

# Cover crops on the intensive market farm



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# Cover crops on the intensive market farm

## Introduction

Crops that are grown solely to provide soil cover or for the purposes of increasing soil fertility are referred to as cover crops or green manures. In general, these crops are incorporated into the soil while green or just after flowering. Due to their ability to protect and enhance soils, cover crops are considered a fundamental aspect of any sustainable cropping system. However, the benefits of cover crops extend beyond soil quality. In particular, more and more growers are realizing the insect, disease and weed management benefits of cover crops.

This publication is meant to serve as a practical guide to using cover crops on small- to moderate-size fresh market vegetable operations. Cover crops are especially vital on organic vegetable farms. Organic growers rely on cover crops to build organic matter in the soil, provide nutrients to subsequent cash crops, help reduce weed pressure, and manage other pests. The recommendations in this report are appropriate for a certified organic grower.

## The benefits of cover cropping

Cover crops bring a host of benefits to farms of all types. Due to the intensive nature and high fertility needs of fresh market produce farms, cover crops assume a crucial role in protecting and enhancing soil quality. In fact, they help farmers follow one of the basic tenets of sustainable agriculture: keep the soil covered. Soil quality benefits of cover crops include:

- protecting against soil erosion
- building and maintaining both active and stable organic matter
- improving soil structure and tilth
- improving the capillary action, or upward movement of water, within soils
- increasing the biological activity in soils
- fracturing of hardpan by deeply rooting cover crops
- adding nitrogen to the soil with legumes (peas, clovers, vetch, etc.)
- closing the “nutrient loop” by rotating leguminous and non-leguminous covers, allowing farmers to rely less on purchased fertilizers

Cover crops can also play an extremely important role in managing various kinds of pests. One fundamental way to minimize these challenges is to ensure overall plant and crop health. By improving soil quality and fertility, cover crops contribute to holistic weed, insect and disease management strategies. Cover crops support pest management strategies by:

- smothering or suppressing weeds
- breaking insect and disease cycles



Photo: John Hendrickson

*Cover crops at work: fall-planted rye on the left, spring-planted oats on the right*



Photo: John Hendrickson

*Oats and vetch are a great cover crop combination.*

- providing habitat, pollen and nectar for beneficial insects

Additional benefits of cover crops include:

- providing animal feed
- providing a source of mulch
- adding to farm aesthetics
- balancing the stress of increased production with the satisfaction of soil building

## Cover crop challenges

The benefits of cover crops are clear. However, given the complexity of diversified vegetable rotations and the limitations of time, land and equipment, managing cover crops can be challenging.

One challenge is the relationship between soil building and tillage. Commonly employed implements on many market farms—namely the rototiller, moldboard plow and disc—can damage soil structure. It is easy to overwork the soil, especially when growing on a small scale and relying on a rototiller for field preparation, weed control, incorporation of cover crop seed, or cover crop termination.

Another challenge market growers face is balancing soil building and fertility management with the requirements of succession planting and harvesting. The demands of making a living on the land may not always align with the needs of the soil. Many market growers lack enough land to implement adequate cover crop rotations, particularly longer term rotations involving season-long cover crops. Market growers farming near urban areas with high land prices can feel especially pressured to push the land to produce as much as possible.

Finally, maximizing the pest and weed management benefits of cover crops requires careful selection of cover crop species, attention to timing, and a willingness to experiment. There is both anecdotal and researched evidence about cover crops reducing weed, insect and disease pressure, and more experimentation and research on how to incorporate cover crops on diversified farms will help farmers maximize their benefits.

## The market farmer's advantage

While market farmers may face challenges with time availability, lack of necessary equipment, land availability and economic pressures, they have some cover cropping advantages as well.

1. Short-season vegetables allow for many cover cropping options.
2. Small fields are ideal for experimenting with a wide range of cover crop varieties.
3. Cover cropping can create interest and open doors with neighboring farmers.
4. Cover crops make a market farm look lush and dynamic throughout the entire growing season.
5. Cover crops help keep growers' busy lives in balance by keeping them focused on long-term soil building, in addition to the next day's produce delivery.

There is no shortage of creative, devoted market growers who are adept at finding new solutions to age-old problems. The rest of this publication is devoted to sharing ideas and information that will help both new and experienced vegetable growers make the best use of cover crops in their farming systems.

## Equipment for cover crop management

### *Field preparation*

The state of the existing field will dictate the tools required. If starting with sod or an overwintered cover crop, for example, a moldboard or chisel plow may be necessary for termination and incorporation. Though generally more expensive, a spader can also accomplish this task. From there, simple tools such as field cultivators or harrows are generally sufficient to prepare a cover crop seedbed.

Where vegetables have been harvested and mowed, or where winter has killed a cover crop, a new cover crop can be seeded right over the residue and incorporated with a shallow field cultivation using a harrow or, as a last resort, a rotovator. A hand rake can be used to prepare small areas, especially when they are already clear of residue. Intensely working the soil with a rotovator prior to cover crop planting is neither necessary nor advisable in most circumstances.

### *Seeding*

A simple broadcast seeder can be used on a small scale with good success. A drag, harrow or cultipacker helps cover seeds and provides adequate seed to soil (seed to moisture) contact. Some market farmers use old grain drills to plant cover crops. These can be found at auctions or used equipment dealerships for a reasonable price. The hand-pushed Earthway seeders that growers commonly use to plant vegetables can also be used for drilling in cover crops in narrow strips or beds. The Virginia Association for Biological Farming has an excellent fact sheet<sup>1</sup> that lists research-based recommendations for Earthway seed plates to use with various cover crop seeds.

Compared to broadcast seeding, drilling uses less seed and can result in more uniform stands. Drills need to be calibrated for each cover crop seed to ensure accuracy. Even with a drill, a cultipacker will hasten germination. Like all plants, cover crops need water to germinate. Timing a planting before rain is ideal. As a last resort, sometimes overhead irrigation is used in order to germinate a cover crop in a timely manner and get a jump start on any weed species present.



Photo: John Hendrickson

*A small seed drill works well for planting cover crops and can result in more uniform stands than broadcast seeding.*



Photo: Alex Hamrick

*A walk-behind flail mower can work well for clipping cover crops on a small scale but is time consuming.*



Photo: Claire Strader

*A walk-behind rotary mower is especially useful for managing living aisles.*



Photo: John Hendrickson

*This Perfecta field cultivator can prepare ground for seeding cover crops and can be used to lightly incorporate broadcast seed.*

### ***Residue management and termination***

A flail chopper (or stalk chopper) is the implement of choice for cutting or clipping cover crops before incorporating the residue. A small rotary mower (or brush hog) can also do the job, but will not chop the residue as finely or distribute it as evenly as a flail chopper. Either tool requires a tractor with at least 30 to 40 horsepower. Old sickle bar mowers are often less expensive, but they do not chop as finely and can leave a relatively thick mat of vegetation. Furthermore, a sickle bar mower often cannot handle a dense stand of vetch. Without tractor-mounted implements, it is wise to clip more often so as to avoid a tall, dense stand. Small flail mower attachments are available for walk-behind tractors and walk-behind rotary mowers (or brush hogs) can also be used. In a small market garden, light, succulent covers such as oats, peas and buckwheat are fairly easy to mow.

Dense, matting cover crops such as hairy vetch can be more tricky with small-scale equipment, but mixing them with a grass such as winter rye can make them more manageable.

In no-till or reduced tillage systems, a roller-crimper is used to lay down and kill dense cover crops and no-till planters are used for seeding and transplanting. These are specialized tools that are relatively expensive, but no-till cover cropping is an exciting new frontier for sustainable vegetable production that deserves consideration. See the “Cover crop-based reduced tillage systems” section on page 10 for more information.

