

Beating the Weeds without Herbicides: Soil-friendly Organic Weed Management

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Presentation Notes

Slide 2 – Weeds: the organic farmer’s dilemma

Organic production of annual crops generally requires some tillage and cultivation to manage weeds, cover crops, residues, and seedbed preparation. When cultivation becomes the main tool for weed control in annual crops, the farmer often faces a tradeoff between adequate weed suppression to sustain crop yields on the one hand, and soil conservation, soil structure, and soil health on the other.

Slide 3 – USDA national organic standards on tillage and weeds

The USDA National Organic Program (NOP) set a high bar for organic soil and weed management. The NOP standards require tillage and cultivation practices to “maintain or improve soil condition,” and outline a preventive approach to weeds, as well as a list of several non-soil-disturbing control measures in addition to mechanical cultivation.

Slides 4-5 – Weeds are the #1 challenge in organic farming.

In 2020, the Organic Farming Research Foundation (OFRF) conducted a survey of over 1,000 certified organic and 71 transitioning-organic producers to document their use of resource stewardship and production practices, their leading production and enterprise management challenges, and technical assistance needs.

Top two challenges cited in an open ended question: Weeds most often cited followed by soil health, then pest management (22%), climate change (19%), and disease management (13%).

Survey respondents also rated each of a long list of potential production challenges on a scale of 1 (not a challenge) to 5 (strong challenge). Controlling weeds was cited most often as a substantial challenge (4 or 5 on the five-point scale), followed by managing production costs, of

which labor for weed control is a major component. Almost one in three cited minimizing the adverse effects of tillage on soil health as a substantial challenge – one that makes organic weed management decisions more complex.

Top three technical assistance needs (not shown on slides) are: managing weeds, pests, and diseases (74%), soil fertility and crop nutrients (65%) and soil conservation and soil health (60%).

Farmer quotes on climate change in full:

“Weather makes it hard to control weeds, it is getting more and more unpredictable. Last year we had no weeds, and then the end of July the super dry, hot weather just made everything go crazy, and there was nothing I could do.”

“Weeds are a symptom...not a primary problem. But when you’re facing a drought it is the biggest thing we face. When there’s just not enough moisture to grow a competitive crop, nature puts something there, and that’s not always something we want and certainly we don’t benefit from. Weed problems are our worst, both in excessively dry and excessively wet circumstances because our systems are designed around what used to be the expected precipitation in both amount and timing, and that doesn’t have a lot of meaning anymore.”

“We had a really wet two first years, and so then trying to control weeds in direct seeded crops through stale seed bedding is a real challenge.”

Slide 6 – *What makes organic weed control so tough?*

Weed management without herbicides requires an ecological understanding of weeds and a knowledge-intensive, site-specific approach. The weed community is a “moving target” in that a strategy that successfully suppresses certain weeds may allow others to increase. For example, reducing tillage can reduce the flushes of annual weeds that germinate and emerge in response to tillage, but may allow creeping perennial weeds to increase.

Weeds pose the #1 barrier to successful organic production because:

- Every cultivation causes some loss of SOM and soil structure.
- Organic minimum-till systems build soil health but often reduce yields due to increased weed competition (Barbercheck et al., 2008; Menalled, 2019)
- Organic farmers devote substantial labor and financial resources to weed control, yet weed populations often remain high in organic fields (Hooks et al., 2016).
- Historically, NOP-allowed herbicides have not been cost-effective at the field scale (Baker and Dyck, 2012). However, some newer materials, including caprylic and capric acids and D-limonene, have shown promise, and are currently undergoing trials with precision camera-aided applications of these materials (Carpenter-Boggs, 2021).
- Rotating fields to cover or sod crops to build SOM and suppress weeds can entail foregone income.

Slide 7 – *Weed ecology 101 – why are weeds growing in my field?* [subheading]

Slide 8 – *Weeds are pioneer plants*

Pioneer plants spring up rapidly after fire, landslide, clearcut, tillage, or other disturbance leaves the soil exposed. Their ecological role is to cover and protect the soil from erosion as soon as possible after disturbance, to begin restoring soil organic matter, soil life, and soil health, and to initiate the process of secondary succession toward the region's natural forest, prairie, or other plant community. Without weeds, the world's soil erosion problems would be much more severe; sometimes it is the weeds that stand between soil disturbance and catastrophic erosion.

