Cover Crop (340) in Organic Systems

Western States Implementation Guide

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Figure 2. Six-foot-tall fava bean cover crop, Fong Farms, Woodland, California 2006.

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Figure 1. (on front cover) A phacelia flower cover crop, grown to provide beneficial insect habitat, over-winter erosion control, weed suppressant and contributes to organic biomass in the soil. (Tim Kirkpatrick)

Purpose

This document provides an overview of how the NRCS Cover Crop (340) conservation practice can be implemented on organic operations. It discusses different purposes for the practice's use, design considerations, and how installation might differ in organic systems. Specifically, it outlines techniques and specifications to help NRCS conservationists and partners meet the requirements of the NRCS Cover Crop (340) practice standard and comply with USDA National Organic Program regulations.

Cover Crops in Organic Systems

The purposes for cover cropping in organic systems do not differ from those in conventionally managed systems. However, the role of cover crops to support soil function takes on greater importance in organic systems because the use of synthetic chemical fertilizers and pesticides are generally not allowed. Cover crops are also essential on organic operations to meet National Organic Program (NOP) requirements to minimize erosion; maintain or improve soil organic matter and the biological condition of the soil; and manage crop nutrients and soil fertility through cover crops and other techniques (see text box on next page).

Producers and planners may decide to implement cover crops to address a variety of purposes on a particular operation. This purpose will impact design and implementation of the practice.

The following purposes are recognized by the NRCS Cover Crop (340) standard:

- ➢ Reduce erosion from wind and water;
- ➢ Increase soil organic matter content;
- ➢ Capture and recycle or redistribute nutrients in the soil profile;
- ➢ Promote biological nitrogen fixation and reduce energy use;
- ➢ Increase biodiversity;
- ➢ Suppress weeds and pests;
- ➢ Manage soil moisture;
- ➢ Minimize and reduce soil compaction; and
- ➢ Reduce particulate emissions into the atmosphere.

Depending on the purpose, cover crops can also be used to provide supplemental forage, but this use may be restricted by NRCS cover crop guidelines.

Relevant National Organic Program (NOP) Regulations

The entire NOP regulautions, as well as lists of approved and prohibited materials and other information can be found at the NOP website: www.ams.usda.gov/AMSv1.0/nop

Section 205.203 Soil Fertility and Crop Nutrient Management Practice Standard
(a) The producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion.
(b) The producer must manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials.
(c) The producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.

Section 205.204 Seeds and Planting Stock Practice Standard
(a) The producer must use organically grown seeds, annual seedlings, and planting stock: Except, That,
(1) Nonorganically produced, untreated seeds and planting stock may be used to produce an organic crop when an equivalent organically produced variety is not commercially available:
Except, that, organically produced seed must be used for the production of edible sprouts;
(2) Nonorganically produced seeds and planting stock that have been treated with a substance included on the National List of synthetic substances allowed for use in organic crop production may be used to produce an organic crop when an equivalent organically produced or untreated variety is not commercially available*;
(3) Seeds, annual seedlings, and planting stock treated with prohibited substances may be used to produce an organic crop when the application of the materials is a requirement of Federal or State phytosanitary regulations.

Section 205.205 Crop Rotation Practice Standard
The producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops that provide the following functions that are applicable to the operation:
(a) Maintain or improve soil organic matter content;
(b) Provide for pest management in annual and perennial crops;
(c) Manage deficient or excess plant nutrients; and
(d) Provide erosion control.

* Commercially Available: The ability to obtain a production input in an appropriate form, quality, or quantity to fulfill an essential function in a system of organic production or handling, as determined by the certifying agent in the course of reviewing the organic plan. (Sec. 205.2).

Selecting a Cover Crop

The main consideration when choosing a cover crop is to first identify the purpose and objectives for its use. Subsequent factors to consider include seed availability, cost, crop rotation, and equipment for seeding and incorporation. Table 1 on the following page identifies a selection of purposes for cover crop use and provides related practices and techniques to help achieve those goals. Additionally, it includes recommendations for appropriate cover crops to meet those goals.

Most cover crop stands are grasses, legumes or mixes of the two. Cover crop species can be grouped into six major categories: cool season grasses; cool season legumes; cool season broadleaves; warm season grasses; warm season legumes; and warm season broadleaves. Native annual forbes, legumes and brassicas are becoming more popular for their support of pollinator and beneficial insect habitat.

Cover crop mixes, often referred to as cocktails, may be more expensive and could be more complicated to plant than a single species cover crop; however, these cocktails can satisfy multiple purposes in one planting. They are often more resilient, can provide a higher quality residue, and their carbon:nitrogen ratio can be targeted to satisfy cover cropping objectives (see Treadwell et al., 2010). They may also provide better cover, weed suppression, and biomass, especially during drought or other non-optimum conditions (Stika, 2013). A further advantage to planting cover crop mixes, or rotating cover crops, may be to avoid buildup of plant pathogens or parasitic nematode populations in the soil. It is more cost effective to limit mixtures to species that will reliably achieve cover cropping objectives than to try too many species at once.

