



Cover Crops on the Intensive Market Farm

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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 their ability to protect and enhance soils, cover crops are considered a fundamental aspect of any sustainable cropping system. The benefits of cover crops extend beyond soil health, however, as described below. In particular, more and more growers are realizing the pest management benefits of cover crops.

This publication is meant to serve as a practical guide to using cover crops in small- to moderate-size fresh market vegetable operations—farms that may not always have access to “conventional” equipment when it comes to managing cover crops. For more complete and thorough information on cover cropping principles, see the Resources section on page 11.

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 vital role. As vegetable grower Dan Guenther notes, “vegetable farms export a significant percentage of their nutrients in the form of harvested crops each year.” By using cover crops and rotations, growers can begin to “close the nutrient loop” on their farms and rely less on purchased and imported fertilizers. The soil health benefits of cover crops include:

- protection against soil erosion
- building and maintaining both active and stable organic matter
- improving soil structure and tilth
- improving the capillary action within soils (the upward movement of water in soils)
- increasing the biological activity in soils
- the fracturing of hardpan by deeply rooting cover crops
- the addition of nitrogen to the soil by legume cover crops (peas, clovers, vetch, etc.)



Cover crops at work: winter-killed oats on the left and rye on the right

On market farms using organic and other sustainable agricultural practices, cover crops also can play an extremely important role in managing weeds, insects and diseases. One fundamental way to minimize the impact



Oats and peas are a great cover crop combination

of pests is to ensure overall plant and crop health. By improving soil health and fertility, cover crops contribute to pest management. However, there are more direct benefits as well.

Cover crops can:

- smother or suppress weeds
- break insect and disease cycles, and provide habitat, pollen, and nectar for beneficial insects

Additional benefits of cover crops include:

- providing animal feed
- providing a source of mulch
- adding beauty to the farm
- helping balance the stress of increased production with the satisfaction of soil building

Questions and Challenges

The benefits of cover crops seem clear. But questions and challenges remain as vegetable growers at different scales of operation try to maximize those benefits, given the limitations of time and equipment. One challenge, as outlined by Dan Guenther at the Upper Midwest Organic Farming Conference (1), is the relationship between soil building and tillage. “The most commonly employed implements on most market farms—namely the rototiller, moldboard plow, and disc—can damage soil structure,” says Dan. “It is easy to overwork the soil, especially when growing on a small scale and relying on a rototiller for field preparation.” In response to the situation, Dan asks, “How can green manure crops best be incorporated? Can tools and implements be redesigned to deal effectively with higher amounts of surface residue (or ‘trash’)? Can the amount of exposed soil area in a market garden be reduced?”

Another challenge facing market growers is how to balance soil building and fertility management with the demands of succession planting and harvesting. The demands of making a living on the land may not always align with the needs of the soil. Furthermore, many market growers lack enough land to develop adequate cover crop rotations—especially longer term rotations involving season-long cover crops. Market growers who farm near urban areas with high land prices can be pressured into pushing the land to produce as much as possible.

Finally, how can growers maximize the pest management benefits of cover crops? There is much anecdotal evidence about cover crops reducing weed, insect and disease pressure, but far more research and experimentation is needed.

The Market Farmer's Advantage

While market farmers face the real challenges of time availability, lack of necessary equipment, land availability, and economic pressures, they have some advantages as well. Dan's list includes:

1. Short season vegetables lend themselves perfectly to cover cropping.
2. Small fields are ideal for experimentation.
3. Cover cropping can create curiosity and open doors with neighboring "conventional" farmers.
4. Cover crops keep a garden/farm looking lush and dynamic throughout the full length of the 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 growers make the best use of cover crops in their farming systems.

