Ecological Weed Management

Research-based Practical Guidance for the Western Region

eOrganic Soil Health and Organic Farming Webinar Series
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Presentation notes, additional information, and references to research literature on which webinar slides are based.

Slide 1 – *title slide*.

Slide 2 – *Research priorities identified by Western region organic farmers*
A total of 555 respondents from the Western region participated in OFRF's 2015 survey to identify top research priorities. Listening sessions with producers in California, Oregon, and Idaho supplemented survey responses. The full report can be downloaded at http://ofrf.org/.

Slide 3 & 4 – *The organic farmer's dilemma: how to control weeds and protect soil health.*
Since diversified crop rotation is such an important component of integrated weed and soil management, the greater flexibility in rotation design and implementation offered by no-herbicide production systems confers an important advantage for organic producers striving for both weed control and healthy soil.
Fungal networks, earthworms, and other soil macro-biota are most vulnerable to tillage and cultivation. Frequent tillage and cultivation tend to shift soil biota in favor of bacteria, and to maintain rapid mineralization of nutrients and organic matter – conditions that favor additional weed germination and growth.

Slide 5 – *Western weed research priorities*
Based on OFRF's 2015 farmer survey and 2016 National Organic Research Agenda (NORA) report.

Slide 6 – *Problem weeds for western region organic farmers*
These are some of the weeds most frequently mentioned by Western region organic producers in the OFRF survey. Field bindweed clearly emerged as the #1 priority for developing more effective, integrated management strategies, and one farmer noted that "we are losing organic farmers due to field bindweed."
Bindweed and Canada thistle are especially problematic in low-rainfall regions. They are especially tough to control because they have very deep, extensive root systems from which new plants readily arise after tillage to remove top growth; the root systems can survive NOP-allowed or conventional herbicides. In their successful 2018 proposal on management of invasive perennial weeds, a Montana State University research team noted: "Increasingly, fields are being removed from organic grain production because of a failure to prevent invasion and infestation by two game-changing weeds: Canada thistle (*Cirsium arvense*) and field bindweed (*Convolvulus arvensis*)."

Carr, P. et al., 2018. *Creep Stop: Integrating biological, cultural, and mechanical/physical tools for long term suppression of creeping perennial weeds in Northern Great Plains and Pacific Northwest cropping systems*. Proposal for OREI project 2018-02850, CRIS Abstracts.

Yellow nutsedge is most problematic in higher rainfall regions and irrigated production systems. Annual weeds like lambsquarters, foxtails, Jimsonweed, and field pennycress can build up large weed seed banks and become more troublesome in rotations with frequent tillage and cultivation.

Slide 7 – *Subheading – Weed ecology 101*

Slide 8 – *Weeds are pioneer plants that fill open niches created by disturbance*

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.

In agriculture, clean tillage to make a seedbed creates an open niche and leaves the soil prone to erosion and compaction. In crops grown in a wide row spacing, or in an orchard or vineyard kept clean by tillage or herbicides curing crop establishment, the niche remains open for an extended period of time. Weed growth is the normal result.

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 – *Cropland weeds*

Knowing what makes weeds "tick" offers clues to effective management. Cropland weeds are those pioneer plants that are adapted to repeatedly disturbed or exposed, yet fertile, soils. Their ability to rapidly take up and utilize soluble nutrients, and to reproduce prolifically within one growing season, equips them to thrive in annual cropping systems.

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.

Slide 10 – *Exotic (non-native) plants often become aggressive, invasive weeds*

Many of the most common and troublesome agricultural weeds in the Western US are not native to North America, but were brought to this continent from overseas for specific purposes (Johnsongrass as forage, lambsquarters as green vegetable) or by accident (Canada thistle, field bindweed), and became established in the weed flora. Without their natural checks and balances (e.g., herbivorous insects), some exotic plant species become invasive, not only causing crop losses but sometimes actively displacing native vegetation through multiple mechanisms.

Slides 11 – 13 – *Weeds are nature's cover crop*

These three slides consider weeds in relation to the four NRCS principles of soil health.

Weeds in their ecological role as pioneer plants are nature's cover crop. In some situations they can provide real soil health benefits, or at least prevent erosion when the farmer is unable to get the cover crop in. However, invasive exotic species like Canada thistle, field bindweed, spotted knapweed, and yellow starthistle can reduce diversity by supplanting native vegetation through competition for moisture and/or root exudates toxic to native plants and soil biota. These weeds can seriously degrade both cropland and rangeland.