Slide 9 – *How humans “make” weeds*

Lambsquarters are often grown and eaten as greens in northern India and may have been brought to the US by European colonists for the same purpose. Johnsongrass was imported for use as forage and erosion control, while purple nutsedge, Canada thistle, and field bindweed were probably brought in by accident.

Slide 10 – *Cropland weeds*

Knowing what makes weeds “tick” offers clues to effective management. In addition to a flash of daylight, “tillage clues” may include increased oxygen levels after cultivation breaks up surface crust and soil aggregates, greater temperature fluctuations when soil surface is exposed, and a flush of nitrate-N or other soluble nutrients released when tillage stimulates decomposition of organic matter.

Slides 11-13 – *Weeds: nature's cover crop?*

Weeds in their ecological role as pioneer plants can perform as a natural cover crop. In some situations, they provide real soil health benefits, or at least prevent erosion when the farmer is unable to get the cover crop in. However, invasive exotic plant species can displace native plant communities and severely hurt crops through several mechanisms, including aggressive growth, earlier emergence and longer growing season, and depletion of deep soil moisture in lower-rainfall regions.

In addition, some invasive exotic plants release toxic substances to which the native soil microbiota and/or plant community are not adapted. Garlic mustard, a 3 ft tall herbaceous weed from Europe, can slowly but surely displace New World hardwood forest by inhibiting the mycorrhizal fungi on which the trees depend. Some of our worst cropland and rangeland weeds, such as purple nutsedge, Canada thistle, and spotted knapweed, release intensely allelopathic compounds that hurt crops and native plants, both by direct phytotoxicity and indirectly by affecting soil microbial communities.

Slide 14 – *Ecological weed management – five preventive steps* [subtitle slide]

Slides 15-16 – *Step 1: know the weeds on your farm*

Knowing the strengths and weaknesses of the five or ten most abundant weeds on your farm will help identify the most effective prevention and control strategies. Newly emerged broadleaf weeds can be flamed in lieu of cultivation; however, grasses at the same stage have their growing point below ground, and usually require a shallow cultivation. Purslane is so drought tolerant that it can easily re-root after being severed or uprooted; however, tall crops readily outcompete it through shading. Rhizomatous perennials like purple nutsedge, quackgrass, and bindweeds regrow profusely after tillage; however, they expend reserves to form the first few leaves and can be weakened by cultivation at this stage.

Slide 17 – *Step 2: close the weed niche*

Cover crops planted after annual crop harvest or overseeded into a standing crop before harvest perform the same ecosystem services as pioneer plants. They protect the soil from erosion, feed soil life, recycle nutrients, restore soil organic matter (SOM) and contribute to biodiversity of the agro-ecosystem. Cover crops are crop species and varieties that rapidly and aggressively colonize and cover bare soil, yet are much easier to manage than most weeds, and often generate more biomass and SOM than the local cropland weed flora.

Slide 18 – *Cover cropping for effective weed control*

The southern pea in this photo was planted at about 75 lb/ac into a weedy field and fully suppressed weed growth. All other cover crops in this trial, including forage soybean, sorghum-sudangrass, and several species of millet, became infested with crabgrass and other summer annual weeds. This trial provided an important lesson: if the seedbed is prepared by tillage of any kind, plant immediately! Here, cover crops were drilled five days after shallow tillage to make the seedbed, and millions of weed seeds per acre germinated during that time. The southern pea was the first to close canopy; all other entries were quite weedy.

In the weed suppression game, rapid establishment and early ground coverage is vital. Species selection, timely planting, adequate seeding rates, and optimum growing conditions all contribute to cover crop efficacy against weeds. It may be reasonable to irrigate a cover crop seeded into dry soil to ensure rapid establishment.

For weedy fields or late planting dates, increase seeding rates of single-species covers to 1.5 or 2X normal recommended rates.

