# Practical Conservation Tillage for Western Region Organic Cropping Systems

*Research-based Practical Guidance for Organic and Transitioning Farmers*

eOrganic Soil Health and Organic Farming Webinar Series
January 23, 2019
Developed and presented by Organic Farming Research Foundation, with funding from Western SARE

*Presentation notes, additional information, and references to research literature on which webinar slides are based.*

Slide 1 – *title slide*.

Slide 2 – *2015 OFRF farmer survey results*

A total of 555 respondents from the Western region participated in OFRF's 2015 nationwide survey of organic farmers to identify top research priorities. In addition, six listening sessions took place in the West (four in CA, two in OR).

Healthy, living soil is the foundation of successful organic farming; thus soil health emerged as the #1 research priority among respondents in the OFRF survey in all four USDA regions. Many survey participants wanted research to explore tillage effects on various aspects of soil health, and strategies for minimizing adverse impacts while maintaining sufficient weed control.

Slide 3 – *How tillage affects soil health*

Severity of tillage impacts on soil erosion, compaction, SOM, and overall soil health depend on:

- Tillage tools used
- Soil conditions at time of tillage, especially moisture level (too wet – compaction; too dry – erosion of pulverized soil)
- Weather conditions during tillage and subsequent bare soil period – wind speeds, temperature, amount and intensity of rainfall.
- Existing soil health and recent management history.

Slide 4 – *How tillage affects on soil biology*

Tillage alters soil biotic community function in several ways. Tillage stimulates the activity of certain organisms, especially bacteria, that mineralize (release) nitrogen and other nutrients from organic matter, but it can also disrupt beneficial fungal networks and kill off earthworms and other macroscopic organisms that play important roles in recycling fresh residues and maintaining soil structure, permeability, and drainage.

Any operation that removes or terminates living plant cover temporarily interrupts the flow of root exudates and turnover of fine roots ("rhizodepisiton"), which is a primary source of food for many components of the soil biota or soil food web. In effect, these organisms "go hungry" until living plant roots are re-established.

Finally, inversion tillage "turns the house upside down", destroying habitat for larger organisms and moving parts of the surface biota into a subsurface region with potentially lower oxygen levels.

In a meta-analysis of 62 studies comparing tilled and no-till systems, tillage tended to reduce soil microbial biomass and to increase the amount of respiratory CO2 released per unit biomass, indicating that the soil disturbance increased maintenance respiration relative to microbial growth, an indication of stress on the soil food web. However, sustainable organic soil management (which may include some tillage) can enhance both microbial biomass, and microbial activity measured as respiration

Zuber S. M., and M. B. Villamil. 2016. *Meta-analysis approach to assess effect of tillage on microbial biomass and enzyme activities.* Soil Biol Biochem. 97:176-187.

Lori, M., S. Symnaczik, P. MaEder, G. De Deyn, A. Gattinger. 2017. *Organic farming enhances soil microbial abundance and activity – A meta-analysis and meta-regression*. PLOS ONE **|** https://doi.org/10.1371/journal.pone.0180442 July 12, 2017, 25 pp.

Slide 5 – *The organic farmers dilemma: tillage, weeds, and soil health*

*(Slide quotes NOP rule regarding tillage)*

With the mounting evidence of the soil health costs of tillage, this clause in the USDA Organic Standards is almost paradoxical, yet appropriate, since continuous no-till is generally not feasible for farm-scale organic production of annual crops. Any multi-acre annual cropping system that uses no herbicides must rely to some degree on tillage and cultivation to manage weeds and cover crops.

The "organic farmers' dilemma" of how to manage weeds effectively and build soil health at the same time has emerged as a leading concern for organic producers and researchers in the Western region, across the US, and around the world.

Slide 6 – *NRCS Principles of Soil Health*

USDA Natural Resources Conservation Service (NRCS) has developed four principles of soil health management.

Reducing tillage is one key component of best soil management – but it is not the whole story.

Conventional no-till alone addresses only physical disturbance and, to a limited degree, soil coverage (cash crop residues).

Conservation agriculture is an integrated strategy of diversified, tight rotations, high biomass cover crops, organic amendments, continuous no till / minimum till, with some use of synthetics as needed. This approach addresses all four principles, essentially eliminating *physical* disturbances and allowing some *chemical* disturbance through limited, judicious use of synthetic herbicides and fertilizers as needed.

Sustainable, organic agriculture also addresses all four soil health principles, eliminating disturbance from NOP-prohibited synthetic chemicals, and striving to limit the negative soil health effects of tillage and cultivation, as outlined in the USDA standards cited above.

*The Soil Health principles, based on the work of NRCS Soil Health Teams, are elaborated at* https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

Slide 7 – *Putting no-till into perspective*

Continuous no-till adds about 900 lb SOM per acre annually for about 10-15 years, after which SOM levels off. Much of this SOM is accrued near the surface in a physically-protected form within soil aggregates. Most no-till row crop and grain farmers must till once every few years to manage perennial weeds, which reverses much of the surface SOM gain.

Diversified crop rotations with deep rooted crops build SOM more gradually, but over a longer period of time. Much of this SOM is either tightly adsorbed to silt and clay soil particles, or stored deeper in the soil profile, and is less vulnerable to the effects of occasional tillage.

Several studies have shown similar or greater total SOM gains from integrated organic systems with diversified crop rotations including a perennial sod phase and some routine tillage, compared with continuous no-till systems receiving conventional inputs. For example, in USDA Beltsville, MD trials, diversified organic rotations with cover crops, poultry litter (0.7 – 1.3 tons/ac-yr), and routine tillage were compared with continuous no-till corn-soy with conventional inputs. SOM was measured from surface to 39 inches. The organic rotations accrued 6.7 tons SOM/ac in 13 years, while conventional no-till accrued 2.4 tons /ac.

Other studies have shown that continuous no-till cannot reverse the declines in SOM and soil health that result from the traditional two-year wheat-fallow rotation in semiarid regions such as Montana and the Dakotas. In contrast, adding a cover or cash crop from a different plant family (legume or oilseed) in the fallow year stabilizes or improves SOM, especially in no-till.

