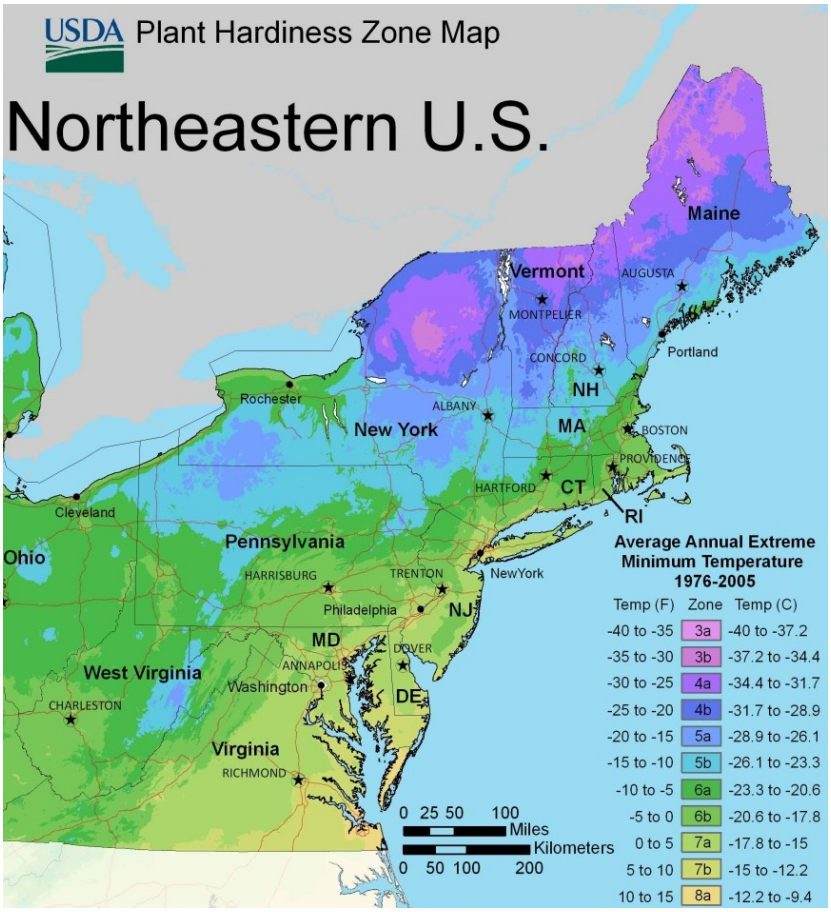
King's AgriSeeds Inc.

FEEDING YOUR FARM'S FUTURE.

*A guide to saving your soil*

# Understanding Cover Crops, Benefits, and Selection

**$10.00**


USDA Plant Hardiness Zone Map
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Average Annual Extreme Minimum Temperature 1976-2005
Temp (F) Zone Temp (C)
-40 to -35 3a -40 to -37.2
-35 to -30 3b -37.2 to -34.4
-30 to -25 4a -34.4 to -31.7
-25 to -20 4b -31.7 to -28.9
-20 to -15 5a -28.9 to -26.1
-15 to -10 5b -26.1 to -23.3
-10 to -5 6a -23.3 to -20.6
-5 to 0 6b -20.6 to -17.8
0 to 5 7a -17.8 to -15
5 to 10 7b -15 to -12.2
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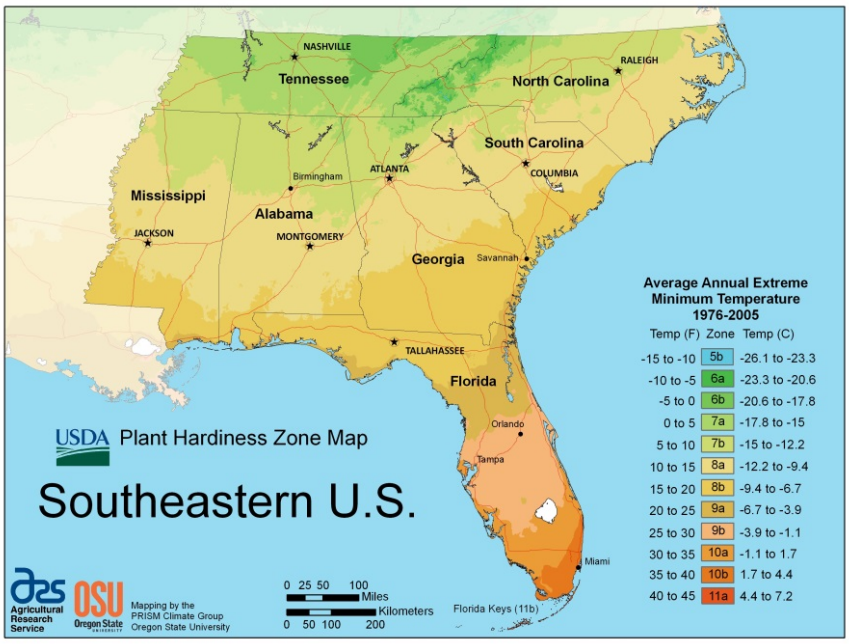
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USDA Plant Hardiness Zone Map
Southeastern U.S.
Agricultural Research Service
OSU Oregon State University
Mapping by the PRISM Climate Group Oregon State University
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15 to 20 8b -9.4 to -6.7
20 to 25 9a -6.7 to -3.9
25 to 30 9b -3.9 to -1.1
30 to 35 10a -1.1 to 1.7
35 to 40 10b 1.7 to 4.4
40 to 45 11a 4.4 to 7.2

# Contents




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## Introduction

Soil is one of the most valuable resources on your farm. Cover crops help protect that resource by slowing its erosion, improving tilth, feeding its microbiological life, and improving water holding capacity with the addition of organic matter and root biomass. Cover crops enhance nutrient cycling and help break up pest cycles. They smother weeds and attract pollinators and other beneficial insects. Planting cover crops is a highly proactive step to take in managing your rotation and improving long term soil stewardship through accumulated benefits.

Long term cover cropping involves a shift in perspective and management, but it should be viewed as an investment that increases yields, saves nitrogen costs over time, and ultimately leads to a more profitable system.

There is a cover crop for almost any soil type, climate, and terrain. There are covers to fit into your rotation, whether it be the most demanding large-scale corn-soybean rotation or a smaller, diversified produce or livestock system. Many cover crops can also double as forages – green chop, hay, or silage, or to help extend grazing systems.

The span of cover crop genetic variety has vast and often untapped potential. **Adaptability** and **versatility** of the cover crop are key in successful soil improvement for profitable long-term production. Wherever you choose to start with cover crops, adding them into your rotation will set the stage for that success by building up nutrients and improving soil structure, fertility, and permeability. They will no doubt enhance conventional tillage, no-tillage, and minimum-tillage scenarios.

**Overwintered cover crop of hairy vetch, crimson clover, and oats. Nodules visible on roots.**

Central to understanding the benefits of cover crops is not necessarily what is seen above ground, but what lies beneath the soil surface. A robust and extensive root system actually provides much of cover crops' benefits, from breaking up compaction to depositing organic matter to housing the bacteria that fix nitrogen for legumes. The plant's root zone environment is also the most active microbial site in the soil. Keeping soil covered with actively growing plant material that maintains a living root zone more months of the year helps in unseen ways, beginning with increasing the biodiversity of soil fauna and leading ultimately to a more resilient soil web of life.

King's AgriSeeds carries a full line of cover crops to fit your cropping system: legumes to fix nitrogen, small grains and brassicas to recycle nutrients, improve soil tilth, build organic matter and help break pest cycles. We have diverse cover crop mixes to fit into various growing zones. We encourage you to talk with our sales reps or a King's dealer close to you to find the right crop for your goals and growing zone.

**Planting note/herbicides:** You must make sure that the cover crop you select is compatible with your current herbicide

program. Be sure that you refer to information on susceptible plants and residual times for herbicides that will be used in fields that will be planted with a cover crop.

After planting the cover crops, take notes on emergence, overwintering capability and stand establishment. Also, be sure to consider the "spatial niches" on your farm. **Strip cropping** provides a simple method for rotating a cover crop with a vegetable planting. Alternate field strips or beds of a fall- or spring-planted cover crop with strips of early-planted vegetables like potato, onion, cabbage, lettuce or peas. Adjust the width of your fields to accommodate easier cover crop seeding (using your seeding equipment as the standard of measure). Strip cropping is a low-cost, low-input way of getting the benefits of a cover crop.

For agronomic crops planted on a larger acreage, the strip-cropping concept can still apply, but the strips will be large, field-sized strips with the width adjusted for your particular farm planting and harvesting equipment. Rotating cover crops in field strips arranged parallel to the contour slope of a hill makes good agronomic sense; these rotated cover crop strips will prevent soil erosion over time. Even where the topography is largely flat, cover crop strips provide other added benefits—such as attracting beneficial insects, providing crop diversification, and buffering effects—which can all help break the rapid spread of disease and insect epidemics that often plague large monoculture cropping systems.

Think about the big picture. How will you get your cover crop established? What type and size of drill is available? What are the speed-ratio drive settings of the gearing for the seeders? Do you need to make adjustments? Check the drill manual to determine the proper fluted feed opening required for your particular cover crop seed. As you try new cover crops some drills may not have a "notch" setting for all the cover crop seed you're using. For example, the John Deere grain drill on our farm does not have a setting for rapeseed. So we planted rapeseed using the grass seed box of the drill, calibrating it to the crimson clover or pearl millet setting (both have a seed size similar to rapeseed). With a little tinkering, we've found that there's usually a solution close at hand.

The biodiversity you bring into your system with good crop rotation delivers many benefits, including improved yields, reduced and often prevented disease transmission, insect control, weed suppression, soil nitrogen management, improving soil tilth and structure, improved water utilization and reduced soil erosion. Cover crops are key in any rotation and, in the case of organic farming, are often the underlying drivers of the system.

A summer pollinator mix that draws beneficial insects and soil building

## Cover Crop Terminology

**Winter-killed Daikon radish (left) and Braco white mustard (right) can leave a weed-free field in the spring, partly with the help of allelopathy.**

**Cover Crops:** Cover crops are those crops that are planted to provide cover for the soil. They may be grown between orchard trees as a more permanent cover, or as a temporary break crop in fields in between cropping seasons, regardless of whether they are later incorporated. They are primarily a biological conservation tool to prevent soil erosion by water and/or wind, and are used to help build soil health. They are usually planted before and after the main designated cash crop in a rotation. Functions of a cover crop may include: ground cover or mulch, green manure, nurse crop, or smother crop. When crops are grown primarily as forage or food for animal and human consumption, they are not necessarily termed a cover crop, but still provide the main benefit of a cover crop – keeping soil covered with a living crop. Cover crops can be annual, biennial, or perennial species, including legumes, grasses, and brassicas. They have many benefits to the crop that follows and improve and protect the soil.

**Allelopathy:** The weed-inhibiting effects of many cover crops. Allelopathy is defined as "the inhibition of one species of plants by chemicals produced by another species." It can be any direct or indirect harmful effect produced in one plant released into the environment. The magnitude of the detrimental effects depends on the extent of any other stressors, such as biological factors or environmental conditions (e.g. insect or disease pressure) that occur at the same time.

Allelopathic compounds and effects of cover crops vary greatly. Some include:

- Peas, lentils, vetches: Beta-(3-isoxazolinonyl) alanine. Released as root exudates. Supresses lambsquarter, yellow foxtail, yellow nutsedge, and pitted morning glory.
- Buckwheat: Diethyl phthalate. Mostly in the stem rather than the shoots, so it is most likely to be active in weed suppression after buckwheat is harvested. It is especially active on pigweed, but not very effective on plants in the mustard family.
- Cereal rye: Contains several compounds. The most active are two hydroxamic acids and their breakdown products.
- Crimson clover has been shown to suppress putted morning glory, wild mustard, and Italian ryegrass.
- Sorghum-sudangrass: Sorgoleone. When residues decay they inhibit pigweed, velvetleaf, large crabgrass, barnyardgrass, green foxtail, and common ragweed.

**Break Crop:** Different plants attract and harbor different populations of insects. Cover crops that are different species from the cash crop can be planted in the rotation to interrupt insect life cycles and break up existing pest patterns. Reducing pest and disease pressure in your fields is one of the top benefits of incorporating cover crops into the rotation.

**Blooming cover crops like Braco White Mustard attract beneficial insects that break up existing pest patterns**

**Catch Crop:** When cover crops are planted with the primary goal of reducing nutrient leaching they are termed "catch crops." These are planted after cash crops are harvested or following legume plowdowns or manure spreading to hold onto easily leached nitrogen and other nutrients.

Catch crops take up and hold nutrients in their tissues, especially those that are in danger of leaching below the active root zone of the soil. One of the most vulnerable times is between fall and spring, during times of heavy rain and/or snow melt. Catch crops can help retain nutrients that are applied too late in the season to plant a regular crop, or when the regular crop has "failed" for one reason or another. Short season crops like millet or buckwheat are often used for this purpose and can help fill in a short gap in the rotation. When catch crops are terminated, they slowly release nutrients as they break down.

***Manure Management:*** Cover crops not only recycle and scavenge unused nutrients left over after crop harvest, but those growing over winter are especially important for uptaking nutrients, including nitrogen, from fall and winter applied manure. Adding a cover crop increases the percentage of fall and winter applied manure nitrogen available to the following year's crop – approximately a 20 percent increase for dairy and beef manure, a 25 percent increase for swine manure, and 35 percent for poultry manure.

These nitrogen benefits to the next crop only apply if the cover crop is left in the field to decompose, rather than being harvested for forage. If the crop is harvested for forage, those nutrients are gained in the forage. Either way, the good news is that far fewer nutrients are lost to either runoff or leaching.

**Green Manure:** Any crop that is grown or incorporated into the soil while green and soon after flowering for soil improvement, fertility, and organic matter addition. Before commercial nitrogen fertilizer was available, green manure was the predominant method of supplying nitrogen to crops. The most common green manure crops include hairy vetch, rye, crimson clover, sweetclover, and alfalfa. Others used on a more limited basis include buckwheat,

lespedeza, cowpeas, soybeans, ladino clover, and field peas.

On a dry matter basis, hairy vetch, Austrian winter peas, field peas, and alfalfa green manures can contain 3-4 percent nitrogen, while other legumes contain 2-3.5 percent, and cereal grains and ryegrass contain 1.2-1.4 percent. 40-60 percent of this nitrogen is available initially.

**Nurse crop of oats, a spring annual, planted with a perennial alfalfa-grass mix**

**Nurse Crop:** A quick-growing crop that is planted with a slower-maturing crop (usually an annual small grain planted with a slower-growing perennial). The nurse crop germinates and emerges quickly, holds the soil with quick cover and root growth, and out-competes weeds for available resources until the main crop can fill out its own canopy. Oats planted in the late summer or fall is a favorite nurse crop for a companion to a fall seeded legume like alfalfa. They can contribute to the first cutting or can be left to grow and winterkill with frost, providing buffer against winter wind, ice sheeting, and frost heaving with their residue. Spring barley, spring triticale, pea-oat mix, and other species have been used in this role as well.

**Scavenger Crops:** Farm soils that have been heavily cropped with shallow-rooted plants such as corn may become deficient in certain micronutrients. Deep rooted scavenger cover crops such as annual ryegrass, alfalfa, red clover, and sweetclover roots grow deep into the subsoil and can bring soil nutrients up into the upper layers. The deep-growing root structure also helps break up soil compaction, and when plants die the decaying root matter leaves channels in the soil for water infiltration (reducing runoff problems) and ease of future root growth.

**Smother Crops:** Smother crops are effective weed suppressors because they produce large amounts of biomass in a short time, and it's easy to reap these weed-suppressing benefits while extending the crop's use to forage. Fast growing buckwheat and sorghum-sudan, hairy vetch and sweetclover help control weeds by growing a thick canopy that reduces the amount of sunlight available to help weed seeds germinate and grow. The annual grass crops and buckwheat also have expansive, fibrous root systems that grow quickly to outcompete weeds for water and nutrients. Smother crops grow quickly and produce leaf canopy or dense growth that shades out lower-growing weeds. Growing different crops in a single season is an effective strategy for weed control. An example of an effective sequence of smother crops would be: oats in the spring, buckwheat or sorghum-sudan in the summer, and rye, triticale, or forage brassicas in the fall. Overwintering crops like hairy vetch can also act as an early spring smother crop.

# Selecting and Using Cover Crops

Cover crops can be a key soil improvement tool for conventional and organic growers alike. There is a cover crop to fit almost every type of cropping system.

For Certified Organic farms: According to the USDA National Organic Program Standards, "the producer is required to implement a crop rotation, including but not limited to sod, cover crops, green manure crops, and catch crops.

The possibilities for plants that can be used as cover crops are almost limitless. They can be perennials or annuals. They generally fall into one of two categories: **Leguminous and non-leguminous (includes both grasses and broadleaves).** Leguminous cover crops fix and add nitrogen to the soil. Non-leguminous cover crops are often preferred on erosive soil. Each type has its distinct advantages, and mixes of both are very beneficial.

## Non-Legume Cover Crops

Most common non-legume cover crops are grasses, good for scavenging nitrogen, building organic matter, preventing erosion, and suppressing weeds. They can be classified as winter annuals, summer annuals, cool season (spring or fall) annuals, biennials, or perennials. Grasses often have dense masses of fibrous roots that improve soil structure and stimulate soil microorganisms, which helps aggregate soil particles. Grasses' fine roots also bind soil crumbs directly.

Non-legume cover crops include:

- Annual Ryegrass
- Brassicas
- Buckwheat
- Small grains – Oats, triticale, wheat, barley, rye
- Summer annual grasses – millet, sorghum-sudan, sudangrass
- Sunflowers

### Small Grains: The Backbone of Many Rotations

*You may look at most small grains – oats, rye, wheat, triticale, barley, spelt – and think of either grain or forage. As it happens, small grains also make excellent cover crops. They are easy and economical to establish and grow, great at building soil, and helpful for uptaking excess nutrients. Get them in the ground on the early side in the fall (or spring, for oats, spring triticale, or spring barley) to*

*get the most benefit.* ***You don't need a fancy mix or even a legume to reap many of the benefits that come with keeping soil covered.*** *Diversity is a bonus, but usually not a necessity in basic cover cropping.*


**Research Plots in Lancaster County, PA show more rapid spring growth of rye (at left) than Triticale Plus (triticale and annual ryegrass mix) on April 26, 2013.**

***Small grain cover crops have more benefits than you think –***

- ***They are cheap to plant.*** *If you intend the crop only for cover crop use, you won't need to use the full seeding rate typical of forage or even grain crops. Often at a third to half of the forage seeding rate (planted on time and managed correctly) many small grains tiller, fill out and provide excellent groundcover and root growth. This could be as little as $15-20/A in seed cost (Hint: the triticale market has become very buyer-friendly at the time of this writing.)*
- ***They're easy to manage.*** *The large seeds establish easily when planted at the right depth (1 inch is ideal), and grow quickly and tiller in the fall when planted on time.*
- ***They're easy to control.*** *The threat of weediness is low if they are properly controlled in spring – whether with tillage, burndown, mowing, or even grazing.*
- ***They are good at uptaking nutrients.*** *Root masses penetrate downward and outward, scavenging nutrients from manure applications and leachate from the previous crop. They often make off-season manure applications possible.*
- ***They are among the best sources of over-winter soil organic matter.*** *Small grains are a better source of active carbon than legumes, which has many benefits for soil. Soil organic matter supports improved soil biological diversity, water infiltration, drainage, nutrient availability, and retention of water and nutrients.*
- ***They can be a blank canvas on which to build a simple or complex mix.*** *Small grains fit with almost any winter annual. However, the planting date needs to be adjusted to accommodate the other species. A brassica like radish or a legume like crimson clover or hairy vetch needs an earlier planting, usually at least 6-8 weeks prior to your frost date. Adjust the seeding rate as well. The small grain should be no more than 75% of full rate, and the smaller seeded companion can usually be 50% to full rate (it will often be slower growing, slower establishing, and need a little more advantage against the small grain's competition). Annual ryegrass also makes an excellent companion and works for planting into mid fall,* ***but must be terminated properly.*** *Annual ryegrass can persist unless plowed under or thoroughly sprayed. Each of these*

*companions add digestible protein and energy to your small grain. Even our more complicated winter cover crop mixes are based on small grains, relying on triticale to anchor soil and shelter less cold-tolerant species. The small grains also provide bulk and substance if the mix is used for forage.*

- ***They can be multi-purpose.*** *Plant at a full rate, and the small grain stand can be grazed or harvested in fall or spring (provided there is enough time for a little regrowth before winter). Most small grains have high levels of fiber digestibility and protein if harvested before heading. Triticale is excellent in this regard. You'll still get the benefits of ground cover, erosion control, some weed control, fertility retention, and more.*
- ***They compensate for gaps.*** *Small grains tiller and can even canopy in the fall if they are planted early enough (after about 6 inches of growth, however, you sacrifice some winter hardiness and risk matting and snow mold). Some small grains also close gaps by virtue of their specific growth tendencies. TriCal 815 Triticale, for example, has a more prostrate and spreading growth pattern that grows both out and up. The quick cool season growth outcompetes weeds, and small grains have the ability to keep growing even as temperatures dip (rye, the most winter-hardy grain, doesn't go dormant until temperatures drop below 40 degrees F). Growth characteristics like these prove to be an advantage over weeds.*
- ***They work hard right out of the gate.*** *Small grains begin growth quickly, especially in early fall with late summer residual heat. Even a few weeks into their growth, soil infiltration is improved.*
- ***They work with most rotations.*** *Small grains are flexible. Most small grains can still be planted after corn silage harvest. In many cases, triticale and rye can still be planted after corn grain harvest. Oats can be planted in late summer and winterkill, in case soil needs to be ready to go first thing in the spring. And all small grains are valuable to break up a rotation with early or late season vegetables, anything from garlic to tomatoes to pumpkins, since they provide the break of grasses in a heavily broadleaf-based rotation.*
- ***They buffer soil against extremes in temperature.*** *Bare soil absorbs much more heat and cold than soil protected or insulated by crop residue or actively growing plants. This wreaks havoc on soil biology. Much of soil health depends on stewarding the life in your soil!*
- ***There are few pests or diseases they host that will be a problem for the rotation as a whole –*** *unless you have an exclusively small grain rotation (not advised)***.**

***What's the exact contribution?***

*Small grains' role in the nitrogen cycle is often debated. They uptake nitrogen as they grow, but how soon can it be made available to the next crops? Much of this depends on when the cover crop is terminated. More mature small grains take longer to decompose, and have a greater ratio of carbon to nitrogen, tying up the nitrogen for longer. Tying up nitrogen will impact yield unless you provide extra fertility. (Another way to offset this is to use a legume companion crop such as hairy vetch, crimson clover, or winter peas, helping to fix nitrogen and build the total amount of nitrogen in the soil.) Therefore, it's better to err on the side of terminating the cover crop at an earlier stage of maturity. Incorporation will lead to faster decomposition and N mineralization than leaving the residue on the surface. Incorporating the crop before it reaches 18 inches tall is considered ideal, since lignin (carbon to nitrogen ratio) is increasing to*

*structurally support a taller plant and grain head. If the crop is taken for forage, you'll be less likely to run into this problem, since you will be leaving less material that will take much less time to break down.*

*In many situations, it's better to sacrifice some cover crop yield and active organic matter contribution to preserve the yield potential of the following crop.*

*It's difficult to quantify the nutrient contribution of the cover crop to your soil with all the possible variables left to account for – your existing soil fertility, your planting date, seeding rate, termination date, and all the possible rainfall, snowfall, and temperature conditions. We can say with confidence that an actively growing small grain cover crop greatly reduces nitrate leaching over the winter and therefore increases the nitrogen credits that will eventually be returned to the root growth zone of the soil. We also know that ultimately the total amount of nitrogen sequestered by the cover follows the total biomass produced (this goes for nitrogen fixation by legumes, as well) – so you fix or sequester more the longer you let it grow. The immediate effects on the next crop are unavoidable considerations, however, and there will usually be a trade-off in place.*

*If you are late in planting, increase the seeding rate, since you risk running out of good growing days fall to get the tillering that is ideal for winter survival and groundcover. Timely or slightly early planting is ideal, since it lets root and tiller growth get a head start.*

## Legume Cover Crops

Legumes use a symbiosis with bacteria to fix atmospheric nitrogen for their own use. Legumes have relatively simple root systems, dominated by a central taproot and are often heavily nodulated. Few other plant families fix significant nitrogen, so legumes are a key component in long-term productive sustainable farming systems. Different legumes require different inoculants.

