Glyphosate Management Strategies to Reduce Risk in Corn/Soybean Cropping Systems

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Overview - 2008

- High percentage of MN acres are planted to:
  - RR soybean
    - Approximately 98% of acres are treated with glyphosate
    - Minimal use of PRE herbicides
  - RR corn
    - Approximately 85% of acres are treated with glyphosate
    - Approximately 50% of acres use a PRE grass herbicide at the “glyphosate rate” (~2/3 of label)
  - RR sugar beet
    - First year of introduction with ~15% use in southern MN and ~50% use in northwestern MN
    - Minimal use of PRE herbicides
Glyphosate Management Strategies to Reduce Risk

- In 2008 we experienced an increase in the number of fields with poor glyphosate performance – especially in soybean

- The following weed species were most frequently reported:
  - Giant ragweed (south central and west central MN)
  - Common ragweed (central and northwest MN)
  - Tall waterhemp (south central, southwest and west central MN)
  - Common lambsquarters (scattered locations)
  - Barnyardgrass (west central and southwest MN)
  - Wild buckwheat (red river valley ND / MN)
The most likely cause for this increase in glyphosate’s lack of performance is an area of uncertainty. Is it due to:

- Poor application technique
- Poor timing
- Environment
- Weed spectrum with extended or delayed emergence patterns and/or inherent tolerance to glyphosate
- Repeated use of the same herbicide resulting in a selection for resistance
Glyphosate Management Strategies to Reduce Risk

• The following species have demonstrated resistant to glyphosate at 4 to 8 X rates:
  – Giant ragweed (south central and west central MN)
  – Common ragweed (central and northwest MN)
  – Tall waterhemp (south central, southwest and west central MN)
  – Note there are indications that some of these biotypes could also be resistant to ALS herbicides

• For the following species poor control is more likely to be due to environment or timing:
  – Common lambsquarters (scattered locations)
  – Barnyardgrass (west central and southwest MN)
Giant Ragweed
McLeod County - 2007

24 oz/A Touchdown Total
4-inch tall weeds

48 oz/A Touchdown Total
4-inch tall weeds

192 oz/A Touchdown Total
4-inch tall weeds

96 oz/A Touchdown Total
4-inch tall weeds
Common Waterhemp
Renville County - 2007
Roundup Weather Max 7 DAT

2 untreated controls
In background

1 qt/A  2 qt/A  4 qt/A  8 qt/A
Common Waterhemp
Renville County
Roundup Weather Max 31 DAT

1 qt/A
2 qt/A
4 qt/A
8 qt/A
Common Waterhemp
Renville County

- Documented resistance to glyphosate in Missouri, Illinois and Kansas
- Some waterhemp biotypes are resistant to multiple modes of action:
  - ALS + Triazine + PPO (Illinois)
  - ALS + Glyphosate (Illinois)
  - ALS + PPO (Kansas)
  - ALS + PPO + Glyphosate (Missouri)
  - ALS + Triazine + PPO + Glyphosate (Illinois)
Glyphosate Management Strategies to Reduce Risk

Fields with the highest frequency of glyphosate resistant giant and common ragweed are associated with:

• Lack of crop rotation – e.g. continuous soybeans

• No-till

• Total postemergence weed control practices – one- or two- glyphosate applications per year

• Lack of chemical rotation – continuous glyphosate applications w/in the corn and soybean rotation
  – Note that Harness/Surpass in corn is Not chemical diversification from the perspective of the ragweed species
Predicting the who, when and where of resistance has a high level of uncertainty

- Frequency of the trait is unknown in each weed population
- Determining the rate of resistance development can only be estimated
- Determining the cost of dealing with resistance is less certain in the early stages of herbicide use
- Therefore adoption of proactive resistance management strategies is not widely accepted
Impacts of Herbicide Resistance to Glyphosate Management Strategies

• What is at risk?
  – Herbicide resistant weeds could, fairly quickly, reduce the value of herbicide resistant crop technology
  – Since selection for herbicide resistance only occurs when you USE the herbicide Not when you plant the crop YOU DO HAVE CONTROL over herbicide resistance
  – The linkage of herbicides to the value of seed and trait could change the perception of loss of herbicide function due to resistance toward an attitude of preservation of herbicides as a resource

• Crop VALUE exceeds Herbicide PRICE
Hypothetical development of a weed population shift

Adapted from Gunsolus. U. Minn. 1993.