Match the cover crop to the season – buckwheat in October or rye in April will not compete with weeds!

Match the cover crop with soil fertility. If soluble N and overall fertility are low, use sunnhemp, southern pea, and pearl millet in summer, rye and vetch over winter. If N is abundant use sorghum-sudangrass in summer, radish in late summer/fall, and rye or wheat over winter. In fall plantings of winter-hardy cereal grain and legume, add a fast-growing species that will cover the ground quickly, then winterkill, such as buckwheat (any locale that will experience frosts of 28°F or colder), or radish or oats (zone 7b and colder).

Slide 19 – *Complementary architecture and nitrogen dynamics: grass + legume*

In these 1989-90 organic no-till field trials on Cape Cod, Massachusetts, the grass-legume mix shaded the ground more completely than either alone, and clearly outperformed the single-species plantings in terms of weed control.

Slide 20 – *Step 2: close the weed niche!*

In Floyd County, VA, CSA farmer Polly Hieser strip-till through winter rye to plant tomatoes (photo A in slide). Alleys were mowed once, after which rye growth slowed and gradually died back in the heat of summer. In the relay planting example (photo D in slide, taken in central Vermont, USDA hardiness zone 4), author Eliot Coleman drilled the clover between brassica rows when the latter were just getting established; after vegetable harvest, the clover was ready to grow and cover the ground.

Slide 21 – *Step 3: keep the weed guessing.*

To deal with a certain weed that is getting out of control, modify timing of field operations strategically. For example, the homestead garden in Floyd, Virginia in which the photo was taken) once had terrible problems with galinsoga, a prolific summer annual weed that routinely emerged after May tillage to overwhelm newly-seeded crops. Rotating the worst areas to garlic (planted and mulched in October, dug the following July), or into a year of red clover (shown here) sharply reduced weed populations. No-till termination of winter covers also curbed galinsoga. However, these practices encouraged another tough weed, hedge bindweed, which required a combination of targeted tillage and manual removal to manage.

Slide 22 – *Step 3: crop rotation to keep the weeds guessing*

Multiple studies have shown that a diverse crop rotation that includes 2-3 years perennial forage or sod as well as annual crops simultaneously improves soil health, builds organic matter, and reduces weeds (Hooks et al., 2016, Menalled et al., 2012; Reberg-Horton, 2012; Sheaffer et al., 2007). A perennial sod break in intensive vegetable or row crop production disrupts annual weed life cycles and allows ground beetles and other weed seed consumers to draw down the weed seed bank. A diverse planting of perennial grasses, legumes, and forbs can be especially

effective for both soil restoration and weed management during the three year transition period when converting a conventionally managed field to organic production.

Slide 23 – Diverse four-year rotation with tillage at same time each year

Organic vegetable growers often encounter intense weed pressure from summer annuals like pigweeds, lambsquarters, galinsoga, crabgrass, and foxtails if they prepare the fields by rototilling in the late spring of each year. No-till termination (roll-crimp or flail mow) of one or two of the cover crops in this rotation may help reduce summer annual weeds. The rotation can be further fine-tuned by placing the rye ahead of the lima bean to reduce soil N levels and give the N-fixing lima an advantage over the weeds.

Slide 24 – Diverse four-year rotation with varied timing of field operations

In this rotation, the clover is grown for a full year (or two years), which interrupts weed seed production. Varying planting methods and timing of soil disturbance will “keep the weeds guessing” and help prevent either annual or perennial weed populations from building up to excess.

Slide 25 – Step 4: grow crops, not weeds!

Nothing beats weeds like vigorous crops growing in healthy, living soil. Anything that stresses the crop, from weather extremes and soil health problems to poor quality seed or non-optimum planting date can result in more weed pressure. Ensuring sufficiently warm soil through good season extension practices (beans in A) or not rushing the planting date (e.g. sweet potatoes set out several weeks after spring frost date, B) helps heat loving crops beat the weeds. Plant genetics play a role, as varieties with tall stature, vigorous top growth, and deep, extensive root systems (C and D) are better equipped to both tolerate and suppress weeds than lower-growing, less vigorous cultivars.