Some common legume cover crops are –

- Clovers, such as crimson clover, red clover, white clover, sweetclover
- Cowpeas
- Hairy Vetch
- Sunn Hemp

### Legumes Grown in Rotation for Nitrogen

The amount of nitrogen fixed annually by rhizobia varies by legume species. (Numbers represent potential under favorable conditions.)

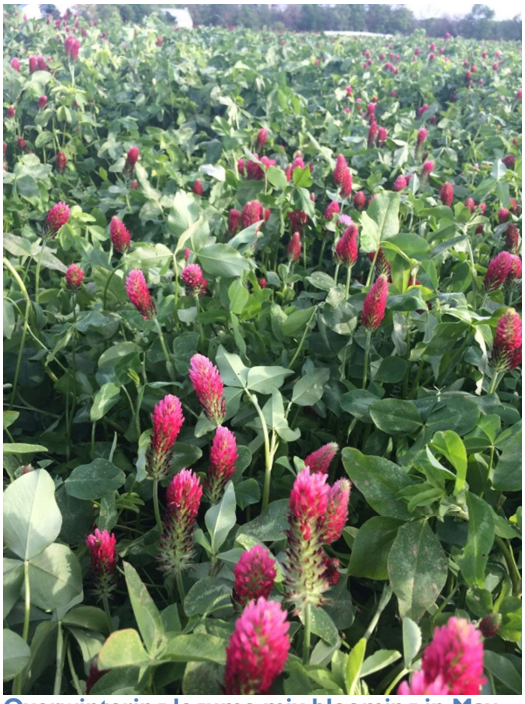
| **Legume Crop** | **Lbs/A nitrogen fixed** |
|---|---|
| Alfalfa | 160-300 |
| Hairy Vetch | 150-250 |
| Field Peas/Austrian Winter Peas | 90-150 |
| Ladino Clover | 85-180 |
| Red Clover | 85-135 |
| Crimson Clover | 60-150 |

The highest nitrogen benefits will be realized by letting the legume grow full term – through most of its lifecycle – before terminating it. Nitrogen production is related not only to a later maturity stage but also to higher amounts of biomass production. An over-wintering legume fixes more nitrogen than the same legume planted in the spring. Legumes that were frost-seeded into small grains and left to grow throughout the year have a growth and nitrogen advantage over those that were planted later in the spring or summer.

**Note:** As a rule of thumb, about 40-60% of the nitrogen from a legume plow-down is available the first year if the crop is incorporated as a green manure. Hairy vetch tends to make more

nitrogen available when rolled and killed as a no-till mulch than other legumes.

The final amount of nitrogen fixed by the legume depends on the species, the maturity at termination, and the legume's growth in the



Overwintering legume mix blooming in May

spring, which depends on the temperatures in the spring. Maximum accumulation of legume nitrogen usually occurs within two months after the legume begins to bloom. 50 percent bloom to full bloom stage is a good time to plow down the legume as a green manure to enrich the soil and obtain a substantial amount of nitrogen for the next crop in the rotation.

## Nitrogen availability

Most of the biologically fixed nitrogen (about 80 percent) is in the top growth of the plant, and becomes available faster than the nitrogen content in the roots. Legumes break down relatively quickly after being incorporated into the soil, and as they do, the nitrogen is gradually released to the soil as nitrates, an available form for the next crop in the rotation. Approximately 40-60 percent of the nitrogen in the legume will be available in the first year after plow-down for following crops; the rest will be released over a period of a few years.

## Inoculation of Legumes

Legume cover crops should be inoculated to ensure that nodules will form on their roots, which means that Rhizobia bacteria have infected the plant's root hairs. Many of these bacteria are found in soil, but they are not all equally effective at fixing nitrogen. To make sure that nodules will form from the strain of rhizobia bacteria that is best suited to the legume, you should properly inoculate the legume seeds before planting. This is important, especially in fields where that family of legume has not been grown before.

Most of the commercially available inoculants are available as a mix of a strain or strains of Rhizobia bacteria along with a finely ground peat, which helps keep the bacteria alive when stored in a cool, dry location. For optimal inoculation and nodulation, the inoculant must be the correct strain for the species of legume and be placed on the seed so it will be in contact with the roots of the legume as the seeds germinate and grow. This association between legume species and rhizobial strain is often highly specific. One bacterial strain is able to infect the root system and produce effective nodules on one legume species but not another.

The groups are divided as follows: **alfalfa, clover, cowpea, lupine, pea/vetch,** and others in the following table.

**Cross-Inoculation Groups and Rhizobium-Legume Association**

| Group | Common Legume Names | Inoculant Bacteria strain | Inoculant Code |
|---|---|---|---|
| Alfalfa Group | Alfalfa<br>Black Medic<br>Bur clover (medic)<br>Button clover (medic)<br>White sweet clover<br>Yellow sweet clover | *Rhizobium meliloti* | A (Lucerne-Medics) |
| Bean | Beans | *Rhizobium phaseolie* | D |
| Clover I | Berseem clover<br>Crimson clover<br>Lappa clover<br>Persian clover<br>Rose clover | *Rhizobium trifolii* | B |
| Clover II | Rose clover<br>Subterranean clover | *Rhizobium trifolii* | B |
| Clover III | Alsike clover<br>Ball clover<br>Hop clover<br>Ladino clover<br>Red clover<br>White clover | *Rhizobium trifolii* | B |
| Clover IV | Arrowleaf clover<br>Persian clover | *Rhizobium trifolii* | B or O |
| Lupine | Lupines | *Rhizobium lupini* | H, G (Lupin-Serradella) |
| Pea | Caleypeas<br>Garden peas<br>Lentils<br>Vetches<br>Winter peas | *Rhizobium leguminosarum* – Biovar viceae | C or E (Pea) |
| Soybean | Soybeans | *Bradyrhizobium japonicum* | S |
| Cowpea | Alyce clover<br>Cowpeas<br>Lespedeza<br>Lima bean<br>Peanut<br>Kudzu | *Bradyrhizobium japonicum* | S |
| Trefoil | Birdsfoot trefoil<br>Narrowleaf trefoil | *Rhizobium loti* | K |

## Why Inoculate, Exactly?

*That little packet of dark powder you are coerced into purchasing along with your clover seed can be mystifying. It only weighs a few ounces, and it has to be kept cool and dry and managed like a living pet (it is, after all, alive). Plus it invariably gets all over your hands and clothes. What is it, anyway, and is it really necessary? The short answer is yes, it is necessary in the vast majority of cases, if you want to do everything possible to stack the deck in your favor.*

*Legumes (clovers, alfalfas, vetches, peas, beans, trefoil, etc.) play a prominent role in many farming systems. Many farms, not just organic systems, use them to fix atmospheric nitrogen and save on application costs of synthetic fertilizers. How do legumes take nitrogen in the air and convert it to a form they can use? They rely on several species of rhizobia bacteria that form symbiotic relationships with their roots. Within a period of 30-40 days, the bacteria form visible nodules along the roots, and you can tell that they are active when you can cut open some of the nodules and they are pink inside. The bacteria rely on the plant for carbohydrates, and in return, they produce nitrogen the plant can use. Many legumes can fix up to 200 lbs per acre of nitrogen by the time of full bloom.*

**Nodulation on pea roots**

***This little packet of dark powder is taking the place of a substantial quantity of synthetic nitrogen fertilizer, and it's costing you far less.*** *Think of it as "Inexpensive insurance", at the very least. 300 grams of inoculant contains the amount of rhizobia in 4 tons of soil that produced well-nodulated legumes – not a bad deal!*

*We introduce these nitrogen-fixing bacteria through that added packaged inoculant. The black powder you see is a finely ground peat substrate for the bacteria to live on. Many people choose to dry mix it with the seed, but the most effective method to get some to adhere to every seed is to mix seed with a mildy sticky substance, such as a 10:1 water and sugar or honey solution. Some people choose soda, which has the right amount of stickiness, but it is not recommended since its acidity kills many of the bacteria. Dry the damp seed in the shade for about an hour prior to planting (direct sunlight kills the inoculant).*

*Penn State Extension provides an excellent explanation for how this process relates to the production and use of synthetic nitrogen fertilizers:*

*"In the industrial (Haber) process, petroleum energy is used to break the triple bond [between nitrogen atoms], and three hydrogen ions from natural gas or another petroleum product are added to each N atom. Therefore, N fertilizer prices increase as energy prices rise.*

*"In symbiotic N fixation, as is the case with legumes, these same steps are required of the Rhizobia bacteria. Sugars or carbohydrates of a legume infected with Rhizobia are the energy and hydrogen source used by the bacteria to fix N from the air at high energy costs to the plant.* ***If the plant can avoid these costs by taking up N from the soil, it will. Therefore, N fertilization inhibits nodule formation and N fixation."***

- *Penn State Extension, http://extension.psu.edu/plants/crops/forages/successful-forage-establishment/inoculation-of-legumes-for-maximum-nitrogen-fixation*

*This is a great reminder that legumes can be as lazy as the rest of us. If they have easily accessible food in the surrounding soil, they won't bear the costs of producing it. You can easily see that this is happening if you dig up the legume roots and they aren't nodulating (and you have planted inoculated seed).*

***One of the biggest reasons to inoculate legumes is to give them access to the fertility they need without helping weeds at the same time.*** *Applying nitrogen fertilizer can really boost competition from weeds, while inoculating legumes gives only legumes the advantage. However, it takes about a month of growth for them to develop good nodulation and nitrogen production, so for forage legumes, 20 lbs/A of applied starter nitrogen is often recommended.*

***In the end, it matters very little if the legume in question is a cover crop or forage – you should still inoculate.*** *As a cover crop, it's likely that the main purpose is to produce nitrogen for subsequent crops, but to maximize N fixation, it has to be grown all the way to bloom. Many farmers struggle with this timeline, since typical bloom may not be until the middle or end of May, past their preferred planting date for corn or other summer annuals. If intended to be grown to bloom, the inoculation is arguably more important, but in all situations it is critical to getting your money's worth out of the crop in terms of the quantity of overall growth. Technically necessary? No, but it's basically common sense and fully cost-effective. You spent the money on expensive seed (and legumes are costly compared to other crops) and you want to get your money's worth of growth.*

*The same goes for forage production. Just as you would apply your 100 units of N to a small grain, you inoculate your legume.*

***How about a mix?*** *Many of our mixes, especially the perennials, come with a coating that contains inoculant, so you really want to take care of the seed as you would handle inoculant – keep cool and dry, out of direct sunlight – and try not to store it for an extended time.*

*If it's not pre-inoculated, it's highly recommended to inoculate for all legume species in the mix. For example, if it contains vetch and clover, you will need the rhizobia strains labeled for pea-vetch and for clover.*

*The earliest species in the mix will likely dictate when it gets harvested, since you don't want those species producing seed and causing weediness in the next crop. For example, if the mix contains barley, rye, or even triticale, these will be producing seed by the time crimson clover or hairy vetch flowers in the spring. So the legume won't be a heavy hitter in the context of the mix, but it's still in there for a reason. To get the most out of it, whether as a diverse cover crop or high-protein forage, you will need to inoculate.*

***What about fields that had the same legume family planted within the last year or two?*** *This won't be critical, but it can still be a big help – especially to increase the population of the relevant rhizobia strain in fields that have suffered unfavorable conditions, such as a low pH (6.5-7.0 is ideal, so liming will be needed in those cases), extremely sandy soil, or periodic flooding. Another critical aspect of the soil environment is the presence of molybdenum, which rhizobia need for the biochemical reaction that produces nitrogen for the plant. Molybdenum is usually present in Pennsylvania soils in sufficient quantity, but* ***this availability will be affected by soil pH.*** *Inoculation is necessary without question in a field*

*that has been out of host plant production for 3-5 years.*

### *A final thought*

*It takes time for the plant to fix a good quantity of nitrogen, and it takes time for this nitrogen to become available. In a long-term perennial mix, the nitrogen fixed by legumes can become available in soil as roots slough off and plant material decomposes, and this free nitrogen can begin to feed some grass roots. In an annual mix, however, the timeline is so condensed that you can't count on the legumes to feed the hungry grasses and broadleaves. Most of the N won't even be fixed until close to the end of the mix's lifespan. Even after you have terminated a mix where legumes have been allowed to reach bloom stage, the material will have to fully decompose for the N it contains to become plant-available. Therefore, we generally say that about half the N in a legume crop is available during the first year after it is terminated – IF the biomass is turned under or mowed/rolled/sprayed and left as residue. If it is removed as forage, you are probably left with a little less than half the total biomass in root material, which greatly cuts down on the remaining nitrogen (and only about half of that is available right away). The available nitrogen depends on how quickly the legume residue breaks down, which is almost exclusively dependent on soil temperature and moisture.*

*Remember, properly inoculated legumes have the nitrogen fuel they need to reach their maximum growth potential – and more biomass produced means more total nitrogen production.*

***Keep in mind that every group of legume has a specific rhizobia species that it can host. These are called cross-inoculation groups.***

## Cover Crop Selection Criteria

1. Reasons for planting
2. Field history – what is the long term rotation? What are the previous and expected crops? **Check previous herbicide application and refer to information on susceptible plants and residual times for herbicides used in fields that will be planted with a cover crop.**
3. Neighboring crops
4. Irrigation methods (if used)
5. Soil (type, pH)
6. Weeds
7. Pest problems
8. Cover crop window in the rotation (timing of establishment and removal/termination)

### The ideal cover crop should:

- Be easily established
- Be highly productive – good biomass yield for best soil coverage and other benefits
- Be easily killed – mechanically or chemically, depending on whether you are organic or conventional
- Not be allelopathic to the main cash crop
- Fit into your site-specific growing conditions
- Fit into the timing of your rotation

### Identify the primary function of your cover crop based on the needs of your system

Ask yourself which of the following need(s) you want your cover crop to fulfill.

1. **Provide nitrogen –** Growing legumes (peas, vetches, clovers, beans) is one of the most important tools to increase soil fertility. Legumes fix nitrogen from the atmosphere and make it available in the soil to other plants. They use a symbiotic relationship with soil-dwelling bacteria (rhizobia), which take gaseous nitrogen from the soil air and convert or "fix" it into a form the plant can use. In exchange, the plant provides carbohydrate nourishment to the bacteria. Legumes vary by species in their nitrogen fixing potential. Legumes produce most of their nitrogen in the top growth, so it's important to let them grow to maturity (terminating them before seed production). The residues provide substantial nitrogen to the following crop as they decompose.

2. **Increase soil organic matter –** A major benefit of green manures is that the addition of carbon compounds in the form of organic matter to the soil. It's important to keep adding to soil organic matter levels with crop residues, as they decrease over time with tillage and biological activity. In no-till systems where residue incorporation is limited, cover crops are important organic matter builders. Their roots physically penetrate soil and release carbon compounds as root exudates at varying depths. When the cover crop is terminated, its root biomass as well as its top growth (herbage) is incorporated as soil organic matter at various depths.

3. **Improve nutrient availability in the soil –** Cover crop plant roots release most of the sugars the plant has produced into the soil to feed soil microorganisms that in turn mineralize, release, and recycle nutrients to the next crop. When incorporated into the soil, cover crop biomass is decomposed by soil bacteria and fungi, releasing

nutrients in the process. High biomass-producing cover crops will be best for nutrient cycling, such as sorghum-sudan for a summer annual, or cereal rye, triticale, or annual ryegrass for a winter annual. The most productive legumes include hairy vetch, alfalfa, medium red clover, ladino white clover, field peas, cowpeas, and crimson clover.

More plant residues associated with cover crops help improve the soil environment for beneficial organisms such as earthworms, insects, and microorganisms. Many of these improve soil quality and nutrient availability by quickly decomposing plant residues and organic matter.

4. **Scavenge nutrients –** Soluble nutrients, especially nitrogen, are left in the soil after the cash crop has been harvested. Over the winter, bare soil is prone to losses of nutrients both to the air by volatilization and to the water by leaching and runoff. Growing a cover crop will reduce those losses by taking up the nutrients into their own tissues and holding them over winter. The nutrients in decomposing cover crops are not always directly available to plants. Soil microbes break down plant residues, taking up some of the nutrients and releasing others to the soil environment. As the plant residues are decomposed, the nutrients in their tissues become available to the next crop in the rotation like a slow-release fertilizer. The rate of cover crop decomposition and subsequent nutrient availability will be dependent on soil temperature and moisture. For best nutrient scavenging, use crops with extensive root systems that develop quickly after planting.

**Daikon Radish tap roots grow deep to alleviate compaction and bring up leached nutrients.**

Non-legumes such as winter annual grasses and small grains (triticale, wheat, rye, ryegrass, etc.) are excellent nutrient scavengers. Grasses make efficient use of nitrogen that might leach down through the soil and eventually be lost out of the root zone, because they scavenge and take up nitrogen rather than fixing their own as legumes do. Their roots are adept at branching outward and downward to tap into plant-available soil nitrogen.

Late summer or early fall planted oats can be grown as a nurse crop in a winter annual mix, and grow very quickly in the fall to take up nutrients before the other slower growing winter annual cover crops are fully established. The oats will eventually winter kill in the mix, but they will do their share of nutrient scavenging up front very quickly. After they die and decompose, the nutrients that they took up in the beginning will be re-released to the rest of the growing winter annual mix or to the subsequent crop in rotation. Brassicas, such as rapeseed, turnip,

radish and mustard blends, also work quite well for this function of quick nutrient scavenging in mixes.

Legumes and grasses have symbiotic relationships with fungi that produce mycorrhizal hyphae (fungus roots) that spread out through the soil and help the plant obtain scarce nutrients growing outside its typical root zone (for example, phosphorus). These fungal helpers need to exist in association with a plant root to survive, so having a living cover growing year round strengthens the microbe-root relationship throughout the rotation to foster nutrient scavenging and cycling.

5. **Prevent soil erosion and runoff –** Cover crops provide a physical sheltering layer for the soil, protecting soil from raindrop impact, water velocity across the surface, and the potential for erosion. Choose species that grow rapidly and cover the soil surface. Most of the same species that are useful as nutrient scavengers also provide good soil cover.

6. **Improve soil structure –** Increasing soil organic matter improves soil physical properties through a complex process. As plant residues degrade, the soil microbes feeding on them release glue-like compounds into the soil (gums, waxes, and other substances and exudates), which cement soil particles together to form stable soil aggregates, resulting in improved soil structure and tilth. Both grasses and legumes have mychorrizal associations, but grasses are characterized by dense masses of fibrous roots that improve soil structure by exuding polysaccharides. These stimulate soil microorganisms, which in turn exude gums that aggregate soil particles. Aggregates contribute to greater soil permeability, soil porosity, aeration, water infiltration and holding capacity, cation exchange capacity (CEC) and ease of crop emergence and root growth. The added organic matter also alleviates compaction by reducing the bulk density of the soil.

7. **Improve drainage, alleviate compaction –** Deep rooted species can help break through compacted layers in the soil like plow pans or hard pans, improving drainage. The penetrating roots of the cover crop make channels through which soil water can move after the root system decomposes. Annual ryegrass has deep branching roots, and species with taproots such as many brassicas and legumes also penetrate deep into soil. Those growing through winter are efficient at breaking up compaction, as the lower layers of soil are wetter and softer over the winter. Daikon radishes are especially adept at "bio-drilling" down into soil and breaking up deeper compacted layers.

   Brassica roots are known to penetrate about one foot deeper than cereals and nearly two feet deeper than grain legumes. The large taproot creates more space for beneficial organisms such as earthworms, which are particularly good at improving water infiltration and soil structure with the channels they create and the organic material they recycle.

8. **Provide mulch to conserve soil moisture –** The higher the carbon to nitrogen ratio of the crop, the more slowly it will decompose and the longer the residue will serve as a moisture-conserving, weed-suppressing mat. If this is your goal, choose a cover crop with a combination of high above-ground biomass and moderate to high carbon to nitrogen ratios. The microbes that decompose crop residues use carbon as an energy source and nitrogen to build tissue. If residues have a C:N ratio higher than 25:1, microbes will need to use N from the surrounding environment to do their job.

   Small grain cover crops are generally better for this purpose. Most legumes have a higher nitrogen content and will decompose more rapidly, making them less effective as mulches. Mature rye and triticale can be effectively used as weed-suppressing mulches when rolled down before planting the main crop; this suppresses weeds and hampers soil moisture evaporation.

### Identify the best place in your rotation for the cover crop

Cover crops can fit into many different cropping systems during portions of the year when no cash crop is being grown. Both agronomic and vegetable rotations can accommodate and benefit from the biodiversity and soil health bonuses that cover crops provide.

Consider the timing of your field operations to plan both the planting, typical time to maturity, and incorporation/termination of the cover crop around the needed timing for cash crop production. Many legume cover crops have hard seed coats and often take two weeks to germinate and emerge with adequate soil moisture present, but longer if planted during a dry spell or when soil temperatures are cooler.

Consider both cool weather and warm weather crops, including winter annuals, summer annuals, and biennials. Learn the typical lifecycle times of these and find one that fits the timing of the current cash crop operation and the required field operations.

**Winter Annual or Cool Season Cover Crops:** Most of the winter cover crops are planted in the fall after the cash crop is harvested, and provide cover over the winter months. Overwintering cover crops include annual, biennial, and perennial clovers, vetches, winter peas, cereal grains such as triticale and rye, and grasses like annual and perennial ryegrass. Spring oats and many brassicas planted in the fall will grow quickly and winterkill to provide a soil-covering dead mulch.

There is some flexibility in fall establishment. Sometimes winter cover crops can get a head start with an overseeding/relay cropping in the living cash crop earlier in the season after the last cultivation in corn (lay by) or before leaf drop in soybeans. In vegetable production systems, cover crops can be broadcast or spun on by hand. Cover crops such as annual ryegrass, cereal rye, or crimson clover can be broadcast underneath fall-growing cauliflower, cabbage, and broccoli to get a jump on germination and establishment before the vegetables are harvested.

**Summer Annual Cover Crops:** Summer annuals need to be planted in late spring or early summer when soil temperatures are warmer. With warm temperatures and enough moisture, many of these will grow quickly and produce lots of biomass in a short time. Examples include sorghum-sudangrass, sudangrass, tillering corn, buckwheat, millet, cowpeas. Buckwheat is especially handy in vegetable rotations as it grows fast and can follow a spring crop like lettuce, but can still be plowed down in time for fall broccoli.

**Cover Crop Mixes:** We often encourage planting cover crops as mixes, since they combine some of the advantages of each of the component species. The mix as a whole benefits from the synergism of the individual species. The blend of two or three species is often enough to provide needed diversity and benefits, but mixes of five or more species are gaining in popularity. The most common cocktails include a grass and a legume, such as cereal rye and hairy vetch, or barley and crimson clover. For best results, species in a mix should be well-aligned in terms of planting date and maturity date.

Cereal grains like rye and triticale germinate and grow rapidly in the fall, protecting soil as the nitrogen-fixing legume gets established (legumes grow more slowly and won't fix as much nitrogen). The earlier they are planted, the better soil cover they provide and the more soil nitrogen they can rescue that might be otherwise lost to leaching during heavy spring rains and snowmelt. Legumes put on most of their growth and fix the most nitrogen in the spring. Mixing a legume with a grass or other species helps raise the C:N ratio, keeping nitrogen tied up in the plant residues longer.

If you are unfamiliar with a cover crop, obtain a small amount of seed to test it and observe it at first. Before planting, find out –

**MasterGraze corn and cowpeas in starting out in early summer, a good mix for summer weed suppression or forage**

- Can it be broadcast, or does it have to be drilled?
- How fine does the seedbed have to be? Can it be no-till planted, or does it need minimum tillage like light disking or more thorough preparation like cultipacking?
- How much time before the first frost is needed for establishment and growth?
- What type of fertility and soils does it need to do well?

Look at the size of the seeds. Small-seeded legumes such as true clovers, alfalfa and sweetclovers, have very small seeds and should not be planted too deep – ¼" to ½" is adequate. These small seeds can be "frost-seeded" – broadcast in late winter and worked into the ground naturally through the expansion and contraction of freezing and thawing soil. In fall or spring, they can be broadcast and just covered lightly. Larger legume seeds like crimson clover can be planted ½" deep; hairy vetch should be planted ½" to 1" deep; and field peas should go in at 2" to 2 ½" deep.

By testing the cover crop in a small area, you will get a feel for how long it takes to germinate and establish. Small-seeded legumes need good seed-to-soil contact and do not establish well if planted too deep. They take more time to imbibe enough water to germinate than larger seeds like small grains would. This has to be factored into the time needed for them to establish in the fall before the first killing frost.

