL OR SUPPRESS WEEDS BY TYPE AND GROWTH STAGE](image)

Glyphosate = low carrier volume
Everything else = spray to near runoff

Examples of labels with spot treatment sections: *glyphosate, dicamba, Sharpen, paraquat*
Davenport 2007-2008 using a Weed Seeker (18 GPA)

- Paraquat
- Carfentrazone + Dicamba
- Bromoxynil
- Huskie
- 2,4-D
- Glyphosate + Carfentrazone + Dicamba
- Glyphosate + Bromoxynil
- Glyphosate + Huskie
- Glyphosate + 2,4-D
- Glyphosate (3.0 lbs)
- Glyphosate (1.5 lbs)
- Glyphosate (0.75 lbs)
- Glyphosate Broadcast (1.5 lbs)

Tumble Mustard

Prickly lettuce  2008  2007
Dealing with 2,4-D Resistance

- Walla Walla
- Treated with glyphosate + 2,4-D
- Decided to put out plots
- Grower applied Huskie + MCPA
- Conditions were very dry
Prickly Lettuce Control – Walla Walla 2016 (15 GPA)

- Talinor (16 oz/A)* + CoAct (3.2 oz/A) + COC (1%)
- Tough (20 oz/A)* + NIS (0.5%)
- Brox (2 pt/A) + NIS (0.5%)
- Impact (2 oz/A)* + NIS (0.5%)
- Arylex Active (2.85 oz/A)* + NIS (0.5%)
- Garlon 4EC (3 oz/A)* + NIS (0.5%)
- Widematch (1.33 pt/A)* + NIS (0.5%)
- Huskie (15 oz/A) + MCPA (1 pt/A) + NIS (0.5%)
- Sharpen (4 oz/A)* + MSO (1 %)
- Paraquat (15.8 oz/A) + Diuron (4.94 oz/A) + NIS (0.5%)
- 2,4-D (Formula 40) (16 oz/A) + Roundup Powermax (21.3 oz/A)

Nontreated

*Not a labeled use or labeled use rate.
Sharpen @ 4 oz/A
Waterville, 2017 (15 GPA)

- Talinor (16 oz/A)* + CoAct (3.2 oz/A) + COC (1%)
- Tough (20 oz/A)* + NIS (0.5%)
- Brox (2 pt/A) + NIS (0.5%)
- Impact (2 oz/A)* + NIS (0.5%)
- Arylex Active (2.85 oz/A)* + NIS (0.5%)
- Garlon 4EC (3 oz/A)* + NIS (0.5%)
- Widematch (1.33 pt/A)* + NIS (0.5%)
- Huskie (15 oz/A) + MCPA (1 pt/A) + NIS (0.5%)
- Sharpen (4 oz/A)* + MSO (1%)
- Paraquat (15.8 oz/A) + Diuron (4.94 oz/A) + NIS (0.5%)
- 2,4-D (Formula 40) (16 oz/A) + Roundup Powermax (21.3 oz/A)
- Nontreated

*Not a labeled use or labeled use rate.
Conclusions

• First pass with LASC will treat a higher percentage area (should be treated as a broadcast treatment unless scouting reveals otherwise).

• Second and following passes should be scouted carefully for weed composition, and the right product selected (the approach may not include glyphosate).

• Carrier volume should be much higher for all products except glyphosate!
Managing Glyphosate-Resistant Kochia

Phil Stahlman
Kansas State University
Agricultural Research Center-Hays
POST kochia control 3-4 WAT averaged across eight trials in KS (4), CO (2), MT (1) and NE (1), 2011.

