Reduced Tillage and Cover Cropping Systems for Organic Vegetable Production

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Virginia Association for Biological Farming Information Sheet

Number 9-07 4/01/07 http://www.vabf.org/pubs.php

Healthy living soils comprise the foundation for organic food and fiber production. Sustainable soil management integrates cover cropping, other organic and natural mineral inputs, and judicious tillage practices to obtain high crop yields (soil productivity), while building and maintaining high soil quality (long term production capacity). For more on biologically based soil building, see the VABF Information Sheet #2-06, *Caring for the Soil as a Living System.*

Cover crops play a key role in organic vegetable production because they protect and feed the soil, improve tilth, promote nutrient availability and balance, reduce weed pressure, and provide habitat for beneficial insects. Organic exudates from living cover crop roots sustain beneficial root-zone bacteria and fungi during off-seasons in annual vegetable rotations. For more on the benefits of cover crops see the VABF Information Sheet #1-06, *Cover Cropping: On-Farm, Solar Powered Soil Building.*

Tillage stimulates soil life, accelerating residue decomposition and release of soluble nitrogen (N) and other crop nutrients – and burning up organic matter in the process. Clean cultivation can facilitate crop establishment, but prolonged bare-soil periods increase the risk of erosion and crusting, depress soil biological activity and open niches for weed growth. Since 2003, the Virginia Association for Biological Farming has participated in a research effort coordinated by Professor Ron Morse and colleagues in the Horticulture Department at Virginia Tech to develop cover crop-based, reduced-tillage systems for organic vegetable production.

Contents:

The Organic Grower's Dilemma

Because organic production excludes the use of synthetic herbicides, organic vegetable growers rely on timely tillage and cultivation for weed control. Initial tillage to prepare the seedbed is normally followed by two or three additional cultivations to control weeds during crop establishment. Repeated tillage can damage soil structure, disrupt soil life, degrade organic matter, and increase the risk of soil erosion. Nothing is more devastating for the organic farmer than watching the farm's natural capital wash or blow away. Yet losing a crop to weeds because a timely cultivation has been missed, is little better.

Organic mulches, such as straw or spoiled hay, can reduce the need for cultivation, protect soil from erosion and crusting, and replenish organic matter. However, purchasing and spreading these materials may not be economically feasible in farm-scale production. Furthermore, mulch hay can carry weed seeds, and heavy annual applications may lead to soil nutrient imbalances.

Soil scientists in the USDA Natural Resources Conservation Service (NRCS) have developed a Soil Conditioning Index based on three key determinants of soil quality in agro-ecosystems: annual biomass input (cover crops and other residues), soil cover (vegetation or mulch) over the season, and tillage (the less, the better). This highlights the organic grower's dilemma: *how to manage weeds effectively without tilling the soil to death.* Researchers and growers are now seeking to address this challenge by:

- Maximizing the use of cover crops.
- Planting vegetables no-till into cover crop residues.
- Reducing frequency and intensity of tillage in general.

First Step: Maximize the Use of Cover Crops

The first step toward improving soil quality is to maximize cover crop biomass production within the existing crop rotation. Many vegetable growers plant winter cover crops such as cereal rye, hairy vetch and crimson clover in rotation with warm season vegetables like tomato, corn or squash. Not as many farmers grow cover crops at other times of the year, yet diversified crop rotations provide year-round opportunities to build soil health through cover cropping. Examples include:

•Oats, barley, field peas or vetch planted in early spring can add substantial organic matter ahead of July plantings of squash, cucumber or beans.

•Buckwheat can add organic matter and suppress weeds during short (30-45 day) time niches during the frost-free period.

•Millets, sorghum-sudangrass, cowpeas and soybeans can add tremendous biomass during a 60-day fallow between spring and fall vegetables.

•Non winter-hardy cover crops planted in July or early August and grown until they frost-kill can add biomass and protect the soil ahead of early spring vegetables.

