Cover Crops for Soil Health: Selection and Management

Research-based Practical Guidance for Organic and Transitioning Farmers

eOrganic Soil Health and Organic Farming Webinar Series
October 17, 2018
Developed and presented by Organic Farming Research Foundation, with funding from the Clarence Heller Foundation

Slide 1 – *title slide*

Slide 2 – *Subheading – how cover crops enhance soil health*

Slide 3 – *Soil health benefits of cover crops (summary)*

Slide 4 – *Cover crops and soil health in the NOP standards*

Sod = perennial legume + grass cover crop for one or more years in the rotation; green manure = cover crop tilled in; catch crop = cover crop that recovers nutrients and prevents nutrient leaching.

Slide 5 – *Living plant cover and soil health*

Why are cover crops emphasized in the NOP standards?

Organic agriculture is based on an integrated and holistic approach to soil and ecosystem health. As the primary source of organic carbon on Earth, the living plant is nature's way of creating and improving soil, and is also the farmer's primary soil health management tool.

In annual cropping systems, cover crops play a vital role in keeping the soil covered and fed during "off seasons" between successive cash crops. Organic farmers cannot "fall back" on soluble fertilizers to maintain yields, and thus depend on cover crops to maintain soil health and fertility in annual cropping systems.

Other practices – compost and other organic amendments, reduced tillage, and best nutrient management – provide complementary benefits to soil life and SOM, and can work synergistically with the living plant to build agricultural soil health and fertility.

Slide 6 - *Cover crops work with organic amendments and careful tillage to build healthy soil*.

Other organic practices – compost and other organic amendments, reduced tillage, and best nutrient management – provide complementary benefits to soil life and SOM, and can work synergistically with the living plant to build agricultural soil health and fertility.

Multiple studies show that cover crops + compost or manure enhance SOM and fertility more than either one alone.

Delate, K., C. Cambardella, and C. Chase. 2015. *Effects of cover crops, soil amendments, and reduced tillage on Carbon Sequestration and Soil Health in a Long Term Vegetable System*. Final report for ORG project 2010-03956. CRIS Abstracts.

Hooks, C. R., K. H. Wang, G. Brust, and S. Mathew. 2015. *Using Winter Cover Crops to Enhance the Organic Vegetable Industry in the Mid-Atlantic Region*. Final report for OREI project 2010-01954. 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.)

Slide 7 – *Sustainable crop intensification*

Sustainable crop intensification means maximizing living plant cover and plant growth throughout the crop rotation. Some of the soil benefits of crop intensification, especially SOM accrual, are reduced in proportion to biomass removals through harvest. This "debit" is greatest for root crops (in which the whole plant goes to market), moderate for greens, head brassicas, and silage corn (roots remain), smaller for fruiting vegetables, grains, and forages, minimal for perennial fruit crops, and of course none for cover crops that are not harvested.

Examples at left in slide: sunnhemp + sorghum sudangrass during a summer fallow; berry field with alleys left in perennial sod, managed by periodic mowing.

Orchard or vineyard floor kept "clean" by tillage or herbicide may lose half their SOM compared to organic orchards with cover crops

Lorenz and Lal, 2016. Advances in Agronomy 139: 99-152.

Slide 8 – *Corn-soy rotation without winter covers*

Even under organic management, researchers have found that a corn-soy rotation without winter cover crops is detrimental to soil health.

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.

Baas et al., 2015. Final report for ORG project 2011-04952. CRIS Abstracts.

Slide 9 – *Sustainable crop intensification in a corn-soy rotation*

When cover crops are planted after harvest and tilled in prior to the next row crop, soil exposure still occurs while cover crops are just emerging and getting established, and again during the 2-4 week waiting period between tilling-in cover and planting cash crops.

Interseeding minimizes the post-harvest soil exposure, and adding a perennial sod phase to the rotation further improves soil health.

Compared to a two-year corn-soy system, a four-year corn-soy-cereal-alfalfa rotation (alfalfa overseeded into cereal grain) can accrue an additional 500 lb SOM/ac annually. Increased diversity and root biomass build SOM in the latter (Delate et al., 2015. Sustainable Agric. Res. 4(3): 5-14; Moncada and Sheaffer et al., 2010 *Risk Management Guide for Organic Producers,* http://organicriskmanagement.umn.edu/.).

