Ecologically Based Weed Management

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Weeds remain a problem for both conventional and organic farmers

• Herbicide resistance
• Off-site movement of herbicides in air and water
• Incomplete control with cultivation
• Complications due to weather
Weed control efficacy with a rotary hoe and interrow cultivator in corn and soybean (multiple passes)

Gunsolus (1990): 92%
Renner & Woods (1998): 83%
Mohler et al. (1997): 68%
Weed control efficacy with pre- and post-emergence tine harrowing in cereals

Kolb et al. (2010): 40%
Steerage hoe, Switzerland
Cultivating carrots, Switzerland
Steerage hoe in spring wheat, Maine
System Cameleon
Farmer and researcher tour
Östergötland, Sweden, April 2016
(Source: E. Gallandt)
Cultivation is important, but durable improvements in weed management are based on:

• Understanding ecological principles and processes
• Learning the life history characteristics of problematic weed species
• Carefully considering and comparing management options
Weed population dynamics
Population dynamics equation

\[ N_t = N_{t-1} + B - D + I - E \]

- \( N_t \): the number of organisms at time \( t \)
- \( N_{t-1} \): the previous number of organisms
- \( B \): births
- \( D \): deaths
- \( I \): immigrants
- \( E \): emigrants
Life history of an annual weed:

1. **Spring Seedbank**
   - Seedbank survival

2. **Seedlings**
   - Seedling recruitment
   - Seedling survival

3. **Reproductive Adults**
   - Seed production

4. **New Seeds**
   - New seed survival

The diagram illustrates the flow of life history stages, including seedling recruitment, seedling survival, and seed production.
Weed seedbank dynamics
Seeds in soil

Seedling emergence

Seed dormancy and persistence

Seed death in soil
- pathogens
- aging
- fatal germination

Seed inputs

Seed loss to predators
A case study: giant ragweed
Giant ragweed
Ambrosia trifida
Results of Survey of Certified Crop Advisors in the Corn Belt Regarding Difficulty of Managing Giant Ragweed

Source: Regnier et al. 2016
Key characteristics of giant ragweed contributing to its success in agroecosystems (with an emphasis on organic systems)
Large seeds with substantial energy reserves
Large cotyledons

Rapid leaf production and growth

Capable of overtopping crops
Early seedling emergence and cold tolerance
Giant ragweed seedling emergence patterns differ among locations and populations

Source: Hartzler 2003
Distribution of emergence period of giant ragweed, in months

Source: Regnier et al. 2016
Extended periods of seedling emergence make giant ragweed control more challenging.
But giant ragweed has several vulnerabilities....

• High rates of seed consumption by predators (e.g., rodents, invertebrates, and birds)
• Short lifetime of seeds in and on the soil (i.e., it has a transient seedbank rather than a persistent seedbank)
• Relatively low rates of seed production (1,000s rather than 10,000s or 100,000s)
Seed Predators

*Peromyscus maniculatus*

*Gryllus pennsylvanicus*
Removal of giant ragweed seeds by predators: 60%, fall-to-spring; 88%, full-year

Cumulative seed removal (%)

Time after deposition (months)

Source: Harrison et al., 2003
Fates of giant ragweed seeds buried at different depths over a four-year period

- Most seedling emergence occurred within the first two years.
- About 90% of seeds buried in the top 10 cm (four inches) of soil were eliminated after two years.

Source: Harrison et al. 2007
Giant ragweed seed production on field edges and in soybean

Source: Goplen et al. (2016)
Giant ragweed seeds are not dispersed from parent plants until late summer and fall.
Situation analysis
Giant ragweed seed population density in the soil of a field in Minnesota

Figure A-2. Spatial distribution of starting seed bank density in experiment 1 at Rochester, MN taken in 2012. The krigging method of spatial interpolation was used to interpolate data and produce the seed density map.

100 seeds/m² = 404,686 seeds/acre
It can be hard to beat the numbers

- 100 seeds per square meter in the soil seedbank = 404,686 seeds/acre
- 30% of the seeds germinate and emerge → 121,406 seedlings/acre
- 90% effectiveness in cultivation → 12,140 plants/acre
- 1,400 seeds produced per plant → 16,996,812 seeds/acre
- 60% seed loss to predators → 6,798,725 seeds/acre added to the soil seedbank
Cropping systems and weed management
Consider two kinds of crops

(1) Row crops that can be cultivated, sprayed, and/or hand-weeded. Weed control may be less than 100% effective.

