INTEGRATED HERBICIDE MANAGEMENT
Getting to Two Modes of Action

• Introduction to Integrated Herbicide Systems
• Opportunities and Limitations in the PNW
• Practical Experience
  – Online Decision Support Tool
• Discussion of Results

Outcome: Awareness of just how much trouble we may be in!
# Risk of Resistance on a Per Species Basis

<table>
<thead>
<tr>
<th>Management Option</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide mix or rotation in cropping system</td>
<td>&gt; 2 modes of action</td>
<td>2 modes of action</td>
<td>1 modes of action</td>
</tr>
<tr>
<td>Weed control in cropping system</td>
<td>Cultural, mechanical, and chemical</td>
<td>Cultural and chemical</td>
<td>Chemical alone</td>
</tr>
<tr>
<td>Use of same mode of action per season</td>
<td>Once</td>
<td>More than once</td>
<td>Many times</td>
</tr>
<tr>
<td>Cropping system</td>
<td>Full rotation</td>
<td>Limited rotation</td>
<td>No rotation</td>
</tr>
<tr>
<td>Resistance status to mode of action</td>
<td>Unknown</td>
<td>Limited</td>
<td>Common</td>
</tr>
<tr>
<td>Weed infestation</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Control in last 3 years</td>
<td>Good</td>
<td>Declining</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Moss 1998
Integrated Weed Management

- Any management action that reduces selection by an individual input:
  - Rotation
  - Manipulation of planting time
  - Crop competitiveness
  - Cultivation techniques
  - Herbicides with different mode of action
  - Using two herbicides with different modes of action with activity on the same weed
Why is ‘Mode of Action’ Important?

- Resistance to herbicides with the same mode of action appears to be much more common than resistance in the same weed to multiple modes of action (assuming the same mechanism).

- Examples:
  - Group 1/A
  - Group 2/B
### Group A/1 ACCase Target Site Resistance

<table>
<thead>
<tr>
<th>Mutations</th>
<th>Discover Clodinafop</th>
<th>Hoelon Diclofop</th>
<th>Puma Fenoxaprop</th>
<th>Haloxyfop</th>
<th>Fops</th>
<th>Dims</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>S</td>
<td>R</td>
<td>R</td>
<td>S</td>
<td>R</td>
<td>R</td>
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<tr>
<td>B</td>
<td></td>
<td>R</td>
<td></td>
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<td>S</td>
<td>R</td>
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<tr>
<td>C</td>
<td></td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
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<td>D</td>
<td>S</td>
<td>R</td>
<td>R</td>
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<td>R</td>
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<tr>
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<td>R</td>
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<td>R</td>
<td>R</td>
<td>S</td>
<td>S</td>
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<tr>
<td>F</td>
<td>R</td>
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<td>R</td>
<td>S</td>
<td>S</td>
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<tr>
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<td>R</td>
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<td>R</td>
<td>S</td>
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<td>S</td>
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<td>R</td>
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<tr>
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<td>R</td>
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<tr>
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<td>R</td>
<td>R</td>
<td>R</td>
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</tbody>
</table>
## Group B/2 Target Site ALS Resistance

<table>
<thead>
<tr>
<th>Residue</th>
<th>SU</th>
<th>IMI</th>
<th>PTB</th>
<th>TP</th>
<th>SCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ala&lt;sub&gt;122&lt;/sub&gt;</td>
<td>S</td>
<td>HR</td>
<td>S</td>
<td>S</td>
<td>Nd</td>
</tr>
<tr>
<td>Pro&lt;sub&gt;197&lt;/sub&gt;</td>
<td>HR</td>
<td>S</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
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<tr>
<td>Ala&lt;sub&gt;295&lt;/sub&gt;</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>Nd</td>
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<tr>
<td>Asp&lt;sub&gt;375&lt;/sub&gt;</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
</tr>
<tr>
<td>Trp&lt;sub&gt;574&lt;/sub&gt;</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
</tr>
<tr>
<td>Ser&lt;sub&gt;653&lt;/sub&gt;</td>
<td>S</td>
<td>HR</td>
<td>HR</td>
<td>S</td>
<td>LR</td>
</tr>
</tbody>
</table>

**S** = Susceptible  
**LR** = Low Resistance Level (<10 fold)  
**HR** = High Resistance Level (>10 fold)

**SU** = Sulfonylurea  
**IMI** = Imidazolinone  
**PTB** = Pyrimidinylthiobenzoate  
**TP** = Triazolopyrimidine  
**SCT** = Sulfonylaminocarbonyltriazolinone
To take a lesson...
Functionally, is >2 modes of action achievable?

- Depends on the
  - Compatibility of the herbicides
  - Cost of the herbicides
  - Weed species
  - Resistance status
Herbicide Compatibility

• Compatibility is measured a few different ways:
  – Can they be mixed in the spray tank?
  – Is the mixture additive, antagonistic, or synergistic?

• Rules of thumb:
  – Group 1/A herbicides are always antagonized by Group 2/B herbicides
  – Contact herbicides antagonize systemic herbicides
Fig. 1. Schematic presentation of herbicide interactions (ID$_{50}$ = rates of herbicides, applied alone or in mixture, for a 50% weed control) (modified from Green, 1989)
Ideally...

- The herbicides should have similar soil residual durations
- Should be relatively lethal when applied alone
- Fit into the system (i.e., not carryover, for example)
- Should be additive or synergistic
• In order from most to least favorable:
  – PRE and POST applied herbicides in a system
  – Rotation of modes of action with crop rotation
• Go to smallgrains.wsu.edu
• Select weed resources
• Scroll to the Wheat MOA tool
• Select ‘Search by Trade Name’
The Options

ACCcase (A)  ALS (B)  PSII (C)  PSI (D)  Protox (E)  4-HPPD (F)  EPSP (G)

Glutamine Synthetase (H)  Cellulose Synthesis (L)  Microtubule Inhibition (K)  Lipid Synthesis (N)  Synthetic Auxins (O)

Unknown (Z)

YR 0

YR 1

WINTER WHEAT

YR 2

SPRING WHEAT

YR 3

SPRING LEGUME

WINTER WHEAT

SPRING WHEAT

SPRING LEGUME

JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
Italian Ryegrass Control

ACCase (A)  ALS (B)  PSII (C)

EPSP (G)

Microtubule Inhibition (K) (with or without Protox (E))

WINTER WHEAT  SPRING WHEAT  SPRING LEGUME
Russian Thistle Control

- ACCase (A)
- ALS (B)
- PSII (C)
- PSI (D)
- EPSP (G)
- Microtubule Inhibition (K)

YR 0: WINTER WHEAT

YR 1: WINTER WHEAT

YR 2: WINTER WHEAT

YR 3: WINTER WHEAT

WINTER WHEAT

SPRING LEGUME
Prickly Lettuce Control

- Synthetic Auxins (O)
- ACCase (A)
- ALS (B)
- PSI (D)
- Protox (E)
- 4-HPPD (F)
- EPSP (G)
- Microtubule Inhibition (K) (with or without Protox (E))

Year 0
- Winter Wheat

Year 1
- Winter Wheat

Year 2
- Spring Wheat

Year 3
- Spring Legume

Month:
- JAN
- FEB
- MAR
- APR
- MAY
- JUN
- JUL
- AUG
- SEP
- OCT
- NOV
- DEC