West, T.O., and W.M. Post. 2002. *Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis*. Soil Sci. Soc. Am. J. 66(6): 1930–1946.

Kane, D. 2015. *Carbon sequestration potential on agricultural lands: a review of current science and available practices*. Breakthrough Strategies and Solutions and National Sustainable Agriculture Coalition. http://sustainableagriculture.net.publications. 35 pp.

Grandy, A.S., G.P. Robertson, and K.D. Thelen. 2006. *Do Productivity and Environmental Tradeoffs Justify Periodically Cultivating No-till Cropping Systems?* Agron. J. 98(6): 1377-1383.

Syswerda, S.P., A.T. Corbin, D.L. Mokma, A.N. Kravchenko, and G.P. Robertson. 2011. *Agricultural Management and Soil Carbon Storage in Surface vs. Deep Layers*. Soil Sci. Soc. Am. J. 75(1): 92 – 101.

Wander, M. M., C. Ugarte, E. Zaborski, and E. Phillips. 2014. *Organic systems and climate change*. Proposal and final report for ORG project 2010-03954. CRIS Abstracts.*

Cavigelli, M. A., J. R. Teasdale, and J. T. Spargo. 2013. *Increasing Crop Rotation Diversity Improves Agronomic, Economic, and Environmental Performance of Organic Grain Cropping Systems at the USDA-ARS Beltsville Farming Systems Project*. Crop Management 12(1) Symposium Proceedings: USDA Organic Farming Systems Research Conference. https://dl.sciencesocieties.org/publications/cm/tocs/12/1.

Engel, R. E., P. R. Miller, B. G. McConkey, and R. Wallander. 2017. *Soil Organic Carbon Changes to Increasing Cropping Intensity and No-Till in a Semiarid Climate*. Soil Sci. Soc. Am. J. 81 (2): 404-413.

Halvorson, A.D., B.J. Wienhold, and A.L. Black. 2002. *Tillage, nitrogen, and cropping system effects on soil carbon sequestration*. Soil Sci. Soc. Am. J. 66(3): 906–912.

Slide 8 – *Cover crops and bio-tillage*

In addition to improving and maintaining topsoil tilth through abundant root exudates, cover crops can penetrate subsurface hardpan, improving moisture infiltration and allowing deeper root development and improved moisture and nutrient uptake efficiency in subsequent cash crops.

Radish and other deep rooted cover crops provide some of the benefits of tillage without the drawbacks.

Delate, K., C. Cambardella, C. Chase, and R. Turnbull. 2015. *A review of long term organic comparison trials in the US*. Sustainable Agricultural Research 4(3): 5-14.

Marshall, M.W., P. Williams, A. Mirzakhani Nafchi, J. M. Maja, J. Payero, J. Mueller, and A. Khalilian. 2016. *Influence of Tillage and Deep Rooted Cool Season Cover Crops on Soil Properties, Pests, and Yield Responses in Cotton*. Open Journal of Soil Science , 6, 149-158. http://dx.doi.org/10.4236/ojss.2016.610015

Gruver, J., R. R. Weil, C. White, and Y. Lawley. 2016. *Radishes A New Cover Crop for Organic Farming Systems*. http://articles.extension.org/pages/64400/radishes-a-new-cover-crop-for-organic-farming-systems.

Slide 9 – *Perennial sod phase in the rotation*

Many studies have shown multiple benefits of integrating a perennial sod break (one to three years) into annual vegetable or row crop rotations. In addition to reducing average intensity of tillage over the entire rotation, the sod provides an extended period without disturbance and feeds soil life with continuous rhizodeposition (exudates from living roots and sloughing of fine roots), restores tilth and fertility, and provides habitat for weed seed consumers while disrupting the life cycle of annual weeds. All of these benefits can reduce the amount of tillage and cultivation needed during annual crop production.

However, in drier regions such as Montana, integrating a perennial sod such as alfalfa into dryland grain rotations can deplete soil moisture so severely that subsequent grain yields are reduced for more than one season. In addition, intense weed infestation can follow when the sod is broken for annual crop production.

Deep-rooted annual cover crops also need to be chosen carefully for semiarid regions: pearl millet, cowpea, and barley are light users of soil moisture, while radish, sunflower, and rye are heavy users, and sorghum-sudangrass and sweetclover are intermediate in moisture demands.

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/.

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

USDA, Agriculture Research Service (ARS), 2018. Cover Crop Chart, V 3.0. Northern Great Plains Research Laboratory at Mandan, ND. 74 pp. 1. https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/docs/cover-crop-chart/

Slide 10 – *organic reduced-till strategies*

The simplest way to reduce tillage is to till less often when practical. Each pass through the field disturbs the soil to a greater or lesser degree; thus, simply reducing the number of passes mitigates adverse impacts on soil health.

Field preparation for direct seeding often entails at least two passes – “primary” and “secondary” tillage. However, some of the newer implements, such as rotary spader or rotary harrow, can make an adequate seedbed in a single pass, at least for larger seeds or propagules such as corn, beans, or potatoes, as well as for transplanting vigorous starts.

Ecologically based organic weed management that integrates multiple tactics can lessen the need for cultivation. For example, organic mulch applied on vegetables after crop establishment can eliminate one or more cultivations and add organic matter. Plastic mulch or weed mat can eliminate all post-plant cultivation, though they do not add organic matter or feed the soil life.

In addition, different tillage tools and methods cause different degrees of disturbance. NRCS has established a "soil tillage intensity rating" for each implement and method; examples include 100 for moldboard plowing, 45 for chisel plowing, and 20 for a light finishing disk.

Shallow tillage leaves most of the soil profile intact and undisturbed. Implements include rotary harrow, rototiller set to work to <4 inch depth, and, for cover crop termination, the blade plow or sweep plow undercutter.

Non-inversion primary tillage implements include chisel plow, spading machine, and, at garden scale, the broadfork.