Equipment Needed to Effectively Manage Cover Crops

Seeding: A simple broadcast seeder can be used on a small (garden) scale with good success. A drag, harrow, or cultipacker helps cover seeds and provides adequate seed to soil (seed to moisture) contact. Many small farms use old six-foot grain drills to plant cover crops. These can be found at auctions or used equipment dealerships for a reasonable price (\$100-400). With a drill, more uniform stands can be achieved than by broadcasting. Even with a drill, a cultipacker will hasten germination.

Residue management: A flail chopper (or stalk chopper) is the implement of choice for cutting or clipping cover crops before the residue is incorporated into the soil. A small (6') used flail chopper can be purchased for around \$300 to \$1,000. These require a tractor with sufficient horsepower, 30 to 40hp. Tractor-mounted sickle bar mowers are less expensive but do not chop as finely and can leave a relatively thick mat of vegetation. Without tractor-mounted implements, it is wise to clip more often so as to avoid a tall, dense stand. A good tool for clipping at a small scale is a walk behind sickle bar mower—although these can be expensive. Rotary mowers can also be used, especially for cover crops that become



A small seed drill works well for planting cover crops



A flail chopper works well for clipping cover crops

too tall or dense for a flail chopper. In a small market garden, it is best to stick with low-growing, “succulent” covers such as oats, peas, and low-growing clovers. Avoid dense, matting cover crops such as hairy vetch that are very difficult to deal with using small scale equipment. Appendix A on page 12 includes notes on which cover crops are best suited for smaller scale growers.

Tillage: Cover crops are most commonly incorporated with rototillers at smaller scales and tractor-mounted rotovators at larger scales. Spaders (walk behind or tractor mounted) can also be used. These are less damaging to soil structure than rototillers. A traditional approach would be to turn cover crops under using a moldboard plow and then follow this with a series of cultivations using some combination of a disc, field digger, and spike tooth harrow. Turning the cover crop under, however, places it in an anaerobic environment (lacking oxygen)—not the ideal condition for decomposition. Inverting the soil also brings weed seeds to the surface where they can germinate. Field diggers and power harrows are more gentle on the soil and can be used effectively. The following basic sequence, used by Dan Guenther at Common Harvest Farm, will incorporate most cover crops and create a nice seed bed:

1. First, flail chop the cover crop.
2. At least 24 hours later, follow with a five-foot field digger with sweeps that operate at four to six inches deep.
3. Follow with a Lely Roter power harrow (this stirs the soil and lightly incorporates the residue without inverting the soil).
4. Finally, use a chisel plow (that operates at 18 inches deep) to aerate the soil and lay out your beds.

Between stages 3 and 4, you can elect to express some weeds and use the harrow again to create a clean seed bed.

At a small scale, rototillers or small spading tillers are about the only options (aside from hand digging). Because rototillers can be damaging to soil structure—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 find a neighboring farmer to do primary tillage for you (with a tractor-mounted digger and/or chisel plow) before using a rototiller 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. It is also important to have seed on hand and a well thought out plan. The following section provides several sequencing options for planting cover crops.



A field digger and spike tooth harrow can be used to prepare the ground for seeding

Cover Cropping Sequences

There are several different windows of opportunity for planting cover crops and a variety of cropping sequences, based on the length of the cropping season. For example, in a field or section of a 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 winter kill, making it easy and quick 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 perennial cover such as winter rye works well. This strategy will prevent soil erosion and keep weeds in check during the early spring until it is time to till and plant. There are many different options for a full season of over cropping. The following are sample sequences that Dan Guenther and other market growers in the Upper Midwest have found useful and successful.

Cover crop options by season (more specific planting times are included in Appendix A)

Spring	Summer	Fall
Mow fall seeded rye/vetch	Rape	Rye
Oats and peas	Millets	Rye and vetch
Nitro alfalfa with oats	Sudangrass	Winter rape
Berseem clover	Oats and peas	Peas
	Buckwheat	Turnips
	Clovers	Oats
	Fallow cycle (for weed control)	

Given the diversity on most fresh market vegetable farms, there are many different potential cover cropping sequences depending on when a cash crop is planted and how long it remains in the ground. In addition to fitting cover crops in before and after a cash crop, season-long cover cropping (full fallow season) is a highly recommended practice to improve soil health and to address weed, insect and disease problems.

