Organic Matters

ATTRA's *ORGANIC MATTERS* SERIES

PURSUING CONSERVATION TILLAGE SYSTEMS FOR ORGANIC CROP PRODUCTION

By George Kuepper, NCAT Agriculture Specialist, June 2001

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.

Planting or transplanting of early spring crops can follow after mowing and/or strip tillage.

Among the benefits of such winter-kill systems is that they offer a good opportunity for extending killed-mulch options to early spring crops. Attempts to kill winter annuals at early growth stages have not worked well. More importantly, most winter annuals have not produced sufficient biomass by early spring to offer much weed suppression.

Winter-killed mulches cease transpiration as soon as they are killed. In dryer climates this is an advantage due to reduced soil moisture depletion. In wetter climates, however, a living cover crop would help remove excess water and allow earlier field operations. Moisture conditions play an important role in the viability of a winter-kill system. A late-summer or early-fall drought can result in a poor cover crop going into the winter and much too little biomass for weed suppression.

Cover Crops for Killed Mulch Systems

In general, cover crop selection in killed mulch systems should favor dense, tall-growing species in wetter climates and water-use efficient species in drier climates. In either case, the crop should be easily killed and leave considerable biomass. Research appears to concentrate most often on the winter annuals hairy vetch, grain rye, and winter peas. In this same category is black medic—in northern climates a short-lived perennial that reseeds itself annually. Where summer annuals are needed, research seems focused on soybeans, forage sorghums, and, to a lesser degree, on buckwheat.

Combining cover crop species—a legume with a grass—is often noted as a good strategy. Nitrogen fixation from the legume can be optimized, a maximum level of biomass is usually produced, and the carbon-to-nitrogen ratio of the mulch is generally in a range that releases nitrogen to the crop at a desirable rate (9). In the case of winter cover crops, combinations are also desirable because harsh conditions may eliminate one of the species. In such instances, the survivor still succeeds in providing an acceptable level of soil protection.

Particular interest has been shown in grain rye. This is due not only to its winter hardiness and ability to generate biomass, but also to its allelopathic characteristics. Rye produces chemicals that inhibit the germination and growth of a large number of broadleaf and grassy weeds. These chemicals, along with their breakdown products, continue to be active as rye residue decays on the soil surface, making it an especially effective weed suppressant (14).

Rye is not the only cover crop with allelopathic characteristics; other grasses like oats also exhibit some allelopathy. Researchers are also investigating various brassica species such as rape and mustard, though most studies have looked into the effects of soil-incorporated residues (15, 16). While brassicas do provide some weed suppression through allelopathy, they will likely do best in combination with another cover crop capable of producing more biomass. It should be noted that allelopathy is a two-edged sword. Crops, too, can be damaged and researchers are working to determine which cover crops can be used safely with which cash crops. Further research on this subject is discussed later in the text.

The Challenges of Killed Mulches

Most killed mulches do not provide thorough, long-season weed control without some additional effort. Studies on light penetration done in California found that even the densest of killed mulches still allowed roughly 20% of sunlight to leak through to the soil surface (10). This percentage increases as the mulch layer decomposes and weeds will begin to emerge. Some form of hoeing, cultivation, or both may be needed later in the season.

High-residue cultivators have been tried in such circumstances. Farmers report that they do work but may still "hang up" in especially heavy, viney mulches (13). Where weed problems are anticipated, and relatively early cultivations are a certainty, it may be desirable to favor a killed mulching system in which the biomass breaks down more rapidly to facilitate cultivation. This would suggest flail mowing, for example, and the preference for a legume or buckwheat cover crop that would decompose more rapidly (17).

One strategy that is being used to improve stands is to shift from direct seeding to the use of transplants. Transplanting can be done somewhat later than direct seeding, allowing for greater warming of the soil. It also assures a better stand and allows the crop a more competitive jump on weeds (12). Transplanting is somewhat limited, however, as it is not appropriate for all crops. Another strategy that works to improve stands is zone tillage. It will be discussed later on.

Additional Resources & Research on Killed Mulch Systems

The USDA has conducted some excellent research on the use of killed mulches at its research station in Beltsville, Maryland. Researchers Aref Abdul-Baki and John Teasdale have investigated the (flail) mow-killing of a number of cover crops for no-till culture of summer vegetables, particularly tomatoes. The results are well-detailed in the USDA Farmers' Bulletin 2279 (18). Note that page 8 of that bulletin features a picture of a homemade crimper-roller also used to kill cover crops in their trials.

Later research by this USDA team has extended into fall broccoli production (19, 20). The mow-killed cover crops were, in this case, soybeans and millet. The soybeans were a recent USDA release called *Donegal*, which was bred for size, biomass production, and early growth. The reported research was not done entirely within an organic context, as herbicides were used in the establishment of the cover crop. However, it appears it would still adapt well to an organic system.