Get familiar with its growth habit, the amount of biomass it produces, and its time of bloom and maturation. If it's a winter annual, gauge its ability to over-winter in your climatic zone. Some legumes are not very winter-hardy and will not survive the winter in northern area.

Understanding these qualities of your cover crop will help you identify both the planting niche and how the cover crop can be worked into your rotation. The conditions each year are different, and just like the main crop, cover crops have a different biological response to changing environmental conditions such as temperature, soil fertility, soil moisture, soil drainage, soil pH, amount of rainfall throughout the season, and the date of the first killing frost and last spring frost. Temperature ends up being one of the most important factors.

## Cover Crops in Grazing Systems: Building Soils with Good Forage

You may have thought that planting a cover crop and leaving it alone until termination and planting of the cash crop is the best way to get all the soil benefits of the ground cover. Cover crops by themselves certainly improve soil biodiversity, soil organic matter levels (which influence tilth and moisture capacity), nutrient cycling, and weed suppression, among many other benefits. And usually less disturbance means soil life and structure has the chance to flourish.

From a strictly soil health perspective, planting followed by mechanical harvest does defeat many of the soil improvement objectives of cover crops. **Bringing animals out to graze the cover crop, however, may deliver even more soil health returns than a hands-off approach.**

Think of rich, deep prairie soils. What made them that way? A combination of the impacts of grazing herds of buffalo and extreme biodiversity. It's not unusual for over 100 plant species to be evident in any given area of a prairie! Obviously, you can't create a synthetic version of this system on your finite acreage, but it can't hurt to come a little closer to the ideal.

**When grazing a cover crop, you close the nutrient cycle** – similar to what you do when you plow a mature cover crop into the ground as green manure or spray and leave the residue to decompose. If managed right, grazing may actually be expediting this nutrient loop, since the deposition of manure and urine recharges soil organic matter and nutrients, arguably in a more plant-available form.

**As they graze, animals trample organic matter into the ground, jump-starting the degradation process.** Soil microbes are fed

more easily, and they take it from there in integrating the trampled plant material and its nutrients into the ground. As soil organic matter increases, so does moisture-holding capacity. Its structure and tilth also improve – helping prevent compaction in the long term.

A common view of grazing has been that it contributes to compaction, which can become a reality if you graze when soils are too wet (especially if you already have heavy soils). Too much concentrated weight on wet soil weakens soil aggregates. As the cow walks, you have at least 300-500 lbs concentrated over a few square centimeters of soil under the hoof that's bearing weight. To maximize soil health benefits and minimize disturbance, make sure you are grazing half and leaving half. This gives hoofs more organic matter to trample in, while maintaining more residue protection for the soil ecosystem.

To manage that, it's ideal to stock at high densities and move cattle at least once or twice a day. Frequently moving the animals can avoid the potential for compaction that arises when there is excess walking – when cows travel the same path repeatedly to get to water or supplemental feed, for example. They also tend to hang out more near fence rows and streams.

In the ideal scenario, no-till or minimum-till practices are used, and the combination of root biomass, root exudates, and the animal trampling and manure improves soil physical properties. This can comes as a surprise to some who watch it in action. John Stigge, a no-tiller in Kansas, wrote recently in *No-till Farmer,*

> The first year we grazed a cover- crop mixture of triticale and radishes that I seeded in wheat stubble. We grazed weaned calves there in late fall through early winter. They stayed on the field until it got too cold to haul water. The next spring our hired man, Luke, was planting corn in the field. We hadn't grazed the entire field, keeping the calves on roughly half the acres. I was on the other side of the field and was surprised to hear the tractor pull down and struggle as it transitioned from the acres we grazed to the acres that hadn't been grazed. That was the complete opposite of what I expected and it repeated over and over again the whole length of the field.
>
> In theory, the ground we grazed should have been a little more dense and difficult to pull through due to compaction from hoof traffic, while the acres with cover crops only should have been nice and mellow.
>
> ("What I've Learned from No-tilling: Adding Cattle Yields Surprising Results". *No-till Farmer,* www.no-tillfarmer.com, May 14, 2016)

**Annuals and perennials are both beneficial, but there's a time and place for each.** Short term perennial covers may be most beneficial for soil building, enhancing soil biology and carbon sequestration, but it's really about what is the best thing to break up and vary the rotation. In a row crop field, a perennial of 1-2 full years may be the best break crop. Long-term root growth and animal activity helps build soil, and annual weeds and many pests get wiped out without the environment or host they are used to.

Cool season and warm season annuals also present an ideal opportunity to mix up the rotation, use a break crop while keeping a living cover growing year-round, and provide excellent quality forage in a very condensed time frame. This can be as simple as planting a triticale-crimson clover mix after corn silage

comes off, and possibly getting some late fall and/or early spring grazing.

**Give permanent pastures a rest.** Extend the grazing season or simply take advantage of the late fall or early spring growth of winter small grains, legumes, and brassicas. Or graze a diverse soil-building mix like **Ray's Crazy Mix** when the summer slump sets in and pastures need longer rest periods. At the height of summer, you also want to be able to protect a field with a quick canopy of voluminous tall, viney growth. Even when you graze the summer annual, leaving at least half can let the residue continue to shelter the soil from extreme temperatures and hold onto moisture.

This can also be a great way to renovate a pasture for a season or more – and still let the animals take advantage of the forage.

**Great gains are possible.** If grazing timing is managed correctly, many cover crops make high quality feed, high in protein and digestible fiber. This can in turn boost milk production and daily gains.

**Diversity builds the field and the rotation.** Although a seemingly worn concept, diversity is always key in a successful rotation – in both the agronomic and nutritional sense. Each rooting pattern in a diverse mix delivers a unique contribution to soil building and feeding soil life. And each has a specialty when it comes to nutrient scavenging. Brassicas release an acid that helps pull calcium molecules away from other soil particles, while releasing phosphorus and sulfur molecules that are tied up in the soil. Daikon radishes and other deep rooted crops can break through hardpans and mine moisture and nutrients from the subsoil. They are also often used to prevent leaching after a heavy nitrogen feeding. Legume roots host rhizobium bacteria that fix atmospheric nitrogen. Grasses have a dense root mass that can grow deep, scavenge nitrogen, and build soil organic matter. Many small grains and other species also have some degree of allelopathy, inhibiting the germination of other species (i.e. weeds). As feeds, brassicas and legumes contribute protein, while grasses boost digestible fiber and help slow the rate of passage of the richer components.

And more vigorous varieties can take off and get ground covered while slower-growing species in the mix catch up. The same goes for drier or wetter times – species that do best in those conditions can cover for those that don't. A mixture sets up the ground and the animals for the widest range of benefits - never a bad thing.

**Field operations are simplified.** You can temporarily slash the labor and cost associated with harvesting and storing feed, as well as hauling and spreading manure (cows apply it for you).

**Better weed suppression.** Break up your current cropping system, and you disrupt weed lifecycles. Plus, when you regularly graze a field at high stocking densities, almost everything gets eaten. Animals don't discriminate as readily.

**A grazed cover crop is an excellent pasture renovation tool.** Take out your permanent pasture and use a season or a full cycle of annuals to renew the field. And you won't lose out on forage in the process!

**It works if it leaves you enough time to grow ample biomass.** You need to be able to grow enough material that the crop accumulates significant root mass and can be grazed while still providing ground cover and building soil with what remains. Wait to graze until there is adequate feeding potential – for some grasses this is eight inches, while many summer annuals can't be grazed until they have 18 inches or more of growth.

Refrain from grazing on highly erodible land and close to water sources, as well.

**Conserve water.** Cover crops buffer the soil from the hot, dry extremes of summer. Very deep-rooted species like Daikon radishes and annual and Italian ryegrass can also mine moisture from below the plow pan.

In drier regions, blends almost always outshine single species. Species in a mix tend to help each other and work synergistically rather than competing. We can leave our weed mentality at the pasture gate – the idea that one species might become a threat to the others (of course, moderate seeding rates must be used for the seed sizes of each species). Diversity almost always leads to greater stability and survival.

Cover cropping to boost organic matter and overall soil health is relatively new to mainstream thinking. Introducing grazing takes these soil health impacts yet another step further. Each step of this has to be done strategically – you can't approach cover-cropping as simply adding another cash crop to the rotation and expect the same soil health impacts of a cover crop. Sure, a year-round living root is highly beneficial, but so is keeping all the nutrients you grow in a closed loop. If the goal is truly soil improvement, make sure you're growing a cover crop first and a forage second. Grazing fulfills the cover crop purpose if you can manage it to do so. As a result, you can look forward to improved soil resilience, nutrient cycling, reduced need for chemical fertilizers, and likely reduced weed pressure. (But look for this in the long term since soil conditions fluctuate from season to season and year to year.)

Hairy vetch and crimson clover mix to be rolled down for a no-till mulch mat

## Cover Crops in Organic No-Till and Killed Mulch No-Till Systems

Recent progress has been made in organic no-till using a **crimper/roller** that is mounted to the front of a tractor to roll down and mechanically kill small grain or hairy vetch cover crops in the spring. The front-mounted roller saves some time and energy, as it allows planting in the same pass. A no-till planter or transplanter can be used to cut through and plant directly into the rolled cover crop mulch mat.

The cover crop that has recycled nutrients and built the soil over the winter is flattened into a weed-suppressing mat. Preventing light penetration to the soil surface also helps inhibit weed seed germination. The early weed suppression of the cover crop mat helps the crop get established before weeds.

**No-till corn in a rolled hairy vetch/crimson clover mat, providing both weed suppression and nitrogen to the corn. Useful in organic no-till systems**

## Cover Crops and What They Do

| | Build Soil Organic Matter | Scavenge Nitrogen | Improve Soil Nitrogen | Loosen Compacted Subsoil | Suppress Weeds | Suppress Soil Disease | Attract Beneficial Insects and Pollinators |
|---|---|---|---|---|---|---|---|
| 3-Way Clover Mix (Red Clover, Yellow Blossom Sweetclover, Ladino White Clover | | | X | | | | X |
| Alfalfa | | | X | X | | | |
| Annual ryegrass | X | X | | X | X | | |
| Brassicas | | X | | | | X | |
| Buckwheat | | | | | X | | X |
| CARGO Mix (Oats, Annual Ryegrass, and Crimson Clover) | X | X | X | | | | X |
| Crimson Clover | | | X | | | | X |
| Daikon Radish | | X | | X | X | X | |
| Hairy Vetch | | | X | | X | | X |
| Oats | X | X | | X | X | | |
| Other small grains | X | X | | X | X | | |
| Red Clover | | | X | X | | | X |
| Sorghum-sudangrass | X | X | | X | X | X | |
| Spring Champion Mix (Peas, Hairy Vetch, Oats) | | X | X | | | | X |
| Sweetclover | X | | X | X | X | | X |
| White Clover | | | X | | | | X |
| Winter cereal rye | X | X | | X | X | X | |
| Winter peas/spring peas | | | X | | | | |

## No-till Case Study 1: Growing No-till Pumpkins in a Killed Cover Crop Mulch System

Managing a rolled cover crop mulch for vegetables from start to finish

*Winter annual cover crops can be planted in late summer/early fall and then rolled down to form a killed mulch for no-till planting vegetable crops into the following year. Pumpkins growing on a rolled down rye cover crop mat will reduce dirty pumpkins at harvest. The residue also suppresses weeds and minimizes fruit rot by providing a barrier between fruit and soil. This system combines the benefits of two best management practices:*

- ***Using winter annual cover crops to keep the ground covered and the weeds down***
- ***No-till planting to conserve soil organic matter, moisture, and protect soil microbial life.***

*Pumpkins can be no-till planted by seed with a no-till planter, or planted as transplants with a modified no-till transplanter.*

*Both organic and conventional growers can use this system, although management is slightly different for each system. Cultivation between rows is usually not an option in no-till systems, so growers should consider the weed pressure in their fields and choose fields carefully for no-till production. Avoid fields with heavy weed populations of yellow nutsedge or broadleaf weeds that may be difficult to control. Organic growers may want to manage the field using a* ***stale seedbed,*** *leaving the field for a weed flush to grow, then cultivating to kill it before planting the cover crop in the fall.*

*The cover crop provides many soil benefits, including preventing soil erosion over the winter and spring, a period when many vegetable fields are left fallow and prone to erosion. Out of sight below the soil surface, the cover crop roots recycle nutrients, add organic matter to the soil, and host numerous beneficial microorganisms.*

*When rolled down in the spring with a crimper-roller, the cover crop forms a mulch mat that provides weed suppression throughout most of the subsequent pumpkin crop's growing season. The pumpkins growing on this mat are cleaner and much more desirable for sale.*

### *Soil Fertility*

*Good soil nutrient management needs to account for the fact that you are growing two crops in succession: the cover crop (which is later rolled down), and the following pumpkin crop.*

*In more typical cover crop applications using cover crops that are not rolled down, a winter annual cover crop such as winter cereal is often grown to scavenge or recycle nutrients (mostly nitrogen, as it is easily leached). In the spring, the cover crop is killed with herbicides or turned under in its immature vegetative stage as a spring green manure.* ***In contrast, this killed mulch no-till system relies on a cereal rye cover crop grown to near-maturity to use as a straw mulch mat.*** *In essence, you are growing your straw to be used as mulch.* ***Hairy vetch,*** *a winter annual legume, is often grown in combination with winter cereal rye. The hairy vetch fixes nitrogen as it grows, and once it is rolled down, much of this nitrogen becomes available to the pumpkin crop as the leaves decompose.*

### *Rolling the Cover Crop*

*In the spring, roll the rye cover crop with a Buffalo stalk chopper (often used to chop corn stalks), a cultipacker, or a roller-crimper. Other types of field rollers can also be used. If you are using a cultipacker, a double pass may be needed.*

***Conventional farmers:*** *Use a small application of glyphosate on the standing rye cover crop (1/2 to 1 pint), and then it is rolled a day or two later.*

***Organic farmers:*** *Wait until the rye is in full bloom (rye forming yellow pollen, called dehiscence, and hairy vetch in full bloom with purple flowers. At this growth stage, the roller will give adequate mechanical kill. Double-rolling the cover crop gives better control and kill. If you try to roll the cover crop before flowering, it will regrow in an attempt to flower and reproduce. Conventional growers can roll earlier with herbicide use.*

*It is highly recommended to roll the cover crop in the same direction that you will be planting; it's very difficult to plant into rye that is lying perpendicular to the direction of rolling and no-till planting.*

### Weed Control

*If a thick cover crop mulch mat is established, herbicides can be eliminated. Cereal rye is known for its allelopathic characteristics, which means that its residue inhibits the growth and germination of many weed species. The thick mat also discourages weed germination by blocking sunlight from reaching the soil surface, as well as reducing soil temperature through shading.*

A thick stand of rye makes for a thick rolled mat later

*Organic farmers will rely solely on the thick mat for weed suppression, but may have to use hand-weeding later in the season. Conventional farmers use a selective herbicide called 'Strategy', a broad-spectrum, systemic, pre-emergent herbicide used for control of grasses and broadleaves in cucurbits, melons, pumpkins, squash, and watermelons. It can be applied between the rows after emergence or transplanting. For grasses that break through the mat, a post-emergent herbicide called 'Select' is often used. If pigweeds are a problem in the field, another herbicide, 'Sandea' will control pigweeds but not lambsquarter. Sandea will hold back pumpkins about 1 week, even if applied pre-emergence.*

### Evaluating the Stand

*In the spring, you should be able to view the standing rye across the drill rows without seeing bare soil. If you can see soil, the stand is probably not thick enough for good weed control in an* ***organic no-till situation****. If this is the case, I recommend plowing down the stand and going with a full tillage scenario, as weeds that are already growing will become a problem before the pumpkin leaves can form a canopy. Organic growers don't have the rescue weed control options that conventional growers do.*

### No-till Planting

*Seed to soil contact is critical when planting through the rye mulch. Modify, adjust, and add weights to equipment where needed to get the seed into the ground at the proper depth to get a good seed furrow closing.*

*A modified no-till planter can be used to direct seed the pumpkins, such as the Kinze no-till planter with Monosem row units and a vacuum air seeder. Use heavy coulters such as a 'Rawson' coulter (13 wave, 1 inch wide coulter) to cut through the thick rolled-down mat. Apply 130 to 150 lbs of extra weight as ballast for each planting unit on the frame above and to the front of the double disk openers. The extra weight helps the double disk openers to cut down through the mat and into the soil.*

*Adjust the depth gauge wheels to be certain that you are cutting deep enough into the soil. Keep in mind the depth gauge wheels are riding on an inch or two of residue and may need to be adjusted to compensate for this.*

*Plant the pumpkin seeds 1" – 1 ½" deep in the soil. The goal is to have enough weight to cut through the mat and place the seed at the proper depth in the soil, but not to disturb the mat so much that there is lots of soil showing in the row.*

*The exposed soil that is opened up in the furrow is the area where weeds will germinate and grow first.*

*No-till planters can be modified with bigger coulters, deeper knives, and heavier closing wheels to be used for transplanting seedlings. A heavy-duty no-till planter can transplant pumpkin or other vegetable seedlings into this dense mulch-mat.*

**Corn planted green into an overwintered hairy vetch/crimson clover cover crop**

## Planting Green to Keep Soil Life Active

Even a short time without living roots in the soil can impact your farm ecosystem. If you practice no-till religiously, this is one of your founding principles. Although we generally don't preach no-till orthodoxy, we do believe in maximizing time with living roots growing in soil. You may have heard of beneficial fungal organisms like mychorrhizae that form symbiotic relationships with plant roots. In the end, the fungal hyphae greatly expand their hosts' ability to reach water and nutrients. To thrive and get the nutrients they need, though, they require access to living roots almost continuously. The living root system also exhudes labile organic compounds that feed a multitude of soil organisms.

To accomplish all this, many no-tillers "plant green" – establish a cash crop into a living cover crop before spraying to kill it or just after using a roller-crimper to mechanically kill and flatten it. As a result, the lifecycles of the two crops overlap.

Keeping a live root zone to support soil life and health is just the beginning. **Unlike a dead residue mat, a living crop doesn't foster and transmit soil borne disease effectively. It also doesn't harbor pests like slugs that look to the emerging seedling as its only food source –** although slugs will often be drawn into the dying cover crop to feed, rather than the new emerging crop. Plus, by planting more species, you encourage more beneficial slug predators, such as the ground beetle. The overlap of the two growing crops creates a window of biodiversity, and each increase in biodiversity raises the system's defenses.

**What to know about planting green:**

- **At a basic level, it helps manage timing.** It makes more time for double-cropping, so you have less worry about rushing to get the cover crop chopped or incorporated before planting. It removes the primary tillage operation from the schedule (but you still have to fit in rolling or spraying at the same time or later on).
- **Not only is soil quality improved, but so is soil moisture management.** Living crops anchor moisture in soil and hold it in their own tissues to prevent surface runoff or leaching. Plus, they help take up some extra moisture in wet early springs, which may make it easier to get equipment in the field earlier to plant.
- **Managed correctly, it can simplify weed control.** A thick, actively growing cover crop is already competitive with weeds. When you

plant correctly and control the crop at the right time (so the cover crop does not become the weed), you have no window left for weeds.

- **Always know what you're dealing with.** Account for the thickness of the cover, whether you plan to plant into it standing or rolled, and be sure you have enough down pressure to cut through it and the root mass. Stop and get off the drill to check seed-to-soil contact and seed depth. Make sure the seed furrow is closing properly. It also helps establishment to plant into somewhat moist soil that is high in organic matter.
- **If it can be rolled, the cover crop will be much more manageable.** Rolling is still considered "planting green", but since it has been crimped and flattened (and possibly sprayed, in a conventional setting), it's less likely to get caught up in the planter or drill. (Check out the roller attachments designed by Charles Martin of Loysville, PA)
- **In many cases, the short few weeks of extra growth time come at the point when the cover crop is growing fastest.** As spring temperatures warm and the crop breaks dormancy, the growth curve shoots up. According to *No-till Farmer,* "Research has shown that by using this practice, cover crop biomass can easily be doubled." More crop growth means more soil carbon, which greatly improves infiltration and cuts down on soil erosion and runoff. Fewer nutrients are lost as well, as the roots continue growing and uptaking nutrients almost until it can hand off this responsibility to the new crop. If it's a legume like hairy vetch or crimson clover, it has that much more time to fix nitrogen.
- **Hairpinning problems are reduced.** Cutting through live green material is actually much easier than cutting through dying residue that is still rubbery and not yet crisp and dry. It also turns out to be somewhat easier than cutting through fully dead residue. Manure can be applied to the living crop ahead of planting, as well, and is less likely to form an impenetrable plaster-like layer the way it might when applied to dying, matted residue.
- **Some equipment tweaks can make your life easier.** Cover crop rollers can be mounted on some corn planters that flatten the cover crop to the soil surface, parting the plants so that double disk openers have less material to cut through. This also means less competition and shading as the new crop establishes. If you have a crop like hairy vetch that is very prone to tangling, you may also find it helpful to raise up the closing wheels so the vetch doesn't wrap around them.
- **If the cover crop has a high C:N ratio (such as mature rye) you will have to optimize soil fertility –** and possibly even add 30-50 extra units of N/acre so that crop residue can break down faster and won't tie up as much nitrogen.
- **Understand how rapidly C:N ratio can change.** Crops that look small in early spring mature in a matter of weeks, rapidly increasing their lignin content, and along with it, the time they take to break down and return nutrients to the soil. Slow N release over the course of the season can be a benefit, though, if you have enough to get the crop going.

