Chapter 11

Organic Vegetable Tillage Systems

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Tillage is a necessary farming operation albeit at times very daunting. The appropriate tillage type should be chosen for each agricultural task. There are a number of constraints when determining the most effective tillage system. Growers should recognize that each type of tillage may have both positive and negative impacts to the soil and environment. Organic vegetable farmers should review tillage practices that were readily engaged prior to 1950 in the United State before the universal acceptance of herbicides for weed control. Organic farmers should also be compelled to recognize the wide array of modern tillage and planting equipment advancements. Farmers utilizing modern equipment have become proficient at very complex and integrated vegetable cropping systems. For example, a number of modern tillage implements have been designed to manage residue and cover crops, helping to reduce soil vulnerability to erosion and organic matter losses. Organic farmers must fully understand the impact of tillage practices on soil quality. A tillage system goal of sustainability relies upon regular soil quality evaluation, especially focusing on soil structure, tilth, organic matter, soil fauna, nutrient cycling and microbial activity.

Tillage Type Utilization

Conventional tillage entails turning under and thoroughly mixing crop residues or cover crops into the top six to eight inches of soil. Most often, this complete form of tillage is accomplished by inverting the soil with a moldboard plow, followed by successively shallower harrow passes. The goal of conventional tillage is to leave a residue and vegetation-free soil surface, with a uniformly mixed soil horizon to the plow depth. The successive harrow passes uniformly size soil aggregates, to create a firm and level soil; an important prerequisite to planting, transplanting, cultivating, bed-making or plastic-laying. For fields with moderate residue or short cover crops, a similar soil preparation may also be achieved with a roto-tiller. When performing a conventional tillage operation, it is important to plow the field in the same direction of planting. In

Figure 1. Raised bed making, CMREC, Upper Marlboro

Figure 2. Plastic laying, CMREC, Upper Marlboro.)

order to achieve level and evenly mixed soils, multiple harrowing passes are required after plowing. Generally, to close the plow furrows completely and to efficiently achieve a level and uniform soil surface, the first harrowing operation is performed with a disk harrow running in the same direction as the plow furrows. Subsequent harrow passes are performed at alternating modest angles to the plow furrows, to facilitate a level field finish. Farmers need to be thoroughly familiar with their soil type response to tillage harrows, as this is paramount to choosing the appropriate harrow implement. A roller harrow is often used as a final pass to help firm the seedbed in preparation for planting.

Figure 3. Conventionally tilled yellow squash field, CMREC, Upper Marlboro.

Reduced or Conservation Tillage approach focuses on working the soil to a three to four inch depth with a disk harrow, placing less emphasis on thorough mixing to leave some residue on the surface for erosion control. This method will work for organic vegetable producers if the previous crop residue or cover crop is finely chopped prior to shallow incorporation. When finer residues are thoroughly mixed into the soil they will flow without impeding subsequent planting or cultivation operations. For compacted soil, a chisel plow or subsoiler may precede the shallow disking operation to promote proper root development. To avoid covering transplants or emerging seedlings, it is necessary to use cultivation shields when soils have not been completely worked or residues sufficiently mixed. Generally, additional hand-weeding in the plant row will be required to achieve sufficient weed control with reduced tillage organic vegetable production until the crop canopy develops.

No-Tillage organic vegetable systems are challenging and rely on very uniform crop residues and cover crops for adequate weed control. The planter provides the only at-planting tillage in a continuous no-tillage system. No-Tillage planters and transplanters were perfected in the late 1980's, becoming capable of handling residues, cover crops and variable soil conditions, to open a seed slot and place the seed or transplant at a

Figure 4. SST No-Till Transplanter adjustment, CMREC Upper Marlboro

Figure 5. SST No-Till Transplanter setting tomatoes into a mown vetch-rye cover, Claggett Farm, Upper Marlboro.

