USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

Conservation and Soil Health Practices for Organic Production Systems

Cover Cropping

Introduction: the Vital Role of Cover Crops

Cover crops protect the soil surface from erosion and compaction, add organic matter, feed the soil life, fix nitrogen (N), conserve and recycle nutrients, suppress weeds, and support biological pest control.

The practice of cover cropping addresses the four NRCS Principles of Soil Health by:

- Keeping soil covered.
- Maintaining living roots.
- Enhancing plant and soil biodiversity.
- Minimizing disturbance by reducing the need for inputs.

Nationwide surveys of organic farmers have identified soil health and cover crops as top research priorities (Sooby et al., 2007; Jerkins and Ory, 2016). Because the organic method is based on healthy, living soils and excludes the use of synthetic fertilizers and crop protection chemicals, it relies more heavily than conventional systems on cover crops for soil fertility and management of nutrients, pests, weeds, and diseases. In addition, non-use of herbicides in organic crop rotations enhances flexibility in cover crop species selection, planting date, interseeding, and crop rotation design.

Organic producers face several challenges in getting the most out of cover cropping. These include:

- Selecting the best cover crops for the farm's climate, soils, crop rotation, weed pressure, and production system, as well as grower objectives.
- Selecting and managing cover crops for timely N release to the following crop.
- Cover crop selection and timely planting to accrue sufficient biomass to benefit soil health.
- Terminating cover crops without herbicides or excessive tillage that compromises soil health.

Using Cover Crops for Soil Health in Organic Production: Some Tips and Resources

The benefits of cover crops to soil life and soil health are well established (Delate et al., 2015; Hooks et al., 2015; Hu et al., 2015; Kabir & Koide, 2002; Sheaffer et al., 2007) and are directly related to the quantity and quality of biomass generated. A cover crop grown to full bloom can add twice as much organic residue and microbial "food" per acre as one that is terminated even a few weeks earlier (Drinkwater, 2011; Spargo, 2012).

Cover Crops and Organic Certification

Truly sustainable agriculture must maintain effective vegetative cover of the soil, even when the field is not in production.

Living plants are the ultimate source of all soil organic matter and "food" for beneficial soil organisms.

Thus, the USDA Organic Standards require certified organic producers to include cover crops in their crop rotations.

However, an over-mature cover crop may: deplete soil moisture; set viable seeds and become a weed; leave residues with high carbon-to-nitrogen (C:N) ratios that tie up N; or be difficult to terminate and cause problems for future cash crop plantings.

Timely planting will ensure the rapid early establishment essential for erosion and weed control, and enhance biomass and N fixation. Optimum planting dates for a given cover crop can vary with climate and weather fluctuations, farmer objectives, and the subsequent crop species and planting date.

Cover crop mixtures of two or more species are gaining popularity for their potential to provide a wider range of soil health benefits. An all-legume cover crop may break down too rapidly, releasing a large pulse of N that may leach to groundwater or stimulate weed growth (Heilig and Hill, 2014; Teasdale, 2012), while an all-grass cover crop leaves persistent residues that suppress weeds but can tie up N or hamper field operations. Mixing a grass and a legume can provide slow-release N while building soil organic matter (SOM) and maintaining good weed suppression.

Consider the following factors when choosing the best cover crops and management practices for your organic or transitioning-organic farm:

- Desired cover crop attributes for your cover cropping goals (Table 1).
- Region, climate, frost dates, and hardiness zone.
- Soil type and condition, including texture, depth, drainage, tilth, and SOM.
- Rotation niches (non-production periods) into which the cover crop must fit (Table 2).
- Opportunities for pre-harvest interseeding into preceding production crop.

Peppers and eggplant grow in applied straw mulch (left) and a cowpea cover crop near full bloom (right). Photo credits: Mark Schonbeck (L), Brian Geier (R).

- Nutrient, pest management, and other needs of the following production crop.
- Availability and cost of locally-adapted, organic or untreated, non-GMO cover crop seed.
- Available tools and equipment for cover crop planting and management.

Selecting the Cover Crop

Step 1: Identify your priority goals for growing cover crops and use **Table 1** as a guide to desired cover crop characteristics and some suggested cover crops for each goal.