The benefits of cover cropping can be maximized by using optimum planting dates, rates and methods, and by growing the cover crop to maturity (flowering but not setting mature seed). Guidelines for successful cover cropping, and information on a wide range of summer, cool-season and winter-hardy cover crops are given in the VABF information sheets #1-06, *Cover Cropping: On-farm Solar Powered Soil Building,* #3-06 *Cover Crops for All Seasons* and #4-06 *Using Manually-Operated Seeders for Precision Cover Crop Plantings on the Small Farm.*

Cover crops are most often incorporated into the soil as a green manure prior to planting the next vegetable crop. Mow heavy cover crops a few days before tilling. At the garden scale, scythe or weed-whack the cover crop and use clippings to mulch an adjacent bed or to make compost.

Tilling in cover crops (green manure) has some limitations. The freshly incorporated plant material makes the soil temporarily unfavorable to seed germination, so wait three to four weeks before planting. In a tight cropping schedule, this waiting period can delay vegetable planting beyond the optimum date, or necessitate earlier termination of the cover crop. Killing an annual cover crop three or four weeks early can cut biomass production by half.

Tilling in the cover crop accelerates soil organic matter decomposition and stimulates weed seed germination, thus compromising some of the benefits. Nevertheless, annual incorporation of high biomass cover crops can help build and maintain high soil biological activity.

Second Step: Plant Vegetables No-Till into Cover Crop Residues

In "organic no-till," an annual cover crop is grown to full bloom or early (not viable) seed formation, and killed mechanically by mowing, rolling, roll-crimping, or undercutting to form an *in situ* mulch, through which vegetables are planted without tillage. A good cover crop mulch can suppress weed growth until the vegetable crop has passed through its "critical weed-free period," usually the first five to seven weeks after planting for vigorous summer vegetables and transplanted brassicas. Tomato, pepper, brassica and pumpkin starts have been grown successfully in these systems, as have seed potatoes, garlic, onion sets and direct-sown peas, beans, corn and cucurbits. Small-seeded crops like lettuce, carrots and spinach may be stunted by allelopathy (production of natural substances that inhibit seedling growth) from the cover crop.

Over the past 20 years, farmers have had good results with no-till tomatoes and other summer vegetables in winter cover crop residues. Other cropping sequences that have given good results include early spring cover crops (oats, field peas) rolled/mowed in June-July for midsummer vegetables, and summer cover crops (millets, soybean, buckwheat) rolled/mowed in August for fall vegetables. Frost-killed residues of non-hardy cover crops for no-till garlic (planted in October) or spring vegetables (planted in March or early April) have given mixed results thus far.

No-till cover crop management maximizes cover crop biomass and soil cover, minimizes delays between the cover crop and the following vegetable, and helps control annual weeds. No-till reduces germination from the soil's weed seed bank, and the mulch itself retards weed growth through physical hindrance and allelopathic effects.

Generally, a grass + legume cover crop biculture is grown in order to realize both N fixation by the legume, and persistent, weed-suppressive mulch from the grass. In *zone planting*, the legume is planted in the location of future vegetable crop rows (e.g. the tops of raised beds) to provide N to the vegetable, and the grass is planted

Figure 1. The triticale cover crop (left) has accumulated about 2.3 tons/acre biomass and does not completely cover the ground. Spring weeds will likely grow through its residues before a no-till vegetable can get established. No ground is visible through the vigorous biculture of triticale + Austrian winter peas (right), which has reached 4.8 tons/acre, and will provide an effective, weed-suppressive mulch.

in the alleys and traffic lanes to maximize between-row weed suppression and moisture conservation.

Another variant of zone planting is a killed cover crop in the grow-zone, with alleys in a living mulch maintained by mowing. Examples include mow-killed soybean in the grow zone with alleys planted in browntop millet or sorghum-sudangrass (which regrow after mowing), or winterkilled legume or radish in the grow zone with rye in alleys. Although radish is not a legume, its succulent N-rich foliage decomposes rapidly after winterkill, yet suppresses winter weeds through an apparent allelopathic effect. Spring spinach and peas have thrived after radish in preliminary trials. Note that radish is *not* recommended in rotations with brassica vegetable crops due to the risk of clubroot and other diseases. In all these examples, the living mulch in alleys maintains weed suppression and can provide additional mulch material during vegetable production.