Cover crop options by length of garden crop season¹

Full Fallow Season		
Spring	Summer	Fall
Rye from previous fall (2-3 bu/acre)	Buckwheat or Sudangrass (100#/acre)	Oats and peas (2:1 ratio)
Crop residue from previous fall spring sown oats, peas, vetch (2:2:1 ratio)	Buckwheat	Winter rye (100-150#/acre)
Oats and Nitro alfalfa	Mow oats	Winter rye
Clover or clover grass mixture planted previous July	Mow, plow, fallow	Rye/vetch

Early Spring Garden (peas, radishes, lettuce, spinach, etc.)		
Spring	Summer	Fall
Winter killed oats Work ground early Plant spring garden	Early to mid July Buckwheat or oats and peas	Winter rye
Fall plowed field	Clover, oats/peas, Sudan or millet	Rye/vetch

Main Season Garden (peppers, tomatoes, onions, leeks, vine crops, etc.)		
Spring	Summer	Fall
Rye or rye/vetch from previous fall	Garden planted in May/June	Winter rye or oats
Clover or clover grass mixture	Garden planted in May/June	Winter rye or oats

Fall Garden (fall brassicas, carrots, lettuce, etc.)		
Spring	Summer	Fall
Clover or rye from previous fall or spring sown oats and peas	Fall garden planted July and August	Leave crop residue or seed winter rye on crops harvested before Oct. 1

¹Adapted from a handout created by Dan Guenther, Common Harvest Farm, Osceola, WI

Cover Cropping Sequence Notes:

- Between each cover crop and garden crop is a one- to three-week fallow cycle as a transition. This fallow cycle is an opportunity to express weeds. Just after weed seeds germinate, a shallow cultivation provides a stale seed bed for the coming garden crop. Over time, these fallow periods can be reduced as weed pressure diminishes.
- Garden crop foliage should be flail chopped quickly after harvest is complete in order to seed an appropriate cover crop.
- Most cover crops (except buckwheat) are clipped one to three times to encourage tillering (tillers are shoots that sprout from the base of grasses). Clipping also prevents the cover crop from going to seed and becoming a weed in the next garden crop. It is also important to clip cover crops to avoid a dense stand that makes cutting and incorporating difficult using smaller scale equipment. This is especially true for Sudangrass and millets.
- Buckwheat can become a weed problem if the seeds are allowed to mature. The challenge is to walk a fine line between providing flowers for pollinators and clipping the stand before it has set too much seed.
- Winter rye is an aggressive plant that can regrow under moderately moist conditions. It is best to clip rye before it gets too tall. If the rye exceeds 10 to 12 inches before the first clipping, its regrowth potential has diminished.
- Annual rye and perennial rye are two different things. If the goal is weed suppression, an allelopathic effect can be achieved from cereal (grain) rye. Allelopathy refers to chemicals in some plants that inhibit the germination or growth of other plants. Unlike cereal rye, ryegrass has no allelopathic effect. The allelopathic effect lasts four to six weeks after turning it under ... well worth remembering if you plan to seed a market crop behind it.



Buckwheat can become a weed problem if the seeds are allowed to mature

Maximizing the Pest Management Benefits of Cover Crops

Research and experimentation on using cover crops to manage pests is increasing as both growers and researchers recognize the potential for biological and farming system approaches to address pest management challenges. Specific cover crops, cover cropping sequences, and practices have been identified that can help address disease, insect and weed problems. However, some weed, insect and disease suppression research results have proven difficult to replicate. Some information about pest management benefits is purely anecdotal. The following is a partial overview of what is known about using cover crops to manage pests, but growers 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. The latter is called “allelopathy.” Weed suppression by cover crops varies by 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, or even stimulate weed growth. Accordingly, shifts in weed populations can occur when using cover crops in annual rotations. Because of this, it is best to match cover crops and management to the particular weed problems in a given situation (2).