In an extreme example, garlic mustard, a 3 ft tall herbaceous perennial from Europe, can slowly but surely displace New World hardwood forest by inhibiting the mycorrhizal fungi on which the trees depend. European trees and their mycorrhizal and other microbial symbionts, having co-evolved with garlic mustard over the millennia, can coexist with this herb unharmed.

Slide 14 – *Subheading - Integrated weed and soil management: getting the most weed control with the least soil damage.*

Slide 15 – *The "many little hammers" of organic weed management*

Organic weed management requires an integrated, strategic approach using multiple tactics, each of which alone would have little impact on weed populations, but together they knock the weeds back with "many little hammers." Some of the key weed management strategies (e.g. cover crops) also help restore soil and make up for the soil health costs of others (e.g. cultivation).

The Many Little Hammers concept was first advanced by Dr Eric Gallandt, weed ecologist at University of Maine, and is clearly explained by Av Singh, *Many Little Hammers: ecologically based weed management*, Canadian Organic Grower, Summer 2012, pp 10-14. https://cdn.dal.ca/content/dam/dalhousie/pdf/faculty/agriculture/oacc/en/tcog/TCOG_2012_Many_Little_Hammers.pdf.
While the details of application (crop rotation design, cultivation tools, specific tactics, etc) vary with region, the same overall approach is highly recommended for organic and trransitioning growers in the Western region, including areas challenged by severely limited rainfall.

Menalled F., C. Jones, D. Buschena, and P. Miller. 2012. *From Conventional to Organic Cropping: What to Expect During the Transition Years*. Montana State University Extension MontGuide MT200901AG Reviewed 3/12. https://store.msuextension.org/. www.msuextension.org/publications/AgandNaturalResources/MT200901AG.pdf.

Slides 16 – 18 – *Strategy 1: Get to know the weeds*

Knowing the strengths and weaknesses of a farm's most troublesome weeds is the first step toward effective prevention and control strategies.

Slide 15 - 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.

Slide 16 - Purslane is so drought tolerant that it can easily re-root after being severed or uprooted; however tall crops readily outcompete it through shading.

Slide 17 - Rhizomatous perennials like yellow nutsedge, Canada thistle, 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 19 – *Strategy 2: Pre-empt the weeds*

Since the ecological role of "weeds" (pioneer plants) is to cover, protect, and restore soil after disturbance, they will emerge and grow whenever niches – unoccupied and exposed soil –

become available. Cover crops pre-empt weeds, doing the restorative work of pioneer plants, and providing more biomass and easier management than most weeds. Similarly, close row spacing of cash crops (such as wheat and other cereal grains) or intercropping two or more cash crops, can close weed niches that occur in widely spaced crop rows.

In the high tunnel, the farmer set out quick-maturing lettuce and bok choy on either side of the bed, and slower-starting tomato in the middle. In addition to blocking early season weeds the intercrop provided early income and was harvested just as the tomatoes began to occupy the whole bed.

Field tomatoes were planted after a winter rye crop was mowed and strip-tilled. The rye will regrow slowly or gradually die back during the heat of summer, keeping weeds in check.
In the relay planting example from central Vermont (USDA hardiness zone 4), author Eliot Coleman sowed the clover between brassica rows when the latter were just getting established; after vegetable harvest, the clover is ready to grow and cover the ground.

Slide 20 – *Cover cropping for effective weed control*

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. If soil test shows low nutrient levels, a manure application just before planting can enhance early cover crop growth and act synergistically with the cover crop itself in improving soil quality.

If the soil is dry, consider irrigating the newly planted seed to ensure prompt 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. In most parts of the Western region, buckwheat planted in November or rye sown in April will not compete with weeds!

Match the cover crop with soil fertility. If soluble N and overall fertility are low, use sunnhemp, cowpea, and pearl millet in summer; vetch or winter pea with cereal grain over winter. If N is abundant use sorghum-sudangrass in summer, radish in late summer/fall, and rye or wheat over winter to take up the excess before it stimulates weed growth.