With experimentation in our research plots (see the following, No-till Case Study2), we've learned that it's necessary to consider both the physical challenges to planting and the growing degree days lost or gained for corn at different planting dates. **Planting green often involves a direct tradeoff between the growth of the cover crop and the growth period of the main crop, and you will find that you have to manage more closely to maximize the main crop.**

## No-till Case Study 2: Planting Green into a Standing Cover Crop (a no-till practice, but not organic)

*Meadow View Farm, Leola, Lancaster County, PA; Collaborator: Eli Weaver*

*Research: Dave Wilson and Genevieve Slocum*

*"Planting green" is the process of planting directly into a growing cover crop. The major advantages of this practice are improved weed suppression, continuous nutrient uptake until the second crop gets established, and ease of no-till planting. In many cases, a no-till drill or planter can more easily cut through a green crop than partially-dried residue, which often results in hair-pinning and placement of the seed onto the pinned residue, instead of in contact with the soil in the furrow.*

*In the fall of 2014 we prepared a field on this Lancaster County farm for our 2015 corn plots by planting a cover crop mix: Kings' Vetch & Oats mix seeded at 88 lbs/acre and crimson clover seeded at 22 lbs./acre. We no-till drilled these into the field after a second cutting of summer annual teff was taken. We put the Vetch & Oats in the big box and the crimson clover in the small box to plant these in combination. The oats came up as a quick growing cover and companion crop for the slower establishing hairy vetch and crimson clover. The oats winterkilled, leaving their residue and the over wintering legumes.*

*In April 2015, we spread manure on the crop. This was an earlier, alternate approach to the all-at-one-time late spring burndown, manure plastering, and no-till planting into the cover crop – which we had attempted the previous year and made a plaster-like crust of residue and dried manure. That approach was excellent for season-long nitrogen release and weed suppression, but made cutting through for no-till planting quite difficult.*

*This earlier manure application on the living cover crop did suppress the cover crop in places – from a combination of wheel traffic and physical smothering by the manure – but the majority of the stand continued to grow and thrive, uptaking available manure nutrients as the soil warmed up, preventing much leaching or other loss of the manure nutrients.*

***We "no-till planted green" on May 4, 2015, into a manured, green living cover crop.*** *The corn planter easily cut through this succulent living cover crop, which was scheduled to be sprayed and killed before corn emergence, and placed the seed properly. No seed was evident on the surface after planting, as we experienced the previous year when we tried to cut through a plaster-like manure layer and a rubbery, already-dying crimson clover cover crop. The residue from this cover will still provide lots of nitrogen and weed suppression for months to come.*

*We caught it at a good stage for this early-planted corn. A few weeks later, the hairy vetch became a*

*thick, viney mat that would more likely get tangled in the corn planter than it did with this early planting.* ***The mix would have fixed more nitrogen if it were left longer, since both the clover and the vetch would have increased biomass growth and be closer to bloom, but that was a trade-off with the growing degree days we lost for the corn.*** *We will also have to deal with the greater physical difficulty in planting.*

*In the later planted corn plots (June 8, planted 34 days later), we had the same mix with the same manure treatment, the only difference being that it was simply left to grow longer and used the no-till rolling (combined with spraying) method. The vetch was blooming – the appropriate stage for rolling – but had grown much more biomass in the extra month's time. A cultipacker was used for rolling instead of a roller-crimper. For the corn planter to plant through this amount of material, we had to tie up the rolling row cleaners so the long vetch vines would not wrap around them.* ***Even with these extra considerations, it was still easier to cut through this living rolled cover crop than if it were a dead, manure-plastered cover crop layer coating the soil surface.***

## No-till Case Study 3: Dormant Seeding

*Adapted from original article published by the Rodale Institute, February 5, 2009, by Genevieve Slocum and Dave Wilson*
*http://rodaleinstitute.org/almost-never-too-late-to-plant-hairy-vetch/*

*We first heard about dormant seeding in the context of North Dakota farmers who were using it to get a head start on planting wheat, since conditions for driving a tractor in a northern spring can be prohibitively wet. Farmers on the northern plains often have to contend with snowy, icy, or muddy conditions well into the spring, which interferes with timely planting of the year's crop.*

***Not too early, not too late***

*Successful dormant seeding requires that they get the seeds in the ground before the ground freezes and winter-long snow cover arrives, but not so early that warm weather coaxes a tender sprout from the ground to face the violent elements of winter before it has a chance to put on adequate growth and energy reserves for survival. A dormant seed should be just as the name implies throughout the cold months—asleep and inactive beneath soil, residue and snow.*

*Our trial was quite unusual, because we took this practice and applied it to a winter annual, in effect shifting and condensing the vetch's lifecycle to fit our rotation.*

*Fall temperatures during the experiment year were warmer than usual, so many time-strapped farmers were calling in October to ask if they could still plant hairy vetch. The answer was yes and no. Despite the deceptive warmth, growing hairy vetch as it was destined to grow—as a winter annual—would have been risky business. Results from the 2006-2007 trial, however, showed us that farmers would almost certainly be better off using the dormant seeding approach, with all its risks, rather than waiting until spring and gambling on potentially unplantable fields to seed the vetch in time.*

*Warm mid- to late-fall weather can support hairy vetch emergence and early growth, but these hospitable temperatures can plunge without warning, leaving vulnerable seedlings with too little biomass and insufficient energy supplies left to withstand brutal weather. If farmers miss the critical window for planting hairy vetch (typically 40 to 50 days before the first killing frost, or mid-August to mid-September here in Berks County, Pennsylvania), the data shows that dormant seeding may be their next best bet.*

*When used as a winter-annual cover crop and planted during this window in early fall, hairy vetch*

*puts on preliminary growth, goes dormant in seedling form over winter, and blooms the following spring. Farmers often plow it under as a green manure for nitrogen or roll it for the weed-suppressing mulch—a good application for the thick tangle of leguminous tendrils, some reaching 6 or 7 feet in length.*

*Vetch's optimum germination temperature range is 15° to 23° C (59° to 73.4° F). After emergence, the seedlings begin to grow before the frost, form a crown (indicated by several secondary shoots from the base of the main stem), and then use stored root carbohydrate reserves to survive dormancy over the winter. The ideal temperatures for early root growth range from 20° to 25° C (68° to 77° F). Growth correlates with growing degree days (units of average daily temperature compared to a base at which no growth takes place) which are calculated for hairy vetch using a base temperature of 4° C (39.2° F).*

*A later planting date means increased probability of temperatures dipping below these ranges, which means less likelihood that plants will grow enough to conduct adequate energy reserves, through photosynthesis, into their root storage systems.*

***Seeding for delayed germination***

*The idea behind dormant seeding is to plant when it's cold enough to inhibit the seed's germination so that it lies dormant over winter and is ready to germinate when the ground first begins to thaw—but is still too wet to drive through. As temperatures gradually warm and days lengthen, seeds begin to absorb moisture, and the new seedlings grow rapidly as growing degree day units increase.*

*Following a dormant seeding, the seed's metabolic activity will be low, preventing it from germinating, if temperatures remain below 35° F. Once the seed's temperature reaches 38° F to 40 °F, with sufficient moisture, germination begins. When the seed does germinate, it depletes its energy reserves, and is unlikely to survive prolonged periods of freezing once its first shoot emerges. It is therefore vital that dormant seeding be followed by a consistently cold winter.*

*On December 20, 2006, we began filling the grain box of the Tye stubble drill with vetch seed and rode out into the barren winter field. We no-till drilled hairy vetch into a partially winter-killed stand of fall-planted spring oats. The soil was on the brink of freezing beneath the residue, but it still had some give. The trial's comparison had begun with a control September 1 planting of hairy vetch (an ideal, "normal" date for our region) in some plots, and would end with a spring planting on March 28, 2007.*

*We increased the seeding rates for the dormant- and spring-seeded vetch, from the fall rate of 27 lbs/acre to 33.5 lbs/acre. This increased rate helps to compensate for the more extreme conditions that the seedlings are likely to weather during emergence and the earliest and most vulnerable stages of growth.*

*The goal was to follow the vetch cover crop with a no-till corn crop, ideally planted into the rolled vetch mulch. The corn would need not only an ample amount of nitrogen from the vetch but also plenty of dense biomass for weed suppression.* ***Biomass comparisons of the three planting dates on June 1, 2007, revealed that fall-planted fared the best, yielding 7016 lbs/acre of dry matter, followed by the December dormant seeded vetch, at 5983 lbs/acre, and spring seeded with 4255 lbs/acre.***

*So, it turns out that dormant seeding is a feasible Plan B, followed by spring seeding. Although it will not provide winter ground cover (we made up for this by planting into residue), it provides a sound alternative to spring planting.* ***However, neither dormant seeding nor spring seeding is likely to yield enough biomass for an effective weed-suppressing mulch in a no-till system.***

*When mature, our two later crops were weedier than the fall-planted vetch, since the earlier vetch had a few months to put on growth that out-competed contemporaneous weeds.*

*These options are best plowed down for nitrogen for the following crop, and may require additional compost or manure for fertility.*

*With a little creativity, hairy vetch can be worked into almost any rotation, and it's well worth the effort for the soil enrichment, fertility and weed suppression it provides. Dormant seeding is indeed a risk, and like any other planting event it takes careful planning and attention to weather patterns. But it is probably better than nothing for the farmer who missed their ideal fall seeding window. For northern farmers who need a more winter-hardy vetch, look for a northern seed tag origin. Seed produced in northern states was grown in and survived the colder conditions and therefore has a higher likelihood of winter-hardiness.*

**Rolling hairy vetch in the front with a crimper-roller while planting corn in the back**

### Chemical-less No-till: A realistic goal?

Many people envision their farm becoming an "organic no-till" system, but can't quite figure out what this will look like, including weed suppression, controlling the previous crop, and getting all the inputs in the field. Spoiler alert – there is no easy answer about how to put continuous organic no-till into practice. The most realistic solution is a compromise, where we use the conservation tools suited for an organic setting to limit tillage as much as possible, while reaping many of the rewards typically associated with no-till.

The most important consideration in no-till systems is the transition between crops – specifically, terminating one crop (or heavily suppressing it) and managing its weeds when transitioning into the next. For annuals crops this is more easily attainable. When an annual grass crop produces a seed or grain head, or a legume reaches full bloom, this is the point at which it will no longer be able to bounce back fully when mowed or rolled down. **Because perennials continue their lifecycle even after heading or bloom,**

**they need to be chemically burned down with an herbicide or completely plowed under as a green manure to terminate.** Light tillage, mowing, or rolling/crimping is not enough to permanently kill perennials.

Sometimes we can handle this transition period with a relay cropping system – using various tools to interseed or overseed a new crop into one that continues to grow, and likely completes its lifecycle before crop #2. But at some point – especially in perennial pastures - we have to be able to do a full renovation and start fresh, with a clean seedbed and balanced soil.

The moral of the story: No-till practices in organic settings end up looking more like "rotational no-till". Because so few weed control tactics are at your disposal, you will find that you have to resort to tillage at least once every few seasons to deal with weeds, previous crops, or crop residues. After one harvest or cover crop termination, weeds will have to be dealt with for an effective stand of the following crop.

**Rolling it down**

In recent years, the roller-crimper has become the tool of choice for the organic farmer with no-till aspirations. No-till mechanical suppression of a cover crop is possible in select few situations – at full head emergence with pollen shed in cereal grains, or at least 75 percent bloom in legumes. The roller-crimper is one of the most effective ways to do this at cover crop maturity, because it creates a surface mulch while keeping the cover rooted – that way, no loose residue can be dragged, clumped, or clogged in the planter. Once rolled, this residue is much more persistent on the ground as a weed suppressing mat throughout the season. With a roller attachment on the front of the planter, suppression and planting can be accomplished in one pass. This technique can be tricky because you are entirely dependent on the cover crop's biomass for weed suppression, and it takes about 3 tons of dry matter biomass to get reliable weed suppression. A thick residue mat can also be quite salient in beating back perennial weeds.

There are a variety of adaptations to the original large front mounted roller cylinder with metal flanges branching off at an angle to crimp cover crop stems – including the "Charlie Martin rollers" made by Charles Martin of Loysville, PA, that are mounted between the row units on a corn planter.

As with any no-till operation, planting and growing in residue are second only to weed suppression in the challenges they present. Residues lying on the soil surface keep the ground cooler, which can delay germination and slow down growth. They can also preserve a cool, moist environment with shelter and plenty of food for pests like slugs. These pests take advantage of crops that lag in their growth.

Lower soil temperatures under the residue mat can also delay nitrogen mineralization to the growing crop. Organically grown crops often rely heavily on cover crop residue breaking down and mineralizing nitrogen to a plant available form. The slow release from a

decaying cover crop can be well timed, or it can be too delayed if soils stay too cool for too long.

**When you don't have a roller…**

One technique in the absence of a crimper-roller is to "scalp" the cover crop once it reaches that late maturity stage when it has little danger of growing back. Leaving those loose residues on the surface can help provide a mulch cover, but won't have the benefit of the roots anchoring the material in place. This leaves it vulnerable to getting gathered up and pushed around by and tangled with the planter. Loose residue lying around at all different orientations (instead of the single direction produced by the roller) can also get pinned in the seed furrow and interfere with seed to soil contact.

If you can mulch the cover crop into a shorter-length cut, it will break down faster, release its nutrients sooner, and can pose fewer obstacles in planting since it cannot as easily tangle up in equipment. Count on a much shorter-lived suppression effect, however (which may be fine if the next crop has a thick canopy). Equipment with good row-cleaners can be a great help here.

Beware of this termination technique with perennial crops (unless you plan to do full tillage to invert the sod completely). Mowing or grazing down to the ground certainly shocks the plants back, but they do eventually bounce back somewhat. The trick is to get the new crop – annual or perennial – drilled into the sod with a no-till drill and up out of the ground ahead of its latent competition. The best time for this is late summer because few aggressive weeds are germinating, and it's often the time when summer dry spells begin to break and heavy dews set in. If you want to try planting in the spring, you can set up the timing for the close mowing or grazing in the preceding late fall. Just don't make the mistake of thinking that your perennial stand will not eventually come back and be competitive. After seeding, you can turn out the cows and use hoof traffic to get the seed worked in.

A thinning perennial stand can be an excellent candidate for **frost seeding** clovers in late winter, as well. Bare patches let the broadcast clover seed make contact with soil, and overnight freezing of the soil with daytime thawing helps to work the seed in. Whatever technique you choose, an interseeded pasture can prolong the stand's useful life with intentionally placed species in a relay timeline, but stop and think before reseeding a thinning stand to take a hard look at why it's thinning or weedy – it's likely that soil pH and fertility need to be rebalanced so the proper species can fill in and persist. Also take a look at your cutting or grazing management and make sure you are leaving at least 3-4 inches of residual – if it's any lower, many grasses will not persist.

**Smother cropping to help manage weeds**

Whether it's the main event or the cover crop, it should be planted on time and at the high end of the seeding rate range. The higher seeding rate helps overcome the planting challenges that come with no-till, and at the same time expedite ground cover and canopy just from the sheer number of plants. Especially in chemical-free no-till, the new seedlings have to be competitive from the start with existing plants or residue. A cross-hatch planting pattern can also spatially improve ground cover from the outset – just halve the planting rate on the first pass, and go back over in the perpendicular direction at the same rate.

**Let the weather do the dirty work**

Many no-tillers let the cold winters do the work of killing their cover crop in time for them to plant into decomposing residue in the early spring. The classic example of this is a crop of oats, Daikon radish, or a mix of the two planted in late summer to die back with hard frosts, yet continuing to offer ground cover with the decomposing residue. You can take this a step further, and plant many non-winter hardy crops (including most summer annuals like buckwheat, sorghum-sudan, millet, cowpeas, etc.) 60-90 days before the first anticipated frost, and let the cold weather do the terminating and transitioning for you. It's not as good as keeping something actively growing each season, but the ground is covered, and erosion and weeds are kept at bay.

**Not "go big or go home"**

In the real world, no-till is a spectrum. Even when you find that continuous no-till is not feasible, there are many opportunities for reduced tillage – such as strip-till, ridge-till, and shallow tillage. Minimizing soil disturbance can still help build soil structure and preserve organic matter, while keeping the weed seed bank in check. Weed seeds left at the surface are exposed to the elements and insect/slug/bird predation, while seeds buried too deep may reach their natural expiration date before they can be exposed to the light to trigger germination. Tillage is more effective at controlling weeds, meanwhile, yet it also stirs up and exposes more weed seeds.

Some cover crops are allelopathic – they produce chemicals that inhibit germination of weed seeds. Winter rye is famous for this and its effect is quite noticeable, but that same effect can be seen from other cereal grains, as well as brassicas. It's simply the crop's way of defending its turf, beating back the competition to give itself room to grow. This is just one more benefit of leaving residue at the soil surface – the crop will continue to secrete the chemicals for several weeks as it breaks down.

All in all, building a system where tillage events are fewer and farther between is a good thing – the less you can till, the more soil life, structure and soil carbon you can support. One tillage event does not put you at risk of burning up all your soil carbon.

**Is no-till right for me?**

As you move your system in the no-till direction, we suggest trying it on a small scale first. Some things to remember that will make for more success–

- Since the cover crop will be the main form of weed control, it has to be done right – at the right seeding rate, and drilling usually produces a more consistent, successful stand than broadcasting.
- The best stage to terminate a small grain cover crop is at anthesis (flowering). Anthers will be visible as pollen sheds.
- Find compatibility between the cover crop and cash crop. They should not be in the same family, i.e. don't put a small grain cover crop with a small grain cash crop. A heavy nitrogen feeder like corn will benefit from an N-fixing legume cover crop.
- When interseeding, whether drilling into a perennial stand or using an InterSeeder drill to establish a cover crop in standing corn, look for shade-tolerant species, such as clovers, ryegrasses, festulolium, and orchardgrass.
- Too much residue can tie up nitrogen. Residue decomposition and nutrient release should match plant needs.

- When establishing a new pasture, it's better to plow and prepare a clean seedbed.
- Monitor maturity stage closely so your cover crops aren't allowed set seed.
- When planting into a rolled mulch or other residue, your best success will be with transplants or large seeded crops like corn, soybeans, potatoes, etc. Large seeds come with a bigger energy package to help the seedling push up through mulch.
- Understand that heavy, clay soils are slow to warm up.

# For Vegetable Growers

Vegetable production involves many practices that compromise soil health and can limit productivity. An intense vegetable cropping system removes large amounts of nutrients from the soil. A crop rotation that maximizes vegetable growth while including cover crops is the best way to build soil quality and productivity. Cover crops can be planted in the window between the harvest of one crop and planting of the next. A cropping system that includes cover crops will improve soil quality and pest management by enhancing biodiversity and nutrient cycling. Cover crop biomass reduces nitrogen fertilizer requirements and builds soil organic matter over the long term. King's AgriSeeds' diverse cover crop options can be fit into the rotation at various points throughout the year.

Late summer is one of the best opportunities to establish a legume cover crop to supply the following year's nitrogen needs. A late summer planting gives the cover crop time to establish in the fall. If well managed, a legume cover crop can contribute 75-125 lbs per acre of nitrogen. Whether you are committed to raising all your nitrogen on the farm, or concerned about paying for nitrogen fertilizer, that nitrogen contribution looks attractive.

For fields that need a very early spring tillage and/or planting, other options are winter killed mulches, such as oats and Daikon radish. In a rotation with later-planted vegetables, a winter annual cover crop to grow through the winter and spring will help maximize ground cover, erosion control, and organic matter addition.

As in many other types of rotations, all cover crops offer a multitude of benefits –

- Suppress weeds
- Protect soil from rain or runoff
- Improve soil aggregate stability
- Reduce surface crusting
- Increase  active organic matter in soil
- Break hardpan
- Fix nitrogen
- Scavenge and hold soil nitrogen
- Suppress soil diseases and pests

After vegetable harvest, plant a cover crop to compete with late summer and winter annual weeds, recycle nutrients to prevent losses, and anchor soil with root systems that also break up compacted layers of soil. A cover crop sets the stage for the coming year's rotation.

Matching the seasons of vegetable crop production with the planting of the appropriate cover crop can be challenging. Vegetables such as onions, lettuce, cabbage, broccoli, radishes, beets, carrots, and potatoes are planted very early. Overwintering cover crops are usually not an option, since you need time to terminate them in spring before planting.

**Summer Solar Mix: sunn hemp, buckwheat, cowpeas, and sunflower, and can double as a pollinator mix**

For fields that need to go into vegetables first thing in the spring, use a cover crop that will winter kill, such as oats or a summer annual, such as buckwheat, sorghum-sudan, or Daikon radish. These help recycle nutrients and build soil organic matter before spring planting. Keeping the ground covered with a living crop year-round would be ideal, but working with what's available to the timing of your rotation and the length of your growing season will be the reality.

- **Sorghum-sudan, millet, buckwheat, oats, and Daikon radish** can be planted after vegetable harvest, up to about mid-August in the Mid-Atlantic region.
- If potatoes are planned the following year, consider a break crop of **Braco white mustard,** a nutrient bio-accumulator and biofumigant.
- **Annual ryegrass** works well for planting later into the season, up to mid-fall. Deep, overwintering roots help recycle nitrogen, break up hard soil, and add organic matter.
- **Triticale** and **rye** are the latest, most flexible over-wintering options, and can be planted until mid-fall (mid-October in the Mid-Atlantic).

## Minimizing Cultivation with Strip Tillage

Strip tillage allows you to restrict tillage to the planting zone. Any technique that lets you reduce tillage in the field as a whole minimizes disturbance and conserves and builds soil organic matter, while protecting a variety of soil macro- and microfauna. The crop is planted into narrow, tilled strips and the area between these strips is left in growing cover. This allows for continual erosion control, weed suppression and soil building in between rows, both on- and off-season. It saves time that might be spent cultivating or weeding, and the cover crop planting operation is already taken care of by the time the vegetable crop is ready to go in the ground. Depending on the intended growth period and the expected volume of traffic, a low-growing perennial such as **Dutch white clover** or a conservation mix (See Perennial and Long-Term Covers, page 71) may be the best solution.

It's also common to use strip tillage with winter annuals – especially cereal rye - that are killed and rolled down with a crimper-roller before planting. This produces a killed, flattened mulch

**Annual Ryegrass**

mat that can suppress weeds for the duration of the season, and is still anchored in the ground

by its roots. To cover between-row gaps, the rye is generally rolled perpendicular to the direction it was planted.

If herbicides are used in a strip tillage scenario, look for those that are recommended for use with conservation tillage.

## Some Late Summer Legume Cover Crops or Mixes for Overwintering

If nitrogen is needed for summer vegetables the following year, fall-planted legumes to plow down the following spring offer a good solution. Winter annuals or perennials are great for preceding warm season vegetables with biomass and nitrogen. These vegetables are often planted late enough to allow time for spring productivity of the cover crop.

- **Three-Way Clover:** Best option for an early fall overseeding in late-harvested vegetables.
- **CARGO Mix (Crimson clover, annual ryegrass, and oats):** Grass-legume green manure. Oats provide a quick cover while annual ryegrass and crimson clover catch up and then overwinter, recycling nutrients, protecting soil, and building organic matter. Oats winterkill and provide sheltering residue.
- **Broadcaster Mix (Crimson clover, annual ryegrass, medium red clover, yellow blossom sweet clover, Daikon radish):** A diverse mix for varying soil conditions; adaptable from year to year and soil to soil. Clovers fix nitrogen over the winter and spring. Can be broadcast into standing sweet corn or underseeded in rows of tomatoes or other late summer vegetables.

## Early Spring Planted Cover Crops

- **Spring Champion (Hairy vetch, oats, and field peas):** Can be sown in spring as soon as you can get in the field to plant. This mix can grow large amounts of nitrogen-rich biomass to be turned under in late May/early June, or late spring in your area, before the planting of summer annuals or before the "second planting" of tomatoes, sweet corn, and melons.

Ray's Crazy Mix

## Late Spring Planted Cover Crops

**Ray's Crazy Mix:** With seven summer annual species, Ray's Crazy Mix is our most diverse commercial cover crop mix. It is made up of a variety of stress tolerant summer annuals—cowpeas, 2 sorghum-sudans, pearl millet, radish, forage brassica and sunflower—and can be used as a short-term cover crop, a soil building transition crop to renovate depleted soils, a smother crop, a grazing mix, or some combination of these. It also contains several blooming species that, if left to grow and flower, will attract beneficial insect species. The mix is beneficial for both no-till and conventional-till operations.

Ray's Crazy Mix makes an excellent green manure crop to plow down before cool season fall vegetables, such as broccoli, cauliflower, cabbage, radishes, and lettuce. Soil building warm season grasses like sorghum-sudan and millet are complemented by cowpea, a nitrogen-fixing legume, brassicas for nutrient-scavenging and broadleaf weed control, and

sunflower to attract beneficial insects and birds. Also works well as a summer break crop before reseeding pastures.

### Short Term Crop Rotation Benefits

Vegetable growers can improve short term crop rotations by fitting cover crops in between the harvest of one crop and the planting of the next. Following spring vegetable harvest, for example, **AS5201 ("Quick Cover") Sorghum-sudan** can grow 1.5 to 3.5 tons of dry matter in 35 days, which can usually be incorporated into the soil in time for a fall planting. Alternatively, **buckwheat** biomass is easier to work in and its residue breaks down quickly, and it can be ready for disking down and fall planting in 5-6 weeks.

## Pollinator Plantings

### Farmscaping

Why draw more insects to the field? Most row crop fields are acres upon acres of monoculture. If these crops are grown to bloom stage, they will provide food for vitally important pollinators like honeybees for a very short time, and the single plant species creates food for limited insect species. **You can use mixes of flowering annuals (like the newly released Summer Solar Mix – a mix of cowpeas, buckwheat, sunflower, and sunn hemp) or perennials to create a refuge on the farm to attract diverse species of predatory insects, praying mantises, honey bees, ladybugs, birds, and butterflies.** Although many farmers want to build organic matter and soil health with this mix, others will use it primarily for attracting these beneficial species during the summer months.

There is no one right way to do this, but as a general rule, the larger the area, the better. At least 1-2 acres of farmscaping per 25 acres of cropland will give you the most benefit. Large, square blocks are the easiest to maintain in terms of edging, weed maintenance, or planting around the edges.

In reality, many configurations will work and what you choose depends on your management, field layout, and topography. Long corridor strips between fields may be the most practical layout.

Most farms have odd-shaped parcels of land that are not easy to bring equipment into for planting and harvest, and these make good areas to dedicate permanently to pollinator crops. These may include small, awkward wedges between a field and a portion of the creek or woods, waterways, hedgerows, diversion strips, farmed terraces, and other fragile areas that are best left alone for the duration of the season. Long contour strips could also be taken out of production and planted to a summer annual mix like Summer Solar Mix. They could be more permanent or rotated with other crops.

This is also well-suited to produce operations, since pollinator plantings can be rotated between the vegetable rows each season. These vegetable systems would also benefit from planting the mix around the perimeter of a greenhouse—both to reduce mowing needs and to draw beneficial insects to the crops planted inside.

In monoculture fields with limited bloom there are few natural predatory controls, so pests such as moths and their lepidoptera offspring may begin to dominate the area. **Farmscaping draws beneficial predators into adjacent areas so they can begin to move into the field to prey on these pests.**

Pollinator plantings also make great buffers and

transitional zones. For example, planting corn or soybeans right up to the edge of a wooded area won't be the best plan since the field edges will get shading from the trees and be vulnerable to wildlife living in the forest. A pollinator mix planted at the woodline eases this sharp transition and also helps draw beneficial insects out of the woods and into the field.