Slide 26 – Step 4: Feed and water the crop, not the weeds

Drip lines can be used to “fertigate” crops as well, using organic materials such as fish emulsion, seaweed extract, or compost tea. *Subsurface* drip (not shown here) waters and feeds established crops without watering weed seeds in the top couple inches, thereby reducing *within-row* weeds as well.

Slide 27 – Organic co-management of nutrients and weeds

This conceptual diagram summarizes comparative responses of crops (corn, kale) and weeds (lambsquarters, Powell amaranth, common ragweed, foxtails) to composted poultry litter (4-5-2

analysis) in organic vegetable and field cropping systems trials at Cornell University (Cornell, 2005; Little et al., 2012; Mohler et al., 2008). In these trials, high poultry litter rates stimulated *more* weed growth than equivalent amounts of N (feather meal) or K (potassium sulfate), which suggests that weeds were responding to high levels of several nutrients in the poultry litter.

Tilling-in an all-legume cover crop can stimulate a flush N responder weeds.

Many crops form strong, beneficial mycorrhizal associations that assist nutrient and moisture uptake and reduce soilborne crop diseases (exceptions: brassica family, beet-spinach family, and buckwheat), while many agricultural weeds – including pigweeds, lambsquarters, smartweeds, wild mustard, and nutsedges – do not benefit from mycorrhizal fungal symbionts. Thus, active mycorrhizal fungi can give host crops an advantage over weeds. To encourage these valuable fungi, avoid P excesses; reduce soil disturbance; include strongly mycorrhizal crops like legumes, cereal grains, alliums, and solanaceous crops in the rotation; and use mycorrhizal inoculants if needed to restore this component of the soil food web.

Strong N fixers like soybean gain an additional edge over nutrient-responsive weeds when plant available soil N is low; for example, soybean no-till planted after a mature rye cover crop is roll-cripped (Clark, 2019).

Slide 28 – Step 5: drawing down the weed seed bank

Shallow cultivation (<1 inch) when weeds first emerge is a good way to get the most weed control for the least soil disturbance. However, if a large weed seed bank exists, cultivation can stimulate a heavy new flush of weeds to emerge, necessitating more cultivation. A single pigweed “escape” allowed to mature can deposit 100,000 to 500,000 viable seeds.

Slide 29 – Step 5: drawing down the weed seed bank

Many weeds can mature viable seed if they are uprooted or cut during flowering and left in the field as whole plants. They should either be chopped (e.g. flail mowing) or physically removed from the crop production area.

Creeping perennial weeds like nutsedge (whose emerging shoots can penetrate black plastic mulch) pose the most challenging tradeoffs for soil health and weed control. More research is needed to develop effective organic strategies to build soil health while bringing invasive perennial weeds like purple and yellow nutsedges, Bermuda grass, and field bindweed under control.

Slide 30 – Step 5 - bait the weeds with a stale seedbed

Stale seedbed technique deliberately rolls out the red carpet for weeds to trick the seedbank into germinating all at once. Where soil weed seed populations are high, two or three cycles of

stale seedbed may be needed for adequate control. For creeping perennials like bindweed, nutsedge, and Canada thistle repeat shallow tillage or undercutting to sever regrowth when emerging sprouts have three leaves, thereby depleting underground rhizomes and tubers. The farmer on the right has broadcast cover crop just before shallow tillage to weed and plant in one pass, and thereby begin rebuilding soil health after weed control.

Slide 31 - *Step 5: drawing down the weed seed bank: let the cleanup crew do its job*

Late-season weeds that do not threaten yield of the current crop can nevertheless make a big deposit into the weed seedbank. Prompt mowing after harvest to limit further weed seed formation can limit this deposit, but tillage should be delayed if practical. Ground beetles and other weed seed predators can clean up a lot of the late-season seed rain if the soil surface and residues are left mostly undisturbed (e.g. by no-till drilling a cover crop).