Slide 10 – *NRCS principle 1 – keep soil covered*.

In diversified vegetable rotations, cover crops can be planted in early spring ahead of a summer vegetable, late summer after an early vegetable harvest, or mid-summer fallow periods as short as 5 to 6 weeks, during which buckwheat, cowpea, and some millets can develop substantial growth. Where winters are too cold or summers too hot for profitable vegetable production, suitably adapted cover crops can keep the soil covered during the "off season."

Slide 11 – *NRCS principle 2 – maintain living roots in soil profile*.

Plant roots are a key food source for the soil life, which in turn plays a central role in plant nutrition. The soil life performs two essential functions: *mineralization* (consumption of organic materials which releases plant available nutrients and respiratory CO2), and *stabilization* (conversion of organic residues into stable or long-lived SOM). Plant roots, their exudates, and root residues promote both of these vital processes by feeding the soil life with sugars, amino acids, and other organic materials.

The fine roots of winter cover crops like vetch, field pea, and crimson clover comprise 70% of below-ground biomass and contribute substantially to active SOM, biological activity and plant-available nitrogen and other nutrients.

Recent research reviews indicates that plant roots may also be the *primary* source of stable SOM, which is essential for long term soil health and carbon sequestration.

Another review showed the importance of deep, extensive roots and year round living roots in nutrient cycling and water quality. Deep rooted cover crops such as pearl millet, sunnhemp, and chicory can remove most of the excess nitrate from the entire soil profile to 7 or 8 feet deep – the millet can even penetrate hardpan to reach and cleanse the profile to this depth.

Hu, S., S. Hu, W. Shi, A. Meijer, and G. Reddy 2015. *Evaluating the Potential of Winter Cover Crops for Carbon Sequestration in Degraded Soils Transitioning to Organic Production* Project proposal and final report for ORG project 2010-04008. CRIS Abstracts.

Kell, D.B. 2011. *Breeding crop plants with deep roots: their role in sustainable carbon, nutrient and water sequestration*. Ann. Bot. 108(3): 407–418

Kell, D.B. 2012. *Large-scale sequestration of atmospheric carbon via plant roots in natural and agricultural ecosystems: Why and how*. Philos. Trans. R. Soc. B Biol. Sci. 367(1595): 1589–1597.

Rosolem, C. A., K. Ritz, H. Cantarella, M. V. Galdos, M. J. Hawkesford, W. R. Whalley, and S. J. Mooney. 2017. *Enhanced plant rooting and crop system management for improved N use efficiency*. Advances in Agronomy 146: 205-239.

Slide 12 – *NRCS principle 3 – build crop diversity for soil biodiversity*

Multiple studies have shown significant benefits of adding just one or two new cover crops – or even cash crops for that matter – to an existing low-diversity rotation such as corn-soybean:

Mycorrhizal fungi can play a major role in building stable SOM. Soil mycorrhizal populations may double after cover crops such as oats, rye, sorghum, sunnhemp, bahiagrass, and other legumes and grasses

McDaniel MD, L. K., Tiemann, and S. Grandy. 2014. *Does agricultural crop diversity enhance soil microbial biomass and organic matter dynamics?* A meta-analysis. Ecol Appl. 24(3):560-70.

K. Moncada, K., and C. Sheaffer, 2010. *Risk Management Guide for Organic Producers. U. Minnesota. 300 pp. Chapter 13, Winter Cover Crops*. http://organicriskmanagement.umn.edu/.

Douds, 2015. http://articles.extension.org/pages/18627/on-farm-production-and-utilization-of-am-fungus-inoculum

Duncan, 2017. ATTRA bulletin, National Center for Appropriate Technology, www.attra.ncat.org, 20 pp;

Finney et al., 2017. J. Soil & Water Conserv 72(4): 361-373.

Slide 13 – *NRCS principle 4 – minimize soil disturbance*.

The NRCS soil health principles were established by the NRCS Soil Health Team in Greensboro, NC. https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

Organic production usually entails some *physical* disturbance in annual crop production and strives to minimizes *chemical* disturbance by avoiding synthetic inputs. Non-organic conservation agriculture virtually eliminates physical disturbance and embraces judicious use of conventional fertilizers and herbicides, which may entail some chemical disturbance to soil life.

