No-Till Vegetable System at Tobacco Road Farm

by Bryan O'Hara

Over the last twenty-plus years of vegetable growing at Tobacco Road Farm in Lebanon, Connecticut, we have constantly sought ways to improve the health and vitality of our crops and soils. About 3 acres of land is in vegetables, with about half in year-round vegetable production and the other half cover cropped through the winter months.

The crop rotations are very close, with yields very high, so the intensity of production demands very careful soil care. To this end, soil amendments, fertilizers, inoculants and compost have been carefully selected and applied over the years in no small degree. Under this intensity of production, tillage was previously utilized to an excessive degree. This left the soil with a soil structure that was lacking in aggregation, tended toward surface crusting and with a plow pan always in need of mechanical breaking. The loosened soil of the tillage layer dried excessively in summer, leading to irrigation needs, and the soils' air/water balance was constantly in jeopardy. Tillage also imbalanced the soil microbes, including the fungal and bacterial relationships, all of which led to high nitrogen and potassium, and low calcium, magnesium and phosphorus levels in tissue analysis. Some of the signs of this in the field were weed proliferation in the form of *Galinsoga parviflora* along with fungal disease pressure.

To limit soil damage, reduced tillage was steadily adopted over the years. This took the form of permanent bedding and wheel tracks with chisel plowing and very shallow rototilling of the bed surface. Then we moved into prepping the beds' surface with harrows only, disc, springtooth and rod weeders, combined with a roller. No-till began with experimentation in mown annual cover crops at flowering with furrow openers for seeding winter squash, as well as thick mulches applied to the bed surface and transplanted into, or thick mulches which had been in place removed before seeding of various crops. Both of these no-till systems had limited success due to difficulties in applying them to our fast-moving production system as well as difficulties with slugs. We clearly needed a better system.

Measures to improve these conditions were assisted by extensive soil and tissue analysis along with traditional biodynamic approaches. The real push to no-till, however, came from the recommendations of Korean Natural Farming (KNF). KNF is most commonly known for the use and practices around IMOs, or Indigenous Micro-organisms. The use of IMOs involves the culturing of forest organisms into a very high level of activity, much of which is fungal activity. This culture is then applied to soils. To apply tillage to such cultured soils would be counterproductive, as fungus is generally thoroughly damaged by the churning action of tillage implements.

So, a system was developed on the farm which has proven to be quite successful in improving crop and soil health as well as dramatically increasing yields. The techniques involved include ways to eliminate the preceding crop or cover crop and chop their residues, control weeds and achieve weed-free bedding surfaces, apply appropriate fertility application and irrigation, increase biological activity and diversity through IMO, broadcast and interseeding crops and cover crops. The fields where this system was put into place were quite fertile, had few perennial weeds, and previously had plenty of annual weeds. When appropriate, we still use thorough tillage techniques to bring a field into this system: This includes moldboard plowing and immediate disc harrowing, followed by bed-shaping to establish permanent wheel tracks, then chisel plowing the beds, field cultivating and rolling; with additional appropriately timed trips with the field cultivator and rod weeder, if perennial weeds like quackgrass are an issue. An annual cover crop may be then sown to allow the field to restabilize after such intervention. Since we will not be returning to the field in the future with tillage equipment, it is critical to "set the stage" correctly before

entering into no till. In short, this means the tillage addresses plow pan compaction, full elimination of perennial weeds and incorporation of any needed amendments.