The most advanced level of organic conservation tillage is rotational no till, which enhances soil health but can be challenging to manage to ensure economically viable crop yields, especially in colder or drier regions.

Strip tillage, zone tillage, and ridge tillage restrict soil disturbance to the crop row, where weed-free conditions and faster N mineralization are desired early in crop establishment. Between-row areas are left undisturbed.

Some of the strategies and practices discussed here may entail investing in new equipment. However, in lieu of capital outlay for new equipment, farmers can often adjust current tillage tools and practices to reduce soil disturbance. For example, a walk-behind rototiller can be used to work up crop rows rather than the entire field; or a tractor-drawn rototiller can be retooled to work up strips rather than the entire field, or geared-down to lessen soil pulverization.

Slide 11 – *is tillage really needed now?*

When planning tillage, always keep your goal in mind. Do you need a fine seedbed? Or are you planting potatoes or transplanting vigorous starts that will do fine with coarser tilth and some surface residue? Are you aiming to loosen up compaction, work in a cover crop, or remove small or larger weeds? Do you need to till at all right now?

Leaving crop residues undisturbed through winter until a couple weeks before planting benefits soil health, reduces weed seed populations left by the previous season's weeds, and can improve yield of the following crop. In addition, as these coarse residues undergo weathering, they may become easier to work in with shallower and less intensive tillage.

Residues can slow warming and drying of the soil; in situations where this could cause delays or problems in spring planting, fall tillage may be needed. Keep in mind, however, that fall tillage increases risks of erosion losses and nutrient leaching, and may stimulate a heavy growth of winter weeds.

Slide 12 – *Managing invasive weeds with less tillage*

Organic integrated weed management can help producers reduce the amount of tillage and cultivation needed. In the Western region, Canada thistle and field bindweed pose severe problems, both in grain and horticultural crops (as well as rangeland), and may require repeated intensive tillage to reduce heavy infestations. However, a recent meta-analysis showed that integrated, multi-tactic approaches outperform mechanical control by itself, and ongoing studies are exploring promising biocontrols and integrated strategies that reduce the intensity and frequency of tillage needed.

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.

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.

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.

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 13 – *taming the rototiller*.

The rototiller is perhaps the most widely used tillage implement in vegetable production, and it is known for pulverizing the soil and creating a subsurface tillage pan when used repeatedly to the same depth. However, simple adjustments can make this implement far more soil friendly.

Charlie Maloney of Dayspring Farm in the coastal plain of Virginia set his rototiller to work just one inch deep immediately after broadcasting cover crop seeds, taking out tiny weeds and planting the seeds in one pass.

Rick Felker of Mattawoman Creek Farm on the Eastern Shore of Virginia sets the rototiller PTO on a lower rotary speed and increases tractor forward speed to 2.5 mph (most farmers in the region rototill at 1 mph), to avoid pulverizing soil aggregates when preparing beds for transplanting. Combined with a high biomass winter cover crop that is mowed and incorporated with a bed shaper (gentle tillage), this modified approach to rotary tillage allows the farm's loamy-sand soil to develop and maintain visible crumb structure.

Although these examples are from outside the Western region, the simple techniques can be applied in almost any region and soil.

Slide 14 – *shallow tillage*

Often, a shallow tillage can meet weed control or soil preparation needs while leaving the deeper parts of the soil profile intact, thereby avoiding subsurface compaction and reducing harm to earthworms and other soil life. Several conventional tools (light disk, field cultivator, springtooth harrow, rototiller) can be adjusted to till shallowly (<4 inches); the challenge is to avoid pulverizing surface aggregates, which can lead to crusting or erosion. Newer tools such as the power harrow have been designed specifically to till the soil shallowly and conserve aggregates.

Meta-analyses of multiple studies indicate that shallow tillage has less negative impacts on soil life and soil health than deep inversion tillage (moldboard plow or heavy disk), and that shallow tillage in conjunction with organic practices can enhance SOM.

In a long term (21 yr) trial in Germany, "minimum tillage" (3 inches) and organic practices together improved SOM and microbial biomass more than either practice alone.

Cooper J., M. Baranski, G. Stewart, M. Nobel-de Lang, P. Bàrberi, A. Flieûbach, et al. 2016. *Shallow non-inversion tillage in organic farming maintains crop yields and increases soil C stocks: a meta-analysis*. Agron Sustain Dev. 2016; 36(1).

Zuber S. M., and M. B. Villamil. 2016. *Meta-analysis approach to assess effect of tillage on microbial biomass and enzyme activities.* Soil Biol Biochem. 97:176-187.

Sun H, P. Koal, D. Liu, G. Gerl, R. Schroll, A. Gattinger, R. G. Joergensen, and J. C. Munch. 2016. *Soil microbial community and microbial residues respond positively to minimum tillage under organic farming in Southern Germany*. Appl Soil Ecol. 108:16-24.

Slide 15 – *blade plow*

The blade plow, or sweep plow undercutter, is a valuable tillage tool for organic dryland production in regions with limited rainfall. The photos were taken from a U Nebraska Lincoln article on stubble mulch tillage at https://cropwatch.unl.edu/tillage/stubble.

In Nebraska, an early spring cover crop of legumes + mustard terminated by blade plow conserved moisture, reduced weeds, and improved yields of soybean and corn by 23% and 17% compared to a no-cover control, respectively, while the same cover crop terminated by disking promoted soil moisture loss and reduced soybean yields by 14%.

In the Columbia plateau (annual precipitation <12 inches), managing wheat stubble and weeds during the summer fallow period with the blade plow significantly reduced wind erosion, compared to disking. The trials were done on silt loam soils with 1% SOM.

Wortman, S., C. Francis, R. Drijber, and J. Lindquist. 2016. *Cover Crop Mixtures: Effects of Diversity and Termination Method on Weeds, Soil, and Crop Yield*. Midwest Cover Crop Council, http://mccc.msu.edu/wp-content/uploads/2016/12/NE_2016_Cover-Crop-Mixtures_-Effects-of-Diversity-and-Termination.pdf.

