Beating the Weeds without Herbicides

Soil-Friendly Organic Weed Management

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Presenter:
Mark Schonbeck,
Research Associate

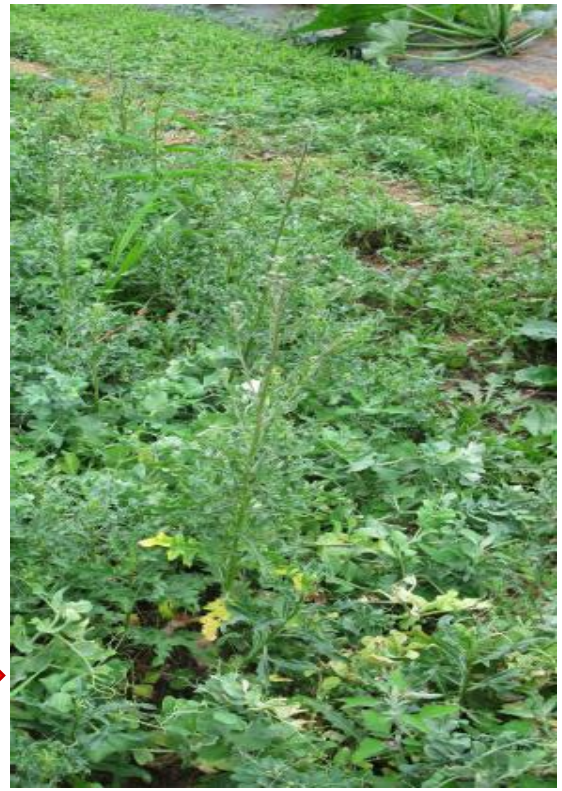
ORGANIC FARMING RESEARCH FOUNDATION

Weeds: the Organic Farmers' Dilemma

Too much

The goal

Too little



USDA National Organic Standards on Tillage and Weeds

Tillage and cultivation practices [must] maintain or improve the physical, chemical, and biological condition of soil and minimize erosion.

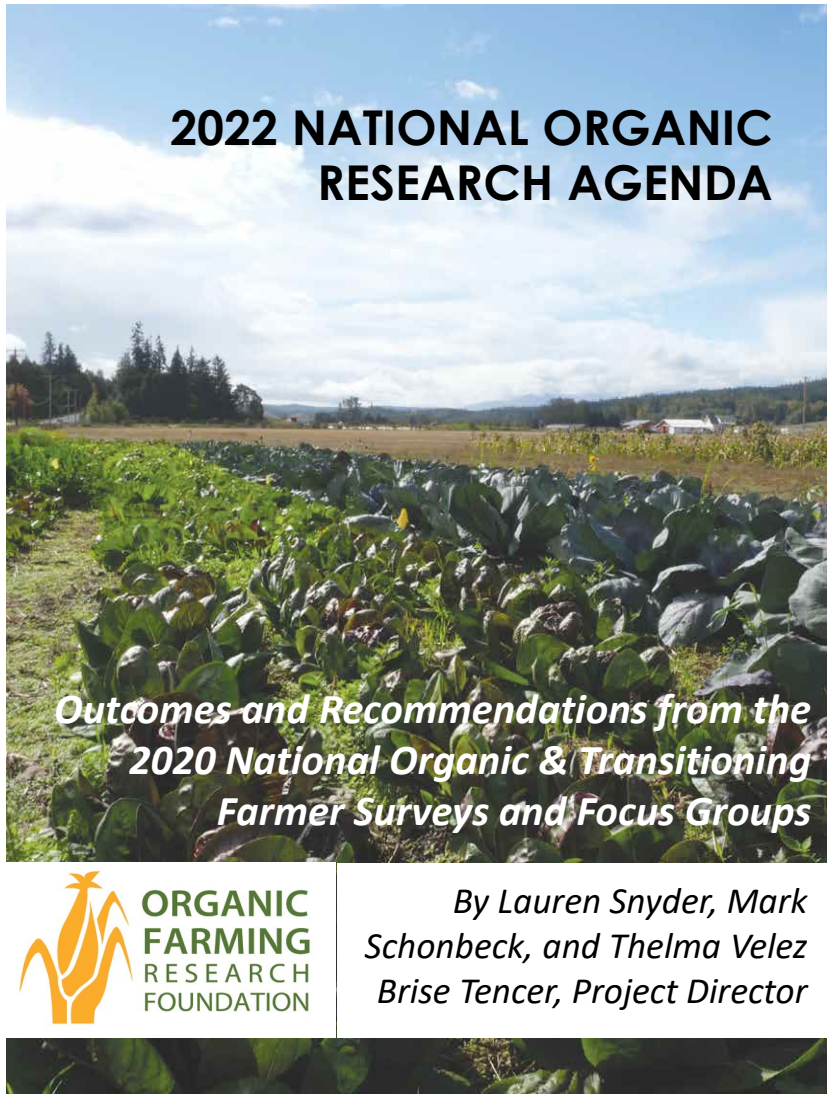
Prevent crop pests, weeds, and diseases [with] crop rotation, nutrient management, sanitation, and [adapted cultivars] with resistance to prevalent pests, weeds, and diseases

