Weed Management in Corn
Questions from Farmers

Peter H. Sikkema
University of Guelph
I was planning to plant soybeans next spring so I applied Guardian for perennial broadleaf weed control last fall. I changed my mind and I would like to plant corn this spring. Will the corn be OK?
Fall Application of Guardian

Corn Injury the Following Spring

Visible Corn Injury (%)

- **7 DAE**
- **14 DAE**
- **28 DAE**
- **56 DAE**

**Sikkema, UG**

- **Control**
- **14 g/ac**
- **28 g/ac**
Fall Application of Guardian

Corn Injury the Following Spring
Fall Application of Guardian

Corn Yield the following Fall

- Control: 181 bu/ac
- 14 g/ac: 175 bu/ac
- 28 g/ac: 172 bu/ac

Sikkema, UG
Fall Application of Guardian

Conclusions

1. The fall application of Guardian results in visible injury in corn the following spring
   a. Purple discolouration
   b. Stunting

2. In our studies there was a trend (9 bu/ac) to reduced yield, but it was not statistically significant
Is weed control reduced if the herbicide is in spray solution in the sprayer for an extended period of time?
Length of Time Herbicide is in Spray Solution

Introduction

1. Sometimes a herbicide already is in spray solution but it cannot be sprayed immediately due to:
   a. Mechanical breakdown
   b. Sudden and unexpected rain
   c. High winds
1. Herbicides were mixed and held in solution for:
   a. 7 days
   b. 3 days
   c. 1 day
   d. 0 days
Time in Solution

Herbicides Tested

<table>
<thead>
<tr>
<th>Preemergence Herbicides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battalion</td>
</tr>
<tr>
<td>Converge</td>
</tr>
<tr>
<td>Frontier + Marksman</td>
</tr>
<tr>
<td>Primextra + Callisto</td>
</tr>
</tbody>
</table>
Time in Solution (PRE)

Converge

Velvetleaf

Pigweed

Lamb's-quarters

Visual Weed Control (% 8 WAA)

0 days

1 day

3 days

7 days

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Converge – Spray Immediately
Time in Solution (PRE)

Yield (bu/ac)

Converge

- 0 days
- 1 day
- 3 days
- 7 days

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Time in Solution (PRE)

Primextra + Callisto

Velvetleaf

Pigweed

Lamb's-quarters

Visual Weed Control (% 8 WAA)

0 days 1 day 3 days 7 days

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Primextra + Callisto – Sprayed Immediately
Time in Solution (PRE)

Summary

1. When herbicides were held in spray solution for an extended period of time there was:
   a. No difference in pigweed control
   b. A decrease in lamb’s-quarters control with Converge
   c. A decrease in velvetleaf control with Converge and Frontier + Marksman
Time in Solution (PRE)

Summary

1. When herbicides were held in spray solution for an extended period of time there was (continued):
   
d. No decrease in corn yield with Frontier + Marksman, Primextra + Callisto and Battalion

e. A decrease in corn yield with Converge
### Herbicides Tested

<table>
<thead>
<tr>
<th>Postemergence Herbicides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callisto + Atrazine</td>
</tr>
<tr>
<td>Distinct</td>
</tr>
<tr>
<td>Liberty</td>
</tr>
<tr>
<td>Roundup</td>
</tr>
</tbody>
</table>
Time in Solution (POST)

Distinct

Velvetleaf
Pigweed
Ragweed
Lamb's-quarters

Visual Weed Control (% 8 WAA)

0 days 1 day 3 days 7 days

Sikkema, UG
Time in Solution (POST)

Roundup

Visual Weed Control (% 8 WAA)

- Velvetleaf
- Pigweed
- Ragweed
- Lamb's-quarters

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Liberty – Sprayed Immediately
Time in Solution (POST)

Yield (bu/ac)

Distinct
Callisto + atrazine
Roundup
Liberty

0 days  1 day  3 days  7 days

Sikkema, UG
Time in Solution (POST)

Summary

1. When herbicides were held in spray solution for an extended period of time there was:
   a. No decrease in weed control with Distinct, Callisto + atrazine, Roundup or Liberty
   b. No decrease in corn yield