In fall plantings of cereal grain and legume, add a fast-growing species that will cover the ground quickly, then winterkill, such as buckwheat (all areas), or radish or oats (zone 7b and colder).

Slide 21 – *Strategy 3 – Keep the weeds guessing*

Varying crops, timing, and management methods can help limit weed propagation by creating less "predictable" patterns of disturbance and crop competition.

Numerous studies in different agricultural regions have shown that rotating annual crop fields into perennial sod (grass-legume, grass-legume-forbs, or "prairie mix") for two or three years can diminish annual weed problems by restricting their seed production and allowing ground beetles and other weed seed consumers to reduce the existing weed seed bank. The sod phase also helps restore tilth, organic matter, and fertility in soils that have become "tired" from intensive annual cropping and cultivation.

Several studies have shown that, in regions with moderate to high annual rainfall, a diverse perennial sod 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 22 – *Crop rotation*

The quote is from the Montana Extension Guide for transitioning organic growers (Menalled et al., 2012 – see web link under Slide 15 notes above).

Slide 23 – *Crop rotation example: diverse crops but predictable disturbance*

Organic vegetable growers often encounter intense weed pressure from summer annuals like common lambsquarters, pigweeds, common purslane, 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 cover ahead of the lima bean to reduce soil N levels and give the N-fixing lima an advantage over the weeds.

Slide 24 – *Crop rotation example: designed to disrupt weed life cycles*

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 – *Strategy 4: Grow competitive crops*

Nothing beats weeds like vigorous crops growing in healthy, living soil.

Choosing crops and varieties that rapidly cover the ground to shade-out weeds also saves soil by protecting the surface from erosion and compaction, and may increase organic matter return (heavier residues). Carrots are notoriously slow-starting and weed-prone, yet some cultivars such as 'Danvers 126' (in photo A) have larger and faster-growing tops. When planted in warm soil, sweet potato will quickly provide dense, season-long cover (photo B).

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. For example, the same sweet potato crop planted too early may become weedy and less able to thrive and yield. Ensuring sufficiently warm soil through good season extension practices can facilitate early production of warm season crops like the snap beans started under low tunnel covers (C).

Transplanting vigorous "starts" (D) gives vegetable crops a several weeks' head start on weeds and greatly reduces the need for cultivation. In addition to lettuce, brassicas, and solanaceous crops, many organic vegetable farmers now transplant cucumbers, melon, squash, and pumpkin, and some even transplant beets successfully.

Slide 26 – *Healthy soil favors crops over weeds*

Maintaining an open, crumbly topsoil structure can deter germination and emergence of some small-seeded weeds such as pigweed, which require a degree of surface compaction to provide sufficient seed-soil contact. Yellow nutsedge thrives at high soil moisture levels and tolerates compaction; thus avoiding over-irrigation and maintaining good drainage and overall soil health can reduce problems with this weed.

Slide 27 – *Strategy 5 - feed the crop, not the weeds*

Drip lines can be used to "fertigate" organic crops, using 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 weed growth *within* crop rows as well as between rows.

Raw, aged, or cool-composted manure is a notorious source of new weed seeds, and the rapid-release nutrients in some manures can further stimulate weed growth. Hot-composting manure and other organic residues with adequate turning and aeration, so that all parts of the windrow reach 140 F for at least 3-7 days, will kill most weed seeds as well as plant and human pathogens.

However, even finished compost can promote emergence and growth of weed seeds already present in the soil, if the compost has a high nutrient analysis and is applied at rates greater than crop needs.

Slide 28 – *Managing nutrients to favor crops*

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. In these trials, high poultry litter compost 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 compost.

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 mycorhizal 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 crops is roll-crimped.

Clark, K. 2016. *Organic weed management systems for Missouri.* Proposal and progress report on OREI project 2014-05341. CRIS Abstracts.*

Cornell University, 2005. *Organic Cropping Systems Project: Compost Experiment*. Protocol at http://www.hort.cornell.edu/extension/organic/ocs/compost/index.html. Results summary at http://www.hort.cornell.edu/extension/organic/ocs/compost/pdfs/20042005results.pdf.

Little, N., C. Mohler, A. DiTommaso, and Q. Ketterings. *Partitioning the Effects of Nutrients from CompostedManure on Weeds and Crops: A Step Toward Integrated Crop-Weed Management*. In Northeast Organic Farming Association of New York, 2012, *Northeast Organic Research Symposium Proceedings*, pp 46-47.