Sharratt, B., and G. Feng. 2009. Friction velocity and aerodynamic roughness of conventional and undercutter tillage within the Columbia Plateau, USA. Soil & Tillage Research 105: 236 – 241.

Slide 16 – *deep tillage without inversion*

The moldboard (turn) plow is commonly used to break sod, incorporate heavy crop residues, or kill and bury weeds. However, inverting the soil profile severely disrupts habitat, especially when the plow is set to work deep enough to bring subsoil (E or B horizon) to the surface, burying the biologically active topsoil (A horizon) to a depth unfavorable to topsoil organisms. Yet, some form of deep tillage is often necessary, especially if repeated use of plow, disk, or rototiller to the same depth year after year has created a “tillage pan” (management caused hardpan) that restricts rooting depth.

The broadfork offers a soil-saving and ergonomically friendly alternative, loosening the soil to a depth of 8 to 12 inches without inversion. As a hand tool, it is most practical for small scale operations, such as market gardens. In conjunction with permanent raised beds with traffic limited to alleys, the broadfork can help maintain good physical condition (aggregation) and prevent compaction.

At a larger scale the chisel plow provides a non-inversion approach to deep tillage that is less likely to cause subsurface compaction than moldboard plow or disk plow. A meta-analysis of multiple tillage studies showed that chisel plowing may also have less adverse effects on soil biological activity than inversion tillage.

Zuber S. M., and M. B. Villamil. 2016. *Cited above.*

Slide 17 – *rotary spader*

The spading machine is highly versatile and many vegetable producers report that it can incorporate a high biomass cover crop or even sod, and create a seedbed suitable for transplanting or large-seeded crops in a single pass – while doing minimal damage to soil life or soil aggregates. It does require a slow tractor speed, and thus may be most practical for small to moderate size horticultural crop production.

Researchers at Washington State University have found that, compared to "conventional" tillage of plow, disk, and rototiller, the spader substantially reduces compaction between 5 and 12 inches below the soil surface, and sometimes improves crop yields.

In more recent studies, the team has adopted the spader as the "conventional" (full field) tillage treatment against which to compare no-till and strip-till treatments for vegetable production.

Cogger, C. G. M. Ostrom, K. Painter, A. Kennedy, A. Fortuna, R. Alldredge, A.; Bary, T. Miller, D. Collins, J. Goldberger, A. Antonelli, and B. Cha. 2013. *Designing Production Strategies for Stewardship and Profits On Fresh Market Organic Farms.* Final report for OREI project 2008-01247. CRIS Abstracts.*

Craig Cogger, Andy Bary, Doug Collins, Liz Myhre, and Ann Kennedy, Washington State University Puyallup Research and Extension Center. 2007. *Soil Quality Research: Organic vegetable crop systems experiment and on-farm evaluations, October 2007.* https://s3.wp.wsu.edu/uploads/sites/411/2014/12/Paper_IF-Sum_SQual1.pdf.

Craig Cogger, Doug Collins, Andy Bary, Ann-Marie Fortuna, and Ann Kennedy. 2012. *Soil quality in intensive organic management systems.* http://smallfarms.oregonstate.edu/sites/default/files/SQNlogos/soilqualityinintensiveorganicmanagementsystems.pdf.

Slide 18 – *Tilling only part of the field: soil functional zone management*

The advantage of zone tillage methods, including ridge till and strip till, is that these practices spatially differentiate two key functions of healthy soils: *mineralization*, in which soil organisms release crop available nutrients by consuming active organic matter; and *stabilization,* in which the soil life converts active organic matter to long-lived organic matter. Tillage favors mineralization, and soil functional zone management practices such as ridge till limit this disturbance to crop rows, where nutrients will be utilized most efficiently, while between-row areas are left mostly undisturbed to facilitates stabilization and protect long-term soil health.

Planting nitrogen-rich legume or brassica cover crops in future crop rows or grow zones, and high biomass grasses in alleys, also contributes to this differential function, as does in-row drip fertigation.

Williams, A., A. S. Davis, A. Jilling, A. S. Grandy, R. T. Koide, D. A. Mortensen, R. G. Smith, S. S. Snapp, K. A. Spokas, A. C. Yannarell, and N. R. Jordan. 2017. *Reconciling opposing soil processes in row-crop agroecosystems via soil functional zone management*. Ag Eco Env 236: 99-107.

Slide 19 – *Tilling only part of the field: strip tillage*

Photos from Cogger et al., 2012, *Soil Quality in Intensive Organic Management Systems*, powerpoint presentation, Washington State University; and from a field day at North Carolina Agriculture and Technology State University in Greensboro, NC.

The following reference provides additional practical information on strip tillage including equipment, applicable to most regions:

*Reduced Tillage in Organic Systems Field Day Program Handbook.* July 31, 2018 at Cornell University Willsboro Research Farm, Willsboro NY. https://rvpadmin.cce.cornell.edu/uploads/doc_699.pdf.

Slide 20 – *crops thrive in strip tilled soil*

After mowing a winter rye cover crop, 20-inch wide strips were tilled with a walk-behind rototiller for planting tomatoes in rows 5 feet apart (center to center). This left 2/3 of the field in undisturbed rye (maintained by periodic mowing), which prevented erosion, protected soil quality, and provided mud-free access for harvest.

The peanut crop canopy has spread out from the strip-tilled planting rows, maintaining nearly weed-free conditions for a crop notoriously susceptible to weed competition.

Slide 21 – *Tilling only part of the field: ridge tillage*

In ridge tillage, the soil functional zone management aspect is enhanced by the rebuilding cultivation, in which residues and severed weeds from alleys are moved into crop rows, thereby enhancing ridge top SOM, feeding within-row soil life, and contributing slow-release nutrients to the developing crop. (Williams et al., 2017, cited above)

Ridge tillage has shown promise in Cornell organic vegetable cropping systems trials.

