PENNSTATE
College of Agricultural Sciences
Agricultural Research and Cooperative Extension

CONSERVATION TILLAGE SERIES
Number Five

Cover Crops for Conservation Tillage Systems

Producers seed cover crops to provide a soil cover or barrier against soil erosion. In addition, cover crops can improve the soil by adding organic matter, nutrients, and stability and by acting as scavengers to trap leftover nutrients that otherwise might leach out. Cover crops are used as ground cover, mulches, green manure, nurse crops, smother crops, and forage and food for animals or humans. Cover crops can be annual or perennial species, including certain legumes, grasses, and non-leguminous dicots.

An understanding of the cropping system is necessary before selecting a cover crop. Characteristics important for cover crop selection include life cycle, seeding date and rate, winter hardiness, nitrogen fixation or scavenging ability, feed or forage value, and establishment costs. There is no single cover crop or system that will provide all these benefits. Therefore, experimentation may be necessary before producers decide on a suitable cover crop for an individual system.

BENEFITS OF COVER CROPS

Erosion control

Erosion occurs most rapidly on cropland where there is no soil cover. Cover crops can provide protection during periods when a primary crop is not present. Plant residues reduce the impact of raindrops that otherwise would detach soil particles and make them prone to erosion. Surface runoff is slowed by the cover, allowing improved moisture infiltration. Not only does the aboveground growth provide soil protection, but the root system helps stabilize the soil by infiltrating the profile and holding it in place. Besides controlling erosion, cover crops and their decaying residues reduce pollution by preventing runoff of nutrients and pesticides into surface water. Also, cover crops may allow earlier field access and improve traction during wet springs.

Greater amounts of organic matter and improved soil tilth

Like crop residues and manure, cover crops can add organic matter to the soil. Although increases in soil organic matter occur slowly over time, including cover crops in the rotation can help maintain or slightly increase soil organic matter. Cover crops are particularly useful if crops such as corn silage are produced, since most plant material is removed from the field. Because Pennsylvania soils are relatively low in organic matter, maintaining or increasing levels is helpful.

Adding organic material to soil improves soil tilth and productivity. As organic matter and plant residues degrade, they produce compounds that cement soil components together into aggregates, resulting in improved structure and tilth. Aggregates contribute to greater soil permeability, aeration, water infiltration and holding capacity, cation exchange capacity, and ease of crop emergence and root growth. Tillage and planting are easier in a soil with good tilth.

Fixation of atmospheric nitrogen

Legumes, in association with certain bacteria, have the ability to acquire and fix nitrogen from the atmosphere. The plants use the fixed nitrogen to produce proteins and other vital components. When high nitrogen legume residues remain in the field, they break down and release nitrogen and other nutrients, which can then be used by subsequent crops. In general, most legume cover crops provide an equivalent of 50 to 200 pounds of fertilizer nitrogen per acre per year. The amount of nitrogen released depends on factors such as species, age, stand density, type of tillage system, and weather conditions.

Recycling or scavenging unused nutrients

Unused soil nitrogen left at the end of the growing season tends to leach out during fall, winter, and spring and may end up in groundwater. Certain cover crops tend to be very efficient at recycling or scavenging excess nutrients. Generally, these species need to be adapted to relatively cool fall and spring conditions in order to continue growing after nutrient uptake by the crop has slowed or stopped. When the cover crop dies or is removed as forage, some of the nitrogen is released and reused by future crops or used as protein in the feed.

Beneficial organisms

Increased plant residues and the tillage practices generally associated with cover crop systems may improve the soil environment for certain beneficial organisms. Organisms such as earthworms, insects, and microorganisms can improve soil quality and increase nutrient availability by quickly decomposing organic matter and plant residues. Earthworms in particular help improve water infiltration and soil structure. Also, other insects that are attracted to the cover crop vegetation may provide benefits by preying on harmful pests.

Partial weed control

Cover crops partially control some weeds by competing with them for light, moisture, nutrients, and space, which can be particularly helpful for suppressing winter annual weed growth or certain cool-season perennials. In addition, cover crops and their residues can act as mulches or physical barriers by smothering weeds, suppressing weed seed germination and growth, and lowering soil temperatures. Cover crops may contain allelopathic compounds, which are released from living or decaying plant tissue. These compounds chemically interfere with weed growth. However, all of these qualities can vary depending on the type and quantity of cover crop and the environmental conditions present during the growing season. Despite these potential benefits, physical and chemical effects from cover crops may not be a major factor for weed control. Mechanical or chemical weed control tactics should still be used to complement cover crops.