Unless alternative weed management practices are taken, the change to resistant biotypes can occur quickly.

Farmer becomes aware of problem.
Perceptions of Herbicide Resistance

1990’s perspective
- Herbicides were more of an expendable resource
- “A dollar today is worth more than a dollar tomorrow” philosophy
- Total postemergence philosophy favored over PRE herbicides
  e.g. Pursuit and Raptor at ~75% of soybean acres in MN

Current perspective
- Herbicide discovery is limited
- Herbicides are linked to value of seed (e.g. yield) and trait (e.g. drought resistance) technology
- One postemergence herbicide greatly dominates the landscape
  ~85% of corn and ~98% of soybean acres in MN receive a glyphosate treatment
Impacts of Herbicide Resistance to Glyphosate Management Strategies

• What is at risk?
  – Simplified weed control and flexibility in choosing your cropping system
  – Herbicide resistance genes often become a part of the weed species gene pool
  – Stopping the use of the herbicide does not cause the resistant population to diminish to a low level
  – e.g. ALS resistant tall waterhemp and ragweed species can still be present in the seed bank
Glyphosate Management Strategies to Reduce Risk

Risk Management Goals:
- Increase glyphosate’s consistency of performance
- Decrease risks associated with poor timing and environment
- Retard selection for glyphosate resistant weeds

How to Address these Goals:
- Increase chemical diversity in corn and soybean acres
- Increase use of residual herbicides
Glyphosate Management Strategies to Reduce Risk

• Residual herbicides help to:
  – Address the impact of timeliness in postemergence weed control
    • Periodicity of weed emergence – consider multiple species
    • Early season weed competition – hidden costs
    • Weed size and environment interactions – inconsistent control
    • Off-target movement of herbicides
Emergence profiles of several common annual weeds. Ames, Iowa, 1996.

Sandell, Buhler and Hartzler. 1998. ISU.

Post – Roundup WeatherMax (22 oz/A)
Pre + Post - Harness (1.25 pt./A) / Roundup WeatherMax (22 oz/A) + AMS
Trt 11 – Harness PRE
Trt 12 – Roundup WeatherMax + AMS / Roundup WeatherMax + AMS at 3”/ 2-4” regrowth

Post 159 bu/A
Pre+ Post 187 bu/A
1-pass Pre 195 bu/A
2-pass Post 197 bu/A

Trt 12
198 bu/A

V4 growth stage

150 160 170 180 190 200
1" 3" 5" 7" 9"

bu/A

Weed Height

Post Pre+ Post 1-pass Pre 2-pass Post
Average nitrogen sequestered by corn and giant foxtail across nitrogen sources. Rate of N applied was 170 lbs./A.

<table>
<thead>
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<tr>
<td></td>
<td>Lbs. of N / A</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>1.48</td>
<td>3.27</td>
<td>---***</td>
<td>---***</td>
</tr>
<tr>
<td>4</td>
<td>3.50</td>
<td>15.04</td>
<td>9.15</td>
<td>11.94</td>
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<td>6</td>
<td>11.92</td>
<td><strong>44.82</strong></td>
<td>19.63</td>
<td><strong>29.60</strong></td>
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<tr>
<td>LSD_{(0.05)}</td>
<td>1.45</td>
<td><strong>9.84</strong></td>
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</tr>
</tbody>
</table>

* Height at which nicosulfuron was applied.
** Comparisons not done due to limited degrees of freedom.
*** Lost due to excessive rain.