Mohler, C, T. Bjorkman, and A. DiTommaso. 2008. *Control of weed size by compost application rate in an organic cropping system.* Weed Science Society of America 2008 Proceedings, Presentation No. 261.

Slide 29 – *Strategy 6 – Cultivate strategically*

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. Advanced cultivation systems that integrate two or more tool types (sweeps, rolling baskets, tine, finger, or torsion weeders) designed to remove both within-row and between-row weeds are widely used in Europe and are undergoing evaluation in the US.

Rangarajan, A., M. T. McGrath, D, Brainard, Z. I. Szendrei, M. Hutton, E. Gallandt, M. Hutchinson, and B. J. Rickard. 2017. *Farmer Designed Systems to Reduce Tillage in Organic Vegetables.* Proposal and progress report for OREI project 2014-05381. CRIS Abstracts.*

Video clips of innovative cultivation tools and techniques are available at the eXtension organic weed management web page, https://articles.extension.org/pages/61887/weed-management-topics.

Slide 30 – *Strategy 7: Use alternatives to cultivation when practical*

With the exception of roll-crimped cover crop mulch and grazing after cash crop harvest to manage late season weeds, these strategies are generally most applicable in smaller scale horticultural cropping systems.

Mulch can include applied organic mulches (straw, hay, tree leaves, etc), plastic film mulch, paper mulches, weed mat or landscape fabric, or roll-crimped or winter killed cover crops.

Hot water and steam weeders are safer than flame in crops growing in organic mulch, roll-crimped covers, or other dry residues, and have given promising results in several studies.

Covering a recently roll-crimped or mowed cover crop with clear plastic for a few hot summer days (solarization) can ensure cover crop termination and enhance weed suppression. Laying weed mat or black plastic tarps for 2 – 4 weeks after mowing or roll-crimping cover crops (occultation) ensures cover crop termination and extends the period of effective weed suppression, giving good yields in subsequent no-till planted organic vegetables. Details on this method are available from Brust, 2014: Organic Weed control in No-till Systems (https://extension.umd.edu/sites/default/files/_docs/articles/OrganicWeedControlUsingNo-till_3-2014_0.pdf)

Efficacy of NOP allowed herbicides is limited; they should be considered a "very small hammer." Yet they may play a role in integrated strategies by delaying weed or cover crop regrowth. In addition, they are less likely to adversely impact soil biology and soil health than synthetic herbicides.

Slide 31 – *Challenge #1: the weed seed bank*

Despite good integrated weed management, it can be surprisingly difficult to reduce weed pressure in organic production. If a large weed seed bank exists, even shallow cultivation can stimulate a heavy new flux of weeds to emerge, necessitating more cultivation. A single lambsquarters "escape" allowed to mature can deposit over 50,000 viable seeds, and a large pigweed plant can shed 100,000 to 500,000. Thus, it is important to remove large weeds as soon as flower buds appear – weeds that are cut or uprooted when their first flowers are open can often set mature seed before they die.

In response to the widely observed phenomenon of steady or increasing weed seed populations in organic fields despite the diligent use of cover crops and crop rotations as well as cultivation, weed ecologists Eric Gallandt and Daniel Brainard have launched a new OREI funded research project to integrate advanced cultivation tools and best weed seed bank management to reduce weed populations: OREI 2018-02869, *Integrating advanced cultural and mechanical strategies for improved weed management in organic vegetables.* CRIS Abstracts.*

Slide 32 – *Challenge #2: Creeping perennial weeds*

Creeping perennial weeds like yellow nutsedge (whose emerging shoots can penetrate black plastic mulch), Canada thistle, and bindweed pose the most challenging tradeoffs for soil health and weed control. Repeated tillage whenever the emerging shoots have three leaves can gradually exhaust underground reserves, but also consumes soil organic matter and risks erosion.

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 33 – *Strategy 8: Bait the weeds with 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 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 begin rebuilding soil health after weed control.