### ***Incorporation***

Cover crops are most commonly incorporated with rototillers at smaller scales and tractor-mounted rotovators at larger scales. Spaders, either walk behind or tractor mounted, can also be used. Spaders do less damage to soil structure than rototillers. A more traditional approach is to turn under cover crops using a moldboard plow and then follow with a series of cultivations using some combination of a disc, field digger and harrow. Turning the cover crop under, however, places it in an anaerobic, or oxygen deprived, environment—not ideal for decomposition. Inverting the soil brings weed seeds to the surface where they can germinate. Field diggers and power harrows are effective and gentler on the soil. The basic sequences shown in Table 1 on the next page will incorporate most cover crops and create a nice seed bed.

Moldboard plows and discs move soil horizontally and can create a plow pan. It is recommended to alternate their use with tools that work vertically, such as chisel plows and subsoilers. Rotovators and rototillers are effective tools to chop, mix and incorporate cover crop residue. A less common but less damaging tool is the power harrow, which stirs the soil and lightly incorporates residue without inverting the soil profile.

**Table 1. Basic cover crop sequences**

Steps	Heavy, fibrous crops (rye, sorghum sudangrass)	Light, succulent crops (peas, buckwheat)
1.	Mow	Mow
2.	Rotovate or plow to kill and incorporate	Incorporate using a field cultivator with sweeps that operate at 4 to 6 inches
3.	Follow with a disk and/or a field cultivator with sweeps that operate at 4 to 6 inches	If desired or if there is time, allow weeds to germinate and cultivate again using a field cultivator, tine rake, or other shallow cultivation tool
4.	If desired or if there is time, allow weeds to germinate and cultivate again using a field cultivator, tine rake or other shallow cultivation tool	Prepare beds for planting
5.	Prepare beds for planting	

At a small scale, rototillers, rotary plows or small spading tillers are the main options (aside from hand digging). Because rototillers can damage soil structure and soil organisms—especially if they are overused—it is generally best to use them at shallower depths and at lower revolutions per minute (RPMs). Another option is to hire a neighboring farmer to incorporate your cover crops with a chisel plow before using shallow tillage for final seedbed preparation.

Regardless of the tools employed, keep them in working condition so that when the time comes to plant, clip or till, you can act quickly and efficiently. Timing is important, and you need to be ready to take advantage of relatively short windows of opportunity during various seasons and between rainstorms.

## General cover crop timing

### *Seeding a cover crop*

Ideally, a cover crop is established as soon as possible after vegetable harvest and stays in place until the next vegetable or cover crop is planted. The easiest way to accomplish this goal is to broadcast the cover crop seed over the mowed vegetable crop and then incorporate the seed with the vegetable residue. In this case, tillage is effective at both speeding decomposition of the residue and achieving the necessary soil-to-seed contact. If the vegetable crop is already incorporated, using a grain drill or broadcast seeder will work as described above in “Seeding.” Sometimes cover crops are sown while the vegetable crop is still standing. See the sections on “Relay planting” and “Living aisles” on page 9 for more information on establishing covers under vegetable crops. In all cases, the season and the specific needs of the following vegetable will determine which cover crop varieties are suitable. See the “Cover cropping sequences” section on page 6 for more information.

### *Terminating a cover crop*

The optimal time to terminate a cover crop depends on the goals for the following vegetable crop. Terminating a cover at full bloom typically provides the most



Photo: Claire Strader

*Oats and peas should be incorporated at full flower for maximum nitrogen availability to the following crop.*



Photo: Claire Strader

*Cover crops that winterkill, such as these oats, are a good choice for field that will be planted to early spring vegetables.*

effective kill, and also results in slower decomposition of the residue and a release of nutrients over a longer period of time. In the case of a leguminous cover, termination at full bloom will maximize the nitrogen contribution to the next crop. Timing incorporation when foliage is green, before flowering, results in rapid increases in soil biological activity, decomposition of the cover crop, and release of nutrients into the soil.<sup>2</sup> If terminated after bloom, the cover crop may reseed itself. Furthermore, waiting too long results in higher carbon-to-nitrogen ratios, leading to slower decomposition and delayed nutrient availability. Some cover crops can be effectively terminated by mowing and/or incorporating well before bloom. Buckwheat, oats, peas and vetch,

for instance, can all be incorporated early without threat of re-growth. Other crops are difficult to kill (even with primary tillage) before bloom. Winter rye, for instance, will continue to regrow if mowed, tilled or crimped before bloom.

### ***Planting following a cover crop***

There are several options for planting vegetables after a cover crop. If the cover crop is being incorporated, it is a good idea to allow some time for decomposition before planting vegetables. Transplants can usually go into succulent covers such as peas, buckwheat and vetch about a week after incorporation. It will usually take two to three weeks before fibrous and/or allelopathic covers like winter rye or sorghum sudangrass break down enough to accommodate transplants. (Allelopathic plants release chemicals that inhibit the germination or growth of other plants.) Direct-seeded vegetable crops need even more time. Succulent covers should sit roughly two weeks and fibrous or allelopathic covers should sit four or five weeks before direct seeding. In general, it is much better to precede a direct-seeded crop with a succulent or winter-killed cover in order minimize the time the soil is bare. It is often wise for growers to err on the side of earlier termination so that wet weather and excessive cover crop growth do not delay incorporation and vegetable crop planting. Some growers will leave cover crop residue on the surface as mulch rather than incorporating it after termination. For more on this method, see the “Cover crop-based reduced tillage system” section on page 10.

## **Cover cropping sequences**

There are several different windows of opportunity for planting cover crops and a variety of possible cropping sequences, based on the length of the cropping season. For example, in a field or section of a

**Table 2. “Go-to” cover crop options by season\***

<b>Spring</b>	<b>Summer</b>	<b>Fall</b>
Oats	Buckwheat	Winter rye
Peas	Sorghum sudangrass	Hairy vetch
Chickling vetch	Annual rye	Oats
Berseem clover	Oats	Peas
	Peas	Clovers (with oat nurse crop)
	Clovers (with oat nurse crop)	

\*Specific planting times and a full list of cover crops are included in Appendix A starting on page 20.

field that will be planted to early spring crops (peas, spinach, radishes, etc.), it is best to plant a cover crop the preceding fall that will winterkill, making it easy to till and plant in the early spring. In an area that will be planted later with main season crops (such as tomatoes, peppers or squash), a winter-hardy cover such as winter rye can work well. This strategy will prevent soil erosion and keep weeds in check until it is time to till and plant. There are many options for a full season of cover cropping (see Table 2 on page 6).

### ***Cover cropping sequence notes***

- A one- to three-week fallow cycle can serve as a transition between each cover crop and garden crop. This fallow period is an opportunity to allow weeds to germinate. A shallow cultivation just after weeds germinate provides a stale seed bed for the coming garden crop. Over time, these fallow periods can be reduced if weed pressure diminishes.
- Garden crop foliage should be flail chopped shortly after harvest is complete in order to expedite cover crop seeding. In most cases, cover crop seed can then be broadcast over the chopped residue and tilled in to uproot the garden crop and establish seed-to-soil contact.
- Most cover crops (except buckwheat) can be clipped one to three times to encourage tillering. Tillers are shoots that sprout from the base of grass plants. Clipping prevents the cover crop from going to seed and becoming a weed in the next garden crop. It also prevents the growth of a tall, dense stand that makes cutting and incorporating difficult with smaller scale equipment. This is especially true for sudangrass and millet.
- Cover crops such as buckwheat and vetch can become weeds if the seeds are allowed to mature. In the case of buckwheat, the challenge is to walk a fine line between providing flowers for pollinators and clipping the stand before it has set seed. It is worth noting that buckwheat is an easy weed to control, so some growers do not fret about whether it sets seed.
- Winter rye is aggressive and can regrow under moderately moist conditions. It is best to clip rye before it gets too tall. If this cover crop exceeds a height of 10 to 12 inches before the first clipping, its regrowth potential diminishes.
- Annual rye (annual ryegrass) and winter rye ('cereal' or 'grain' rye) are different plants. Ryegrass is a tender annual that will typically winterkill, though it can overwinter in some parts of the Upper Midwest. Winter rye is a hardy species that grows into the fall and early winter and overwinters before growing vigorously the following spring, flowering, and going to seed.
- If your goal is weed suppression, consider winter rye, which can be allelopathic. Allelopathy refers to chemicals in some plants that inhibit the germination or growth of other plants. Unlike cereal rye, annual ryegrass is not allelopathic. Winter rye's allelopathic effect, which may suppress the germination of small-seeded vegetables, lasts four to six weeks after turning it under. Keep this in mind if you plan to seed a market crop behind it.