Four Keys to Success in Organic No-Till Planting:

•Establish high-biomass, solid-stand annual cover crops.
•Kill the cover crop, leaving a high residue, uniformly distributed mulch.
•Establish the vegetable crop with minimum disturbance of the killed mulch layer.
•Practice year-round weed management.

A good cover crop containing at least three tons (dry weight) aboveground biomass per acre is needed to obtain adequate weed suppression during the vegetable's minimum weed-free period. A *thick, solid vegetative growth* about three to four feet tall usually contains three tons per acre. The ground should not be visible when looking down on the cover crop from above.

Most annual cover crops can be killed at the late-bloom or early seed-development stages by mowing to a short stubble height. Exceptions include Japanese millet, browntop millet, sorghum-sudangrass hybrid, and possibly cowpea. A flail mower leaves the most uniform mulch, though the finely chopped residues break down fairly quickly, so that weed suppression may be shorter lived than with unchopped residues. Bush-hog rotary mowers tend to leave the mulch in windrows or random piles. If blades are kept sharp, the bush-hog can windrow residues uniformly enough for strip tillage (discussed later). At the garden scale, the cover crop is cut with a scythe or weed whacker, after which vegetables are planted manually.

Rye, barley, crimson clover, oats, buckwheat, pearl millet, foxtail millet and sunnhemp can usually be killed by *rolling*. Mulches of rolled cover crops persist longer and suppress weeds more effectively than flail-mowed residues. Rolling leaves cover crop stems oriented parallel to the direction of travel, which

Figure 2. The roller-crimper (left) has been developed specifically for no-till management of high biomass cover crops. The flail mower (right) is a versatile tool, in that it can be used to generate even, finely chopped mulch, or can be operated with the PTO off to function as a roller, as shown here.

is important for mechanical no-till planting. Vetches, peas and soybeans grown in biculture with these other cover crops will regrow somewhat after rolling. This regrowth can be managed by mowing a week or two later. Research teams in Virginia, Pennsylvania and Alabama have developed *roller-crimpers*, specifically designed for mechanically killing cover crops. The crimping action reduces regrowth. Rolling can also be accomplished with a cultipacker, or a flail mower with the PTO off. Even a tractor-mounted rototiller, again with the PTO off, can flatten and orient a stemmy cover crop, though two or three passes may be needed.

A third way to terminate cover crops without herbicides is frost-kill. July-planted sorghum-sudangrass, cowpea, pearl millet, soybean, and sunnhemp; and August-planted oats, radishes, and some varieties of field pea can produce substantial biomass before they winter-kill.

No-till vegetable planting can be the most challenging step, especially for small-scale farmers working with limited financial resources. Dr. Morse has developed the subsurface tiller-transplanter (SST-T), a

Figure 3. The No-Till Planting Aid (left) prepares a narrow slot in the soil for planting. This snap bean crop (right) was planted in August with a push seeder into furrows prepared with the planting aid. The cover crop residues helped the vegetable by conserving moisture during a hot, dry season.

tractor-drawn one- or two-row implement that parts the mulch, loosens a 2-inch wide by 6-8-inch deep slot in the soil, sets vegetable starts or seed potatoes, firms the soil around them, lays drip tape, and applies water or liquid (organic) fertilizer to the seedling, all in one pass. This is a major capital investment ($7-10,000 per row). For smaller farms, he has developed one- and two-row no-till planting aids (NTPA), which are much less expensive and can be drawn by a small (20-40 hp) tractor.

The NTPA, consisting of a heavy coulter and shank assembly, with an optional wavy coulter mounted behind the shank, slices the mulch and leaves a narrow (2-3 inch wide) swath of prepared soil. Vegetable starts or seeds are then planted manually or with conventional planting equipment.