Summer Solar Mix is convenient in many rotations and scenarios. Consider the following request from a Western New York farmer:

*"We are looking at possible cover crops to plant after the spring peas are harvested mid to late June prior to seeding winter wheat. Last year we had the opportunity to grow a crop of BMR sorghum Sudan for a dairy operation after the peas (19.5 green chop tons per acre). Looking for other options if that opportunity is not available again. Do you have any suggestions?"*

Summer Solar Mix fits well in this particular situation as both a rapid soil builder and insect bio-diversity builder. It is appropriate here to plan it into the normal rotation for temporary farm-scaping rather than placing it in a specially sanctioned area. Both can be done on the same farm, however.

This plan will be different on every farm, and each farmer is likely to know best where these plantings will offer the best fit and benefit to surrounding fields. The most important thing is to first have an understanding of the benefits, and the desire to take advantage of them.

## 3-Way Clover

3-Way Clover is a versatile mix that can be frost-seeded, spring-seeded, or fall-seeded, aerial seeded or broadcast at corn lay-by or just prior to soybean leaf drop. Diversity is important in this mix; the red and white clovers grow in cool spring conditions, while the yellow blossom sweetclover grows well through the summer and during dry spells.

This balance of three blooming clover species also helps ensure more steady blooming throughout the year, attracting honeybees and beneficial insects year-round. Recommended for two years' growth at the most. It also makes a good nitrogen fixer, year-round soil cover, and weed suppressor.

## Berseem Clover

Berseem clover is a summer annual legume with oblong leaflets and hollow stems. It grows upright and produces yellowish-white flowers with small round heads. The plants may grow as tall as 18 to 30 inches. It has a small tap root that is 4 to 6 inches long. It is not winter-hardy and will winterkill in northern climates. Berseem clover can be used to boost production on thinning alfalfa stands or as high protein forage, and is a legume that does not cause bloat. It is also an excellent choice for a cover crop due to its vigorous growth and good nitrogen-fixing potential.

Above 60 degrees F, will be ready to cut in about 60 days. Cutting every 30 days prior to frost encourages growth and N production.

If grown to maturity as a cover crop, it can fix 100-125 lbs/A of nitrogen, providing good fertility to precede a fall-planted small grain crop or fall-planted pasture or hay crop.

Can be planted late summer in the same growing window as fall oats; will winter kill and provide overwinter mulch residue, leaving the soil ready for an early spring planting.

Berseem prefers slightly alkaline loam and silty soils but grows in all soil types except sands. Soil phosphorus can limit berseem clover growth. Fertilize with 60 to 100 lb. $P_2O_5$/A if

soil tests below 20 ppm. Boron also may limit growth, so test soil to maintain levels. Berseem tolerates saline conditions better than alfalfa and red clover.

**Must be inoculated with R-type inoculant suitable for berseem clover and crimson clovers.**

## Cowpeas

Iron Clay Cowpea is a vining summer annual legume, and the beans it produces are also known as black-eyed peas. In a straight stand, cowpeas form a dense weed suppressing mat and fix nitrogen.

For added soil building and diversity, plant in a mix with other summer annuals, such as sunn hemp, sudangrass, buckwheat, or MasterGraze tillering corn. The vining habit combines well with a more erect species that it can climb. Cowpeas are slower to start than many other summer annuals, and also do well in the shelter of a few quicker-establishing species. If planted in a mix with one of the above species, reduce the cowpea seeding rate slightly to 40-50 lbs. Plant millet or sudangrass at 12-15 lbs/A. The MasterGraze should be planted in 15 inch rows with a corn planter, and the cowpeas can then be drilled across the rows in a perpendicular direction.

Cowpeas have excellent drought resistance and a good tolerance of heat, low fertility, and a range of soils. They do well on light, sandy soils, and well-drained, but not excessively wet soil. If left to bloom, they attract many beneficial insects that prey on other pests.

Iron Clay Cowpeas reduce rootknot and soybean cyst nematode populations, making them a beneficial break crop in rotation.

**Besides the flower nectaries, Iron Clay Cowpeas also have "Extrafloral nectaries" which are nectar release sites located on the petioles and leaflets that attract beneficial insects including ants, many types of predatory wasps, honeybees, lady bird beetles, and soft-winged flower beetles.**

The cowpeas are tolerant of heat and drought and can be grown on poor soils. Due to the fact they are somewhat shade tolerant, they work well in cover crop mixes, growing under the canopy of the taller species.

Cowpeas grow a deep tap root that helps the plants find deeper soil moisture; in addition, it fixes nitrogen as a legume and it also scavenges phosphorous, bringing it upward into its above ground biomass for recycling and reuse by subsequent crops. The tap root system also helps build soil structure.

For nitrogen use, turn under as a green manure at flowering. As with many other cover crops, introducing a new species to the rotation will help break up weed, pest and disease cycles.

**Must be inoculated with N-Dure Peanut Inoculant for best nitrogen fixation. If cowpeas have not been grown in the field before, the soil likely won't have the correct strain of rhizobium bacteria for an advantageous inoculation.**

## Hubam Clover

Hubam is a summer annual sweetclover that is adapted from Georgia to Maine. It blooms and sets seeds in the planting year. Its value is largely in its soil health benefits (including nitrogen fixation) and its ability to attract

pollinators with its abundant nectar production.

*Pollinator Benefits*

- Attracts honeybees and many other beneficial insects, such as Tachinid flies and other large predatory wasps.
- High nectar producer. Once it begins flowering, it will flower for about two months, because of the sheer number of flowers (up to about 1500 flowers on a single plant) and the irregularity of bloom.
- Produces nectar from morning into late afternoon during summer months. This is a longer nectar flow than other summer annual nectar producers, such as buckwheat, which will shut down their nectar production in the afternoon.
- Both pollinator and soil improvement attributes.
- Grow in riparian buffers to enhance farm-scaping, where it may re-seed itself for long-term growth as a pollinator.

*Soil Health & Fertility Benefits*

- If left to grow through the summer, the strong tap roots grow down anywhere from 25 to 95 inches, helping to alleviate clay hard-pans, open up heavy soils, and sequester carbon at deeper soil levels. These deep roots also mine and bring up nutrients that have leached down deep.
- After about a month of top growth, the plant starts to put its energy into growing deeper roots, which will eventually supply moisture and essential nutrients to help the steady flow of nectar during flower bloom.
- Tolerates variable soils – can be grown on clay soils or lighter sandy soils.
- Tolerates wet soil and salinity.
- Root exudates have the ability to make insoluble forms of potassium and phosphorous available for the plant and for plants grown in subsequent rotation.
- This crop is a strong nitrogen fixer and should be considered a soil health builder (enhancing soil life) as well as a soil fertility booster.
- Helps to recycle nutrients and open up no-till soils - roots create paths for water infiltration.
- Heat tolerant annual crop, will go to seed in the first year if planted early in spring.
- Not frost tolerant; can overwinter in warm climates.
- Tall, erect (decumbent), stemmy growth, not considered best as a forage, but excellent for biomass production to improve soil organic matter.
- Resistant to cold, frost tolerant.
- Should not be considered as a livestock feed in straight stands, because the crop contains coumarin, toxic to livestock.

## Summer Solar Mix

A diverse legume-forb cover crop mix of aggressively growing summer annuals, with dual use as a forage not intended. The mix includes four very different components—buckwheat, cowpeas, sunflower, and sunn hemp. These species work together to perform several functions during their brief growth period:

- Nitrogen fixation and recycling
- Organic phosphorus liberation and recycling
- Soil organic matter building/carbon sequestration
- Other nutrient cycling and soil health building
- Summer pollinator and beneficial insect attraction with the mix of species achieving a bloom succession
- Summer weed smother crop
- Disease and nematode break crop

Both conventional and organic growers will find this a useful break crop in between spring and fall crops that builds soil nitrogen levels and attracts pollinators and other beneficial insects. It can also be used in farmscaping strips to draw beneficials throughout the season.

Other summer annuals can be combined with this mix if more diversity is desired, such as sorghum-sudan, millet, or brassicas.

**Establishment:** It's best to drill the mix, but can be broadcast on well-worked ground and packed in to cover the seed well. 50-70 lbs/A is recommended, but use higher seeding rates as a fast shorter-season summer smother crop, if you plan to rotate out sooner.

Ideal planting window is early June through summer, after all chance of frost has passed and soil temperatures have reached 65 degrees F and rising. Successful germination at later summer planting dates in July and August will depend on adequate soil moisture.

**Dates:** June/July/August, depending on region, temperature, and soil moisture (use in early August as a quick growing, shorter-lived break crop)

**Seeding Rate:** 50 to 80 lbs/acre (higher seeding rates accomplish quicker weed smothering, biomass production and nutrient recycling).

**Depth:** 1/2" to 3/4"

**Each component performs a unique function:**

- **Buckwheat:** A rapidly growing broadleaf cover crop that outcompetes summer annual weeds and builds soil in short windows between warm season crops, or in the transition periods between winter annuals and summer annuals.

It extracts phosphorus and makes it more available to the following crop. Its fibrous root system improves soil quality in the upper soil profile, increasing short-term soil aggregation and tilth. Blossoms attract beneficial insects such as bees and other predators, including hoverflies,

predatory wasps, insidious flower bugs that attack or parasitize aphids, mites and other pests.

- **Cowpeas:** Iron Clay Cowpeas are a vining summer annual legume, and the beans it produces are also known as black-eyed peas. In a straight stand, cowpeas form a dense weed suppressing mat and fix nitrogen. Blooms attract beneficial insects. Iron Clay Cowpeas reduce root-knot and soybean cyst nematode populations, making them a beneficial break crop in rotation.

  The cowpeas are tolerant of heat and drought and can be grown on poor soils. Due to the fact they are somewhat shade tolerant, they work well in cover crop mixes, growing under the canopy of the taller species.

  Cowpeas grow a deep tap root that helps the plants find deeper soil moisture. It also fixes nitrogen and scavenges phosphorus.

- **Sunflower:** For general cover crop use, sunflowers produce lots of biomass, but become lignified and woody at an earlier maturity stage than other species, and are only suitable as forage while still in the vegetative state. They draw bees, beneficial insects, butterflies, and birds to the field, which boosts overall biodiversity. Strong taproots penetrate vertically downward with widely spreading branch roots, and the enlarged taproot eventually grows many laterals. The root system recycles nutrients and puts organic matter back in the soil, contributing to improved soil health. The ample above ground growth contributes to overall biomass production.

- **Sunn Hemp:** A tall summer nitrogen-fixing legume that gets quite fibrous and lignified prior to bloom. It can reach six feet in height, and its deep taproot has many lateral branches. It is a high biomass producer that's competitive with weeds. Above ground biomass accumulates significant amounts of carbon, which eventually adds to soil organic matter levels when incorporated or left as a heavy surface residue. Sunn hemp can also be used as a rotational break crop for suppressing plant parasitic nematode populations in both vegetable and field cropping systems. It uses various modes of action to do this, making it an efficient crop for nematode management. It is not only a poor host, or "non-host" to many plant-parasitic nematodes, but it has been shown to produce toxic compounds that work against several key nematode pests.

## Interseeding and Relay Cropping

Interseeding a cover crop in corn at V6 stage

*Information, pictures and tables provided by Dr. Bill Curran (PSU)*

*Research Team - W. Curran, G. Roth, C. Dillon, C. Houser, R. Hoover, J. Wallace, M. Dempsey, Penn State University; S. Mirsky, USDA-ARS; and M. Ryan, Cornell University*

Relay cropping cover crops with various methods of interseeding is an adaptive technique that helps fit a cover crop into a time-constrained rotation. Interseeding cover crops into a standing crop is an old practice, but the techniques have evolved over time to include broadcasting, aerial seeding, and now interseeding with a special drill that has been developed expressly for this purpose. This section will focus primarily on this technology and its use in a corn crop.

**Interseeding with a drill or air seeder:** The Interseeder is an exciting technology that has become more commercially available and has been trialed extensively by Penn State University. Essentially a no-till drill, the Interseeder plants a cover crop into standing corn at V5 to V7 stage, creating a more updated and effective version of the traditional technique of broadcasting a winter cover crop into corn at last cultivation which is still utilized by some organic farmers. This maturity stage falls just after the critical weed free period, when corn would be most sensitive to competition from weeds (or an interseeded crop).

King's Agriseeds Inc. supported this project, providing some of the seed for the on-farm research. Dave Wilson, King's research agronomist is on the advisory board for the project and worked with the group to provide cover crop mixes and advice.

Available technologies for interseeding include, but are not limited to:

Closing wheels and N application tube - latest design components of Interseeder

- The Interseeder (Penn State and Interseeder Technologies LLC) – drills cover crops in 7.5" rows
- The Dawn DuoSeed Interseeder (Hershey Farm) – drills cover crops in two 10" rows
- The RoGator interseeder (constructed by farmer Donn Branton) – broadcasts seed between 30" crop rows
- The High Boy Air Seeder (constructed by farmer Charlie Martin)

**Broadcasting** is still frequently done, sometimes using an air seeder or in organic farming scenarios with a seed spinner mounted

on the back of a cultivator, but higher seeding rates must be used, and success is highly dependent on sufficient rainfall very close to the time of seeding, either before or after. Broadcasting is also much more effective on tilled than no-till soil. Some of the seed may also land in the leaf whorl. It is chosen for its ease and the lack of expense and equipment needed, but drilling the seed in with the Interseeder achieves better seed placement into moisture, and better seed-to-soil contact, especially in no-till corn ground.


***Interseeding in an organic context: Hurst Electric Spinner Seeder mounted on cultivator to spin on cover crop seed at last cultivation (Rod Porter farm, Trumansburg, NY)***

Interseeding provides a flexible and innovative way to fit cover crops into the rotation, whether the farm is large or small scale, organic or conventional, conventional tillage or no-till.

Researchers at Penn State continue to examine the delicate balance between corn and cover crop to be sure that a) the cover crop does not introduce too much competition into the corn and b) the corn does not threaten the eventual thriving of the winter cover crop. They are looking at earlier seeding of the cover crop (at the corn's V3-V4 stage) as well as shortening the corn's maturity to allow for better light penetration and greater cover crop growth in the fall. "Often, reduced drying costs, earlier harvest, improved prices, and residual effects of cover cropping can offset modest yield penalties associated with earlier hybrids," explains Penn State Extension.

### Getting more of the benefits of cover crops

Most interseeded cover crops will give you nutrient credits for your following year's corn, but exact amounts depend on the species you use, in what proportions, your management practices, and ultimately the weather effect on growing conditions of both the corn and interseeded cover crop. Legumes fix a good portion of a following corn crop's nitrogen needs if they are allowed to grow to bloom in the spring (if not harvested for forage). Grasses can more than double the value of winter manure applications by uptaking nutrients before they leach. However, depending on maturity stage, grasses may also immobilize some nitrogen, making it available later as they decompose.

Being able to double-crop with a winter cover crop despite timing constraints also gives you the full benefits of ground cover, including erosion prevention, added soil organic matter and other factors contributing to soil health and winter annual weed suppression.

By acting as a "break crop" and adding diversity in the rotation, the cover crop can also improve yields in corn after corn systems.

Interseeding can be more economical than a typical cover crop planting, since it can be combined with another operation across the field (usually N sidedressing) and/or a post emergent herbicide application.

**Weed Management**

Avoid choosing fields for interseeding with pre-existing weed management problems.

Residual herbicides can be problematic for interseeded cover crops. The basic approach to weed management is to use a no- or short-residual (shorter half-life) burndown herbicide, or tillage followed by glyphosate or glufosinate prior to the interseeding. The interseeding occurs about 3-5 weeks after corn planting. Research is ongoing about the most appropriate herbicides to use in a rotation with interseeded cover crops. Non-residual programs based on glyphosate and glufosinate are the best bet until we have more experience.

**Species**

The best species are cool season annuals or perennials, somewhat drought and shade tolerant, and easy to establish.

Among grasses, **annual and Italian ryegrasses** are the most common. Although ryegrass is one of the most successful cover crops for interseeding, it can also be challenging to kill in the spring.

**Medium red clover** is the most widely used legume, not only for interseeding but for the more traditional relay cropping predecessors – broadcasting in corn at last cultivation and frost-seeding into a small grain in late winter.

On many organic farms, medium red clover broadcast at last cultivation has become standard.

**Crimson clover** has also had success, although it's more prone to winter-kill in more northern regions. As an annual, it typically grows more fall and early spring biomass compared to medium red clover.

That being said, endless combinations of cover crops can be used in the Interseeder context, and many factors decide their success -

- Crop Physiology
- Planting date
- Seeding rate
- Seeding depth
- Seed-to-soil contact
- Soil moisture
- Amount of sunlight through the corn canopy

***Interseeded annual ryegrass growing up after corn harvest***

Annual ryegrass and medium red clover have been two of the most consistently successful crops for interseeding.

King's AgriSeeds and Penn State have advocated using mixes of about 3-5 species. **King's Broadcaster Mix** is our primary commercial mix that is Interseeder-ready (contains Annual Ryegrass, Crimson Clover, Common Medium Red Clover, Daikon Radish, and Yellow Blossom Sweetclover).

The **original mix for the PSU interseeder project** has also performed quite well, and it contains Green Spirit Italian Ryegrass, 3-Way Clover (Red Clover, Ladino White Clover, Yellow Blossom Sweetclover). It performed quite well in the 2011-2012 PSU Short-lived trials under the name "King's Mix.

| Blends | | Cut 1 | Cut 2 | Cut 3 | Total |
|---|---|---|---|---|---|
| King's Mix | Italian Ryegrass/ clovers | 2.56 | 2.02 | 1.95 | **6.53** |
| Tritcale plus | Triticale (815@66%+33% ARG) | 3.20 | 1.98 | 1.35 | **6.53** |
| Bristol | Radish/Rootmax | 1.61 | 2.52 | 1.46 | **5.59** |
| Indy Blend | Radish/Rootmax/Crimson Clover | 2.18 | 1.96 | 1.31 | **5.45** |

## Penn State On-Farm Research Trials (about 12 locations each in 2013 and 2014)

| Treatment | Species | Rate (Lbs/A) |
|---|---|---|
| Untreated | No cover crop | 0 |
| Grass | Annual ryegrass | 20 |
| Legumes Mix | Med. Red Clover, Crimson Clover, Hairy Vetch | 10+20+15 |
| Legumes + Grass | Annual ryegrass, Med. Red Clover, Crimson Clover, Hairy Vetch | 10+5+10+7.5 |
| Grass + Radish (2014 only) | Annual ryegrass, Radish | 10+5 |

**Harvest**

Most of Penn State's research has been done on corn for grain, although corn for silage will be evaluated more. There may be more short-term damage to the cover crop in a silage harvest situation, but it can usually recover as long as the field is not too wet at the time of harvest. For grain harvest, the biggest problem can be smothering from the residue, so be sure to set the combine high so there is no stalk shredding, and avoid mowing stalks to prevent damage to the cover crop.

**Summary**

**Penn State's research findings include –**

- Interseeding has the most success when the corn is at V5-V6 stage
- Annual ryegrass is the most successful grass; legume establishment is more variable
- Corn yield is mostly unaffected by the interseeding operation
- Effect of the interseeded cover crops on second year corn is still under evaluation

**Key Aspects of Early Season Interseeding**

- Seed cover crops at V6 stage for corn
- After critical weed-free period for corn
- Previous tests indicate that when timed right, there are minimal or no impact on yields

**Latest Interseeder Version Design Components**

- Drill units between rows
- Liquid N stream can be applied adjacent to corn row
- Herbicide can be applied under corn canopy
- Assist wheels to carry weight
- Ground drive
- Loading platform
- Conversion to complete Drill Unit
- Hitch for towing
- Commercialized by Interseeder Technologies, LLC - http://interseedertech.com/

**Interseeded Cover Crops CIG (Conservation Innovation Grant) Summary:**

- After two years, fairly high level of successful establishment
- About 70% in 2013 and 90% in 2014 in over 70 trials

**Challenges:**

- Geographic limitations – might be better in the North (prefers cooler and heavier soils; provides good answer to short growing season)
- Identifying suitable species and varieties - **Annual ryegrass and medium red clover are consistently two of the best**
- Soil residual herbicides can be problematic – but often necessary to manage HR (Herbicide Resistant) weeds
- Timely cover crop control the subsequent year

***There are many ways to apply cover crops into the rotation.*** *We are doing that with various equipment applications both on the small and large scale. We are doing it both on organic and conventional farms, both in conventional tillage systems and in no-till systems. Keys to successful application that we need to understand are: cover crop physiology; planting date, seeding rate, seed depth, seed to soil contact considerations and soil moisture factors. From an Ag-Engineering point of view we need to understand how to utilize the right equipment to get these cover crop seeds established in various rotations and cropping systems including a relay-crop type scenario.*

- *Dave Wilson, Research Agronomist, 2004*

That was a statement made years ago, and the same fundamentals hold true today in the Interseeder context.

**Crimson clover 4 weeks after interseeding**

**Red clover in fall prior to corn harvest**

## Case Study: Interseeder Research Plots, Mill Hill Farm, Williamsburg, PA

*Farm owner Jim Biddle cooperated with Penn State Extension and King's AgriSeeds Inc*

*Cover crop plots interseeded into MCT 5375 corn, June 18, 2015*

Mill Hill Farm is a no-till dairy farm in Williamsburg, Blair County, PA. Jim Biddle is the owner and also a Certified Crop Advisor, in addition to running the on-site business, Mill Hill Farm Supply.

The farm's soil preservation philosophy is to keep as many acres covered for as many days of the year as possible, in order to feed microbes that help build soil health and structure. To that end, every possible acre is double-cropped.

Everything is no-tilled – as Jim says, "my vertical tillage equipment is my corn planter and my no-till drill, and that's it".

The farm is 570 acres and has 285 mature cows and 250 replacements. The typical rotation is three years of corn silage, followed by three years of alfalfa-grass. Triticale forage is included in half of the corn acres, in rotation with the corn. A third of this triticale is blended with crimson clover, and a third is blended with radish.

Although Jim is a firm believer in the value of the interseeding practice and knows how to manage it in terms of herbicides and timing, he does not currently own the equipment. Since his growing season is long enough and he takes his corn for silage, he usually has enough time to get the double-crop triticale or rye in after the corn with a traditional seeding.

In the corn that he harvests for grain, Jim often drills cover crops through the stalks. Depending on the year, this can turn into a dormant seeding application (if it gets cold early, the seed may not germinate until early spring).

When he started working with cover crops, Jim was a purist, keeping cover crops strictly for soil-building and not forage use. Now he uses about 40 percent of his cover cropped acres for forage, and finds he still gets many of their soil benefits while building his forage inventory.

**Research Plots**

In cooperation with Penn State and King's AgriSeeds, Jim Biddle made plans for interseeded plots. Side-by-side plots would give the team a chance to compare commercial mixes as well as experimental mixes, and judge which species did well in the context of a mix, and which did not express themselves quite as well.

In the corn field where the plots were interseeded, triticale had been planted September 25, 2014, originally intended for cover crop use, to be terminated in the spring before soybeans. 5000 gallons of dairy manure was applied October 2, 2014. Instead of spraying and killing the triticale, however, they decided to take it for forage. They harvested 4.7 tons/A at 65% moisture. They had not applied any additional N in the early spring and decided to follow with corn to use it for the Interseeder research plots.

5000 gallons of dairy manure was applied May 14, 2015, and MCT 5375 was planted May 19, 2015 with 65 lbs/A N. On May 24, the field was sprayed with 2.0 qt/A Degree Xtra; 1.0 qt/A Gramoxone SL; 1.0 qt/A Accomplish LM; and 28 gal/A UAN (90 lbs. N). A post treatment of glyphosate (24 oz/A Touchdown Hi-Tech) and

fungicide (2.0 oz/A Stratego YLD) on June 16, 2 days ahead of the Interseeder. The fungicide was used in response to some Gray Leaf Spot appearing on the lower leaves.

The plots were interseeded into the corn on June 18, 2015.

Any wet weather ended on July 15, the start of an extreme drought and heat wave in the area. On August 28, Jim harvested 20.4 tons/A of corn silage and applied 5000 gal of dairy manure on September 2 on top of the interseeded over crops that remained.

Interseeded mix that includes 3-Way Clover, radish, Dwarf Essex Rape, annual ryegrass, Balansa clover; 5 months after interseeding in June.

Broadcaster mix 5 months after a June interseeding - radish, annual ryegrass, crimson clover, red clover, and yellow blossom sweetclover

# No-till not enough

BY **JOHN VOGEL**

**Key Points**

- Pennsylvania farmer's no-till soils improved with cover cropping.
- Early-fall cover crop plantings fit dairy farm's cropping system.
- Triticale is a key base ingredient for his system.

JIM Biddle has figured it out: Better, healthier soils produce better yields at lower costs. And he didn't have to move to another farm to make it happen.

