Recommendations for the Management of Resistant Weeds in 2014 and Beyond
Glyphosate-resistant Weed Development in the U.S.
2013: 14 species; 35 states

- Rigid Ryegrass (1)
- Horseweed/Marestail (24)
- Common Ragweed (11)
- Italian Ryegrass (6)
- Giant Ragweed (11)
- Waterhemp (14)
- Palmer Amaranth (19)
- Hairy Fleabane (1)
- Johnsongrass (3)
- Kochia (7)
- Junglerice (1)
- Annual Bluegrass (3)
- Goosegrass (2)
- Spiny Amaranth (1)

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Multiple herbicide resistance is now becoming the bigger issue...

pictures taken 3 Weeks After Treatment

Nodaway County
Collected waterhemp seedheads from 187 separate fields across the state of Missouri just prior to soybean harvest in 2012.

Field selection was random but based solely on the presence of waterhemp at the time of harvest.
Response of Missouri Waterhemp Populations to 6 Classes of Herbicides

Survival (% of Total)

- **Classic (Group 2)**: 99.5% at 1X Rate, 99.5% at 3X Rate
- **Glyphosate (Group 9)**: 58% at 1X Rate, 29% at 3X Rate
- **Atrazine (Group 5)**: 51% at 1X Rate, 30% at 3X Rate
- **Cobra (Group 14)**: 11% at 1X Rate, 5% at 3X Rate
- **Callisto (Group 27)**: 14% at 1X Rate, 2% at 3X Rate
- **2,4-D (Group 4)**: 0.5% at 1X Rate, 0% at 3X Rate

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Percent of the Missouri Waterhemp Populations Sampled with Multiple Herbicide Resistance

![Bar graph showing survival rates for Missouri Waterhemp populations with 1X and 3X herbicide rates.]

- **2-way**: 84% survival at 1X rate, 52% at 3X rate.
- **3-way**: 39% survival at 1X rate, 11% at 3X rate.
- **4-way**: 11% survival at 1X rate, 2% at 3X rate.
- **5-way**: 0.5% survival at both 1X and 3X rates.

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And more growers are now reporting more than one resistant species...
#1 Driver weed in the South
#1 Weed to Watch in the Midwest
Palmer Amaranth

Look for:

• Stems without hairs
• Very long petioles
• Poinsettia type leaf arrangement
We have an App for that!

Now available on the I-Tunes App and Android Stores
Missouri Counties With Palmer Amaranth (that we know about)
What makes the pigweeds so problematic?

Season-long competition by Palmer amaranth at 2.5 plants per foot of row can reduce soybean yield by as much as 79%.
I WILL KNOW MY WEEDS.

I will take action against herbicide-resistant weeds.
I will know my weeds. When they grow, when they pollinate, and I will stop them before they go to seed.
I will know their strengths, and I will exploit their weaknesses.
Troublesome weeds won’t go down without a fight. Neither will I. Because it’s worth the trouble.

Now is the time to take action against herbicide-resistant weeds. Visit www.TakeActionOnWeeds.com to learn about the most troublesome weeds.
Pigweed Weaknesses?

1. Seed are relatively short-lived in the soil (4-5 yrs).
Percentage of the Original Waterhemp Seedbank that Remained Viable for Four Years After Burial

1. Seed are relatively short-lived in the soil (4-5 yrs).
2. Seed do not emerge from lower soil depths.
What effect does tillage have on the pigweed species?

*Results summarized across herbicide programs, row spacings, and planting populations.

