Soil and Crop Management

Soil Management

Most high tunnel growers produce their crops in the soil on which the tunnel rests; therefore, the quality of the soil under your tunnel will be critical to your success. Given that you will spend a good deal of money to construct a premium growing structure, it makes sense to complete the job by making certain the soil environment is also a superior one.

A coarsely textured, well-drained soil is best for high tunnel production. Clays, because they drain and warm relatively slowly and have a tendency to accumulate salts, are the least desirable soils for high tunnels. (See “Salinization” on page 56.) However, growers have been able to make do with a wide variety of soils, amending and improving them over time.

The structure of the soil in the relatively small space under a tunnel can be dramatically altered. The addition of substantial amounts of compost or leaf litter will increase the organic matter in the soil, thereby increasing the soil’s capacity to provide oxygen, water, and nutrients to the crop.

To lighten heavy clay soils, organic matter can be added in a variety of forms, besides finished compost. For example, aged wood shavings with leaves or a small amount of manure or another organic nitrogen source can improve the structure of a heavy soil. Avoid fresh wood shavings as they will tie up soil nitrogen. John Biernbaum improves the soils in his high tunnels with significant amounts of animal bedding from weekend livestock shows on campus. This bedding has a low concentration of manure.

Monitoring Soil Health

A good monitoring program evaluates the physical and biological composition of your soil as well as its chemical makeup.

Several important indicators of soil physical health are easy to monitor. To determine if your soil is compacted, for instance, you can use a penetrometer, a tool that measures resistance to penetration. Although these devices are expensive, they can sometimes be borrowed from your local Extension office. You may make an effective penetrometer at home by putting a simple handle on a straight piece of rebar. The tip should be sharpened to a dull point. You should be able to push it at least 12 inches down into the soil before encountering resistance.

You can also check plant rooting depth. If you observe plant roots to be growing horizontally at a shallow depth, then the soil is probably too compacted for good root penetration or water drainage, and should be loosened by some form of tillage. When preparing the soil for planting or when removing crop debris, take the time to determine if earthworms are present and at what level.

Traditional chemical analyses are as important in tunnels as they are in the field. Nutrient and organic matter levels, soil pH, and electrical conductivity (salts) should all be measured periodically.

Adding Nutrients

High tunnel production is intensive, with faster growth than typically found in field production. In some cases, three or even many more successions of crops are grown in a tunnel during a single year. (Greens growers can produce as many as eight crops per year in the Northeast.) Because of this intensity, high tunnel soils benefit from relatively high applications of compost, fertilizer and other soil amendments. Similarly, large applications of organic matter are also beneficial.

Farmers approach nutrient management in high tunnels in a variety of ways, many of which are similar to their field practices. One notable absence from high tunnels is the practice of cover cropping, even on farms that employ cover crops in their fields. Farmers have offered several reasons for the lack of interest in cover cropping in high tunnels: first, there is no risk of erosion inside a tunnel; second, space is at a premium; and third, windows of time for cover cropping are minimal, particularly for farmers who use their tunnels year-round. Some cover crops could potentially serve as over-wintering habitat for pest species.

Many farmers rely heavily on compost as the foundation of their fertility programs. A balanced compost added to a good soil can provide the range of nutrients required for crop development, and some farmers depend upon it exclusively for fertility. Too much of a good thing can create its own problems, however. Using too much compost is not only expensive; it can also lead to the build-up of salts and outbreaks of root-feeding arthropods such as tiny symphyllans.

Several farmers reported adding large amounts of compost to a new high tunnel, and then adding modest levels thereafter. For a new tunnel at Slack Hollow Farm, compost was added at the rate of 10 tons per acre. The Blomgrens also load up at the onset. Then, before each new crop, they spread just five gallons of compost per 40 square foot bed—a layer of less
than an eighth of an inch. They add this compost to enhance microbial activity, nutrient availability, and soil water-holding capacity. These quantities improve the soil’s structure, but don’t affect soil texture. Compost must be free of viable weed seed.

Composted manures typically have an excess of phosphorus in relation to nitrogen. If compost is applied at a rate designed to meet crop nitrogen needs, phosphorus will be oversupplied. Farmers who have recognized this problem are reducing their compost applications and applying alternative sources of nitrogen. When determining fertilizer rates, they are sure to credit the compost for the nutrients it has supplied.

When soils are cool in the spring, microorganisms are not converting nitrogen to an available form fast enough to sustain good plant growth. This is the time to consider adding a soluble nitrogen source, such as Chilean nitrate (guano).

Just as periodic soil testing is advisable, it is also wise to have compost tested for nutrient availability, pH, and the presence of substances like salts or toxics that could be detrimental to crops.

(A persistent herbicide called chlorpyralid has contaminated composts containing lawn clippings and other materials.) Farmers can request test results from commercial composters or submit compost samples to laboratory services like Dairy One.