Since 2002, the veteran no-tiller from Williamsburg, Pa., has been cover-cropping each acre of Mill Hill Farm in Blair County.

"He really saw soils respond to no-tilling once he started using cover crops," says Penn State Extension agronomist Greg Roth. "Last fall, he had a wide range of great cover crops — triticale, triticale-radish mixes, some mixes with ryegrass and/or crimson clover, and loads of earthworm castings."

Triticale is the base ingredient on all 580 acres of corn, soybeans and some double-crop forage sorghum, says Biddle. It fits the dairy farm's systems approach for top-quality feed, plus timing of manure application and planting. Triticale is harvested in mid-May and followed by no-till corn and soybeans.

"That allows three to four weeks extra root growth where we use triticale for a spring forage harvest," adds Biddle.

Biddle and son Josh, who manages the dairy, drill their cover crops between late August and late October.

"Since there are huge advantages to multispecies," Biddle says they add radishes in early September and crimson clover in late September.

Clover needs a longer season to build soil nitrogen. The triticale cover crop benefits, as well, with longer root growth and higher forage protein quality and close to 8-ton yields. Biddle also notes that only 25% of the farm's cover crops are harvested.

No-till helps build soil structure. Cover crops increase soil microbial activity, which in turn feeds the entire food chain up to and including earthworms, he says.

"The key to cover cropping is in the roots, which feed those microbes and create soil pores to allow air and water to flow through a larger portion of the soil profile," notes Biddle. "It's a proactive process to building soil carbon levels and improving soil health."

Biddle considers cover cropping just as important as no-till. It keeps every acre protected and biologically active year-round. That's one reason Mill Hill Farm won Pennsylvania's Chesapeake Bay Clean Water Farm Award.

PHOTO: ENN STATE/ GREG ROTH

**GREEN AND CLEAN:** With every acre cover-cropped, Mill Hill Farm is building soil health and productivity.

**SHOVEL-BUSTER:** Jim Biddle broke the fiberglass handle on his shovel digging out this cover crop "tool."

**SOIL IS ALIVE:** Proper care and feeding of soil's microbial populations will start building organic matter and plant health within two years, says NRCS agronomist Ray Archuleta.

## Where no-till missed the mark

RAY Archuleta may be a fervent no-till "preacher," but even this Natural Resources Conservation Service agronomist agrees: "No-till is not enough — not for building soil health.

"I don't recommend it without cover crops and excellent rotations. No-till stops soil destruction, but doesn't feed it," he says. "While it does better than conventional tillage, it's no match for no-till and cover crops grazed by animals."

NRCS initially promoted no-till incorrectly by making it the central focus. "We missed the mark. However, no-till plus cover crops changes the whole equation."

Thinking in terms of a holistic system best mimics regenerative nature — keeping soils covered 100% of the time and building healthy soil microbial populations to feed crops, he explains. This has reduced fertility needs more than 50%, completely eliminated insecticides and fungicides, and reduced herbicide applications by 90%. Teaming up no-till with covers has improved soil infiltration rates and increased water-holding capacities.

"Our best producers use no-till, cover crops and animals to graze the cover crops," says Archuleta. "These guys have reduced inputs by huge amounts. It's raising great corn yields at costs of only $1.75 per bushel. It's systems synergism!"

**"No-till Not Enough", *American Agriculturalist*, February 2016. No-till farmer and King's AgriSeeds dealer Jim Biddle of Mill Hill Farm featured.**

Healthy cover cropped soil has earthworms, soil aggregates, and organic matter

## Cover Crops and Soil Improvement

Most cover crops serve multiple soil improvement functions. They are a biological means of:

- Conserving and recycling soil nutrients - reducing nutrient leaching losses from soil root zone with plant uptake in between active cash crops
- Carbon sequestration – adding organic matter to soil through both root growth and aboveground growth when killed and incorporated
- Reducing compaction with root penetration of subsoil
- Increasing soil aggregation - Cover crop roots increase soil aggregation in multiple ways. First, they exude monosaccharides (simple sugars) which feed soil microbes in the rhizosphere (root zone). Over time sugars and other root exudates along with microbial exudates contribute to soil aggregation of soil particles in the root zone. In addition, certain cover crops form living symbiotic associations with arbuscular Mycorrhizal fungi. These fungi produce a compound known as glomalin to protect their hyphae as they grow out into the soil. In the long term, glomalin acts a natural glue that boosts soil aggregation. Soil aggregation creates pore spaces that capture air and water in the soil and increase infiltration. Aggregation improves water flow and also boosts soil integrity and physical structure known as "tilth."
- Increasing infiltration, as well as water-holding capacity
- Improving aeration
- Fixing nitrogen (legume cover crops)
- Some species enhance phosphorus availability through acid phosphatase as root exudates
- pH buffering – by adding organic matter and non-acidic nitrogen from legumes
- Reducing erosion by keeping soil covered and anchoring it with root structures
- Reducing sediment from floodwaters and wind
- Reducing soil crusting
- Increasing biological activity – promotes ecological balance, beneficial organisms and biodiversity. Cover crops and green manure increase the food supply – energy and nutrients – for soil microorganisms

### Organic Matter/Soil Quality

Organic matter is one of the most important indicators of soil quality. Organic matter cycles in the soil and includes different forms: living organisms, fresh crop residue, decomposing organic matter, and finally stabilized organic matter known as humus. Some beneficial effects of soil organic matter include: better aggregation and aggregate stability, longer cycling of nutrients, higher microbial activity, more water holding capacity, higher Cation

Exchange Capacity (CEC) and a higher ability to bind to micronutrients, and lower bulk density.

Cover crops provide not only protection for the soil surface but also add residue and root mass to the soil, which becomes soil organic matter. The more you practice cover cropping, the more you build soil organic matter reserves over time.

**Don't forget the roots.** Cover crop growth that you can see is only half the equation. Roots can add half again as much material as above-ground material. In grass-legume mixes, often half of the biomass production is underground in the roots. In no-till situations where surface residue is not regularly tilled into the soil, cover crops roots become especially valuable for both soil organic matter and breaking up compacted soils.

Above ground growth is only half the story

**Grass and legume cover crops support mycorrhizal fungi.** Mycorrhizal fungi are beneficial plant root fungi. Cover crops growing in the off-season support the year-round growth of these fungi, because they require a living plant root to survive. Mycorrhizae grow from the plant root and extend out beyond the root hairs to access a greater soil area. It has a symbiotic relationship with the plant that helps it provide more nutrients to the plant than it could access on its own. These fungal extensions, called **hyphae,** produce an organic compound, **glomalin.** Glomalin is an extremely "tough" organic compound, adding to soil carbon and nitrogen storage. It is resistant to microbial decay, lasting 10 to 50 years, and does not dissolve easily in water. Glomalin acts as a biological "glue" holding soil particles together in aggregates, and is an important component of long term soil organic matter.

## Cover Crops and Pest Management

- Cover crops create a habitat for beneficial arthropods (insects, crustaceans, arachnids, and myriapods)
- Beneficial insects, such as lady beetles or ground beetles, may be encouraged by planting cover crops. Lady bugs attack aphids, mites, insect eggs, and small insects. The lady bug predator can eat its own weight in aphids in a single day.
- Hubam clover attracts beneficial big eye bugs (also called seed bugs) which will attack spider mites, thrips, leafhoppers, aphids, and other insect eggs.
- Buckwheat flowers attract hoverfly (also called Syrphid flies); the larvae are voracious eaters and will attack aphids.
- Brassica cover crops in rotation with different crops will disrupt pest and disease cycles associated with typical grass-legume rotations. Brassicas contribute some control for soil-borne pathogens and nematodes.
- All of the true clovers, including red, white, crimson, and alsike will provide nectar and pollen for honeybees. Sweetclovers are also very good nectar providers. One of the best nectar

sources is 'Hubam' sweet clover, an annual sweetclover that flowers in the same year it was planted, and blooms for about two months, producing nectar from morning until evening. Buckwheat can be planted in succession throughout the summer as a cover crop that attracts many honeybees.

- Buckwheat can be planted late as well, as a nurse crop for hairy vetch or other winter annual legume in early September, and will still flower and provide foraging bees with food until October in Pennsylvania, just before the first frost sets in.

## Cover Crops and Weed Suppression

- Cover crops often grow quickly and present a physical barrier to weed seed competition.
- Small grain cover crops (barley, oats, rye, and wheat) are strong competitors against weeds, and many cover crops – such as rye, buckwheat, hairy vetch, and sorghum-sudangrass - have allelopathic properties, emitting chemicals that inhibit weed seed and other seed germination.
- Many cover crops and their residues can suppress weed growth by altering light and temperature. A "living mulch" cover crop can greatly reduce the amount of sunlight reaching the soil surface, preventing weed seeds from germinating.
- Cover crops prevent weed establishment in fields during "non-crop periods". Perennial weeds will quickly invade a fallow field, starting weed problems that can take years to control. This is why cover crops grown in fallow fields are especially important.
- Cover crops over winter suppress the growth of winter annual and biennial weeds for an early start in the spring. Cover crops are usually easily controlled and leave a clean seedbed for the following crop. They can be plowed under or terminated with herbicides, or in the case of winter annuals, rolled and killed to create a soil covering mat.
- Warm season annuals like spring oats, sorghum-sudangrass, and some of the brassicas can be left over the winter as a winter-killed mulch.
- Sod cover crops, when mowed or grazed regularly, also help manage perennial weeds.
- Brassica crops have been cultivated in India since 4000 BC and utilized as fodder crops, greens, root crops, condiments, green manure crops, oilseed crops, and smother crops. The canopy created by these crops can be harnessed for its smothering ability by selecting the leafiest varieties. Daikon radish drilled at 14-15 lbs/A in late summer will out-compete most winter annual weeds, greatly reducing weed pressure in fall and early spring.

## Disease

- Rolled down cover crop mulches reduce soil-borne diseases that often spread by splashing soil onto crop leaves.
- Rotating into cover crops is often effective in reducing disease. For example, incorporated alfalfa and white sweetclover residues can reduce the fungus *Sclerotium rolfsii,* while cereal rye

has the capacity to reduce the incidence of Phythium.

## Nematodes

Nematodes are very small roundworms that interact both indirectly and directly with plants. Some pathogenic nematodes will feed on plant roots and weaken the plant; some introduce diseases through their feeding activity.

- Brassicas (mustard, rapeseed, radishes) and sorghum-sudangrass have nematicidal properties. Brassicas used in rotation before soybean crops or grown between potato crops can improve production and lower pest control costs.
- Sorghum-sudan hybrids have been shown to help reduce populations of root-knot nematodes.
- Sunn hemp uses different modes of action to suppress plant parasitic nematodes, making it an efficient cover crop for nematode management. It is not only a poor host/"non-host" to many plant-parasitic nematodes, but it has been shown to produce toxic compounds that work against several key nematode pests. Sunn hemp also can enhance natural enemies of plant-parasitic nematodes, such as fungi that trap nematodes or feed on their eggs. Besides suppressing plant-parasitic nematodes directly, sunn hemp can also manage nematode damage on crops indirectly by increasing plant tolerance against these pests. Sunn hemp plantings have been demonstrated to enhance free-living beneficial nematodes in the soil that are involved in nutrient cycling, increasing nutrients available for plant uptake. A healthier plant will then have a higher tolerance to plant-parasitic nematode damage.

**Sunn hemp hosts beneficial nematodes**

# Guide to Cover Crop Products

## Early Spring-Planted Cover Crops

### 3-Way Clover Mix

See description in Late Summer and Early Fall-Planted Cover Crops, p 74.

### Spring Champion Mix

Spring field pea (*pisum sativum),* hairy vetch (*vicia villosa*) and oats (*avena sativa*)

**Best Locations:** Georgia to Maine.

**Planting Windows:** As soon as ground can be worked in the early spring. Up to April 15 in Southeastern PA and further south; up to April 30 north of central PA.

**Seeding rate:** 125 lbs/A, drilled ¾" to 1.5" deep.

Should both be inoculated with nitrogen-fixing **Pea-Vetch Inoculant –** the same inoculant is used for both legumes in the mix.

Once the soil warms up in the spring, this mix germinates and grows very rapidly. The oats grow the fastest and act as a nurse crop for the peas and vetch. Once the peas and vetch get established they will crowd out weeds and fix nitrogen.

**What to Know**

- Spring Champion is a grass-legume mix to build soil organic matter and feed soil microorganisms. Viney pea and hairy vetch growth is a good complement for the erect oat growth.
- Left to grow into mid-June and turned under as a green manure, it will provide nitrogen for summer-planted vegetables or short-season forage crops like millet, sorghum or sorghum-sudan.
- Can be cut as a forage after oats are at flag-leaf stage.
- Beneficial early spring weed suppressor.
- Recycles nutrients in the spring as soil warms up.
- Good rescue cover crop if fall planting window was missed.
- If left to grow into the late summer, can provide up to 4 tons/A dry matter biomass.

## Late Spring to Summer-Planted Cover Crops

### AS 5201 Sorghum-sudangrass

*Sorghum bicolor x S. bicolor var. sudanese*

AS 5201 is a non-BMR hybrid that can be used as a quick-growing summer cover crop.

**Best Locations:** Georgia to Maine. Sorghum-sudans are widely adapted and can be grown throughout the US wherever rainfall is adequate and soil temperatures reach 65-70 degrees F at least two months before fall frost.

**Planting Windows:** Plant as a summer cover crop after soil temperatures have reached 65 degrees F and rising, late spring or early summer.

**Seeding rate:** 50-60 lbs/A; drill at ¾" = 1 ½" deep using the large seed box. Firming the seed after seeding is desirable if it is dry or if rainfall is not anticipated before seedling emergence. This helps conserve soil moisture and optimize seed to soil contact.

At higher seeding rates – 70-90 lbs/A – this makes an excellent smother crop to reduce weed pressure.

**What to Know**

- Flexible summer cover crop, catch crop, and weed suppressor. Its high nitrogen demand makes it a particularly good scavenger and catch crop.
- Good for suppressing summer annual weeds like velvetleaf, large crabgrass, barnyardgrass, green foxtail, smooth pigweed, redroot pigweed, common ragweed, and purslane.
- Non-BMR products have been bred for high biomass production, not digestibility (as most BMR-6 forages have). Sorghum-sudans will produce more biomass than most other summer cover crops.
- Once established, it will tolerate some drought.
- Its rapid and dense growth habit helps it control weeds, prevent erosion, and improve soil tilth.
- Very useful mid-summer cover to prepare the soil for fall planting.
- Vegetable fields with weed problems can be rotated into a series of short-season covers that include small grains over the winter and spring and sorghum-sudan in the summer. Each cover is incorporated into the soil as a green manure before the next crop is planted.
- Subsoil aerator – Mowing whenever the stalks reach 3-4 feet tall increases the mass up to 8 times the extent of unmowed stalks, and forces the roots to penetrate deeper into the soil.
- After mowing, regrowth will occur with increasing tillering until frost, with up to six new, thicker stalks per plant.
- Sorghum-sudans fight nematodes and are not a host crop for many pests and diseases that affect other crops. Planting AS 5201 is a great help in the rotation to break up insect and disease cycles.

## Braco White Mustard

*Brassica hirta*

See under Late Summer and Early Fall-Planted Cover Crops, p. 66.

## Brown Top Millet

*Urochloa ramosa*

**Best Locations:** Georgia to Maine.

**Planting Windows:** Late spring or early summer, after soils are 65 degrees and rising. Same planting window as sorghum-sudan; approximately 60 day growth period that is flexible throughout the summer. In the South, may be planted as late as August.

**Seeding Rate:** 10-20 lbs/A.

Depth: Up to ½"

**What to Know**

- Excellent soil builder. Tolerates acidic soils while adding organic matter.
- Rapid growth suppresses weeds and provides summer groundcover.

- Good biomass production in hot and dry conditions.
- Has been used to suppress root-knot nematode populations in tomato and pepper crops in the Southeast.
- A fast-growing catch crop to retain nutrients in a warm-season gap in the rotation.
- Flexible 60-day growing window comparable to sorghum-sudan; easy to double- or triple-crop with cool season crops or other summer annuals, depending on length of growing season in your region.
- Useful as a cover crop in vegetable and forage rotations; for conservation; and wildlife refuges or bird sanctuaries. Prolific seed producer that attracts turkeys, pheasants, and other wild game.
- Can be used for hay or pasture; one cutting is possible.
- Smaller stems and leafier biomass than forage sorghum, sorghum-sudan, and sudangrass hybrids, but lower dry matter production. Reaches 2-5 feet in height.

## Buckwheat

(*Fagopyrum esculentum*)

**Best Locations:** Georgia to Maine.

**Planting Windows:** Plant in late spring after all danger of frost has passed (about mid-May in central PA and further south, and late May in northern PA and further north).

**Seeding rate:** Drill 50-60 lbs/A, seeding depth 1/2" to 1 1/2" deep. (In drier soil conditions, you may need to drill deeper to plant into moisture.

For quicker canopy development, seed up to 80 lbs/A.

Broadcast: Up to 100 lbs/A for a fast-growing smother crop.

**In rotation:** Don't plant buckwheat after using these **herbicides** on the season's first crop: Atrazine, Pursuit (imazethapyr), Sandea and Permit (halosulfuron) and Reflex (fomesafen).

There are no carryover problems with these chemicals: Basagren (bentazon), Command (clomazone), Dual-Magnum (S-metolachlor), Eptam (EPTC), Prowl (pendimethalin), Raptor (imazamox), Roundup (glyphosate), Sencor (metribuzin), and Treflan (trifluralin).

Buckwheat can be sown after vegetables or other crops any time from early June through mid-August (soil temperatures should be at least 65 degrees).

**What to Know**

- Wide leaves and quick growth shades out weeds and improves soil conditions.
- A quick cover – blooms and reaches maturity in just 70 to 90 days.
- Used to suppress summer annual weeds for over 400 years in the Northeast.
- Buckwheat extracts phosphorus from the soil and makes it more available to the following crop.

- Use as a companion or nurse crop for late summer sown forages such as alfalfa or alfalfa-grass mixtures. Cut back buckwheat rate to a third or less. Rapid buckwheat establishment suppresses summer annual weeds as the forage gets established, and mowing the buckwheat or leaving it to kill with the frost creates a weed suppressing residue into the winter.
- Buckwheat fits nicely in a 6-7 week window in the rotation to suppress weeds and improve soil; works well after spring vegetables are harvested and before a fall crop.
- Can be used to bring idle land back into production.
- A good cover crop to prepare for strawberries – grow for a full growing season in beds before strawberries.
- Perennial weeds, especially quack grass, are weakened by mid-summer tillage and recover poorly in a stand of buckwheat.
- The blossoms attract a variety of beneficial insects that attack or parasitize aphids, mites, and other pests.
- Buckwheat's flowering may start within three weeks of planting and continue for up to 10 weeks.
- Does well on poor soil and improves soil quality.
- Buckwheat's abundant fine roots leave the soil loose and friable.
- Biomass is very succulent and living buckwheat is easy to no-till plant into.
- Although buckwheat can be used as an emergency forage, it is not ideal because of its high moisture content and relatively low dry matter production and nutritional value.

## Cowpeas, 'Iron Clay'

*Vigna unguiculata*

**Best Locations:** Georgia to Maine.

**Planting Windows:** Late spring or early summer. Soil temperatures should be 65 degrees F and rising.

**Seeding rate:** 40-60 lbs/A (70-90 lbs/A in northern areas or cooler, drier soils). Drill 1 ½" to 2 ¼" deep.

**Note:** Must be inoculated with N-Dure Peanut Inoculant for best production and nitrogen fixation.

**Cowpeas work well in many summer mixes, such as this one with BMR grazing corn**

### What to Know

- Warm season legume cover crop to fix nitrogen or use as a high-protein forage.
- Commonly used in summer cover crop mixes with other warm season annuals like buckwheat, sunn hemp, sorghum-sudan, or BMR grazing corn. Viney growth habit forms thick biomass that also grows well in combination with more erect species. One of the few warm-season annual legumes available.
- Dense growth suppresses weeds.

- Excellent drought resistance, tolerant of a wide range of soils, including low-fertility and light, sandy, well-drained soil. Does not do well on excessively wet soil.
- Blooms attract beneficial insects that prey on pests.
- Nitrogen credits will be maximized if turned under at flowering. Flowers in approximately 48-52 days.
- Seed pods mature in approximately 100 days; beans can be used for human consumption (also known as black-eyed peas).
- A novel species in many rotations that helps break up existing pest and disease cycles.

## Hubam Annual White Sweetclover

*Melilotus alba*

A summer legume soil builder and bee forage, not recommended for livestock forage.

**Best locations:** Georgia to Maine

**Planting windows:** Frost seeding in late winter, spring seeding in early spring through July. With a summer planting, it will bloom until frost. Staggered sequential planting dates can be used to ensure continuous nectar flow throughout the summer and fall. **However, later plantings are less successful with limited moisture.**

For successful overwintering, plant no later than late summer (mid-August to early September in the mid-Atlantic region), or 5-6 weeks before the first killing frost. Sweetclover grows very slowly for the first 60 days, and a timely planting is critical for growing enough root biomass for winter survival – and blossoms early in the spring.

**Seeding rate:** Drill **12 to 15 lbs/acre**, seeding depth **1/4" to 1/2"** deep, but not deeper than 1/2". **Broadcast: 20 to 25 lbs/acre.** Seed can be broadcasted on double disked ground and packed for successful germination.

**Frost seeding:** 20 to 30 lbs/acre in February/Late winter.

Can also be over-seeded into corn at 6" to 8" tall and used in interseeding mixes.

In vegetable rotations it can be seeded in between rows of brassica crops or squash.

**Must be inoculated with sweetclover type inoculant.**

### What to Know

*Pollinator Benefits*

- Attracts honeybees and many other beneficial insects, such as Tachinid flies and other large predatory wasps.
- High nectar producer. Once it begins flowering, it will flower for about two months, because of the sheer number of flowers (up to about 1500 flowers on a single plant) and the irregularity of bloom.
- Produces nectar from morning into late afternoon during summer months. This is a longer nectar flow than other summer annual nectar producers, such as buckwheat, which will shut down their nectar production in the afternoon.
- Both pollinator and soil improvement attributes.
- Grow in riparian buffers to enhance farm-scaping, where it may re-seed itself for long-

term growth as a pollinator.

*Soil Health & Fertility Benefits*

- If left to grow through the summer, the strong tap roots grow down anywhere from 25 to 95 inches, helping to alleviate clay hard-pans, open up heavy soils, and sequester carbon at deeper soil levels. These deep roots also mine and bring up nutrients that have leached down deep.
- After about a month of top growth, the plant starts to put its energy into growing deeper roots, which will eventually supply moisture and essential nutrients to help the steady flow of nectar during flower bloom.
- Tolerates variable soils – can be grown on clay soils or lighter sandy soils.
- Tolerates wet soil and salinity.
- Root exudates have the ability to make insoluble forms of potassium and phosphorous available for the plant and for plants grown in subsequent rotation.
- This crop is a strong nitrogen fixer and should be considered a soil health builder (enhancing soil life) as well as a soil fertility booster.
- Helps to recycle nutrients and open up no-till soils - roots create paths for water infiltration.
- Heat tolerant annual crop, will go to seed in the first year if planted early in spring.
- Tolerant of frost and cold temperatures.
- Tall, erect (decumbent), stemmy growth, not considered best as a forage, but excellent for biomass production to improve soil organic matter.
- Should not be considered as a livestock feed in straight stands, because the crop contains coumarin, toxic to livestock.

## Sunn Hemp

*Crotolaria juncea L.*

A tall, competitive, fibrous legume native to the tropics.

**Best locations:** Deep South to Mid-Atlantic.

**Planting Windows:** Late spring to early summer. Needs 8-12 weeks of hot weather for optimal nitrogen production and growth.

**Seeding rate:** 20-40 lbs/A. Large seed box required. Depth: ½" to 1".

**Note:** Must be inoculated with **Peanut Inoculant** for best production and nitrogen fixation.

**What to Know:**

- Grows well in low fertility, sandy soils.
- High biomass production within 8 weeks, and superior weed suppression. Plants often reach 6 feet in height.
- Works well in summer annual mixes, but high lignin content makes it less than ideal for forage. (Sunn Hemp is often grown in tropical regions as a fiber crop.)
- Builds organic matter and sequesters carbon.
- Good break crop – resistant to root-knot nematode.
- Long taproot with many lateral branches.
- It should only be grown if it can be easily terminated with available equipment. Best mowed with flail

mower or chopper and left as residue or incorporated as a green manure. (Not as suitable in small-scale garden situations.)