Participating with Abdul-Baki and Teasdale in the broccoli research was Dr. Ronald Morse, of Virginia Polytechnic, who has led the way in development of no-till transplanting. Morse, Abdul-Baki and Teasdale have also collaborated extensively with Pennsylvania farmer Steve Groff, who has made great strides in no-till vegetable production and farm diversification. Groff has brought particular attention to the use of roll-chopping as a cover crop management technology. Though his system is not organic, observations made in this system should be relevant to organic management (21).

Dr. Morse has written a fine summary on the art and science of no-till transplanting that also summarizes various mulch-killing strategies. Especially notable is his description of the subsurface tiller-transplanter (SST-T), which he worked to pioneer. This tool is designed for transplanting into high-residue conditions and is one of the most promising implements for making an organic low-till system work. Dr. Morse's article, *Keys to Successful Production of Transplanted Crops in High-Residue, No-Till Farming Systems* is reprinted in the *Proceedings of the 21st Annual Southern Conservation Tillage Conference for Sustainable Agriculture* (12).

One of the best summaries of technologies and research into the mechanical killing of cover crops is not yet in print. Nancy Creamer, with North Carolina State University, and Seth Dabney, with USDA-ARS in Oxford, Mississippi, have co-authored an article titled *Killing Cover Crops Mechanically: A Review of Literature and New Research Results* (7), which will appear in the *American Journal of Alternative Agriculture* later in 2001. Creamer and Dabney are among the true pioneers in organic low-till and cover crop research for horticultural crops. It will be good to see this piece in print.

The Kerr Center for Sustainable Agriculture is currently funding some on-farm research on winter-killing cover crops for vegetable systems in eastern Oklahoma. Twenty-four legume-and-grass cover crop combinations are being evaluated. Assistance is being provided by Oklahoma-based ARS personnel and Oklahoma State University researchers and Extension (22). Contact Alan Ware at the Kerr Center (23) for more details.

Another *New Farm* article of particular relevance to killed-mulch farming—in this instance, weather-kill—is a 1993 piece by Bob Hofstetter titled *Smother Crops* (24). The focus of the article is the planting of various cover crop species out of season with the objective of their being killed by expected weather extremes. The experience of Pennsylvania farmer Frank Pollock with winter-killed oats is highlighted. This grower had successfully grown both garlic and specialty potatoes with this cover crop system for 10 years.

Living Mulches

Living mulches represent another alternative to low-till/no-till that organic agriculture must explore. In the broadest sense, the term "living mulch" can apply to any system in which an actively growing or dormant cover crop remains in place as a companion to a commercial crop. As such, this concept encompasses a number of practical and theoretical options. One of the approaches that has generated a lot of interest in recent years involves the interseeding of crops with low-growing smother crops that suppress weeds and reduce erosion both during the growing season and after the crop has been harvested. Interseeding may eliminate one or more weed-controlling cultivations in an organic system. However, it is not a strategy to reduce primary tillage and is less germane to this publication. Our focus will be on living mulch practices that involve the establishment of crops into living cover crops that are not killed, but remain living for all or part of the cropping season.

Erosion control and reduced tillage are among the main attractions that living mulches share with killed mulch systems. A specific benefit of living mulch systems—insect pest suppression—has also drawn attention. Living mulches frequently serve as beneficial insect habitats, thus supporting a population of predators and parasites that help keep crop pest numbers at manageable levels. For example, Costello and Altieri demonstrated the habitat effect in the Salinas Valley of California while growing broccoli in a living mulch of white clover (25).

According to Leary and DeFrank (26), successful living mulch systems manage a balance between weed suppression and competition with the cash crop for light water and nutrients. In a preferred system, the mulch would resume full dominance of the agroecosystem following harvest—crowding out weeds, preventing erosion, providing habitat, and building soil fertility. Even beginning to approach such an ideal can be highly challenging.

One of the more obvious strategies for making a living mulch system work entails supplementing cash crop nutrition and moisture in a targeted way. Sidedress and foliar fertilization strategies can be helpful here; especially promising is the use of drip fertigation—supplying soluble organic fertilizers by injection into the irrigation system. While feasible technically, such strategies may or may not always be environmentally responsible or economical.

Most researchers investigating living mulches are focusing on systems that achieve a balance between the living mulch and the cash crop through:

1) selection of a compatible cover crop
2) some form of mulch suppression (usually dependent on careful timing), and
3) a zone of tilled, weed-controlled seedbed (e.g., *zone tillage*) through the early season.

Cover Crop Selection for Living Mulches

A good living mulch is said to have four desirable characteristics (27):

- rapid establishment to provide early weed and erosion control
- tolerance to field traffic
- tolerance to drought and low fertility
- low cost of maintenance

These characteristics are considerably different from those desired for killed mulches, where tall, easily-killed annuals typically predominate. Preferred living mulch species are typically prostrate in growth habit and often perennial. Annual species, however, can also be effective choices. Particular interest has been shown in subterranean clover, or "subclover."