Dominguez, Gunsolus, Johnson, 1998
Ph.D. dissertation. Univ. of MN
Nitrogen Uptake by Corn vs Weeds (averaged across N rates in 2006)

Weed control timing

Nitrogen uptake (lb/a)

Pre 4-inch 12-inch Nontreated

Crop

Weeds

w/ permission of Boerboom et al., U of WI
Economics of Corn and Soybean Weed Management Trials

The objective is to evaluate current and emerging weed management systems (not individual herbicides) for:

- Weed control
- Crop injury potential
- Economic return on investment
  \[(\text{bu/A} \times \$/\text{bu}) - \$/\text{A} \text{ (herbicide + tech. and application costs)}\]
- Consistency of performance
2007 Corn Weed Management - Glyphosate & Glufosinate Tolerant Hybrid

One- vs Two-pass Systems

Red = One pass systems w/ Gly
Blue = Two pass systems w/Gly
Green = Two pass systems w/ Glufosinate

- 12 - SureStart @ 1.75 pt/A / Gly
- 10 - Lumax @ 3 pt/A / Gly
- 11 - Lumax @ 3 pt./A / Ignite
- 9 - Harness @ 1.25 pt/A / Gly
- 18 - SureStart + Gly @ 1.75 pt/A + 24 oz/A
- 19 - Halex GT + atrazine @ 4 pt/A + 16 oz/A
- 22 - Resolve Q + atrazine + Gly @ 1.25 oz/A + 16 oz/A + 22 oz/A

P = 0.10 Level of sig.

Corn= $3.80/bu
2007 Corn Weed Management - Glyphosate & Glufosinate Tolerant Hybrid

One- vs Two-pass Systems

2x Gly prices per gallon:
- Original Max - $67.98
- Weather Max - $89.73
- Touchdown Total - $72.56
- Durango - $49.14

- **2x Glyphosate price**

- **17** - Roundup Weather Max/ Roundup Weather Max @ 22 oz/A
- **12** - SureStart @ 1.75 pt/A / Durango @ 24 oz/A
- **10** - Lumax @ 3 pt/A / Touchdown Total @ 24 oz/A
- **11** - Lumax @ 3 pt./A / Ignite
- **22** - Resolve Q + atrazine + Orig. Max @ 1.25 oz/A + 16 oz/A + 22 oz/A
- **18** - SureStart + Durango @ 1.75 pt/A + 24 oz/A V2 corn
- **19** - Halex GT + atrazine @ 4 pt/A + 16 oz/A V2 corn

P = 0.10
Level of sig.

Red = One pass systems
Blue = Two pass systems
Green = Two pass systems w/Glufosinate

Corn= $3.80/bu

Pre + Post - Boundary (1.5 pt/A) + Touchdown Total (24 oz/A) + AMS
Post - Touchdown Total (24 oz/A) + AMS
Pre – Boundary (1.5 pt/A)
2-pass Post - Touchdown Total + AMS / Touchdown Total + AMS at 3”/ 2-4” regrowth
2007 RR Soybean Weed Management

Pre/Post & Post/Post treatments

- Sonic @ 3 oz/A / Gly
- Valor SX @ 2 oz/A / Gly
- Gangster @ 1.8 oz/A / Gly
- FirstRate @ 0.3 oz/A / Gly
- Valor SX + Sencor @ 1.75 and 4 oz/A/ Gly
- Authority First @ 3.2 oz/A / Gly
- IntRRo @ 4 pt/A / Gly

P = 0.10
Level of sig.