2. It is recommended to spray the herbicide held in solution
   a. Monitor field closely and re-spray if necessary
Is there a benefit of adding Crop Booster to glyphosate in RR corn?
No effect on weed control

Crop Booster – 6 studies

Lamb's-quarters
Lady's thumb
Nightshade
Pigweed
Ragweed
Velvetleaf
Foxtail

Visual Weed Control (% 8 WAA)

Sikkema, UG

Glyphosate
Glyphosate + Crop Booster
Crop Booster on RR Corn

Roundup
No effect on RR corn yield

Crop Booster – 6 studies

- Check: 72
- Glyphosate: 140
- Glyphosate + Crop Booster: 143
Crop Booster

Summary

1. No difference in weed control
2. No difference in RR corn yield
Question # 4

My corn is at the 8-10 leaf stage and I have weed escapes. Which herbicides are safest to apply at this late stage?
Late Herbicide Application in Corn

Corn Injury – 7 studies

- Accent
- Option
- Distinct
- Callisto + atrazine
- Pardner + atrazine
- PeakPlus
- Shotgun

Visible Crop Injury (% 2 WAA)

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Late Herbicide Application in Corn

Distinct Injury in Corn
Late Herbicide Application in Corn

Decrease in Corn Height – 7 studies

- Accent
- Option
- Distinct
- Callisto + atrazine
- Pardner + atrazine
- PeakPlus
- Shotgun

Decrease in corn height (% 4 WAA)

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Late Herbicide Application in Corn

### Corn Yield – 7 studies

- **Accent**
- **Option**
- **Distinct**
- **Callisto + atrazine**
- **Pardner + atrazine**
- **PeakPlus**
- **Shotgun**

**Corn Yield (bu/ac)**

- **Recommended Rate**
- **Spray Overlap**

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Late Herbicide Application in Corn

Summary

1. Option results in greater injury than Accent
2. Distinct and Shotgun result in greater injury than Callisto + atrazine, Pardner and PeakPlus
3. There was no effect on corn yield in these studies
I heard about glyphosate-resistant weeds. What are my weed management options in RR corn?
Roundup Ready Corn

Introduction

1. There are many approaches to weed management in Roundup Ready corn
   a. Yield was maximized when Roundup was applied before weeds were 10 cm in height
   b. Profitability was maximized with one early postemergence application of Roundup

2. BUT, the over-reliance on Roundup has resulted in the selection of glyphosate resistant weed biotypes or weeds naturally tolerant to glyphosate in other jurisdictions

1 Nelson, 2007
2 Thomas et al. 2007
Roundup Ready Corn

Weed Management Strategies

1. One application of Roundup applied early postemergence (EP)
2. One application of Roundup applied late postemergence (LP)
3. A tankmix of Roundup plus a residual herbicide (Marksman) applied EP
4. A sequential application of a preemergence (PRE) residual herbicide (Converge) followed by Roundup applied LP
5. A sequential application of Roundup applied EP and LP
Roundup Ready Corn

Velvetleaf Control – 8 WAA

Weed Control (%)

<table>
<thead>
<tr>
<th>Product</th>
<th>Env # 1</th>
<th>Env # 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup EP</td>
<td>38</td>
<td>93</td>
</tr>
<tr>
<td>Roundup LP</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>Roundup + Marksman EP</td>
<td>70</td>
<td>99</td>
</tr>
<tr>
<td>Converge PRE; Roundup LP</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Roundup EP; Roundup LP</td>
<td>98</td>
<td>99</td>
</tr>
</tbody>
</table>
Roundup Ready Corn

Roundup + Marksman EP
Roundup Ready Corn

Pigweed Control – 8 WAA

- Roundup EP: 93%
- Roundup LP: 100%
- Roundup + Marksman EP: 100%
- Converge PRE; Roundup LP: 100%
- Roundup EP; Roundup LP: 100%