Table 3 on page 8 shows sample cover crop sequences used by market growers in the Upper Midwest.



Photo: Claire Strader

*Buckwheat can become a weed if the seeds are allowed to mature, but it is an easy weed to control.*

**Table 3. Cover crop sample sequence options<sup>3, 4</sup>**

<b>Full Fallow Season</b>			
<b>Spring</b>	<b>Summer</b>	<b>Fall</b>	<b>Spring</b>
Crop residue or cover crop from previous fall	Buckwheat or sudangrass	Oats and peas	Spring vegetable crops
Crop residue from previous fall or spring-sown oats and peas	Buckwheat	Winter rye	Plow rye 2-3 weeks before planting a vegetable crop Summer/fall vegetable crops
Oats and nitro alfalfa or oats and clover	Mow oats to prevent seed set	Overseed winter rye into nitro alfalfa, which will winterkill or leave clover to overwinter	Summer/fall vegetable crops
Clover or clover/grass mixture planted previous June or July	Mow, plow and fallow period to express and cultivate weeds	Rye/vetch or oats and peas	Summer/fall vegetable crops or spring vegetable crops
<b>Early Spring Garden</b> (peas, spinach, radishes, lettuce, onions, etc.)			
<b>Fall</b>	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>
Oats and peas that winterkill	Early spring vegetable crops	Buckwheat or sudangrass or oats and peas	Winter rye or rye/vetch mix or leave oats/peas to winterkill
Fall-plowed field	Early spring vegetable crops	Buckwheat or sudangrass or oats and peas	Winter rye or rye/vetch mix or leave oats/peas to winterkill
<b>Main Season Garden</b> (tomatoes, peppers, vine crops, etc.)			
<b>Fall</b>	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>
Winter rye or rye/vetch mix	Plow rye 4-6 weeks before planting vegetable crop	June-planted vegetable crops	Winter rye or oats
Clover or clover grass mixture	Plow clover 3-4 weeks before planting vegetable crop	May- and June-planted vegetable crops	Winter rye or oats
Oats and vetch planted in late August or early September	Plow vetch 3-4 weeks before planting vegetable crop	May- and June-planted vegetable crops	Winter rye or oats
<b>Fall Garden</b> (fall brassicas, carrots, lettuce, spinach, etc.)			
<b>Fall</b>	<b>Spring</b>	<b>Summer</b>	<b>Fall</b>
Clover or rye	Mow as needed to control weeds or manage cover crop	Garden planted in July and August	Leave crop residue or seed winter rye in crops harvested before early October

*Adapted from materials created by Dan Guenther, Common Harvest Farm, Osceola, Wisconsin*

## *Relay planting*

Relay planting is the establishment of cover crops between rows of vegetables within a bed, usually during the summer or early fall. When the vegetable crop is harvested, the cover crop is already in place and poised to protect the soil during the winter. Ideally, the cover crop is seeded after the vegetable is established and before the cover is completely shaded out by the vegetable. Seeding the cover crop two weeks after transplanting vegetables is common. Growers and researchers have successfully used rye, vetch and clovers in relay systems with corn, beans, spinach and brassicas. With sweet corn, cover crop varieties that do not cast heavy shade are recommended.

Although relay planting is a bit more involved than seeding into bare ground, it can help ensure that more land is planted to cover crops in the fall. Relay planting also provides cover crops with additional time before frost and decreasing day length terminate the growth of tender annuals, or limit the growth of hardy crops. Relay planting can potentially increase the amount of farmland protected by cover crops.

## **Living aisles**

Cover crops planted into aisles between vegetables can smother weeds, allow access to fields even when soil is wet, and create a space for multi-year covers. Because newly seeded or transplanted vegetable crops leave soils vulnerable to erosion, establishing living aisles can be especially helpful in keeping soil in place.

Living aisles can be any width, as long as they can accommodate a mower. Open vegetable planting strips should be wide enough to prevent competition between the cover and vegetable crops. Tall single-row crops like Brussels sprouts and tomatoes can do well in a planting strip of at least 24 inches. Multi-row crops need wider planting strips. Sprawling crops like winter squash are not as well suited to living aisles, because the aisles need to be mowed regularly.

Dutch white clover is the most common cover crop used in aisles because it is short, dense, and stands up well to foot traffic. When seeded in late summer, the clover has time to establish in fall and will crowd out weeds the following spring. Planting strips can be seeded to winter-sensitive cover crops at the same time and will be ready for planting as soon as soils warm in the spring.



Photo: Claire Strader

*A variety of cover crops keep soil in place over winter. The clover in the foreground was established under winter squash.*



Photo: Claire Strader

*Clover living aisles can work well with tall crops like Brussels sprouts. Marsh hay mulch helps keep clover out of the planting strip.*

Julia Fiser at Regenerative Roots Farm establishes a whole field of 50/50 Dutch white and medium red clover in late summer, and tills 30-inch planting strips into the established clover the following spring. The medium red clover is taller and tends to extend from the aisle to cover the vegetable bed edges, thus providing some weed control and moisture retention in the bed. No matter how they are established, properly maintained clover aisles can be left in place and provide good weed control for two to three years, according to Fiser.

Living aisles can also be sown between established vegetable beds. In this case, it is a good idea to take one shallow cultivation pass to kill newly germinated weeds soon after planting the vegetables. Cover crop seed can then be sown into the clean aisle with a seeder/drill or broadcast and lightly worked into the soil with a rake, wheel hoe or second cultivation pass. When seeding the aisles, it is important to keep the cover crop out of the vegetable bed where it can compete with vegetables much like a weed. Mike and Cassie Noltnerwyss at Crossroads Community Farm use a mix of annual rye and white clover in aisles between beds covered with plastic mulch. Any cover crop that establishes quickly, stands up to foot traffic and can be easily mowed can work as a living aisle.

Cover crops in living aisles should be thick and quickly smother weeds that germinate in the understory. Mowing the aisles every one to three weeks can help the cover crop stay ahead of weeds and keep it short enough to easily maintain and harvest the vegetable crop. A typical walking lawn mower is not generally up to the job and can be very difficult to use in the field. A walk-behind brush hog that can be set higher than a lawn mower and propels itself easily down the aisle is ideal. Attention to where the cover crop residue lands is also important. A side discharge can be useful to blow residue under tall crops as mulch. In general, however, dropping the residue into the living aisle is best, especially where a side discharge can damage tender crops.

## Cover crop-based reduced tillage

Given concerns about the impacts of tillage on soil health and erosion, growers and researchers have developed various reduced-tillage systems. In addition to being good for the soil, these systems can reduce weed pressure by leaving weed seeds buried under a layer of surface mulch. The most prominent organic reduced tillage system uses a combination of hardy winter cover crops (often winter rye with a legume such as hairy vetch) before row crops such as corn or soy. These cover crops are planted



Photo: Erin Silva

*Winter squash in rolled rye*



Photo: Erin Silva

*Roller-crimper taking down winter rye*

in the late summer or early fall and terminated with a mower or roller-crimper after they begin to flower the following spring, usually in late May. Though little work has been done on how this system could work with vegetables, there is reason to believe vegetable crops could be transplanted directly into the resulting layer of organic mulch. Ensuring a sufficient supply of nitrogen to the vegetable crop and transplanting efficiently through the mulch layer are two likely challenges with this approach. Crops such as broccoli, kale, tomatoes, peppers, eggplant, squash or cucumbers can be planted with a no-till transplanter or by hand, while large-seeded crops such as sweet corn or beans can be seeded directly using a no-till drill.