Weed problems may be controlled through mulching, mowing, grazing, hand weeding and mechanical cultivation, flame, heat, and electrical means.

Synthetic mulches must be removed at the end of the season.

USDA National Organic Program (NOP) Regulations, §205.203 Soil fertility and crop nutrient management, §205.206 Crop pest, weed, and disease management

Weeds are the #1 Challenge in Organic Farming



Top two production challenges:

- Weed pressure – 40% of respondents
- Soil health – 30%

Substantial challenges:

- Controlling weeds – 67%
- Managing production costs – 59%
- Effects of tillage on soil health – 31%

From farmer focus groups:

"How to manage weeds while minimizing tillage."

"Ideal planting and harvest dates to conquer weed pressure."

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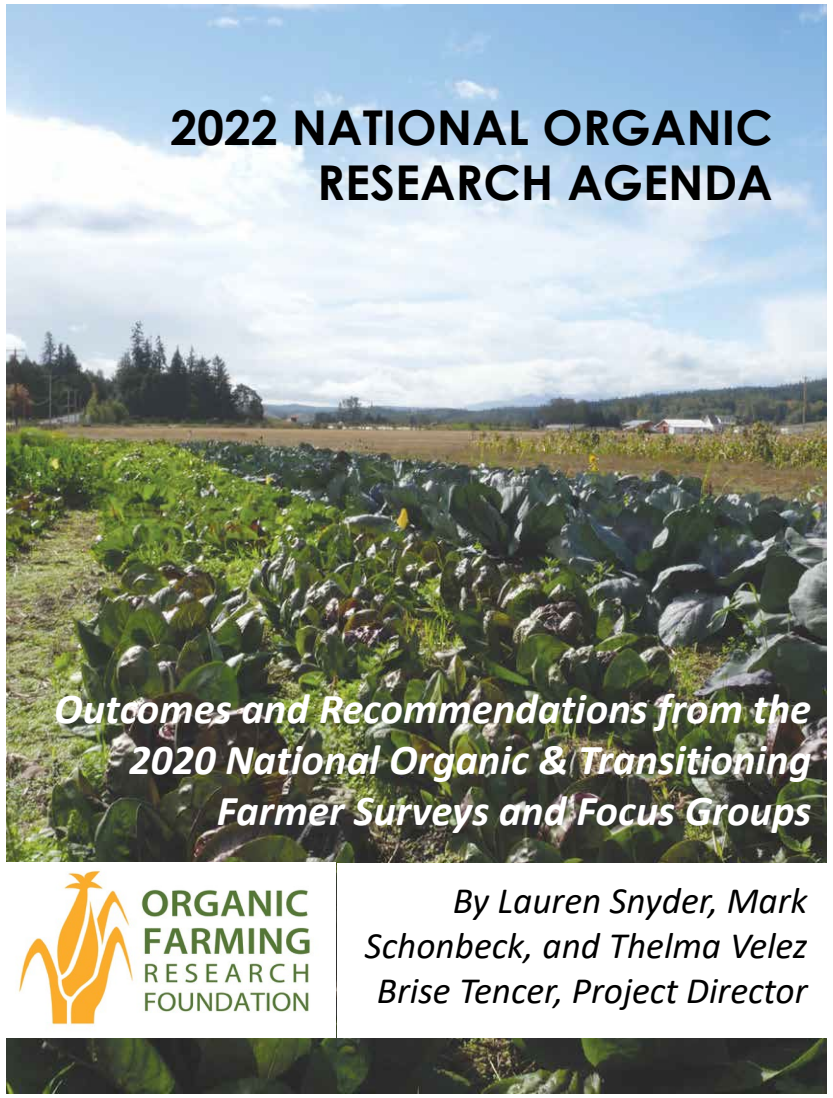