Drinkwater, L., H. Van Es, Q. Ketterings, E. Nelson, B. Rickard, and A. Seaman. 2014. *Building on success: a research and extension initiative to increase the prosperity of organic grain and vegetable farms.* Final report for OREI project 2009-01340. CRIS Abstracts.
Full URL for the photograph:
https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs144p2_026395.jpg.

Slide 22 – *Rotational no-till for organic crops. Step 1 – grow high biomass cover crop*

In rotational no-till systems, a high biomass cover crop is grown to a reproductive stage at which it can be killed mechanically without tillage, usually late flowering to early seed development, but not viable seed development. The cover crop must attain high biomass (3 to5 tons aboveground dry weight per acre) with uniform, relatively weed-free stands that will provide a thick, even mulch after rolling or mowing.

While conventional crops can be produced no-till without cover crops, a high biomass cover crop plays a central role in organic no till systems, providing weed control as well as building soil health and fertility.

Slide 23 – *Rotational no-till for organic crops. Step 2 – terminate cover crop without herbicides or tillage*

The roller-crimper (photo taken from Cogger et al, 2012) crushes stems to prevent regrowth, leaves stems otherwise intact to create a longer lived weed-suppressive mulch, and orients residues to facilitate mechanical no-till planting. Cover crop maturity is critical, as many cover crops will stand back up and resume growth if roll-crimped early in flowering. In addition, some cultivars may be more amenable to roll-crimp termination than others.

Flail mowing can terminate cover crops slightly earlier in development. A row cleaner may be needed for no-till planting, and the finely-chopped residue breaks down faster, which can shorten the period of effective weed suppression. However, if supplemental weed control with a high residue cultivator is needed, this operation is more easily done in flailed than in roll-crimped residues.

Non-hardy cover crops can be reliably terminated by freezing temperatures regardless of growth stage; however a high biomass residue is essential to prevent late winter and spring weed growth necessitating tillage prior to planting.

Note that sicklebar or rotary mowers and winterkill leave randomly oriented residues not amenable to mechanical no till planting. Rolling a non-hardy cover crop when falling temperatures have stopped its growth can orient the winterkilled residues.

Slide 24 – *Rotational no-till for organic crops. Step 3 no-till planting of the production crop*

This no-till planter model, called the subsurface tiller-transplanter, includes a coulter to part residues, followed by a shank to open a slot in the soil, a transplanter wheel, and tank to water starts with liquid organic fertilizer solution, and closing press wheels.

Another approach is to use a "no-till planting aid" that parts residues and prepares a narrow slot in the soil for mechanical or manual transplanting.

The photos here were taken at North Carolina Agricultural and Technical State University (Greensboro, NC) and at Virginia Tech (Blacksburg, VA), showing the SSTT developed by Dr. Ron Morse and colleagues at Virginia Tech. Similar technologies are in use at Washington State University and elsewhere in the Western region.

Slide 25 – *Rotational no-till for organic crops. Step 4 manage weeds as needed*

It is common to need some weed control during cash crop production in rotational no-till. Some cultivation tools are designed to work in the presence of substantial crop residues, without burying the residues themselves. Heavy duty finger weeders do better than light torsion or tine weeders, and sweep undercutter tools set to work between and near crop rows can also work.

Slide 26 – *Weeds: the #1 organic no-till challenge.*

Any cover crop that has not achieved at least 3 tons/ac aboveground dry weight (preferably 4-6 tons/ac), and that does not cover the ground completely when viewed from above cannot provide sufficient weed suppression for organic crop production.

Careful planning is needed to ensure that the cover crop can be grown until mature enough to terminate without herbicides or tillage without unduly delaying planting of the cash crop. Weeds are the biggest challenge with organic rotational no-till. This system is most suitable fields with low to moderate weed population dominated by small seeded annuals, whose seedlings are easily hindered by the cover crop residues. Perennial weeds such as nutsedge and johnsongrass will easily break through the cover crop residue, and a heavy weed seedbank of vigorous summer annuals like pigweed can also result in excessive weed competition against the cash crop.

If the cover crop is planted immediately after breaking sod, residual grass clumps therefrom are likely to grow through a mowed or roll-crimped cover crop. Problems can also arise if the cover crop itself becomes overmature and self-seeds.

The squash in this photo, overwhelmed by self-seeding barley and crimson clover, was planted at the same time and by the same methods as the successful crop in rolled rye + vetch shown two slides earlier – the key difference was maturity date of the cover crops.

Slide 27 – *Other organic no-till challenges*

Cash crop planting can be delayed by the need to let the cover crop reach sufficient maturity or biomass for no-till termination. The cover crop residue slows soil warming and drying, which can further delay planting and slow crop establishment. Moisture consumption by the cover crop prior to termination can help remove excess soil moisture – but can also leave the soil too dry in limited-rainfall regions or dry seasons. Cooler soil under the mulch can also delay the release of plant-available nitrogen and other nutrients, especially if the cover crop has a high carbon:nitrogen ratio (e.g., mostly or all grass, or overmature).

Snap bean and dry common bean fix only a little N, and thus can be adversely affected by tie-up of soil N.

In organic farming system studies in the north-central US, rotational no-till with high biomass cover crops gave best results for soil health but reduced corn and cereal grain yields by some 60%, and soybean yields by 30%. Challenges with delayed cash crop planting and N nutrition for the cash crop are greatest in cooler regions with short growing seasons, and moisture is often limiting in low-rainfall regions.

Slide 28 – *When organic rotational no till is most likely to succeed*

In warmer regions with longer growing seasons, it is easier to ensure sufficient time for both cover and cash crop. No-till yields are often equal and sometimes better than after cover crops are tilled in, especially when a combination of hot rainy climate and sandy soil might mineralize N <u>too</u> quickly after a cover crop is tilled in. For example, in Hawaii, green onions planted no-till into mowed sunnhemp yielded better and had fewer pests than onions planted in bare ground or black plastic mulch after the sunnhemp was tilled in.