Compared to tilling in freeze-killed or drought-killed cover crop residues, leaving them on the surface can protect and improve the soil, and possibly conserve moisture, as well as maintaining habitat for beneficial ground beetles and other weed seed consumers (Bjorkman et al., 2014).

Slide 32 – *Organic integrated weed management – better weed control with less damage to soil* [subtitle slide]

Slide 33 – *Cultivate smart: kill more weeds and fewer soil organisms*

Timely, shallow cultivation when weeds are in the “white thread” stage or at most 1 inch tall effectively removes the weeds with minimal damage to soil structure and minimal stimulation of additional weed emergence. Many ingenious cultivation implements have been developed for different crops, weeds, growth stages, soil conditions, and management systems (including conservation tillage). See the eOrganic weed control videos at <https://eorganic.org/menu/1045>.

Newer tools that have been used with some success in organic cereal grains (Mallory, 2020) include:

- Robotic camera and side shift weeding system
- CombCut for selective cutting of larger weeds in standing crops to reduce weed seed set <https://www.youtube.com/watch?v=ASZAf2n8HLs>.

Slide 34 – *Alternatives to cultivation*

Historically, the efficacy of NOP allowed herbicides is limited, yet they may play a role in integrated strategies by delaying weed or cover crop regrowth. Some newer NOP-compliant herbicides – caprylic and capric acids and the citrus essential oil D-limonene – show promise for

field application, using camera-recognition precision technology that greatly reduces the amount of herbicide used per acre (Carpenter-Boggs, 2021).

Tarping to terminate a cover crop or “hold” an area until planting date can reduce the weed seed banks by stimulating seeds to germinate and then die for lack of light.

Organic mulch is most effective against annual broadleaf weeds, less so against annual grasses (pointed coleoptile can penetrate a few inches of mulch), and least against perennials emerging from rhizome, tuber, bulb, or rootstock (mulch may even enhance their growth by improving soil conditions and conserving moisture).

Plastic film mulches exclude most weeds except nutsedges (very sharp growing point will puncture the film and benefit from the warming and moisture conservation). Some other weeds, notably morning glories and other viny weeds, can grow toward the light of a planting hole, emerge, and climb the plant. Some hand weeding is needed.

Never flame or electric-zap a field in dry organic mulch! Use steam or hot water instead.

Slide 35 – *Tarping: no-till weed control for the smaller scale*

Tarping – covering the ground with landscape fabric, silage tarp, or other reusable opaque cover for several weeks after a high biomass cover crops is mowed or roll-crimped – ensures cover crop termination, kills emerging weeds through light deprivation, and provides several weeks’ weed control after tarps are removed and the production crop is planted. This approach enhances soil health and provides better weed suppression and nitrogen mineralization than other methods to organic no-till cover crop termination, thereby sustaining higher yields. Georgia organic vegetable and strawberry farmer Bryan Hager replaces the pre-plant tarp with landscape fabric with planting holes at the desired spacing for the crop to be planted, thereby ensuring season-long weed control. This approach is feasible at a scale of up to a few acres and is gaining popularity among organic market farmers.

Slide 36 – *Grazing turns weeds into organic meat, dairy, and eggs*

Slide 37 – *Organic integrated weed management: farmer innovations and research findings* [Subtitle slide]

Slide 38 – *Solving a problem weed: giant ragweed*

This innovation was suggested by Ed Snavelly, a farmer participant in an ORG funded project, and validated in replicated trials in collaboration with Ohio State U (Stinner and Phelan, 2008). Organic grain farmers in Ohio have encountered severe problems with giant ragweed in the soybean phase of a four-year rotation of corn-soybean-cereal grain-hay. Adding a fifth year

to the rotation after corn and before soybean, consisting of early season cultivated fallow and midsummer planting of buckwheat (for grain or green manure) substantially reduced ragweed in soybean. The farmer realized a further reduction in weed pressure when he added livestock enterprises and extended the rotation to seven years to grow feed grains and forages (Ed Snaveley, March 2016, personal communication).