On weed management and climate changes:

"Weather makes it hard to control weeds; it is getting more and more unpredictable."

"When we're facing a drought [weeds are] the biggest thing we face."

"[In wet years] trying to control weeds through stale seed bedding is a real challenge."

On creeping perennial weeds:

"Our biggest challenge is controlling perennial weeds [which] can take over entire fields."

"Canada thistle and field bindweed hold back production." [several farmers]

What Makes Organic Weed Control so Tough?

- Knowledge-intensive, site-specific
- Labor-intensive, high costs.
- Moving target
- High weed seed populations even with diligent cultivation.
- Cover and sod crops entail foregone income.
- Organic minimum-till builds soil health but weed pressure often reduces yields.
- Organic herbicide R&D is in its infancy.

Organic no-till broccoli in roll-crimped rye suffers from N deficiency and competition from weeds

Weed Ecology 101

Why are weeds growing in my field?

Weeds are Pioneer Plants

Their role is to protect and restore soil after disturbance

Weeds can make trouble …

and the alternative is worse!

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How Humans "Make" Weeds

- Decide what plants are "unwanted."
- Hold succession back at early stages to produce desired crops (tillage).
- Create open niches (bare soil).
- Bring exotic plants into the region:

Lambsquarters: weed or nutritious greens?

Johnson-grass

"Canada" thistle

Field bindweed

Purple nutsedge

Cropland Weeds

Cropland weeds are pioneer plants that:

- Are adapted to frequently disturbed, fertile soils.
- Germinate in response to light and other tillage cues.
- Grow and develop rapidly.
- Respond to abundant nutrients.
- Reproduce prolifically by seed or by rhizome or other vegetative means.

Ragweed and jimsonweed in tomato (left); pigweed in broccoli (right).

Weeds: Nature's Cover Crop?

Keep soil covered

Diversify crops

Maintain living root

Minimize disturbance

Benefits

As pioneer plants, weeds provide cover, diversity, and living roots, protect and restore soil after tillage, and absorb excess nutrients.

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Weeds compete with crops for water, nutrients, light, and space in the field.

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Direct Costs

Weeds compete with crops for water, nutrients, light, and space in the field.

Ecological Costs

Invasive, exotic weeds displace native plants, deplete soil moisture, and disrupt indigenous soil biota, thereby reducing biodiversity.

Ecological Weed Management:

Five preventive steps for organic producers

Step 1 - Know the Weeds on Your Farm

- Life cycle, season, habit of growth
- Modes of propagation
- Germination cues
- Preferred growing conditions.
- Impacts on crops – competition, allelopathy, disease host, etc.
- Response to management – tillage, cultivation, nutrients, etc.
- **Weak points**

*Broadleaf weed seedlings (left) are **easy to kill with flame or light cultivation**, while grass weed seedlings (right) require slightly deeper cultivation because their growing point is below ground.*

Step 1 - Know the Weeds on Your Farm

Short-statured summer annual weeds like common purslane ***can be shaded out by tall crops*** *like corn.*

Yellow nutsedge thrives in wet soil. ***Repeat cultivation when regrowth reaches the 3-4 leaf stage to deplete underground reserves.***

Step 2: Close the Weed Niche!

Put the weeds
out of work…
grow cover crops!

An idle field is the weeds' workplace.

Pearl millet

Cereal rye

Tillage radish

Buckwheat

Triticale + peas

Cover Cropping for Effective Weed Control

- Select and manage cover crops for *rapid early growth* and *canopy closure.*
- In multifunctional mixes:
  - Combine complementary growth habits, e.g. grass + broadleaf.
  - Include one or more species that will cover the ground quickly
- Optimize growing conditions:
  - Seeding date, rate, and method
  - Fertility, moisture

Buckwheat sown at 100 lb/ac, 14 days after planting (left). 'Iron and Clay' southern pea 37 days after planting (right).