Possible feed source

Certain cover crops, especially grass species, also can be used for livestock feed. These crops can be grazed or mechanically harvested as haylage or hay. Generally, mechanically harvesting the cover will not have a negative impact on erosion control benefits, especially when a no-till planting follows. With proper management, grazing will have a similar effect, because even though the tops are harvested or grazed, root mass and stubble remain to provide protection from erosion. However, removal of the cover crop also removes nutrients that eventually must be replaced.

DISADVANTAGES OF COVER CROPS

Additional costs

There are additional costs above and beyond normal cropping practices that must be considered in systems that include cover crops. Extra expenditures include the cost of the cover crop seed as well as labor and time for planting. Also, special or alternative equipment may be needed to handle the greater amounts of residue present in no-till systems. Cover crops must be managed like any other crop produced in the farm operation.

Interference with primary crop

Unmanaged cover crops can act as weeds by competing with the primary crop for light, moisture, nutrients, and space. In a dry year, cover crops can rob primary crops of valuable soil moisture. In other years, they may also compete for other resources such as nitrogen if not managed properly. For most cropping systems with cover crops, the use of starter fertilizer during planting of the primary crop should compensate for nutrients used by the cover crop. Immobilization of nitrogen by the cover crop generally is negligible, especially if manure has been applied. However, if large amounts of vegetation are being tilled under, producers raising corn should split the nitrogen requirements between planting (one-third) and side-dressing (two-thirds).

Cover crops also may be affected by the same chemical and physical factors that contribute to weed control. As with weeds, crop species can be hampered by chemicals released from cover crops, cooler soil temperatures, and the smothering effects of cover crop residues. Cooler temperatures may delay the germination and growth of the grain crop. Crop residues also may act as physical barriers, making uniform spray coverage more difficult. These residues also may bind herbicides, resulting in reduced activity. Preemergence herbicide programs may need to be adjusted to account for this interaction.

Pest problems

Cover crops, like weedy fields, may harbor insects, diseases, and nematodes that could be harmful to the cover crop and detrimental to future crops. Consider specific pest/crop interactions that may become a problem. For example, cereal rye or orchardgrass can attract armyworms. Clover root curculio, a pest common to red clover, also can attack alfalfa. Heavy populations of certain weeds such as chickweed attract black cutworm or slugs, while johnsongrass is a host to maize dwarf mosaic virus (MDMV), which can infect corn. Understanding these potential interactions and the conditions that favor them helps producers make proper management decisions.

High management systems

Improper management of a cover crop can overshadow its benefits. Management of the primary crop can be difficult enough without having additional problems caused by mismanagement of the cover crop.

TYPES OF COVER CROPS

Cover crops can be annual, biennial, or perennial plant species that serve a variety of purposes. Annuals such as rye can be used as a fall and winter cover while crown vetch, a perennial, can serve as a living mulch. Producers must select the right species for their particular situation. Table 1 describes several of the more commonly used cover crops. Characteristics of each species listed include life cycle, winter hardiness (see Figure 1 for hardiness zones), seeding rate and date, nitrogen fixation or nutrient scavenging potential, average cost, and several advantages and disadvantages.

COVER CROP MIXTURES

Cover crops can be planted as a single species or in mixtures. The most common mixtures include a legume such as hairy vetch and a cereal grain such as rye. Mixtures provide both advantages and disadvantages over single species.

In a rye/hairy vetch mixture, rye protects the vetch during establishment and throughout the winter, and provides physical support for the climbing vetch during the spring growth period. The rye also protects the soil from winter erosion better than a pure stand of

FIGURE 1. WINTER HARDINESS ZONES (average annual minimum temperatures).