Since mowing does not typically leave an evenly distributed mulch, organic reduced-tillage systems usually rely on a roller-crimper that both kills the cover crop and leaves a uniform mulch mat. There are two concerns with this piece of equipment. First, the timing of rolling (or mowing) is particularly important. For example, cutting vetch before the bud stage allows regrowth that competes with the crop.<sup>5</sup> In general, terminating the cover crop at flowering (also known as anthesis) is the best time to get a reliable kill. Second, roller-crimpers are relatively expensive. Some growers are fabricating them on their own farms and others are experimenting with alternative cover crop termination techniques.

In order to avoid the equipment expense and precise timing needed for roller-crimping, some work is being done with terminating high-residue winter-hardy covers with lower-cost, reusable black plastic tarps. Using tarps to kill weeds and decompose crop residues was popularized by Jean-Martin Fortier.<sup>6</sup> Fortier first chops residues into small pieces with a mower and then applies the tarp for two to four weeks to speed decomposition. The warm, moist conditions under the tarp not only decompose the residue but also germinate weed seeds, which then die due to lack of light. This process is called occultation. For cover crop-based reduced-tillage, however, the goal is to kill the cover crop while preserving as much residue as possible for mulch. So, instead of mowing, the cover crop is rolled with a disengaged tiller before applying the tarp. While this action might simulate rolling and crimping enough to get some kill, its real purpose is to flatten and align the cover crop, making it easier to apply the tarp and more likely that the residue will cover the soil and create an even mulch layer. Preliminary research shows that leaving the tarp in place for one to three weeks is enough to kill a rye/vetch mix even if the crop is not yet flowering (as is required for successful roller-crimping). Dense plantings of rye/vetch that produce more biomass will result in thicker mulch layers more suitable for no-till planting.

Winter weather can also terminate frost-sensitive cover crops for use in reduced-tillage planting systems. For instance, in Wisconsin, sorghum sudangrass, oats or an oat/pea mix planted in August or September will winterkill and can leave enough residue to suppress early spring weeds. Rolling these cover crops with a disengaged rotovator just before fall frosts can help flatten and align the residue for no-till planting the following spring. Early transplanted crops such as broccoli, kale or lettuce will likely work best in this system, as the residue will break down quickly after the winter and an early crop canopy will be important for further weed suppression. Using a supplemental mulch (marsh hay, straw, landscape fabric or plastic) on top of the cover crop residue can make this system suitable for later crops such as tomatoes.<sup>7</sup>



*No-till transplanters such as this one designed for a walk-behind tractor can make reduced tillage vegetable systems more efficient.*



Photo: John Hendrickson

*Late spring is a good time to mow rye and vetch.*

Experiments with a wider range of cover crop species for reduced-tillage vegetables planted in other seasons are yielding promising results (not necessarily tested in the Upper Midwest), according to researchers at the Rodale Institute.<sup>8</sup> They found that cool-season annual cover crops such as oats and fava beans can be planted in early spring and then killed mid-summer for late plantings of cucumber, bean or summer squash. Summer annual (frost-tender) cover crops including millet and cow pea can be planted after the last spring frost and knocked down at the end of summer before planting brassicas or other fall crops.<sup>9</sup>

There are potential drawbacks with cover crop-based reduced-tillage systems. First, nitrogen may be less

available to the vegetable crop, as it is used by microorganisms to decompose the cover crop residue. Using a legume in the cover crop mix and adding compost or supplemental nitrogen can help. Second, soil temperature may be lower due to the light-colored residue. While cool-loving brassicas may benefit from lower soil temperature, warm-loving Solanaceae may see a delay in fruiting. Third, perennial weeds can be difficult to control in this system. Starting with a field that is fairly weed free will yield better results. And finally, the special equipment (roller-crimpers, no-till transplanter and no-till drills) that can make the system more efficient can be expensive. Organic reduced-tillage systems are still quite new and experimental.

## Cover crops and fertility management

Different legume crops typically supply varying amounts of nitrogen to the following vegetable crop. Vetch produces high levels of nitrogen—as much as 100 to 150 lbs. per acre. Clovers are also excellent nitrogen fixers, contributing about 80 to 100 lbs. of nitrogen per acre while peas and beans often fix 40 to 80 lbs. of nitrogen per acre.<sup>10, 11, 12</sup> The amount of nitrogen produced will be greater if the legume seed is properly inoculated and the cover crop is in place for the entire previous season. In the case of summer- and fall-planted legumes, the earlier the legume is planted and the better the stand, the more biomass and nitrogen that will be produced.

Not all of this nitrogen may be available to the following crop, and the timing of its availability can vary with decomposition rates due to field and weather conditions. In many cases, additional nitrogen may need to be supplied with a fertilizer. Growing at least a portion of your own nitrogen is still a good practice, and cover crops have other direct and indirect benefits such as pest, weed and disease control.

A cover crop mix of a grass and a legume can enhance soil fertility while providing more biomass, enhanced weed suppression and higher levels of organic matter. Grass-legume mixtures lead to a more optimal carbon-to-nitrogen ratio. This combination results in a more gradual release of nitrogen for the following vegetable crop. In contrast, an all-grass cover crop tends to tie up nitrogen because the residue is high in carbon. A stand-alone legume cover crop is prone to a rapid release of nitrogen, which can potentially leach into ground and surface water. Legumes and grasses affect other nutrients as well: legumes often increase the availability of phosphorus, while many grasses increase the availability of potassium.<sup>13</sup>

## Cover crop mixes

As mentioned above, planting a mix of cover crops can provide multiple benefits. Legumes and grasses are a classic combination. Legumes will provide nitrogen to the soil and will often fix more nitrogen when grasses are using the available supply for their own growth. Grasses then provide support for the legumes and greater biomass to hold soils in place and increase soil organic matter. Rye-vetch and oats-peas are two classic cover crop mixes that combine a legume and a grass. Growers typically use rye and vetch for long-term cover that will survive winter. Oats and peas are a great option to seed in the fall when planting vegetables early the following spring, since both cover crops will winterkill. Oats and peas are also frequently planted in the spring to offer cover, nutrients and organic matter for later vegetable plantings. A newer and more experimental trend is planting cover crop “cocktails” of three or more species. These mixes are often meant to provide cover for longer periods of time, with each species contributing unique benefits.

A final reason to plant multiple species mixes is to provide a “nurse crop” for a slower developing cover crop. The classic example of this technique is planting an annual crop such as oats or barley with a perennial crop such as clover or alfalfa. Many perennial legumes germinate more slowly and irregularly than annuals. By planting a nurse crop, the soil is covered more rapidly, allowing fewer weeds a chance to grow before the perennial cover has a chance to establish itself.

Using a diversity of cover crop species is likely to increase the diversity of microbes in the soil and improve soil health in general. As growers become more comfortable with cover crops, using mixes and less common species can be exciting for the grower and beneficial to the soil.

## Cover crops and pest management

Research and experimentation on the use of cover crops for both weed and insect management is increasing as both growers and researchers recognize the potential for biological and farming system approaches to address pest management challenges. Specific cover crops, as well as cover cropping sequences and practices, have been identified to address disease, insect and weed problems. However, some research results on this topic have proven difficult to replicate. Some information about pest management benefits is purely anecdotal. Growers using cover crops to manage pests may find it challenging to get the same results in all circumstances.

### *Cover cropping for weed management*

Cover crops suppress weeds by competing for light and nutrients or, in some cases, releasing compounds that inhibit the germination or growth of weeds through allelopathy. Weed suppression varies by cover crop species, management (planting dates, planting densities, tillage and residue management, etc.), existing weed populations, and weather conditions. Particular cover crops and management approaches can suppress, have no effect on, or even stimulate weed growth. Accordingly, shifts in weed populations can occur when using cover crops in annual rotations. As a result, it is best to match cover crops and management to the particular weed problems in a given situation.