uniform depth with great accuracy. Modern no-till planters are generally equipped with heavy coulters and row cleaners that are able to cut through and sweep away residues that would impede seed placement into the soil. Planter coulters and row cleaners are often aggressively set to create a narrow tilled seed zone, sometimes referred to as zone tillage. Zone tillage of the seed slot enhances seed placement accuracy to promote very uniform spacing, depth and emergence. Beyond the planter advancements, there have also been significant advances made in no-tillage cultivators to further assist in weed control. Recently, a few herbicides labeled for organic production have been marketed and have proven to work well when applied to emerging weeds. Even with all of the stated advances, organic no-till vegetable farming method will still have to rely on substantive hand-weeding to achieve adequate weed control. One important advantage of no-tillage is the predictability of weed germination, both species and timing. Generally, the same weeds have very synchronized flushes of emergence in no-tilled fields; this weed emergence is much less predictable in tilled fields.

Figure 6. No-Till Planting into a rye cover with row cleaners aggressively set, USNAD.

Figure 7.No-Till sugar snap peas into German foxtail millet planted August 20th without herbicides, CMREC Upper Marlboro.

Figure 8. No-Till sugar snap peas into German foxtail millet harvested October 15th, CMREC Upper Marlboro.

Strip-Tillage is a modified tillage practice that combines the advantages and efficiency of no-tillage with the benefits of a larger tillage zone around the seedling or transplant. A strip-tillage implement is heavy, requiring as much as 40 horsepower per row, and is capable of thoroughly incorporating residues and cover crops, completely tilling and mixing a soil strip twelve inches wide and six inches deep. A strip-tillage implement generally consists of a conditioning shank (optional), a series of aggressive coulters and

Figure 9. Strip-Tillage Machine, CMREC Upper Marlboro.

leveling baskets. Depending upon the amount of residue or the cover crop, strip-tilling may require a couple of passes, which is still a quick and energy saving process when compared to conventional or reduced tillage systems. Strip-Tillage may also be accomplished by first mowing a strip in the cover crop, followed by a roto-tiller pass in the middle of the mowed strip. A tractor mounted roto-tiller may be used with the removal of some of the tiller tines to accommodate the appropriate width. After utilizing the strip-till machine or roto-tiller method, planting may proceed with any conventional planter or transplanter; this system will even facilitate easier hand-planting. Hand-weeding in the crop row will also be easier in the strip-tilled zone.

Ridge-Tillage is another modified tillage practice which requires conventional tillage to establish permanent raised beds or ridges. This system is recommended only for low lying flat fields that are prone to being wet. The permanent raised beds are flat and generally 12 to 24 inches wide and four to six inches high. Specialized equipment is required, as the beds are tilled and reformed at the establishment of each crop. Sweep cultivation is used during the crop season to keep the beds level and weed-free. Ridge-tillage should be avoided on sloping ground as water tends to dam between the ridges and cause severe erosion.

Understanding of Tillage Impacts

The complexity of soil type responses to tillage has led to the myriad of tillage options and implements. Heavy soils, soils that contain an abundance of clay and silt are easily damaged by tillage, especially deep tillage. The soil structure, aggregate stability, porosity, organic matter and friability are generally negatively impacted by repeated tillage. Often the most severe soil structure damage occurs when soil is tilled while too wet. Compaction layers brought about by excessive tillage may become severe enough to limit root growth. Farmers need to balance their tillage method, always striving to improve soil quality and productivity. To understand the impacts of tillage, we must fully weigh the benefits against the consequences.

Tillage Benefits for Organic Vegetable Farming

1. Tillage has an important role in soil amendment. Tillage incorporates lime, nutrients and organic matter to create non-limiting growth environment for roots. Soil amendment should be based on soil testing and soil quality assessment.

2. It is especially important in vegetable production to incorporate crop residues into the soil to hasten the breakdown of disease organisms. After incorporating the crop residues during the fall, it is advisable to plant a non-host cover crop (e.g. cereal rye) to protect the soil from winter erosion and to capture the nutrients that may be lost. This cropping process will also reduce weed development.