Chen, G., C. R. Hooks, M. Lekveishvili, K. H. Wang, K. H., N. Pradhan, S. Tubene, S., R. R. Weil, and R. Ogutu. 2015. *Cover Crop and Tillage Impact on Soil Quality, Greenhouse Gas Emission, Pests, and Economics of Fields Transitioning to Organic Farming.* Final report for project ORG 2011-04944. CRIS Abstracts.*

Organic soybeans planted no-till into roll-crimped rye show less "yield drag" than organic no-till corn, and in central or southern regions often yield as much or more than organic soybean planted into a tilled seedbed. By tying up N, the rye residues provide selective control of N-responder weeds like pigweed, lambsquarters, and foxtails, without stunting soybean, which can meet most of its N requirement through symbiotic fixation. Other strong N fixers such as southern pea or lima bean might also do well in a rolled cereal grain cover crop.

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

Caldwell, B., J. Liebert, and M. Ryan. 2016. *On-Farm Organic No-Till Planted Soybean in Rolled Cover Crop Mulch*. What's Cropping Up Blog vol 26, no. 5 (Sept-Oct, 2016). http://blogs.cornell.edu/whatscroppingup/2016/09/29/on-farm-organic-no-till-planted-soybean-in-rolled-cover-crop-mulch/.

Slide 29 – *Tips for organic rotational no till*

These tips are based on OREI-funded studies outside of the Western region (discussed in more depth in the OFRF Soil Health Guide, Practical Conservation Tillage), but likely applicable or adaptable within the region. Opaque tarp or landscape fabric laid immediately after flail mowing or rolling the cover crop for two to four weeks prior to no-till cash crop planting, or between rows of the cash crop, enhances weed control and often crop yield. This solution is most applicable to small scale applications such as a vegetable market garden.

Slide 30 – *Organic reduced till in the western region*

Much of the organic reduced till and rotational no till research and practice to date has taken place in the central and eastern US, with many success stories as well as challenges identified. One of the leading concerns expressed by Western region organic farmers seeking to reduce tillage for soil health is that methods developed for Corn Belt field crop production or vegetable production in the mid-Atlantic and Northeast may not be applicable without adaptations to address the challenges of Western region climates, soils, topography, and production systems.

The rest of this presentation explores these challenges and current research and practical strategies to address them.

Slide 31 – *Organic minimum-till challenges in the maritime Pacific Northwest*

Information in this slide is based on field trials (research station and on-farm) and farmer focus groups in the region.

The maritime PNW climate presents several challenges: short growing season, heavy rain and excess soil moisture from late fall into late spring, followed by dry conditions in summer. Thus, precipitation greatly exceeds evapotranspiration early in the growing season, and the reverse is true later – so that producers must often cope with waterlogging and drought / need for irrigation during the life cycle of the cash crop. The challenges faced in this region are different from the Midwest, where more growers have adopted no-till.

Farmers in the region have observed the problems of soil health decline with years of tillage after breaking sod, the formation of subsurface tillage pans. Many have tried to reduce tillage as much as practical, and are eager to try minimum tillage with cover cropping, but few have seen successful models for their region.

Farmer focus groups in the maritime Pacific Northwest identified several constraints on adoption of cover crop based organic minimum tillage methods, including timing challenges in a short growing season, wet or flooded soil conditions at planting time, delayed warming under cover crop residue, nutrient tieup by the cover crop, slugs in the residue, and within-row weeds after no-till planting.

Collins, Doug. 2015. *Tillage reduction and cover cropping for enhanced soil quality and weed management in western Washington organic vegetable farms*. Part of: *Soil Health in Organic Farming Systems*, (Collins with Mark Smallwood and Ben Bowell) http://articles.extension.org/pages/72568/organicology-2015:-selected-live-broadcasts-and-recordings-from-the-conference.

Corbin, A. T., D. P. Collins, R. L. Krebill-Prather, C. A. Benedict, and D. L. Moore. 2015. *Adoption Potential and Perceptions of Reduced Tillage among Organic Farmers in the Maritime Pacific Northwest*. http://articles.extension.org/pages/68283/adoption-potential-and-perceptions-of-reduced-tillage-among-organic-farmers-in-the-maritime-pacific-.

Slide 32 – *Washington State U trials*

In long term trials at Washington State U, winter cover crops of rye and vetch were found to germinate and establish most reliably in the challenging weather and soil conditions (often too wet for some crops). Rye + vetch were terminated by flail mowing or roll-crimping, followed by spader incorporation (full field), strip tillage (ground driven strip tiller), or no-tillage before vegetable planting.

In Washington State U trials, tillage (spader) speeds soil warming, drying, and microbial respiration, and often improves vegetable yields over no till (planting aid) or strip till. The warming (~5 degrees) puts soil temp in optimum range through most of growing season. The drying effect of tillage is beneficial early in the season, but can become detrimental later.

Soil texture has a major effect on outcome. In multi-site trials, organic squash yielded better in the no-till treatment on loamy sand, better in the spaded treatment in fine sandy loam, and failed altogether in no-till in a silt loam.

Collins et al., 2015, cited earlier.

Slide 33 – *Practical tips and resources for maritime Pacific Northwest*

Cover crop cultivar selection: Aroostook rye gave higher biomass, 3-wk earlier maturity, and more complete termination by roller-crimper than 'common' (VNS?) rye. 'Strider' barley had high biomass but matured too quickly to viable seed, and also stood back up after roll crimp (>50%).

Weed control with a high residue cultivator (undercutter design) was facilitated by flail mowing versus roll-crimping, sometimes resulting in better strip till / no till crop yields from mowed treatments. The undercutter works best in relatively dry soil conditions (August); in spring, the soil is so wet that an undercutter would not terminate cover crops or weeds – the plants simply re-root!