Slide 14 – *subheading – cover cropping for organic system – challenges and resources*.

Slide 15 – *Challenge #1 – selecting the cover crop*

Selecting your cover crop is a "matching game" that must take into consideration many factor pertaining to production system and the cover crop itself.

Because of the region- and site-specific nature of this process, *this webinar will not attempt to tell you what cover crops to use*. Refer instead to decision support tools and informational resources available in your region.

Slide 16 – *Other challenges – cover crop establishment, termination, nutrient management.*

A thin stand at emergence (in this case, resulting from poor seed quality in the soybean variety on the right) becomes a weedy cover crop. Inadequate stands can also result from unfavorable (dry or excessively wet or cold) soil conditions after planting, inadequate seeding rates, or poor seed-soil contact resulting from poor soil tilth or difficulties in planting through surface residues in reduced-tillage systems.

Slide 17 – *Nationwide information resources*

Slide 18 – *Challenges in north-central region – short growing season*

In colder regions with limited growing seasons and severe winters, it is difficult to fit cash and cover crops into the rotation – and growers are often faced with a tradeoff between terminating cover crops early (greatly reducing organic matter and other benefits) or shortening the available growing period for the cash crop, resulting in lower yields.

While roll-crimping or mowing the cover crop may save some time, yield tradeoffs with no-till cover crop management are often most severe in cooler regions because of stand establishment challenges with cover crop residues and slower soil warming.

Cover crops can be interseeded into standing corn, soybean, and other row crops. Rye + vetch planted into standing corn improved soil quality in Minnesota (very short growing season), while post-harvest cover crop plantings did not develop sufficient biomass to confer benefits. In upstate New York, cover crops were successfully established at last cultivation, at 4-leaf stage in soybean, 5 leaf stage in corn. Cash crops were planted in rows 30 inches apart, and a drill interseeder was used to plant three rows of cover crop (7.5 inch spacing) in each alley.

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.

Caldwell, B., C. Pelzer, and M. Ryan. 2016. *Cover crop interseeding research in New York*. What's Cropping Up, vol. 26 no.2. http://blogs.cornell.edu/whatscroppingup/2016/03/15/cover-crop-interseeding-research-in-new-york/.

Slide 19 – *Resources for North Central region*

Cover crop decision tools and resources are most developed for the North Central Region. The MCCC has developed cover crop decision tools in which the user enters state and county, cash crop, soil drainage, and cover cropping goals, and then receives recommendations on cover crop species and planting dates. Decision tools are available for field crops in all states in the region, and for vegetable crops for Michigan only.

The video by Erin Silva of University of Wisconsin shows a highly successful example of "planting green" in organic systems, in which soybeans were planted into standing winter rye cover at the boot stage, and the rye was roll-crimped as beans emerged, resulting in an excellent, weed-free stand.

Slide 20 – *Challenges in Northeast region – short growing season*

These are some creative ways in which vegetable growers in the Northeast region meet the growing season challenge through relay cropping. Sweet corn/soybean and tomato/clover examples are from Eliot Coleman's market garden in central Vermont. The potato example, an experiment conducted by Dr. Ron Morse of Virginia Tech in the Appalachian region of Virginia (climate similar to New Jersey) gave substantially greater cover crop biomass as well as a potato yield increase of about 17% compared to tilling the cover crop in before planting.

Slide 21 – *Resources for Northeast region*

The Northeast Cover Crop Council web site is still in development, but substantial resources are already available. Cornell University and Pennsylvania State University have also conducted extensive research on cover crops for organic systems, and have published findings in Extension bulletins, newsletters, and eOrganic articles and videos.

For Penn State cover crop research findings and extension bulletins for organic systems, visit https://extension.psu.edu/, and search "cover crops for organic farming.

For Cornell organic farming systems research, including cover crops and rotations, visit http://www.hort.cornell.edu/extension/organic/ocs/.

Slide 22 – *Challenges in Southern Region – excessive summer heat*

In the hotter parts of the South, many vegetable growers take fields out of production during summer months, when high temperatures, dry spells, intense weed competition, and other pest problems complicate crop production. Some weeds such as Palmer amaranth and purple nutsedge attain their greatest growth rates near 100 degrees F, a temperature that severely limits growth, pollination and fruit or grain set in most food crops.

