Ecology of Weed Management in Organic Systems

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- Cornell University
Outline

• Intro – How to think about weeds and weed management
• Perennial weeds: exhausting reserves
• Seed germination and tillage
• Seed survival in the soil and tillage
• Season of germination and crop rotation
• Seed size, growth rate and the competition between weeds and crops
• Nutrients and weed management
• Prevention
• Conclusions
Weeds are plants that thrive in disturbed environments

- For example, in a farm field
- Our crops are mostly annual plants - they live for one season
- We kill off natural vegetation & disturb the soil to make conditions suitable for crops
- But this also creates habitats for weeds
Understanding the biology of weeds is a key to their control

- Managing the weeds without harming your crops depends on the biological differences between the weeds and crops.
Ecological weed management requires multiple tactics

- Conventional agriculture relies on a few big hammers (broad spectrum herbicides)
Ecological weed management relies instead on many little hammers

- Crop rotation
- Enhanced crop competition
- Mulches
- Nutrient management
- Timing and type of tillage
- Cultivation
• Requires an integrated approach
• Based on the biological characteristics of the weeds present in a particular field
System re-design

1. Get to know the weed species you have – who they are, how they make a living
   • And your soil, crops, cover crops, pests etc. too
2. Design your system to prevent the weeds from causing problems
   • And supply nutrients, insure crop health etc.
3. Return to 1 (keep learning and tinkering)

Ecological management works best for people who find learning fun.
Multiple ways to be a weed

- **Annuals**
  - Summer annuals
  - Winter annuals

- **Perennials**
  - Stationary perennials
  - Wandering perennials
Perennial weeds
-- where is the food stored?

• **Stationary**
  – Taprooted – dandelion, curly dock
  – Fibrous rooted – plantain

• **Wandering**
  – Bulb – nutsedge, wild garlic
  – Shallow storage organ – quackgrass, perennial sowthistle
  – Deep storage organ – bindweeds, milkweed
Common bindweed

Broadleaf plantain

Yellow nutsedge
Stationary perennials

- Mostly a problem of hay fields and pastures
- Usually not competitive the first year
- "Easily" eliminated by tillage
- Establish from seed
- Control in adjacent habitats
Wandering perennials

- Spread by thickened storage roots or by rhizomes (underground stems)
Apical dominance in perennials

Tillage
Shoot above ground
Shoot below ground
New rhizomes
Old rhizome fragment
Management of perennials

- Key is exhaustion of reserves.
- Time relative to growth – 3 leaf rule
- Shallow roots & rhizomes – chop & bury,
- Deep roots & rhizomes – hit them low and often
- Competitive crops, frequently cultivated crops, short season crops
Annual weeds

- Live less than one year
- Establish from seed each year
- Seeds/seedlings are critical stages
Seeds of most weeds are tiny – why?

- Disturbed environments are risky
- Tiny seeds spread the risk over many offspring
- Seedlings can be small because in a recently disturbed environment they have little competition.
- Seedlings have limited resources
Small seeded species only emerge if near the soil surface.
Germination cues

• Seedlings compete poorly with established plants
• So weed seeds need to know when other plants are absent
• Respond to cues associated with
  – absence of plants
  – Near-surface conditions
  – soil disturbance
Light promotes germination of most weed species

<table>
<thead>
<tr>
<th>Species</th>
<th>Light</th>
<th>Dark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redroot pigweed</td>
<td>98</td>
<td>14</td>
</tr>
<tr>
<td>Annual bluegrass</td>
<td>89</td>
<td>1</td>
</tr>
<tr>
<td>Purslane</td>
<td>28</td>
<td>12</td>
</tr>
</tbody>
</table>
Redroot pigweed

Common purslane
Warm temperatures

<table>
<thead>
<tr>
<th>Location</th>
<th>68° F</th>
<th>95° F</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>6</td>
<td>93</td>
</tr>
<tr>
<td>N. Dakota</td>
<td>23</td>
<td>80</td>
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<tr>
<td>Minnesota</td>
<td>15</td>
<td>100</td>
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Redroot pigweed
Day/night temperature fluctuation

<table>
<thead>
<tr>
<th>Species</th>
<th>+Fluct.</th>
<th>-Fluct</th>
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<tbody>
<tr>
<td>Chickweed</td>
<td>93</td>
<td>47</td>
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<tr>
<td>Curlydock</td>
<td>100</td>
<td>0</td>
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</tbody>
</table>
Response to chemical environment

- Absence of volatiles (like ethanol and acetone)
  - Velvetleaf, tall morningglory
- Presence of nitrate
  - lambsquarters
Consequences

- Can use tillage to flush seeds out of the soil
  - Cultivated fallow
- Conversely, soil cover and absence of tillage suppresses germination of weed seeds
  - Stale seedbed
  - Mulch
  - Dense crop canopy
# Seed longevity

<table>
<thead>
<tr>
<th>Species</th>
<th>Loss per year (%)</th>
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<tbody>
<tr>
<td></td>
<td>Cultivated</td>
<td>Uncultivated</td>
</tr>
<tr>
<td>Lambsquarters</td>
<td>31</td>
<td>8</td>
</tr>
<tr>
<td>Annual bluegrass</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>Common chickweed</td>
<td>54</td>
<td>32</td>
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<tr>
<td>Common groundsel</td>
<td>High</td>
<td>45</td>
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Seeds survive better deep in the soil.