Some innovative examples and considerations for cover crop mixes include:

- Summer sown Sudan grass with crimson clover. The Sudan provides summer cover, weed suppression, and organic matter; it is winter killed to provide mulch; and the crimson clover provides winter/spring cover, nitrogen fixation, and habitat for beneficials.
- Late summer or fall sown phacelia and crimson clover. Phacelia is quick growing to provide cover and habitat while the crimson establishes. The phacelia is winter killed and the crimson provides winter/spring cover, nitrogen fixation, and habitat for beneficials.
- Cool season soil building mixes often include: rye or oats, winter peas, crimson clover, a vetch, and fava beans. This mix can meet many purposes including: weed suppression, pollinator habitat, organic matter building, and nitrogen fixation. (Figure 3)
- A cereal-legume mix provides more flexibility on the kill date for the cover crop plant available nitrogen (PAN) provided by the cover crop. This is discussed in more detail in the Cover Crop Termination Options section on page 13.

Figure 3. Fall seeded annual rye, vetch, winter peas, favas, and crimson clover serve multiple purposes in Western OR. (Sarah Brown)

Figure 4. A mixed bag of buckwheat and bell bean seed ready for broadcasting. (Oregon Tilth)

The use of rhizobial seed inoculants for legumes is encouraged to ensure a robust nodulation of legume roots. Make sure that the correct inoculant is used for each type of legume that is seeded. Inoculants may be required by NRCS if the purpose of the cover crop is to provide biological nitrogen fixation. Producers should ensure inoculants are not genetically modified and confirm with their certifier as needed before applying any new input on their farm.

Table 1. Optimizing Cover Crop Objectives

Objective	Practice	Cover Crop Options
Weed management	Increase legume seed rate by 100-200%, normal non-legume seeding rates are adequate in most cases if the cover crop provides 100% ground cover in approximately 30-40 days after planting. To ensure rapid cover crop establishment: prepare fine seedbed, consider stale seedbed, ensure good seed to soil contact, irrigate if needed. Planting with a drill with close spacing between seed lines (i.e. 6-7") is ideal to ensure an even stand, however where broadcasting methods are used seeding rates should be approximately 50% greater than for a drilled cover crop. Maintain high percentage cereal or forb in cover crop mixtures (i.e. 50-75% of solo stand).	Sudan grass*, buckwheat*, rye, oats, and legume-grass mixes
Biological nitrogen fixation	Use solo legume or mixed stands with high legume seeding rate (80-100% of solo legume stand). Reduce cereal seeding rate (0-30% of solo cereal stand); inoculate legumes unless same Rhizobia species is already well established in soil. For maximum N release, terminate legumes at early flowering. In stands with low percent legume, the risk of nitrogen immobilization from mature cover crops is minimal when final cover crop biomass contains at least 25% legume.	Vetch species, clovers, winter peas, fava beans, cowpeas*, and black medic*
Organic matter contribution	Optimize cover crop biomass at termination; maintain high cereal or forb seeding rate (50-75% of solo stand); terminate as late as possible without delaying cash crop planting (i.e. late flowering); minimize tillage; rotate to perennial cover crops when possible; consider high biomass cereals that frost kill (i.e. Sudan grass, spring oats, etc.). Eliminate bare ground fallow.	Consider high biomass cereals that frost kill (i.e. Sudan grass*, spring oats*, etc.). Mixes work well too: ryegrass, rye, lana vetch, medic*, sweet clover, rye, and barley
Enhance beneficial insects	Use broadleaf species (legume or forb) that supply nectar, consider beneficial insect blends; allow strips or whole fields to flower especially when nectar and pollen sources are scarce (i.e. spring). State-specific plant lists, technical notes, and implementation guides be found at Xerces' Pollinator Conservation Resource Center.	Vetch species, red & crimson clover, phacelia, and buckwheat*
Reduced tillage	Minimize tillage during cover crop establishment and termination; relay seed at establishment; at termination consider roller crimpers, flail mowing, strip tillage and undercutting (under development in Pacific Northwest rotations); terminate late in cover crop development but before viable seed is formed (i.e. late anthesis or watery ripe for grains and full bloom for vetches).	For relay seeded options see Table 5. For more information on no-till see 'Organic No-Til Farming' listed in Resources, Appendix B.
Plant pathogen and nematode management	Ensure that cover crops do not serve as alternative hosts to key soil-borne pathogens in crop rotation. Some cover crops are known to reduce soil-borne fungal and nematode pathogens in some rotations.	Radish, mustards, rye, sorghum-sudan hybrid*, clover species, and barley
Reduce compaction	Select species with robust rooting ability to break up compaction and open channels to support root growth of subsequent cash crops. Radishes that are winter-killed often will leave open channels at the surface which improves infiltration, surface drainage and soil warming.	Radish, sorghum- sudan hybrid*, and sweet clover

* frost sensitive.