Leaving fields unplanted will burn up SOM and degrade soil health, but planting them in heat-loving crops like these tropical grasses and legumes will protect and build soil.

Photos were taken at NC State U Center for Environmental Farming Systems (CEFS) at the 2016 Southern SARE Cover Cropping Conference, July 19 2016. Other heat loving cover crops include pearl millet and all forms of cowpea (southern pea).

Slide 23 – *Additional challenge in South – highly weathered, low fertility soils*

In a coastal South Carolina study, a rye cover crop, facilitated by adequate soil moisture from winter rains, was able to penetrate the compacted E horizon, allowing the following cash crop (cotton) to send its roots deeper, obtain sufficient moisture, and give good yields. Without the

cover crop, cotton yielded poorly unless deep (subsoil) tillage was performed before planting. Two years of rye cover cropping also significantly enhanced SOM over the no-cover treatment on these sandy soils.

Sorghum-sudangrass, pearl millet (summer), tillage radish (fall), and sweetclover (biennial) are even more powerful subsoiling crops than rye.

Reference on rye/cotton study: 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 24 – *Resources for Southern region*.

The Southern Cover Crop Council was launched after the July, 2016 Southern SARE Cover Crop Conference, and the website is still in early stages of development, with information only available for the Coastal Plain region as of August, 2018. However, several excellent articles on best equipment, methods, and timing of cover crop planting and termination, and best equipment for improving cash crop establishment on sandy yet compaction-prone coastal plain soils are now available.

Slide 25 – *Western region – leading challenge is limited moisture*

The traditional wheat fallow rotation (with one wheat crop every two years, and > 12 months continuous bare fallow) cannot maintain SOM levels even when continuous no till is practiced.

Simply adding one cover or cash crop to the fallow year has improved soil health in multiple studies, especially when a multispecies cover crop cocktail is used. However, effects on dryland grain yields in multiple studies from western Nebraska and the Dakotas through the interior Pacific Northwest have varied from positive or neutral to severe yield tradeoffs, depending on moisture dynamics.

A winter cover crop of field peas such as Austrian Winter Pea has shown promise for building soil health without moisture-related yield penalties in two studies:

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.

Slide 26 – *Resources for Western region*

A two day meeting convened earlier this year to explore establishment of a Western Cover Crop Council was announced in a May 29, 2018 on line article in No till Farmer.

Slide 27 – *SARE annual cover crop surveys*.

Annual surveys conducted through the USDA Sustainable Agriculture Research and Education (SARE) program document a steady increase in successful implementation of cover

cropping by both organic and non-organic farmers, most of whom see evidence of improving soil health, often within a year or two of adopting the practice.

Yield benefits of cover crops were greatest where cover crops have been used for four or more seasons.

Both number of farmers using cover crops, and acres cover cropped per farm rose steadily through the five years of survey. Farmers surveyed in 2017 cover cropped average of 400 ac in 2016 with plans to expand to 450 ac in 2017.

"Planting green" means sowing the cash grain into standing cover before termination (lengthens cover crop growth period, reduces seed-soil contact issues). Note that these were mostly non-organic farmers (48% used herbicide termination in 2012). Planting green may be risky in organic systems, and should be tried on a small area first.

Slide 28 – *subheading – selecting and managing cover crops for soil health*

Slide 29 – *selecting cover crops – getting started*

Diverse crop rotations and multi-species cover crops can give the greatest soil health benefits by "stacking" functions (such as nutrients, organic matter, and soil biology), but can be challenging to design, plant, and manage.

If you are new to cover cropping, start simple, and gradually build more diversity into the crop rotation. You don't have to plant a fancy, 10-species "cocktail" to realize substantial soil health benefits. Plant an adapted, easy-to-manage cover crop wherever there is a significant time gap in the rotation.

A winter rye monoculture is far kinder to the soil than winter fallow; and planting buckwheat during a 40-day summertime gap in the production schedule can save soil from an untimely cloudburst.

When practical, plant cover crops that are dissimilar from your production crop – for example, a cereal grain after summer vegetables, or a legume following corn or wheat. Avoid using a cover crop that is closely related to the preceding or following cash crop, especially when diseases are a concern – hairy vetch, bell bean, or Austrian pea prior to snow, snap or shell peas; or mustard, canola, or tillage radish immediately before or after broccoli, cabbage, or other cruciferous vegetables.