**Means followed by the same letter are not different, $P \leq 0.05$
It emerges early and all at once. Take advantage of that weakness!
## Preplant Management of Glyphosate-Resistant Giant Ragweed in Roundup Ready Soybeans (2011-2012)

| Pre-plant Herbicide Treatment | Rate                      | Gly-R Gt Ragweed Control 6 Weeks After Preplant Application | Gly-R Gt Ragweed Control 4 Weeks After POST Applications  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup PowerMax</td>
<td>22 fl ozs</td>
<td>34</td>
<td>29</td>
</tr>
<tr>
<td>Roundup PowerMax + 2,4-D Ester</td>
<td>22 fl ozs + 1 pt</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Roundup PowerMax + Sharpen</td>
<td>22 fl ozs + 1 fl oz</td>
<td>89</td>
<td>85</td>
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<tr>
<td>Roundup PowerMax + Firstrate</td>
<td>22 fl ozs + 0.3 oz</td>
<td>69</td>
<td>59</td>
</tr>
<tr>
<td>Roundup PowerMax + Valor XLT</td>
<td>22 fl ozs + 3 oz</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>Roundup PowerMax + Authority 1st</td>
<td>22 fl ozs + 3.2 oz</td>
<td>73</td>
<td>78</td>
</tr>
<tr>
<td>Roundup PowerMax + Clarity</td>
<td>22 fl ozs + 8 fl oz</td>
<td>97</td>
<td>96</td>
</tr>
<tr>
<td>Roundup PowerMax + Clarity</td>
<td>22 fl ozs + 16 fl oz</td>
<td>97</td>
<td>95</td>
</tr>
<tr>
<td>Ignite + Clarity</td>
<td>22 fl ozs + 8 fl oz</td>
<td>97</td>
<td>95</td>
</tr>
<tr>
<td>Ignite + Clarity</td>
<td>22 fl ozs + 16 fl oz</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Gramoxone Inteon + Clarity</td>
<td>3 pts + 8 fl oz</td>
<td>91</td>
<td>92</td>
</tr>
<tr>
<td>Gramoxone Inteon + Clarity</td>
<td>3 pts + 16 fl oz</td>
<td>96</td>
<td>95</td>
</tr>
<tr>
<td>LSD (0.05):</td>
<td>7</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

*aAll treatments received a POST (4”) application of 22 fl ozs Roundup Pmax + 1.3 pts Flexstar*
For horseweed, we have to target this...
Not this...
Influence of Pre-plant Herbicide Treatments on Glyphosate-resistant Horseweed Control Across 3 Sites in Tennessee

I WILL
SCOUT MY FIELDS.

I will walk my rows, and I will stand my ground.
I will take action against herbicide-resistant weeds.
I will scout my fields and field borders, ditches and waterways. I will scout them early and often.
I’ll be here when weeds emerge. And I’ll be back after I spray.
I will track down escapees and late emergers.
I will take action before weeds take over.

Now is the time to take action against herbicide-resistant weeds. Visit www.TakeActionOnWeeds.com to learn how you can prevent herbicide-resistant weeds from spreading.
Apply the labeled herbicide rate at recommended weed sizes.
These weeds don’t lie...
Dicots - Waterhemp
Monocots
Waterhemp

Average Weed Height at the Time of the POST Treatment (n=85)

Waterhemp: 9.0 in
Monocots: 7.9 in
Dicots - Waterhemp: 5.1 in
2011-12 Missouri Soybean Weed Survey

Estimated Soybean Yield Loss by 1st POST Herbicide Application (n=85)

Survey Locations

Yield Loss (Bu/A)

1.9 Bu/A Avg. Yield Loss
I WILL
THINK BEYOND HERBICIDES TO CONTROL WEEDS.

I will take action against herbicide-resistant weeds. Every action I can. I will do whatever I can to defend this ground. They aren’t ordinary fields. They’re battlefields. And I’m fighting a war on weeds.

I will think beyond herbicides and expand my arsenal. I will crowd weeds out and knock them down. I will smother them with foliage. I will farm to win.

Mistakes will be made, and weeds will emerge. But I will emerge on top. And I will continue to take action. Because every action counts.

Now is the time to take action against herbicide-resistant weeds. Visit www.TakeActionOnWeeds.com to learn about diversified weed management strategies.
What effect does soybean row spacing have on pigweed control?

- Drilled
- 15-inch
- 30-inch

*Results summarized across herbicide programs, tillage types, and planting populations.