Complementary Architecture and Nitrogen Dynamics: Grass + Legume

A. *A cover crop of rye + vetch fills the niche.*
B. *Broccoli planted no-till into mowed rye + vetch is vigorous and nearly weed-free.*
C. *Broccoli after rye alone is N-deficient and weedy.*
D. *Vetch alone encourages pigweed to compete with the crop.*

Step 2: Close the Weed Niche!

A. Strip tillage through cover crop leaves alleys between tomato rows covered.

B. Intercropping occupies the entire high tunnel bed.

C. Straw mulch blocks weed seedling emergence.

D. Relay interplanting clover into standing vegetable crops minimizes bare soil after harvest.

Step 3: Keep the Weeds Guessing

- Develop a diversified crop rotation:
  - Cool and warm season
  - Grass and broadleaf
  - Deep and shallow-rooted
  - Tall-erect and low-spreading
  - Crops with contrasting nutrient needs
- Vary timing of tillage, planting, and harvest.
- Vary method and depth of tillage.
- Vary weed control tactics.

Rotating annual cropland to perennials such as red clover (above) interrupts annual weed life cycles and allows weed seed predators to reduce the weed seed bank.

Step 3: Crop Rotation to Keep the Weeds Guessing

“Crop rotation is … the most important integrated weed management tool and should be the cornerstone of any weed management plan.”

(*Hooks et al., 2016; U Maryland*).

“Short duration rotations with only corn and soybean are detrimental to soil health … inclusion of a perennial like alfalfa … is critical for weed control and soil maintenance.”

(Sheaffer et al., 2007; U Minnesota).

“Crop rotation is at the core of organic weed management. Establish crops with different [growth habits and] growth periods to keep weed communities off balance.”

(Menallet et al., 2012, Montana State U)

Cucumber

Crimson clover

Till

Lima bean

Barley + clover

Till

Pepper

Hairy vetch

Till

Okra

Cereal rye

Till

This diverse, 4-year rotation may become weedy because of predictable tillage timing.

Winter cereal (for grain)

Red clover overseeded before harvest

Red clover

Till

Potatoes

This 4-year rotation yields three vegetables and one grain harvest and disrupts weed life cycles.

Lettuce

Till

Butternut squash

No-till roll-crimp

Triticale + Austrian winter pea

Step 4: Grow crops, not weeds!

Healthy soil and good crop management yield vigorous crops with fewer weeds.

A. *Low tunnels give early snap beans a head start.*
B. *Sweet potato forms a solid shading canopy.*
C. *Tall, vigorous crops like 'Tennessee red cob' corn are less susceptible to weeds.*
D. *The heavy canopy of 'Danvers' carrot suppress later-emerging weeds.*

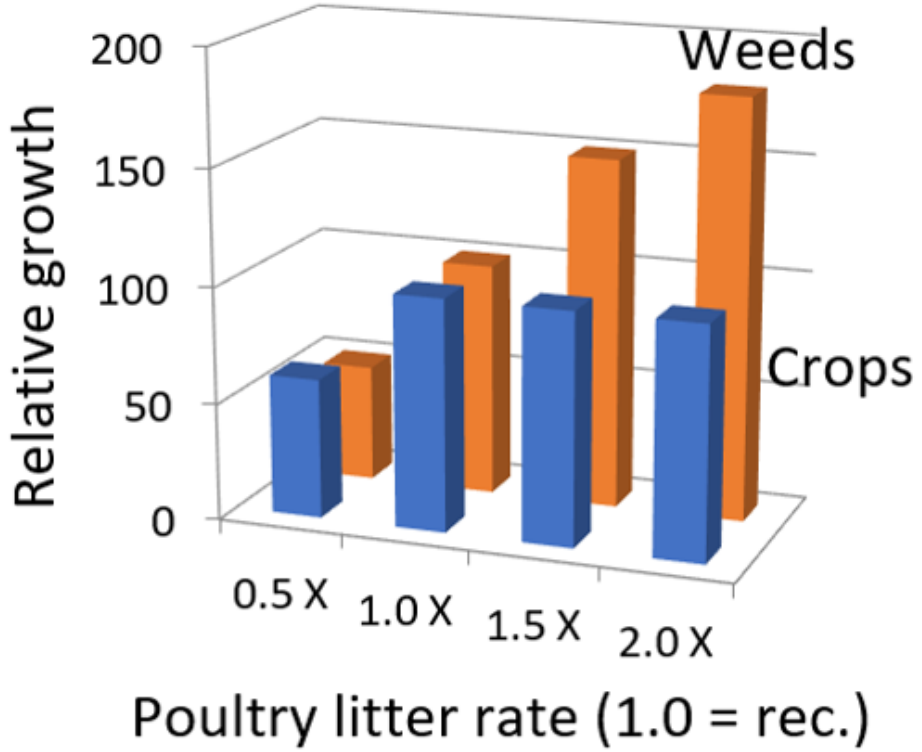
Step 4: Feed and Water the Crops, not the Weeds