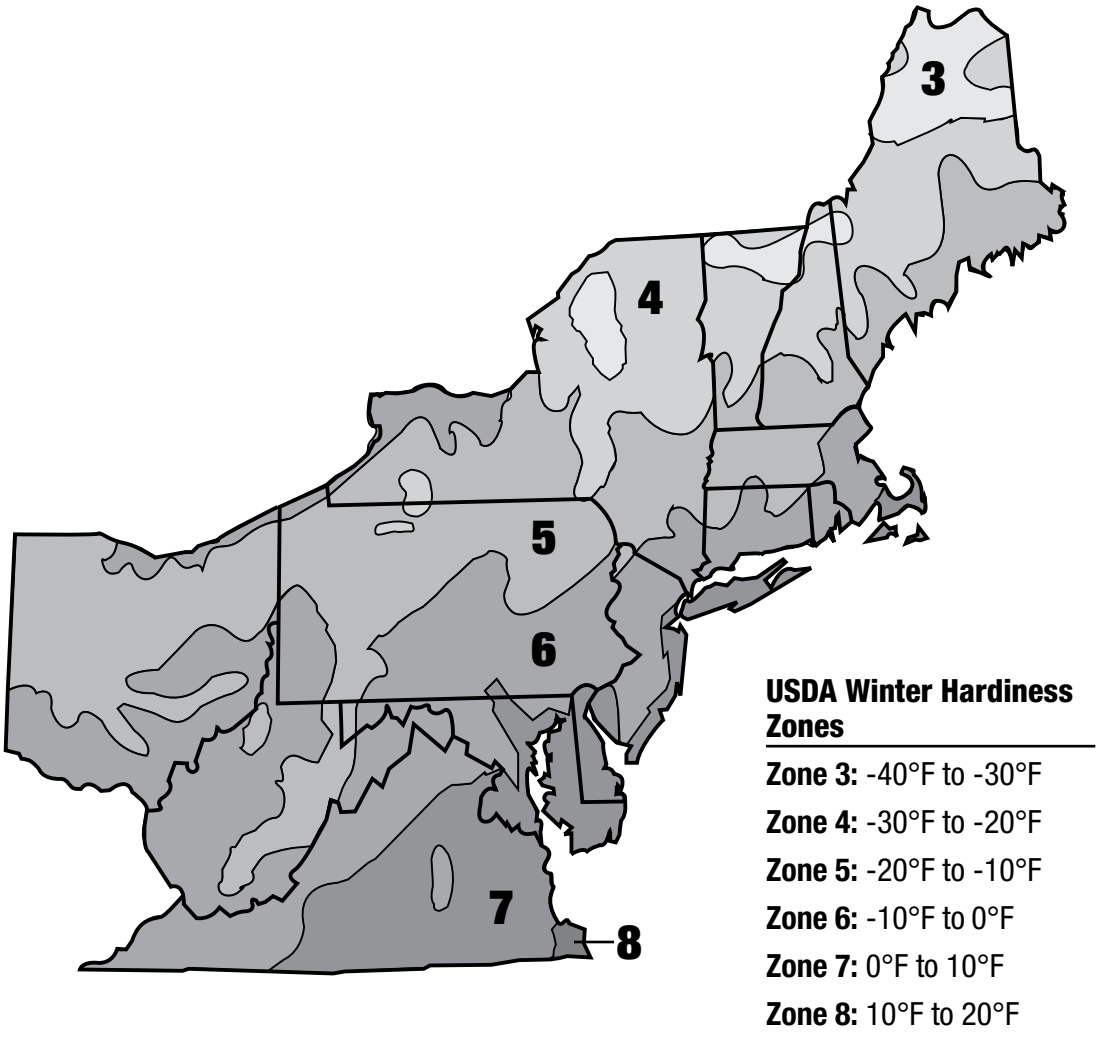

TABLE 1. OUTLINE OF COMMON COVER CROPS.

