Organic Matters

ATTRA's *ORGANIC MATTERS* SERIES

PURSUING CONSERVATION TILLAGE SYSTEMS FOR ORGANIC CROP PRODUCTION

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Contents:

ATTRA's Organic Matters publication series was created to speed the flow of technical information on current topics to organic farmers, researchers, and others involved in organic production. Support in initiating this series has been provided by the Organic Farming Research Foundation, the USDA's Agricultural Marketing Service, and the Kerr Center for Sustainable Agriculture.

Introduction

This publication takes a brief look at conservation tillage as it may be applied to organic cropping systems. A number of the most promising strategies and technologies are described, and abstracts of recent research are provided. The focus is on annual cropping systems. Both agronomic and vegetable cropping systems are discussed.

Very little no-till/low-till research has been done under conditions typically found on organic farms. To achieve a true organic context for a research trial, it is not enough simply to avoid the use of prohibited fertilizers and pesticides. The fields on which the trial is conducted should be certified, or be close to certifiable, as organic. In this way, the real-world conditions of an organic farm—conditions that follow from crop rotation, natural nitrogen cycling, lack of herbicide carryover, enhanced beneficial populations, and so on—can have their effect on the outcome of the trial. These factors can make a big difference in how a system performs over time when a new practice or product is tested.

At present, the amount of research being done that meets organic criteria is very small, and only a tiny portion deals with conservation tillage. We have had to cast a wider net and review—in addition to the few organic studies—a considerable volume of conventional research, to find applications that might be adaptable to organic farming. This was challenging because "adaptability" was not always readily apparent. The use of herbicides and commercial fertilizers in conventional crop production—especially no-till—is a given, and mention might not be made in articles and reports. Depending on how and when such inputs are used, they can make a vast difference in predicting how a practice might work in an organic context.

Making conservation tillage work in organic systems is, apparently, not easy. Many of the approaches discussed are clearly not "field ready." More research is definitely needed. Also, a high degree of sophistication will be necessary on the part of the farmer, which leads to an interesting observation. The pursuit of no-till/low-till organic systems clearly bucks the "dumbing-down" trend in conventional crop farming. It contrasts with commercial packaging of genetically engineered crops and over-the-top herbicides that minimizes skill and knowledge required at the farm level.

Make no mistake, conventional crop production is not lacking in information or skill. Most of that knowledge, however, resides with the researchers, technicians, advisors, and sales persons involved in developing and delivering technology to the grower. The farmer's role increasingly resembles that of a production line worker who is simply told what to do and when. This is in stark contrast to traditional farming, where the skill and knowledge base resides mainly in the head of the farmer, and demands much of him or her as scientist, artist, and manager.

Without a doubt, the pursuit of conservation tillage by organic farmers and researchers is a very good thing. It is consistent with the compelling need for more sustainable technologies within organic farming, and the wider trend towards environmental conservation in all of agriculture.

Organic Farming & the Tillage Dilemma

In the first half of the 20th century, clean tillage was such an integral part of mainstream American agriculture that no qualification or explanation was necessary. If you farmed, you plowed to break the sod, typically using either a moldboard or disc plow that inverted the soil cover, leaving virtually no plant material on the surface. This was usually followed by harrowing several times to create a seedbed, frequent cultivations to control weeds in the growing crop (in row crops), and plowing again to bury residues and re-start the cycle.

As herbicide use became widespread, the importance of some tillage operations—especially post-planting weed cultivations—began to decline. Organic farmers, and some others who chose not to use herbicides, continued to cultivate their crops using steel and flame. However, one thing common to both the organic and conventional farmers at mid-century was that both had a lot of bare soil between the seasons and between the rows.

Bare soil, whether left exposed by tillage or by herbicide, means potential for wind and water erosion, nutrient leaching, reduced biological diversity, loss of organic matter, and further challenges to the sustainability of farming. These downsides of clean tillage were not so much denied as they were simply accepted as the necessary costs of crop agriculture. Even to those concerned with conservation, other options were not readily apparent. This viewpoint began to change around 1960.