- Can be grown after early season vegetables, tobacco, or small grains. In the South, can fit into the rotation after early corn and before a winter crop. Best to follow with a nitrogen feeder like a small grain.
- Grown as a full-season crop in Hawaii and other tropical regions.
- Can produce 120-140 lbs of nitrogen per acre if grown to flowering.

**Note:** Must be inoculated with N-Dure Peanut Inoculant for best production and nitrogen fixation of legume.

## Mixes: Summer Annuals

### *Ray's Crazy Summer Mix*

**Best Locations:** Deep South through Pennsylvania

**Planting Windows:** Late spring or early summer. Soil temperatures should be 65 degrees F and rising.

**Seeding Rate:** 40-60 lbs/A, ½ - 1 inch depth

**Product Formula:** Cowpea (*Vigna unguiculata)*, AS 6501 and AS 6401 Sorghum-sudan (*Sorghum bicolor x S. bicolor var. Sudanese*), Daikon radish (*Raphanus sativus var. Longipinnatus*), Hybrid Pearl Millet (*Pennisetum glaucum*), T-Raptor Hybrid Brassica, Peredovik Sunflower (*Helianthus annuus*)

**What to Know:**

- Seven summer annual species, including a variety of drought- and heat-tolerant species - cowpeas, two sorghum-sudans, pearl millet, radish, forage brassica and sunflower.
- Works as a short-term cover crop or a soil-building transition crop to renovate depleted soils.
- Can be grazed
- Contains several blooming species that attract beneficial insects.
- Beneficial for both no-till and conventional-till operations.
- Excellent green manure crop to plow down before cool season vegetables.
- Soil building warm season grasses like sorghum-sudan and millet are complemented by cowpea, a nitrogen-fixing legume, brassicas for nutrient-scavenging and broadleaf weed control, and sunflower to attract beneficial insects and birds.
- Good summer break crop before reseeding pastures.

### *Summer Solar Mix*

**Planting windows:** June- July - August, depending on region, temperature, and soil moisture (use in early August as a quick growing, shorter-lived break crop)

**Seeding Rate:** 50 to 70 lbs/acre (higher seeding rates accomplish quicker weed smothering, biomass production and nutrient recycling). It's best to drill the mix, but can be broadcast on well-worked ground and packed in to cover the seed well. 50-70 lbs/A is recommended, but use higher seeding rates as a fast shorter-season summer smother crop, if you plan to rotate out sooner.

**Depth:** 1/2" to 3/4"

**Product Formula:** Cowpeas (*Vigna unguiculata*), Buckwheat (*Fagopyrum esculentum*), Sunn Hemp (*Crotolaria juncea L.*), Sunflower (*Helianthus annuus*)

**What to Know:**

- Cover Crop mix with flowering species that attract pollinators and many other beneficial insects
- Summer soil health builder that works well in rotation before fall planted crops, such as garlic or small grains (wheat, barley, triticale, winter spelt or winter cereal rye) or in a shorter rotation before late summer planted vegetable crops.
- Broadleaves suppress weeds early on
- Summer nutrient cycling—crops cycle nutrients during the summer months, and root exudates also make nutrients that are tied up in the soil more available for the next crop in rotation.

**Summer Solar Mix 12 days after planting. Its weed-suppressing canopy is already closed.**

## Late Summer and Early Fall Planted Cover Crops

### Annual Ryegrass

*Lolium multiflorum*

**Best locations:** Georgia to Maine

**Planting window:** Best in the early fall. Annual ryegrass needs about 60 days of growth in the fall before the first killing frost to get established. Snow cover over winter, as well as pairing with a small grain such a triticale, improve winter survival in northern regions.

In the Northeast, mid-August to the end of September.

Central PA and north: Plant by the middle of September.

Annual ryegrass growing in fall after being interseeded in corn

Mid-Atlantic and South: Plant by the second week of October.

Seeding in August or early September is critical if it will be used for fall forage.

**Seeding rate:** 20 lbs/A. Can be drilled ¼" – ½" deep, conventional drill or no-till drill. Use main box.

- 35 lbs/A if aerial seeded or broadcast.
- Drill setting for annual ryegrass at 20 lbs/A is the equivalent drill setting for tall fescue at 15 lbs/ A.

**What to Know**

- Deep growing roots break up natural hardpans (fragipans) and man-made plow pans or compacted layers. Root biomass also adds organic matter to soil, sequestering carbon.
- Good cover crop for transition to continuous no-till.
- Good cover crop to break up a corn-soybean rotation. Roots introduce diversity and reach 3-4 feet deep between planting time and the following spring.
- Biological activity of roots makes phosphorus more available.
- Recycles nutrients after manure application, preventing nutrient losses.
- Ground cover prevents erosion after corn silage, wheat, or vegetables.
- Reduces soybean cyst nematode through rotation effect
- Extensive root network makes channels in soil for water infiltration and subsequent deeper crop root growth.

## Braco White Mustard

*Brassica hirta*

**Best Locations:** Georgia to Maine

**Planting Window:** Spring or early fall. May flower in fall if planted too early; best to plant in early to mid-September in the Mid-Atlantic, or approximately barley planting dates.

**Seeding rate:** 8-10 lbs/A. Can be drilled or broadcast up to ½" depth.

Can be seeded in combination with a small grain and/or legume, such as triticale, rye, or hairy vetch.

White mustard can be used in vineyards, annual crop rotations, or vegetable rotations. A natural nematode suppressant, Braco both interferes with completion of the feeding nematode larvae lifecycle and acts as a natural bio-fumigant when turned under into the soil just before or at flowering.

**What to Know**

- Suppresses nematodes, other soil-borne organisms and weed seed germination.
- Rapid growth suppresses weeds.
- Increases soil tilth and soil organic matter – mustard tap roots grow to the depth of 1 to 3 feet.
- Produces a large amount of high-protein green material that can be grazed or plowed down to recycle soil N for the next crop.

- Flowers attract honeybees and hover flies (*Syrphidae*). Hover fly larvae are predators of soft-bodied insects like aphids, scale insects, thrips, and caterpillars.
- White mustard winterkills in colder climates, leaving a dead residue that makes for easy no-till planting in early spring.
- Quick spring cover crop. Can be frost-seeded in late winter in corn stubble before planting soybeans; incorporate and kill after flowering. Works well before summer vegetables, such as tomatoes, peppers, sweet corn. Do not use in rotation before other brassicas.
- Use for disease control after onions, lettuce, or garlic.
- Suppresses verticillium wilt in potatoes and reduces weeds in the following crop.

**Planting White Mustard for Biofumigation**

- Allow 60-70 days of growth before cutting.
- Flail mow or chop to reduce particle size.
- Incorporate plant material into the soil with a disk 5-6 inches deep.

## Common Medium Red Clover

*Trifolium Pratense*

**Planting Windows**

- Frost seeded in late winter (when ground is frozen overnight but thaws during the day).
- Early spring (March-April) – seed with a small grain like oats or spring barley.
- Summer – overseeded/broadcast into standing corn at last cultivation (Check herbicide labels – should be at least 6-7 weeks after application of pre-emergent herbicides such as atrazine).
- Overseeded/aerial seeded into soybeans at leaf yellowing or prior to leaf drop.
- Late summer planted with oats or forage grasses.

**Seeding rate:**

Drilled: 15-20 lbs/A, ¼" to ½" deep

Drilled with a grass: 8-10 lbs/A

Broadcast: 15-20 lbs/A

Frost-seeding into a grass: 10-12 lbs/A

**Inoculate with Clover-type inoculant for best performance.**

**What to Know**

- Red clover can be easily frost-seeded into thin pastures and small grain crops with bare ground exposed. It begins growing under the canopy of the small grain, and can be cut for hay or grazed.

- Can be turned under in fall for fertility for fall-planted vegetables, or left over the winter for a spring plow-down.
- If frost-seeded, provides soil cover and nitrogen after the small grain harvest.
- In livestock systems, can be used for hay or grazing.
- In vegetable rotations, strips can be managed for long-term cover crop use or plowed down as a green manure at various points throughout the year.
- Excellent nitrogen source; fixes more N the longer it is left to grow.

- Red clover will grow well in the cooler, moist conditions of spring and fall and slow down over the summer months.
- Red clover flowers attract beneficial insects such as honey bees, tachinid flies, and large predatory wasps.
- Can be no-till drilled into thinning pastures to build up legume population.
- Can be drilled in late summer after sorghum or sorghum-sudan comes off.

## Crimson Clover

*Trifolium incarnatum*

**Best locations:** In the Northeast, Harrisburg, PA and south. North of this, crimson clover does not **consistently** overwinter. The exception is the Finger Lakes region of New York and some other New England coastal areas that get buffered by lake or ocean effect. Aside from these exceptions, crimson clover is

not recommended as a winter annual for these northern locations, but it can be spring seeded as a summer annual.

**Planting window:** Seed 6-8 weeks before the first killing frost, or in the spring after all danger of frost is passed. If spring planted, it will bloom in the same year and will not overwinter.

Zone 7: August 20 – October 1 or the first opportunity in the spring.

Zone 6: August 10 – September 20 or the first opportunity in the spring.

Zone 5: Spring plant.

Zone 4: Spring plant.

**Seeding rate:** 15-20 lbs/A drilled, 22-30 lbs/A broadcast. When planted with another crop as a companion, lower the seeding rate to 10-14 lbs/A.

It can be broadcast and rolled or drilled into a firm seedbed.

Like other legumes, crimson clover is a good nitrogen producer. It can be terminated before summer annual planting with herbicides or moldboard plowing.

Note: Crimson clover seed should be inoculated with "crimson clover" type inoculant for best growth and nitrogen fixation.

There are two major types of crimson clover available commercially – hard seeded and soft seeded. The hard seeded type contains a higher percentage of hard seed, which delays germination until fall, when conditions are favorable for growth. They are also referred to as "reseeding types". These varieties tend to germinate in the fall if allowed to set seed in the late spring.

When planted in the fall, crimson clover will grow as a winter annual and will flower early to mid-May in the northeast.

When planted in the spring, crimson clover will grow in an annual habit, flowering in 70-90 days.

**Nitrogen:** Fall-planted crimson clover can fix 50-80 lbs of N by mid-April. This nitrogen is primarily in the above-ground growth. Approximately 50 percent, or 25-40 lbs N per acre, is available for the following crop in the first year.

If the crimson clover is left to grow until June, 140-260 lbs/A of N can be accumulated with about 70-130 lbs becoming available in the first year. Spring growing conditions will affect the growth of crimson clover and have influence on the amount of biomass and nitrogen produced.

**What to Know**

- Use as a cover crop or green manure.
- Overseed into small grains and other vegetable crops.
- Mix with grasses and small grains as a hay or forage.
- Can be spring seeded for early season weed control and nitrogen.
- Roll down or spray at full bloom to kill and use as a nitrogen-rich no-till mulch.
- Make use of crimson clover's shade tolerance – use it in orchard systems. The clover can be disked into the soil as a green manure. Reseeding varieties can reestablish every fall.
- For winter cover use, can be overseeded in summer or fall row crops in August or September.
- In a corn-soybean rotation (for warmer areas of the Northeast and Mid-Atlantic), crimson clover can be aerial seeded into soybeans before leaf drop, as leaves start to yellow. It overwinters after soybean harvest and provides nitrogen for the following corn crop.
- Grows well under cool, humid conditions, forming a quick groundcover that competes well with weeds.
- Tolerates many soil types and can yield up to 200 lbs/A of N in its biomass, although 70-130 lbs is more common.
- As a forage, vegetative crimson is very palatable and rarely causes bloat. It can be kept vegetative through the summer with repeated mowing, but growth declines in hot weather. It will not regrow if cut or grazed after flowering begins.

## Daikon Radish

*Raphanus sativus*

**Best Locations:**
Georgia to Maine

**Planting Windows:**

Early spring: Before a summer annual like sorghum-sudan. To prevent it from becoming a weed, kill the crop at or before flowering to prevent it from going to seed.

Late summer: needs plenty of time to grow before frost; will kill when temperatures reach low 20s.

**Seeding rate:** 14 lbs/A, best drilled in rows 6-8 inches apart. Plant ¼ - ½" deep.

Can also be broadcast into tilled soil and cultipacked or lightly harrowed less than 1 inch deep. Can be no-till planted into a grass sod that has been grazed or mowed very close or suppressed with herbicides.

Avoid planting in water-logged areas. The radishes grow rapidly and establish quickly in cool weather. They grow extremely large roots. Lower seeding rates/lower populations produces thicker roots; higher rates produce thinner roots from more crowding. Roots grow deep and are useful for improving tilth and reducing nitrate loss.

**What to Know**

- **Weed suppression:** highly competitive with weeds and other companion crops. If planted with small grain cover crops, works best every 3-4 rows with the small grain in the rows between. Baffles are needed in the drill to accomplish this.
- If spring planted, strongly suppresses weeds in early spring before soil disturbance.
- Thick taproot "biodrills" by loosening compacted soil and improving soil physical characteristics. A thinner extension of the taproot can penetrate deeper layers of soil compaction. This is one of the best covers for penetrating plow pans and fragipans.
- **Bio-fumigant/"break crop":** If you're seeking a bio-fumigation effect to disrupt pest and disease cycles typical of grass-legume rotations, consider incorporating or timing winterkill for when plants are about two months old. If the residues are turned under and covered with plastic, this effect is enhanced. Works well before potatoes in rotation.
- **No-till mulch:** Leaves a protective winter-killed mulch. The residue can be easily worked in in the spring or no-till planted into. Often leaves an almost weed-free field for early spring planting, along with channels where radish root tissue decomposed, aerating the ground and helping soil warm up and dry out faster in the spring.
- **Catch crop:** Scavenges residual soil nitrate-N after previous cash crop. Radishes are efficient nitrogen, phosphorus, and calcium feeders; they will catch and bioaccumulate these nutrients in the soil.
- **Forage:** Daikon radishes make excellent quality, highly digestible forage and can be grazed or harvested as green chop for feeding. Their fiber content is quite low and the protein is high, so to avoid bloat and other livestock problems, feed only up to 50-75% of the diet and supplement with grass pasture or dry hay.
- Edible for human consumption; roots are edible raw or cooked, leaves edible cooked.

### Hairy Vetch "VNS" (Variety not stated)

*Vicia villosa*

'Purple Bounty' and 'Purple Prosperity' are recent USDA variety releases that have been selected for winter hardiness in northern climates and for earlier bloom.

**Planting Windows:**

**Option 1:** Fall planting. Must be planted 30-40 days before the first killing frost. Late summer to Sept 20th in Southeastern PA and further south, or before mid-September in central PA and north.

Zone 7: August 15 – October 10

Zone 6: August 10 – September 20

Zone 5: August 1 – September 10

Zone 4: July 15 – August 20

**Option 2:** Planting too late in the fall leaves the vetch short of enough growth to overwinter. If the optimal fall window is missed, hairy vetch can be **dormant-seeded** just before the ground freezes (to germinate and grow in early spring) or it can be spring seeded as early as you can get in the field. Dormant and spring seeding won't provide the benefits of a winter cover crop, nor will it grow as much biomass as a fall seeding. This option is best as a green manure before summer annual crops or later planted summer vegetables such as tomatoes, sweet corn, or peppers, but not preceding early spring seeded vegetable or agronomic crops. An early spring planting can be mixed with oats and cut as a forage, then allowed to regrow for fertility for summer planted sorghum-sudan. Hairy vetch also pairs well with other small grains, such as rye, triticale, and winter barley. Rye is the most common of these combinations.

**Seeding rate:**

Straight stand, PA and north: 25-30 lbs/A.
Southern regions: 15-25 lbs/A.

In mixes: 15-20 lbs/A.

Drilling is best, but can also be broadcast and covered with a roller or harrow. The seed should be ½" to 1" deep.

**Hairy vetch should be inoculated for best performance with nitrogen-fixing Pea-Vetch inoculant.**

**What to Know**

- If planted in the fall, hairy vetch starts growing, then becomes dormant over winter. As weather warms up and days get longer, it puts on quick, abundant growth and fixes large quantities of nitrogen.
- Conventional farmers can benefit too – the nitrogen fixed by the hairy vetch can reduce their fertilizer expenses by a third to a half.
- **Nitrogen:** Fall-planted hairy vetch can fix and accumulate 80-130 lbs/A of nitrogen by mid-April, most of which is in above-ground growth. **Approximately 50 percent of that amount, or 40-65 lbs N/Acre is available for the following crop in the first year.**
    - If the vetch is left to grow to full bloom – usually into June – then 150 to 250 lbs/A of N is accumulated with approximately 75-125 lbs nitrogen/A becoming available the first year.

- Spring growing conditions, especially temperature and moisture, affect growth and biomass production – which affects nitrogen production.
- Like other cover crops, reduces pesticide loss and soil erosion by runoff.
- On an organic farm, meets cover crop requirement as well as a primary source of on-farm grown nitrogen.
- In the spring, vetch can be tilled in as a green manure for best nitrogen release.
- Can also be rolled down into a weed suppressing mat for organic no-till, ¾" – 1 ½" thick

### Triticale

*X Triticosecale*

**Best Locations:** Georgia to Maine

**Planting Window:** Early to mid-fall.

Southeastern PA and south: Early fall to October 20.

Central PA and North: Late August to mid September.

No-till triticale after corn

**Seeding rate:** 80-100 lbs/A.

If mixed with legumes, such as crimson clover or hairy vetch, cut back triticale to 60 lbs/A.

For southern locations, can be mixed with 10 lbs/A crimson clover. In northern locations, mix with 15 lbs/A hairy vetch.

Depth: ½- ¾ inch.

**What to Know:**

- Provides excellent soil cover to prevent erosion. Fibrous root system improves soil tilth.
- Winter hardy – grows longer in the fall and resumes growth earlier in the spring than many other small grains.
- Hardiness and erect growth make it an excellent companion or nurse crop.
- Catch crop to prevent leaching of soil nitrogen.
- Can be plowed under in the spring as a green manure at any point, but best organic matter and biomass production if left to grow until close to heading.
- Grow in strips between vegetable rows as a cover and windbreak. If grown in between black plastic rows, mowed clippings can cover black plastic and protect it against UV degradation. If left to grow to anthesis (flowering) can be mowed or rolled to create a weed-suppressing mat of residue for no-till soybeans or pumpkins.
- High biomass production with long lasting residue for conservation tillage systems.
- Can also be mixed with crimson clover or hairy vetch for a rolling or mulching scenario, to supply some nitrogen.
- Good break crop for vegetable rotations.
- Can be broadcast under late-growing fall vegetables, such as cauliflower or broccoli.

- High quality forage if taken at flag leaf stage – either grazed or harvested as baleage.

## Winter Cereal Rye

*Secale cereal*

**Best locations:** Georgia to Maine

**Planting dates:**

Zone 8 and south: plant by early December

Zone 7: Early September to mid-November

Zone 6: Late August to late October

Zone 5: Mid-August to mid-October

Zone 4: mid-August to late September

Zone 3: mid-August to mid-September

Rye is the gold standard of cold-climate cover crops

Of all the small grains, cereal rye has the lowest seed germination temperature and thus can be seeded later in the fall. For this reason, cereal rye offers the most flexibility in rotation systems. Rye is the most winter hardy of all the small cereal grains, its cold tolerance exceeding even that of the hardiest winter wheats. Rye grows taller and, as a result, produces more biomass than wheat or barley.

If sown late, it's important to ensure proper depth and seed-to-soil contact for an adequate stand. Also remember that later plantings (past recommended dates) compromise fall tillering, so high seeding rates to compensate for this become especially important.

**Seeding rate:** 60-200 lbs/A.

As a green manure, 90-160 lbs/A. If seeded late, increase rate up to 300 lbs/A to provide adequate cover.

Rye at flowering stage

If the crop is intended as a rolled-down no-till mulch, seed at 196-224 lbs/A.

In mixtures with legumes, lower seeding rate to 50-60 lbs/A. 56 lbs/A with clover; 60 lbs/A with hairy vetch.

Drill or no-till drill ½" to ¾" deep.

Cereal rye can be aerial seeded or broadcast into tasseling and silking corn.

As a green manure, till under when rye reaches 8 inches tall.

Rye can be killed by mowing or rolling if plants have initiated flowering. An early fall planting leads to an earlier flowering date in the spring.

**In rotation:** Crop suppression has been observed following incorporated rye residue, which may be a result of nitrogen tie-up or allelopathic chemicals in rye. This effect can be minimized by turning the rye under 2-3 weeks before planting the following crop. Incorporating rye while it is still in the vegetative stage (before it reaches 18 inches tall) also helps reduce N tie-up, since it is lower in lignin before maturity and will break down faster.

**What to Know**

- Best cover crop fit for a full-season cropping system to still get germination and growth in the fall.
- Its winter hardiness allows it to grow later in the fall and resume growth earlier in the spring.
- Rapid growth outcompetes winter annual weeds, and its allelopathy provides some weed control for summer weeds.
- Hardiness and erect stature make it a good companion crop or nurse crop.
- Fibrous root system helps build soil tilth and organic matter, and slow erosion.
- Catch crop used to prevent leaching of excess soil nitrogen.
- Plow under as a green manure in the spring while still vegetative.
- In vegetable systems: can be grown in between rows as a windbreak, or mown so mulch falls over black plastic to protect it from UV degradation. It can also be mowed or rolled for walkways.
- High biomass production means long-lasting residue cover for conservation tillage systems.
- Can be mixed with crimson clover or hairy vetch to supply nitrogen. This can be used for a rolled down mulch mat for no-till planting.
- Green straw can be used for horse bedding.
- Use as a break crop in vegetable systems.
- Can be broadcast underneath late-growing fall vegetable crops, such as cauliflower and broccoli.
- Can be used as forage (either grazing or baleage) if taken at flag leaf stage.

## Mixes: Late Summer and Early Fall

### *3-Way Clover Mix*

*Red Clover (Trifolium pretense), Yellow Blossom Sweetclover (Melilotus officinalis), Ladino White Clover (Trifolium repens)*

**Planting Windows:**

- Late winter – frost-seeded into winter annual small grains (wheat, barley, rye, triticale, or spelt)

**Three-Way Clover Mix interseeded in oats**

- Early spring (March-April) – Seeded along with spring oats or another small grain
- Mid-summer – Overseeded/aerial seeded into corn at last cultivation or into soybeans at leaf yellowing, prior to leaf drop. (Check herbicide labels – should be at least 6-7 weeks after application of pre-emergent herbicides such as atrazine.)
- Late summer – planting with oats or pasture/forage grasses.

**Product Formula:**

Red clover, yellow blossom sweetclover, ladino white clover

Red clover and white clover use **Clover type inoculant**; yellow blossom sweetclover uses **Alfalfa/Sweetclover type inoculant**.

**Seeding Rate:**

Drill this mix at 10-15 lbs/A, 1/4"- 1/2" deep
Broadcast at 15-20 lbs/A
Drill with small grains 10-12 lbs/A

Depth: Surface to 1/2"
Fine, firm seedbed recommended

This is a versatile mix that can be frost seeded, spring seeded, fall-seeded, or broadcast/aerial seeded at corn lay-by or just prior to soybean leaf drop. The diversity helps the mix thrive throughout the year, with the red and white clovers growing best in cool spring and fall weather, and the yellow blossom sweetclover doing well in the summer and dry spells.

**What to Know**

- Can be frost-seeded easily, begins growing with the small grain and continues as a cover crop after harvest that can keep soil covered for the rest of the year. Can be cut or grazed in livestock systems, or turned under as a green manure.
- Can be turned under in the fall or spring as a nitrogen-rich green manure for vegetables or agronomic crops.
- In vegetable rotations, can be managed in long-term strips for soil cover and nitrogen fixation and plowed down at various points in the year as needed.
- Abundant biomass and high nitrogen producer.
- Yellow blossom sweetclover has more warm weather growth potential than any other legume and is more drought-tolerant than most other cover crops, while red and white clover fulfill their potential in the cooler months.
- Builds soil structure and fights compaction with root growth. Tap roots can grow over two feet deep, with branches that may grow five feet long and break up the subsoil.
- Blooms attract a variety of beneficial insects.
- The diversity makes it ideal in a range of soil types.
- Can be no-tilled drilled into a thinning pasture to boost the legume population.
- Can be drilled after sorghum or sorghum-sudan comes off.

***Broadcaster Mix***

*Crimson clover (trifolium incarnatum), Annual ryegrass (Lolium multiflorum), Medium red clover (trifolium pretense), Daikon radish (Raphanus sativus), and Yellow Blossom Sweetclover (Melilotus officinalis)*

**Best locations:** Best adapted to southern PA and south, because of lower winter-hardiness of crimson clover.

**Planting windows:**

Overseed/broadcast into corn at last cultivation, or aerial seeded into soybeans at leaf yellowing, prior to leaf drop.