Slide 30 – *Timely cover cropping averts disastrous soil loss in Floyd, VA flood of 2015.*

This demonstration of the value of cover crops took place in the co-presenter's home community. His farmer neighbor, Abel Duffy, planted a cover crop promptly after potato harvest in July. The sorghum-sudan was flattened by the torrent, but not killed; it bounced back and resumed growth until first frost.

Slide 31 – *Cover cropping for soil health – protect the surface, stop erosion*

The photo was taken 53 days after seeding alternate rows of cowpea and foxtail millet at Charlie and Miriam Maloney's Dayspring Farm in the Tidewater region of Virginia.

Slide 32 – *Cover cropping for soil health – building SOM*

High biomass cover crops with persistent residues – primarily cereal grains and other grasses – are most widely recommended for building SOM. However, soil life needs *both* organic carbon and organic nitrogen to thrive, grow, and transform organic residues into stable SOM.

Studies have shown that organic inputs with a balance of carbon and nitrogen (C:N ratio ~25 – 30:1) build SOM more effectively than inputs with very low (chicken litter) or very high (corn stover) C:N. The same may be true for cover crops; it is known that succulent, low C:N green manures stimulate microbial activity and enhance active SOM, but do not accrue much stable SOM.

Several studies have shown that perennials maintain much higher root biomass than annuals, and that a perennial sod or "prairie mix" is most effective for restoring soil health during the three-year organic transition period.

Fortuna, A., D. Collins, and C. Cogger. 2014a. *Management to Reduce N_2O Emissions in Organic Vegetable Production Systems*. Webinars at: http://articles.extension.org/pages/70280/two-part-webinar-series-on-greenhouse-gas-emissions-and-soil-quality-in-long-term-integrated-and-tra.

Grandy, S., and C. Kallenbach. 2015. *Microbes drive soil organic matter accumulation in organic cropping systems*. Recording from the Organic Agriculture Research Symposium LaCrosse, WI February 25-26, 2015. http://eorganic.info/node/12972.)

Hurisso, T. T., S. W. Culman, W. R. Horwath, J. Wade, D. Cass, J. W. Beniston, t. M. Bowles, A. S. Grandy, A. J. Franzluebbers, M. E. Schipanski, S. T. Lucas, and C. M. Ugarte. 2016. *Comparison of Permanganate-Oxidizable Carbon and Mineralizable Carbon for Assessment of Organic Matter Stabilization and Mineralization*. Soil Sci. Soc. Am. J. 80 (5): 1352-1364.

Borrelli, K., R. Koenig, I. Burke, E. Fuerst and R. Gallagher. 2011. *Nitrogen Dynamics in Nine Rotation Systems From Transition to Certification of Organic Dryland Grain Production*. ASA Annual Meeting. https://a-c-s.confex.com/crops/2011am/webprogram/Paper66429.html.

Briar, S.S., S.A. Miller, D. Stinner, M.D. Kleinhenz, and P.S. Grewal. 2011. *Effect of organic transition strategies for peri-urban vegetable production on soil properties, nematode community and tomato yield*. Applied Soil Ecology 47:84-91.

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.

Slide 33 – *Cover cropping for soil health – topsoil tilth*

Dense, fibrous root systems, such as those of ryegrass and cereal grains, provide a rich supply of root exudates to support the growth of soil microbes, which in turn promote soil aggregation and improve tilth.

Slide 34 – *Cover cropping for soil health – relieving subsurface compaction or hardpan*

Pearl millet has demonstrated an ability to penetrate naturally compacted and acidic subsurface soil layers that stop the root growth of most other crops, effectively scavenging nitrate-N from within and below the compaction layer. Tillage radish leaves deep macropores that enhance rooting depth and nutrient uptake of a following corn corp. As mentioned earlier, winter rye confers similar benefits to no-till cotton grown in compaction-prone southeastern US coastal plain soils.

Menezes, R. S. C., G. J. Gasho, W. W. Hanna, M. L. Cabrera, and J. E. Hook. 1997. *Subsoil nitrate uptake by grain pearl millet*. Agronomy Journal, Vol. 89 No. 2, p. 189-194.

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.

Marshall et al., 2016 – cited earlier.