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 but they can be used in combination with grains and grasses to achieve both weed suppression and nitrogen fixation. To achieve the best results,

drilling is the recommended planting method (rather than broadcasting) because this hastens germination and results in a more even stand. Higher seeding rates (by as much as 50%) are also recommended (2, 4).



Clover interseeded in corn helps keep down weeds

The tillage required to incorporate winter cover crops can bring new weed seeds to the surface, however. Some growers are experimenting with leaving cover crop residues on the surface as mulch, but this can create obvious challenges with direct seeded crops (particularly those that require a fine seed bed) as well as transplanting. Summer weeds can be smothered with warm season annual cover crops such as buckwheat or Sudangrass, or by season-long cover crops.

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 (4). 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 observed shortly after killing and/or incorporating cover crops (2). Because of this effect, it is wise to wait three weeks or so after incorporation before planting direct-seeded crops.

Many new vegetable growers face enormous weed pressure as they convert old hay fields, pastures, and lawns into vegetable gardens. Appendix B on page 16 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 insect pests and beneficials by providing shelter and food as well as making cash crops more difficult to locate. Management is complicated given that cover crops can act as a source and/or a sink for beneficial and pest insects (3). Given this complexity, careful observation, planning and timing are important.



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

The simplest strategy to achieve insect management benefits is to provide a diverse array of vegetation (3). Diversity in plant species and habitats contributes to overall farm diversity and helps ensure a balanced insect community, including beneficial predators. Increasing diversity can be achieved by:

- selecting a diversity of cash crops
- utilizing a diversity of cover crops (such as planting both buckwheat and Sudangrass as summer cover crops since each has unique insect associations)
- 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 beneficial habitat 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 packets 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 types of 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 (3).

The following table, published by Plotkin, list insects (both pest and beneficial) attracted to common cover crop species.

Insects attracted to common cover crop species

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	Ladybugs	Aphids

In addition to above-ground interactions, plants can impact soil-dwelling 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 reveals 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 (4).



Peas grow in a new seedbed where cover crops have been incorporated

Other species may actually increase detrimental species. Vetch can cause increases in root-knot nematodes as well as the soybean cyst nematode.

Cover Cropping for Disease Management

Cover crops can help 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* (4). 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 (4).

Seed sources

Some cover crop seed, such as oats and rye, can be bought from neighboring farmers. Other types, such as oats and peas, clovers, and sorghum-Sudangrass, are readily available at a local co-op elevator or feedstore. More specialized seed, such as hairy vetch, rape, ryegrass, berseem clover, annual alfalfa, and millet, is available from various seed companies. Upper Midwest sources include:

- Premium Seed Co., Shakopee MN, 800-752-0407
- Albert Lea Seed House, Albert Lea, MN, 800-352-5247
- L.L. Olds Seed Co. Madison, WI, 800-356-7333

Citations

1. Dan Guenther, Common Harvest Farm, 212 280th St. Osceola WI 54020; 715-294-2831. Dan has given several presentations on cover crops at the Upper Midwest Organic Farming Conference. An earlier version of this publication was co-authored by Dan and this paper borrows extensively from his workshop handouts.
2. *Cover Crop Weed Suppression in Annual Rotations*, Edward Peachy et al., Oregon State University Extension Service, 1999. www.eesc.orst.edu
3. *Using Cover Crops and Green Manures to Attract Beneficial Insects*, Jeremy Plotkin, University of Connecticut Integrated Pest Management Program. www.hort.uconn.edu/ipm
4. *Managing Cover Crops Profitably*, Sustainable Agriculture Network, 1998. www.sare.org

Other Recommended Resources

- Anne and Eric Nordell; Rd. 1, Box 205, Trout Run, PA 17771; (717) 634-3197. 52-minute video and booklet on cover cropping and soil building, \$10.
- Appropriate Technology Transfer to Rural Areas (ATTRA). Call and ask for free information about cover crops and green manures. 1-800-346-9140. www.attra.org
- *Green Manuring: Principles and Practice*, 1989, Woods End Agricultural Institute.
- *Green Manuring: Principles and Practice*, 1927 (out of print and hard to find but worth the search).