Species	Life cycle[a]	Hardiness zone	Seeding rate[b] (lb/A)	Seeding date	N-fixation (lb/A)/ resource scavenger	Average cost ($)	Advantages	Disadvantages
LEGUMES								
Hairy vetch *(Vicia villosa* Roth)	WA	4	20-40	August/ early Sept.	80-250 (avg. 110)	1.50-2.50/lb	• most cold tolerant and highest yielding of all winter annual legumes • above average drought tolerance • adapted to a wide range of soil types	• requires early fall establishment, and slow to establish • little winter cover possible • matures in late spring • high P and K requirement for maximum growth • can harbor pests • potential weed problem in winter grains
Crimson clover *(Trifolium incarnatum* L.)	WA/ SA	6	9-40 (avg. 18-20)	August	70-130	1.00-1.50/lb	• rapid growth • above-average shade tolerance • forage use (no bloat) • good nematode resistance	• poor heat and drought tolerance • no-till planting in residue is difficult, due to stemminess
Red clover *(Trifolium pratense* L.)	SLP (2-3 yr)	4	7-18	Mid-August	100-110	1.50-3.00/lb	• thick, deep taproot • adapted to humid areas • tolerates wet soil conditions and shade • forage use; only if mixed with grasses	• initial growth slow • high P and K requirements for maximum growth • seed can persist, creating volunteer problems • pure stand forage causes bloat • vulnerable to several pathogens and insects
White clover *(Trifolium repens* L.)	LLP	4	6-14	August or spring	100-130	2.00-4.50/lb	• adapted to most temperate zones • good heat, flood, drought, shade tolerance • low-maintenance and tolerates high traffic • forage use with grasses (better yields)	• as a living mulch, may compete with crop if not mowed or tilled under • no yield during hot-dry weather • good nutrient management necessary • susceptible to several diseases and insect pests
Field peas *(Pisum* spp.) (e.g., Austrian winter pea)	SA/ WA	7	70-220	August or spring	50-150	0.50-1.00/lb	• rapid growth in cool weather • versatile legume • interseed with cereal and brassica spp. • used as food or feed	• Austrian winter pea will not overwinter north of Maryland • shallow root system • sensitive to heat and humidity • susceptible to diseases and insect pests
Crownvetch *(Coronilla varia* L.)	LLP	4	5-20	Spring or early summer	40 (suppressed)	10.00-15.00/lb	• deep rooted and long-lived • good tolerance for heat, drought, and cold • excellent erosion control • no pest problems	• slow germination and establishment • high degree of management necessary • can become weedy if uncontrolled
Birdsfoot trefoil *(Lotus corniculatus* L.)	SLP	1	5-10	Spring or early summer	40	4.00-5.00/lb	• quick establishment • tolerates poorly drained soils and low pH • can be managed as living mulch	• competes with crop if not suppressed or killed • does not spread vegetatively

TABLE 1. OUTLINE OF COMMON COVER CROPS, *continued.*

Species	Life cycle[a]	Hardiness zone	Seeding rate[b] (lb/A)	Seeding date	N-fixation (lb/A)/ resource scavenger	Average cost ($)	Advantages	Disadvantages
GRASSES								
Cereal rye *(Secale cereale* L.)	WA	3	60-200	Fall	excellent nutrient and moisture scavenger (esp. N)	7.00-12.00/bu	• most cold tolerant of commonly used cover crops, late seedings possible; germinates and grows rapidly • tolerates poor soil conditions and drought • rapid growth may provide some weed control • various uses: cover crop to food source	• regrowth may occur if not completely controlled (mature rye difficult to manage) • possible crop suppression due to allelopathy or nutrient tie-up by rye • pest problems: small grain insects, diseases
Spring oats *(Avena sativa* L.)	SA	8	100 (approx. 3 bu)	Spring or fall	good nutrient scavenger (less if fall seeded)	3.85-5.00/bu	• rapid growth in cool weather • ideal for quick fall-cover or nurse crop with legumes • winterkills • various uses: cover crop to food source	• high lodging potential • susceptible to diseases and insect pests • winter kills
Cool-season grasses: Annual/ perennial ryegrass *(Lolium* spp.); Tall/fine fescue *(Festuca* spp.); Bluegrass spp. *(Poa* spp.); Smooth bromegrass *(Bromus inermis);* Orchardgrass *(Dactylis glomerata);* Timothy *(Phleum pratense)*	spp. variation	4-6	15-50+	Spring or fall	fair to excellent nutrient and moisture scavenger	0.45-3.50/lb	• tolerate wide range of soil conditions (TF, SBG, PRG*) • rapid establishment (RG, OG, Tim.) • tolerate shade, low pH, and fertility (FF, TF) • tolerate drought and heat (TF, SBG) • winter-hardy (KBG, SBG, FF) • form dense sod (KBG, SBG) • most can be used as feed • adapted for orchard/ ornamental uses (FF, TF, KBG, PRG) * species names are abbreviated	• slow establishment (KBG, SBG, FF*) • low heat tolerance (PRG, FF, Tim.) • may winter kill (PRG, TF, OG) • bunch-type growth (FF, TF, PRG, OG, Tim.) • may harbor insects and disease • living mulch requires high management * species names are abbreviated