**Means followed by the same letter are not different, P≤0.05
Influence of Herbicide Program, Soybean Row Spacing, and Tillage Type on Late-season Pigweed Density

*Means followed by the same letter are not different, $P \leq 0.05$
Cover crops for weed management...
Some species we really need to think about...
Annual Ryegrass
*Lolium multiflorum*
a.k.a. “Italian Ryegrass” or just “Ryegrass”
*NOT Annual Rye or Rye*
Top 15 Resistant Weeds According to # of Herbicide Modes of Action

- Rigid Ryegrass: 11 modes of action
- Barnyardgrass: 9 modes of action
- Annual Bluegrass: 9 modes of action
- Goosegrass: 7 modes of action
- Blackgrass: 6 modes of action
- Waterhemp: 6 modes of action
- Junglerice: 6 modes of action
- Annual Ryegrass: 5 modes of action
- Palmer Amaranth: 5 modes of action
- Common Ragweed: 5 modes of action
- Wild Oat: 5 modes of action
- Horseweed: 5 modes of action
- Redroot Pigweed: 4 modes of action
- Downy Brome: 4 modes of action
- Common Lambsquarters: 4 modes of action

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Herbicide Resistance in Annual Ryegrass, 2014

- Group 1 / ACCase
- Group 2 / ALS
- Group 9 / Glyphosate
- Group 10 / Liberty
- Group 15 / Chloroacetamides

© Dr. Kevin Bradley
# Annual Ryegrass Control as Influenced by Rate and Application Timing

(graph adapted from Lins et al. 2005)

<table>
<thead>
<tr>
<th>A. Ryegrass Application Timing</th>
<th>Glyphosate Rate (lb ae/A)</th>
<th>Roundup PowerMax Rate (fl ozs/A)</th>
<th>A. Ryegrass Control (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Tiller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>22</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>44</td>
<td>75</td>
</tr>
<tr>
<td>Second Node</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>11</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>22</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>44</td>
<td>66</td>
</tr>
<tr>
<td>Boot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>11</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>22</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>44</td>
<td>86</td>
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<tr>
<td>Early Flower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>11</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>22</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>44</td>
<td>88</td>
</tr>
</tbody>
</table>

*Results summarized across 6 locations in 3 states
### Influence of Herbicide Treatments and Timings on the Control of an Annual Ryegrass Cover Crop (Columbia, Missouri 2013)

<table>
<thead>
<tr>
<th>Herbicide Treatment</th>
<th>Rate</th>
<th>Early (April 2)</th>
<th>Mid (April 22)</th>
<th>Late (May 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>---product/A---</td>
<td>5.75”; Tillering</td>
<td>14”; Pre-boot</td>
<td>36”; Boot</td>
</tr>
<tr>
<td>Roundup PowerMax</td>
<td>36 fl ozs</td>
<td>93</td>
<td>80</td>
<td>63</td>
</tr>
<tr>
<td>Roundup PowerMax + 2,4-D</td>
<td>36 fl ozs + 1 pt</td>
<td>92</td>
<td>75</td>
<td>57</td>
</tr>
<tr>
<td>Roundup PowerMax + Clarity</td>
<td>36 fl ozs + 1 pt</td>
<td>87</td>
<td>65</td>
<td>64</td>
</tr>
<tr>
<td>Roundup PowerMax + Sharpen</td>
<td>36 fl ozs + 1 fl oz</td>
<td>90</td>
<td>76</td>
<td>54</td>
</tr>
<tr>
<td>Roundup PowerMax + Aatrex</td>
<td>36 fl ozs + 1 qt</td>
<td>91</td>
<td>81</td>
<td>55</td>
</tr>
<tr>
<td>Roundup PowerMax + Canopy</td>
<td>36 fl ozs + 4 ozs</td>
<td>88</td>
<td>79</td>
<td>47</td>
</tr>
<tr>
<td>Roundup PowerMax + Basis Blend</td>
<td>36 fl ozs + 1.25 ozs</td>
<td>83</td>
<td>78</td>
<td>56</td>
</tr>
<tr>
<td>Roundup PowerMax</td>
<td>72 fl ozs</td>
<td>90</td>
<td>78</td>
<td>65</td>
</tr>
<tr>
<td>Gramoxone Inteon</td>
<td>4 pts</td>
<td>78</td>
<td>77</td>
<td>44</td>
</tr>
<tr>
<td>Gramoxone Inteon + 2,4-D</td>
<td>4 pts + 1 pt</td>
<td>90</td>
<td>77</td>
<td>52</td>
</tr>
<tr>
<td>Gramoxone Inteon + Aatrex</td>
<td>4 pts + 1 qt</td>
<td>87</td>
<td>82</td>
<td>54</td>
</tr>
<tr>
<td>Gramoxone Inteon + Lorox</td>
<td>4 pts + 24 ozs</td>
<td>89</td>
<td>83</td>
<td>50</td>
</tr>
<tr>
<td>Gramoxone Inteon + Sencor + 2,4-D</td>
<td>4 pts + 4 ozs + 1 pt</td>
<td>90</td>
<td>87</td>
<td>60</td>
</tr>
<tr>
<td>Liberty</td>
<td>29 fl ozs</td>
<td>35</td>
<td>50</td>
<td>34</td>
</tr>
<tr>
<td>Liberty + Atrazine</td>
<td>29 fl ozs + 1 qt</td>
<td>71</td>
<td>50</td>
<td>45</td>
</tr>
</tbody>
</table>

