

Selecting and Managing Cover Crops for Rotations in the Western Region

Research-based Practical Guidance for Organic and Transitioning Farmers

eOrganic Soil Health and Organic Farming Webinar Series

February 27, 2019

Developed and presented by Organic Farming Research Foundation, with funding from USDA Western Region Sustainable Agriculture Research and Education (SARE)

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

Slide 1 – *title slide.*

Slide 2 – *Cover crop research priorities for western region organic farmers*

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).

Soil health emerged as the #1 research priority among respondents in the OFRF survey in all four USDA regions. Western region organic farmers need more research on building soil health through cover cropping when moisture is limiting. Fertility management was the #2 priority, and specific topics included use of cover crops to build fertility in perennial crops, and N fixing cover crops for arid regions, including between-bed cover crops in drip-irrigated systems.

During the question and answer time in earlier webinars of this series (weed management, conservation tillage), questions included:

- Cover cropping for arid region (7 inches a year).
- Short season self-seeding covers, and high diversity mixes (8+ species) for Northern Great Plains.
- Cover crops to suppress pigweed and bindweed in alleys.

Slide 3 – *How cover crops protect and build soil health: basic concepts and research findings*

Slide 4 – *Soil health benefits of cover crops*

Slide 5 – *NRCS soil health principle #1 keep soil covered*

When fields are left unplanted without soil protection after crop harvest, exposed soil surfaces undergo temperature extremes and intense drying that can inhibit or injure soil life and “burn up” organic matter. Bare soil is subject to wind and water erosion, which intensify the loss of organic matter and fertility. Living cover crops and crop residues can prevent much of this degradation.

Too many fields in the Western region and across the US stand idle with little or no cover after harvest, and continue to erode, lose organic matter, and leach leftover nutrients through the winter. Winter hardy annual cereal grains and legumes can protect and build the soil between early fall harvest and planting of another warm-season cash crop. A fall cover crop that

winterkills (e.g., millet, cowpea, and buckwheat in Zone 8, or oats and bell bean in zone 6) can protect the soil with their residues through the winter ahead of an early spring vegetable.

In diversified rotations that include both warm- and cool-season production crops, cover crops can be planted in early spring ahead of a summer crop, late summer after an early harvest, or mid-summer fallow periods as short as 5 to 6 weeks, during which buckwheat, cowpea, and some millets can develop substantial growth.

In moisture-limited regions where water consumption by continuous living cover might limit dryland cash crop yields, residues of mowed, undercut, or weather-terminated cover crops can be left undisturbed through a dry summer season to prevent erosion, conserve moisture, and reduce weed growth until the next cash crop.

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/mgmt/>.

Slide 6 – NRCS soil health principle #2 maximize living roots

Plant roots are a key food source for the soil life, which in turn plays a central role in plant nutrition. Production crops also perform this vital function; cover crops ensure that the process continues after harvest and takes place between as well as within wide-spaced crop rows, such as vineyard.

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 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. In addition, recent research indicates that plant roots may be the *primary* source of stable SOM, which is essential to long term soil health and carbon sequestration.

An abundance of living roots also protects water quality by recycling nutrients. Deep-rooted cover crops such as pearl millet, sunnhemp, and chicory can remove most of the excess nitrate-N 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 7 – NRCS soil health principle #3: increase crop diversity

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. Even when overall crop intensity (biomass, duration of living cover) remains constant, a greater diversity of plant families and species, seasonal life cycles, and root depth and architecture supports a greater and more balanced diversity of soil life that can perform a more complete range of functions vital to soil fertility and crop production.

High-diversity cover crop mixes or “cocktails” are designed to maximize soil functional biodiversity. It can be tricky to balance the seed mix to ensure that all components play significant roles. When one or two species dominate and choke out the others, some of the diversity benefits are lost – though the outcome is still far better than bare fallow.

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/>.

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.”

Douds, D. 2015. *On-farm production and utilization of an AM fungus inoculum*. <http://articles.extension.org/pages/18627/on-farm-production-and-utilization-of-am-fungus-inoculum>;

Duncan, J. 2017. *Cover crop options for hot and humid areas*. ATTRA bulletin, National Center for Appropriate Technology, www.attra.ncat.org, 20 pp;

Finney, D. M., J. S. Buyer, and J. P. Kaye. 2017. *Living cover crops have immediate impacts on soil microbial community structure and function*. *J. soil & Water Conserv* 72(4): 361-373.

Slide 8 – NRCS soil health principle #4: minimize disturbance

The fourth soil health principle – minimizing soil disturbance – is the most challenging for annual cropping systems, as some form of physical (tillage) or chemical (herbicide) disturbance is generally required to manage cover crops, weeds, and residues to prepare the field for planting the next cash or cover crop in the rotation. Organic production of annual crops usually entails some *physical* disturbance and strives to minimize *chemical* disturbance by avoiding all synthetics. Note that reliance on concentrated organic nutrient sources rich in P and soluble N (e.g., poultry litter) can also affect soil health by reducing the activity and function of mycorrhizal fungi and other microbes involved in nutrient cycling and formation of stable SOM.

Non-organic conservation agriculture virtually eliminates *physical* disturbance and embraces judicious use of conventional fertilizers and herbicides, which results in some chemical disturbance to soil biota.