Slide 34 – *Strategy 9: Let the cleanup crew do its job*

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, T, Masiunas, J. B.; Brainard, D.; Bornt, C. D.; Hadad, R. G.; Kikkert, J. R.; Gloy, B.. 2014. *Summer cover crops for weed suppression and soil quality.* Final report on OREI project 2009-01311. CRIS Abstracts.*

Gallandt, E., 2012. *Cultivation and Seedbank Management for Improved Weed Control Webinar* http://articles.extension.org/pages/62445/cultivation-and-seedbank-management-for-improvedweed-control-webinar.

Gibson, K. D., C. Alexander, J. Beckerman, S. G. Hallett, I. Kaplan,L. Hoagland, E. Kladivko, M. Marshall, and C. Sadof. 2015. *Ecology, Economics, and Education: an Integrated Approach to Ensure the Success of Organic Vegetable Growers.* Final report on OREI project 2010-01913. CRIS Abstracts.*

Reberg-Horton, C. 2012. *Organic Weed Management in Organic Grain Cropping Systems*, in Carolina Organic Commodities and Livestock Conference 2012: Selected Live Broadcasts. https://articles.extension.org/pages/61970/carolina-organic-commodities-and-livestock-conference-2012:-selected-live-broadcasts.

Slides 35 & 36 – *Strategy #10: turn weeds into organic meat, dairy, and eggs.*

Slide 35: While mechanical harvest and removal of cover crops, corn stover, and other crop residues can severely compromise soil health, grazing has much less negative impact, and can help prevent weed seed set after crop harvest or from a weedy cover crop. Grazing can also make the perennial sod phase of a crop rotation pay for itself in farm income as well as weed management.

Blanco-Canqui, H., A. L. Stalker, R. Rasby, T. M. Shaver, M. E. Drewnoski, S. van Donk, and L. Kibet. 2016a. *Does Cattle Grazing and Baling of Corn Residue Increase Water Erosion?* Soil Sci. Soc. Am. J. 80 (1): 168-177.

Blanco-Canqui, H., J. Tatarko, A. L. Stalker, T. M.Shaver, and S. J. van Donk. 2016b. *Impacts of Corn Residue Grazing and Baling on Wind Erosion Potential in a Semiarid Environment*. Soil Sci. Soc. Am. J. 80(4): 1027-1037.

Franzluebbers, A. J., and J. A. Stuedemann. 2015. *Does grazing of cover crops impact biologically active soil carbon and nitrogen fractions under inversion or no tillage management?* J. Soil & Water Conserv. 70(6): 365-373.

Slide 36: Management intensive rotational grazing (aka holistic management, mob grazing, adaptive multipaddock grazing) minimizes selective grazing that allows the least-palatable species to become pasture weeds. Brief (1 – 2 days) intense grazing followed by sufficient rest and regrowth (1 -2 months) encourages a vigorous, diverse forage plant community that builds soil organic matter (1 – 3 tons/ac annually) and does not allow unpalatable or invasive species to become dominant. Without rotational management, the same stocking density will lead to declining soil health and a degraded pasture dominated by unpalatable or potentially toxic pasture weeds such as star thistle (*Centaurea solstitialis*), spotted knapweed (*C. maculosa*), spiny amaranth (*Amaranthus spinosus*), and Klamath weed (*Hypericum perforatum*).

Teague, R. 2016-17. *Regeneration of soil by multi-paddock grazing.* Transcript of Sept 7, 2016 presentation at Harvard by Jack Kittredge. The Natural Farmer, winter 2016-17: B26-B30.

Teague, W.R., 2018. Forages and pastures symposium: cover crops in livestock production: whole-system approach: Managing grazing to restore soil health and farm livelihoods. Journal of Animal Science 96, 1519–1530.

Slide 37 – *Subheading: soil health and weed management in the West: challenges, opportunities, and strategies*

Slide 38 – *Weed management challenges in organic grain rotations in the Northern Great Plains*

In semiarid regions, farmers must simultaneously manage moisture, fertility, and weeds to maintain viable crop production; and must design crop rotations that meet all three objectives. While cover crops generally help with weed suppression, dryland farmers must limit soil moisture use by *both* weeds and cover crops throughout the rotation so that sufficient moisture remains for production crops.

Droughts are expected to become more intense as a result of climate change. Although half of the season's rainfall in Montana comes during May through August, summer heat and moisture consumption by crops and weeds often leads to "terminal drought" by the time crops set grain, which limits yields.