Pooled across environments
Roundup Ready Corn

Lamb’s-quarters Control – 8 WAA

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ridgetown A-2006</th>
<th>Exeter-2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup EP</td>
<td>71</td>
<td>100</td>
</tr>
<tr>
<td>Roundup LP</td>
<td>78</td>
<td>100</td>
</tr>
<tr>
<td>Roundup + Marksman EP</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Converge PRE; Roundup LP</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Roundup EP; Roundup LP</td>
<td>99</td>
<td>100</td>
</tr>
</tbody>
</table>

Sikkema, UG Nurse, AAFC
Roundup Ready Corn

Converge PRE; Roundup LP
Roundup Ready Corn

Green Foxtail Control – 8 WAA

Weed Control (%)

- Roundup EP: 45, 97
- Roundup LP: 100, 99
- Roundup + Marksman EP: 71
- Converge PRE; Roundup LP: 97, 99
- Roundup EP; Roundup LP: 100, 99

Sikkema, UG Nurse, AAFC

Harrow - 2007
Ridgetown A-2007
Roundup Ready Corn

Yield (bu/ac)

- Weed-free: 200
- Roundup EP: 191
- Roundup LP: 180
- Roundup + Marksman EP: 194
- Converge PRE; Roundup LP: 196
- Roundup EP; Roundup LP: 199

Average of 11 studies

Sikkema, UG
Nurse, AAFC
Roundup Ready Corn

Profit Margins

Profit Margin ($/ac)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Profit Margin ($/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup EP</td>
<td>698, 689</td>
</tr>
<tr>
<td>Roundup LP</td>
<td>642, 620</td>
</tr>
<tr>
<td>Roundup + Marksman EP</td>
<td>747</td>
</tr>
<tr>
<td>Converge PRE; Roundup LP</td>
<td>718, 618</td>
</tr>
<tr>
<td>Roundup EP; Roundup LP</td>
<td>739, 650</td>
</tr>
</tbody>
</table>

Vyn, UG

Legend:
- Ridgetown B-2007
- Exeter-2007
1. Weed management is field specific
2. The most consistent weed control was provided by the two-pass programs
   a. Residual herbicide (PRE) fb glyphosate (LP)
   b. A sequential application of glyphosate applied EP fb LP
Roundup Ready Corn

Comments

1. Due to the possibility of glyphosate-resistant weeds or weed shifts, the following are recommended:
   a. A diverse crop rotation
   b. Inclusion of multiple herbicide modes-of-action
      a. Preemergence residual followed by glyphosate postemergence
      b. Postemergence tankmix of glyphosate + another effective effective herbicide
Question # 6

When is the best time to apply glyphosate in RR corn?
1. There is a temptation to delay the application until all the weeds have emerged
Roundup Ready Corn

Application Timing

Weed Control (%)

- Velvetleaf
- Pigweed
- Foxtail, Green

Spike, 1 leaf, 2 leaf, 3 leaf, 4 leaf

Sikkema, UG
Roundup Ready Corn

Roundup - Application Timing (20 sites)

<table>
<thead>
<tr>
<th>Corn Leaf Stage</th>
<th>Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed Free</td>
<td>143</td>
</tr>
<tr>
<td>1</td>
<td>141</td>
</tr>
<tr>
<td>2</td>
<td>139</td>
</tr>
<tr>
<td>3</td>
<td>138</td>
</tr>
<tr>
<td>4</td>
<td>136</td>
</tr>
<tr>
<td>5</td>
<td>133</td>
</tr>
<tr>
<td>6</td>
<td>131</td>
</tr>
<tr>
<td>7</td>
<td>129</td>
</tr>
<tr>
<td>8</td>
<td>127</td>
</tr>
</tbody>
</table>

Average of 20 experiments

Hamill, AAFC
Sikkema, UG
## Roundup Ready Corn

### Roundup - Application Timing

<table>
<thead>
<tr>
<th>Delay in Application (Days)</th>
<th>Yield Loss (bu/ac)</th>
<th>Value ($/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>2.00</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>6.00</td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>14.00</td>
</tr>
<tr>
<td>10</td>
<td>5.0</td>
<td>20.00</td>
</tr>
</tbody>
</table>
Roundup Ready Corn