A growing toolbox of strategies, tactics, and implements for reducing soil disturbance in cover crop intensive organic production systems is becoming available to producers. The cover crop itself reduces soil disturbance by maintaining the flow of root exudates for soil life while the field is not in production, and sometimes by suppressing weeds sufficiently to eliminate one or more cultivation passes, or by reducing the amount of concentrated organic fertilizers needed to sustain cash crop yields.

Newer tools and techniques for managing cover crops and preparing seedbeds can improve soil health compared to “standard” moldboard plow-disk or rotary tillage. Examples include flail-mowing the cover crop so it can be mixed in more shallowly (as shown here) terminating the cover with a blade plow or sweep plow undercutter, or incorporating it with a rotary spader.

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%.

The spader provides deep non-inversion tillage, and can incorporate a substantial cover crop biomass and create a seedbed in one pass. 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. They have adopted the spader as their “full tillage” control treatment in further research into cover crop based reduced tillage in organic vegetable rotations.

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.

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 9 – Cover crops and soil health in the National Organic Standards

The National Organic Standards clearly require certified organic producers to integrate soil building crops into their rotation (crops whose primary purpose is to perform key soil health functions, not to make income directly). “Sod” refers to a perennial grass, legume, or (best) a

grass-legume-forbs mix grown for one or more years in the rotation, with or without grazing. “Green manure” generally indicates a cover crop (often but not always a legume) that is tilled in to provide crop available nutrients, while a “catch crop” is a cover crop (usually deep rooted and/or heavy N feeder) that recovers surplus nutrients from the soil profile and prevents nutrient losses to leaching.

Slide 10 – *Living plant cover*

Why are cover crops emphasized in the NOP standards and NRCS working lands conservation programs? Healthy, living soils develop through an ongoing partnership between plant roots and beneficial soil micro and macro-organisms. Paleo-botany research (reviewed by Montgomery, 2017) indicates that this has been true since living plants first appeared on the land about 450 million years ago. The earliest land plants had to make a living on very primitive and infertile soils at best – a feat apparently made possible by mycorrhizal fungal symbionts.

Organic agriculture is based on an integrated and holistic approach to soil and ecosystem health. As the primary source of land-based organic carbon on Earth, the living plant is nature’s way of building soil, and is therefore 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.

Based on an extensive review of soil health research across regions, Dr. Sara Via of University of Maryland estimates that up to 40% of plant photosynthetic product is delivered to the soil life via the roots, and that the majority of stable SOM is derived from microbial processing of root exudates and root residues.

Montgomery, D. R. 2017. *Growing a Revolution: bringing our soil back to life*. W. W. Norton & Co., New York. 316 pp.

Via, S., 2019. *Sequestering Carbon in Agricultural Soils: What Works?* Webinar presented by the USDA Northeast Climate Hub, February 12, 2019.

Weil, R. R., and N. C. Brady 2017. *The Nature and Properties of Soils, 15th Edition*.

Slide 11 – *Sustainable crop intensification*

The understanding that “the more plant growth, the more soil organic matter and soil life, and the healthier the soil” has led to the concept of *sustainable crop intensification*, defined as maximizing living plant cover and growth throughout the crop rotation. Some of the soil health 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, silage corn, and hay crops (roots remain in soil profile), smaller for fruiting vegetables and grains (roots and stover left in field), minimal for perennial fruit crops, and of course none for cover crops and sod that are not harvested. Well-managed rotational grazing does not create a “debit” and can even enhance plant biomass and nutrient return over ungrazed sod, whereas poorly managed grazing or overgrazing can sharply reduce plant biomass and root depth, and thereby degrade soil.

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

Note that crop intensification must also meet the “sustainable” criterion in relation to moisture availability – total annual precipitation, seasonal patterns, and inherent soil properties that may affect water holding capacity. For example, while adding a year or two of alfalfa sustainably intensifies a corn-soy-wheat rotation and builds SOM in humid climates of the Midwest, alfalfa is a high-water-demand crop that may not fit well in a dryland rotation receiving 10 inches per year. More on this later in the presentation.

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

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

Slide 12 – *Cover crops work with organic amendments and careful tillage to build healthy soil*

Other organic practices – compost, manure, biochar, humates, microbial inoculants, 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, biological activity, 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.*

Tavantzis, S. M., R. P. Larkin, A. V. Alyokhin, M. S. Erich, and J. M. Jemison. 2012. *A Systems Approach to Optimize Organic Crop Production: Enhancing Soil Functionality and Plant Health to Suppress Plant Diseases and Pests*. Final report for ORG project 2007-01405. 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 13 – *Subtitle slide – Adding cover crops to organic production systems – research examples from the Western Region*

Slide 14 – *Organic vegetables with winter fallow in Salinas Valley, California*

In the Mediterranean climates of California and the Pacific Northwest, most of the annual rainfall occurs during the winter months, yet crop production takes place during spring, summer and autumn, with fields often left fallow in winter. Depending on locale and the timing of cash

crop harvest, cover crop planting and establishment can be complicated by either dry or excessively wet soil conditions. Winter cover crop establishment and growth can also be constrained by excessive moisture, or by freezing temperatures in northern or inland locations.