[a] A=annual; WA=winter annual; SA=summer annual; B=biennial; SLP=short-lived perennial; LLP=long-lived perennial; NFT=no frost tolerance

[b] higher rates may be necessary for broadcast seedings

TABLE CONTINUES

TABLE 1. OUTLINE OF COMMON COVER CROPS, *continued.*

Species	Life cycle[a]	Hardiness zone	Seeding rate[b] (lb/A)	Seeding date	N-fixation (lb/A)/ resource scavenger	Average cost ($)	Advantages	Disadvantages
OTHERS								
Buckwheat *(Fagopyrum esculentum* Moench)	SA	NFT	35-135	Spring or fall	efficient nutrient scavenger (esp. P & Ca)	15.00-40.00/bu	• grows on wide variety of soils (infertile, poorly tilled, low pH); rapid growth • quick smother crop and good soil conditioner • cool, moist climates • food and feed source	• limited growing season, frost sensitive • poor growth on heavy limestone soils • occasional pests
Brassicas *(Cruciferae* family) (e.g., rape, kale, turnip, radish)	A/B	6-8	5-12	Spring or fall	good nutrient scavenger (esp. N, P, Ca)	varies	• quick establishment in cool weather • withstands light frost (but winter kills) • deep, thick root systems; drought tolerant • highly-digestible forage crop and other uses • continuous growth even with shorter days • may help insect and weed management	• low tolerance to wet soils • potential bloat problems (mix with 25% grass) • long-term "weed" problem if allowed to set seed (spreads by seed) • occasional pests • winter kills

[a] A=annual; WA=winter annual; SA=summer annual; B=biennial; SLP=short-lived perennial; LLP=long-lived perennial; NFT=no frost tolerance
[b] higher rates may be necessary for broadcast seedings

vetch. The amount of nitrogen available to the subsequent crop is not as great as with a pure vetch stand because of the lower amount of vetch. In addition, more nitrogen is tied up during decomposition of the mixture due to the greater C:N ratio of the rye.

Another mixture to consider is crimson clover and oats seeded in spring or fall. The oats act as a nurse crop for the crimson clover. This mixture is especially effective at smothering young weeds. When planted in the fall, oats winterkill and provide a dead protective mulch. Planting crimson clover with forage grasses provides a good feed crop for livestock.

MANAGEMENT OF COVER CROPS

Preplant considerations

Producers must consider several factors before establishing a cover crop. Soil fertility is an important consideration in any cropping system. Having a reliable soil test that determines soil pH and the nutrient limitations of a soil is a good way to begin the planning process. If certain nutrients are limiting, follow the soil test recommendations for the primary crop, keeping in mind that high fertility also will maximize cover crop growth.

Another important consideration is the pest history of the field. In general, additional pest management inputs are unnecessary when using cover crops. However, as with any crop, pests can become a problem in the cover crop system. If possible, select fields that have minimal pest problems when establishing the cover crop. Since there are generally crop/pest associations such as alfalfa or clover and leafhopper or winter small grains and winter annual weeds, these pests can also become a problem in the newly planted cover crop within a cropping system.

Producers also should consider the herbicide applied the previous season. Certain herbicide residues can carry over and injure sensitive rotational crops. If these residues have not dissipated before a sensitive crop is planted, injury or death of the cover crop may occur. Herbicides, including atrazine and simizine, can injure both grass and legume crops. Several of the herbicides belonging to the sulfonylurea and imidazolinone families also can carry over and injure legumes. Always refer to current crop protectant product labels to be certain of crop rotation restrictions or other limitations before establishing any crop.