**LSD<sub>0.05</sub> (treatments x timings):**

---15---
What kind of weed control can we expect from cover crops?
Influence of Vetch and Cereal Rye Cover Crops on Winter Annual Weed Density in Maryland

<table>
<thead>
<tr>
<th>Cover Crop Species</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-treated Control</td>
<td>431 a</td>
<td>1,120 a</td>
</tr>
<tr>
<td>Vetch</td>
<td>108 b</td>
<td>500 b</td>
</tr>
<tr>
<td>Cereal Rye/Vetch Mix</td>
<td>123 b</td>
<td>323 b</td>
</tr>
<tr>
<td>Cereal Rye</td>
<td>48 b</td>
<td>364 b</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not different.

Influence of Cover Crops vs. Herbicide Treatments on Cumulative Summer Annual Weed Emergence (Columbia, MO 2013)

- Nontreated Control
- Late Spring Burndown (Rndup+2,4-D)
- Fall Trtmt (Rndup+2,4-D+AthrtyXL)
- Austrian Pea
- Cereal Rye/H. Vetch
- Hairy Vetch
- Crimson Clover
- Tillage Radish
- Oats
- Annual Ryegrass
- Cereal Rye
- Wheat

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Influence of Cover Crops vs. Herbicide Treatments on Cumulative Resistant Waterhemp Emergence (Moberly, MO 2013)

- Nontreated Control
- Late Spring Burndown (Rndup+2,4-D)
- Fall Trtmt (Rndup+2,4-D+AthrtyXL)
- Austrian Pea
- Cereal Rye/H. Vetch
- Hairy Vetch
- Crimson Clover
- Tillage Radish
- Oats
- Annual Ryegrass
- Cereal Rye
- Wheat

Cumulative Summer Ann Weed Emergence (#/m²)

© Kevin Bradley, Univ. Missouri
Influence of Cover Crops on Pigweed Emergence in Georgia


<table>
<thead>
<tr>
<th>Legume Cover Crop</th>
<th>Early June - Cereal + Cereal</th>
<th></th>
<th>Late July - Cereal + Cereal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rye</td>
<td>Rye</td>
<td>Rye</td>
<td>Rye</td>
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<tr>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Palmer Pigweed Density (#/m²) ---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austrian Winter Pea</td>
<td>4</td>
<td>1</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>Vetch</td>
<td>3</td>
<td>0</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>18</td>
<td>3</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>None</td>
<td>46</td>
<td>8</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>LSD0.05</td>
<td>------ 18 ------</td>
<td></td>
<td>------ 9 ------</td>
<td></td>
</tr>
</tbody>
</table>
My Perspective

