Practical Conservation Tillage

Research-based Practical Guidance for Organic and Transitioning Farmers

eOrganic Soil Health and Organic Farming Webinar Series
September 19, 2018
Developed and presented by Organic Farming Research Foundation, with funding from the Clarence Heller Foundation

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

Slide 1 – *title slide*.

Slide 2 – *NOP rule on tillage and soil quality*.

Slide 3 – *tillage impacts on soil physical properties*

Slide 4 – *tillage impacts on soil biology*

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 CO_2 released per unit biomass, ("metabolic quotient," an indicator of stress on the soil food web); in other words, the soil disturbance increased maintenance respiration relative to microbial growth (Zuber and Villamil, 2016. Soil Biol Biochem. 97:176-187.) However, sound organic soil management systems that include some tillage can enhance *both* microbial biomass, and microbial activity measured as respiration (Lori et al., 2017, PLOS ONE | https://doi.org/10.1371/journal.pone.0180442).

Slide 5 – *NORA 2016 – farmer research priorities regarding soil, weeds, tillage.*

In the 2015 survey and listening sessions conducted by OFRF farmers specifically asked questions about how different tillage systems affect soil and weeds.

Slide 6 – *no-till and conservation agriculture*

The Soil Conservation Service (now the Natural Resources Conservation Service or NRCS) was established in the 1930s in response to the Dust Bowl, helping farmers to conserve soil by increasing plant coverage, improving rotations, cover cropping, plowing on contour, planting windbreaks, and reducing tillage when practical. Since the 1970s, increasing numbers of farmers have adopted no-till or conservation tillage systems, most using herbicides in lieu of the plow and other tillage implements to prepare seedbeds and manage weeds.

In 2012, only about 10% of the 173 million acres of no-till and conservation tillage acreage were planted to cover crops between successive cash crops, although annual SARE Cover Cropping Surveys have shown a steady increase in the use of cover crops since then.

Slide 7 – *reducing tillage in organic systems*

Weed pressure, especially invasive perennial weeds that multiply asexually through rhizomes, tubers, and other underground structures, make *continuous* no-till impractical in organic production of annual crops. .

In lieu of capital outlay for new tillage equipment, farmers can often use or adapt current tillage tools to reduce soil disturbance. For example, a walk-behind rototiller can be used to work up crop rows rather than the entire field, as shown in the photo.

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.

Slide 8 – *rotational no till for organic crops*

Definition of the method and first step – hi biomass cover crop.

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

Slide 9 – *rotational no till for organic crops – second step – cover crop termination*

Several designs of roller-crimpers are now available for mechanical no-till termination of annual cover crops that have reached the full-bloom to early seed-set stages of development.

The flail mower is a heavy implement that, with PTO off, can roll-crimp the cover fairly effectively. Farmers without access to a roller-crimper have attempted "jury rigs" with other implements such as a tractor mount rototiller (again PTO off) with mixed results.

Weed suppression by flail-mowed cover is shorter lived, as finely chopped covers break down faster. Mechanical no-till planters may require different adaptation to plant in flail-mowed versus rolled residues. Other mowers (sicklebar, bush hog) and winterkill leave randomly oriented residues not amenable to mechanical no till planting. However, roll-crimping a non-hardy cover crop when falling temperatures have stopped its growth can orient the winterkilled residues.

Slide 10 – *rotational no till – third step – no-till planting of cash 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 fish fertilizer, and press wheels to close the furrow around the starts.

In a successful application of this technology, organic summer squash gave marketable yields of 15 tons per acre at Virginia Tech.

Slide 11 – *rotational no till – fourth step – managing weeds; weed challenges.*

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. Organic rotational no-till should not be attempted when weed pressure is high or weed flora is dominated by perennial species.

Most perennial weeds emerging from rootstocks, tubers, or rhizomes will easily break through the cover crop residue; in fact, nutsedges can even penetrate black plastic mulch. If the cover crop is planted immediately after breaking sod, residual grass clumps therefrom are likely to grow through the roll-crimped or mowed cover crop.

Slide 12 – *organic no-till challenges – timing / maturity, equipment, etc*

A cover crop that has not achieved at least 3 tons/ac aboveground dry weight (preferably 4-5 tons/ac in warmer climates), 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 it is mature enough to terminate without herbicides or tillage without unduly delaying cash crop planting.