Both the SST-T and the NTPA can function properly only when cover crop residues are oriented parallel to the direction of travel (by rolling) or chopped finely by flail mowing. Freeze-killed residues of stemmy, high-biomass cover crops should be rolled just prior to mechanical no-till planting.

Organic no-till vegetable planting should only be attempted in fields with good year-round weed management, few or no perennial weeds, and light to moderate seed banks of annual weeds. Keep the ground covered by vegetation and/or thick mulch as much as possible, and destroy weeds before they set seed. Problem weeds, such as nutsedge, Johnsongrass, docks, Bermudagrass and Canada thistle should be controlled before initiating no-till systems.

Organic No-Till Pitfalls

Because a cover crop mulch can delay soil warming and crop maturity, no-till planting is not recommended when earliness is an important objective, such as tomatoes for an early market. Cool wet soil conditions under the mulch can exacerbate problems with slugs, damping-off and some other fungal diseases. These problems occur most often in heavy soils, in cooler climates such as higher elevations in the Appalachian region, and in early spring vegetable plantings.

The organic grower will need to pay particular attention to crop N nutrition in no-till vegetable planting. Soil N will mineralize more slowly in the cooler, untilled soil under mulch. On biologically active soils, summer vegetables like tomato, corn and winter squash may obtain all the N they need from the soil's organic matter cycle regardless of tillage. However, fast-maturing spring vegetables like lettuce, spinach, broccoli and cauliflower require a *lot* of N from fairly *cool* soil in a *short* period of time. Organic no-till brassicas and greens will likely need side-dressing with fast-releasing organic N fertilizers to give satisfactory yields.

In very sandy soils and hot climates, tillage can cause N to mineralize *too* rapidly, so that the N is lost to leaching before crops can take it up. In these circumstances, no-till cover crop management and vegetable planting can enhance vegetable yields through better synchrony of N mineralization with crop N needs.

Perhaps the most common pitfall of organic no till is inadequate weed suppression by the cover crop residue. This can result from insufficient cover crop biomass (less than three tons per acre), large weed seed banks, or the presence of perennial weeds that are *not* effectively suppressed by mulch. Organic no-till should not be attempted during the first season after a field has been transitioned out of hay or pasture, because surviving fragments of tall fescue and other perennials can emerge readily through the cover crop mulch and compete severely with vegetable crops.

If a bad weed situation is detected *before* vegetable planting, it can be remedied by any of the reduced-till strategies discussed in the next section. If weed problems develop *after* vegetable planting, weeds can be pulled, mowed, removed with a high-residue cultivator, sprayed with an acetic acid herbicide allowed in organic production, or mulched over. Two or more of these measures may be needed.

Finally, *continuous* no-till is generally not feasible in organic annual crop production, because perennial weeds will eventually increase to a level at which tillage is required. Normally, some tillage is needed to plant the next cover crop after a no-till planted vegetable. Thus no-till organic vegetable planting should be viewed as one component of a *reduced tillage cropping system*. Depending on soil conditions and weed pressure, the field might require only light harrowing or shallow rototilling, or deeper tillage with a spading machine, chisel plow or rototiller. Deep inversion tillage with moldboard plow or heavy disk is usually not recommended as this can disrupt soil structure and soil life, and may create a hardpan.

Reduced Tillage Options for Managing Cover Crops

Some form of tillage is recommended when:

•The cover crop mulch is not thick enough to suppress

weeds for at least four weeks after vegetable planting,
•Weed pressure appears heavy, or
•No-till would delay soil warming or N mineralization sufficiently to hinder the vegetable crop.

Several reduced-till options for cover crop management include shallow tillage, zone tillage, strip tillage, and ridge tillage. Experiments have shown that shallow tillage (rototilled 2 inches deep) of winterkilled cover crops allowed early spring vegetables to yield at least as well as deeper (4-6 inches) tillage. A winterkilled cover crop followed by shallow tillage can give better weed control, less soil disruption and more organic matter input than a weedy winter fallow followed by deep tillage.