Establishment options

Several options exist for seeding cover crops, including conventional, no-till, or broadcast seedings. Good seed to soil contact is necessary for proper germination and emergence. (When broadcast seeding, increase the seeding rate for proper stand establishment.) In general, preplant tillage to prepare the seedbed, control weeds, and disrupt insect and disease life cycles improves cover crop establishment. However, with some covers such as cereal rye or other small grains, no-till establishment is an effective option that allows maintenance of the no-till system.

Conventional seedbeds are prepared by plowing, disking, and harrowing the soil prior to seeding. Seeding depth depends upon the species being sown. For most cover crops, small seeded legumes require shallow seed placement (.25 inch), while larger seeded legumes and small grains are generally planted 1.0 to 1.5 inches deep.

No-till seedings are suitable for highly erodible soils and for late-season establishment. In both cases, erosion at establishment will be minimized. Modern no-till drills provide an excellent way to establish cover crops. They can handle residue and provide uniform seeding depth and adequate seed to soil contact. Producers should consider potential pest problems, including the use of an appropriate burndown herbicide (e.g., Roundup), if live vegetation is present at planting time.

Broadcast seeding also may be acceptable, although this is often the least successful method. Small-seeded species, such as the clovers, tend to establish better by broadcast than larger seed species. Several broadcast techniques and timings may be used. Surface seeding with a drop-type or cyclone-type seeder provides a uniform distribution of seed. For larger areas, aerial seeding by fixed-wing aircraft or helicopter in late summer during crop die-down can be effective. As the leaves of soybean plants drop off, they act as a mulch by covering the seed and allowing for retention of moisture and soil protection. Another broadcast seeding method is frost-seeding, which occurs during late fall or early spring when the ground is "honeycombed." This type of ground cover allows the seed to fall into the cracks and germinate when the temperature rises in the spring. Successful cover crop seeding at lay-by or last cultivation generally has been inconsistent.

SUPPRESSION OR CONTROL OF COVER CROPS

Cover crops that interfere with growth of primary crops defeat their purpose. Effective control or suppression of the cover crop generally is necessary before emergence of the main crop. Commonly used methods include tillage, mowing, herbicides, or selection of species that winterkill or have a short life cycle.

Tillage not only controls cover crops but also incorporates them into the soil, allowing them to degrade quickly and release nutrients for the primary crop. An example of incorporation is a cover crop used as a green manure. Moldboard plowing often is necessary if large amounts of cover crop biomass are present. Chisel plowing followed by disking may be inadequate for certain cover crops such as cereal rye if large amounts of residue are present.

If timed properly, mowing can successfully control certain covers prior to planting the primary crop. Producers should mow hairy vetch when the first purple flowers are visible. Mowing vetch prior to flowering can fail to provide adequate control and can

result in both crop competition and the production of vetch seed, which could affect future small grain production. Mowing vetch after pod formation may result in seed production, which may impact the primary crop or subsequent crops.

Producers should mow cereal grains after heading to insure successful control. Mowing prior to head emergence will likely result in regrowth from tillers. Regrowth from cereal grains harvested for forage in the boot stage of development is a common problem for producers who do not use an appropriate herbicide program or tillage.

Certain crops, such as oats, can be either mechanically incorporated, mowed after heading, or used as forage. Pasturing with animals or cutting for hay or silage are viable ways of utilizing cover crops for other means besides soil improvements. Species that have short life cycles or are not winter hardy also may be a means of controlling cover crops. Generally, crops such as spring oats that are planted in the fall, produce vegetation, and are killed by cold temperatures in late fall/early winter provide adequate ground cover and are effective in conserving and improving soil as well as holding moisture. However, adequate winterkill occasionally may not occur, particularly in more southern areas of Pennsylvania.

Producers can effectively control or suppress cover crops with herbicides. In addition to product selection, application timing is important. In general, make herbicide applications at least one week ahead of planting. This insures complete kill as well as some dry down of the cover crop prior to planting the primary crop. Several options exist for managing cover crops with herbicides. For more information about product selection, consult the individual commodities sections within the *Penn State Agronomy Guide* or related publications.

Prepared by William S. Curran, professor of weed science; Dwight D. Lingenfelter, program development specialist; Lyn Garling, project associate; and Peggy Wagoner, formerly of Rodale Institute Research Center

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