Slide 35 – *Cover cropping for soil health – feeding soil life, building biodiversity*

Cereal grains, most other grasses, and legumes are strong mycorrhizal hosts. Buckwheat and crucifers (radish, mustard) are non-hosts; a cover crop dominated by crucifers may temporarily depress soil mycorrhizal activity.

Plant biomass and biodiversity support abundant, diverse soil life, and can be accomplished either through complex mixes or cocktails, or by using different one- or two-species cover crops throughout the rotation.

Slide 36 – *Selecting cover crops for challenging soils*.

Soils with existing "health challenges" may require special considerations in selecting cover crops – and cover crops that can successfully establish under these conditions will also help correct them and restore soil health. In addition to the examples listed here, including legumes in the mix will help address low or spatially-variable levels of plant-available N in the soil. Where N is low, the legume will tend to dominate and enhance N levels; where N is ample or excessive, the non-legumes will dominate, mop up the surplus, and slow-release it to future crops. As noted earlier, deep rooted cover crops (radish, pearl millet, sorghum-sudangrass, sweetclover) address subsurface compaction, and thereby markedly improve soil productivity.

Slide 37 – *Stacking functions, cover crop mixes*

Organic producers commonly seek to "stack functions" in selecting cover crops and mixtures; for example, reducing pest and pathogen populations and suppressing weeds while improving soil health and fertility. This is the rationale for planting multispecies cover crops. The most widely used mixes consist of a grass and a legume with similar seasonal requirements (e.g. winter rye + crimson clover, or millet + forage soybean). Farmer experience and research findings confirm that the legume-grass biculture often yields better soil health outcomes and perform more functions than either grass or legume alone. Biomass and ground coverage is enhanced especially when a tall grass provides support for a vining legume (cereal grain + vetch or pea; or sorghum-sudan + cowpea, lablab, or velvet bean).

Over the past 15 years, farmers, researchers, and conservation professionals have used highly diverse "cover crop cocktails" composed of five to 15 species from three or more plant families in an effort to maximize soil health and fertility. Results have been mixed, but at time truly impressive:

Dave Brandt in Ohio had maximal corn grain yields with no added N the year after a season long 10-species cover crop mix of cool and warm season grasses, legume, and forbs.

Ray Archuleta (NRCS scientist) demonstrated greatly improved soil health and moisture holding capacity in North Dakota from growing such cocktails in lieu of the traditional fallow year.

In other studies, stands have been dominated by the most aggressive species in the mix, often buckwheat in summer and rye or crucifer in winter, so that the functions of other components may be lost, such as legume N fixation.

Barbercheck, M. E., J. Kay, D. Mortensen, C. White, M. Hunter, J. Hinds, and J. LaChance. 2014. *Using Cover Crop Mixtures to Achieve Multiple Goals on the Farm* http://articles.extension.org/pages/71186/using-cover-crop-mixtures-to-achieve-multiple-goals-on-the-farm-webinar. Additional results at http://agsci.psu.edu/organic/research-and-extension/cover-crop-cocktails - Click on "annotated figures and findings."

Drinkwater, L. E., and D. H. Buckley. 2010. *Optimizing Biological Nitrogen Fixation in Organic Cropping Systems for Sustainable Nutrient Management*. Final report for ORG project 2006-02030. CRIS Abstracts.

Slide 38 – *Cover cropping for nutrient management*

The complementary traits of grass and legume are clearly demonstrated with regard to nutrients. Most farmers know from experience that a single species cover crop of cereal grain or sorghum-sudangrass can tie up N and increase crop requirements for applied N; while a legume cover crop can reduce or even eliminate the need to add N for optimum yields.

However, researchers have documented substantial leaching of nitrate-N after tilling-in an all-legume cover crop such as hairy vetch or red clover. In addition, a recent meta-analysis and modeling study covering 8,000 site across Europe indicated that regular use of all-legume cover crops can release the powerful greenhouse gas nitrous oxide in quantities that would negate the climate-mitigation benefits carbon sequestration from the cover crop itself.

Lugato, E., A. Leip, and A. Jones. 2018. Mitigation potential of soil carbon management overestimated by neglecting N_2O emissions. Nature Climate Change 8: 219-223. www.nature.com/natureclimatechange.