Stahlman et al., KSU Agricultural Research Center-Hays
Kochia control 3-4 WAT averaged across eight trials in KS (4), CO (2), MT (1) and NE (1), 2011

<table>
<thead>
<tr>
<th>Herbicide treatment¹</th>
<th>oz/A + % v/v</th>
<th>Appx. $/A²</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup PowerMax</td>
<td>32</td>
<td>$5.80</td>
<td>48 h</td>
</tr>
<tr>
<td>Distinct + NIS</td>
<td>4 + 0.5%</td>
<td>$15.07</td>
<td>65 fg</td>
</tr>
<tr>
<td>Distinct + 2,4-D LV4 + NIS</td>
<td>4 + 8 + 0.5%</td>
<td>$16.21</td>
<td>67 efg</td>
</tr>
<tr>
<td>Sharpen + 2,4-D LV4 + MSO</td>
<td>1 + 8 + 1%</td>
<td>$10.00</td>
<td>73 def</td>
</tr>
<tr>
<td>Sharpen + Atrazine 4L + MSO</td>
<td>1 + 12 + 1%</td>
<td>$9.87</td>
<td>79 a-d</td>
</tr>
<tr>
<td>Laudis + MSO</td>
<td>3 + 1%</td>
<td>$19.17</td>
<td>76 b-e</td>
</tr>
<tr>
<td>Laudis + Atrazine 4L + MSO</td>
<td>3 + 8 + 1%</td>
<td>$20.59</td>
<td>83 abc</td>
</tr>
<tr>
<td>Callisto + Atrazine 4L + COC</td>
<td>3 + 8 + 1%</td>
<td>$17.53</td>
<td>67 efg</td>
</tr>
<tr>
<td>Impact + Atrazine 4L + MSO</td>
<td>0.75 + 8 + 1.5%</td>
<td>$21.86</td>
<td>80 a-d</td>
</tr>
<tr>
<td>Starane NXT + NIS</td>
<td>14 + 0.5%</td>
<td>$8.81</td>
<td>60 gh</td>
</tr>
<tr>
<td>Huskie + NIS</td>
<td>15 + 0.5%</td>
<td>$12.67</td>
<td>74 c-f</td>
</tr>
<tr>
<td>Rage D-Tech + MSO</td>
<td>32 + 2%</td>
<td>$12.17</td>
<td>52 h</td>
</tr>
<tr>
<td>Linex 4L + Atrazine 4L + COC</td>
<td>24 + 16 + 1%</td>
<td>$26.69</td>
<td>77 b-e</td>
</tr>
<tr>
<td>Gramx. + Atrazine 4L + COC</td>
<td>48 + 16 + 1%</td>
<td>$14.91</td>
<td>90 a</td>
</tr>
<tr>
<td>Gramx. + Linex 4L + COC</td>
<td>48 + 24 + 1%</td>
<td>$24.42</td>
<td>87 ab</td>
</tr>
</tbody>
</table>

¹Includes AMS. ²Retail cost; does not reflect program discounts/rebates.

Stahlman et al., KSU Agricultural Research Center-Hays
Russian-thistle Control in Fallow

![Bar graph showing treatment means, Lind, 15WAT](chart.png)
Growth Stage Affects Kochia Response to Clarity, Hays, KS, 2011

![Bar chart showing the effect of growth stage on Kochia response to Clarity.

- **17-Jun 3-6"**
- **23-Jun 4-10"**
- **29-Jun 8-12"**

Exp 1107, 15 gpa
Stahlman et al.
Control Summary

• Control the initial flush; extended control is needed for later emerging plants.

• PRE herbicides generally have been more effective than POST herbicide treatments.

• Mixtures of atrazine, dicamba, metribuzin, isoxaflutole, and/or sulfentrazone applied PRE in late-fall or early spring.

• Increasing evidence of GR kochia evolving resistance to dicamba.
Management Strategies

• Diversity is key to preventing resistance
• More than just herbicides
  - cultural and mechanical practices too
  - multiple tactics better than only one
• Proactive vs. reactive management
• Community effort required
Herbicide Diversity and Use Rates

• Herbicides with two or more sites-of-action
  - mixtures and/or sequential applications
  - overlapping residuals; PP & PRE’s *fb* POST
  - change herbicide program between years

• Proper rates at the proper time
  - low use rates hasten resistance evolution
  - stress, poor spray coverage or timing, and weed size & density can equal ‘low rate’

• Proper adjuvants
Questions?