Application Timing

1. Early application is recommended
   a. Improved control
   b. Reduced weed interference
   c. Increased corn yield

2. Weed management is always field specific
   a. The appropriate application timing ranged from the 1 to 8-leaf stage in our experiments
What is the effect of glyphosate drift on conventional corn?
Glyphosate Drift
Glyphosate Drift

Corn Injury – 14 days after drift occurred

Visible Corn Injury (%)

<table>
<thead>
<tr>
<th>Glyphosate Concentration (%)</th>
<th>Visible Corn Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
</tr>
<tr>
<td>1%</td>
<td>1</td>
</tr>
<tr>
<td>5%</td>
<td>9</td>
</tr>
<tr>
<td>10%</td>
<td>20</td>
</tr>
<tr>
<td>20%</td>
<td>52</td>
</tr>
</tbody>
</table>

Average of 9 experiments (ON, OH, IN, IL)

Brown, UG
Glyphosate Drift

Corn Yield

![Bar chart showing the effect of glyphosate drift on corn yield. The chart includes different concentrations of glyphosate (1%, 5%, 10%, 20%) and their corresponding corn yields (157, 152, 147, 125, 76 bu/ac). The chart notes that the data is an average of 12 experiments (ON, OH, IN, IL).]
Glyphosate Drift

Corn Yield

![Bar graph showing corn yield for different glyphosate concentrations: Control (157 bu/ac), 1% (152 bu/ac), 5% (147 bu/ac), 10% (125 bu/ac), 20% (76 bu/ac), and 52% (52%). The graph indicates a decrease in corn yield with increasing glyphosate concentration.]

- Control: 157 bu/ac
- 1%: 152 bu/ac
- 5%: 147 bu/ac
- 10%: 125 bu/ac
- 20%: 76 bu/ac
- 52%: 52%

Average of 12 experiments (ON, OH, IN, IL)

Brown, UG
1. There are large differences in injury and yield loss from one field to another due to:
   a. Concentration of the drift
   b. Size of the corn at the time the drift occurred
   c. Weather conditions prior to and after the drift event
   d. Management after the drift event occurred

2. Corn yield loss ranged from 0 to almost 100% due to glyphosate drift in these studies
Does the time of day that I spray have an effect on weed control?
Time of Day

Pardner

Weed Control (%) 8 WAA

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Velvetleaf Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 am</td>
<td>61</td>
</tr>
<tr>
<td>9 am</td>
<td>79</td>
</tr>
<tr>
<td>12 pm</td>
<td>92</td>
</tr>
<tr>
<td>3 pm</td>
<td>92</td>
</tr>
<tr>
<td>6 pm</td>
<td>81</td>
</tr>
<tr>
<td>9 pm</td>
<td>30</td>
</tr>
<tr>
<td>12 am</td>
<td>24</td>
</tr>
</tbody>
</table>
Weedy Corn Yield (2 experiments at Ridgetown)

Time of Day

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Corn Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 am</td>
<td>143</td>
</tr>
<tr>
<td>9 am</td>
<td>144</td>
</tr>
<tr>
<td>12 pm</td>
<td>144</td>
</tr>
<tr>
<td>3 pm</td>
<td>148</td>
</tr>
<tr>
<td>6 pm</td>
<td>142</td>
</tr>
<tr>
<td>9 pm</td>
<td>135</td>
</tr>
<tr>
<td>12 am</td>
<td>125</td>
</tr>
</tbody>
</table>

Corn Yield (2 experiments at Ridgetown)
Time of Day

Liberty

Weed Control (%) 8 WAA

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Velvetleaf Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 am</td>
<td>18</td>
</tr>
<tr>
<td>9 am</td>
<td>88</td>
</tr>
<tr>
<td>12 pm</td>
<td>97</td>
</tr>
<tr>
<td>3 pm</td>
<td>96</td>
</tr>
<tr>
<td>6 pm</td>
<td>96</td>
</tr>
<tr>
<td>9 pm</td>
<td>76</td>
</tr>
<tr>
<td>12 am</td>
<td>68</td>
</tr>
</tbody>
</table>
Time of Day