Invasive "creeping" perennial weeds, especially field bindweed and Canada thistle, can be "game-stoppers" in organic dryland grain production.

The fragile nature of arid and semiarid region soils and the high risks of erosion (especially wind erosion) requires special care in the use of tillage and cultivation for weed control, cover crop termination, and seedbed preparation.

Soil health building practices such as high biomass cover crops and organic rotational no-till may entail severe yield tradeoffs, as the cash crop gets caught in the "vise" of aggressive perennial weeds and scarce moisture.

Slide 39 – *Organic weed management strategies for the Northern Great Plains*

Most of the organic weed management strategies discussed earlier play equally vital roles in semiarid regions. Menalled et al. consider crop rotations designed to "keep weed communities off balance" as "the core of organic weed management." Cultivar selection (tall, rapid earlly growth, high tiller number and leaf area) and management (closer row spacing, optimum planting date and fertility) for crop competitiveness toward weeds is also vital.

Without herbicides, the traditional wheat-fallow rotation hurts weed control as well as soil health in organic systems. In Montana State U trials, winter wheat itself or safflower (a summer oilseed crop) halted bindweed spread, while bindweed numbers increased 10-fold during tilled fallow.

When applied organic sources of N or other nutrients are needed, placement and timing should feed the crop, not the weeds. In addition to common lambsquarters, wild oat is a "N-responder" and reduces wheat yields more severely at higher N application rates.

A meta-analysis of research into organic bindweed and thistle control found mechanical cultivation alone insufficient, and indicated need for an integrated approach including biocontrol, mowing, grazing, crop diversification, solarization, shading, flaming, and/or crop competition in addition to cultivation..

While perennial forages have an excellent track record for replenishing soil fertility and reducing annual weed seed banks during the organic transition period or as a "sod break" in an intensive annual crop rotation, this practice can pose major risks in semiarid regions. Experience in Montana indicates that forages such as alfalfa and deep rooted perennial grasses can deplete moisture throughout the soil profile so severely that subsequent crop yields may be reduced for several years. Nutrient depletion occurs if forage is harvested and removed; however grazing or on-farm feeding with manure return would cycle nutrients and minimize depletion.

Montana State U scientists report that, when sod is broken to rotate back into cereal grain or other annual crops, a severe infestation of perennial and annual weeds often follows, exacerbating water limitations on crop production.

Information in slides 32 and 33 based on:

Lehnhoff, E., Z. Miller, P. Miller, S. Johnson, T. Scott, P. Hatfield, and F. D. Menalled. 2017. *Organic Agriculture and the Quest for the Holy Grail in Water-Limited Ecosystems: Managing Weeds and Reducing Tillage Intensity*. A review article in *Agriculture* 2017, 7, 33; doi:10.3390/agriculture7040033 www.mdpi.com/journal/agriculture.

Menalled et al., 2012. *From Conventional to Organic Cropping: What to Expect During the Transition Years*. (See slide 15 above).

Integrated Strategies for Managing Agricultural Weeds: Making Cropping Systems Less Susceptible to Weed Colonization and Establishment (MT200601AG). http://msuextension.org/publications/AgandNaturalResources/MT200601AG.pdf.

Weed Seedbank Dynamics & Integrated Management of Agricultural Weeds (MT200808AG). http://msuextension.org/publications/AgandNaturalResources/MT200808AG.pdf.

Orloff, N., J. Mangold, Z. Miller, and F. Menalled. 2018. A meta-analysis of field bindweed (Convolvulus arvensis L.) and Canada thistle (Cirsium arvense L.) management in organic agricultural systems. Agriculture, Ecosystems and Environment 254: 264-272.

Menalled, F. *Assessing the resiliency of integrated crop-livestock organic systems under current and predicted climate*. Proposal and progress reports through 2018 for ORG project 2015-06281. CRIS Abstracts.

Slide 40 – *Creep Stop: a 2018 OREI Award*

Annual rainfall in the Northern Great Plains and interior Pacific Northwest is similar; however, summer moisture limitation may be even 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. Thus, studies spanning both regions can yield important new insight.