To begin seedbed preparations, the existing vegetation must be reduced. This is achieved most often with a mowing machine front-mounted on a BCS two-wheel tractor. If we desire a chopped residue for quick decomposition, a rotary mower implement is utilized. If we desire a slow decomposition, a sickle bar mower is the implement of choice. The rotary mower is essentially a heavy-duty lawn mower and has a bagging capacity which is useful for removal of residues which contain weed seed. With the infrequency of weeds, however, in the system most residues are left on the soil surface, which aids in fertility and enhances the overall layering effort to reduce weed seed germination. The sickle bar mower is able to more easily handle taller residues, and also is gentler on beneficial insects such as spiders, lady beetle larvae, etc. Though we have quite a few larger tractors, the lighter weight and superior maneuverability of the BCS have made it the machine of choice for this job. Other methods used to chop residues include hand tools such as the machete, scythe, or sickle. These tools need to be kept very sharp to be effective and are obviously much slower than the mowing machine, but occasionally have an appropriate use. Often weed seed heads are removed with knives before mowing. Low-growing weeds with seeds are grub hoed and removed if necessary. Excess residues may also be raked to the side and reapplied on top of the compost layer.

Once the vegetation has been reduced and weakened by mowing, the possibility of regrowth from its roots is then addressed. From approximately May through September this is achieved through solarization with sheets of clear plastic in the hot sun. The plastic is secured with sandbags along the sides every 20 feet or so (it is important to limit air from getting in under the cover so the residues are mown relatively low). One to two days of sunny, roughly 75°F-plus weather are usually sufficient, but depending on conditions, slightly lower temperatures may work as well.

Solarization quickly kills any annual plant, however perennial roots are entirely resistant to such quick solarization and are manually removed. The surface soil temperature increases about 50°F above air temperature, so an 80°F day will give a 130°F soil surface temperature. This temperature drops significantly at a 1-inch soil depth to about a 10°F gain however, so damage to soil biology is minimal. The plastic sheets are taken off the field as soon as possible to avoid soil damage. The sheets are often previously used high or low tunnel covers though large sheets of 4 mil construction grade plastic are also utilized. These sheets are rotated in order to cover large areas. For instance, we may mow a quarter acre of cover crop, solarize for two days and then mow the next quarter acre and move the sheets over. During the cooler months, roots are hoed with very sharp wide hoes just below the soil line. In this case the roots are often simply vegetable residue, weak and easily hoed. Winter-killed cover crops such as oat and field pea are also utilized for early sown vegetables. Another practice is mowing and leaving roots in place, then burying the roots with the weed-free compost and chopped mulch is also practiced.

Once the previous vegetation has been dealt with, the next step is to apply weed-free compost, if required. The preparation of this compost is relatively easy as it is top dressed, which allows for much more flexibility in its state of decomposition. This compost goes a long way toward burying weed seeds and feeding soil biology. The compost is prepared with high-carbon materials, making it fungal-friendly, and contains large amounts of silica as well as other added minerals. Biodynamic preparations are utilized. The basic ingredients are: wood chips, cattle manure, weed-free farm residues, vegetable scraps from the local food co-op, spent hay, leaves, aged sawdust, basalt dust (from a local quarry's rock crushing), clay subsoil, and minerals like gypsum, hydrated lime, sea salt, sulfur, zinc sulfate and a small amount of boron, molybdenum, and cobalt.

The piles are turned a couple of times, then applied to the surface of the beds with wheelbarrows (loaded from a tractor bucket), a dump cart mounted on a Farmall Cub, or for wider beds straight from a pickup truck bed or a manure spreader which straddle the beds. Since the material is applied to the surface of the bed, larger volumes of carbon in various forms are possible and beneficial for our conditions. In the first year of transitioning to no-till we applied a 1-2-inch thick layer of compost to the bed surface; now a typical application would be about ½-inch thick. A high percentage of wood chips, say about 40 percent, greatly aids in passively aerating the pile which reduces turning needs. Compost application definitely gives better seed germination as most seed is broadcast, though compost is not necessary at every seeding.

Following compost application, inoculant is often applied to the bed surface. This is in the form of an IMO, which is cultured from forest microbes from the farm's surroundings. The techniques are from Korean Natural Farming, manuals for which were previously purchased from Acres U.S.A. This inoculant looks like a mycelium-rich compost and aids greatly in enhancing fungal and microbial activity. The compost and inoculant are very sensitive to drying and should be carefully applied — often this is done late in the day, with immediate seeding, irrigation and covering with mulch. The inoculant is also applied through irrigation and foliars, and sometimes inoculant is not applied at all, depending on the crop and availability.