Black = Pre / Glyphosate
Red = Glyphosate/Glyphosate

Soybean = $9.75/bu
2007 RR Soybean Weed Management

One- vs Two-pass Systems

- **16** - Roundup WeatherMax @ 22 oz/A / Roundup WeatherMax @ 22 oz/A
- **18** - Roundup WeatherMax @ 22 oz/A
- **20** - Harmony GT + Classic @ 0.5 and 0.33 oz/A + Gly
- **22** - FirstRate @ 0.3 oz/A + Gly
- **23** - Resource @ 2 oz/A + Gly
- **24** - Roundup WeatherMax @ 22 oz/A

**Legend:**
- **Black** = One-pass Post w/ Glyphosate
- **Red** = Glyphosate / Glyphosate

**Soybean = $9.75/bu**

**P = 0.10 Level of sig.**
What are the risks and benefits of chemical diversification via PRE herbicides?

**Benefits**
- Improves control of weeds that are more difficult to control with glyphosate or weeds with extended emergence periods
- Reduces likelihood of “hasty” glyphosate application (e.g. drift)
- Provides other mode(s) of herbicide action

**Risks**
- Requires some rainfall for activation
- Potential for crop injury increases under cold and wet conditions
- Potential for some PRE herbicides to limit crop rotation
## 2007 – 2008 PRE/GLYPHOSATE SEQUENTIALS – Soybean
(Roundup Original @16 oz/A) at Rochester, MN (Breitenbach, Behnken and Miller)

<table>
<thead>
<tr>
<th>PRE</th>
<th>GIRW</th>
<th>COLQ</th>
<th>COWH</th>
<th>VELE</th>
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<tr>
<td><strong>SEQUENTIALS</strong></td>
<td>2007</td>
<td>2008</td>
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<td>2008</td>
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<tr>
<td>Prowl</td>
<td>NR</td>
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<td>NR</td>
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<tr>
<td>Gangster</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
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<tr>
<td>Gangster+ Cobra</td>
<td>++</td>
<td>NR</td>
<td>++</td>
<td>NR</td>
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<td>Enlite</td>
<td>NR</td>
<td>+</td>
<td>NR</td>
<td>++</td>
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<tr>
<td>Valor</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
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<tr>
<td>Valor+Cobra</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
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<tr>
<td>Sonic</td>
<td>+</td>
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<td>Authority MTZ</td>
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</tr>
<tr>
<td>Authority Assist</td>
<td>NR</td>
<td>+</td>
<td>NR</td>
<td>++</td>
</tr>
<tr>
<td>One Pass Glyphosate</td>
<td>78%</td>
<td>71%</td>
<td>60%</td>
<td>76%</td>
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</table>
### 2007 – 2008 Glyphosate Tank Mix Partners - Soybean (Roundup Original @16 oz/A) at Rochester, MN (Breitenbach, Behnken and Miller)

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<td>Flexstar</td>
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<td>NR</td>
<td>+</td>
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<td>Cobra</td>
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<td>NR</td>
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<tr>
<td>Resource</td>
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<td>=</td>
<td>NR</td>
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<tr>
<td>Cadet</td>
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<td>NR</td>
<td>=</td>
<td>NR</td>
<td>-</td>
<td>NR</td>
<td>++</td>
</tr>
<tr>
<td>FirstRate</td>
<td>++</td>
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<td>+</td>
<td>+</td>
<td>=</td>
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<td>-</td>
<td>NR</td>
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<tr>
<td>Classic LR</td>
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<td>NR</td>
<td>=</td>
<td>NR</td>
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<td>NR</td>
<td>NR</td>
<td>NR</td>
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<td>Classic HR</td>
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<td>+</td>
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<td>NR</td>
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<td>Synchrony</td>
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<td>+</td>
<td>NR</td>
<td>=</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Harmony GT</td>
<td>=</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>=</td>
<td>NR</td>
<td>=</td>
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<tr>
<td>Pursuit</td>
<td>+</td>
<td>=</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>NR</td>
<td>+</td>
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<tr>
<td>One Pass Glyphosate</td>
<td>78%</td>
<td>71%</td>
<td>60%</td>
<td>76%</td>
<td>73%</td>
<td>65%</td>
<td>NR</td>
<td>61%</td>
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</table>
Glyphosate Management Strategies to Reduce Risk