Step 2. Identify the cover crop niches in your crop rotation, including target planting and termination dates. Map out a timeline and refer to **Table 2** to help plan and select cover crops.

Step 3. Consider other challenges and opportunities related to your climate, soils, and crop rotation. Cover crops differ in their tolerances to drought and other stresses. Cover crops for semi-arid regions must not deplete soil moisture reserves for the following cash crop. N-demanding cash crops like corn require a preceding cover crop that will provide plant-available N. Conversely, organic no-till soybean does well in roller-crimped rye, which immobilizes N and thereby curbs weed growth (Barbercheck et al., 2014; Clark, 2016). **Table 3** suggests some cover crops that may be well suited to specific challenges.

Step 4. Choose your cover crop(s).

- Use regional and other information resources (Table 4) to help you make the best selections.
- Use locally produced seed and locally adapted cover crop varieties when available.
- Think outside the box – other plant species not mentioned here can be excellent cover crops. Some farmers have successfully managed certain annual weeds as cover crops.
- Avoid noxious weeds, invasive-exotic plants, and difficult-to-control species.

TABLE 1. COVER CROPPING GOALS, DESIRED CHARACTERISTICS AND SUGGESTED COVER CROP SPECIES.

Goal	Cover Crop Characteristics	Suggested cover crop selections
Protect the soil from erosion and compaction.	Rapid establishment and canopy closure; persistent residues.	Buckwheat, southern pea (cowpea), radish and other crucifers (canopy), cereal grains, millets, sorghum-sudangrass (residues).
Add organic matter, sequester carbon (C).	High shoot and root biomass, moderate C:N (~30:1), long-season or perennial.	Sorghum-sudangrass, millets, sunflower, cereal/perennial grass or grass-legume sod.
Feed soil life, enhance soil biodiversity.	Diversity of cover crops including high and low C:N species, and hosts for mycorrhizal fungi.	Combine grasses, legumes, and crucifer or other forbs.
Improve topsoil tilth.	Extensive fibrous root systems.	Cereal grains, ryegrass, millets, other grasses, buckwheat.
Relieve subsurface hardpan.	Deep, robust root system.	Radish, canola, alfalfa, red clover, sweetclover, sorghum-sudangrass, pearl millet, rye.
Maximize plant available nitrogen (PAN) for next crop.	Symbiotic N fixation (legumes), N scavenging with low C:N (crucifers).	Clovers, vetches, peas, soybean, etc. (Radish, other crucifers before non-crucifer crops).
Maximize total N fixation and slow-release PAN.	Mix of legume and N-demanding crop, 50% legume biomass at maturity.*	Cereal grains or other grasses + legumes in season. Add crucifer or other forbs (optional).
Retain excess PAN, protect water quality.	Heavy N feeders with deep roots.	Sorghum-sudangrass, pearl millet, rye, other cereal grains, radish, other crucifers.
Retrieve and mobilize subsoil nutrients.	Heavy N feeders with deep roots.	Buckwheat, Sorghum-sudangrass, pearl millet, rye, other cereal grains, radish, other crucifers.
Suppress weeds.	Rapid establishment and canopy closure; persistent residues.	Buckwheat, southern pea, crucifers (canopy); cereal grains, other grasses (residue)
Disrupt life cycles of plant pests.	Unrelated to production crops, suppresses or does not host pathogens, varies timing of field operations.	Varies with production crop. Perennial sod (2 yr) reduces annual weeds. Grasses and sunn hemp reduce pest nematodes.
Feed and host natural enemies of insect pests.	Flowers with accessible pollen and nectar, ground coverage.	Buckwheat, phacelia, sunflower, most legumes, some grasses (nectar, pollen); low-growing cover or surface residues (habitat).