Please note these tips need to be adapted to fit in with various crop rotations and regional conditions. This table is based on contributor's professional experience and judgment in Oregon, Washington and California. For more species specific information, visit eOrganic's Cover Cropping in Organic Systems.

Table 2. Examples of Cover Crops for Organic Production

	Cover Crop	Seeding Rates	Advantages	Considerations
Warm Season (spring sown)	Buckwheat	50 to 60 lbs/acre at 0.5 to 1.5 inches deep; 6 to 8 inch rows. For weed suppression, use up to 96 lbs/ acre (2 bu./acre)	Fast-growing cover crop can be incorporated 40 days after planting and breaks down quickly. Does well on poor soils. Good alley crop for vineyards.	➢ Prefers lighter soil to heavy clays. ➢ Not frost or drought-tolerant. ➢ Avoid planting on high calcium soils.
	Sorghum- Sudan grass	Broadcast 40 to 50 lbs/ acre, or drill 35 to 40 lbs/ acre as deep as 2 inches to reach moist soil.	Drought tolerant and wide pH tolerance (5-9). Good crop for rehabilitating poorly managed, low-organic matter soils (high biomass, good root structure, weed and nematode suppression.)	➢ Requires good soil fertility (70-100 lbs N/acre) to produce medium biomass. ➢ Biomass can become woody, so mowing midseason and fine chopping of residue will aid decomposition. ➢ Toxic compounds in the plant, especially when young, can poison animals; do not graze until the plant is at least 18 inches tall.
Cold Season (fall sown)	Sunn Hemp *Crotalaria juncea*	40-50 lbs/acre minimum rate for organic (75-100 lbs/acre for weed suppression, or for 4-5 week cover crop)	Tolerates poor, sandy soils, but needs good drainage. Can make a green manure crop in 60 days. Fast growing, good at smothering weeds.	➢ Not winter hardy; a hard freeze will kill it. ➢ Requires cowpea-type inoculant. ➢ Some species in Crotalaria genus contain alkaloids poisonous to livestock. ➢ Suppressive to root-knot nematode. ➢ Seed might be difficult to source.
	Hyacinth Bean *Lablab purpureus*	Broadcast 70–120 lb seed per acre, or drill 30–90 lb seed per acre. Broadcast and cover, or drill to a depth of 2 inches	Fast early growth effective to smother weeds and cover ground. In northern California, a 75-day Lablab crop was estimated to contribute 65–140 lb/acre of nitrogen. Very palatable to livestock, and can be mowed near to ground level and regrow. Performs very well with minimal irrigation.	➢ Requires well-drained soils. ➢ Inoculate with "cowpea-type" rhizobia (Bradyrhizobium sp.) ➢ Does not easily nodulate with native rhizobia. ➢ Susceptible to root-knot nematode, bacterial wilt, and fusarium.
	Brassicas	Canola: drill 5 to 10 lbs/ acre no deeper than ¾ in. or broadcast 8 to 14 lbs/acre. Mustard: drill 5 to 12 lbs/ acre, ¼–¾ in. deep or broadcast 10 to 15 lbs/ acre. Radish: drill 8 to 12 lbs/ acre, ¼–½ in. deep, or broadcast 12 to 20 lbs/ acre. Turnip: drill 4 to 7 lbs/ acre about ½ in. deep or broad- cast 10 to 12 lbs/ acre.	Good N scavenger. Natural fumigant potential against bacteria, fungi, insects, and weeds.	➢ Minimum soil temp. for planting is 45°F; maximum is 85°F. ➢ Prefers pH range of 5.5 to 8.5. ➢ Avoid planting into fresh-killed mustards as biotoxic compounds can effect cash crop growth. ➢ Attractive to flea beetles and possible alternate hosts of vegetable brassica diseases such as clubroot ➢ Can become very weedy. ➢ Fall seeded mustards will generally produce more biomass, a stronger taproot, and require much less water.