Slide 13 – *getting the timing just right – photos show examples of good timing, terminated too late (self-seeded), and too early.*

Slide 14 - *more challenges with organic no-till – planting thru residues, N availability*

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 15 – *conditions that favor success with rotational organic no till*

In warmer regions with longer growing seasons, it is easier to ensure sufficient time for both cover and cash crop. Organic no-till yields are often similar and occasionally better than organic yields after cover crops are tilled in. A combination of hot rainy climate and sandy soil (e.g. southeast US coastal plain) might mineralize N *too* quickly after a cover crop is tilled in.

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. The rye ties up soluble soil N, giving the N-fixing soybean a competitive advantage over most weeds.

Slide 16 – *tips for organic rotational no-till*

References: repeating roll-crimp to control regrowth – based on experiments in PA, MD, DE by researchers at Penn State (Barbercheck, M. E., W. Curran, J. Harper, R. Hoover, D. Voight, and G. Hostetter. 2014. *Improving Weed and Insect Management in Organic Reduced-Tillage Cropping Systems*. Final report on OREI project 2010-03391. CRIS Abstracts. Farmers at Windy Acres Farm in Tennessee have also had success with this strategy.

Holden Thompson of Windy Acres Farm has observed significant variation among hairy vetch cultivars in ease of roll-crimp termination. A combination of 'Purple Bounty' vetch (easy termination) and 'Abruzzi' rye has worked well at their site. It may be worth comparing cultivars at your site in a simple field trial to determine which ones have the best maturity date and easiest termination for your system. *(Presentation by Holden Thompson at January 2017 at Southern Sustainable Agriculture Working Group conference in Lexington, KY).*

In the 2016 SARE cover cropping survey, over one third of respondents who use cover crops are using or trying the "plant green" approach, though efficacy of this method in organic systems requires more study.

Slide 17 – *tips for small scale organic no-till – opaque tarps or clear plastic for cover crop termination and weed control*

Opaque covers on rolled or mowed cover for 2 – 4 weeks prior to cash crop planting have been successfully demonstrated in trials with tomato (MD), cabbage and winter squash (NY, ME). References:

Brust, G. 2014. *Organic Weed Control in No-Till Systems*. https://extension.umd.edu/sites/default/files/_docs/articles/OrganicWeedControlUsingNo-till_3-2014_0.pdf.

Rangarajan, A., M. T. McGrath, D, Brainard, Z. I. Szendrei, M. Hutton, E. Gallandt, M. Hutchinson, and B. J. Rickard. 2016. *Farmer Designed Systems to Reduce Tillage in Organic Vegetables*. Proposal and progress report for OREI project 2014-05381. CRIS Abstracts.

Maher, R., A. Rangarajan, M. Hutton, B. Caldwell, M. L. Hutchinson and N. Rowley. 2017. *Comparison of Reduced Tillage Practices for Small-Scale Organic Vegetable Production.* Special Session Symposium--Organic Agriculture Soil Health Research, TriSocieties meeting, Tampa, FL, October 2017. http://articles.extension.org/pages/74555/live-broadcast:-organic-soil-health-research-special-session-at-the-tri-societies-conference.

Organic grower and author Anthony Flaccavento of Abingdon, VA used solarization (clear plastic) for two days immediately after mowing a high biomass summer cover crop of pearl millet and cowpeas before setting out organic fall broccoli. This gave very high broccoli yields (1.5 – 2 lb heads) with no response to added N, and slightly better than broccoli grown without cover crop and with 180 lb N/ac from organic fertilizers.

Slide 18 – *Putting no-till into perspective.*

Reference for estimate of SOM gain during continuous no-till: West and Post, 2002. Soil Sci. Soc. Am. J. 66(6): 1930–1946.

References for no-till related SOM accrual near surface: multiple studies reviewed by Kane, 2015, white paper posted at http://sustainableagriculture.net.publications. Also Grandy et al., 2006. Agron. J. 98(6): 1377-1383. Grandy et al (2006) note that most no-till farmers till every few years for weed control. While a single tillage pass can reverse much of the surface SOM gain from no-till, it has less impact on the deeper SOM derived from plant root growth, exudates, and residues.