A. *Transplanting vigorous starts gives crops a six-week head start on weeds.*
B. *In-row drip irrigation gives lettuce an advantage over between-row weeds.*
C. *In-row drip lines feed and water tomatoes while leaving between-row weeds dry.*
D. *The slow-release nutrients in finished compost are less likely to overstimulate weeds than fresh manure or poultry litter.*

Organic Co-management of Nutrients and Weeds

To keep crops ahead of weeds:

- Avoid over-application of available N, P, and K, including organic forms.
- Encourage mycorrhizal fungi.
- For soybean and other strong N fixers, maintain low soluble soil N levels with higher C:N cover crops or amendments.



Lambsquarters, ragweed, pigweed, and foxtail respond to poultry litter rates well above saturation rate for crops (corn and kale).

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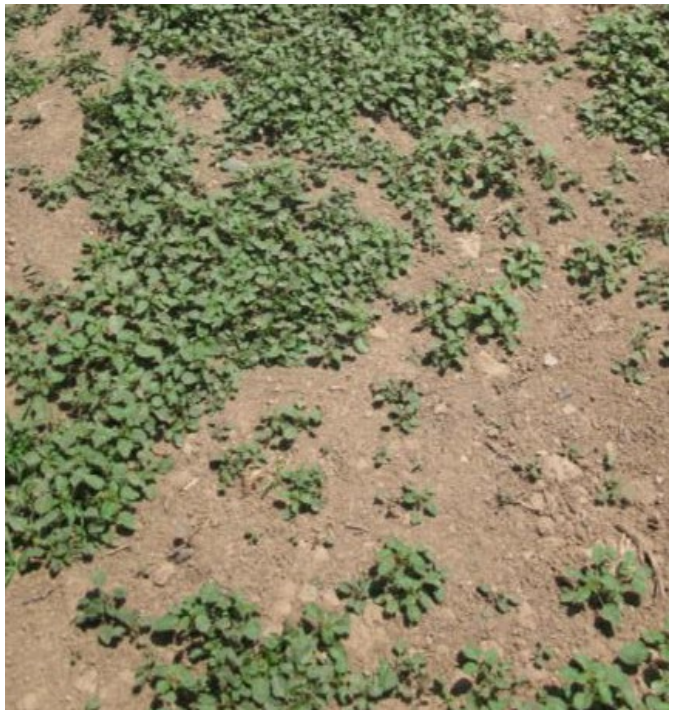
Step 5: Draw Down the Weed Seed Bank

Early season cultivation …



can fail to give season-long weed control …

if last year's weeds were allowed to make a big "bank deposit"!

Step 5: Draw Down the Weed Seed Bank

- Prevent weed seed set:
  - Mow, cut, pull, or till larger weeds before flower buds open.
  - Chop or remove flowering weeds from field.
- Prevent / interrupt vegetative reproduction:
  - Know when perennial weeds form tubers, etc.
  - Remove top growth before that happens.
- Avoid importing new weed seeds in:
  - Mulch hay, manure, compost
  - Poorly cleaned crop seed

Purple nutsedge can spread by rhizomes and tubers a few weeks after tillage and long before flower heads appear.