Appendix A: Management Guide for Specific Cover Crop Species*

Crop	Characteristics	Planting Time	Seeding rate:		Management and Comments	Suitable for small scale?
			#/1000ft ²	#/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 use or market for hay. If grown, Nitro is the best choice for market growers.	No. Heavy equipment needed for incorporation.
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.
Yellow Blossom Sweet-clover	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 veg. crop or 1-year soil building crop. Mix with oats for added biomass. Cheap and easy to plant.	No, requires plowing to incorporate.
Berseem Clover	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 in. 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 1-season soil building.	Yes. Can be controlled by mowing and no heavy tillage is needed.

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

Crop	Characteristics	Planting		Seeding rate:		Management and Comments	Suitable for small scale?
		Time	#/1000ft ²	#/acre			
Soybean	Upright bushy legume. Must be planted in warm soil. Strong N fixer. Grow on most soils. Use soybean inoculant.	Late May through early August	2 to 4	50 to 150	Drill or harrow in. Excellent for planting after an early vegetables; mowed residue leaves friable seedbed next spring. Early plantings best incorporated by Sept. to maximize benefits. If field is new or weedy plant a fast-growing cover crop first (buckwheat). Let beans grow 80-100 days to maximize biomass. Can be plowed, disked or mowed (leaving residue on the surface). Cost, availability, rapid growth and N fixing make it an excellent choice.	Yes.	
Field Peas	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.	
Annual White Clover	Similar to yellow-blossom sweetclover. Deep taprooted 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.	
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 to 140 (1-2 bushels) if mixed; up to 4 bushels 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.	

Crop	Characteristics	Planting Time	Seeding rate:		Management and Comments	Suitable for small scale?
			#/1000ft ²	#/acre		
Buck-wheat	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.
Japanese Millet	Fast growing summer annual grass. Limited frost tolerance and will winterkill. Requires fertile soil for rapid growth. Tolerates frequent clippings and makes excellent forage/hay. Tolerant of both droughty and wet soils.	Late spring through August	1 to 1-1/2	25 to 30	Drill or broadcast and till shallow. Manure or fertilizer for best results. When intended as summer long trap crop, mowing is important. Clip before heading out (~60 days) and leave 3" of stubble. Not suitable for mixing but a good choice for a full season smother crop following early vegetables. Good choice for cleaning weedy fields or converting land to vegetable production. Also excellent if there is a need for mulch or feed.	Yes, but make sure soil is fertile enough to support multiple cuttings.
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.
Forage brassicas (cabbage family crops)	Most common types are turnips, rape and kale. Use readily available cheap varieties such as Purple Top Turnips. Will tolerate low fertility but do best under fertile conditions. Rape's long tap root loosens heavy soils.	Spring, summer or fall	1/4 for turnips 1/3 for rape or kale	5 to 7 for turnips 8 to 15 for rape or kale	Drill or broadcast with light incorporation. Not recommended if vegetable brassicas are grown nearby. Will tolerate mowing or grazing. Will trap N and other nutrients and provides ground cover after winterkill. Value as a cover crop is limited unless livestock forage is needed. Best used following early vegetables, mixed with summer legumes, or in mixes with peas, oats, vetch, etc. Can also be used under sweet corn.	Doesn't require heavy equipment but value is limited unless livestock forage is needed.