Inspired in part by Edward Faulkner's 1943 classic book *Plowman's Folly* (1)—a critique of moldboard-plow tillage—researchers in the '60s started taking a serious look at tillage alternatives that not only reduced the number of field operations, but left a crop residue mulch on the soil surface. Expectations were modest at first, but soon agronomists and farmers began envisioning productive cropping systems with a perpetual cover of living and/or decaying vegetation. With that sort of soil protection, most of the soil and environmental damage done by clean tillage might be halted and even reversed. Erosion-prone slopes might be cropped indefinitely.

To visionaries of that era, herbicides were the technological key to making such systems a reality. Herbicides had already made many cultivation operations appear to be optional and even obsolete in clean-tillage farming. It was logical to assume that they could be used to eliminate tillage operations entirely.

Soon, a considerable body of low-till and no-till information and technologies emerged, the bulk of it centering on the use of pesticides. The trend has continued up to the present. And now, as more and more environmental problems are being laid at the feet of agriculture, the accelerating trend towards conservation tillage—along with the requisite pesticide technology—is being used as an image-builder for modern farming.

Some Benefits of Conservation Tillage:

- *reduced wind erosion*
- *reduced water erosion*
- *erodible land brought into production*
- *increased options for multiple cropping*
- *improved soil moisture management*
- *flexible timing for field operations*
- *improved soil structure*
- *better humus management*
- *moderation of soil temperature*

It has been taken for granted by many that organic farming, which does not use herbicides, is forever shackled to clean cultivation. This assumption has been used disparagingly to characterize organic crop production as erosive and environmentally destructive. This charge was bolstered when the results of a long-term Midwestern study were published in the journal *Science* in September 2000 (2). The study contrasted the net global warming potential (GWP) of several natural and agro-ecosystems. It looked at such factors as the release of greenhouse gases CO_2, CH_4, and N_2O, sequestration of carbon as soil organic matter, and the use of CO_2-generating inputs like fertilizer, lime, and fuel.

All annual cropping systems, including those with legume cover crops in rotation, increased GWP to varying degrees. While the organic system scored considerably better than the conventional tillage alternative, its net GWP was still much higher than that of the no-till comparison. Clearly, organic agriculture would benefit if no-till or low-till technologies could be adapted. Advances in this area are now much further along than many critics acknowledge.

Organic producers have long nurtured an interest in conservation tillage. This was well documented in the mid-1970s as part of the Washington University study of organic agriculture in the Corn Belt. The researchers observed that the vast majority of organic farmers taking part in the study were using chisel plows rather than conventional moldboard plows. Chisel plowing is a form of *mulch tillage*, in which residues are mixed in the upper layers of the soil; a significant percentage remains on the soil surface to reduce erosion. Some organic growers had adopted ridge-tillage—another conservation tillage system with even greater potential to reduce erosion (3). The ready adoption of these technologies stood in sharp contrast to neighboring conventional farms of that time where there was, as yet, little-to-no evidence of conservation tillage practices being implemented.

The remainder of this publication will describe some of the advances in no-till and low-till farming pioneered by the USDA, land-grant universities, and farmers, with an eye towards those currently used by organic producers or with significant potential for use.

Mulch Tillage

Mulch tillage has already been described as a tillage system in which a significant portion of crop residue is left on the soil surface to reduce erosion. It is usually accomplished by substituting chisel plows, sweep cultivators, or disk harrows for the moldboard plow or disk plow in primary tillage. This change in implements is attractive to organic growers because residues are not buried deep in the soil, and good aerobic decomposition is thus encouraged. Of all the agronomic-scale options, mulch tillage is the most easily adapted to organic management and is appropriate for most agronomic and many horticultural crops. However, the additional environmental benefits of mulch tillage are not as great as those possible with other, more challenging approaches.

Ridge Tillage

Ridge tillage is characterized by the maintenance of permanent or semi-permanent ridge beds across the entire field. It is primarily intended for the production of agronomic row crops like corn, soybeans, cotton, sorghum, and sunflower. The ridge beds are established and maintained through the use of specialized cultivators and planters designed to work in heavy crop residues. In contrast to most forms of mulch tillage, more crop residue remains on the soil surface for a greater portion of the season. Additionally, when done on contour, the ridges themselves largely supplant the need for larger soil conservation structures like terraces on many fields.