Winter fallow (bare soil) intensifies risks of N leaching and denitrification, as well as compaction, erosion, waterlogging, and other adverse impacts on soil health. Studies at UC Davis have documented severe N leaching and denitrification losses during fallow after a heavily fertilized organic broccoli crop. Similar N losses took place when strawberries were planted in November after a September broccoli harvest, as strawberry N utilization takes place mostly in late spring, long after broccoli residue N has leached away. This puts environmentally conscientious organic producers in a dilemma, as organic broccoli responds so abundantly to increasing N up to 200 lb/ac (from feather meal and other NOP allowed sources), that it returns \$4 – 34 for every \$1 spent on fertilizer.

Collins, D. P. and A. Bary. 2017. *Optimizing nitrogen management on organic and biologically intensive farms*. Proceedings of the Special Symposium on Organic Agriculture Soil Health Research at the Tri-Societies Annual Meeting, Tampa, FL, October 22-25, 2017. <http://articles.extension.org/pages/74555/live-broadcast:-organic-soil-health-research-special-session-at-the-tri-societies-conference>.

Li, C., Salas, W. and Muramoto, J. 2009. *Process Based Models for Optimizing N Management in California Cropping Systems: Application of DNDC Model for nutrient management for organic broccoli production*. Conference proceedings 2009 California Soil and Plant Conference, 92-98. Feb. 2009. <http://ucanr.edu/sites/calasa/files/319.pdf>.

Muramoto, J., C. Shennan, and J., M. Gaskell. 2015. *Nitrogen management in organic strawberries: challenges and approaches*. (Webinar) <http://articles.extension.org/pages/73279/nitrogen-management-in-organic-strawberries:-challenges-and-approaches>

Slide 15 – *Organic vegetables + cover crop*

In an eight-year farming systems trial conducted on a loamy-sand soil in the Salinas Valley of California by Dr. Eric Brennan of USDA Agricultural Research Service (Salinas Organic Cropping Systems Experiment), a double cropping system of spring lettuce followed by fall broccoli sustained high lettuce yields (1000 boxes/ac, about 30 lb/box) only when a winter cover crop was grown prior to the lettuce. In the system that left the field fallow three winters out of four, lettuce yields declined sharply to a few hundred boxes per acre, and sometimes to a total crop failure. Cover crops of rye alone, mustard, or rye with vetch, fava, and pea were similarly effective, indicating that their main benefit was not N fixation per se, but recovery of N left over from the broccoli crop. The broccoli crop was fertilized with about 145 lb N/ac (from NOP allowed organic sources), only about 25% of which was removed in harvest. During winter fallow, leaching by heavy winter rains falling on the sandy soil depleted soil N, whereas vigorous winter cover crops recovered N and their residues delivered it to the lettuce.

In addition, the combination of cover crops plus compost enhanced soil microbial activity to a much greater degree than the compost alone, even though the compost comprised the majority of organic carbon inputs and contributed most of the stable SOC accrual over the eight year period.

The studies also highlighted the challenge of P balance in organic systems. Organic N sources such as compost, manure, and poultry litter based fertilizers add far more P than crop harvests remove, resulting in buildup of excessive soil P. Legume cover crops can play a vital role in providing N without P, and allowing a substantial reduction in P-rich organic fertilizer inputs and better overall nutrient balance.

Brennan, E. 2018. *Lessons from long-term, cover crop research in the Salad Bowl of the World* – 10 minute youtube video, <https://www.youtube.com/watch?v=JurC4pJ7Lb4>

Brennan, E. B., and V. Acosta-Martinez. 2017. *Cover cropping frequency is the main driver of soil microbial changes during six years of organic vegetable production*. *Soil Biology and Biochemistry* 109: 188-204.

Maltais-Landry, G., K. Scow, E. Brennan, E. Torbert, and P. Vitousek. 2016. *Higher flexibility in input N:P ratios results in more balanced phosphorus budgets in two long-term experimental agroecosystems*. *Agriculture, Ecosystems, and Environment* 223: 197 – 210.

Slide 16 – *Alternate year fallow in organic dryland grain production*

Multiple studies across the Northern Great Plains and the interior Pacific Northwest have shown that the traditional two-year wheat/fallow system (one wheat crop every two years, and > 12 months continuous fallow without living vegetation), intended to store up two years' moisture for the crop, invariably depletes soil organic matter (SOM) and reduces the soil's moisture holding capacity. Even in continuous no-till or in organic systems, alternate year fallow harms soil health.

Engel, R. E., P. E. Miller, B. G. McConkey, and R. Wallander. 2017. *Soil organic carbon changes to increasing cropping intensity and not-till in a semiarid climate*. *Soil Sci. Soc. Am. J.* 81:404-413.

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*. Proposal and final progress report for ORG project 2005-04477. CRIS Abstracts.*

Norton, J. B., M. B. Press, and J. P. Ritten. 2014. *Marketing Opportunities and Constraints Confronting Organic Farming Operations in the High Plains*. Proposal and Final Report for OREI project 2009-01436. CRIS Abstracts.*

Slide 17 – *Adding cover crops to organic dryland grain production*

In moisture limited regions, adding cover crops to the fallow year requires care to balance their many benefits with the tradeoff of moisture consumption. In the long run, intensifying a wheat-fallow rotation by growing cover crops in the fallow year will build soil moisture holding capacity along with SOM, microbial activity, and other soil health parameters; however, allowing a vigorous cover crop to grow until close to grain planting time can deplete soil moisture enough to compromise crop establishment and hurt yields. The moisture impacts can be especially severe with certain deep rooted perennial crops such as alfalfa, which has depressed subsequent organic grain yields for several seasons in Montana.