**Seed mixture of a legume at its full seeding rate with a N-demanding crop at a reduced seeding rate to yield a cover crop that is about 50% legume biomass at maturity. Exact rates may depend on locale, climate, soil type and cover crop species.*

Developing a Cover Crop Mix

Mixtures of two or more dissimilar species can perform more functions and may build soil health and suppress weeds more effectively than a single species cover crop (Cardina et al., 2006; Hooks et al., 2015; Schonbeck et al., 1993). Many farmers plant a grass-legume or a grass-legume-crucifer mix, and some have developed highly diverse "cocktails" of eight to 15 species from five or more plant families. Grass-legume mixes provide a balanced C:N ratio with a slow release of plant-available N, while all grass can tie up N, and all legume can release N too fast and stimulate weed growth (Baas et al., 2015; Drinkwater, 2011; Grossman, 2012; Teasdale, 2012). A 10-species cocktail has been reported to eliminate the need for fertilizer on corn (Archuleta, 2012), but results from such mixes have been inconsistent (McSpadden-Gardner et al., 2014; Drinkwater and Walter, 2015). Multi-species cover crops also present some practical challenges including:

- Logistics of planting seeds of different seed sizes, shapes, and optimum seeding depths.
- Increased per-acre seed costs.
- Adjusting seeding rates so that faster-growing components do not smother the others.
- Managing and terminating a cover crop mix in which maturity dates may differ.
- One or more components may harbor pests or diseases of the following production crop.

Because of the complexity of species interactions and environmental factors, no formulae can be given for the "right" mix.

To develop a mixture for your farm:

- Identify your goals, rotation niches, and soil and climate considerations as outlined above.
- Select two or more component species that can meet your needs.
  - Set component seeding rates:
    - ◊ Start by dividing recommended sole seeding rates by number ofspecies in the mix.
    - ◊ Go light on buckwheat, crucifers, and cereal grains, and heavier on legumes.
- Increase total seeding rate if planting late or if weed pressure is significant.
- Observe outcomes and adjust the mix next time as needed.

TABLE 2. SUGGESTED COVER CROP SPECIES FOR DIFFERENT NICHES IN THE CROP ROTATION.

Timing of cover crop to cash crop	Suggested cover crop selections
Fall planted winter cover to late spring cash crop.	Cereal grains, winter legumes and crucifers that are hardy in your zone.
Winter cover for northern locations with short growing season.	Shade-tolerant species interseeded into standing cash crop: red or white clover, hairy vetch, ryegrass, cereal grains.
Early spring cover to mid-late summer cash crop.	Spring oats, barley, fava bean, vetches, field peas, crimson or berseem clover, mustards, etc.
Early summer cover to fall cash crop.	Sudangrass, sorghum-sudan hybrids, buckwheat, sunflower, millets, soybean, southern pea, sunn hemp, tropical legumes.
Mid-late summer cover after an early summer cash crop harvest.	Cool season grasses, legumes, crucifers that will winterkill in your zone.
Early fall covers to early spring cash crop.	Cool season grasses, legumes, crucifers that will winterkill in your zone.
Short time niches during frost-free season.	Buckwheat, Japanese millet, southern pea.
Longer-season crops for hot weather.	Sudangrass, sorghum-sudan hybrid, or pearl millet with cow- pea, sunn hemp, or tropical legume. Mow and let regrow.

Perennial Sod Breaks

Many organic field crop operations, livestock-crop integrated systems, and a few organic vegetable farms include a perennial sod break in their rotations.

Rotating intensively cropped fields into perennial sod for two or more years restores SOM, tilth, biodiversity, and fertility, and can reduce annual weed pressure by depleting the soil's weed seed bank (Moncada and Sheaffer, 2010; Sheaffer et al., 2007). A mixture of perennial grasses, legumes, and forbs provides greater benefits than grass alone or a pure stand of alfalfa orclover (which may lose considerable N through leaching and denitrification when the sod is broken to resume annual crop production). Sod may be hayed or grazed, and advanced rotational grazing management can further enhance the soil health benefits of the sod break.