Photo: John Hendrickson

*A swath of spring-sown oats and peas next to a recently plowed bed*



Photo: John Hendrickson

*A solid stand of rye and vetch is suitable for strip cropping*

Cereal grains and grasses are excellent choices to suppress late fall and spring weeds because they establish themselves quickly in cooler temperatures, cover the soil, remain in place through winter and grow rapidly in the spring. Legumes grow too slowly to be effective on their own, but can be used in combination with grains and grasses to suppress weeds and fix nitrogen. Summer weeds can be smothered with warm season annual cover crops such as buckwheat or sorghum sudangrass, or with season-long cover crops. Drilling, rather than broadcasting, is the recommended planting method for weed control because it hastens cover crop germination and results in a more even stand. Higher seeding rates (by as much as 50 percent) are also recommended.<sup>14</sup>

The tillage required to incorporate cover crops can bring new weed seeds to the surface. As noted above,

some growers are experimenting with no-till systems that leave cover crop residues on the surface as mulch. These systems can create obvious challenges with direct-seeded crops (particularly those that require a fine seed bed) as well as transplanting.

As mentioned above, some cover crops have an allelopathic effect, cereal rye being the most notable. Rye and rye/vetch combinations are common winter covers that are tilled before transplanting or seeding large seeded crops such as beans. Another approach is to bale the rye and then use it for mulch. In addition to rye, oats and barley can inhibit germination and root growth.<sup>15</sup> Simply incorporating large amounts of residue, especially if succulent, often causes a sharp increase in soil-borne pathogen populations, especially damping-off fungi, which attack seeds as they germinate. This may account for some of the reduced weed and crop germination rates observed shortly after killing and/or incorporating cover crops. Because of this effect, it is wise to wait three weeks or so after incorporation before planting direct-seeded crops. Transplanted crops can generally go in sooner.

Many new vegetable growers face enormous weed pressure as they convert old hay fields, pastures and lawns into vegetable gardens. Appendix B on page 24 contains several cover cropping scenarios to ease this transition.

### ***Cover cropping for insect management***

Cover crops can affect a farm's insect community in several ways. They can attract both pests and beneficial insects by providing shelter and food, as well as making cash crops more difficult for insects to locate. Management is complicated given that cover crops can act as a source and/or a sink for beneficial and pest insects.<sup>16</sup> Given this complexity, careful observation, planning and timing are important.

The simplest strategy to manage insects is to provide a diverse array of vegetation.<sup>17</sup> Diversity in plant species and habitats helps ensure a balanced insect community, including beneficial predators. Increased diversity can be achieved by:

- selecting diverse cash crops
- utilizing a variety of cover crops (such as planting both buckwheat and sorghum sudangrass as summer cover crops since each has unique insect associations—see Table 4 on the next page)

**Table 4. Insects attracted to common cover crop species<sup>18</sup>**

Cover crop	Beneficial insects	Pest insects
Buckwheat	Parasitic wasps, ladybugs, tachinid and hover flies, lacewings	Tarnished plant bugs and aphids (note: aphids can act as a food source for beneficials)
Clovers	Parasitic wasps, big-eyed bugs, minute pirate bugs, ladybugs, tachinid flies and aphid midges	Spider mites & flower thrips (note: flower thrips can prey on spider mites and provide food for several predatory insects)
Hairy vetch	Minute pirate bugs, ladybugs, predatory and parasitic wasps	Tarnished plant bugs
Cereals/grains	Ladybugs	Aphids

- establishing permanent or semi-permanent hedgerows
- planning cover crop plantings and mowings to ensure that something is always in bloom (such as waiting until buckwheat has flowered before plowing a rye/vetch combination, or mowing/plowing only portions of a stand at a time)
- strip cropping (the practice of growing crops in strips between adjacent stands of cover crops)

Strip cropping can be a particularly useful strategy because it provides habitat for beneficial insects close to cash crops. For example, a solid stand of rye/vetch or clover can be mowed and plowed in strips, leaving habitat for ladybugs and other predators. The list of cover crops in Appendix A includes notes on whether various cover crops are suitable for strip cropping.

Planting special hedgerows to attract beneficial insects is another approach. Some seed companies (such as Johnny's Selected Seeds) offer mixtures that can be used to create borders or strips of beneficial habitat. Some growers have created more permanent hedgerows that not only attract and harbor beneficials, but also yield a marketable crop such as curly willow or various perennial flowers and herbs. For example, members of the Umbelliferae family (such as caraway, dill and fennel) are attractive to parasitic wasps. Flowers in the Compositae family (sunflowers, asters, goldenrod, daisy, cone flower, etc.) attract insects such as ladybugs, pirate bugs and spined soldier bugs, can be maintained in permanent beds and are readily marketed as cut flowers.<sup>19</sup>

Table 4 above lists insects (both pest and beneficial) attracted to common cover crop species.

In addition to above-ground interactions, plants can impact soil-dwelling insect species. Oats, barley and sorghum sudangrass have been shown to reduce root-knot nematodes—a pest that can reduce carrot quality and affect other vegetable crops such as onions and potatoes.

Research on various sorghum sudangrass hybrids and cultivars shows that the leaves of these plants produce a nematicidal compound. To take advantage of this, sorghum sudangrass must be mowed and well-incorporated before first frost and while still green.<sup>20</sup> Other cover crops may actually increase soil-dwelling insect pests. Vetch can cause increases in root-knot nematodes as well as the soybean cyst nematode.



Photo: Claire Strader

*Tillage radish can loosen compacted soils and will leave almost no spring residue, making it suitable for early vegetable plantings.*



Photo: Claire Strader

*Sorghum sudangrass produces a great deal of biomass and has been shown to reduce root-knot nematodes.*

### ***Cover cropping for disease management***

Cover crops can reduce disease problems in vegetables in various ways. Most obviously, cover crop rotations break disease cycles in the soil. Other benefits can come from strip cropping or utilizing cover crops as mulches. Mulches can delay the onset of early blight in tomatoes by reducing soil splash onto leaves. Preliminary research suggests that oats may help reduce vegetable crop diseases caused by *Rhizoctonia*.<sup>21</sup> Because some cover crop species are related to cash crops (most notably field peas), it is wise to rotate cover crops. Pea diseases such as *Sclerotinia* can build up quickly if peas are planted in successive years in the same location.<sup>22</sup>

### **How to choose a cover crop**

Use the following questions to help select a cover crop to suit your needs:

- What are your goals, based on the needs of the field/farm (erosion control, soil building, weed control, pest management, etc.)?
- Which vegetable crops will precede and follow the cover crop?
- What is the season and the duration of the open cover window between vegetable crops?
- Does the following crop have specific needs related to fertility, weed control or pests?
- How and when will you terminate the cover crop to accommodate the following vegetable crop?

Answers to these questions combined with the characteristics of specific cover crop varieties (see Appendix A on page 20) can lead you the best species for your situation. For instance, if your primary goals are erosion control and soil building after summer squash and before early spring broccoli the following year, a good choice might be a legume that will fix nitrogen (N) and winterkill. Straight field peas, or peas mixed with a small percentage of oats, planted in late August will fix N, hold the soil in place over winter, and leave a dead mat that is easily incorporated in the spring before early vegetables. Cornell's cover crop decision tool can help you identify suitable cover crops based on

your goals, planting time and the duration of the open window between vegetable crops (<http://covercrop.org/mobiledecisiontool>).

## **Seed sources**

Some cover crop seed, such as oats and rye, can be bought from neighboring farmers. Other types, such as grain and field pea mixtures, clovers and sorghum sudangrass, are readily available at a local co-op elevator or feed store. More specialized seed, such as hairy vetch, ryegrass, berseem clover, annual alfalfa and millet, is available from various seed companies throughout the Midwest and beyond. Sources for organic cover crop seed can be found in the *Organic Resource Directory* published by the Midwest Organic and Sustainable Education Service (MOSES). This publication is free and is also available online at [www.mosesorganic.org/resourcedirectory.html](http://www.mosesorganic.org/resourcedirectory.html).