3. Depending upon the type of equipment available, tillage becomes a prerequisite to planting and cultivation.

4. Tillage will aerate, warm the soil and dry the soil; this is indeed an advantage in the early spring. Be sure to create a firm seedbed by utilizing a roller-harrow to minimize erosion and soil moisture losses at planting time.

5. Tillage temporarily reduces soil compaction issues; however, the source of compaction should be understood and mitigated against. Try to avoid the "tillage addiction" cycle necessitating repeated tillage due to damaged soil structure.

Tillage Consequences for Organic Vegetable Farming

1. Tillage reduces soil organic matter by increasing biological activity releasing soil carbon as carbon dioxide (CO_2). Soil organic matter loss may be greatly reduced by practicing cold soil tillage, when biological activity is low. When tillage is required, always strive to incorporate cover crops and organic amendments to offset these potential organic matter losses. Monitor soil organic matter, with the goal of increasing the percent soil organic matter level over time.

2. Every tillage event leaves a soil vulnerable to erosion. It is important to limit the width of strips tilled on slopes. Utilize grass buffer waterways and field borders to capture and contain the soil losses.

3. Continued tillage may lead to compacted soils caused by soil structure damage. Biological life has difficulty surviving and associated activities significantly decreased in compacted soils, a condition referred to as "soured soils". The use of deep-rooting crops or cover crops to create macropores and rebuild soil aggregates may help compacted soils without the need for tilling. Farmers have recently adopted daikon-type radish as a cover crop that creates deep-rooting channels, a process termed "bio-drilling" for soil compaction alleviation.

4. Tillage is expensive and time consuming. Tillage operations require substantial horsepower inputs, which puts enormous wear and tear on equipment, also requiring significant quantities of fuel. Tillage reduction is in harmony with the goals of organic production and sustainable systems.

Tillage a Systems Approach - Sequence & Tasking

Profitable farming requires careful consideration prior to performing any task on the field. Successful tillage requires the full understanding of the "narrow window concept", which implies that there is an optimum time to complete each task, based on field condition. Farming is a sequence of tasks fully constrained by weather and time. Each successive farming task needs to enhance the previous steps taken. This requires pre-determining the time requirement of each task in order to use machinery at its economic and environmental maximum. Seek guidance from the Operator's Manual for farm equipment to properly set the machine for field conditions. For example, soil may be damaged by tilling when it is too wet. If the outcome of the tillage task is undesirable, then cease the activity until field conditions improve. In some cases, tillage implements may require added attachments to properly conduct the task.

Integrated Tillage Systems

Innovative organic vegetable producers have developed fully integrated tillage systems for their farming operation. They have adopted state-of-the-art field preparation equipment and cropping technology advances to plant directly into heavy crop residues

Figure 10. Monosem no-till vacuum planter front view, CMREC Upper Marlboro

Figure 11. Monosem no-till vacuum rear view, CMREC Upper Marlboro

and cover crops. Specific planter technology advances include: heavy no-till coulters, row-cleaners, and gauge wheels. Strip-tillage and root zone conditioning implements also may provide strategic tilling. Utilizing modified tillage regimes allows organic vegetable growers to (1) build and protect soils with cover-crops, (2) farm in a sustainable manner that reduces inputs, and (3) add crop diversity.

Figure 12. Strip-Tilling German foxtail millet, CMREC Upper Marlboro.

Figure 13. Strip-Tilling and No-Tilling into German foxtail millet, CMREC Upper Marlboro.

Figure 14. Pak Choi transplanted into strip-tilled German foxtail millet, CMREC Upper Marlboro.

Soils that are tilled less have better soil structure with stratified layers that support vehicle traffic with less risk of compaction. Soils with stratified layers, root channeling, surface residues, and macro pores will drain faster and reach field capacity quicker--this allows for timely rotations and avoids costly planting delays.