Seed is often broadcast by hand over the bed surface. This needs to be done very carefully to get an even spread. In order to achieve this at a proper crop spacing we measure volume of seed per bed surface area. Broadcasting allows for maximum coverage of the bed with vegetation, which increases overall photosynthesis and thus helps feed the soil life and increase yield as well as inhibiting weed growth.

Crops and cover crops can also be interseeded at any time since the soil surface is generally weed-free. This allows for crop mix combinations which can also enhance soil life as well as yield. This flexibility to seed cover crops into a weed-free environment is very useful. Interseeded cover crops are seeded more heavily, before rain or irrigation. Transplants are also set into the bed, though often they are set after the mulching step described below. Some crops are still seeded in rows, accomplished with the use of warren hoes or single tine hoes to rip a furrow through the mulch residue. Seeding can then be accomplished with a hand push seeder or placed by hand. This is often done for large seeded crops like corn and beans. The broadcast seed applied to the bed surface germinates better if it is worked into the soil surface, accomplished with the use of a drag, which is a group of chain rings attached to a bar similar to a chain harrow but with more flexibility. The rings are grain drill covering rings, purchased from Agri-supply company, and were not expensive. The drag is pulled one way over the length of the bed and then back the other way and is very quick and effective. A rake can also be used, but it is much more difficult to achieve similar results with one. Another tool that is sometimes used for larger seed is a garden weasel, which resembles a hand pulled rolling cultivator. The garden weasel works the seed further into the soil before dragging. Also, a roller is sometimes employed, which further enhances seed-to-soil contact though often rolling occurs after the next step, mulching. The entire process of mowing to reseeding usually occurs in a matter of one to two days. This allows for higher yields and more soil coverage with a growing crop, thus enhancing soil biology.

Once the seed is worked into the soil, mulch is applied to cover the seed; which aids seed germination, further reduces weed germination, and protects the compost and inoculant as well as provides food for the soil life. The mulch is chopped hay, straw, wood chip, and/or leaves. The bales of straw, hay, and sometimes leaf are run through a bale chopper to make a fine material that spreads easily and does not inhibit germination. Unchopped bales can also be carefully used. The hay is preferably from a late first cutting,

which helps avoid some of the seed heads and is a more carbonaceous material, however the danger of weed seed, and the lower carbon level, makes hay the least desirable.

Straw is used, but needs to be free of grain, and both of these materials need to be free of herbicide residue. Chopped leaf is even better as a material as it contains virtually no weed seed, is more carbonaceous, and is most appropriate for feeding the soil. It is much harder to handle in bulk, however, and is easier to use when dry. Wet leaves have a tendency to mat, which is not conducive to germination. The use of partially decomposed unground leaf has been successfully used by itself on some crops. Presently, a mixture of straw and leaf with a little woodchip mixed in after grinding is the mulch of choice. Those materials should be applied in proper amounts to help cover seedless for small seeds; more for crops like potato. The mulch does cool the soil which is of benefit during the summer, but may slow growth in the cooler months, so is sometimes not applied for winter production. We also experimented with laying down a foot or more of fresh cut hay to "burn out" a patch of quackgrass in the winter squash with success.

Immediately after seeding or planting, the crop is irrigated. This gives the crop a jump on any possible weeds and helps preserve the compost and inoculant. It is possible to irrigate before mulching as significantly more water is needed to saturate and penetrate a dry mulch. However, a soaked mulch is superior for moisture retention needs. Often this is the only irrigation necessary for a crop because of the tremendous benefit of no-till and mulching on soil water retention and movement. If the crop requires additional fertilizing, liquid nutrient can be applied through irrigation. Specific composts are also used as side dressing and foliars are applied.