Carr, P.; Menalled, FA, .; Miller, PE, .; Gaskin, JO, F..; Gramig, GR, G..; Burke, IA, CR.; Bekkerman, AN, .; Grimberg, BR, IR.; Seipel, TI, .; Fuller, KA, BI.; Glunk, EM, .; Miller, ZA, .; Formiga, AL, .; Murphy, TH, WA.; Eberly, JE, .; Estrada, HE. 2018. *Creep Stop: Integrating biological, cultural, and mechanical/physical tools for long term suppression of creeping perennial weeds in Northern Great Plains and Pacific Northwest cropping systems* OREI project 2018-02850, CRIS Abstracts.

Slide 41 – *Biocontrol and IPM for field bindweed in perennial horticultural crops*

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.

A 2017 OREI award is funding a new organic IPM study on managing field bindweed in these crops, with emphasis on the field bindweed moth, described as a “voracious herbivore specific to bindweed.” Farmer participants have worked with researchers to estimate the impacts of organic pesticide use (spinosad, Bt) on the moth, and to develop integrated bindweed control strategies to test.

Steam treatments with the boiler set at 250 F and the tractor forward speed at 0.25 mph gave the best knockdown control of bindweed. The researchers have also ruled out benzaldehyde, a volatile compound from bindweed, as an attractant for the moth, and are seeking other leads.

Peachey, R. E., C. A. Mallory-Smith, Y. E. Choi, and M. A. Moretti. 2018. *Harnessing the voracity of the biocontrol Tyta luctuosa to improve management of field bindweed during transition to organic and beyond.* Proposal and progress report for ORG project 2017-03399. CRIS Abstracts.

Slide 42 – *Organic IPM for Canada thistle*

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 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.

In this project, the 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.

Bean, D. W. 2018. *Developing biological control of Canada thistle for Colorado's organic producers using the host-specific rust fungus Puccinia punctiformis.* Proposal for OREI project 2018-02845. CRIS Abstracts.

Slide 43 – *Tackling Canada thistle: hints from outside the Western region.*

In Illinois, a sudangrass cover crop was planted in a Canada thistle infested field, mowed when it was several feet tall and thistle has 7-10 leaves, and allowed to regrow. The cover crop regrowth further suppressed the thistle, and reduced its numbers by 98% in the following year's soybean crop. Combining a sorghum-sudan cover crop with the rust fungus might yield a winning organic strategy against Canada thistle.

Studies in Minnesota and Iowa showed that adding a year of two of alfalfa, harvested for forage, to organic reduced-till grain rotations, also considerably reduced Canada thistle. This strategy may be applicable in higher-rainfall parts of the Western region.

Bicksler, A., and J. Masiunas. 2008. *Management of Canada Thistle with Summer Annual Cover Crops and Mowing*. In Padgham, J. 2008. *Midwest Organic Research Symposium, Feb 21-23, 2008, Research Summaries*, p. 58.

Cardina, J., J. Felix, D. Doohan, D. Stinner, D, and M. Batte. 2011. *Transition Strategies that Control Perennial Weeds and Build Soil.* Final report on OREI project 2006-02014. CRIS Abstracts.*

Sheaffer, C. C., P. Nickel, D. L. Wyse, and D. L. Allan. 2007. *Integrated Weed and Soil Management Options for Organic Cropping Systems in Minnesota.* Final report for ORG project 2002-03806. CRIS Abstracts.*

Slides 44 and 45 – *Crop-livestock integration for organic management of perennial weeds*

Poultry (30 birds per 10 by 10 ft chicken tractor) were grazed on winter cover crops for one day (removing most of aboveground growth), and again after 14 days regrowth (during which the cover attained 8-12 inches). Compared to ungrazed control, weed biomass was similar, but weed seed set was far less, spring cover crop was doubled, and yields of subsequent winter squash and sweet corn were increased.

In a five year rotation of safflower underseeded with bienial sweetclover green manure, winter wheat, lentil, and winter wheat, sheep were used to terminate the sweetclover by grazing in lieu of tillage. Compared to the tilled organic system, the grazed system had higher and increasing weed populations, and 50% yield reductions in wheat and lentil in wet season when sheep compacted the soil, and 20-30% reduction in normal season (no compaction)

Menalled, F. ORG 2015-06281 – Assessing the resiliency of integrated crop-livestock organic systems under current and predicted climate. Proposal and progress reports through 2018. CRIS Abstracts.*

Lehnhoff, E., Z. Miller, P. Miller, S. Johnson, T. Scott, P. Hatfield, and F. D. Menalled. 2017. *Organic Agriculture and the Quest for the Holy Grail in Water-Limited Ecosystems: Managing Weeds and Reducing Tillage Intensity*. A review article in Agriculture 2017, 7, 33; doi:10.3390/agriculture7040033 www.mdpi.com/journal/agriculture.