Subterranean clover is a self-seeding winter annual with a prostrate growth habit. Well adapted throughout much of the South, subclover is typically planted in the late summer or fall. It grows vegetatively but is held dormant throughout much of the winter. Flowering and seed development occur in late spring and early summer. The plant then senesces and dies during the heat of summer, leaving a dense vegetative mulch that is non-competitive with the growing crop. The next generation of subclover arises from seed. Like the peanut, subclover is *geocarpic*—its seed pod develops at and below the surface of the soil. This assures soil-to-seed contact and improves the chances for reviving the stand without tillage operations.

Ilnicki and Enache (28) reported considerable success in New Jersey using subclover as a living mulch in field corn, soybeans, and a number of vegetable crops. No herbicides were used for mulch suppression, though mowing was tested. The researchers noted that mowing subclover just prior to planting improved the yields of some crops like sweet corn. It was believed that mowing allowed earlier warm-up of the seedling bed, giving the crop a better start.

Living Mulch Suppression

In instances where a cover crop like subterranean clover is used, some suppression is provided by the natural cycle of the plant itself as it senesces and dies, or goes into seasonal dormancy. Still, mowing has been shown to be beneficial, as previously pointed out. Most living mulches require some form of suppression during the cropping season. In conventional systems, it is not uncommon to use sub-lethal applications of herbicide for this purpose. Two mechanical means of suppression that are suited to organic systems are mowing and partial rototilling.

Mowing appears to be the most commonly cited option used in research on living mulch. Sometimes efforts are even made to collect the trimmed biomass and use it as an applied mulch on the cash crop.

Partial rototilling entails the tillage of the living mulch, while leaving one or more strips of the cover crop to re-grow. This can be accomplished in a number of ways. Most tiller designs naturally leave a narrow strip of untilled soil. If this is inadequate, one or more sets of tiller tines can be removed. Partial rototilling has been used most successfully in stoloniferous cover crops like Dutch white and Ladino clover (7).

Additional Resources & Research on Living Mulches

One good example of research on insect management with living mulches is provided later in this publication. For a good overview, the article *Fighting Insects with Living Mulches* in the October 1993 issue of *The IPM Practitioner* is recommended. Somewhat dated, it still provides an excellent summary (29).

One of the best discussions of living-mulch agriculture from an organic perspective was published in the October–December 2000 issue of *HortTechnology* (26). After a good review of the literature, authors Leary and DeFrank describe an idealized organic living mulch system that would have the following features:

- a compatible, non-aggressive cover crop
- zone tillage to open and maintain a good seedbed
- concentration of composts, amendments, and organic fertilizers in the tilled production strips
- mowing for living mulch suppression, with the clipped residue collected and applied as an organic mulch to the crop

Zone Tillage

According to the strict definition, zone or strip tillage is similar to no-tillage except that a narrow 5–7" wide seedbed is established for planting. In no-till, a mere slot is opened into the soil for planting. The narrow seedbed in zone tillage is usually created by one or more gangs of fluted coulters mounted on the front of the planter. In the broader sense used here for organic farming, strip tillage will refer to any system in which a seedbed strip is established through a cover crop or crop residue, while still leaving a wide, untilled inter-row area.

Strip tillage offers certain advantages by encouraging the earlier warming and drying of the immediate seedbed area. This can be especially valuable in cold, wet spring weather. In traditional no-till, where planting is done into a narrow slot, harvest can be delayed by as much as 2–3 weeks in some areas. This can be a real problem for growers trying to target a market window (30). The loosening of the soil through zone tillage can also make for a more desirable seedling environment. Farmer experiences, especially with vegetable production, suggest that these are some very significant advantages. Several organic vegetable growers in California, for example, have reported that zone tillage made a great difference in the success of their killed mulch systems (13).

Zone tillage appears to be one of the key technologies that make killed mulch and living mulch systems work. In some instances, the tilled zone may need to be fairly wide. It typically needs to be managed with additional cultivation, hoeing, or traditional mulching during the cropping season.

An early, farm-based living mulch system of this sort was described in a 1991 *New Farm* article by Craig Cramer (31). The featured farmer was an organic produce grower in Minnesota, who did much of his farming with draft horses and walk-behind equipment. Winter squash was grown on fields planted to a winter cover crop of oats and field peas the previous fall. When the soil warmed sufficiently in spring, 2.5–3.5' strips were tilled on 6' centers and immediately direct-seeded or transplanted to squash. For several weeks, weeds in the cash crop strips were managed through horse-drawn cultivation and hand-hoeing. When the remaining cover crop reached about 3 feet of growth, it was mown using a walk-behind sickle mower. The residue was then hand-raked into the squash-row as a mulch.

Cover Crop Technologies

There is no doubt that research and development of cover crops has made—and will continue to make—a considerable difference to the suitability and adaptability of conservation tillage to organic systems. This is most obvious, of course, with killed or living mulch systems—these approaches are defined by the specifics of how cover crops are managed.

Though not a defined aspect of mulch or ridge tillage, cover crops are also being given increased attention where these systems are concerned. A particularly interesting article that highlighted the need and potential for cover crops appeared in the March–April issue of *The New Farm*. In *Micromanaged Cover Crops* (32) author Craig Cramer describes an Iowa ridge-till farmer's attempts to simultaneously drill several different species of cover crops into the varied micro-terrain of a ridge-tilled field. Oats, crimson clover, and/or berseem clover were seeded on the ridge peaks; these species winter-kill readily in Iowa and made early planting easier.