Table 2. Examples of Cover Crops for Organic Production *(continued)*

	Cover Crop	Seeding Rates	Advantages	Considerations
Cold Season (fall sown)	Rye and Vetch	20:80 or 30:70 rye: vetch at 120 lbs/acre is standard, but for weed suppression that rate can be doubled or more.	Fast growing with potential to suppress weeds.	➢ Depending on variety, about 20% of vetch seed will not germinate in the first season and can become a weed in subsequent crops. For better weed suppression, use higher seeding rates. Check with local extension to determine the appropriate variety as many are available.
	Crimson Clover	15-20 lbs/acre drilled or 22-30 lbs/acre broadcast. This can be increased for more effective weed suppression. Plant at .25-.5 inch depth.	Grows well in mixes of small grains, grasses and other clovers. Flowers support bees and minute pirate bugs (a mite & thrip predator). Excellent for grazing and haying.	➢ Wait 2-3 weeks after incorporation of crimson to plant seeds or transplants to allow decomposition. ➢ Secondary host for corn earworm (also known as the tomato fruit worm and cotton bollworm).
	Phacelia *Phacelia z*	7-12 lbs/acre drilled, 11-18 lbs/acre broadcast (use cultipacker or rake). This can be increased for more effective weed suppression. Plant at .25 inch depth.	Attractive to flower flies (Syrphid larvae eat aphids), bumble bees and honey bees. Grows well in dry soil and can limit nitrate leaching if planted in early fall.	➢ Phacelia can host verticillium; flower attractive to lygus (especially avoid planting near strawberries). ➢ Will winterkill if temperatures fall to mid-teens.
	Fava beans *Vicia faba* (bell bean is a small-seeded selection of fava bean) (See Figure 2.)	80-200 lbs/acre (more for weed suppression), plant 1-4" (deeper range for large-seeded cultivars, shallow range for smaller seeded cultivars).	Fava beans do well in wide range of soils, including heavy clays. Fava bean residue persists longer than that of other leguminous cover crops, which can help improve heavy soils.	➢ Technically a vetch, but is more susceptible to frost damage, and fixes a bit less N than most vetches (100-150 lbs N/acre). ➢ Has extra-floral nectaries which attract beneficials. ➢ Host to root-knot nematode.

Adapted from Clark (ed.) 2007 with input from reviewer's professional experience and judgment in Oregon, Washington, Idaho, and California.

Organic Seeding Rates: Higher seeding rates than are typically used on conventional farms are important in organic systems to ensure that the cover crop produces a dense canopy and is therefore able to suppress weeds. It may be worthwhile to increase the seeding rates by 1.5 to 3 times when there is heavy weed pressure or less than optimum fertility, seedbed prep, or planting dates used (Brennan, et al, 2011, Schonbeck, 2011).

Field Preparation

To establish a cover crop successfully, field preparation is the first critical component to address. Two of the primary issues to consider are weed management and the development of a smooth seed bed for good seed-to-soil contact. Ideally field preparation will mirror that for annual cash crops, but can be less intensive. Soil should be worked at an appropriate moisture level to be free of clods and ensure good seed-to-soil contact. In order to gain the maximum benefit from the cover crop, producers should provide appropriate moisture. In some cases producers can relay seed into young vegetable plantings at the end of the weed management period and establish cover crops with no seedbed preparation or seed incorporation. If cash crops are harvested very late, consider relay seeding options, or broadcast annual ryegrass and common vetch after harvest.

Figure 5. Stand of a vetch and oats, unbedded.

Annual vegetable operations may have fields with compaction or a plowpan layer where heavy equipment has been run frequently. Clay soils with low organic matter, or those with heavy traffic and grazing, are especially vulnerable to compaction. Compacted soils may not allow rainfall or irrigation water to infiltrate the lower soil horizons, so some deep ripping may be required. While this is more of an issue for cash crops, it could impact the establishment of a non-irrigated cover crop. Subsoiling should be done when soil is dry, often before seeding a fall cover crop. Cover crops such as tillage radish can also be used specifically for the purpose of breaking up compacted soils.

Figure 6. Vetch and rye cover crop on beds.

Once the field is sufficiently worked, it is critical to plant as soon as possible. Even the slightest delay will give germinating weed seeds a head start and a weed infested cover crop can cause more problems than it is worth. Competition from weeds can out-compete cover crop growth requiring the producer to prematurely incorporate the cover crop. Investing some time and effort in creating a weed-free site through methods such as solarization, stale seedbed, or planting timing will pay off in better growth, establishment, and biomass of the cover crop. These methods are discussed in more detail in 'Conservation Buffers in Organic Systems'.

Planting

Correct seeding depth helps improve stand establishment. Planting methods will vary depending on the purpose for implementing cover crops. Seed or grain drills are the most common way to plant cover crops. No-till planting into the previous crops' residue is an option to reduce soil disturbance, but it may require specialized equipment to handle heavy residues. Some seed suppliers and Conservation Districts have no-till drills to rent. Seeding options, arranged from those appropriate for small to large acreages include: 1) broadcast by hand, 2) broadcast using a "belly grinder" hand spin spreader or spread via a wheeled walk-behind broadcast spreader or drop spreader, 3) tractor driven spin spreaders or seed drills, 4) aerial broadcasting. See Table 3 for more details about planting equipment and methods. Options for working in the broadcasted seed include irrigation or rainfall only, ring roller, spring-tooth harrow, Lilliston cultivator (for larger seeds), or cultipacker to lightly work the top layer and provide good soil- to-seed contact. For small seeds, incorporate with rain or irrigation; if seedbed is crusted (i.e. after cabbage on a silty soil) use a cultipacker. Larger seeds should be covered by lightly scratching them into the soil surface.