Figure 15. Turnips direct seeded strip-tilled and no-tilled into German foxtail millet, CMREC Upper Marlboro.

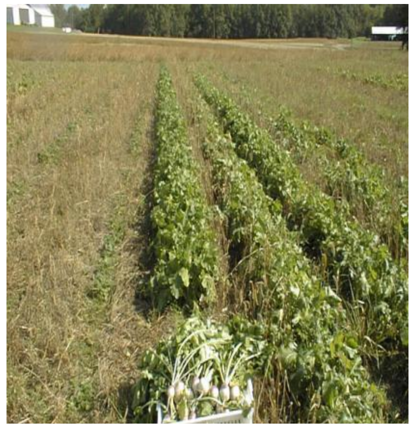

Figure 16. Harvested turnips direct seeded strip-tilled and no-tilled into German foxtail millet, CMREC Upper Marlboro.

Figure 17. Strip-Till vs. No-Till watermelon, pumpkins and squash direct seeded into a rye cover, CMREC Upper Marlboro.

Table 1 reveals the yield differences of strip-tillage verses no-tillage vegetable systems based upon vegetable research conducted at the University of Maryland, Research and Education Center, Upper Marlboro Facility from 1999 to 2010. Although the studies were not always conducted utilizing organic methods, the following conclusions have relevance:

1. Response to strip-tillage may be variety sensitive. During the study, it was observed that some squash and corn varieties responded economically to strip-tillage while others varieties did not (see table 1).
2. For most crops investigated in this study strip-tillage led to a 20% to 30% increased plant population at emergence than no-tillage.
3. Strip-tillage warms the soil which provided a 15% to 35% yield increase in early spring planted leafy greens and vegetables.
4. Strip-tillage eliminated the cover crop competition, which led to robust seedling growth.
5. Early pre-plant chemical burndown (EPP) or rolling of the cover crop is recommended when soil moisture is limiting. During drought conditions, EPP one week prior to planting for each foot of cover crop canopy. Scythe® (pelargonic acid) and Burn Out® or Nature’s Glory® (25% acetic acid) are a few examples of burndown herbicides labeled for organic production.
6. EPP or rolling of the cover crop prior to planting will also reduce the chance for seed germination inhibition due to allelopathy from the cover crop.
7. No-tillage may be more cost effective than strip-tillage for summer vegetables with fast germination and quick seedling growth.

Table 1. Vegetable Strip-Till & No-Till, CMREC Upper Marlboro

Yield Averages 2004-2006

Crop	Variety	Yield lbs/acre	
		Strip-Till	No-Till
Kale	*Blue Curled Scotch*	11,315a	8,345b
Turnips	*Purple Top*	32,625a	26,100b
Chinese Cabbage	*Pak Choy*	15,950a	11,600b
Chinese Cabbage	*Michili*	20,300a	17,400b
Radish	*Red Globe*	4,644a	4,060b
Swiss Chard	*Fordhook*	7,975a	7,685b
Sweet Corn	*Argent*	8,350a	7,940a
Popcorn	*South American Yellow Giant*	4,900a	5,082a
Ornamental Corn	*Indian*	10,527a*	8,258b
Summer Squash	*Goldbar*	15,518a	8,276b
Summer Squash	*Seneca Zucchini*	23,413a	22,596a
Watermelon	*Jubilee*	20,283a	16,063b
Pumpkins	*Autumn Gold,*	12,524a	12,251a
Gourds	*Mixed*	3,405a	3,367a
Gourds	*Birdhouse*	14,422a	14,520a

*a, b - same letter denotes no significant statistical difference.

REFERENCES:

Myers, R.D. 2008. Sustainable and Low Input Strip-Till & No-Till Vegetable Planting Tactics. Anne Arundel County Cooperative Extension. Glen Burnie, MD. 3 pp. Authored a bulletin that examines different vegetable planting tactics into cover crops.
http://annearundel.umd.edu/files/Strip_Till_No-Till_Vegetable_Systems.pdf.