## Notes

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## Appendix A. Management guide for specific cover crop species\*

Crop	Characteristics	Planting time	Seeding rate**		Management and comments	Suitable for small scale?
			#/1000ft <sup>2</sup>	#/acre		
Alfalfa	Deep-rooted perennial legume. Excellent N fixer; drought tolerant; does not tolerate wet soils or flooding. Requires soil pH above 6 and moderate levels of P and K. Use alfalfa/clover inoculant.	Spring or late summer to early fall.	1/2 to 2	15 to 20	There are 2 kinds of alfalfa: dormant and non-dormant. Dormants stop growing in mid-autumn and are very winter hardy. Non-dormants (such as Nitro) grow faster but are less hardy. Excellent forage crop and soil-builder but not an ideal cover crop—unless a grower has haying equipment and a use or market for hay. If grown, Nitro is the best choice for market growers.	No. Heavy equipment needed for incorporation.
Barley	A cool season annual grain. Grows rapidly and offers multiple benefits including weed and pest suppression, scavenging nutrients and contributing organic matter.	Late summer or spring	1 to 1 1/2	40 to 60	Inexpensive and easy to grow. Prefers light textured soils. Good choice for mixing with other covers such as peas and clover as a nurse crop. Will winterkill. Prefers cool, dry climates and is an excellent option in northern areas. Select a regionally adapted variety for best results.	Yes
Buckwheat	Fast-growing, warm season annual (matures in 40-50 days). Not drought or frost tolerant.	Late spring to late summer	2 to 3	50 to 100	Drill or broadcast and harrow. Fast growth enables buckwheat to smother weeds and for several sequential plantings to be made in one season. Once mowed, residue decomposes rapidly and soil is friable; little tillage is necessary for next crop. Will reseed itself and can become a weed if flowers mature to seed. Buckwheat residue can be a good winter cover if late plantings are thick and growth is adequate.	Yes. Excellent choice to follow early vegetables or to help clean up a weedy field.
Clover, annual white	Similar to yellow-blossom sweet clover. Deep taproot and a strong N fixer. Use alfalfa/clover inoculant.	Spring or early fall	1 to 2	15 to 30	Drill or broadcast and harrow. Grows rapidly and can become woody when mature and difficult to incorporate. Mow as needed. Mix with oats for a nurse crop. Later plantings make good growth before being winterkilled. Seed is hard to find (most common variety is Hubam). As most clovers are biennial, make sure what you are getting is annual sweetclover.	Yes

\* Adapted from information published by Charles Marr, Rhonda Janke and Paul Conway in "Cover Crops for Vegetables Growers," Kansas State University, 1998.

\*\* Generally, higher seeding rates are used for cover crops than for seed or forage production. Use lower rate listed for drilling, and higher rates for broadcasting.

Crop	Characteristics	Planting time	Seeding rate**		Management and comments	Suitable for small scale?
			#/1000ft <sup>2</sup>	#/acre		
Clover, Berseem	Extremely vigorous, tall annual white clover. Tolerant of wet conditions. Excellent nitrogen fixer. Use alfalfa/clover inoculant.	Spring or late summer (if moisture is adequate)	1/2 to 2	15 to 25	Best if drilled but can be harrowed. Makes excellent hay or heavy quantities of mulch. Cut when 7-20 inches. Don't mow close; leave 1-3 inches of stubble. Berseem leaves a friable seedbed so spring tillage requirements are minimal. Transplant directly into beds. Excellent weed suppressor. Good for interplanting because of slower summer growth. Mix with oats for biomass or one-season soil building.	Yes. Can be controlled by mowing and no heavy tillage is needed.
Clover (red and white)	Red (Medium, Mammoth, Alsike) and white (Dutch, New Zealand, Ladino) clovers are slow-growing legumes. Whites are shorter and longer lasting. Tolerates soils too wet for alfalfa. Use alfalfa/clover inoculant.	Late winter (for frost seeding), spring or July/August (if moisture is adequate)	1/2 to 1	Red: 8 to 15 White: 5 to 15	Clovers grow slowly in the seeding year but rapidly the second year. Mow as needed to control weeds. Reds are the better N fixers, as is the New Zealand white. Clovers mixed with oats or annual ryegrass produce large amounts of biomass for soil improvement. Seed at lower rates if sown with grasses. White and red clovers can also be mixed. Well suited as cover crops.	Reds best incorporated by plows, chisels or heavy tillers; lower growing whites can be incorporated with rototillers.
Clover, sweet, yellow blossom	A biennial. Flowers and completes life cycle after overwintering. Deep taproot, drought tolerant, excellent nitrogen fixer, and adapted to all soils except wet. Use alfalfa/clover inoculant.	Late winter (for frost seeding), spring, summer, or fall (40 days before killing frost)	1/2 to 1	10 to 20	Mow as needed to control weeds and growth. Mow high; it is intolerant of low mowing. Plow under in fall if an early vegetable crop will follow in spring. If overwintering, plow before flowering; do not allow to set seed. Mature sweetclover is fibrous and breaks down slowly. Excellent choice for intercropping if planted before the vegetable crop or one-year soil building crop. Mix with oats for added biomass. Cheap and easy to plant.	No. Requires plowing to incorporate.
Millet	Fast-growing summer annual grass. Foxtail, proso, and Japanese millets are best for early plantings. Pearl millet is very tall; rivals sorghum sudan in biomass production. Also excellent if there is a need for mulch or feed.	Late spring through summer. Late plantings do not produce much biomass.	1 to 1 1/2	25 to 30	Drill or broadcast and till shallow. Manure or fertilizer for best results. Can be mixed with cowpeas or soybeans. Good choice for a full season smother crop, cleaning weedy fields or converting land to vegetable production. When used as summer-long crop, mowing is important. Clip before heading out (~60 days) and leave 3" of stubble. Japanese and browntop millet grow back more readily than other types after clipping.	Yes, but make sure soil is fertile enough to support multiple cuttings.
Oats	Fast growing and frost-tolerant annual. Extensive, fibrous roots hold soil and produce biomass. Tolerant of wet soils and low pH. If allowed to mature, oats will reseed and new growth will winterkill.	Late winter (frost seeding) and spring or fall	2 to 4	100-140 (1-2 bushels) if mixed; up to 4 bu. if seeded alone	"Feed" or "seed" oats are acceptable for cover crop use. Drill or broadcast and harrow. To produce mulch, mow when needed. Oat straw decomposes rapidly and acts like leaf mulch in the forest. Oats are a good trap crop; late summer plantings will hold N from manure applications. Oats provide good winter erosion control. Oats are excellent for mixing with legumes. Versatile, available and cheap.	Yes

\*\* Generally, higher seeding rates are used for cover crops than for seed or forage production. Use lower rate listed for drilling, and higher rates for broadcasting.