Mammoth red clover was seeded into the ridge valleys to control erosion, and sweetclover into the wheel-track valleys to break up compaction. These two species would be killed with the first pass of the high-residue cultivator. Various difficulties were encountered involving the differences in seeding rates required for uniformly good stands, and with the capability of the cultivator to fully kill well-established sweetclover. The story, however, illustrated the kind of out-of-the-box thinking required to develop more sustainable low-till technologies for organic cropping.

Good resources are now available to assist in researching and selecting cover crops. The Sustainable Agriculture Network's *Managing Cover Crops Profitably* is among these (33). Also recommended are the *Northeast Cover Crop Handbook* (34) and *Covercrops for California Agriculture* (35). ATTRA also has a useful publication on this topic, titled *Overview of Cover Crops and Green Manures*.

Selected Abstracts: No-Till/Low-Till Research and Writings Relevant to Organic Systems

Living Mulches for Vegetable Production: Researchers at the University of Illinois evaluated four perennial "living mulch" covers—Dutch white clover, red clover, perennial ryegrass, and canola—for the production of Hungarian wax pepper and okra. The vegetables were established by transplanting into tilled strips in the mulch treatments. A reasonable level of in-row weed control was maintained by hand hoeing.

Crop yields were reduced by all the living mulch treatments, but were lowest in the canola and perennial ryegrass treatments. Mowing, as a means of living mulch suppression, improved crop yields generally.

Biazzo, Jeromy and John B. Masiunas. 1998. Using living mulches for weed control in Hungarian wax pepper (*Capsicum annum*) and okra (*Abelmoschus esculentus*). Illinois Fruit and Vegetable Crop Research Report. University of Illinois—Champaign. January. p. 6.

Spring-Sown Cover Crops and Undercutting: The research on undercutting begun at Ohio State early in the 1990s continues. Investigators spring-planted two winter annuals, grain rye and field peas, both as monocultures and as bi-cultures in varying proportions. The cover crops were undercut after two months and tomato seedlings transplanted. Weed suppression was effective for roughly six weeks. However, by that time, tomato growth was sufficiently advanced to be unaffected by weed competition.

Yields were highest in plots that had 50% or more of the cover in peas, apparently in response to greater nitrogen availability. The soil loosening accomplished by undercutting also appeared to have a positive effect on the transplants when contrasted to control plots where this tool was not used.

Christine, Akemo Mary, Mark Bennett, and Emily Regnier. 1998. Weed control in tomato production using spring-sown cover crops killed by undercutting. HortScience. Vol. 33, No. 3. June. p. 495.

A Living Mulch System for the South: In the mid-1990s, farmer researchers on a CSA farm in Alabama began a research project with funding from the Organic Farming Research Foundation. The objective of that research actually related to composting. However, the information provided in their research report describes a cropping system centered on annual use of living mulches.

As a general practice, the entire growing area on this farm is planted to Dutch white clover every fall. In the spring, production beds are created by tilling to leave strips of clover as walkways. The clover is managed during the growing season through regular mowing. The trimmings are then composted and re-applied to the beds. The viability of the living mulch walkways is dependent on weather conditions. Hot and dry conditions strongly suppress the growth of the clover.

Walz, Erica. 1998. Evaluating the use of living clover mulch as a nitrogen source for compost. Organic Farming Research Foundation Information Bulletin. No. 5. Summer. p. 10–11. Copies of the full research report are available upon request from: Organic Farming Research Foundation, P.O. Box 440, Santa Cruz, CA 95061 Tel: 831-426-6606, Fax: 831-426-6670 Email: <research@ofrf.org>.

Snap Beans in Killed Mulch Culture: The work done by USDA researchers Abdul-Baki and Teasdale is among the most informative on the matter of killed cover crops, highlighting both the potentials and the challenges of this approach. Their efforts at growing transplanted broccoli and tomatoes have already been discussed. For three years, they also evaluated direct-seeded snap beans, again using a flail-mowed mulch of hairy vetch.

Compared to conventional tillage plots, the killed mulch plots produced higher yields with no additional nitrogen fertilizer. Weed control was managed with a minimal amount of hand weeding in two out of three years. In the third year, a flush of grassy weeds in the no-till plot proved a problem. The researchers chose to control it with an herbicide. The problem would have been more significant under organic management where chemicals are not an option.

Abdul-Baki, Aref A. and John R. Teasdale. 1997. Snap bean production in conventional tillage and in no-till hairy vetch mulch. HortScience. Vol. 32, No. 7. December. p. 1191–1193.

More Research from Maryland: Cover Crop Mixtures vs. Monocultures: For three years, Abdul-Baki and Teasdale studied the winter cover crops hairy vetch, grain rye and crimson clover, as monocrops and in combination, as part of a mow-kill production system for fresh tomatoes.