Late summer after vegetable production. Early seeding is especially important in northern areas so that clovers can get established before the frost.

**Seeding rate:**

Drilled: 18-25 lbs/A
Broadcast: 25-30 lbs/A
Drilled with small grains: 10-15 lbs/A
Drilled for thick forage: 30-35 lbs/A

Surface to ½" deep

**Product Formula:**
Annual Ryegrass, Crimson Clover, Common Medium Red Clover, Daikon Radish, Yellow Blossom Sweetclover

**What to Know**

- Best for over-seeding, broadcasting, aerial seeding, or used with a high-boy seeder into standing corn or soybeans. Can be broadcast after summer vegetable production, packing with roller or harrow to improve stand.
- Adaptable for broadcasting into many soil types.
- Use in continuous no-till rotations to add soil organic matter with deep-growing roots.
- Deep-growing roots of annual ryegrass and Daikon radish scavenge nutrients, aerate subsoil, and break up hardpans. Roots often grow down 3-4 feet by the following spring.
- Crimson clover and annual ryegrass grow quickly for fall cover and overwinter, protecting the other slower-growing species. Daikon radish grows quickly in late summer and fall, uptaking nutrients with its deep taproot, then winterkills and releases nitrogen and other nutrients for the other species from its decomposing tissues.
- This mix is a diverse combination of nitrogen fixers and nitrogen scavengers. Depending on seeding date and growth, 30-100 lbs of N per acre can be recycled or fixed and made available to the following crop.
- Ground cover to prevent erosion right after corn and other summer crops come off.

### *CARGO Mix*

*Crimson Clover (Trifolium incarnatum), Annual Ryegrass (Lolium multiflorum), and Oats (Avena sativa)*

**Best locations:** In the Northeast, Harrisburg, PA and south. North of this, crimson clover does not **consistently** overwinter. The exception is the Finger Lakes region of New York and some other New England coastal areas that get buffered by lake or ocean effect. Aside from these exceptions, crimson clover is not recommended as a winter annual for these northern locations, but it can be spring seeded as a summer annual.

**Planting Window:**

Fall Planting – Seed 6-8 weeks before the first killing frost.

Seed early enough that the crimson clover can get well-established before the first killing frost. Young clover plants are susceptible to frost-heaving, and the oats and annual ryegrass help buffer them from this freezing and thawing.

Zone 6 – August 10-September 20

Zone 7 – August 20-October 1

**Seeding Rate:** 60 lbs/A

Best to drill, ¼" – ½" deep

Can also be broadcast, then covered with roller or harrow.

Note: Crimson clover should be inoculated with 'crimson clover' type inoculant

**Product formula:**

Oats, Annual Ryegrass, and Crimson Clover

**What to Know**

- Used as a grass-legume cover and green manure in regions where the crimson clover will overwinter.
- Good for preventing erosion over the winter and spring.
- Builds soil organic matter and adds nitrogen.
- Nutrient catch crop, nutrient scavenger, and nitrogen fixer.
- Deep roots of annual ryegrass are good for scavenging nitrogen and contributing organic matter to lower levels of soil, helping break up subsoil compaction.
- Weed suppressor.
- Can double as a forage – grazing or wet hay.

### *Ray's Crazy Fall Mix*

**Best Locations:** Georgia to Maine. Note: In the Piedmont and Coastal Plain VA, NC, SC regions, the oats and turnips may not winter kill depending on variety and winter hardiness.

**Planting Windows:** Early fall (about one month before wheat planting dates) or early spring.

**Seeding Rate:** 40-50 lbs/A. Depth: ½" – 1"

**Product formula:** Lynx Winter Pea (*Pisum sativum*), Foragemaker 50 Oats (*Avena sativa)*, Triticale (*X Triticosecale*), Hairy Vetch (*Vicia villosa*), Crimson Clover (*Trifolium incarnatum*), Marshall Ryegrass (*Lolium multiflorum)*, Daikon Radish (*Raphanus sativus*), Barkant Turnips (*Brassica rapa subsp. rapa*)

**What to Know:**

- Versatile cool season mix made up of grasses, legumes, and brassicas that can be used a short-term cover crop

- Soil-building transition crop to renovate depleted soils
- Can be used as a grazing mix
- Contains several blooming species that, if left to grow and flower, will attract beneficial species.
- Beneficial for both no-till and conventional-till soils and consists of all Non-GMO seeds.
- Winter peas, hairy vetch and crimson clover grow through the winter and fix nitrogen. N production will be maximized if the hairy vetch and clover are left to grow to bloom in the spring.
- Oats grow quickly in the fall, providing weed suppression, nutrient uptake, and shelter for the slower-growing species in the mix. The oats winterkill with hard frosts.
- The turnips and radishes also winterkill with a hard frost, but like the oats, grow quickly in the fall, suppressing weeds and scavenging nutrients with their deep tap roots. They also help to break pest cycles. Ryegrass and wheat grow over winter, anchoring and building soil with their dense, fibrous root systems.
- Can be grazed in late fall/early spring. The mix of species will provide an ideal balance of effective fiber and protein, if taken for forage when grasses reach boot stage.
- If more emphasis is placed on the mix being a cover crop, let it grow until the clovers and vetch bloom. For maximum nitrogen production, wait until the legumes flower before grazing or harvesting.

### *Soil Builder Plus*

**Planting Windows:** Early fall (about one month before wheat planting dates) or early spring

**Seeding rate:** 120-140 lbs/A. Depth: ½" – ¾"

Best drilled; can also be broadcast and covered with a roller or harrow.

**Product formula:** Triticale (*X Triticosecale*), Crimson Clover (*Trifolium incarnatum*), Hairy Vetch (*Vicia villosa*), Annual Ryegrass (*Lolium multiflorum)*, Daikon Radish (*Raphanus sativus*).

**What to Know**

- An excellent spring forage and/or overwintering cover crop.
- Clovers and vetch provide protein in a forage application, and triticale and ryegrass contribute effective fiber and bulk. This mix is ideal for a spring grazing or cutting when the triticale reaches flag leaf or boot stage.
- Daikon radish grows quickly in the fall and scavenges nitrogen, holding it in its tissues. The large taproot also breaks through compacted layers of soil. As the radish winter-kills, its decomposing

tissue gradually releases nutrients that were scavenged at deeper levels early in the fall with its rapidly growing tap root. These nutrients (especially nitrogen) may have otherwise been leached. As these nutrients are re-released by the decomposing radish, the slower growing over-wintering grass and legume species in the mix carry them forward to spring.

- The combination of species anchors soil and provides weed suppression with its diverse canopy, also protecting soil from erosion over winter. The mixture of diverse over-wintering root structures also builds soil organic matter and feeds soil microbes, contributing to long-term soil health and fertility.

**Grazing Application** -

- **If late summer planted** (late August or early September in Southeastern PA and to the south). It can be grazed in fall and early winter. In northern locations, earlier planting dates may be needed for this to be successful. The daikon radish leaves provide good grazing at this point, and will winterkill, while the rest of the species in the mix can over-winter and be grazed the following spring.

- **If planted in early spring,** the winter triticale will typically not vernalize, and therefore will not form a viable head. If spring planted, this should also be ready to graze in about 65 to 70 days depending on growing conditions, though yield may not be as high with the crop getting fewer days of growth. This depends heavily on region.

# Perennial/Longer Term Cover Crops

For Vineyards, Orchards, Riparian Buffers, Conservation Areas, Between Vegetable Rows or Around Raised Beds

*Conservation mixes can help stabilize high traffic areas in orchards and vineyards, between permanent raised beds, in berry production and nursery stock areas; as well as in riparian and buffer areas including alleyways and headlands, and other vulnerable or erodible areas. These plantings are often intended to be left for a year or more; once they get well established, they are rugged and can take animal and equipment traffic. The key is that they must be protected until well-established. These are best seeded in the late summer, but the early spring pasture-seeding window can also work.*

*Long-term mixes that contain clovers or other legumes build up soil nitrogen and boost the productivity of grasses in the mix.*

*Many of these mixes can work as forage as well. Depending on the size and layout of the area they may be machine cut and harvested or grazed in a managed grazing scenario. This should be done appropriately and with care, however, since they often contain species that are not optimal for high-producing livestock. As long-term cover crops, depending on how the area is situated, it may be difficult to manage them for harvest at optimum quality (before heading).*

**3-Way Clover:** Year-round soil cover, weed suppressor, and nitrogen-fixer. This is the mix to use if you're rotating strips of vegetables with a cover every year. Ideal growing time is 1-2 years; in this time, the mix builds up soil nitrogen and organic matter, while attracting beneficial insects and pollinators. 3-Way Clover is a versatile mix that can be frost-seeded, spring-seeded, fall-seeded, aerial seeded or broadcast at corn lay-by or just prior to soybean leaf drop. Diversity is important in this mix; the red and white clovers grow in cool spring conditions, while the yellow blossom sweetclover grows well through the summer and during dry spells. This balance of species also helps ensure more continuous bloom throughout the year, attracting honeybees and beneficial insects year-round. When drilled in fall or spring, can be mixed with a small grain or perennial pasture grass.

Seeding rate: 10-15 lbs/A drilled.

Contains: 33% Red Clover, 44% Yellow blossom sweetclover, 23% Ladino white clover.

**Clean and Green:** Can also be used for forage. The uses for Clean & Green are many including: Exercise lots, waterways, filter strips, around farm structures, and cow calf operations. Clean & Green will typically contain two durable endophyte free tall fescue varieties and annual ryegrass to give quick cover while the tall fescue establishes. Seeding rate: 30-70 lbs/A.

Contains: 80% Rugged, endophyte-free tall fescue, 20% Annual ryegrass.

**Creekside:** Useful for wet buffer areas; works best in colder climates.

Forms a good sod to handle traffic, and holds quality well in wet conditions if the mix is to be grazed or cut. Seeding rate: 25 lbs/A.

Contains: 36% Perennial Ryegrass, 34% Meadow Fescue,11% European/Premium Timothy, 10% Kentucky Bluegrass, 5% White Clover, 4% Ladino White Clover.

Photo credit: beesource.com

**Dutch White Clover:** The perfect living mulch. Grows low and slow, with a creeping habit, while fixing nitrogen. It helps provide soil cover and fights compaction in heavy traffic areas like permanent walkways. It is also frequently used in buffer areas or in between vegetable rows. It can be interseeded in a growing crop and will grow slowly without competing with the established crop. Can also be frost-seeded.

Dutch white clover propagates by both seed and creeping stolons. It grows well in cooler and moist conditions, and tolerates wet conditions well.

Avoid following Dutch white clover with other legumes, since it can be a host for root rot diseases like Pythium and Rhizoctonia. Seeding rate: 2-4 lbs/A drilled or broadcast.

**Econo-Graze:** An economical and durable option for conservation or forage. Contains durable endophyte free tall fescue and festulolium, giving it quick cover while the tall fescue establishes. Excellent traffic tolerance. Good for waterways. Seeding rate: 35-40 lbs/A.

Contains: 73% Rugged, endophyte-free tall fescue, 27% Festulolium.

**Equinemaster Paddock:** Innovative formula for exercise paddocks. Specially formulated for excessive utilization areas, Equinemaster Exercise Paddock is made up of grass species and varieties that are very tolerant to the traffic pressure of horses and persist under heavy use. Rapid establishment. Seeding rate: 100 lbs/A.

Contains: 50% Soft Leaf Tall fescue, 35% Kentucky Bluegrass,15% Perennial Ryegrass.

**Greenfast:** A fast starting mix that is of very high quality in a situation where it would be needed for grazing or baleage. The main component, festulolium, is fast starting, high yielding and of excellent forage quality, but short lived (typically three years). Also contains longer lived species. Best used north of the Mason Dixon Line. If not grazed or cut for forage, this mix needs more mowing than low-growing or turf-type mixes. Seeding rate: 30-40 lbs/A.

Contains: 38% Festulolium, 27% Grazing tolerant orchardgrass, 22% Premium perennial ryegrass, 9% Freedom! MR Red Clover, 4% Alice White Clover.

**Horse Supreme:** Horse Supreme was developed as a palatable mixture for continuous or managed horse grazing, which means it stands up well to traffic and animal abuse. The mix will do well under mowing or grazing. Clovers help build soil nitrogen. High productivity during drought.
Seeding rate: 25-30 lbs/A.

Contains: 37% Orchardgrass, 20% Meadow Brome, 20% Diploid Perennial Ryegrass,15% Kentucky Bluegrass, 6% Timothy, 2% White Clover.

**Sale Topper:** An all-grass mix sold primarily for use as dry hay for horses or cows. Can do well to stabilize and provide long-term cover for drier soils. 3-5 year expected lifespan.
Seeding rate: 15-20 lbs/A.

Contains: 80% Late maturing orchardgrass, 20% Premium timothy.

**Wellington Birdsfoot Trefoil:** Long-lived, persistent legume that builds soil nitrogen. Useful for wildlife conservation area or pasture (no threat of bloat as with many other legumes). Birdsfoot trefoil can be seeded in combination with grasses. Yield may reach 4 tons of hay per acre on well-drained soils with plenty of moisture (at least 20 inches/year). It does well on soil with moderate to poor fertility (although plenty of phosphorus is needed), and tolerates a pH range of 5.5-7.5. It's often less productive than alfalfa on deep, fertile, well-drained soils, but tolerates periods of drought. Stems are smaller and less rigid than alfalfa stems, and plants reach a height of 18-20 inches. More palatable than alfalfa, and is recommended as a good alternative in areas that are not suitable for alfalfa production. Seeding rate: 20-25 lbs/A.

## Turf-Type Products for Long-Term Ground Cover

**Balin Kentucky Bluegrass:** Winter-hardy, sod-forming grass that spreads by rhizomes and can tolerate short grazing or cutting. Excellent persistence, but slow establishment. The majority of growth is in the spring and fall. Balin is a variety that is bred for forage quality. Can be seeded in mixtures with other grasses and/or clovers. Seeding rate: 15 lbs/A.

**Companion Mix:** A slow-growing ryegrass/red fescue mix for orchards, vineyards, between vegetable rows, or around buildings or other hard to reach areas, requires less mowing. Shade and wear tolerant.
Seeding rate: 50 lbs/A.


Contains: 80% Perennial Ryegrass, 20% Creeping Red Fescue.

**Sun and Shade:** A multipurpose fine-leaf turf, for areas that are sunny or moderately shaded.

Seeding rate: 175 lbs/A

Contains: Kentucky bluegrass, perennial ryegrass, and fine-leaf fescues.

**Water Saver Pro:** A three-way blend of turf-type tall fescues that are lower-growing and have excellent heat and drought tolerance. This mix gets its name from its exceptionally deep

root system that reduces water needs. Ideal in full sun and partial shade. Traffic tolerance is high. Excellent disease resistance, tolerant of high and low soil pH. The turf is dark green with medium density. This mix has the advantage of less mowing—it is both durable and low-maintenance.
Seeding rate: 300 lbs/A.

## Quick Starters for Temporary Patches

For soil areas that become bare from animal or equipment pressure, or perhaps from erosive wash outs, we recommend using these quick starters to fill in as short-term or temporary patches.

These will be best planted in either early spring or late summer.

**Annual Ryegrasses—** fast starting, winter hardy. Varieties include MO1, Marshall, Kodiak. Seeding rate: 35-45 lbs/A.

**Italian Ryegrasses (biennial)** - Green Spirit Blend, Kingfisher Allegro Brand. Seeding rate: 35-45 lbs/A.

**Perennial Ryegrasses—**BG-24T Blend, BG 34 Blend, Kentaur, Tivoli. Seeding rate: 30-50 lbs/A.

**Festulolium** – Perseus (Italian Ryegrass type) is persistent, has a strong root system, improved winter hardiness, increased summer performance, and high drought tolerance. Perseus is fast-starting and can be mixed with legumes or used as a pure stand, and has good regrowth. Seeding rate: 30-40 lbs/A.

**Red Clover** – Medium Red Clover mixed with any of the above, to include a quick growing legume in with the grass mix. Seeding rate: 6-8 lbs/A in mixes, 20 lbs/A in straight stands.

## Renovating Wooded Areas for Pasture

Wooded ground is typically acidic, so liming as early as possible is recommended. Pelletized lime may be easier to spin on than ground limestone, especially if the ground is littered with lots of stumps and debris. You may be able to drive into the area with a small 4-wheeler and Hurst spinner-spreader on the back to spin on pelletized lime. Or you can walk over it with a body-held spinner, completing sections at a time. It will be critical to get the pH right for both grasses and legumes. Legumes especially need a neutral to slightly acid pH (6.5-6.8) for best rhizobium inoculation.

Letting livestock into the area to trample in the seed may be the best option, since it will be hard to drive a packer in with the presence of stumps.

**Greenfast** - Contains faster establishing perennial ryegrass and festulolium species for soil stabilization, along with some red and white clover, with the orchardgrass being slower to establish but disease resistant. Seeding rate: 30-40 lbs/A.

Contains: 38% Perseus Festulolium, 27% Grazing-tolerant Orchardgrass, 22% Premium Perennial Ryegrass, 9% Freedom! Medium Red Clover, 4% Barblanca Clover

**Grazeall** - Again the perennial ryegrass content is faster starting; Endurance Orchardgrass and HDR Meadow Fescue are a little slower establishing but longer term components. Seeding rate: 25 lbs/A.

Contains: 30% Perennial Ryegrass, 30% HDR Meadow Fescue, 25% Endurance Orchardgrass,

15% Balin Kentucky Bluegrass

**Reed Canarygrass -** An extremely durable grass that tolerates more acidic soil. Slow to start, it is quite persistent once it establishes. Reed canarygrass does best in the long term under closely managed grazing; otherwise, it has the potential to spread and thicken invasively, choking out other species. This will be a good transition crop to help build soil and alleviate weed pressure in an interim year, before being terminated if a more diverse pasture or hay stand is desired. It is resistant to foliar diseases, and the stand spreads and thickens by rhizomes. It is adapted to wet or droughty conditions, so it make a good conservation planting in waterways. When used for forage, it will be quite high-yielding, but quality drops off quickly after heading. Seeding rate: 12-18 lbs/A.

Reed canarygrass used in waterway conservation.

(Photo source: http://www.naturalheritage.state.pa.us/)

**STF 43 Tall Fescue Blend** - Tall fescues are also a little slow to establish, but once they do, they are in it for the long haul. Tall fescues are the best for adapting in slightly acidic soils and can take moisture and drought stress once established, so these would be a longer term hedge in a former woodlot until the pH was brought up closer to 6.5 to 6.8. Using a blend of two of Barenbrug's soft-leaf varieties rather than a straight stand makes this an even more durable mix. Seeding rate: 35-45 lbs/A.

## Putting it all Together: How a Mix is Born

### *4 Rules for Perfect Pairings*

When you make a mix or interseed one crop in another for a "relay effect", you're looking for the most bang for your diversity buck. Taking care to mix a few carefully selected species that are well matched always trumps throwing together a hodgepodge of random selections. The species you choose will depend heavily on your goals for the crop and whether you plan to seed all the species together or at staggered times (i.e. interseeding).

King's AgriSeeds and Southeast AgriSeeds are continually look for ways to make better mixes. Combining products for unusual applications have given us invaluable information that we use for both the commercial mixes that we have available and the carefully formulated custom mixes we make on demand. Here are a few lessons learned over the years -

1. ***Mixing annuals and perennials can be done, but use caution when mixing two species with different growth speeds (and in some cases, similar growth speeds too).*** You probably know that annuals grow faster than perennials, since they accomplish all their vegetative and reproductive growth in one season. Taking advantage of that quality can make good sense, for example, by growing oats or another small grain as a nurse crop for alfalfa.

Interseeding a fall cover crop in standing corn planted in 30-inch rows is another case where these lines are blurred and you can use crop differences to your advantage. This works perfectly since slower-growing crops like perennial clovers and winter annuals are used so they can begin growing without offering too

much competition to the corn. The corn is usually unharmed by this form of competition, precisely because it grows so rapidly in the summer heat and dry spells while the cover crops hang back and wait for the corn to come off and for the arrival of cooler, wetter weather. Broadcaster Mix has proved to be a perfect fit for this scenario; its mix of clovers, annual ryegrass, and Daikon radish each contribute to soil health and start off slowly in the heat of summer

However, planting clovers or another perennial crop in combination with a heat-loving summer grass like millet or sorghum-sudan makes little sense, because these grasses are usually planted in 7 inch rows and would quickly smother the perennial. Plus, their multiple harvests would likely do damage to the intended relay perennial crop.

Likewise, interseeding a crop with TOO similar a lifecycle to corn can present too much competition, such as seeding summer annual Ray's Crazy Mix into corn. Both crops will grow rapidly in the summer heat and compete heavily for moisture and nutrients.

2. ***Know how each species grows and adjust for differences with the right seeding rates.*** Whether your mix will be for a cover crop or a forage, every component will grow a little differently and have different demands. Account for differences in competitiveness and growth habit. Brassicas grow outward in an aggressive, leafy pattern and need to be kept to a low seeding rate in a mix, while many grasses generally grow upward, confined to a small area around their original seeding spot. Combining varying heights and structural growth is a great way to maximize the benefits from diversity, but it also has to be planned in such a way that each species has space and ability to express itself.

It may seem obvious, but seed size also has a big impact on the final mix. Smaller seeds mean more seeds per pound, and a lower seeding rate is needed for those species to be expressed in the mix as much as a larger-seeded crop. Plus, if everything is planted together from the large box of the drill, you have to be able to plant at a seeding depth that will be acceptable for all the seed sizes in the mix. If you can't, you may have to seed smaller-seeded products separately from the small box. (If very small seeded species are planted at the depth needed by larger seeds, they will have poor emergence and there is little point in including them.) For this reason and the limited early vigor of very small-seeded plants, teff is difficult to fit well in a mix because its seed size is so much smaller than most other species.

Think about the most competitive species in the mix. Limiting its seeding rate should be your priority. This could be your oats nurse crop, since oats grow faster than alfalfa and could be overly competitive if the rate is not kept low (about one bu/A, depending on location). It could be a tall species like sunflowers or sunn hemp with more nutrient and water demands, and perhaps some shading. Or it could be a very leafy crop like brassicas, buckwheat or sunflowers that will physically shade out plants in its vicinity that grow the same speed or a little slower. Competition takes the form of both growth to fill physical space and the more subtle "hogging" of water and soil resources.

Some species are more easily outcompeted, while vining crops like cowpeas and hairy vetch adapt and climb other species to find the sun. Balancing these two types will be very important.

3. ***Make sure every species is being used in the correct growth window.*** You may have two components that can be classified in different seasonal windows yet still overlap,

which is fine. Back to the interseeding example, many fall cover crop species are pushed up to fit this June planting date because of the circumstances – they are suppressed a bit, growing in the shade of the corn canopy for most of these extra months until they can take off, and because of that slow initial growth, this doesn't detract from their natural growth cycle.

Then there are other situations where certain components would be completely out of place. Using sorghum-sudan in a fall mix would be a waste, since it will kill off with the first frost (and be toxic to grazing animals at this point). However, summer annuals like this are sometimes used as nurse crops to keep weeds back in winter annuals that grow a little slower in the fall, but again, the rate would have to be kept low.

Most of the time, it's not advisable to combine a summer annual with a winter annual, but cool season fall and spring crops like oats, spring small grains, spring peas, and brassicas can generally cross those lines more readily.

Clover is quite versatile and can be planted at almost any point throughout the year (including late winter frost-seeding), but most cool season perennial grasses and alfalfas must be planted in early spring or late summer for good success. It's often not recommended to try to establish them in the heat of summer regardless of what you plant them with.

Again, nurse crops are common examples, but this is one of the few times you should consider planting an annual with a perennial. In many mixes, where these are combined at normal seeding rates (as opposed to the reduced nurse crop rate), perennials don't have the early vigor to compete with an annual.

4. ***Consider the lifecycle of each species in the mix and the method of harvesting or termination.*** Will they all reach maturity within the same time frame? You may not care as much if you plan to plow the mix under as a green manure, but if you plan to harvest for baleage, you want the correct maturity for every species, and the right moisture level in each species for ensiling. You also won't want one species going to seed as you wait for the others catch up.

If the crop will be grazed or hayed, will every species regrow? If not, you'll have gaps after the first harvest where weeds can invade. If you want primarily a pollinator mix, you want each species to be able to reach bloom within your time constraints, and preferably for the blooms to be staggered enough to lengthen the total period of bloom and create a "relay bloom effect".

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