Risk Management Goals:

• Increase glyphosate’s consistency of performance
• Decrease risks associated with poor timing and environment
• Retard selection for glyphosate resistant weeds

How to Address these Goals:

• Increase chemical diversity in corn and soybean acres
• Increase use of residual herbicides
Glyphosate Management Strategies to Reduce Risk

- Increased chemical diversity helps to delay herbicide resistance development:
  - Consider in which crop you could most easily substitute other herbicides for glyphosate?
    - Liberty Link Corn or Soybean
    - Crop with the most “Conventional” herbicide options
  - Consider in which crop you are most dependent upon the effectiveness of glyphosate?
  - Consider influence of herbicide on Crop Rotation Interval
Herbicide Crop Rotation Intervals (RI) – Soybean PRE’s

<table>
<thead>
<tr>
<th>PRE Herb.</th>
<th>Corw Control</th>
<th>Girw Control</th>
<th>Colq Control</th>
<th>Cowh* Control</th>
<th>Corn RI</th>
<th>Sugar beet RI</th>
<th>Wheat RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>G/E</td>
<td>8 mo.</td>
<td>18 mo.</td>
<td>8 mo.</td>
</tr>
<tr>
<td>Prefix</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>G/E</td>
<td>10 mo.</td>
<td>18 mo.</td>
<td>4.5 mo</td>
</tr>
<tr>
<td>Valor</td>
<td>F/G</td>
<td>P</td>
<td>G/E</td>
<td>G/E</td>
<td>1–2 mo.</td>
<td>8-12 mo.</td>
<td>1-2 mo.</td>
</tr>
<tr>
<td>Sonic / Authority First*</td>
<td>E</td>
<td>E</td>
<td>G/E</td>
<td>G</td>
<td>10 mo.</td>
<td>30 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>FirstRate*</td>
<td>E</td>
<td>E</td>
<td>P</td>
<td>P</td>
<td>9 mo.</td>
<td>30 mo.</td>
<td>3 mo.</td>
</tr>
<tr>
<td>Gangster*</td>
<td>E</td>
<td>E</td>
<td>G/E</td>
<td>G</td>
<td>9 mo.</td>
<td>30 mo.</td>
<td>3 mo.</td>
</tr>
</tbody>
</table>

* Product effectiveness will be reduced if target weed is ALS resistant
# Herbicide Crop Rotation Intervals (RI)– Soybean POST

<table>
<thead>
<tr>
<th>POST Herb.</th>
<th>Corw Control</th>
<th>Girw Control</th>
<th>Colq Control</th>
<th>Cowh* Control</th>
<th>Corn RI</th>
<th>Sugar beet RI</th>
<th>Wheat RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobra</td>
<td>G/E</td>
<td>G</td>
<td>F</td>
<td>G/E</td>
<td>0 mo.</td>
<td>0 mo.</td>
<td>0 mo.</td>
</tr>
<tr>
<td>Flexstar</td>
<td>G/E</td>
<td>G</td>
<td>F</td>
<td>G/E</td>
<td>10 mo.</td>
<td>18 mo.</td>
<td>4 mo</td>
</tr>
<tr>
<td>Harmony GT*</td>
<td>P/F</td>
<td>P</td>
<td>G/E</td>
<td>P</td>
<td>0 mo.</td>
<td>45 days</td>
<td>0 mo.</td>
</tr>
<tr>
<td>Classic*</td>
<td>G</td>
<td>F/G</td>
<td>P</td>
<td>P</td>
<td>9 mo.</td>
<td>30 mo.</td>
<td>3 mo.</td>
</tr>
<tr>
<td>FirstRate*</td>
<td>E</td>
<td>E</td>
<td>P</td>
<td>P</td>
<td>9 mo.</td>
<td>30 mo.</td>
<td>3 mo.</td>
</tr>
<tr>
<td>Ignite</td>
<td>G/E</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>0 mo.</td>
<td>4 mo.</td>
<td>70 days</td>
</tr>
</tbody>
</table>