Figure 7: This Lilliston cultivator can be used for light tillage for weed control in the top few inches of soil as well as for incorporation of cover crop residues.

Figure 8: A cultipacker, or ring-roller, is used to firm the soil surface which helps seed-to-soil contact and breaks clods of soil. They can be used successfully to lightly incorporate cover crop seed.

One major problem with many methods of incorporating broadcast seed is that often they place the seed too deep, requiring seeding rates 1.5 to 2 times higher than drilling. However, if not set properly, seed drills can easily place seeds too deep as well. Conversely, it is equally important not to place seeds too shallow and avoid them being eaten by birds or drying out after germination and before establishment. Use the recommended seed depth for each cover crop species and be especially careful when seeding mixes. Some drills have an additional hopper where smaller seeds like clover can be placed so that they are broadcasted over a drilled grass seed. In warm, dry conditions, plant a little deeper (up to 50% deeper); in cool wet conditions plant a little shallower (Schonbeck, 2011).

Figure 9: A broadcast seeder, or 'belly grinder', appropriate for small acreage seeding. (Earthway).

Cover crops can be planted in the fall, spring, or even the summer. The timing depends on the purpose for implementing the practice as well as equipment and the cover crop species chosen. In the maritime Pacific Northwest, during most years a cover crop planted in the fall can germinate and grow simply on rainfall. However, it may require sprinkler irrigation in order to bring up a fall-planted cover crop if the rains are late or it is a dry year. A summer cover crop will be more expensive because in most locations it will require irrigation and involves a higher opportunity cost as a cash crop is foregone during the main growing season. Drought tolerant summer cover crops like Sudan x Sorghum hybrids can grow well with little to no irrigation. Fall covers are generally used to "fix" low-cost N, scavenge residual nitrogen, compete with weeds and protect the soil from erosion. Summer covers may be used for pest management, to smother warm season annual weeds, or as a food source for beneficial insects.

Relay Seeding

Relay seeding, also known as over-seeding, under-seeding, or inter-seeding is the planting of a cover crop into a growing cash crop. It can be done by air, broadcast or drill during a mid- or late-season cultivation of the cash crop. The practice is more common in Midwest field crops, but can be another tool for western organic growers and can be adapted to vegetables in the Northwest. This strategy promises to help annual cash crop growers incorporate cover crops into their crop rotations with late harvested cash crops. By not waiting for the cash crop to be removed, earlier seeding provides quicker canopy cover, reducing weed pressure and providing over-winter erosion control.

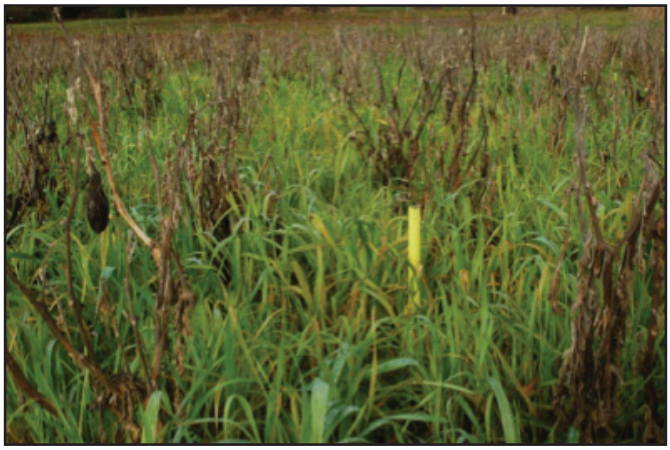

Figure 10. Eggplant oversewn with oats in Western Oregon. (Nick Andrews)

In a western context, establishment of a relay-seeded cover crop will depend on the type of irrigation used. Sprinkler or furrow irrigation will support this approach, but over-seeding into a field using buried drip will likely not be successful. Ideally, over-seeding should occur just prior to a rain event or scheduled irrigation. Over-seeding will likely require higher seeding rates to overcome light, moisture, and nutrient competition. Producers may consider using a more shade tolerant variety based upon the crop they are seeding. White clover, annual ryegrass, rye, hairy vetch, crimson clover, red clover and sweet clover tolerate some shading (Clark, 2007). Broadcasted seed should be heavy enough to fall through the crop canopy. More information about relay-seeded cover crop opportunities and rotations can be found in Table 4, Appendix A.

Figure 11. Butternut squash oversewn with red clover in late June/early July just before last cultivation and canopy closure. (Nick Andrews)

Table 3. Cover Crop Planting Methods

METHOD: Broadcast Seeders

Pros	Cons
➢ Inexpensive (many "belly grinders" are less than $100). See Figure 9 above. ➢ Easy to use. ➢ Drop seeders can accommodate both large and small seed. ➢ Can often accommodate poorly cleaned seed. ➢ Many models and sizes are commonly available, including hand-held crank, wheeled walk-behind, and larger tractor or ATV-mounted broadcasters; hand-powered turf grass seeders and larger tractor-drawn "pasture- seeder" models.	➢ Requires a smooth seed bed. ➢ Seed should be pressed into the soil after planting. ➢ Can be difficult to calibrate. ➢ Some models of seeders cannot accommodate large seed. ➢ Hand-powered models are time consuming for large areas (over half an acre). ➢ Seeding rates need to be higher due to variable seed depth and other factors.