Enhancing Cover Crop Benefits with Organic Amendments

Compost, manure, and other organic soil amendments can work in a complementary and synergistic manner with cover crops to enhance active and stable SOM, microbial activity and diversity, nutrient cycling, soil structure, and other aspects of soil health (Cavigelli et al., 2013; Delate et al., 2015; Hooks et al., 2015; Tavantzis et al., 2012). In addition, cover crops reduce the amount of compost and manure needed to sustain SOM and soil fertility in an organic farming system, thereby reducing the risks of excessive soil phosphorus (P) or other nutrient imbalances from high rates of organic amendments (Cavigelli et al., 2013). Heavy reliance on low C:N organic fertilizers such as poultry litter, can "burnup" SOM and promote N leaching (Li et al., 2009; Wander et al., 2016), while soils managed with cover

A roller-crimper (top photo) can be used to terminate cover crops while leaving behind residues that provide mulch (bottom photo). Photos credit: Zahangir Kabir

TABLE 3. COVER CROPS FOR SPECIAL CHALLENGES.

Challenge	Suggested cover crops
Hot, dry weather and soil conditions.	Pearl millet, sorghum-sudangrass, sunn hemp, southern pea.
Cool, wet soils.	Japanese millet, oats, alsike clover.
Low fertility (tolerates and improves).	Sunn hemp, millets, southern pea, buckwheat, legumes (N).
Low (acidic) soil pH.	Oats, rye, buckwheat, pearl millet, sunn hemp, hairy vetch, southern pea.
Salinity or high (alkaline) soil pH.	Barley, canola, safflower.
For dryland crops (low water use).	Millet, winter pea, lentil, pigeon pea, southern pea, medic, mustard.
For weed-prone legume (e.g. soybean).	Rye, other high-biomass annual grasses with high C:N.
For heavy N feeder (e.g., field corn).	Alfalfa or clover sod, legume-rich winter cover crop mix.

crops and organic inputs of moderate C:N ratio build active and stable SOM and exhibit excellent nutrient cycling (Jackson and Bowles, 2013; Bowles et al., 2015).

Planting & Managing the Cover Crop

Cover crops are not as fussy as most production crops. However, good planting techniques and favorable soil conditions are critical for optimum results. Some tips include:

- Remedy severe hardpan, extreme pH, or critically low nutrients before planting.
- Follow regional guidelines for best seeding dates, rates, depths, and methods.
- Drill seed, or broadcast (increase rates ~1.5X) and work into desired depth.
- Apply manure or other organic nutrient sources based on soil testing to maximize biomass.
- Irrigate newly seeded cover crops if conditions are dry.

Organic producers can terminate cover crops through reduced-intensity tillage, such as shallow tillage, strip tillage, sweep plow undercutter, or spader, which leave the soil in much better condition than plow-disk or intensive rototilling.

In northern regions, short growing seasons can severely restrict options for integrating an effective cover crop of sufficient biomass with cash crop production. Many organic farmers in this region use overseeding or interseeding methods to establish the cover crop in a timely manner without adding a tillage pass.

These methods include drilling cover crops between rows of established corn, soybean, or vegetables (Caldwell et al., 2016); broadcasting the seed just before the final cultivation for weed control; and “frost-seeding” clovers and/or grasses into cereal grains in late winter.

Cover crop termination for production crop planting can pose a special challenge for organic growers, since tilling-in a cover crop can compromise some of the soil health benefits of the cover crop itself and can stimulate weed emergence. No-till cover crop termination and production crop planting can work in organic systems where weed populations are low, but may not be feasible when weed pressure is heavy or dominated by invasive perennial species.

TABLE 4. REGIONAL AND NATIONWIDE COVER CROPPING RESOURCES.

Region	Resources
Western	USDA Cover Crop Chart for the Northern Great Plains USDA Cover Crop Chart: Common Cover Crops for California Cover Crop (340) in Organic Systems, Western Region
North Central	Midwest Cover Crop Council Risk Management Guide for Organic Producers, chapters 13 and 14
Northeastern	Northeast Cover Crop Council Special Supplement on Legumes as Cover Crops, The Natural Farmer
Southern	Southern Cover Crop Council Cover Crops for Vegetable Growers, by Pam Dawling
Nationwide	Managing Cover Crops Profitably, 3rd Edition, SARE Cover Cropping in Organic Farming Systems, eOrganic SARE Cover Crop Topic Room NRCS Cover Crops and Soil Health including cover crop plant guides NRCS provides technical and financial assistance in cover cropping for organic and other producers through EQIP, CSP, and RCPP

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* For project proposal summaries and final reports for USDA funded organic research, 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