Slide 46 – *Suggested improvements to the rotation and crop-livestock system*

Producers working with the Montana State University team helped develop some recommendations for an improved crop rotation for the next phase of this research. (Lehnhoff et al., 2017). The changes included mustard in lieu of safflower in year one (more weed competitive), foxtail millet overseeded into sweetclover (reduced compaction by sheep), a flax-chickpea intercrop in lieu of lentil in year 4 (more weed competitive), and spring Khorasan wheat in lieu of winter wheat in year 5.

Doug and Anna Crabtree of Vilicus Farms in Havre, MT (https://www.vilicusfarms.com/), have developed a highly diversified cropping system that includes 15 species of production crops and 10 species of cover crop. They sometimes intercrop two species of production crop or relay-plant cover into cash crop. They use the blade plow, or sweep plow undercutter, to terminate cover crops. By cutting just below the soil surface, this implement leaves most of the cover crop top growth on the surface and most of its root mass undisturbed in the soil profile, yet terminates cover crop growth and knocks out any weeds present. As a result, the soil surface is protected from erosion, moisture is conserved, and soil organic matter and soil life benefit from the root mass.

Slide 47 – *Orchards and vineyards: managing weeds during tree/vine establishment*

The practice of keeping orchard or vineyard floor "clean" with repeated herbicide application or tillage severely degrades soil health. Studies in European olive orchards showed twice as much soil organic matter under living cover (either perennial sod or series of annual covers) than in herbicide or tilled bare fallow.

Living mulch growing too close to the crop can compete for moisture and nutrients, especially during the early establishment years. Research in Oregon and Washington showed that using weed mat (landscape fabric) during the establishment phase generally gave better weed control and crop growth than organic mulch or living mulch, and better soil health than bare fallow.

Once trees or vines are established, a permanent legume or grass-legume sod cover, maintained by mowing, can be established; "mow and blow" can provide additional organic N to fruit crop.

Lorenz, K., and R. Lal. 2016. Environmental Impact of Organic Agriculture. Advances in Agronomy 139: 99-152.

Strik, B., D. Bryla, D. Sullivan, and C. Seavert. 2011. Integrated Weed Management and Fertility in Organic Highbush Blueberry Production Systems to Optimize Plant Growth, Yield, and Grower Return. Final report for OREI project 2008-01237. CRIS Abstracts.*

Strik, B., D. Bryla, and D. Sullivan. 2015. Organic Blueberry Production Research Project. http://articles.extension.org/pages/31680/organic-blueberry-production-research-project.

Strik, B., D. Bryla, and L. Valenzuela. 2014. Organic Blackberry Production: Tips Learned from an Ongoing Research Study. http://articles.extension.org/pages/70279/organic-blackberry-production:-tips-learnedfrom-an-ongoing-research-study.

Ingalls, C. 2012. Effects of Weed and Nutrient Management Practices in Organic Pear Orchards. Presentation at 2012 International Organic Fruit Symposium; recording at: http://www.extension.org/pages/64359/2ndinternational-organic-fruit-research-symposium.

Reeve, J. 2012. Organic and Integrated Orchard Floor Management. Presentation at 2012 International Organic Fruit Symposium; recording at: http://www.extension.org/pages/64359/2nd-international-organicfruit-research-symposium.

Rowley, M., B. Black, and G. Cardon, 2012. Alternative Orchard Floor Management Strategies Utah State University Extension bulletin Horticulture/Fruit/2012-01pr (4 pp). https://extension.usu.edu/productionhort/htm/organic/organic-stone-fruit-production.

* For project proposal summaries, progress and final reports for USDA funded Organic Research and ExtensionInitiative (OREI) and Organic Transitions (ORG) projects, enter proposal number under “Grant No” and click “Search” on the CRIS Assisted Search Page at: http://cris.nifa.usda.gov/cgi-bin/starfinder/0?path=crisassist.txt&id=anon&pass=&OK=OK.