Like mulch tillage, ridge tillage has proven quite adaptable to organic management, particularly with improvements in high-residue cultivation equipment. Some of the best documentation of the challenges and potentials of ridge tillage in organic systems was provided in the *Nature's Ag School* series. These publications—produced by the Rodale-sponsored Regenerative Agriculture Association in the late 1980s—focused on research done on the Richard Thompson farm in Boone, Iowa. While these are now out of print, the Thompsons are producing their own updated reports annually with assistance from the Wallace Institute. The series, titled *Alternatives in Agriculture*, continues to report on the Thompsons' research—much of it still focused on ridge tillage and cover crops (4).

High-residue cultivation equipment appears to be a key to making herbicide-free ridge tillage (and sometimes even mulch tillage) function successfully, by allowing cultivation through dense surface mulches. While there is considerable variation in equipment, the typical features of high-residue cultivators are large coulters followed by large sweeps mounted on single shanks. The coulters cut through residue in the middle of the interrow area to assure that the residue will not hang up on the sweep shanks. The sweeps are run shallow, yet deep enough so that the flow of soil helps carry crop residues over the sweep during cultivation. Furrowing wings are used on the sweep to aid in rebuilding ridges.

For good, general information on mulch tillage, ridge tillage, and conventional no-till systems, the Conservation Technology Information Center (5) is a good place to begin.

An excellent basic text that compares these and other tillage systems is *Conservation Tillage Systems and Management: Crop Residue Management with No-till, Ridge-till, Mulch-till, and Strip-till*, which was revised and expanded in 2000 (6).

Killed Mulch Systems

Advances in cover crop research have generated some innovative approaches to conservation tillage that show great potential for organic conservation tillage. Systems are now evolving centered on the concept of growing a dense cover crop, killing it, and planting or transplanting into the residue. The dense biomass provided by the killed cover crop not only protects and builds the soil, it also provides substantial weed suppression. On a small scale, organic gardeners have long relied on dense mulches as an alternative to hoeing and cultivation for weed management. Killed mulch systems are an attempt to capture the benefits of that practice on a larger scale.

In conventional conservation tillage, herbicides are primary tools for killing cover crops. The non-chemical alternatives being tried for organic systems include a number of mechanical implements and weather stress. The mechanical technologies currently being explored include mowing, undercutting, rolling, and roll-chopping.

Mowing

Several mowing technologies are in common use on mechanized farms. These include sickle bars, rotary (bushhog), flail, and disc mowers. Each has different characteristics that affects its utility in creating a suitable mulch.

Sickle bar mowers have been fairly effective. Sickles cut close to the soil surface, increasing the chances of a good kill; they also lay the cover down uniformly over the soil surface—an important characteristic in weed suppression. As a further advantage, sickle mowing does not chop up the cover crop. The major problem with this technology is encountered when mowing viney legumes like hairy vetch or field peas. The vines easily get hung up on the machine, slowing field operations and leaving a very uneven mulch. Researchers speculate that a reel-assisted sickle bar—such as a mower-conditioner—would probably work better if it can be modified to not create a windrow (7).

Disc mowers do a good job of cutting viney crops and mow close to the soil surface. However, the resulting mulch layer is uneven and bare strips are frequently left. Rotary mowing is perhaps the least suitable option. Rotary mowers do not cut as low as sickle bars. They distribute the mulch unevenly and chop it up so that decomposition is rapid and soil coverage is short-term.

Flail mowing appears to be the preferred technology at present. It cuts low and leaves an even layer of residue. However, it also chops the biomass quite finely, leading to rapid breakdown and short-term coverage (7).

Timing is important when mowing. Rye is most effectively mow-killed at flowering. If mowing is done earlier, the plant re-grows readily. Optimum control of hairy vetch is managed when mowing is done at mid-bloom or later, though stem length appears to be a more important factor; the greater the stem length at mowing, the easier the kill.

Mowing has several advantages. It is less dependent on soil moisture conditions than mechanical methods like undercutting that involve some tillage. It can also be done at relatively fast field speeds and involves the use of commercially available equipment that requires little to no modification.

Undercutting

Undercutting is not a new concept. V-blade field cultivators have long been used in the western states to control weeds for summer fallow by severing the plants below the crown and leaving the residue on the soil surface. They were especially popular in the 1940s and 1950s. There has been a resurgence in their use among organic growers since the late 1980s.