Slide 39 – *Solving a problem weed: Canada thistle*

Canada thistle (*Cirsium arvense*) is an aggressive perennial weed of cropland and pasture that propagates by sending up new shoots from its deep, extensive root system. Canada thistle deters grazing and tolerates drought, flood, aggressive tillage, and cover crop competition. Yet, it does have a point of vulnerability: mowing the weed just before flowering depletes its underground reserves.

Researchers at Ohio State University planted sorghum-sudangrass in thistle-infested fields, then mowed when both crop and weed were several feet tall. The mowing set the weed back while the cover crop regrew rapidly, expanding its roots system and releasing the allelochemical sorgoleone. This strategy reduced Canada thistle growth in the next year's soybean crop by 98%, while mowing alone or a buckwheat cover crop were ineffective (Bicksler and Masiunas, 2008; Cardina et al, 2011). Rotations that include alfalfa can also control Canada thistle if the alfalfa is mowed several times per year for forage harvest (Sheaffer et al., 2007).

Slide 40 – *Tackling field bindweed and Canada thistle in dryland crops*

This project aims to develop integrated management strategies against field bindweed and Canada thistle in organic dryland grain rotations and horticultural crops in two semiarid regions: the Northern Great Plains (NGP) and interior Pacific Northwest (PNW) (Carr et al., 2018). While total annual precipitation in the two regions is similar, summer moisture limitation is more severe in the semiarid interior PNW, where most of the year's moisture occurs as winter snowfall, than in the NGP, where half of the year's moisture comes as showers during May-August. This difference can have subtle but significant impacts on best crop rotation design and cover crop species for co-managing soil health and weeds. This study spans both regions, with four-year trials in WA, MT and ND, of which 10 are located on working farms, three at University experiment stations and, one at a student farm.

Slide 41 – *Biological controls against bindweed and Canada thistle*

The biological control agents shown in the slide and bindweed gall show potential as a component of organic IPM against these two weeds.

In addition to thwarting organic dryland grain production, bindweed causes devastating losses in organic berry, vineyard, nut, and nursery crops, especially during organic transition, by physically climbing over the crop. Farmer and researchers are working together to explore the

efficacy of the field bindweed moth, to estimate the impacts of organic pesticide use (Spinosad, Bt) on the moth, and to develop and test integrated bindweed control strategies that include a steam treatment for knockdown control of bindweed (Peachey et al., 2021).

Canada thistle, invader from Eurasia, has met its match in the fungal rust pathogen, *Puccinia punctiformis*, native to the US. Initial studies by Colorado Department of Agriculture (CDA_ and USDA scientists indicate that the fungus is “safe and effective.” It attacks the extensive, propagating root system of the thistle, eventually killing the plant. CDA is working with organic farmers to test the biocontrol agent for efficacy, develop methods to inoculate thistle patches, and disseminate materials and information to promote widespread and successful utilization. One orchard reported excellent thistle control with the rust fungus, while other farmers reported partial control and a gradual reduction in thistle populations. (Bean, 2022).

Slide 42 – *Rye before bean provides selective weed control*

An all-rye cover crop takes up soluble N from the soil and its residues are slow to release it after roller-crimping. The resulting low levels of plant-available N slows emergence, establishment, and growth of “N-responder” weeds like lambsquarters, pigweeds, ragweed, and foxtails, while soybean, a strong N fixer, is little affected by the N deficiency. The outcome is selective weed control by the rye mulch for soybean and using high soybean seeding rate guarantees a good stand and high yield (Menalled et al., 2021). The rye mulch has also been found to inhibit white mold, one of the most severe diseases of soybean, dry bean, and other pulses (Pethybridge and Ryan, 2021). Additional experiments with no-till organic dry bean in roll-crimped rye have given promising results as well. The researchers will also try this method with oilseed sunflower crops.