Cover cropping for N fixation and nutrient cycling will be explored in more depth in the Nutrient Management webinar in this series, Feb 20, 2019. (W. SARE Oct 24, 2018).

Slide 39 – *Cover cropping for weed management*

The cowpea was grown in a summer cover crop trial that was planted in a weedy seedbed; it was the only cover crop that did not become weedy by the time this photo was taken.

In another trial, a winter cover crop of rye + vetch remained nearly weed free for eight weeks after no-till termination by mowing, while rye alone became infested with horseweed (which tolerates low soil fertility, and vetch alone with pigweed (which responds to high soluble N levels).

Organic integrated weed management including the use of cover crops was covered in greater depth in the Weed Management webinar in this series (June 13), which is archived on the Organic page of the Extension website.

Slide 40 – *Cover cropping for pest management – attracting beneficial insects*

The adult phases of many pest predators and parasitoids, such as micro-wasps, hover flies, and lady beetles, depend on pollen and nectar for nourishment, while low-growing cover crops and surface residues provide habitat for many generalist predators including ground beetles, spiders, and minute pirate bugs.

Slide 41 – *Cover cropping for pest and disease management – crop rotation.*

Some pests and diseases can be managed by lengthening and diversifying the crop rotation and adding strategically selected cover crops.

Choose cover crop species that are not closely related to the immediately preceding or following production crops – from a different plant family as a rule, though winter cereal grains can often follow corn or sorghum, and cool- and warm-season legumes from different sub-families can often follow each other. On the other hand, some pests can affect unrelated plant families, for example, root-knot nematode can proliferate on some clovers and seriously affect a subsequent tomato or pepper crop.

Cowpea, sunnhemp, and sorghum-sudangrass have been recommended for reducing populations of plant root feeding (pest) nematodes, but their efficacy appears related to both cover crop cultivar and nematode species.

The crop rotation manual, jointly published by SARE and the Natural Resources, Agriculture, and Engineering Service (NRAES) is based on input from a dozen experienced organic producers in the northeastern US, combined with research findings regarding impacts of different cover crops on a range of crop pests, including insects, weeds, plant root-feeding nematodes, and microbial pathogens. The manual provides extensive tables that help users identify the best cover crops to avoid or manage specific pest problems.

Slide 42 – *Cover crop management tips –planting*

Cover crops are not as fussy about fine seedbed and ample nutrients as most production crops. However, it pays to attend to basics to ensure prompt establishment of a good stand and vigorous growth. Poor seed-soil contact, old or low-vigor seed, and delayed planting of fall and winter cover crops are common causes of poor or weedy stands and reduced biomass.

When restoring nutrient-depleted fields or converting fields from conventional to organic production, applying compost or manure before cover crop planting can enhance biomass and soil health outcomes. If soil pH is excessively acidic or alkaline, select cover crops adapted to these conditions and amend soil (lime or sulfur) to address the pH.

When combining two or more species, each species can be sown at lower than its recommended rates for single-species stands. Reduce rates most for the most competitive species (e.g. in an oats-crimson clover mix, sow oats at 50% and clover at 75% of their respective full rates). You can also start by simply dividing sole seeding rates by the number of species in the mix, then observe results to adjust rates in future years.

Increase rates somewhat for weedy field and late plantings – however note that very high seeding rates (e.g., each specie of a four-way mix at 100% of its sole-species rate) can be counterproductive, as overcrowding reduces vigor and biomass. It is also more expensive!

If soil and weather are dry, irrigate immediately after planting if practical, to get the stand established.

Slide 43 – *Example of cover crop planting technique*

Normal seeding rates in this region for rye alone are 100-150 lb.ac, and for vetch alone 30-40lb/ac - thus rye rates were reduced proportionally more than vetch.

Slide 44 – *Cover crop management tips – termination*

Terminating cover crops any time between full bloom and early seed development, but before seeds begin to mature or foliage begin to turn yellow or dry up gives best results in term of total biomass and nitrogen, SOM, soil biological activity, and overall soil health. Tillage can compromise some of the cover crop benefits to SOM and soil life, but no-till and minimum till

methods can be more challenging to implement and manage, especially in northern regions with shorter growing seasons.

Planting a non-winter-hardy cover crop early enough in the fall to generate substantial biomass before winterkill can be a good strategy ahead of an early spring cash crop. When practical, allow frost-killed cover crops to remain on the surface until shortly before planting. The weathered residues may require only light tillage to prepare the seedbed.