Without tillage the weeds are far less prone to germinate, and conditions are far less conducive to their growth. This system also buries weed seed, and with the layering techniques this control improves every year. Some weeds, however, still slip through and must be dealt with. Since the soil is mulched and crops are broadcast, hoeing is usually not an option. The tool of choice, then, is a serrated weed knife purchased from Johnny's Selected Seeds, though an aggressive steak knife can also work. They are used to cut annual weeds just below the soil line.

For perennial weeds, the roots must be removed, so they are either hand pulled or a trowel or drain spade is used for removal. If the weed has gone to seed it is removed from the field. The greatest challenge for this system seems to lie in the potential for perennial weed build up, so attention is paid to removing them. Perennial weeds are generally not as fast-growing as annual weeds, so offer less direct competition to a crop. Their strength, however, lies in their tenacity! Canada thistle, quackgrass and yellow dock are the most prominent weeds presently. Last year part of a field required tillage for quackgrass. Perennial weeds are often intolerant of thorough, careful tillage, so the tillage equipment stands ready for action if required. In general, however, the soil structure has improved to such an extent that many of the perennial roots are now able to be extracted simply by pulling on the plant.

Another potential difficulty is slugs, particularly for spring plantings. The high residue and wet conditions may encourage slugs, so irrigation is carefully applied so as not to keep the soil/mulch wet for extended periods. The mulch may be dispensed with during this period. Techniques that keep the area drier, such as raised beds, proper drainage (tiles, ditches), and eliminating slugs by solarizing larger areas, are useful. The lush growth from excess nitrogen fertilization especially needs to be avoided. Growing sturdy, hardy plants through proper fertilization is of greatest benefit. Foliar application of leaf "hardening" materials such as vinegar, at rates of about 1:300 of water, would be an example. For problem areas, a slug repellent dust is applied to the surface at seeding. This is a mixture of approximately 40 percent talc (magnesium silicate), 40 percent diatomaceous earth

(calcium silicate) and 20 percent hydrated lime. These materials are drying to slugs, and also enhance crop growth in our soils.

Overall, the system has greatly improved the biological activity and diversity of soil organisms. Higher worm populations are obvious, as well as a much improved crumb structure to the soil. Fungal activity is obvious with lots of mycelium present, along with mushrooms. Vastly improved soil water characteristics include the great benefit of proper wicking from lower soil levels, which helps keep the soil life hydrated throughout the seasons, as well as better drainage, water retention and in-soaking. Soil air is also enhanced through the ability of the soil to breathe through the crumb structure, while excess oxygenation from tillage is avoided. The soil temperature is much more stable, staying cooler in the summer heat and warmer during the winter months. The soil structure is not pulverized through tillage, and erosion is decreased through mulching and constant vegetative cover. Theoretically there is better nutrient retention and management.

There have been significant decreases in insects and diseases, including: greatly reduced brassica flea beetle, absence of root maggot in rutabaga and turnip, no cabbage losses to black rot, and much less leek leaf disease, among others. Though a little more effort is required to prepare the beds and make the appropriate compost, overall there is great savings because of much higher yields, reduced weed control, reduced irrigation (including no need for a drip system), as well as a significant reduction in tractor time. Crops are also always planted on time as the soil is never "too wet" to work. All of this has led to higher yields of higher quality. The crops are even sweeter and more flavorful; there are very few culls; storage quality is enhanced, and the vibrancy of the crops is noted and appreciated by the customers.

The system has proven to be quite economically rewarding on our farm, and has also been successfully adopted by other farmers in our region. The low level of mechanization is an attractive benefit to beginning farmers, as well as the intensity of production and high yields. This puts a farming livelihood into the hands of people with a small land base with little initial capital investment. The techniques are also appropriate for scaling to a much larger area as well. No-till systems such as this work in a more harmonious relationship with nature, which has become critical to successful vegetable production.