They observed, as expected, that combinations of cover crop species generally produced greater biomass, and that greater biomass provided better weed suppression. Also anticipated was their observation that small-seeded annual weeds were the most easily managed with this system, with a shift towards perennial weed species likely over time. Also noted was the high carbon-to-nitrogen ratio of the monocrop rye residue, suggesting the possibility of nitrogen tie-up in the soil.

Of particular interest were the varying yield results from year to year. In cool, wet years, mulched plots often showed delays in crop maturity. Also of interest was the relative performance of comparative plots where herbicides were used. As in their other studies, Abdul-Baki and Teasdale used flail mowing to kill the cover crops. They duly noted that this may not be the optimum cover crop killing technology, due to the rapid decomposition of the shredded biomass, which gives weeds a better chance at resurgence.

Teasdale, John R. and Aref A. Abdul-Baki. 1998. Comparison of mixtures vs. monocultures of cover crops for fresh-market tomato production with and without herbicide. HortScience. Vol. 33, No. 7. p. 1163–1166.

Vetch Mulch Repels Colorado Potato Beetle: ARS entomologist Kevin Thorpe monitored the Abdul-Baki/Teasdale trials for their effects on insect pests. He was able to document that the hairy vetch mulch was decidedly repellent to Colorado potato beetle—a pest of tomatoes in much of the country.

Anon. 2001. Vetch thwarts beetle. Small Farm Today. January. p. 11. For more information, contact Kevin Thorpe, ARS Insect Biocontrol Laboratory, 301-504-5139, <thorpe@asrr.arsusda.gov>.

Living Mulch as Beneficial Insect Habitat: Providing a beneficial insect habitat is one of the possible benefits of living mulches. Researchers in Virginia looked into the potential of various living mulches to assist pest management in cucurbits (cucumbers and heirloom pumpkins). They made a number of comparisons among buckwheat, oats/vetch, and oats/white clover living mulches, with conventional and straw-mulched plots. Living mulches clearly increased the numbers of key predator species and demonstrated the potential of keeping the major pest—cucumber beetle—below economic threshold levels.

Yields of living mulch plots lagged well behind those of conventional practices. It was observed, however, that increasing the crop-to-living mulch ratio could make a dramatic difference. When a twin-row planting system was tried in the buckwheat plots, the crop:mulch ratio was increased from 3:5 to 5:3. The yields from the twin-row system increased 4.8 times over the single-row approach. However, this greater yield was still only 72% of that achieved on the conventional plots, indicating much more research is needed to develop systems capable of "economically viable" yields.

Amirault, Jean-Pierre and John S. Caldwell. 1998. Living mulch strips as habitats for beneficial insects in the production of cucurbits. HortScience. Vol. 33, No. 3. p. 524.

Combining Killed-Mulch and Living Mulch Technologies: In 1998 and 1999, the Virginia Tech researchers continued their conservation tillage work with cucumbers. In this instance, they planted and transplanted cucumbers into a rye/vetch cover crop that had been killed by rolling. Inter-row strips of cover crop were left untouched and allowed to flower as habitat for beneficial insects. One hand-weeding was required at 3 weeks after planting to obtain the same control achieved by herbicides. When compared to conventional cucumber production using black plastic, the mulch plots had higher numbers of predator insects, fewer cucumber beetles, lower incidence of bacterial wilt, and yields 59% higher in '98 and 23% higher in '99. The Virginia Tech folks appear much further along in finding the "economically viable" systems they were seeking just a few years earlier.

Caldwell, John and Maurice Ogutu. 2000. Effects of rye-vetch no-till and habitat strips and black plastic mulch on insect densities, weed control, and fresh-market cucumber growth and yield. HortScience. Vol. 35, No. 3. June. p. 478–479.

Allelopathic Effects on Crops: It has been observed that allelopathy may not only suppress weeds, but also damage certain crops, especially small-seeded vegetable crops. Transplanting has occasionally been viewed as a means of circumventing this problem.

Kentucky State researchers explored the possibility of allelopathic damage to tomato, broccoli and lettuce crops transplanted into a mow-killed sorghum-sudan mulch. All three crops suffered significant allelopathic damage in the mulched plots. This killed mulch cover is therefore not suitable for these crops.

Mitchell, J.P., et al. 2000. Potential allelopathy of sorghum-sudan mulch. HortScience. Vol. 35, No. 3. June. p. 442.

Bell Peppers in Cowpea Mulch: A two-year conservation-till study was done in Thermal, California to see if bell peppers could be successfully grown using a mow-killed cowpea mulch. The bell peppers were transplanted into the mulch and provided supplementary irrigation through a drip system. Peppers in the cowpea mulch yielded 202% and 156% more in dry weight, as compared to bare-ground culture, in '97 and '98 respectively; resulting fruit size was comparable.

McGiffen, Milton E. and Chad Hutchinson. 2000. Cowpea cover mulch controls weeds in transplanted bell peppers. HortScience. Vol. 35, No. 3. June. p. 462.