Simply adding another production crop to the fallow year, even wheat (i.e. wheat every year) can improve SOM and soil health over wheat/fallow. Studies in Pendleton, OR showed soil

microbial biomass carbon levels of 1066, 740, 504, and 280 mg/kg after 43 years in pasture, wheat-pea, wheat-wheat, and wheat-fallow rotations, respectively.

Soil health benefits appear greatest when a legume or a multispecies cover crop cocktail is planted in the “off year;” however, effects on dryland grain yields in the interior Pacific Northwest, Montana, Nebraska and the Dakotas have varied from positive or neutral to severe yield tradeoffs, depending on moisture dynamics.

Doug and Anna Crabtree of Vilicus Farms (<https://www.vilicusfarms.com/>) grow 7,400 acres of dryland organic grains in north-central Montana (11 inches/year average rainfall). Their diversified 5 – 7 year rotations integrate 15 cereal grain, legume, and oilseed cash crops and 10 cover crops, with no extended fallow periods. Soil organic matter has climbed steadily since they first began farming this land in 2009, with SOM increasing by a quarter on their best fields.

Collins, H.P., P.E. Rasmussen and C.L. Douglas, Jr. 1992. Crop rotation and residue management effects on soil carbon and microbial dynamics. *Soil Science Society of America Journal* 56:783-788.

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/>.

Smith, R. G., and F. Menalled. 2012. *Integrated Strategies for Managing Agricultural Weeds: Making Cropping Systems Less Susceptible to Weed Colonization and Establishment* (MT200601AG). <http://msuextension.org/publications/AgandNaturalResources/MT200601AG.pdf>.

Slide 18 – *Soil health problems in organic strawberry in plasticulture*

Plastic film mulch provides weed control without herbicides, conserves moisture, modulates soil temperature, and minimizes fruit rot in organic strawberry. However, the impermeable plastic sheds rainfall into furrows between beds, where much of it runs off, eroding soil and carrying sediment and nutrients into water bodies. The runoff also reduces rain infiltration for the crop, and increases need for irrigation the following summer.

In a 2006 field trial, cereal grain (barley or triticale) was planted in furrows between plastic mulched strawberry beds in November. The cover crops were mowed in January to prevent competition with strawberry. The trial was conducted on a poorly drained soil and the cover crop did not reduce the quantity of runoff or soluble N or P losses; however sediment (mineral and organic materials) and total N and P losses were reduced 70, 47, and 40% respectively by the cover crop.

Cahn, M., M. Bolda, and R. Smith. 2006a. Winter cover crops for reducing storm run-off and protecting water quality in strawberries, p. 2–4. Crop notes. Univ. California Coop. Ext., Monterey County, CA. 5 Mar. 2018. http://cemonterey.ucanr.edu/newsletters/November-December_200632272.pdf.

Slide 19 – *Cover cropping furrows to save soil and nutrients in organic strawberry*

Because cereal grains regrow after mowing and may be difficult to manage in organic systems, Brennan et al tested ‘Ida Gold’ mustard as a furrow cover planted in November or December, several weeks after strawberry transplanting. This crop scavenged about 22 lb

nitrate-N per acre, and was easily killed with a weed whacker in February (just before it grew tall enough to begin shading the strawberry crop).

Brennan, E. B., and R. F. Smith. 2018. Mustard Cover Crop Growth and Weed Suppression in Organic Strawberry Furrows in California. *HortScience* 53(4):432–440.

Eric Brennan video *Furrow cover crops for 'Greener' strawberries and other plastic mulched crops*. <https://www.youtube.com/watch?v=fesxbH03diY>.

Slide 20 – Orchard floor management

Maintaining bare orchard floor with tillage or herbicides can cut SOM by half, severely damage soil health, and may not save on irrigation water. In an Oregon State University study of organic sweet cherry orchard floor management, keeping the orchard floor in living plant cover maintained higher SOM and microbial enzyme activity and better nutrient cycling than either landscape fabric or applied organic amendments, while herbicide bare fallow resulted in the lowest values.

Azarenko, A. N., R. E. Ingham, D. D. Myrold, and C. F. Seavert. 2009. *Ecological Soil Community Management for Enhanced Nutrient Cycling in Organic Sweet Cherry Orchards*. Final report for ORG project 2005-04461. CRIS Abstracts.*

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

Vicente-Vicente, J. L., B. Gómez-Muñoz, M.B. Hinojosa-Centeno, P. Smith, R. Garcia-Ruiz. 2017. *Carbon saturation and assessment of soil organic carbon fractions in Mediterranean rainfed olive orchards under plant cover management*. *Agriculture, Ecosystems and Environment* 245: 135-146.

Slide 21 – Grazing orchard cover crop

Year round cover crops managed by grazing have recently been recommended for a drip-irrigated walnut orchard in California in an award winning essay on application of the NRCS Four Principles of Soil Health Management.

Turner, S. N., 2017. *Cropping System Soil Health Implementation Plan*. 2017 Conference Proceedings: California Plant and Soil Science Conference, pages 14 – 18. <https://calasa.ucdavis.edu/files/257056.pdf>.