Crop	Characteristics	Planting Time	Seeding rate:		Management and Comments	Suitable for small scale?
			#/1000ft ²	#/acre		
Hairy Vetch	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.
Other Vetches	Less winter hardy than Hairy. All require pea/vetch inoculant.	Same as Hairy	Same as Hairy	Same as Hairy	Similar to Hairy but not as exacting. Seed prices are higher.	Yes.
Grain Rye (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.
Annual Ryegrass	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 compliments 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.

Appendix B: Bringing Land into Production and Tackling Persistent Weeds*

Getting off to a good start is important in any new enterprise. In organic vegetable production, 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 handout 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.

In Dan Guenther's experience—after relocating his farm operation five times—it is difficult to find certifiable organic ground that has been recently cultivated. As a result, many market growers are forced to follow a deeply rooted sod. It is also 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 a full season before you intend to garden on this land. Dan likes to bring new land into production in July or August of the preceding year. This allows time to cultivate the ground a number of times so that he can dry up the rhizomes in the sod. By starting this process in mid-summer, he also avoids having too much exposed ground during the traditionally rainy months of May and June. In most cases he then follows this four- to six-week cultivating process with a fall-seeded cover crop of winter hardy rye. The fast-growing rye assists in breaking up the remaining residue.

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 dry them up. Dan's main tillage tools include a 5-shank field cultivator with 16" sweeps. This tool undercuts the residue at a depth of four to six inches. He then follows with a Lely Roterra (power harrow) that stirs the soil and knocks off the roots of the sod residue.

3. **Fall apply nutrients.** By starting early to bring land into production, you will have an opportunity to learn about your soil. Dan likes to begin with a cropping history going back as far as possible. He may choose to have a soil test conducted, but if a leguminous sod precedes the crop he may not. Correcting the pH level, if necessary, is important. Dan typically fall applies turkey manure at a rate between 5 and 8 tons/acre. He then covers the ground with a fall cover crop. But he often leaves a small area fallow. This allows him to plant garlic the first fall as well as have some ground bare for the earliest spring crops.

"I cannot underscore enough the importance of starting early with this process," says Dan. One of the most important reasons for this 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.

Dan also likes to use the late fall and early winter to 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 to you.

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.**¹ This method will sacrifice growing a marketable crop 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 area is dry enough. If the area is small, you can walk over the area 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 again immediately before planting to eliminate grassy regrowth and early spring weeds that may have sprouted. Seed the

buckwheat heavily (60-90 pounds per acre or 3 pounds per 1,000 square feet). The buckwheat must form a dense canopy in order to be effective. 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 3 weeks before first frost.

Let the area rest for one week before seeding winter rye at a rate of 90-120 pounds per acre or 3 pounds 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 as it will become very difficult to till down with small-scale equipment.

- ***Winter cover – Fallow – Winter cover.***² 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 sweetclover is overseeded at 20 to 24 lb./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 sweetclover (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.

The following spring, the sweetclover 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 sweetclover 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 in 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 pounds rye and 30 pounds vetch per acre. The rye 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 cash crop—tomatoes, peppers, summer broccoli or leeks—around the end of May.

- ***Spring fallow – Pumpkins – Fall/winter cover.*** This method allows a marketable crop to be grown. 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 digger) 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 on smaller scale gardens. First, apply a thick layer of organic mulch (hay, leaves, even fresh manure ... but only if the area won't be producing crops for a year). 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.

Plan only a fall garden

If you are unable to cultivate the 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.

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!

* Prepared by John Hendrickson, Center for Integrated Agricultural Systems, UW-Madison and Dan Guenther, Common Harvest Farm. 2002

¹ Adapted from *Weed Ending Secrets*, Rodale Press Inc., Emmaus, PA, 1994.

² Adapted from *Managing Cover Crops Profitably*, Second Edition, by the Sustainable Agriculture Network, reprinted 2000, SAN, Beltsville, MD, pp. 34-42. Complete text: www.sare.org/handbook/mccp2/index.htm

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