Tomatoes in Killed Rye/Vetch in Massachusetts: As indicated earlier, it is a challenge to find professional no-till/low-till research conducted in an organic context. This piece of research is among the few exceptions. The investigators (Mark Schonbeck, Peggy Elder, and Ralph DeGregorio) are well known in sustainable and organic farming circles.

A series of experiments relating to cover crop management were done on soils in Massachusetts that had a lengthy history of biological farming management. The objective was to develop information for gardeners and market gardeners. Among the trials was one that tested a mow-killed mulch of hairy vetch and rye against a more standard organic option in which the same cover crops were tilled into the soil in advance of planting.

The results were quite positive. The tilled plots produced more heavily early in the season, but the yield difference shrank as the season progressed. In the end, the difference in total yield between the mulched and tilled plots was not significant. The time spent in later weed management on the killed-mulch plots was about three-fourths that spent on the tilled plot. Mulched plots clearly showed better moisture conservation.

The researchers alluded to potential problems from pests—especially slugs—in mulch systems, though their trials did not appear to be bothered. It is interesting to note that few other investigators allude to problems with such pests; most appear more focused on the pest control benefits mulches provide as beneficial habitat.

Schonbeck, Mark, Peggy Elder, and Ralph DeGregorio. 1995. Winter annual cover crops for the home food garden. Journal of Sustainable Agriculture. Vol. 6, No. 2–3. p. 29–53.

No-till Pumpkins in NY State: In 2000, Cornell researchers investigated no-till pumpkin production in a flail-mowed rye mulch. They looked at a number of variables including the relative merits of transplanting vs. direct-seeding, and short vs. long season varieties.

They found that the long-season variety ('Howden') generally performed adequately under no-till, but did rather better under conventional tillage. Transplanting was clearly better than direct-seeding for 'Howden'. Apparently it responded well to the earlier warming of soil under conventional tillage.

The situation was different for the short-season variety 'Rocket'. 'Rocket' seemed to be especially well suited to no-till and performed equally well whether transplanted or direct-seeded. The investigators noted that future weed management research for these systems needs to focus on suppression at 4–6 weeks after planting, when weeds begin to push through the mulch.

Blomgren, Ted. 2001. Reduced-tillage pumpkins studied in New York. The Vegetable Growers News. March. p. 15–16.

Optimum Timing for Rolling: Alabama researchers took a hard look at rolling as a means for killing small-grain cover crops. The specific roller under investigation was the roll-crimper—a large cylinder with strips of angle iron welded lengthwise. This implement was of particular interest because the manner in which it lodges the cover crops is believed to be especially soil-protective. It also facilitates no-till planting when the planter follows in the same direction taken by the roller. Finally, rolling is inexpensive—about $1.50/acre, which is the same as the cost of cultipacking.
Most of the experimental variations tested in this trial involved the use of herbicides; investigators were seeking to combine reduced-rate herbicide kill with the roller. The roller was evaluated on its own, however, and this information is particularly useful in an organic setting.

The cover crops tested in this trial were black oats, rye, and winter wheat. The optimum stage for roll-killing any of these cereals appeared to be after flowering and pollen shed, but before soft-dough. The early milk stage seemed ideal. Black oats reaches this stage earlier than either rye or wheat. This provides an advantage for the grower needing to get into the field earlier to hit a market window. Black oats, however, produces less biomass than either rye or wheat so there is some loss of weed suppression.

Ashford, D.L. et al. 2000. Roller vs. herbicides: an alternative kill method for cover crops. Proceedings of the 23rd Annual Southern Conservation Tillage Conference for Sustainable Agriculture. June. p. 64–68.
<http://www.agctr.lsu.edu/wwwac/tillage/>.
Note that the highlights of Ashford's research are featured in the May–June 2001 issue of *Progressive Farmer*, in an article titled *Cover Crops Too Tall? Roll 'Em Down*. The piece, by John Leidner, is of particular value due to the excellent photos showing a home-built mower mounted on the front of a John Deere 4840 tractor, and a partially rolled stand of grain rye. To obtain a back issue of *Progressive Farmer*, call 1-800-292-2340.

No-till Organic Broccoli: Virginia Tech's Ronald Morse included an organic broccoli treatment as one part of a trial conducted to assess further no-till potential. The organic system entailed transplanting broccoli into a number of different monoculture and bi-culture cover crops that were killed by flail-mowing. A side-dressing of blood meal was used to supply supplemental nitrogen. The organic system was compared to conventional clean tillage and conventional no-till systems in which rolling was combined with herbicides, and ammonium nitrate was used as a supplemental nitrogen source.

Soybeans, cowpeas, and foxtail millet were evaluated as monoculture cover crops. Combinations of cowpeas/millet and soybeans/millet were also tested. Dr. Morse observed that the soybeans/foxtail millet was the most effective weed-suppressive mulch tried in the organic plots. He noted that one hand-weeding or mechanical cultivation was still required in these plots to keep weeds below "weed-limiting threshold levels."