Step 5: Bait the Weeds with a Stale Seedbed

Prepare seedbed as if to plant (left). Let weeds emerge (center), then till shallowly or flame. To rebuild soil health in a stale seedbed, Virginia organic farmer Charlie Maloney (right) broadcasts cover crop seed, then knocks out tiny weeds and incorporates seed in one pass with rototiller set to work just one inch deep.

Step 5: Drawing Down the Weed Seed Bank: Let the Cleanup Crew Do its Job

- When a cover crop such as millet or radish winterkills, leave residues on the surface until spring to let ground beetles and other weed seed feeders reduce the weed seed bank.
- Delaying tillage improves soil health and can increase yield of the next crop.

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Organic Integrated Weed Management:

Better weed control with less damage to soil

Cultivate Smart: Kill More Weeds and Fewer Soil Organisms

- Cultivate shallowly (<1 in) when weeds are small ("white thread").
- Cultivate during the crop's critical weed free period – first 4-8 weeks.
- Use the best tool for the crops, weeds, stages of growth, and soil conditions.
- High residue cultivators for reduced till.
- "Stack" tools for greater efficacy.
- Use camera guidance technology and robotics for precision weed removal.

Rolling baskets (left) stir the top inch of soil, taking out small weeds. Finger weeders (right) remove small, within-row weeds from established crops.
See eOrganic videos at:
https://eorganic.org/menu/1045.

Alternatives to Cultivation

- Mowing
- Flame weeding, electrical zapper
- Directed hot water or steam – safer with mulch than flame or electrical.
- Mulching – organic, plastic, weed mat.
- Tarping
- Grazing
- NOP allowed herbicides (vinegar, fatty acids, or essential oils)

Flame weeding

Mulching with plastic (beds) and straw (alleys)

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Tarping: No-till Weed Control for the Smaller Scale

Tarping – covering the soil with opaque silage tarp or landscape fabric for a few weeks after mowing or roll-crimping a cover crop – ensures cover crop termination and kills emerging weeds. After initial preplant tarping, farmer Bryan Hager of Bremen, GA lays landscape fabric with planting holes for season-long, no-till weed control.

Grazing Turns Weeds into Organic Meat, Dairy, and Eggs

Graze livestock and poultry on:

- Crop residues and late season weeds after harvest.
- Cover crops.
- Perennial sod phase of a crop rotation.

Management intensive rotational grazing:

- Reduces pasture weeds.
- Improves soil health and forage quality.

Rotationally grazed dairy (top) and beef cattle (bottom)

Organic Integrated Weed Management:

Farmer innovations and research findings

Solving a Problem Weed: Giant Ragweed

- Major problem in soybean phase of 4-year organic corn-soybean-cereal grain-forage rotation in Ohio.
- Modified rotation added a fifth year before soybean:
  - Early cultivated fallow (stale seedbed), then
  - Mid-summer buckwheat for grain or cover crop.
- Substantially reduced ragweed levels.
- Seven-year grain and forage rotation with livestock integration was even more effective.

Weed flush after grain harvest includes giant ragweed.

This strategy was developed by innovative organic farmer Ed Snavely of Ohio as part of a USDA-funded organic research project conducted by Ohio State University.

Solving a Problem Weed: Canada Thistle

Canada thistle spreads by seed and through creeping roots that send up new shoots.

- Major problem in organic reduced till grain rotations and dryland grains.
- Set back by mowing at 7-10 leaves, pre-bloom.
- Suppressed by sudangrass or sorghum-sudan hybrids.
- Plant sorghum-sudan in infested field, mow when grass is 3-5 ft and thistle is in pre-bloom stage.
- Sorghum-sudan regrows aggressively, reduces thistle numbers 98% in following season.
- Can also be suppressed by alfalfa with several forage harvests per year.

Tackling Field Bindweed and Canada Thistle in Dryland Crops

- These two weeds pose the leading barrier to organic dryland grain production.
- Researchers and farmers in WA, MT and ND are developing organic IPM strategies against thistle and bindweed, including:
  - Changes in crop rotation
  - Mowing and tillage
  - Grazing
  - Biological control

Carr et al., 2022

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Field bindweed climbing wheat. Bindweed infests grain, forage and tree fruit crops. Deep roots and extensive creeping rhizomes make this weed extremely difficult to control. Photo credit: Thomas from Pixabay.