* Product effectiveness will be reduced if target weed is ALS resistant
## Herbicide Crop Rotation Intervals (RI) – Corn PRE’s

<table>
<thead>
<tr>
<th>PRE Herb.</th>
<th>Corw Control</th>
<th>Girw Control</th>
<th>Colq Control</th>
<th>Cowh Control</th>
<th>Soy RI</th>
<th>Sugar beet RI</th>
<th>Wheat RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetochlor</td>
<td>F</td>
<td>P</td>
<td>F/G</td>
<td>G/E</td>
<td>NCS</td>
<td>NCS</td>
<td>4</td>
</tr>
<tr>
<td>Dicamba</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>G</td>
<td>4 mo.</td>
<td>4 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Callisto</td>
<td>F/G</td>
<td>F</td>
<td>G/E</td>
<td>E</td>
<td>NCS</td>
<td>18 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Hornet</td>
<td>G/E</td>
<td>F</td>
<td>G</td>
<td>F</td>
<td>10.5 mo.</td>
<td>26 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Lumax</td>
<td>G</td>
<td>F/G</td>
<td>E</td>
<td>E</td>
<td>NCS</td>
<td>18 mo.</td>
<td>NCS</td>
</tr>
<tr>
<td>SureStart</td>
<td>G/E</td>
<td>F</td>
<td>G</td>
<td>G</td>
<td>NCS</td>
<td>26 mo.</td>
<td>4 mo.</td>
</tr>
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## Herbicide Crop Rotation Intervals (RI) – Corn POST

<table>
<thead>
<tr>
<th>POST Herb.</th>
<th>Corw Control</th>
<th>Girw Control</th>
<th>Colq Control</th>
<th>Cowh Control</th>
<th>Soy RI</th>
<th>Sugar beet RI</th>
<th>Wheat RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicamba</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>4 mo.</td>
<td>4 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Atrazine</td>
<td>G</td>
<td>G</td>
<td>E</td>
<td>E</td>
<td>NCS</td>
<td>2CS**</td>
<td>NCS</td>
</tr>
<tr>
<td>Callisto</td>
<td>F/G</td>
<td>G</td>
<td>G</td>
<td>E</td>
<td>NCS</td>
<td>18 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Hornet</td>
<td>G/E</td>
<td>G/E</td>
<td>P/F</td>
<td>P/F</td>
<td>10.5 mo.</td>
<td>26 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Laudis</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>E</td>
<td>8</td>
<td>18 mo.</td>
<td>4 mo.</td>
</tr>
<tr>
<td>Ignite</td>
<td>G/E</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>0 mo.</td>
<td>4 mo.</td>
<td>70 days</td>
</tr>
</tbody>
</table>

** Next cropping season if 3/8 lb/A or less
Glyphosate Management Strategies to Reduce Risk

Advantages to weed management, by crop:

• **Corn**
  – Producer’s more open to chemical integration
  – Liberty Link technology

• **Soybean**
  – Competitive with late-season weed emergence
  – Critical time of weed removal is later than in corn

• **Wheat**
  – Competitive with early-season weed emergence
  – Adds chemical diversification
Glyphosate Management Strategies to Reduce Risk

The “best” strategy depends upon:

- Weed species present
- “Chronic / persistent” weed species
- Weed density
- Weed emergence patterns
- Duration of weed – crop competition
- Crop rotation
- THE crop where RR technology matters the most
Glyphosate Management Strategies to Reduce Risk

Is glyphosate always that easy?

• Time demands on the producer
• One pass to two passes to three passes, leads to more dollars and ineffective control
  – It is best to put your higher glyphosate rate earlier in the growing season because the slow rate of glyphosate breakdown in the plant makes timing and success of sequential “clean up” operations difficult.

Are you ready for some other approaches?