Basic Instructions for Broadcasters and Drop Seeders:

Remove as much stubble as possible prior to seeding, creating a smooth, lightly-packed seedbed. The soil surface can be lightly hand-raked or harrowed to break-up crusted surfaces, but do not cultivate the site as this will bring up additional weed seed.

Seed of similar sizes can be mixed together and bulked up with an inert carrier ingredient such as sand, fine-grained vermiculite, clay-based kitty litter, gypsum, or polenta (fine cornmeal). Use at least two to three parts bulking agent for each part seed by volume. These inert carriers ensure even seed distribution in the mix, visual feedback on where seed has been thrown, and make calibration easier.

The broadcast seeding equipment can be hand operated or tractor mounted (spin spreaders). They should have a flow gate that closes down small enough to provide a slow, steady flow of the smallest seed. Models with an internal agitator are preferred. Planting should begin with the flow gate set to the narrowest opening to allow at least two perpendicular passes over the seed bed for even distribution. Very large seed can be planted separately with the flow gate set to a wider opening.

For small sites (e.g., less than one to two acres), seed can also be hand broadcast (similar to scattering poultry feed). When hand broadcasting, divide the seed into at least two batches, bulk the seed mix with an inert carrier, using at least two to three parts bulking agent for each part seed by volume and sow each batch separately. To ensure that seed is evenly distributed, scatter the first batch over the site while walking in parallel passes across the site and then walk in passes perpendicular to the previous passes to scatter the second batch.

Smaller seeds may not need to be covered with soil after planting; a water-filled turf grass roller (available for rent at most hardware stores) or a cultipacker should be used to press the seed into the soil surface. Larger seeds, including grains and legumes, should be covered by lightly scratching them into the soil surface (but should not be cultipacked). Natural precipitation or light overhead irrigation can also help ensure good seed-soil contact. A floating row-cover can be used if necessary to protect seeds and small seedlings against predation.

METHOD: Drill

Pros	Cons
➢ No-till drills allow for planting of crop immediately after harvest of previous crop. ➢ Potential for fewer disturbances of soil microorganisms and increased carbon sequestration. ➢ Generally reduces fuel use on-farm due to decrease in working the soil. ➢ More even cover crop establishment. ➢ No need for separate operation to incorporate cover crop seed. ➢ Lower seed rates and seed cost. ➢ Local seed dealers or conservation districts may have drills for rent, saving producers from having to buy new equipment.	➢ Soils with high clay content must be "workable". ➢ No-till drills will not work well on hard clay ground. ➢ No-till drills may require a larger tractor to use ➢ due to extra weight and extra pressure on the coulters to cut through plant residue.

Table 3. Cover Crop Planting Methods *(continued)*

Basic Instructions:

1. Do not till ground or incorporate plant residue prior to planting as this will bring up weed seeds into the germination zone and destroy the weed-suppressive layer of crop residue. The purpose of no-till is to plant the cover crop seed into an undisturbed bed.

2. Before drilling seeds, consider coulter positioning, planting depth, and type and size of plant residue.

3. If planting seed rows close together (closer than 6 to 8 inches), for faster canopy development the openers usually must be staggered by mounting on two or more parallel bars (Pfost, 1993).

Cover Crop Termination Options

The method of cover crop termination is also related to the purpose for implementing cover crops and the equipment available. In organic systems, cover crops can be terminated by frost, mowing, tillage/disking, roller-crimping, or some combination of mowing and tillage. The cover crop may not be burned and grazing may be restricted by NRCS (check with your state office).

Leaving the cover crop residue on the surface will protect the soil from wind and rain erosion and provide habitat for spiders and ground beetles. However, it keeps the soil cooler, more moist, and can support higher populations of slugs and snails. Planting or transplanting through the residue can be a problem unless the grower has access to a no-till drill or no-till transplanter. There must be sufficient time between incorporation of the cover crop and planting of the cash crop so that the cover crop residue has decomposed. Too much residue in the soil may attract seed maggots and reduce germination of the cash crop. There are many variables that impact organic matter decomposition but in general, producers will have to wait a four to five weeks before planting the subsequent crop. Where early cash crops are planned, some growers are able to bury cover crops with a moldboard plow or remove cover crop foliage with a silage chopper and disc under the stubble. It is sometimes possible to plant cash crops immediately using both techniques.

The timing of termination will vary based on the crop and purpose.