With the environmental changes that have occurred it has become much more difficult to produce vegetable crops than it used to be even 20 or 30 years ago. The effects of erratic weather conditions and environmental toxins are extensive. In our region, we are faced with severe acid rain and other rain-based pollutants. This has damaged the soil biology and changed the nutrient capacities of our soils. As well, the sun's energy has been blotted out by airborne particulate matter which has lessened the photosynthetic potential to feed the soil biology. Combined with the many other pollutants such as massive electromagnetic transmissions and radiations, the crops struggle. Not only do the crops suffer, but the forest is ridden with insects and disease, has sparse foliage in summer, lacks colorful pigmentation and defoliates early in autumn. Several tree species have already died out or are on the verge of massive die-off.

The bright side of this is that humans must now adapt their agricultural practices to survive. This has led to a more harmonious relationship with nature in terms of our agricultural practices, as the old exploitative systems simply no longer work well. The progress in understanding of soil systems and the move toward gentler approaches in the last few years is astounding and a shining example of human progress.

Broadcast Seed Rates (to 30 sq. ft.) 2016

PLEASE NOTE: these ounces are fluid-- by volume; NOT by weight. There are, for example, 2 Tablespoons (6 teaspoons) in 1 fluid ounce.

Arugula, 1/5 oz; Sylvetta, 1/20 oz
Basil, 1/3 oz
Beans, use seeder in row
Beets, 1/4 to 1/2 oz, depending on seed size
Borage, 1/2 oz
Broccoli, seedbed 1/6 oz
Brussels, transplant
Cabbage, seedbed 1/6 oz
Callaloo, 1/12 oz
Carrot, 1/6 oz, more in the summer, watch seed size
Cauliflower, seedbed 1/6 oz
Celery, transplant
Celeriac, transplant
Chard, 1/2 oz
Chervil, 1/6 oz
Chinese cabbage, 1/16 oz
Cilantro, 1 oz
Claytonia, 1/12 oz
Collard, 1/8 oz
Corn, use seeder in row
Cress: curly, 1 oz; broad, 1/2 oz
Cucumber, use seeder in row
Daikon, 1/8 oz
Dandelion 1/8 oz
Dill, 1 oz
Eggplant, transplant
Fava, use seeder in row
Fennel, leaf: 1 oz; bulb: 1/4 oz or transplant
Garlic, 6" x 6" spacing
Kale, 1/6 to 1/8 oz depending on seed size
Kholrabi, 1/12 oz
Leeks, 1/5 oz: 3/4 oz for seedbed
Lettuce, 1/6 oz for salad mix
Mache, 3/4 oz
Melons, use seeder in row or transplant
Mizuna, 1/4 oz
Mustard, 1/6 oz
Nasturtium, 1 ½ oz
Okra, use seeder in row
Onion, seedbed 1/2-3/4 oz
Pac Choi: baby, 1/12 oz; full 1/16 oz
Parsley 1/4 oz
Parsnip, 1/4 oz, but watch seed size
Peas, use seeder in row
Peppers, transplant
Potatoes 9" x 34" spacing
Pumpkin, use seeder in row
Purslane, 1/4 oz
Radish Leaf, 1 oz
Radish (red), 1/4 oz
Radish (winter), 1/6 to 1/8 oz or less depending on seed size
Rutabega, 1/16 oz
Scallion, 3/4 oz
Scorzonera, 2/3 oz?
Shallot, 6" x 6" spacing
Spinach, 1/2 oz
Squash (Summer), use seeder in row
Squash (Winter), use seeder in row
Tatsoi, 1/4 oz
TokyoBekana, 1/6 oz
Tomato, transplant
Turnip: Hakurei, 1/12 oz; regular, 1/16 oz

RATES ARE VARIABLE

Factors include:

- Weather
- Temperatures
- Use of compost
- Seed size
- Use of roller
- Use of hoes, ring draggers