Dr. Morse also noted that nitrogen was a limiting factor in the organic system. Though blood meal was applied at levels to deliver the same amount of total N, yields were significantly lower than in those plots receiving ammonium nitrate. Manures, additional sidedressings, and/or foliar sprays were suggested as means for making up the deficit.

It seems somewhat strange that nitrogen would be deficient in the organic plots given the application of blood meal at equivalent agronomic rates; it is among the most readily available of organic supplements. Since it is likely that this research was done on a field with a history of conventional management, it would be interesting to learn if the same nitrogen deficit would be found were the trial conducted on soil with years of organic care.

Morse, R. 2000. High-residue, no-till systems for production of organic broccoli. Proceedings of the 23rd Annual Southern Conservation Tillage Conference for Sustainable Agriculture. June. p. 48–50. <http://www.agctr.lsu.edu/wwwac/tillage/>.

<u>Desert Production of Transplanted Lettuce:</u> The desert valleys of Coachella and Imperial in California produce a wide array of vegetables. The use of cover crop mulches could not only suppress weeds but moderate soil temperatures and possibly extend production windows. Trials in the Coachella Valley evaluated cowpea residue as a mulch. Results were largely positive. The residue mulch reduced weed control costs and allowed for earlier planting due to moderated soil temperatures.

Ngouajio, Mathieu, et al. 2001. Reducing Weed Population and Soil Temperature in Desert Vegetable Production with Cowpea Mulch. Paper distributed at 2001 Eco-Farm Conference, Asilomar, California. Author can be contacted at Department of Botany and Plant Sciences, University of California, Riverside, CA 92521-0124.

<u>Farm Production of No-Till Garlic:</u> Pennsylvania farmers Eric and Anne Nordell have earned a reputation as highly innovative organic market gardeners, making a modest living on limited acreage. Articles by them are a frequent feature in *Acres USA*, the *Small Farmer's Journal*, and other alternative agriculture publications. An article in the May 2001 edition of *Maine Organic Farmer & Gardener* details their no-till system for growing garlic, which is still under development:

> *They [the Nordells] adapted a subsoiler so that it makes slits in a cover crop of oats and peas. They plant garlic by hand into the slit, and the oats and peas die back over the*

> *winter. In the spring, their no-till garlic came two weeks earlier than garlic that had been heavily mulched and grown in the traditional manner.*

The Nordells utilize a number of techniques involving planned rotations, interseeding, beneficial insect refuges, summer fallowing, and cover cropping. Their farm is a fascinating study in low-input sustainable farming. They have produced a video that presents an overview of their farming system, plus a collection of articles they've written. The video and the information packet are available for $10 each (p&h included) from: Anne & Eric Nordell, RD 1, Box 205, Trout Run, PA 17771.

English, Jean. 2001. Rotating out of weeds. Maine Organic Farmer & Gardener. March–May. p. 18–19.

<u>An On-Farm Living Mulch System in Montana:</u> Helen Atthowe, a part-time horticulture agent in Missoula County, Montana, farms about 3 acres of intensive organic vegetable crops. Among the production systems she is using and refining are living mulches, consisting mostly of clovers and medics. With financial support from a SARE grant, Helen has documented nutrient changes over time in the living mulches and the production beds.

For the details of Atthowe's study contact Western Region SARE, Rm. 322, Agriculture Science Bldg., 4865 University Blvd., Utah State University, Utah 84322. Helen Atthowe can be contacted directly at Biodesign Farm, 1541 South Burnt Fork Rd., Stevensville, MT 59870, email <mslss@mssl.uswest.net>.

Weiss, Christine Louise. 1999. Biodesigning your farm. Acres USA. May. p. 21–23.

<u>California Research Underway:</u> In late 2000, UC Santa Cruz's Center for Agroecology & Sustainable Food Systems announced that they had begun experimentation with organic conservation tillage. The first trials will evaluate several cover crop combinations and management methods to assess their suitability for organic pumpkin production. The principal investigators involved in this effort are Jim Leap and Jeff Mitchell. Results of the Center's work will be published in their newsletter *The Cultivar*.

Brown, Martha. 2000. Center takes part in conservation tillage study. The Cultivar. Vol. 18, No. 2. Fall–Winter. p. 5. Subscriptions to and back issues of *The Cultivar* are available from: CASFS, University of California, 1156 High St., Santa Cruz, CA 95064 Tel: 831-459-4140, Fax: 831-459-2799, Website <http://zzyx.ucsc.edu/casfs>.

<u>A Guide To Zone Tillage:</u> For many years, the late Don Schriefer was one of a "stable" of speakers and authors on sustainable farming promoted by the popular publication *Acres USA*. His insights into soils, tillage, and fertilization were practical and highly respected.

The posthumous publication of his book *Agriculture In Transition* is most welcome. Several pages are spent contrasting the effects of different tillage systems on soils and crops. He speaks most strongly about zone tillage and why it works so well for a growing number of farmers.

Agriculture In Transition is available in softcover (238 p.) for $27 (p&h included) from Acres USA, P.O. Box 91299, Austin, TX 78709, Tel: 800-355-5313, Fax: 512-892-4448.