- ➢ If planting only a legume, the best time to kill the crop for maximum PAN (Plant Available Nitrogen) is at the budding growth stage.
- ➢ PAN from cereal cover crops is low to negative. At tillering (i.e. March) PAN can be zero to slightly positive.
- ➢ For mixes with lower percentages of legumes, the crop should be killed earlier (i.e. before cereals reach boot stage) so that the PAN is not tied up in the cereal's carbon. If a cover crop is 75% legume, it will behave essentially like a pure legume stand. However, if the legume is less than 25% of the cover crop biomass, the cover should be terminated before cereals reach boot stage to avoid N immobilization (Sullivan & Andrews, 2012).
- ➢ Cover crops grown to provide beneficial insect habitat should be allowed to reach maximum flowering but be terminated before viable seed is set. Buckwheat, for example, is usually mowed 10 days after flowering begins.
- ➢ Additional recommendations for termination considerations and timing are included in Table 1.

Figure 12: Vetch cover crop being flail mowed close to the bed surface.

Mowing: Mowing is often used to terminate a flowering cover crop before incorporation with a disc. It is a quick method to ensure that cover crops do not go to seed. There are three basic types of mowing machines: sickle bar, rotary and flail. Sickle bars are fast and leave large pieces of stalks on the surface of the ground. They are optimal for a slow decomposing mulch to cover the soil. Rotary mowers (like those commonly used for lawns) are useful in orchard settings to cut groundcover close to trees, but they do not chop residue, leaf litter and prunings as finely as flail mowers. Flail mowers generally require more horsepower than rotary mowers and provide a finer chop may allow for slightly quicker decomposition of the residue. Some producers might opt to transplant directly into a mowed cover crop, a minimum-till option that is usually easier to adopt than roller crimpers. Be aware of challenges inherent with this approach such as cooler, wetter soils and potential pest problems (i.e rodents or slugs).

Figure 13: Flail-mowed vetch beds.

Figure 14: Residue of vetch cover crop is about 3-4" thick. In this situation the residue was be allowed to dry down, and then lightly incorporated with a Lilliston cultivator.

Tillage or Disking: Tillage or disking is generally used to incorporate crop residue into the soil. If the amount of residue is small, it might be left on the surface. Lilliston cultivators can be used for light amounts of residue, but for higher biomass covers, or for crops with dense root masses, such as sorghum-sudan, disking or spading the residue into the soil is needed before the next crop is planted. If cover crop residues can be left on the surface, the risk of erosion can be reduced.

Figure 15. A field one week after disking down a robust legume cover crop and vetch. After the residue decomposes further, the producer will disk one more time prior to forming the planting beds.

Roller-crimping: Roller crimping is an appropriate option if the purpose is to address soil quality as this method leaves mulch on the soil surface which protects against erosion and rain impacts. Additionally, this approach provides habitat for spiders and ground beetles. Roller Crimping has been done successfully in the Midwest, East and South, in combination with no-till planters, but does not fit easily into raised bed systems of the irrigated West. Research on roller crimpers in organic systems in Salinas, California showed that raised beds made it difficult to effectively roller crimp-kill the cover crop as some of the cover crop fell into the furrows between beds. Regrowth of the cover crop and weed growth through the rolled mulch are common problems in organic systems.

Figure 16: This Salinas, California cover crop was a mix of rye on top of the beds and mustard in the furrows. (Eric Brennan)

Cover crop varieties and timing of termination are crucial components to ensure success in an organic system. Cover crops must reach early flowering to be effectively terminated with roller crimpers. For more information see 'Organic No-Till Farming' listed in resources, Appendix B.

Figure 17: This rye cover crop was terminated using a roller crimper. (Eric Brennan)

Figure 18: Terminating cover crops on beds using a roller crimper. (Eric Brennan)

Grazing: Depending on the cover crop's purpose, grazing can be an effective method for cover crop management. Grazing removes a substantial portion of the vegetation and may interfere with the goal of enhancing soil organic matter. Grazing animals deposit manure and urine on the soil which has nutrient management as well as potential food safety implications. Producers should consult with their organic certifier as well as NRCS prior to grazing any cover crops.

Figure 19: Walnut orchard floor prior to grazing. Note the tall grasses and mix of cover crop species compared to the grazed orchard floor on the right.

Figure 20: This organic walnut orchard has been grazed by sheep which left the bell beans standing, but devoured the Austrian peas, vetch, and in-row grasses.

Annual Cover Cropping in Perennial Systems

Most perennial producers will opt to incorporate perennial covers, or Conservation Cover (327), rather than annual cover crops into their systems. However, annual cover crops can provide many of the same benefits to perennial systems.

Figure 21. Disking cover crops in every other alley in a vineyard allows the grower access to all vines when the rainy season arrives and keeps down dust.