Slide 43 – *Strategic crop rotations for extended organic no-till*

The information in this slide is based on a new OREI project award (Ryan et al., 2021) and on interview for farm story with organic grain farmer Klaas Martens who is a participant in this project and has collaborated with Cornell organic agricultural researchers for many years. Martens has studied the ecological roles of weeds and interactions among crops in rotation sequences to develop rotations that promote favorable conditions for crops and reduce weed pressure. The following tips are excerpted from the farm story:

- Know your reasons for tilling. These can include reducing weed competition against crops, yet *not* tilling can avoid stimulating weed seeds to germinate.
- Heavy growth of chickweed, deadnettle, and henbit over winter, or galinsoga in summer indicate a loss of soil carbon due to excessive tillage or soluble N. The winter weeds tend to die back in late spring, making organic no-till corn or even spring wheat feasible.
- Adding mustard or buckwheat to a rotation of grasses and legumes can reduce root rot in dry bean and wild mustard weed pressure in wheat.
- Canada thistle and perennial sowthistle commonly infest organic corn-soy-wheat-red clover rotations in upstate New York. Adding winter barley followed by buckwheat or

dry bean reduces thistle populations because the timing of barley harvest corresponds to the thistles' most vulnerable stage of development.

- Adding a winter grain to a corn-soy rotation makes the field environment unfavorable to velvetleaf, turning it from an aggressive competitor to a weak, disease-prone plant with stunted roots.
- Planting Austrian winter pea with rye stimulates rye growth by providing N, creating a heavier, more weed-suppressive roll-crimped cover for organic no-till soybean. No-till planting the rye + peas into sorghum-sudan stubble (after forage harvest) protects the winter crops from wind desiccation and winterkill, thus further enhancing the stand.

Slide 44 – *Breeding crops to beat the weeds*

Crop genetics can play a substantial role in the outcome of crop-weed competition, and several plant breeding projects to develop cultivars for organic systems include weed competitiveness among their breeding objectives. Carrot breeding lines with vigorous early growth and large tops need fewer cultivations, and an ongoing farmer-participatory breeding efforts has combined weed competitiveness with resistance to the leading carrot disease (*Alternaria dauci*, leaf blight) and desired market traits including color, flavor, and nutritional value (Simon, 2021; Simon et al., 2016). Weed-tolerant and weed-competitive cultivars of rice and wheat that perform well in organic production systems have been identified (Jones et al., 2011; Zhou, 2018). In wheat, weed competitiveness is based on morphological and developmental traits (rapid early growth, tall stature, heavy tillering, etc) rather than allelopathic potential (Worthington et al., 2015).

A nationwide endeavor to develop improved and regionally adapted cover crop cultivars of hairy vetch, crimson clover, Austrian winter pea, and rye for organic producers has prioritized weed-suppressiveness as well as vigor, disease resistance, N fixation, and other traits (Mirsky, 2020; Moore, 2021). Another study of weed suppression by cover crop mixtures and single-species cover crops found that mixing multiple cultivars of a single cover crop or forage crop can improve weed competitiveness as effectively as multiple species (Drinkwater and Walter, 2017).

Slide 45 – *New and emerging technologies*

Gallandt and Brainard (2022) have set up a physical weed control website and network that is highly informative (<https://forum.physicalweedcontrol.org>).

Mallory et al. (2020) have successfully used advanced tools and robotics to enhance weed control in organic cereal grains.

Ryan et al, (2021) and Moretti et al. (2022) are conducting trials with electrical weed control in organic cereal grains and tree fruit, respectively.

Wortman (2022) is experimenting with germinating spinach and carrot in compost spread on top of a biobased, biodegradable and root-penetrable film mulch, and Gramig et al. (2022) are formulating biodegradable hydromulches for weed control in organic vegetables.

Carpenter-Boggs (2021) has combined caprylic/capric acid herbicide with precision spray technology (WEED-IT, spray applied selectively to weeds, 90% reduction in application).

<https://www.weed-it.com/>) and winter pea intercrop for no-till dryland organic production in the interior PNW.

Slide 46 – *Organic integrated weed management: a practical summary*. [subtitle slide]

Slide 47 – *Ecological weed management: prevention*

Slide 48 – *Ecological weed management: control*

Summary lists based on preceding slides

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All project summaries, progress reports, and final reports for OREI and ORG projects are available at the NIFA Gateway database, <https://nifa.usda.gov/data/data-gateway>.

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