Slide 22 – Managing for healthy soil in irrigated organic orchard in Utah

Irrigated orchard in Utah showed unchanged irrigation demands and significantly improved soil health and tree root development with legume (trefoil) alleys and straw mulch in tree rows. Researchers also confirmed that “mow and blow” management of the trefoil alleys contributed to tree nutrition (nitrogen uptake).

Reeve., J. 2014. *Organic Stone Fruit Production: Optimizing Water Use, Fertility, Pest Management, Fruit Quality and Economics*. Final report for OREI project 2009-01338, CRIS Abstracts.*

Rowley, M., B. Black, and G. Cardon. 2012. *Alternative Orchard Floor Management Strategies*. Utah State University Cooperative Extension, Horticulture/Fruit/2012-01pr, 4 pp.

Slide 23 – *SARE cover crop surveys 2012-2016*

Beginning in 2012, the USDA Sustainable Agriculture Research and Education (SARE) program has conducted annual surveys of farmers to determine yield and other impacts of adding cover crops to their cropping systems. The surveys have documented a steady increase in successful implementation of cover cropping by both organic and non-organic farmers. Some 85% of respondents see evidence of improving soil health, often within a year or two of adopting the practice. While a minority of producers reported some yield cost to the practice, there was, on average, a slight but statistically significant improvement in corn and soybean yields. The greatest increases were seen in drought years (i.e., the cover crops provided yield stability). In “normal” years, the yield benefits of cover crops were greatest where cover crops have been used for four or more seasons.

Data on wheat yields with versus without cover crops were collected for the first time for the 2016 growing season.

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

Relatively fewer Western region growers participated in the SARE survey (2016 season) than from other regions, especially North Central. However, yield trends in the drier part of North Central (ND, SD, NE, KS) were generally similar to higher-rainfall areas.

<https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/Cover-Crop-Surveys>.

Slide 24 – *Does cover cropping pay?*

Some economic analyses of cover cropping have given mixed results, partly because it is so hard to put a current-season dollar value on long term soil health benefits. In addition to direct costs for seeds, planting, and termination, some farmers incur additional costs for fertilizer for the cover crop, and income foregone if the cover crop replaces a cash crop in the rotation. At roughly \$4.60/lb for organic fertilizer N (based on the price of feather meal 13-0-0 through Seven Springs Farm, www.7springsfarm.com), even a modest increase in plant-available N from cover crops (legume N fixation, N recovery, improved soil biological activity) can save \$200 or more per acre.

For in-depth economic analysis of cover crop costs and benefits, see: Jason S. Bergtold, Steven Ramsey, Lucas Maddy and Jeffery R. Williams. 2017. *A review of economic considerations for cover crops as a conservation practice*. Renewable Agriculture and food Systems 34(1): 62-76.

Slide 25 – *Subtitle slide – Cover cropping for soil health in the Western region: challenges and resources to help you meet them*

Slide 26 – *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.

The “rotation niche” is the time (or space) gap between cash crops that the cover crop will fill. In addition, the contributions of the preceding cash crop and needs of the subsequent crop

will also play a part in cover crop choice. For example, an inefficient heavy N feeder like broccoli or sweet corn might be followed by a strong N scavenger like rye, pearl millet, or sorghum-sudangrass to recover unused N and minimize nitrate leaching. Tillage radish is an outstanding N scavenger, suitable after corn but not after broccoli or other crucifers because of the risk of disease buildup.

If the subsequent cash crop is a strong N fixer such as soybean, a high-carbon, N-immobilizing cover like rye can slow weed growth without affecting the soybean, while a cash crop with strong N demand might be preceded with a cover crop rich in legumes, crucifers, and other succulent, low C:N species.

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

Slide 27 – Cover cropping for soil health: SOM and 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. These carbon-rich cover crops should be supplemented with legume (N fixing) or other succulent broadleaf (N scavenging) crops in order to provide a “balanced diet” for the soil life, which plays a central role in regenerating and maintaining soil aggregation (structure or tilth), and in forming stable SOM.

For best results in terms of SOM and all soil health benefits, grow cover crops to maturity and high biomass (within practical constraints of moisture availability and cash crop timing).

Slide 28 – Cover cropping for soil health: feed soil life

Cereal grains, most other grasses, and most 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.

Biomass + biodiversity supports 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. Combine high- and low C:N species (e.g., grasses + legumes or forbs).

Slide 29 – Cover cropping for soil health:

Radish, canola, sweetclover, and alfalfa form deep, heavy taproots, leaving large macropores that enhance rain infiltration and drainage, and provide channels for subsequent cash crops to send their roots deeper in the profile, improving their access to moisture and nutrients. Winter rye can also perform this service to a significant degree

Pearl millet and sorghum-sudangrass form robust, fibrous root systems. Mowing the topgrowth of these grasses when they are 3-5 feet tall and not yet heading stimulates deeper and denser root formation during tillering and regrowth.

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 can “mop up” mobile N, P,

and K throughout the top five feet of the soil profile, returning them in plant-available form to the next crop and thereby enhancing yields.

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, 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 30 – *Cover cropping for soil health: nutrients*

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.

Combining a legume and grass balances the functions of adding N and holding N against leaching and denitrification. In addition, in soils with low to moderate levels of plant-available P and K, legumes (and also buckwheat and crucifers) help solubilize organic or mineral-bound P, while grasses help mobilize K from subsoil mineral reserves. On soils with optimum or surplus P and K, cover crops will not develop or aggravate nutrient excesses.