In zone tillage, the top of the raised bed (the vegetable grow zone) is tilled (shallow or deep as needed), while a killed or living mulch is left in the alleys and sides of the bed. Various strip tillage implements have been developed that clear and work up a narrow (8 to 12 inch) swath for vegetable planting, leaving much of the residue on the surface between tilled strips. Sometimes, a simple "sweep" or "duck foot" attachment can accomplish this, especially in a winterkilled cover crop. Though weeds will emerge within the tilled zone or strip and require hoeing or cultivation, these approaches can reduce soil disturbance and add organic matter, while providing rapid soil warming and N mineralization for the vegetable crop.

In ridge tillage, the field is shaped into ridges that correspond to the future cash crop rows, then planted in cover crop. Shortly before vegetable planting, the cover crop is mowed and the tops of the ridges are scraped off leaving a narrow, prepared seedbed, with plenty of surface residues left in the valleys between ridges.

At the garden scale, reduced till can be accomplished by cutting and clearing the cover crop (reserve clippings for mulch, or add to a compost pile), then shallow-tilling or strip-tilling. The roots and stubble are much easier to manage with garden tools than the entire cover crop biomass.

Perennial Sod Crops

Another way to reduce the intensity and frequency of tillage in a crop rotation is to alternate several years of annual crop production with several years in a perennial sod crop like hay or pasture. Three years in a diverse grass-legume sod can replenish soil and reduce annual weed pressure after a period of intensive vegetable production. This approach works best for diversified farms producing both vegetables and livestock, and for farms that have sufficient land area to keep 35-50% of working land in perennial sod at any one time.

Remember that the first year of transitioning out of any perennial sod is not the time to attempt no till vegetable planting. When hard-to-manage perennial weeds are present, plan on a two-year transition. Utilize grazing, tillage and smother cropping to: 1) eliminate existing vegetation, weed seeds and vegetative propagules (rhizomes, tubers, etc); 2) maintain soil health and organic matter level; and 3) produce a cash crop, if needed for farm income. *First*, deplete root reserves of the existing sod plants using repeated mowing and/or grazing for 6-8 weeks. Hogs can be especially helpful, as they root out and consume rhizomes of noxious perennials like Johnsongrass and Bermudagrass. *Second*, employ stale seedbed techniques for an additional 6-8 weeks, using non-inversion tillage implements (chisel plow, subsoiler, spader, power harrow) to uproot and desiccate perennial vegetation. *Third*, plant a diverse rotation of high-biomass cover crops and weed-competitive vegetables like sweet potato, winter squash, pumpkin, or crowder peas. Till after each crop

NOTE: while we normally do not recommend moldboard plowing, the moldboard plow may be the most practical means for some farmers to break sod. The plow should be set so that the furrow-slice is only partially inverted, so that air can reach the severed and decaying sod. Minimize erosion on moderate slopes, by plowing on the contour, or utilizing a contour strip-cropping system. Leave steeper slopes in sod if at all practical; otherwise plan on building terraces.

The Bottom Line

Plant cover crops wherever and whenever they fit into your crop rotation. Plant them well, and let them grow until they flower. Then manage them the best way you can, given available equipment, weed pressure, and vegetable crops to be grown. Till as little as practical, and as much as necessary to ensure adequate weed control, satisfactory vegetable yields and good cover crop stands. Even with some tillage, including one high-biomass (three to five tons per acre) cover crop per year can go far toward replenishing the soil's organic matter. Supplement with a little compost, aged manure and/or applied organic mulch, plus any amendments indicated by the soil test, and the soil food web will be well fed and will support good crops in the long run.

Resources – Equipment for Organic Minimum Till Systems

Dr. Ron Morse, Department of Horticulture, Virginia Tech, Blacksburg, VA 24061. Tel. 540-231-6724; e-mail *morser@vt.edu*, can provide up to date contact information for manufacturers of roller-crimpers, flail mowers, no-till vegetable planters and no-till planting aids.

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