Some farmers manage soil fertility more strictly by the numbers and with less bulky materials. Fertigation, with soluble fertilizers injected into a drip irrigation system, is the basic program employed by many farmers who operate in controlled or managed environments, such as high tunnels and greenhouses. Growers, like Keith Cramer at Cramer’s Posie Patch in Pennsylvania, incorporate a chemical fertilizer into the soil prior to bed preparation. Steve Groff, also in Lancaster County, Pennsylvania, also uses his drip irrigation system to supply his high tunnel tomato crop’s nutrient needs.

Like fertigation, foliar feeding makes soluble nutrients immediately available. Two farmers in this project foliar feed Epsom salts, kelp, and fish products respectively. This practice can be used with a variety of micronutrients as well.

Day Length Affects Flowering

If you extend the season at either end to achieve earlier or later harvest dates, some cut flowers will not perform as anticipated. Plant physiologist Chris Wien, a Cornell professor, realized that day length was the culprit when his several of season extension trials failed.

He attempted to get sunflowers to bloom in the spring rather than summer and he started Rudbeckia hirta (Black-eyed Susan) late to get fall flowers. To prevent mishaps, he suggests experimenting on a small scale before you decide to grow a flower cultivar off-season. He found that seed catalogs are not always correct on this point.

(See “Daylength affects rudbeckias, sunflowers,” June 2006 Growing for Market.)

Nitrate Uptake in Low Light Greens

It has been well documented that the ingestion of excessive nitrates from our diet and water can be detrimental to human health, especially in the very young. The European Union has set limits for nitrate levels in greens. The United States has not yet taken action. Farmers should be aware of this food safety issue and act accordingly in order to produce healthy food.

Greens grown in low light (off-season, winter production) have greater potential to accumulate unhealthy nitrate levels. Plants can take up nitrates in excess of their needs. There are a number of management strategies that can moderate nitrate uptake and improve its assimilation, giving the end result of healthy greens with low levels of nitrates.

The range of suggested practices includes:

• Harvest greens later in the day.
• Do not sell older, more mature leaves.
• Supply adequate soil moisture.
• Maintain soil pH on the high side of the normal range.
• Provide balanced soil fertility.
• Grow in warmer temperatures.
• Select cultivars that better assimilate nitrates (when this characteristic is known).
• Use legume-based compost as a source of nitrogen.
Salinization

Like irrigated lands in arid climates, high tunnels may be vulnerable to the accumulation of salts. If allowed to build up, salts may cause damage to crops. If soils within the high tunnel are well-drained, irrigation water may leach some of the salts through the soil profile, as occurs with adequate, regular precipitation outside. However, if the soil is poorly drained, accumulated salts will actually be brought up to the surface when soil moisture evaporates.

The application of synthetic fertilizers, animal manures, or manure-based compost (all with significant salts) can result in the build up of salts over time in high tunnel soil. Sodium chloride—table salt—is not the only problematic salt in soil. At excess levels, other salts also cause drought-like stress, interfere with seed germination, and inhibit plant growth. Plants with higher drought tolerance typically handle increased soil salt concentrations better than more drought susceptible plants. Nutrient uptake and other metabolic processes can also be disturbed by soil salinity.

In addition to directly affecting the plants, elevated salinity levels have been anecdotally associated with damaging outbreaks of symphylans, tiny arthropod pests (also known as garden centipedes) that feed on plant rootlets and root hairs. “The effects of high soil salts aren’t pretty on plants or income,” says Steve Moore, speaking from personal experience.

Salt stress can mimic the symptoms of drought stress, nutrient deficiency, and root rots caused by soil-borne pathogens. Thus, it makes sense to pursue a proper diagnosis of the problem. One way to test for salinity is with an electrical conductivity (EC) meter (available for under $100). (See “Ben Meadows” and “Pike Agri-Lab” on page xx.) Electrical conductivity is a measure of the ability of a solution to transmit an electrical current. The higher the salt level, the greater the current. EC readings are usually given in deciSiemens per meter (dS/m). In general, readings over 1 dS/m may indicate problems for some fruits and vegetables. When comparing your EC values to those that are published, be sure you are using equivalent sampling procedures. Otherwise, you will not be comparing “apples to apples.”

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(Continued on next page.)
**“Salinization” continued from page 56.**

EC is the electric conductivity of the extract using a water saturated paste solution. Note the reduction of yield as a function of increased salts. From Utah State University Extension, [http://extension.usu.edu/files/agpubs/salini.htm](http://extension.usu.edu/files/agpubs/salini.htm).