Based on our research and the results of other *PUBLISHED* studies, the ability of cover crops to reduce the emergence of *SUMMER ANNUAL* weed species is determined by the:

1. Cover crop species selected
2. Amt. of cover crop biomass accumulated
3. Time of cover crop termination
4. Type of weed species
Conclusions

Cover Crop Burndown: Timely applications of herbicides are required to achieve acceptable kill of certain cover crop species, especially annual ryegrass, wheat, and crimson clover.

Cover Crop Effects on Weed Emergence: Only cereal rye and wheat provided substantial reductions in the emergence of *summer annual* weeds like waterhemp.

Herbicide Carryover to Cover Crop Species:
- tillage radish: Python, Flexstar (fomesafen), Pursuit
- crimson clover: Stinger, Flexstar (fomesafen)
- hairy vetch: Stinger
- Annual ryegrass: Warrant (acetochlor), Zidua, Fierce
- oats: Zidua, Fierce (pyroxasulfone)
I WILL
USE MULTIPLE HERBICIDE SITES OF ACTION.

I will take action against herbicide-resistant weeds.
I will defend my crops with careful herbicide management.
And I will use multiple herbicide sites of action because every action counts.
I will take action before weeds outgrow control. I will apply the right herbicide at the right rate at the right time.
I will take action. This time, for all time.

Now is the time to take action against herbicide-resistant weeds. Visit www.TakeActionOnWeeds.com to learn how you can preserve herbicide technology.
We must use multiple effective mechanisms of action against the most troublesome or herbicide-resistant weeds.
“Overlapping” or “layered” residuals doesn’t fit every weed, but it does fit the pigweeds....
Liberty provides a mechanism of action that still works, but if we abuse it we will break it.

Only with a pre-emergence herbicide
Only with timely POST applications of Liberty

© Dr. Kevin Bradley, University of Missouri
Influence of Soybean Row Spacing and Herbicide Programs on Late-season Waterhemp Density in LL Soybean (2012-13, Moberly Missouri)

*Results summarized across soybean seeding rates.
**Means followed by the same letter are not different, P≤0.05

Herbicide Program: 29 fl ozs Liberty followed by 29 fl ozs Liberty

<table>
<thead>
<tr>
<th>RowSpacing</th>
<th>Density</th>
<th>Seed #</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 ½-inch rows</td>
<td>34/m² = 137,500/A</td>
<td>41.3 billion/A</td>
</tr>
<tr>
<td>15-inch rows</td>
<td>65/m² = 263,000/A</td>
<td>79 billion/A</td>
</tr>
<tr>
<td>30-inch rows</td>
<td>43/m² = 635,000/A</td>
<td>191 billion/A</td>
</tr>
</tbody>
</table>
I WILL
REDUCE THE WEED SEEDS
IN MY SOIL.

I will take action against herbicide-resistant weeds.
I will know my weeds. I will target their strengths and exploit their weaknesses.
Escapees don’t stand a chance.
I will seek them out and take them down before they go to seed.
Because fewer seeds today mean fewer weeds tomorrow.

Preventing weed seed production is essential to weed management. Visit www.TakeActionOnWeeds.com to learn how you can prevent herbicide-resistant weeds from spreading.
Whatever management approach you take, the ultimate objective must be to reduce the soil seedbank.
Welcome to the University of Missouri's Weed Science homepage. Here you can find information related to our extension, research, and teaching programs or visit some of our web resources like the Missouri Weed Identification or Herbicide Injury Guides. In our "Research Results" section, you can search results from our field research by year, herbicide, weed, or crop. Additionally, you can click on our publication section to see all of the publications and newsletter articles we provide. We welcome your comments and/or suggestions about this site.

Download our new Weed ID App at the Apple App or Google Play Stores for i-phones, i-pads, and Android devices:

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