Cogger, C. G. M. Ostrom, K. Painter, A. Kennedy, A. Fortuna, R. Alldredge, A.; Bary, T. Miller, D. Collins, J. Goldberger, A. Antonelli, and B. Cha. 2013. *Designing Production Strategies for Stewardship and Profits On Fresh Market Organic Farms.* Final report for OREI project 2008-01247. CRIS Abstracts.*

eOrganic hosts an "inter-disciplinary group of researchers and producers working towards the common goal of developing an organically approved reduced tillage production system for the Pacific Northwest" at:

Benedict, C., A. T. Corbin, A. Bary, and D. P. Collins. 2012. Organic reduced tillage in the Pacific Northwest. Group website under the eOrganic Community of Practice for eXtension. (Available online at: http://eorganic.info/node/4988). The site links to an up to date video with power strip tiller demo at http://eorganic.info/node/8245.

Collins, 2015; Corbin et al, 2015, cited above.

Slide 34 – *Strip tillage for organic broccoli in coastal Oregon.*

In this OFRF funded study by John Luna and others, organic broccoli was grown in Corvallis, OR (average annual precipitation 43.7 inches, of which 26.5 inches fall during Nov-Feb and only 4.2 inches during June-Sept) after a cereal grain-common vetch-phacelia cover crop (~3,000 – 3,800 lb/ac, containing ~ 80 lb total N/ac) was mowed, followed by non-inversion full width tillage (FT, spader followed by rotary harrow) or strip tillage (ST, 6 inch wide strips on 3 ft centers, done by a rotary strip tiller working 6 inches deep).

Broccoli was fertilized preplant with 980 lb/ac of a 9-3-5 fish fertilizer (88 lb N/ac), and was planted May 28.

In strip till, weeds and cover crop regrowth were managed by mowing (weed trimmer) or by mowing + one pass with a high residue cultivator. The cultivator was used as needed to take emerging weeds out in FT (repeated cultivations). Within-row weeds were hand-hoed in all treatments.

Broccoli was harvested Aug 10 and 16. Marketable yields were 4.2, 4.4, and 5.1 tons/ac in ST mowed, ST cultivated once, and FT, respectively; numbers of marketable heads were same in all treatments, but average head size was less in ST.

Reduced soil disturbance greatly reduced annual broadleaf weed seed emergence in ST (at least 5-fold fewer than FT), though more annual bluegrass was observed in ST. Flea beetles came early season, caused visible damage in FT (six to ten-fold fewer in ST) but did not much affect yields.

Crop foliar N was lower in ST than FT, especially at 46 DAP (July 13: FT 5.0%, ST-cultivated 3.9%, ST mowed 3.7%), suggesting slower soil N mineralization (though soil nitrate N was similar in all treatments).

Although fewer broadleaf weeds emerged in FT than CT, the former had more annual bluegrass and some cover crop regrowth; and weeds + cover crop regrowth became, in effect, an interrow living mulch that competed with the broccoli (in 6" wide clean swath).

The authors planned additional research including the following modifications to the system: wider and deeper strip till (a "trans tiller" designed to work 12" wide by 14" deep); increasing fertilizer N rates; and supplementing mowing / cultivation with thermal weeding to control between-row vegetation.

They also note that their full-till treatment is already a step-up from conventional (plow-disk) tillage in terms of soil health impacts.

Slide 35 – *Organic conservation tillage in a drier Mediterranean climate*

In this two-season OFRF trial, organic tomatoes were transplanted and grown after a legume mix (vetch, bell bean, Magnus pea) or grain-legume mix (rye, triticale, vetch, bell bean, pea) winter cover crop was terminated with a Buffalo stalk chopper, followed by four treatments:

- Full tillage – incorporated pre plant.
- Delayed tillage – tomato planted no-till, then cover crop incorporated between crop rows 17 – 19 days later.
- Strip tillage – crop rows prepared with a Unverferth Ripper-Stripper Subsoiler (coulter, row cleaner, subsoiling shank, double coulter, rolling basket); cover crop residue left intact between rows.
- No-till.
- A control treatment – full till, no cover crop (winter fallow) was included.

A subsurface tiller-transplanter was used to set tomato starts in all treatments, which facilitated the delayed tillage strategy as well as no-till.

Slide 36 – *Outcomes of Meridian, CA organic reduced till trial:*

Cover crop planting was more timely in 2001 (Oct) and therefore produced greater biomass than in 2000 (planted Nov).

In 2000, a dry winter resulted in low soil moisture and soil N levels at the time of cover crop termination and tomato transplanting. Soil soluble N increased rapidly in fallow and legume cover crop treatments, but recovered only toward end of the season in the legume-grain treatments, which appeared to tie up N. Low cover crop biomass allowed more weed competition in the strip till and no till treatments, resulting in severe yield reductions, and 90% losses in no-till and strip till grain-legume treatments.

Timely cover crop planting and adequate winter/spring rains created much more favorable conditions in 2001, with similar soil soluble N levels and yields across all treatments, despite higher weed levels in the no-till and strip till treatments.

The authors identified the delayed till treatment as most promising, in that it allows flexibility in cover crop management (whether and when to till between rows) and provides weed control approaching that of preplant till with fewer cultivations and less bare soil exposure.

Question: would a high biomass cover crop combined with a dry late winter / spring result in severe soil moisture depletion at time of vegetable planting?

Cahn, M., and J. P. Mitchell. 2004. *Conservation tillage and cover crop systems for organic processing tomato production (year 2*). Final project report to Organic Farming Research Foundation, 16 pp.

Slide 37 – *Organic conservation tillage challenges in dry interior climates*

In semiarid regions, cash crops and cover crops in the rotation vie with one another- and with weeds – for limited moisture. As a result, it is more difficult to grow a cover crop to sufficient biomass to suppress weeds if roll-crimped, and to provide enough organic matter and N to sustain soil health and grain yields. If the cover crop does attain high biomass, it may also consume so much moisture that grain yields become severely water-limited.

In the Northern Great Plains, long cold winters and short growing seasons further limit options for cover crop-based rotational no-till.

Climate change is intensifying the challenges with warmer, drier springs and more intense summer drought and heat.