Liberty

Corn Yield (bu/ac)

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Corn Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weedy</td>
<td>93</td>
</tr>
<tr>
<td>6 am</td>
<td>138</td>
</tr>
<tr>
<td>9 am</td>
<td>141</td>
</tr>
<tr>
<td>12 pm</td>
<td>154</td>
</tr>
<tr>
<td>3 pm</td>
<td>152</td>
</tr>
<tr>
<td>6 pm</td>
<td>145</td>
</tr>
<tr>
<td>9 pm</td>
<td>137</td>
</tr>
<tr>
<td>12 am</td>
<td>115</td>
</tr>
</tbody>
</table>

Corn Yield (2 Experiments at Ridgetown)
Time of Day

**Roundup**

Weed Control (%) 8 WAA

- 98% at 6 am, 9 am, 12 pm, 3 pm, 6 pm
- 95% at 9 pm
- 82% at 12 am

*Velvetleaf Control*
Roundup
Time of Day

Weedy Check
6 am
9 am
6 pm
9 am
12 pm
3 pm
6 pm
9 pm
12 am
# Time of Day

## Summary – Herbicides

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>&gt; 10% Difference</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pardner</td>
<td>7 out of 9</td>
<td>78</td>
</tr>
<tr>
<td>Liberty</td>
<td>7 out of 13</td>
<td>54</td>
</tr>
<tr>
<td>Atrazine</td>
<td>2 out of 4</td>
<td>50</td>
</tr>
<tr>
<td>Accent</td>
<td>2 out of 6</td>
<td>33</td>
</tr>
<tr>
<td>Distinct</td>
<td>2 out of 12</td>
<td>17</td>
</tr>
<tr>
<td>Roundup</td>
<td>1 out of 7</td>
<td>14</td>
</tr>
</tbody>
</table>
## Time of Day

### Summary – Weed Species

<table>
<thead>
<tr>
<th>Weed Species</th>
<th>&gt; 10% Difference</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velvetleaf</td>
<td>8 out of 12</td>
<td>67</td>
</tr>
<tr>
<td>Lamb’s-quarters</td>
<td>6 out of 14</td>
<td>43</td>
</tr>
<tr>
<td>Pigweed</td>
<td>2 out of 5</td>
<td>40</td>
</tr>
<tr>
<td>Barnyard grass</td>
<td>2 out of 5</td>
<td>40</td>
</tr>
<tr>
<td>Common ragweed</td>
<td>4 out of 11</td>
<td>36</td>
</tr>
<tr>
<td>Green foxtail</td>
<td>1 out of 3</td>
<td>33</td>
</tr>
</tbody>
</table>
1. Change in efficacy during the day is thought to be affected by:

   a. Air temperature – 9.5-11.5 °C (Martinson et al. 2002)
      i. Less viscous epicuticular wax (Price, 1983)
      ii. Increased membrane permeability (Anderson et al., 1993)
      iii. Increase in rates of diffusion (Price, 1993)
      iv. Increased enzyme activity and metabolic processes (Price, 1993)

   b. Leaf angle – decrease in spray interception and retention - 85% (Andersen and Koukkari, 1978; Martinson et al, 2002)
Leaf orientation during the day

Leaf orientation during the night
2. The effect of time of day on herbicide efficacy is dependent on:
   a. Herbicide
      i. Pardner, Liberty and Aatrex were affected the most
      ii. Accent, Distinct and Roundup were affected the least
   b. Weed species
      i. Velvetleaf was affected the most
      ii. Green foxtail was affected the least
   c. Environment
      i. Velvetleaf control with glyphosate varied 1, 1 and 16% in 2005, 2006 and 2007 respectively

3. The level of weed control due to time of application can affect corn yield
Actually, there is a silver lining. The herbicides with greatest potential for off-site injury (systemic herbicides) are affected the least by time of day. So apply them when weed speeds are lowest.
Contact herbicides which are more sensitive to time of day have less potential for off-site injury. Apply them during the warmest, brightest sunlit hours of the day.