Crop	Characteristics	Planting time	Seeding rate**		Management and comments	Suitable for small scale?
			#/1000ft <sup>2</sup>	#/acre		
Pea, cow	Summer N fixer with potential for 130 lbs/acre or more. Needs soil temp of at least 65 degrees F to germinate. Use cow pea inoculant. Available in semi-bush and vining varieties. Attractive to beneficial insects.	Summer	2 to 3	50 to 100	Can be drilled or broadcast. Can be planted in combination with sorghum sudangrass (or other upright summer cover) at a 90/10 ratio to help support the cow peas for easy mowing. Mowing will stop vegetative growth and light tillage will terminate the crop.	Yes
Pea, field	Grow like garden peas, only taller. Very cold tolerant and good N fixers (most N fixed before flowering). Use pea/vetch inoculant.	Spring	2 to 8	50 to 200	Drill or broadcast and harrow. For max. biomass, N and weed suppression, seed heavily. Mow and disk to incorporate. Heavy stands will clog sickle bar mowers. Produces so much biomass that small-seeded crops cannot be sown immed. following. Peas mix well with oats or barley. Pea, oat, and hairy vetch mixtures are excellent for soil building and available from some suppliers. Best use is on ground to be planted in June/July.	Yes. Mow to control peas. Tilling is easier if vines rot 1-2 weeks or are removed and used as mulch.
Radish, Daikon (tillage)	Large-rooted fall cover crop used to loosen compacted soils and improve aeration, water absorption, and rooting depth of subsequent crops. Winterkills leaving friable soil the following spring, also suppressing early spring weeds.	Late summer or fall (spring crops are very attractive to flea beetles)	1/8 to 1/4	6 to 12	Radishes germinate and establish quickly, whether drilled or broadcast. For best results, plant 6 weeks before regular frost. Mixes with oats, ryegrass and clovers can improve seed distribution and stand establishment while reducing seed cost. Be cautious if there are brassica family crops in your rotation.	Yes. Tillage radishes are the biological substitute for subsoiling using deep tillage tools.
Rye, grain (winter rye)	Very hardy small grain. Grows longer in fall than other grains and resumes growth earlier in spring. Grows on most soils. Extremely efficient nutrient scavenger, making it an excellent N trap crop. Dense, fibrous roots help build organic matter and make soil more friable.	Late summer to fall. Can be spring planted but will die before flowering and cheaper options exist.	2 to 5	50 if mixed with legume. 60-200 if seeded alone.	Can be broadcast and tilled, but best if drilled. Can germinate on the surface if moisture is adequate. In spring, till when rye is 6-8" or wait until it flowers. Can be used as windbreak by leaving strips between beds. Often sown with hairy vetch, but this mixture can get away from you unless soil is sandy or very well drained. Rye shows weed-suppressing (allelopathic) abilities (include rye straw) and is useful to help clean weedy areas. Tremendous biomass production can create challenges for incorporation and problems with planting and germinating small-seeded vegetables. Main challenge is having time for adequate incorporation between spring rains.	It can be managed without plows or heavy disks if incorporated early enough. Or let flower, mow, allow to decompose, and plant summer legume or fall cash crop.

\*\* Generally, higher seeding rates are used for cover crops than for seed or forage production. Use lower rate listed for drilling, and higher rates for broadcasting.

Crop	Characteristics	Planting time	Seeding rate**		Management and comments	Suitable for small scale?
			#/1000ft <sup>2</sup>	#/acre		
Ryegrass, annual	Fast-growing, cool season grass. Tolerates most soils, including wet. Dense root system is excellent for trapping N, holding soil and loosening heavy soils. Growth habit complements clovers. Not drought tolerant. Will self seed.	Spring or late summer to early fall	1 to 2	18 to 40	Best drilled but can be tilled in shallowly. Easy to establish and grows rapidly. Mowing is not necessary except to avoid setting seed. Unlike other mature small grains, annual ryegrass stays green and is easier to incorporate, although the dense root system can take time to decompose (small-seeded vegetables are not recommended following ryegrass). Excellent choice as a nurse crop with legumes or for pathways.	Yes. Easily incorporated if tilled early in spring.
Sorghum sudan-grass	Fast-growing, drought tolerant annual grass. Will grow over 6' if left uncut. Grows on most soils but needs fertile soils for best results. Winterkills.	Late spring through July	1 to 2	15 to 40	Drill or broadcast and harrow. A good N trap crop and excellent smother crop that produces tremendous biomass (more than any other cover crop) even with mowing. Decomposes slowly; allow 1 month before planting next crop. Needs plentiful manure to reach full potential. If left too long it can become unmanageable.	No. Too rank in growth habit. Even large-scale farmers need heavy duty mowers to cut for hay or silage.
Sunn Hemp	Summer N fixer with potential for 120 lbs/acre. Needs soil temp of at least 65°F to germinate. Use cow pea inoculant. Grows well in poor soils, is drought tolerant, and can reach 6' in 60 days when temps are high. Very attractive to Japanese beetles	Summer	1 to 2	20 to 35	Can be drilled or broadcast. Can be planted in combination with sorghum sudangrass at a 50/50 ratio. Terminate at 60 to 90 days by mowing and incorporating.	Yes
Vetch, chickling	Looks more like peas than hairy vetch. Excellent N fixer in as little as 60 days. Use pea/vetch inoculant.	Spring or fall	1 to 2	50 to 60	Broadcast and till or harrow in. Uneven seed size makes it difficult to drill. It is fairly drought tolerant, but will benefit from moisture in long dry spells.	Yes
Vetch, hairy	Cold-tolerant, viny legume. Excellent N fixer (100 lbs/acre). Needs pH of 6 or 7 for best results. Tolerates most soils but will not survive flooding. Drought tolerant once established. Tolerant of mowing but intolerant of shade. Use pea/vetch inoculant.	Spring, summer or fall (summer plantings generally less successful)	1 to 2	25 to 50	Best if drilled but can be harrowed in. Sow with a nurse crop of small grain in 1:1 or 1:2 ratio by volume (vetch to small grain). For overwintering, plant 3-4 weeks before a hard frost. A wet spring can delay incorporation and a mature small grain may hinder breakdown of the vetch following incorporation. Mow vetch/small grain mixtures if incorporation is delayed. Incorporate in April for a May-planted cash crop. Plow to incorporate or use heavy disk and chisel plow. Spring-sown vetch is easier to manage and can be left standing, tilled under or disked in the fall.	In general, no. It can be mowed until it dies, but other crops are easier to manage. Viney growth will quickly clog a rototiller.

\*\* Generally, higher seeding rates are used for cover crops than for seed or forage production. Use lower rate listed for drilling, and higher rates for broadcasting.

## Appendix B. Bringing land into production and tackling persistent weeds

Getting off to a good start is important in any new enterprise. Decisions made early in your planning process can have significant influence on the success of the farm for years to come. Rather than delve into the question of how to find land suitable for vegetable farming, this section assumes you already have a site selected.

The first question to answer is: *Has the land been in crop production in the preceding year?* If a row crop (corn or beans) or a small grain has been grown in the previous season, the tillage necessary to convert the land to vegetables will be considerably less than if you are following extensively rooted crops such as alfalfa, pasture or grass hay ground.

Many beginning market growers are forced to convert a deeply rooted sod into productive vegetable land. It is likely that this sod will contain Quackgrass and other rhizomes with well-established root structures. These grasses are difficult to control using organic methods. However, in the process of preparing your ground for intensive vegetable production, these same grasses can teach you about your soil structure, weed pressure and how water moves over and through your soil.

Here are some general guidelines for bringing fallow ground into production:

1. **Start early.** Plan on starting this process at least one full season before you intend to grow vegetables. Bringing new land into production in July or August of the preceding year allows time to cultivate the ground a number of times to dry up the rhizomes in the sod. By starting this process in mid-summer, you also avoid having too much exposed ground during the traditionally rainy months of May and June. Following a four- to six-week cultivating process, plant a fall-seeded cover crop of winter hardy rye or oats and peas.
2. **Be careful not to overwork the ground.** A heavily matted sod may require the use of a moldboard plow. If you do not own one, consider hiring a neighboring farmer to plow your field or garden for you. If you do plow, do so only to the depth of the root zone of the sod. In this process, the plow is used as an under cutter. The resulting action will turn the sod up to dry rather than burying it deep where it may not fully decay and may create a sponge-like mat that disrupts the capillarity of the soil. Many gardeners use rototillers to dice up this heavy sod structure. In doing so, they can spread the rhizomes rather than keeping them intact and effectively drying them up. An excellent tool for working new ground is a field cultivator with 16-inch sweeps. This tool undercuts the residue at a depth of four to six inches. This type of field cultivator can be used in conjunction with a power harrow or rotovator that stirs the soil and knocks off the roots of the sod residue.
3. **Observe and gather information.** By starting early to bring land into production, you will have an opportunity to learn about your soil. It is useful to know the cropping history of your farmland going back as far as possible. It is recommended to test your soil and correct the pH level, if necessary. One of the most important reasons for starting to prepare ground early is to gain a better understanding of the *variety and amount of weeds to anticipate your first season*. This window of time allows you an opportunity to express weeds and identify areas of your field that may be better suited for specific crops. Carrots and onions in particular benefit tremendously from being planted in areas with less weed pressure.