Much attention is now being given to an adaptation of the traditional undercutting concept. It entails the use of specialized equipment that both severs the roots of the cover crop and flattens the biomass on the surface of the soil. The unit is primarily suited to bed production systems. Originally designed by Nancy Creamer and fellow researchers at Ohio State, the undercutter features a large blade or blades (adapted from a V-blade plow) that are run just under the surface of the soil to cut cover crops off just below the crown. A rolling basket is positioned to the rear of the blades for depth adjustment and to flatten the severed cover crop.

The undercutter has proved successful in killing a variety of winter annual cover crops including rye, hairy vetch, bigflower vetch, crimson clover, barley, and subterranean clover. Kill was most effective when these were allowed to reach mid-bloom or later. Undercutting is much less successful at killing biennial and perennial species such as red clover, ladino clover, sweetclover, fescue, orchardgrass, and perennial ryegrass (8).

Undercutting is also effective for killing a variety of spring and summer annual cover crop species including soybean, buckwheat, lentil, German foxtail millet, and Japanese millet, sesbania, and lab lab. It is less successful with cowpeas, pearl millet, sudangrass and sorghum-sudangrass (9).

A big advantage of the undercutter (and the V-blade) is that it achieves a good kill while not chopping the cover crop, resulting in a more persistent, weed-suppresive mulch. It also loosens the soil, which makes for easier transplanting. The undercutter is somewhat limited, however, if soil moisture levels are high. Soil type can also be a limitation. University researcher Jeff Mitchell observed poor performance with undercutting in the heavy clay soils he works with in California (10).

Though the V-blade or Noble plow is still widely available in the West, the bed-style undercutters are not commercially available and must be home-built. Ample detail on construction is provided in a 1995 article by Nancy Creamer, published in the American Journal of Alternative Agriculture (8). For those with access to back issues of *The New Farm* (once published by the Rodale Institute), the July–August 1994 issue featured a good picture on page 31 along with some enlightening text (11).

Rolling & Roll-Chopping

Rolling is essentially mechanical lodging. Implements are used to bend or break the plant stems and press them uniformly against the soil surface. The kinds of equipment used for rolling are surprisingly varied. The most recognizable are field rollers; turf or construction rollers can also be used. A modified version of these basic rollers features angle-iron bars welded horizontally along the length of the roller. This adds a crimping action for better kill. Similar rolling action can be achieved using cultipackers or similar implements.

Rolling can also be done using a grain drill with closely spaced cutting coulters and cast-iron press wheels. In addition to lodging the crop, this implement also kills by cutting the cover crop stems and leaves. Another piece of equipment that has been employed is a flail mower with the power disengaged. The roller gauge wheel apparently serves the purpose. One of the big advantages of rolling is that suitable equipment can usually be found on the farm and easily adapted (12).

In North Carolina research trials, rolling was the least successful means of killing a range of summer cover crops, when compared to mowing and undercutting (8). According to Virginia Tech's Ronald Morse, it is the least physically damaging to the cover crop and, therefore, is the least effective overall. However, he does not consider this a significant disadvantage where mechanical transplanting is used. The passage of the transplanter itself further damages the cover crop to the point where competition with the crop is nil and the benefits of a slow-decomposing, non-chopped mulch can be realized (12)

Roll-chopping involves the use of specialized equipment that is commecially available. Rolling stalk choppers—such as those marketed under the trade name Buffalo™—cut the cover crop stems perpendicular to the direction of travel. Roll-chopping has gained considerable visibility among no-till/low-till investigators. Several farmers have reported significant success, but stressed the need for a more flexible design to handle conditions like raised beds (13). A significant advantage of both rolling and roll-chopping is that they can be done at relatively fast field speeds.

Weather-Kill

The concept of weather-killing cover crops involves the strategic planting of a cover crop that will be reliably killed by temperature shifts as seasons change. It appears that the most common strategies being researched involve the planting of summer annual covers like forage sorghums, millet, cowpeas, buckwheat, berseem clover, haybeans, or annual medic that are easily killed by even mild winter freezes, while leaving a dense mulch.