Seed survival (%) vs. Depth in soil (inches)

- **Velvetleaf**
- **Pigweed**
Death near the soil surface

- Seed predation
- Wetting and drying
- Freeze-thaw
Plowing vs. minimum tillage?

- Small seeded species with short lived seeds → plow them under
  - Most will die before they find their way to surface again
  - Example: hairy galinsoga

- Large seeded species with long lived seeds → keep them near the surface
  - Their mortality will be greater at the surface
  - And most that are tilled under will come back to bother you later
  - Example: velvetleaf
Weeds emerge at different times of year.
Seed dormancy

• Seasonal emergence is controlled by seed dormancy
• Ragweed germinates mostly in the spring
• Hot weather induces dormancy so it stops germinating in the summer
• Cold weather breaks dormancy
  – Could germinate in mid-winter but soil is too cold
• Germinates in spring when the soil starts to warm
Rotate spring, summer and fall planted crops

• This favors different suites of species in different years
• Prevents build-up of any one species.
• Fall germinating species get wiped out by spring tillage
• Spring germinating species get wiped out by summer tillage
• Spring germinating species get suppressed by competition from overwintering crops
More advantages of crop rotation

• Can use different cultivation methods in different crops
• Short season crops can be harvested before weeds go to seed. – break the life cycle
  – Also allow extra soil disturbance to deplete perennials
• High value crops that are worth hoeing also can break reproductive cycle of some species
Crop seeds are mostly much larger than weed seeds.

<table>
<thead>
<tr>
<th>Redroot Pigweed</th>
<th>Lambsquarters</th>
<th>Giant Foxtail</th>
<th>Velvetleaf</th>
<th>Wheat</th>
<th>Soybeans</th>
<th>Corn</th>
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Average seed weight (n = 10)

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<tbody>
<tr>
<td>0.6 mg</td>
<td>0.7 mg</td>
<td>1.7 mg</td>
<td>10.1 mg</td>
<td>38.6 mg</td>
<td>150.8 mg</td>
<td>283.8 mg</td>
</tr>
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Seed size controls growth rate

<table>
<thead>
<tr>
<th>Species</th>
<th>Seed weight (mg)</th>
<th>Initial growth rate (mg/d)</th>
<th>Relative growth rate (mg/mg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambsquarters</td>
<td>0.41</td>
<td>0.14</td>
<td>0.35</td>
</tr>
<tr>
<td>Velvetleaf</td>
<td>7.8</td>
<td>1.9</td>
<td>0.24</td>
</tr>
<tr>
<td>Cockle bur</td>
<td>38</td>
<td>7.1</td>
<td>0.19</td>
</tr>
<tr>
<td>Sunflower</td>
<td>61</td>
<td>12</td>
<td>0.20</td>
</tr>
<tr>
<td>Soybean</td>
<td>158</td>
<td>24</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Enhance the crop’s head start!

• Plant when crop will emerge and grow quickly
• Breed for larger seed size?
• Use transplants for small seeded vegetables
• Don’t delay between seedbed prep and planting
• Or use a stale seedbed and kill the weeds right before planting
Take advantage of the crop’s head start

- High density planting
- Space plants for quick canopy closure
  - Trade-offs with cultivation
- Use competitive cultivars
  - Put the competitive cultivars in the weediest fields/beds
- In-row cultivation
Using crop competition
Nutrients and weeds

- A lot of mythology and not much data
- Weeds are nutrient sponges
  - Avoid pulsed release of nutrients
- Most agricultural weeds are highly responsive to N and P
  - Over fertilization leads to weed problems
Response of corn to compost
Response of weeds to compost

- Lambsquarters
- Ragweed
- Foxtail

Fitted curve
Prevention
Seed production

- A big lambsquarters can produce 100,000 seeds
- A big redroot pigweed can produce 250,000 seeds
Hairy galinsoga, 40,000 seeds
Most seeds come from a few large plants.

Redroot pigweed
Most agricultural weeds depend on humans for dispersal

- In feed grain -- velvetleaf
- In manure
- On tractor tires and tillage machinery
- On combines
- Contaminated seed
Some key points

• Breaking up perennials promotes sprouting
• Tillage, surface conditions, and absence of plants stimulates germination
• Species have characteristic seasons
• Seeds often persist in the soil for many years; they die at a constant rate, survive better when buried
• Produce many small seeds
• Seed size controls depth of emergence, ability to emerge through mulch, and growth rate
• It is easy to bring in “new” weed species
Opportunities for control

• Breaking up perennials increases sprouts but each sprout is weaker
• Can use cultivation to flush weeds out of the soil
• If seeds miss their annual opportunity, many may die before next year; more die with tillage
• The difference in seed size between crops and weeds provides opportunities for control
• Avoid seed production
• Guard against invasion of “new” weeds