Organic with some tillage versus conventional no-till: Total SOM measured from surface to 24 inches (Syswerda et al., 2011, Soil Sci. Soc. Am. J. 75(1): 92 – 101) or surface to 39 inches (Wander et al., 2014, Proposal and final report for ORG project 2010-03954. CRIS Abstracts) was similar in organic systems and conventional continuous no till.

Slide 19 – *NRCS four principles of soil health*

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

Conservation agriculture (no till with some synthetic herbicide use) addresses all four, eliminating physical but not chemical disturbance.

Organic agriculture addresses all four, eliminating disturbance from NOP-prohibited synthetic chemicals, and striving to limit the need for tillage and cultivation.

Slide 20 – *no-till versus organic- research example from USDA Beltsville, MD*

Reference: 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.

Slide 21 – *other strategies for reducing tillage intensity in organic systems*

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 just as well with with 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?

Some of the strategies and practices discussed here may entail investing in new equipment; others can be done with what you have.

Nothing builds soil like living plant roots – and root residues decaying *in situ* is a close second. When practical, work only the surface 2 – 3 inches and let the rest of the soil profile remain undisturbed.

Slide 22 – *can you till less often? Examples – seedbed prep; winterkilled cover crop*

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 23 – *can you till less often?*

Organic integrated weed management can help producers reduce the amount of tillage and cultivation needed during intensive vegetable and row crop production. This topic is covered in depth in the Soil Health Guide on weed management.

Slide 24 – *shallow tillage – potential synergism between reducing tillage depth and using good organic practices.*

References to shallow tillage benefits to SOM and soil life in organic systems:

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.

Long-term trial in Germany: 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 25 – *shallow tillage implements – rotary harrow, sweep plow undercutter.*

Reference for research findings on the sweep plow undercutter for terminating an early spring cover crop ahead of corn in Nebraska: 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/wpcontent/uploads/2016/12/NE_2016_Cover-Crop-Mixtures_-Effects-of-Diversity-and-Termination.pdf

Slide 26 – *deep, non-inversion tillage – chisel plow and broadfork.*

When deeper tillage is needed, consider alternatives to the moldboard (turn) plow and heavy disk. Meta-analysis reference: Zuber S. M., and M. B. Villamil. 2016. *(cited above)*

Many intensive vegetable farms routinely rototill several times a year, which can degrade soil structure by pulverizing the surface and creating a till pan at the working depth of the tool. The broadfork offers a soil-saving and ergonomically friendly alternative which may be viable for the smallest scale operations.

Slide 27 – *spading machine.*

The spading machine is highly versatile and many vegetable producers report that it can incorporate a high biomass cover crop 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.

NOTE: In the photo, the soil is actually too dry to till – some of the dust visible behind the implement will become wind erosion losses. Had this been a rototiller run at normal speeds, this loss would have been much greater.

Reference for Pacific Northwest trials: 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

Slide 28 – *Soil- friendly rototilling: Rick Felker of Mattawoman Creek Farm.*

Slide 29 – *tilling only part of the field – strip tillage.*

Slide 30 – *tilling only part of the field- ridge tillage*

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

Slide 31 – *soil functional zone management*

The advantage of 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.

Reference: 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.

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.

Slide 32 – *cover crops: let plants do the tillage.*

These cover crops have been shown to actively penetrate and help break up subsurface hardpans. Although rye is not as widely known for "subsoiling" as sorghum-sudan, radish, and sweetcover, it has been shown to relieve subsoil hardpan in Georgia coastal plain soils sufficiently to enhance water uptake and yield in a subsequent cotton crop. Very often, these cover crops can enhance drainage, aeration and rooting depth of subsequent cash crops, and make mechanical subsoiling or chiseling unnecessary.

Reference on rye/cotton observation: 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

Slide 33 – *cover crops are fundamental*

References: Cavigelli et al., 2013 *(cited above);* 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.

Slide 34 – *perennial sod phase in rotation – gives soil a rest.*

Slide 35 – *crop-livestock integration – Elmwood Stock Farm – 3 yr veg 5 yr pasture.*

Slide 36 – *New resource:*

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.
Excellent information including

- Zone tillage equipment and methods, link to video by Dr. Anu Rangarajan, Cornell U.
- Roller crimper designs and troubleshooting tips for roll-crimping cover crops
- Farmer stories.
- Soil biology and soil health

Slide 37 – *Soil Health Guides available at www.ofrf.org.*

Slide 38 – *questions??*