The following strategies can help reduce soil salinity in high tunnels:

- Provide adequate soil drainage through natural means (locating tunnels on well-drained soils) or improve soil drainage through artificial means (drainage tiles or pipes).
- Allow the soil to dry and then scrape off a top layer of soil and salts. Add more soil as needed.
- Flush out the salts periodically. This can be done either by removing the cover or by flooding the high tunnel during the off-season. This second approach requires a great deal of irrigation water, however. When changing the poly film every four years, consider leaving the tunnel uncovered and exposed to natural precipitation for a period of time.
- Reduce the amount of salt-forming fertilizers and use vegetable-based compost containing legumes.

In caterpillar and multi-bay tunnels such as Haygroves, which are uncovered during the off-season, salt build-up is eliminated because precipitation flushes away the excess.


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**Interior Tunnel Layout**

The growing space in a high tunnel is often broken up into beds. Some farmers create raised beds slightly or substantially higher than the surrounding pathways by adding compost and/or soil. Beds can be made manually with hand tools, or mechanically with equipment such as a roto-tillers or bed shapers. A good tunnel layout optimizes crop production and accessibility. Farmers strive to maximize the growing area since space is costly and limited, while allowing ready access to all portions of the tunnel.

**Longitudinal Beds**

Setting up the rows or beds along the long axis of the tunnel is the most typical high tunnel layout, and is especially suited to growing tomatoes or other trellised or staked single row crops (see Diagram 13). Tomatoes benefit from goods air circulation, which longitudinal rows can provide via large gable end vents and doors.

A long row configuration has other advantages. It makes it easier to utilize inner row covers on a bed-by-bed basis. Fewer connections are needed for T tape. Long rows facilitate the use of tractor-driven equipment. They can also make for a simpler system, especially if only one or very few different crops are grown in the tunnel. Long rows also allow the easier use of overhead grow troughs.

Plants grown along the perimeter of a tunnel may exhibit an “edge effect,” with poorer growth common closest to the side walls because temperatures are lower there. Wider high tunnels have less of this chillier growing space relative to their overall area than narrower high tunnels, and this should be considered when determining high tunnel size. Some farmers reserve this space for especially hardy crops. For example, the Zemelskys grow hardy pea tendrils around tunnel perimeters in winter.
Lateral Beds
Orienting beds laterally across the width of a high tunnel is another solution to the twin challenges of access and crop optimization (see diagram below). This layout utilizes a center aisle, with beds running perpendicular to the aisle. Even in a 30’ wide tunnel, a worker never has more than 14’ to go from the aisle to the far end of a bed. For harvesting as well as for transplanting, this kind of accessibility means a lot. Using this configuration, the farmer can afford to make the single, center aisle generously wide without worrying about squandering prime growing space. In fact, this layout provides slightly more growing space than one divided into longitudinal beds.

The central aisle makes it easier to move materials in and product out. Worker movement is also more efficient. Flats for transplanting and harvest lugs can be put in the lateral pathways so that workers don’t have to walk over them when coming and going. A monorail or overhead tram can even be installed to mechanically move materials down the center. The central aisle layout simplifies the use of hoses. A drawback for those using drip irrigation is that many more drip starts are required because there are so many more short beds. A 30’ x 144’ high tunnel with a center aisle and beds spaced 4 feet apart has as many as 70 individual beds.

For tunnels with an East-West orientation (which is best for winter growing), configuring lateral North-South beds will result in less shading of crops. When using interior covers, the lateral bed layout enables the farmer to cover the entire tunnel with just two pieces of row cover, one to the right of the central aisle, and one to the left. Steve Moore has designed a simple rail system that supports the row cover over each half of the tunnel’s beds, making covering and uncovering a relatively quick process (see page 52 for the “tunnel within a tunnel” discussion). This approach saves labor and retains heat better.

Lateral beds can also be laid out across the entire structure, with aisles situated along the long sides of the tunnel. This layout makes sense under cold growing conditions, as the edges offer the least protected microclimate, but has a drawback in that it situates aisles where there is the least amount of headroom in a high tunnel. Slack Hollow Farm is currently using a variation on this layout.

Crop Establishment

Seedbed Preparation
High tunnel growers use both flat and raised beds, and some use both in different situations. Raised beds are especially beneficial to spring crops because they improve soil aeration and facilitate water drainage, resulting in warmer soils, increased microbial activity and nutrient availability, and enhanced root development.

There are many ways to prepare the seedbed within a high tunnel. The spectrum of possibilities ranges from hand tools to small-scale, tractor-powered field equipment. Self-propelled roto-tillers are an intermediate option between tractors and hand tools. As long as a tractor can be found that fits inside the structure, equipment such as chisel plows, spaders, tillers, bed shapers, and mulch layers can be used in high tunnels. Equipment manufacturers have begun to make specialized tunnel-scale equipment. Ample ventilation will make the use of diesel and gasoline engines in high tunnels a safer and more tolerable task.