Practical Conservation Tillage in organic production was covered in an earlier webinar (September 19), now archived on the Organic page of the Extension website.

Slide 45 - *Questions*

Cover Crop Resource Section: Details

General / National

SARE Learning Center – Cover Crops Topic Room:
https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/
Annual SARE farmer surveys (latest 2016-17)
Selection and management (links to regional decision tools)

Cover Cropping in Organic Farming Systems
eOrganic articles on Extension web site
https://articles.extension.org/pages/59454/cover-cropping-in-organic-farming-systems.

Southern Region

Southern Cover Crop Council
https://southerncovercrops.org.

- Website in development.
- Decision tool in development
- Divided into subregions –subtropical, coastal plain, piedmont / mountain ridge and valley, etc
- Only coastal plain info now available – several excellent articles including:
- How to plant cover, how and when to terminate – valuable practical guidance on planting and termination tools, timing, etc. Guidelines for organic as well as conventional.
- How to get good seed-soil contact when planting in cover crop residue – good tips for sandy, compaction-prone coastal plain soils.

Southern Cover Crop Conference (SSARE) https://www.southernsare.org/Events/Southern-Cover-Crop-Conference. Links to videos and info sheets, addressing cover crop selection and mixtures, soil biology and soil health, economics of cover crops (three info sheets), and

improved roll-crimper for field scale and 2-wheel walk behind tractor; narrow and wide strip till applications. Also grazing cover crops (which, unlike baling off residues, can be sustainable).

Videos – mechanical termination, summer cover crops, grazing, reseeding (crimson clover) in cotton, cover crop for high tunnel (legume-grass for biomass SOM, sunflower for taking up excess salts; mustard for biofumigation).

Northeast Cover Crop Council
http://northeastcovercrops.com/.

- Website in development.
- Decision tool coming in fall 2018
- Guidance for doing on-farm cover crop trials, invitation to share photos, results (interactive function)
- Extensive state by state info – links to research and extension bulletins, etc.
- Annual Conference – next one in State College, PA – Nov 15-16, 2018.

Midwest Cover Crop Council
http://mccc.msu.edu/.

- Decision tools for field crops (all states), vegetables (MI only) giving cover crop species and planting dates based on cash crop, soil drainage, and cover crop goals.
- State by state info and links to research and extension bulletins.
- Information by cover crop species.
- Getting Started – planting, equipment, termination. Erin Silva – planting organic soybeans into boot stage rye, roll crimp later as soybeans emerge - https://www.youtube.com/watch?v=YuvSbmumgcI.
- Interseeding cover crops into standing grain or soybean crops.
- Annual Conference – next one Feb 20-21, 2019 in Springfield, IL.

Western Region

Western Cover Crop Council – just getting launched
Article on line in No Till Farmer: https://www.no-tillfarmer.com/articles/7907-new-cover-crop-council-taking-shape-in-western-us.
Being launched by Grassland Oregon (forage and cover crop seed company) - working with universities, SARE, agencies.

Jerry Hall, research director of Grassland Oregon, states, “It’s important that we move past speaking of species only and start talking about varieties. We’ve made great strides in breeding varieties with significant improvements such as increasing Nitrogen contribution and cold tolerance. These advancements provide powerful new tools to farmers who expect performance and consistent results. When recommending cover crop species – varieties make a huge difference.”

Article dated May 29, 2018, states that “at a recent 2 day meeting” organized by Grassland Oregon, Hall indicated that USDA SARE is supportive of creating a Western CCC.

Cover Crops in Organic Systems
https://www.sare.org/Learning-Center/SARE-Project-Products/Western-SARE-Project-Products/Organic-Conservation-Training/Cover-Crops-in-Organic-Systems/Cover-Crops-in-Organic-Systems.
Authors Rex Dufour (National Center for Appropriate Technology); Sarah Brown, Ben Bowell and Carrie Sendak (Oregon Tilth); Mace Vaughan and Eric Mader (Xerces Society)

Based on NRCS practice CPS 340 Cover Crop adapted for western region with emphasis on vineyard, orchard, vegetable crops. Also available on ATTRA, listed at https://attra.ncat.org/organic/.

2013 – 20 pp.