Starting a year ahead also allows ample time to measure or pace off a new field and mark row lengths and room necessary for headlands and roadways. Getting to know the texture, slope and general qualities of your soil a full season ahead will pay immediate dividends.

## *Tackling persistent weeds*

Even after a year of cover cropping, troublesome weeds may remain. Dealing with grassy areas—and Quackgrass in particular—can be a challenge, but there are cover-cropping methods that can greatly reduce, if not eliminate, these weeds. Here are several approaches that have worked for other growers:

- **Buckwheat – Buckwheat – Rye.**<sup>1</sup> This method will sacrifice growing a marketable crop for one season, but can be very effective. It also contributes nutrients and improves soil structure and tilth. Till the area in the spring as soon as the soil is dry enough. If the area is small, you can walk over it and remove exposed rhizomes and roots. When the weather turns warm and all danger of frost is past, plant the first crop of buckwheat. It will likely be necessary to till immediately before planting to eliminate grassy regrowth and early spring weeds that may have sprouted. Seed the buckwheat heavily (60 to 90 lbs./acre or 3 lbs. per 1,000 square feet). The buckwheat must form a dense canopy in order to be effective. Mow and till the buckwheat when it just begins to flower to prevent it from setting seed. Allow weeds to germinate and then till the area again and reseed buckwheat at the same heavy rate. This second crop should be tilled under in late summer or early fall, at least three weeks before first frost.

Let the area rest for one week before seeding winter rye at a rate of 90 to 120 lbs./acre or 3 lbs. per 1,000 square feet. It will germinate and grow a few inches before going dormant for the winter. In early spring, the rye will green up with new growth. Till in the rye at least two weeks before planting vegetable crops. In any case, do not let the rye grow much beyond 12 inches tall as it will become very difficult to till down with small-scale equipment.

- **Winter cover – Fallow – Winter cover.**<sup>2</sup> Anne and Eric Nordell in Pennsylvania grow back-to-back winter cover crops to manage weeds. A brief stint of aggressive summer tillage between the two cover crops keeps annual weeds from setting seed. First, yellow blossom sweet clover is overseeded at 20 to 24 lbs./acre into early crops such as onions or spring lettuce. Lettuce is overseeded a week or two after planting but before leaves open up to trap sweet clover seeds, while onions are overseeded near harvest. The Nordells walk up and down every other row with a hand-crank broadcast seeder. They harvest the cash crop, then let the clover grow through summer. Yellow blossom sweet clover (one of the best cover crop choices for warm-season nitrogen production) puts down a deep taproot before winter if seeded in June or July, observes Eric. Note: the clover alone will not suppress weeds. It works on their farm because of their successful management efforts over a decade to suppress overall weed pressure by crop rotation and varied cover crops. If you are dealing with a more weedy situation, a nurse crop planted with the clover would be recommended.

The following spring, the sweet clover grows until it is about knee-high in mid-May. Then the Nordells clip it just before it buds. They let the regrowth bloom to attract pollinators and beneficial insects to the field, before clipping it again in July. In early- to mid-July, the Nordells moldboard plow the sweet clover to kill it. They then leave the ground in bare fallow, working it with a spring tooth harrow to hit perennial weeds at the weakest point of their life cycle. Harrowing every two to three weeks brings weed roots and rhizomes to the soil surface, where they bake in the summer sun. The harrowing also kills flushes of annual weeds before they can set seed.

After five years of practicing this weed-killing rotation, the Nordells have been able to cut back on harrowing. In mid-August, the Nordells plant a second, overwintering cover crop. In this rotation, they seed a mix of rye and hairy vetch. They broadcast and lightly incorporate about 80 lbs. rye and 30 lbs. vetch per acre. The rye

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1. Rodale Press, *What Weeds Don't Want You to Know: Weed Ending Secrets*. Emmaus, PA: Rodale Press Inc., 1994.

2. Andy Clark, editor, *Managing Cover Crops Profitably*. College Park, MD: USDA SARE Outreach, 2012. Accessed 9/4/18, [www.sare.org/content/download/29733/413984/Managing\\_Cover\\_Crops\\_Profitably.pdf?inlinedownload=1](http://www.sare.org/content/download/29733/413984/Managing_Cover_Crops_Profitably.pdf?inlinedownload=1)

establishes quickly, putting on good growth both above and below the surface, while the vetch fixes nitrogen. Another combination is yellow, red and white clover in a 2:2:1 ratio by volume. Rye and vetch are a popular combination to manage nitrogen. The rye takes up excess N from the soil, preventing leaching. The vetch fixes additional nitrogen, which it releases after it is killed the following spring prior to planting the next cash crop. With the August seeding, the Nordells' rye/vetch mixture produces most of its biomass in fall. The Nordells plow the rye/vetch mix after it greens up in late March to early April, working shallowly so as not to turn up as many weed seeds. They forego maximum biomass and N for earlier planting of their next cash crop—tomatoes, peppers, summer broccoli or leeks—around the end of May.

- **Spring fallow – Pumpkins – Fall/winter cover.** This method lets you grow a marketable crop. First, allow weeds/Quackgrass to grow in the spring until six- to eight-inches tall. At this point, the Quackgrass begins transferring energy resources away from its roots and into producing a seed stalk and head. While it is vulnerable, moldboard plow and disk the area lightly. A series of cultivations with a spring tine harrow (field cultivator) will knock back regrowth, bring rhizomes up to the surface to dry out, and can also drag rhizomes to the edge of the field. Pumpkins are then transplanted into the field. Cultivate again as necessary before the pumpkins begin to vine. The pumpkin vines will quickly form a closed canopy and suppress weed growth. You may want to consider a closer spacing than normal (four to five feet between rows rather than six feet) to be assured of a quick-forming, dense canopy. As the pumpkin vines die back in the fall, a late fall cover crop (oats and peas, rye or rye and vetch) can be overseeded. This method requires a sufficiently long growing season to achieve a decent pumpkin harvest (the transplants may not go into the field as early given the series of cultivations prior to planting), but it has been used successfully in southern Wisconsin.

### *Mulching*

Another non-chemical means of removing weeds is mulching heavily for a year. Note: this method is more feasible and appropriate for smaller scale gardens. First, apply a thick layer of organic mulch (hay, leaves, even fresh manure). Then, top this with some kind of material that will block out light (black plastic, layered newspaper or old tin roofing). Leave this on for one full year. An exception is plastic. This should be removed before winter or else it will begin to break apart. After the spring thaw, remove the covering and pull back the mulch. Check to see if any roots or rhizomes survived their year of darkness. The soil should be ready for planting, but if not, cover the garden plot back up for another year. For additional ideas about using tarps to kill sod or cover crops, see the section titled “Cover crop-based reduced tillage systems.”

### *Plan only a fall garden*

If you are unable to cultivate new ground during the preceding season, a garden is still possible, albeit more difficult. One consideration would be to not push for a spring crop. Rather, give yourself time to get the land adequately ready and plan for a summer or, better yet, a fall garden. On a small scale, almost anything is possible. One can plant into spring-plowed sod within three weeks. However, yields are usually compromised and weed pressure can be significant.

Check in with your county extension office to see if they have information on cover crops. And don't be afraid to ask neighboring farmers for advice. Many will offer it whether you ask for it or not! ***Remember to start small, be realistic and enjoy the work.*** Good luck!