Winter growing pioneer Eliot Coleman has devised a market garden production system relying solely on hand tools, some of which he designed. After adding soil amendments, he loosens the soil with a broad fork (a 24” wide fork that harnesses body weight rather than muscle power to loosen soil without inverting it). Next, the beds are leveled, and debris, roots and rocks are removed using an extra-wide bed preparation rake. Short tubular fingers (which can be purchased with the rake) can be placed over selected rake tines to individually mark rows or a grid pattern for seeding or transplanting. (See “Johnny’s Selected Seeds” on page 69.)
Seeding and transplanting
Because of the tight spacing in a high tunnel, seeding and transplanting is usually done manually. Northern producers use transplants for long-lived, warm weather vegetables and for most cut flower species (other than those grown from vegetative structures like bulbs or corms). In contrast, direct seeding is the popular method for starting short season, more closely spaced crops like salad greens and spinach.

There are a variety of push seeders on the market costing between $100 and $500 and up. Earthway Company manufactures one of the least expensive one-row seeders on the market. Several of these light-weight plastic seeders can be attached in a gang and pushed by hand. The more durable old Planet Junior seeders are still available from used equipment dealers (see “Tools” on page 70) and on eBay. In addition, Planet Junior production has resumed. Johnny’s sells a European push seeder modeled after the Planet Junior (though welded rather than cast) for half the price of the new $500-plus version. One-, four-, and six-row pin-point seeders are another mainstay of tunnel growers. Designed for seeding salad crops in close-row spacing, they create uniform plantings that do not need to be thinned.

Crops that are transplanted in the field are also usually transplanted in the high tunnel, including tomatoes, peppers, eggplants, cucumbers, summer squashes, melons, basil, and other herbs. Early season transplants are usually started in a heated greenhouse (or in compost-heated hot beds within the high tunnels), and transplanted into the unheated high tunnel when the climate becomes conducive to their growth.

Most cut flowers are also transplanted. For some slow-growing or hard-to-germinate species, purchasing plugs from a nursery can save on labor and fuel costs. However, plugs bring the risk of thrips and other pest outbreaks that can cause difficulties in the entire house or, worse, the multiple houses into which the starts from the greenhouse are transplanted.

Direct seeding is not the only way to start salad and braising mix crops like Asian greens, lettuces, chards, bok choy, and other relatively quick-growing greens. For greens following tomatoes, Ted Blomgren finds that transplanting allows him to keep the tomatoes in the ground three weeks longer. Then, within days of removing a tomato planting in the fall, the newly transplanted winter crops are well-established for his winter CSA.

Additional tomato yields, in his view, more than offset the cost of soil mix and labor for tending flats of seedlings in the greenhouse. This approach also reduces the risk of germination failure and gives him the plant stands for which he is looking.

For these mid-fall plantings, Ted sows up to five seeds per cell in 98-cell trays. This seeding yields clumps of plants that are set six inches apart within and between rows in 3’ wide high tunnel beds. Arugula, kales, Asian brassica greens, chard, and Red Salad Bowl (his favorite lettuce cultivar for winter growing) are among the crops he grows this way.

As a rule, the way to boost the economic return from the high tunnel investment is to keep its growing space well utilized. Intercropping and succession cropping are strategies for making optimal use of space. Interplanting scallions or fast-growing greens with slow-growing tomatoes, for example, are ways to boost economic returns from a high tunnel.

Watering
Careful attention should be paid to irrigation in high tunnels. The plant canopy in a high tunnel is usually greater than it is in the field, and water needs are correspondingly greater. During the spring and summer, when high tunnel crops are growing especially fast, their demand for water is quite high. It is not uncommon for high tunnel tomato and cucumber growers to irrigate every day during the height of summer. Water needs shrink as the days become shorter and colder. By winter, very little irrigation is required. Over the course of the year, and depending upon the growth stage of a crop, growers will adjust the amount of water provided.

Drip irrigation is a common method for providing water to plants in high tunnels. High tunnel systems are identical to those used in the field. Drip tape delivers water without wetting foliage. Preventing prolonged leaf wetness, which contributes to crop disease, is especially important in warm season crops. Drip systems are often automated with a timer to ensure regular watering. Using multiple drip lines on a bed will also provide for the water needs of multiple rows of crops. Drawbacks to drip irrigation include the cost and amount of plastic involved and the fact that drip tape interferes with crop cultivation.

Direct seeded plantings, especially the greens and root crops that are closely spaced, may be less suited to drip irrigation. For these applications, overhead sprinklers have a place in high tunnels. To break the disease cycle, watering should be done in the morning to allow plants to dry before evening.

An irrigation system can be devised that uses either drip tape or overhead sprinklers, depending on the crop rotation in the high tunnel. Low pressure, small volume micro sprinklers are available that can run off the same main trunk as drip tape, making the conversion of an irrigation system simple. New irrigation technology and products are becoming available all the time.