For faster N delivery to a subsequent heavy N feeder like corn or broccoli, plant legumes at 80-100% of sole seeding rate and grass at 10 – 30%. For more effective N retention and slower release, plant grass and legume each at 50%. Observe performance of mix

Lugato, E., A. Leip, and A. Jones. 2018. *Mitigation potential of soil carbon management overestimated by neglecting N₂O emissions*. *Nature Climate Change* 8: 219-223. www.nature.com/natureclimatechange.

Slide 31 – *Cover cropping for soil health: prevent erosion, suppress weeds*

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, and vetch alone with pigweed. In general, two or more cover crop species with contrasting and

complementary growth habits will suppress weeds and prevent erosion more effectively than single-species covers.

Slide 32 – *Cover cropping for 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 33 – *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 34 – *Other cover crop challenges*

Stand establishment can be especially challenging in many parts of the Western region. In dry seasons and semiarid climates, insufficient soil moisture can interfere with germination, emergence, and early growth. In high-rainfall regions such as the maritime Pacific Northwest, excessively wet soil conditions often delay or prevent timely cover crop planting after cash crop harvest. In moderate-rainfall regions such as northern California, the Mediterranean climate pattern of dry summers and rainy winters can leave a narrow time window between too-wet and too-dry conditions, which may or may not correspond with cash crop harvest time.

Slide 35 – *Cover cropping in a maritime Mediterranean climate*

Timely and effective cover cropping can be especially difficult in a climate where it rains all winter and shines all summer, such as northern California or the maritime Pacific Northwest. Many cool season cover crops – bell bean, winter pea, crimson clover, cereal grains – are well adapted to winter conditions, but their use is limited by late harvest dates of many warm season vegetable crops, and difficulties getting into the field to plant if heavy winter rains set in before harvest is complete. Nick Andrews and colleagues at Oregon State U are using a drill designed for interplanting cover crops into standing cash crops. A wide range of cool season cover crops, including cereal grains, sorghum-sudangrass, crimson clover, vetches, and some perennials like orchardgrass, fescue, and red clover, have been planted into production crops at midgrowth, for example, sweet corn at the six-leaf stage, just before last cultivation.

Andrews, N. 2016. Innovations Help Vegetable Growers Find that Cover Crop Niche. <https://extension.oregonstate.edu/crop-production/vegetables/innovations-help-vegetable-growers-find-cover-crop-niche>.

Andrews, N. 2014. Relay Seeding Cover Crops in Fall and Winter Harvested Vegetables. <https://extension.oregonstate.edu/crop-production/vegetables/relay-seeding-cover-crops-fall-winter-harvested-vegetables>.

Slide 36 – *Interseeded cover crops in organic vegetables*

Slide 37 – *Dryland challenges*

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 control erosion control, suppress weeds, or add sufficient organic matter and N to benefit grain yields. If the cover crop does attain high biomass, it may consume so much moisture that grain yields become severely water-limited. Terminating the cover crop by tillage can further compromise benefits, as semiarid regions soils are especially prone to wind erosion, SOM loss, and reduced fertility. No-till termination is often complicated by perennial weeds. Yet, not growing a cover crop can further reduce SOM and fertility, aggravate erosion, and reduce long term soil water holding capacity.

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 – *Cover crops for semiarid climates*

A winter cover crop of field peas has shown promise for building soil health and providing N to subsequent crops without depleting soil moisture.

Gallagher, R. S., D. Bezdicsek, 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 blog post 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 39 – *Drought resilience and water use*

Plants can be drought resilient because they use water efficiently, needing less moisture to generate a given amount of biomass or reach desired maturity and yield (low water usage), or because their deep, extensive root systems can tap subsurface soil moisture reserves. Pearl millet and cowpea combine deep roots with fairly light moisture use, while medic has shallow roots and

low water requirements. In contrast, the drought resilience of alfalfa, sunflower, safflower, and sainfoin is based largely on their capacity to tap – and deplete – moisture reserves throughout the soil profile. For example, alfalfa typically extends roots to 6 to 10 feet, and sometimes as deep as 30 to 40 feet. Montana State U researchers report that crops grown for the first few years after alfalfa sod is broken can suffer increased moisture deficits and lower yields compared to crops grown after less moisture-demanding covers or fallow.

Thus, it can be important to seek cover crops that have both high drought tolerance and low water use intensity.

Data on this slide are based on the USDA cover crop chart for Northern Great Plains, the SARE manual *Managing Cover Crops Profitably*, the New Mexico State Extension bulletin on cover cropping for arid regions (all cited in Resource slides below), and Wikipedia entries.

Slide 40 – *Some less-known cover crops for moisture-limited regions*

Winter cover crop use in the Central Valley of California is limited by scarce and unreliable (highly variable) rainfall. The most commonly planted winter legumes include bell bean, vetches, and winter peas, which do well if fall and early winter are relatively wet followed by drier conditions later in the winter, but can fail if the reverse pattern occurs.