Cover crops are an important component of organic orchard floor management. They may be planted in the grass alley, legumes planted for nitrogen, or flowering species planted for beneficial insects. While living mulches in the tree row are often used, cover crops can also be grown in the alley and used on the tree row. Often called "mow and blow," this system blows clippings from mowing the alley on to the tree row with side discharge mowers. The alley planting can be grass that produces biomass for mulch, a legume to generate nitrogen, insectary plants, or any combination. This method can reduce irrigation, weed control, and cost. Vineyards often use cover crops in alternate rows (see picture below) which are alternated the following season. The cover crop planted rows allow the grower to use machinery in the alley more readily during the wet season.

Considerations when choosing orchard or vineyard cover crop (Barney, 2012):

- Competition for moisture and nutrients;
- Habitat for rodents and rabbits, gophers are brought in by exclusively legume covers;
- Habitat for beneficial organisms;
- Improvements to soil quality; and
- Length of bloom and time of bloom to attract pollinators. Avoid pollinator competition from flowering cover crops in crops with flowers that are less desirable to pollinators (i.e. pears).

Figure 22. This cover crop in a vineyard provides good habitat for beneficial insects and is aesthetically pleasing.

Appendix A. - Table 4. Cover Crop Interseeding Systems

Note: Only systems that cause negligible yield reduction have been included. All of these systems provide a cover which lives through the winter or is winter-killed. All cover crops resist major damage during harvest of the cash crop unless otherwise noted.

Cover Crop	Cash Crop	Method	Benefits	Problems
Red clover, annual or perennial ryegrass [i]	Corn, late sweet corn	Broadcast after last cultivation [ii]	Good organic matter production; N-fixation by red clover	Establishment may be poor in a dry summer; annual rye-grass may winter-kill
Rye [iii]	Corn, late sweet corn	Broadcast in early fall at 3 bu/acre	Reasonable establishment most	Stand may be patchy; stand may be poor if the fall is dry
Red clover, alsike clover, alfalfa, yellow sweet clover	Winter wheat, spelt	Sow on frozen ground in early spring	Good organic matter production and N-fixation before next spring crop	Ground may not freeze sufficiently to support tractor
Bell bean [iv]	Fall brassicas	Plant two rows of bell bean between crop rows after last cultivation	N-fixation for next crop; grows fast and then winter-kills; upright growth does not interfere with crop	Expensive seed; cover crop will be damaged at harvest
Annual rye-grass	Tomato, pepper	Broadcast after last cultivation [ii]	Good dry matter production by next spring	May winter-kill
Hairy vetch	Late harvested vegetables	Plant 1 or 2 rows between rows of vegetables after last cultivation	N-fixation for next crop; no interference with crop; spreads out to give fair winter cover and good spring production	May become a recurring weed
Rye	Late harvested vegetables	Plant 1 or 2 rows between rows of vegetables after last cultivation	Falls over to give fair winter cover; no interference with crop	None apparent
Rye	Late harvested vegetables	Broadcast at 2 to 3 bu/acre 3 to5 weeks before harvest	Provides more uniform cover than drilling between rows	Stand may be patchy; stand may be poor if the fall is dry; interferes with harvest of short, leafy crops

Adapted from Mohler & Johnson, 2009.

[i] Alfalfa, yellow sweetclover, crimson clover, birdsfoot trefoil, white clover, alsike clover and hairy vetch can also be established by this method, but fall cover and spring dry matter production tend to be less than for red clover, annual ryegrass or perennial ryegrass.

[ii] Seed can be applied at cultivation by attaching a forage seeder box to dribble seed onto the ground behind the cultivator tools. It can also be spun on with an attachment or by hand. Seeding should be completed before the first rain after cultivation.

[iii] Rye is the only cover crop that usually establishes well when surface sown in the fall. Spelt and annual ryegrass also have a reasonable chance of success. Other surface seeded cover crops usually either fail to germinate or are heavily consumed by seed and seedling feeding insects (species that are normally considered beneficials due to their consumption of weed seeds and pest insects).

[iv] Bell bean is a small-seeded variety of fava bean. It is preferred over field pea in this application because it does not fall over or twine into the crop.

Appendix B. - References

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Resources

Conservation Buffers in Organic Systems Implementation Guide is a companion resource to this guide. It includes a discussion of relevant NOP regulations, organic management practices, and technical guidance for NRCS practice design in an organic context.
http://tilth.org/education-research/organic-conservation-program/wsare-project

Cover Crops and Soil Health is a NRCS resource which includes cover crop plant guides and other resources.
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/plants/projects/?cid=stelprdb1077238

Organic No-Till Farming is a Rodale Institute book by Jeff Moyer that describes a system that limits or eliminates tillage and focuses on cover crops as a source of fertility and weed management.
http://rodaleinstitute.org/shop/organic-no-till-farming/

www.eOrganic.info is an online resource for organic research and outreach. The site hosts a range of resources on cover crops including profiles of various crops, the use of cover crops for weed and disease management and more.
http://www.extension.org/pages/59454/cover-cropping-in-organic-farming-systems