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 38 – *Two approaches to reduced tillage in the northern Great Plains*

A research team at Montana State University has tested a five year rotation of safflower underseeded with biennial 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 a wet season when sheep compacted the soil, and 20-30% reduction in normal season (no compaction). They are fine tuning the system with more weed-competitive crops, and use of the blade plow when tillage is needed.

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.

Doug and Anna Crabtree of Vilicus Farms (https://www.vilicusfarms.com/) in Hill County, Montana, manage over 7,000 acres of organic dryland crops. They have developed a complex crop rotation including 15 production crops (grains, oilseeds, pulses) and 10 cover crops, using the blade plow to terminate covers without disturbing the soil profile, leaving residues on the surface. The combination of integrated organic practices, annual cropping (no fallow), diverse rotation, intercropping, high biomass cover crops, and blade plow cover crop termination has resulted in gradually increasing SOM in the 2 – 3% range and good production on an average of 11 inches of moisture per year.

Slide 39 – *Other research findings in dryland organic grain rotations*

Farmer-participatory research consistently identify weeds, fertility and soil erosion as top constraints on organic dryland grain production in the Northern Great Plains, the Palouse region of Washington State, and other limited-rainfall regions. Summary findings in slide based on:

Burke, I. C. E. P. Fuerst, R. T. Koenig, K. Painter, D. Roberts, D. Huggins, A. M. Fortuna, S. Machado, B. K. Baik, J. Goldberger, J. Johnson-Maynard. 2014. *Sustainable Dryland Organic Farming Systems in the Pacific Northwest.* Final report for OREI project 2009-01416. CRIS Abstracts.*

Gallagher, R. S., D. Bezdicek, and H. Hinman. 2006. *Various Strategies to Achieve Ecological and Economic Goals in the Transition Phase of Eastern Washington Organic Dryland Grain Production.* Final report for ORG project 2002-03805. CRIS Abstracts.* Also see 2012 web log update at http://cahnrs.wsu.edu/blog/2012/04/transitions-people-small-bites-events/.

Miller, P. R.; D. E. Buschena, C. A. Jones, B. D. Maxwell, R. E. Engel, F. Menalled, and B. J. Jacobsen. 2009. *Organic Production in the Challenging Environment of the Northern Great Plains: from Transition to Sustainability.* Final report for ORG project 2005-04477. CRIS Abstracts.*

Norton, U., J. B. Norton, A. Garcia y Garcia, A., J. P. Ritten, S. J. DelGrosso, and G. W. Hergert. 2014. *Soil Carbon and Nitrogen Dynamics in Organic Crop and Forage Production of the Northern High Plains Ecoregion, Wyoming and Nebraska.* Final report for ORG project 2010-03952. CRIS Abstracts.*

Slide 40 – *Reduced till / living mulch in irrigated vegetables in Montana*

Helen Atthowe has 35+ years experience as farmer, consultant, and horticulture Extension agent developing soil-building organic systems that combine living mulches to maximize ground coverage and living root with reduced tillage intensity in organic vegetable production. She has adapted and applied these concepts in Georgia, New Jersey, Montana (1992-2010), Colorado, and now eastern Oregon.

She managed 30 acres of organic vegetable and fruit crops for 28 years at Biodesign Farm in Montana. Limited plant-available N early in the season emerged as a key constraint on production. Based on earlier work by Masanobu Fukuoka, Helen used clovers and other legume living mulches to address this issue. Drip and overhead irrigation were applied as needed to support continuous living cover and high vegetable yields. Throughout that time, she experimented with various approaches to reducing tillage intensity and frequency.

Slide 41 – *Fine tuning the system*

Over her 28 years in Montana, Dr. Atthowe continually evolved the system, obtaining SARE grants to experiment with ways to further reduce or eliminate tillage, managing the clover by mowing and/or flame. While no-till resulted in decreased yields and net returns and allowed grasses to invade the living mulch, the studies also showed that monthly mowing of clover enhanced earthworms and microbial activity compared to unmowed living mulch, and mowing also minimized problems with slugs.

The annual shallow-tillage system not only gave excellent yields and returns, but also maintained soil coverage 11 months of the year, through clover self-seeding or, if needed, prompt seeding after tillage.

As P and other nutrient levels began to soar, Helen cut back the use of manure compost from 10 to 2 tons/ac annually, and believes that minimal inputs might sustain better nutrient balance and may reduce grass and other weed pressure. Her current farm in eastern Oregon is "veganic" – depending entirely on living plants and plant based compost to maintain soil health and crop nutrition.

The research summarized on slides 40 and 41 was conducted with support from the USDA Western Region Sustainable Agriculture Research and Education (SARE), (see report at www.westernsare.org/content/download/1475/10808/FW06_025_txt.pdf), and the Organic Farming Research Foundation (OFRF, https://ofrf.org/).

Helen presented a webinar on eOrganic on December 13, 2011, entitled *Reduced Tillage in Organic Vegetable Production*, available at https://articles.extension.org/pages/61629/reduced-tillage-in-organic-vegetable-production-webinar.

Current web site: One Path to Veganic Permaculture http://www.veganicpermaculture.com/.

Slide 42 – *Summary*

In a region as diverse as the West, there is no formula for best organic conservation tillage practices. The four NRCS principles must be adapted to each farm, considering soil, climate, rainfall, topography, and production system.

It is not necessary to go strictly no-till in order to build soil health – attempting organic no till in the presence of heavy perennial weed pressure or other serious constraints could spell economic disaster. It is better to have an organic farm using some tillage than have it go out of business, letting the land be neglected or (worse yet) developed and paved over!

So, till with care, till only when necessary, with your goals clearly in mind, and using the best tool for the job and circumstances.

Keep in mind the concept of soil functional zone management, and explore strip, zone, or ridge tillage options that concentrate the benefits of tillage in the crop row, and the benefits of no-till between rows.

Above all, be creative. The working farm examples in this presentation each developed unique systems for their climate, soils, crops, and needs.

Slide 43 – *OFRF Soil Health Guides*

Archived and future webinars in this series address each of these topics.

Slide 44 – *Questions?*