(2) Solid seeded crops that are harvested in mid-summer, mowed, and/or removed for fodder. **Cutting these crops in a timely manner can prevent reproduction by giant ragweed.**
No-till seeding of a winter cereal crop into soybean residue
Winter triticale in April, Boone Co., IA
Winter cereals mature in mid-summer
Winter triticale harvest in July
Alfalfa
Key questions for giant ragweed management

• How effective does control need to be to prevent infestations from getting worse?
• Is the length of a crop sequence important?
• Is the sequence of crops within a given rotation important?
• How can hand-weeding supplement cultivation?
Key performance indicators

- Weed seed population density in soil
- Weed plant density
Consideration of weed management options using models
Life history of an annual weed

- Seedlings
- Reproductive adults
- New seeds
- Spring seedbank

Seedling recruitment
Seedling survival
Seed production
New seed survival
Seedbank survival
Population dynamics computer model (constructed in STELLA)
How effective does giant ragweed control need to be?

3-Year Rotation, Solid-Row-Row

Control in row crops

- Red: 90%
- Magenta: 91%
- Green: 92%
- Orange: 93%
- Purple: 94%
- Blue: 95%
How effective does control need to be?

3-Year Rotation, Solid-Row-Row

96.3% control in row crops
Is the length of a crop sequence important?

<table>
<thead>
<tr>
<th>Rotation length</th>
<th>Control required in row crops to prevent giant ragweed population increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-year: Solid-Row-Row</td>
<td>96.3%</td>
</tr>
<tr>
<td>4-year: Solid-Solid-Row-Row</td>
<td>90.2%</td>
</tr>
</tbody>
</table>
Is the sequence of crops within a given rotation important?

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Control required in row crops to prevent giant ragweed population increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid-Solid-Row-Row-Row</td>
<td>90.2%</td>
</tr>
<tr>
<td>Row-Row-Solid-Solid-Solid</td>
<td>97.7%</td>
</tr>
</tbody>
</table>
How can hand-weeding supplement cultivation? (solid-solid-row-row-row sequence)

<table>
<thead>
<tr>
<th>Control strategy</th>
<th>Cultivation</th>
<th>Hand-weeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivate only</td>
<td>90.2%</td>
<td>0%</td>
</tr>
<tr>
<td>Cultivate + hand-weeding</td>
<td>80.0%</td>
<td>50.7%</td>
</tr>
</tbody>
</table>
Meanwhile, back in the real world…

Hybrid winter rye & Tom Frantzen
Frantzen Farm, New Hampton, IA
Some points to remember

• Certain crops and management activities can minimize weed seed inputs.
• Starting new rotation sequences with weed suppressive crops is useful.
• Weed emergence without subsequent reproduction depletes the seedbank.
• Leaving weed seeds on the soil surface for as long as possible maximizes seed predation.
And now, the test...
Sharon & Dick Thompson
Boone, Iowa
Table 3. Weed density prior to crop harvest near Boone, IA.

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Common waterhemp</th>
<th>Foxtail species</th>
<th>Other species$^a$</th>
<th>Plants/10 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Hay</td>
<td>350</td>
<td>410</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>Corn</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>Soybean</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>Corn</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Oat</td>
<td>750</td>
<td>510</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ Included common lambsquarters, Pennsylvania smartweed, and velvetleaf.
Table 2. Density of viable weed seeds of the upper 20 cm of a Nicollet loam soil near Boone, IA. Samples were collected in October of each year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Common waterhemp</th>
<th>Foxtail species</th>
<th>Other species $^b$</th>
<th>All species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Hay</td>
<td>27,880 b</td>
<td>4,840 b</td>
<td>8,650 a</td>
<td>41,370 b</td>
</tr>
<tr>
<td>1995</td>
<td>Corn</td>
<td>13,750 c</td>
<td>510 c</td>
<td>1,780 b</td>
<td>16,040 c</td>
</tr>
<tr>
<td>1996</td>
<td>Soybean</td>
<td>7,260 d</td>
<td>130 c</td>
<td>630 c</td>
<td>8,020 d</td>
</tr>
<tr>
<td>1997</td>
<td>Corn</td>
<td>1,910 e</td>
<td>500 c</td>
<td>400 cd</td>
<td>2,810 d</td>
</tr>
<tr>
<td>1998</td>
<td>Oat</td>
<td>64,160 a</td>
<td>6,490 a</td>
<td>130 d</td>
<td>70,780 a</td>
</tr>
</tbody>
</table>

$^a$ Means within a column followed by the same letter are not significantly different according to Fisher’s LSD ($\alpha = 0.05$).

$^b$ Included common lambsquarters, Pennsylvania smartweed, and velvetleaf.