Biological Controls Against Bindweed and Canada Thistle

Field bindweed moth (Tyta luctuos*a, left), shows promise as a biocontrol agent against bindweed. Canada thistle heavily infested by rust fungus* Puccinia punctiformis *(right), which also attacks the weed's extensive root system.*

Researchers are using these two agents and the bindweed gall mite (Aceria malerbae) *as components of organic IPM strategies that include crop rotation and targeted tillage.*

Rye Before Beans Provides Selective Weed Control

Organic no-till soybeans in roll-crimped cereal rye:

- Rye residue hinders weed emergence.
- Low soil soluble N slows weed growth without affecting soybean.
- Rye suppresses white mold disease.
- Higher seeding rate enhances weed control.
- Promising results with dry bean.

Menalled et al., 2021; Pethybridge and Ryan, 2022

Photo credit: USDA

Strategic Crop Rotations for Extended Organic No-till

Building on rye-soy success, farmers and researchers are developing extended no-till rotations.

Adaptive management for weather, soil conditions, and specific weeds:

- Barley → buckwheat / dry bean for thistles
- Add winter grain to corn-soy for velvetleaf
- Mustard or buckwheat for wild mustard in wheat
- Winter annual weeds do not affect no-till corn

Ryan et al., 2021

Organic grain farmer and project collaborator Klaas Martens no-tills rye and peas into sorghum-sudan stubble. In spring, he will roll-crimp the winter cover for no-till soybean.

Breeding Crops to Beat the Weeds

- Rice (Zhou, 2018).
- Wheat (Jones et al., 2011; Worthington et al., 2015)
- Cover crop (vetch, peas, crimson clover, rye) breeding for multiple traits including weed competitiveness (Mirsky, 2020; Moore et al., 2021)
- New carrot cultivars combine weed competitiveness, disease resistance, and desired market traits (Simon, 2021).
- Weed suppressiveness related to rapid establishment, tall stature, heavy tillering, dense canopy, etc. (competitive traits) rather than allelopathy.
- Growing multiple cultivars of a forage or cover crop can enhance weed competitiveness (Drinkwater and Walter, 2014)

New and Emerging Technologies

- Selective cutting tools to remove weeds from standing crop before they set seed (Mallory, 2020).
- Stacking tools (finger weeder + flextine) and practices (cover crop + tarping or flaming + cultivation)to reduce weed populations (Gallandt and Brainard, 2022). Website https://forum.physicalweedcontrol.org
- Electrical weed control for grains (Ryan et al., 2021) and tree crops (Moretti et al., 2022).
- NOP allowed herbicides + precision spray technology + field pea cover crop in organic dryland grains (Carpenter-Boggs, 2021)
- Biobased and biodegradable film and hydromulches in development (Wortman, 2022; Gramig et al., 2022).

Organic Integrated Weed Management:

A practical summary

Ecological Weed Management: Prevention

- Learn about the farm's worst weeds and identify their weak points.
- Practice good sanitation: clean tools, use weed-free seeds and inputs.
- Implement the four NRCS principles of soil health:
  - Keep soil covered by desired plants – cash, cover, or forage crops.
  - Fill soil profile with living roots – shallow, deep, taproot, fibrous.
  - Implement a diversified and strategic rotation.
  - Limit soil disturbance – use tillage and inputs judiciously.
- Feed and water the crop – not the weeds!
- Vary timing of planting, tillage, and harvest to keep weeds off balance.

Ecological Weed Management: Control

- Deplete the weed seed bank.
  - Use stale seedbed, tarping, solarization, etc.
  - Manually pull, cut, mow, or graze “escapes” before they flower.
  - Hit regrowth of creeping perennials at the 3-4 leaf stage.
- Cultivate smart to kill more weeds and fewer soil organisms.
  - Cultivate shallowly (<1 in) when weeds are in white thread stage.
  - Use stacked cultivation tools, camera recognition, robotics, etc.
- Utilize alternatives to cultivation:
  - Mulching, mowing, tarping, grazing.
  - Flame, steam, hot water, or electrical.
  - NOP-allowed herbicides with precision application technology.

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