USDA conducted trials of several reputedly drought tolerant cover crops to determine which might be practical for Central Valley farmers to use. Soil was pre-irrigated (2 inches) in October, cover crops (mustard, two brome cultivars, triticale, and burr medic) were planted on November 26, 2013 and grown with no further irrigation (rain total 6.08”, 0.43” in Dec, none in Jan, 5.65” in during Feb-Mar)

Biomass production of ‘Cucamonga’ California brome (*Bromus carinatus*) and ‘Bracco’ white mustard (*Sinapis alba*) significantly exceeded triticale, while ‘Blando’ soft brome (*B. hordaceus*) had lower biomass and ‘Scimitar’ Spineless Burr Medic (*Medicago polymorpha*) largely failed due to poor germination and establishment. Dry weight biomass at termination was cited as near 11,000 lb/ac for Cucamonga brome and Bracco mustard (with virtually no weeds) , 8,000 for triticale (which maintained the highest soil moisture in April), 4,700 for ‘Blando’ brome, and 1,500 lb/ac plus 3,368 lb weeds/ac for burr medic.

Evaluation of Drought Tolerant Cover Crops for California’s Central Valley

Margaret Smither-Kopperl, Manager and Shirley Alvarez, Biological Science Technician, USDA Lockeford, CA

https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmcsr12523.pdf

Slide 41 – *Cover cropping for organic dryland grains in the Northern Great Plains*

Montana State University Extension bulletins emphasize that cover crops, green manures, and legume cash crops (lentils, peas, other pulses) are foundational to soil fertility in organic dryland rotations. Cover crop benefits go well beyond the N contribution from the legume. While direct transfer of N to legume may be limited, subsequent winter or spring cereal crops also benefit from the rotation effect of following an unrelated (legume or crucifer) versus another cereal grain or fallow. Legume, buckwheat, and some crucifer cover crops are also more able than cereals to mobilize and absorb phosphorus (P), which is often limiting in alkaline or

calcareous soils; while the covers do not appear to deliver the P directly to the following crop, they may enhance P availability over the long term.

While cover crops may extract soil moisture in the short run, they build SOM and moisture holding capacity in the long run. Planting promptly in fall after preceding grain harvest gives better weed control and biomass than spring planting, and terminating early enough (bud to bloom stage) can minimize short term moisture deficits. Terminating later (pod set) increases risk of insufficient moisture for the following crop, yet increases long term benefits to SOM, organic N reserves, and soil health. Winter pea can be killed by roller-crimper at the pod stage but not the bloom stage, and no-till termination may help conserve moisture.

Fall planted winter pea outperformed other legumes (lentil) and spring-planted pea in terms of biomass, N fixation, timely termination for moisture, and subsequent winter wheat yields (37 vs 26 bu/ac after winter vs spring pea). Best cover crop management maintains grain yields (similar to wheat/fallow), gradually builds SOM and fertility, and can reduce N fertilizer bills.

Olson-Rutz, K., C. Jones, and P. Miller. 2010. *Soil nutrient management on organic grain farms in Montana*. Montana State University Extension bulleting EB0200, 16 pp. <http://msuextension.org/publications/AgandNaturalResources/EB0200.pdf>.

Menalled et al 2012. *From Conventional to Organic Cropping*: (cited earlier).

Slide 42 – *Western SARE cover crop trials in Montana organic grains*

While the outcomes of this project were disappointing in terms of soil moisture, N, and yields, a close look at cover crop choices, planting dates, and management generally support the Montana State Extension advice summarized in the preceding slide.

Eight farms tested various high-diversity mixes, such as camelina, flax, oat, pea, radish, turnip, vetch; or buckwheat, camelina, clover (berseem), pea, safflower, turnip. Cover crops were planted between April and June, and terminated June – September (~40 -90 DAP). Biomass was 900 – 2600 lb/ac, with little weed biomass; however, compared to herbicide fallow, the cover crops depleted soil moisture (at surface to 36 inches) by 2.9 (0.7 – 5.3) inches, and soil nitrate-N by 54 (22 -86) lb/ac. Cover crops reduced yields by an average of about 17.4 bu/ac or 25% (range 3 to 58%).

Additional research station trials were planted and terminated earlier (~April 1 / July 15) in six site-years, generated high biomass (1500 – 4000 lb/ac), consumed less soil moisture relative to fallow (1.8 inches), and caused moderate (9.4 bu/ac) yield losses at one site (northern MT) and no significant loss at a second site (Gallatin Valley) with better winter moisture recharge.

Miller, P., 2016. *Using cover crop mixtures to improve soil health in low rainfall areas of the northern plains*. Final report for Western SARE project SW11-099, 40 pp. <http://landresources.montana.edu/soilfertility/documents/PDF/reports/CCMFinalRptSW11-099Apr2016.pdf>.

Slide 43 – *Montana farmer survey findings*

This survey of 161 Montana farmers was conducted as part of Western SARE project SW11-099. Of those who are cover cropping, most are willing to continue to invest in cover crops for one to a few years before seeing a financial return. Almost half of the farmers using cover crops grazed them, and grazing was the second most common reason for cover cropping.

Jones, C. , R. Kurnick, P. Miller, K. Olson-Rutz, and C. Zabinski. *2015 Montana Cover Crop Survey Results*. Dept. of Land Resources and Environmental Sciences, Montana State University. 15 pp.