Summary

The rapid growth in organic agriculture has helped to spur research in herbicide-free conservation tillage. Interest, however, is not confined to the organic sector. A recent article in *No-Till Farmer* (36) spotlighted a fledgling Canadian group called the *Pesticide Free Farmers Association*. The formation of this group was motivated by a now familiar set of factors—the growing costs of chemical-intensive farming, opportunities in 'green' marketing, and concerns about sustainability. While not organic, this group of farmers is intent on developing successful no-till production systems that work without pesticides. These growers have the relatively modest objective of not using pesticides for one or more years within a rotation and marketing their production in those seasons under a "green" label. Pesticides—particularly herbicides—will be allowed in "off years" to keep control of weed populations.

Compared to these Canadian growers, organic farmers face greater constraints and challenges because synthetic herbicides can **never** be an option. This IS an important point. Unless cultivation is already comfortably integrated into the system—as it is with mulch and ridge tillage—there must be a fall-back option for weed control. The fall back options will certainly be needed at two points. The first of these involves controlling biennial and perennial species that escape and predominate under no-till/low-till culture. Organic growers can still use traditional tillage options in such cases. Certain crops in rotation can be grown with traditional organic cultivation so that low-till/no-till culture can be employed for some, if not most, of the years within a cycle. For the near future at least, this appears to be a reasonable strategy for most farmers.

Similarly, some forms of hoeing or cultivation will likely be needed within most low-till systems. Where zone tillage and living mulches are used, some mechanical weed control will likely be needed for much of the season. With killed mulches, it will be needed mostly in the late season.

Some of the new classes of herbicides may also play a role in expanding organic conservation tillage options. Contact herbicides with active ingredients such as fatty acids, vinegar, lemon juice, and clove oil might be allowed for organic production in the future. They might be used as a means of killing or suppressing cover crops and/or as in-season weed control tools if protective shielding is used to protect the crop. Some forms of thermal weeding may also be useful. However, flaming could be a fire hazard if used where significant amounts of dried residue are accumulated.

There are additional dimensions to conservation tillage that this publication barely addresses. Among the most glaring is the relationship between conservation tillage and insect pest and disease incidence. While a few abstracts—primarily dealing with insects—are provided in the text, the available research on these developing systems is still quite limited. While there is a natural tendency to extrapolate from the experiences under conventional conservation tillage, insect pest and disease pressure under organic management may be considerably different. Predictions and conclusions should be drawn with caution.

While organic conservation tillage systems are certainly worthy of pursuit, it is clear that there is much to be learned before the more radical of these—killed mulches, living mulches, etc.—can be widely adapted. Most, if not all, strategies will require some cultivation…at least for the near term. As imperfect as such systems might be, they will still contribute greatly to the sustainability of organic agriculture and should be pursued vigorously.

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4) The *Alternatives in Agriculture* Reports are updated annually. The 2001 report is available for $10 postage paid from: Thompson On-Farm Research, 2035–190th St., Boone, IA 50036-7423. Tel: 515-432-1560.

5) Conservation Technology Information Center, 1220 Potter Drive, Rm. 170, Purdue Research Park, West Lafayette, IN 47906-1383 Tel: 765-494-9555, <http://www.ctic.purdue.edu>.

6) *Conservation Tillage Systems and Management: Crop Residue Management with No-till, Ridge-till, Mulch-till, and Strip-till*, Publication #MWPS-45, is available for $30.50 ($25 plus $5.50 p&h) from NRAES, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701, Tel: 607-255-7645, Fax: 607-254-8770, Email: <nraes@cornell.edu>.

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32) Information on Steve Groff's experience with no-till can be found in a number of places. Of particular note is a cover article, *Making No-Till Work*, by Christine Weiss, in the February 1999 issue of *Acres USA*. Back issues of *Acres USA* are available for $5 from Acres USA, P.O. Box 91299, Austin, TX 78709-1299, Tel: 512-892-4400. Information can also be found at Groff's website <http://www.cedarmeadowfarm.com/> and through a video highlighting his no-till practices. The video is especially instructive as it shows Groff's Buffalo™ rolling stalk chopper in action. The video is available for $24.95 (s&h included) from Steve Groff, Cedar Meadow Farm, 679 Hilldale Rd., Holtwood, PA 17532 Tel: 717- 284-5152, Email <sgroff@epix.net>.

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Further ATTRA Resources:

The following ATTRA publications are directly related to the subjects discussed in this document. For copies, call ATTRA at 1-800-346-9140. Or read them on-line at: <http://www.attra.ncat.org>.

Overview of Cover Crops and Green Manures
Conservation Tillage
Overview of Organic Crop Production
Principles of Sustainable Weed Management
Farmscaping to Enhance Biological Control

ATTRA program specialists Steve Diver and Preston Sullivan have made diligent efforts to follow developments in conservation tillage for vegetable and agronomic crops respectively. Both have additional information and materials to share on these topics.

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By George Kuepper
NCAT Agriculture Specialist
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