Slide 44 – *Organic dryland cover cropping in the interior Pacific Northwest*

Twenty dryland wheat farmers in northeast Washington participated with the Okanogan Conservation District in a NRCS Conservation Innovation Grant (CIG) to adapt the Four Principles of Soil Health Management to their region, which poses unique challenges. Many of the farms have shallow, stony soils, and most of the year’s limited moisture (average 11 inches) comes in the wintertime, so that summers are extremely dry. In contrast, the Northern Great Plains receive a similar amount of moisture more evenly distributed through the year (Montana) or mainly in summer (Dakotas), and inherent properties of many of the soils are more favorable (order Mollisols). Thus, eastern Washington growers may need to use different cover crops, planting and termination dates, and management practices from Northern Great Plains farmers working with similar total annual moisture.

Participants conducted four years of trials in which various cover crops were grown during the fallow year in a wheat/fallow system. In the control (standard practice), wheat was planted about August 20 and harvested the following July or August, followed by 12 – 13 months fallow maintained by herbicides or by tillage every 6-8 weeks. After testing a range of cover crop species and mixes, the team settled on three cover crop treatments during the fallow year:

- Fall cover: pea, lentil, barley, triticale, radish, planted late September and terminated in mid April.
- Spring: pea, lentil, oats, triticale, turnip, planted in April, terminated ~ July 1
- Summer: millet, sorghum, radish, sunflower, pea, planted May 15 (frost free date), terminated ~ July 10.

While this was not organic systems research (cover crops terminated by herbicide) most of its findings are relevant to all production systems.

Initial trials with a range of cover crops turned up some surprises: cowpea and sunnhemp known for their heat and drought tolerance and strong performance across the South, did not do well in the eastern Washington trials, possibly because nights are too cool and/or soil moisture was inadequate. Field pea did well in all three planting dates, while fava bean suffered from lack of moisture.

Meeting the Challenges of Soil Health in Dryland Wheat. NRCS webinar by Leslie Michel, Oct 9, 2018. Archived at the Science and Technology Training Library archive, <http://www.conservationwebinars.net/listArchivedWebinars>.

Slide 45 – *On-farm trial outcomes*

Fall planted covers were often “dusted-in” and lay dormant until spring, during which weeds got the jump on them. Spring planted covers established more promptly on winter moisture, and kept weeds down.

When cover crops were seeded at the 30 – 40 seeds per square foot recommended by NRCS, the stand was too dense, as plants competed with one another for moisture and nitrogen, turning

yellow and ceasing growth when small. Lighter seeding rates based on annual precipitation gave better stands. The team used the formula of 12 seeds per square foot for 10" annual precipitation, add another seed per square foot for each additional inch of moisture.

Wheat yield after the cover crop averaged 85-90% of control, but varied from severe losses (as low as 34% of control) in a few trials to measureable yield increases (102 – 122% of control) in about a quarter of trials. The yield response to cover crop seemed to depend on depth to moisture (DtM): the drill can set seed to about 4 inches; thus soil drying that goes any deeper interferes with germination and establishment.

Taking soil cores during cover crop growth can inform the farmer when it is time to terminate the cover crop.

Surprisingly, the summer cover crop (terminated just four weeks before wheat planting) did not necessarily cause the greatest drying or poorest yield outcomes; some trials with summer covers.

Slide 46 – *Blade plow for terminating dryland cover crops*

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.

Slides 47 and 48 – *Nationwide information resources*

The USDA Cover Crop chart was developed for the Northern Great Plains and is relevant to much of the Western region.

Slides 49 and 50 – *Resources for the Western region*

While some of these resources are not addressed specifically to organic systems, they provide much valuable information for all producers.

The ATTRA information sheet, based on the NRCS Conservation Practice Standard 340 Cover Crop as applied to organic systems in the states of Washington, Oregon, Idaho, and California provides excellent information on cover crop selection, planting, and termination, and

includes sections on cover cropping for orchard and other perennial cropping systems, and interplanting cover crops.

The Cover Crop and Organic Fertilizer Calculator developed by Oregon State University includes modules for the coastal (high rainfall) and inland (low rainfall) Pacific northwest. An additional module for Hawaii is under development.

Full URL for the Montana State U bulletin (slide 49): <http://msuextension.org/publications/AgandNaturalResources/EB0200.pdf>.

The webinar by Leslie Michel can be found at the Science and Technology Training Library archive, <http://www.conservationwebinars.net/listArchivedWebinars>.

The California Cover Crop Chart, similar in layout to the chart for the Northern Great Plains, emphasizes cover crops used or researched for California's diverse agro-ecoregions and climates. It includes information on life cycle and maturity dates, recommended planting dates, seeding rates, termination methods and timing; tolerances to drought, flooding, and other stresses; information on pests harbored (nematodes, aphids, other insects); and weedy /invasive potential with recommended precautions.

Each of the four major SARE regions have or are planning to establish a Cover Crop Council. The Midwest Cover Crop Council has become a major cover cropping network and information clearing house for the North Central region. The Northeast and Southern Cover Crop Councils have established websites and are developing their information resources. A two day meeting convened early in 2018 to explore establishment of a Western Cover Crop Council was announced in a May 29, 2018 on line article in No till Farmer. See <https://www.no-tillfarmer.com/articles/7907-new-cover-crop-council-taking-shape-in-western-us>.

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

Note that many of the final reports on the CRIS database include lists of publications in refereed journals that provide research findings in greater detail.