

Tomatoes, Peppers and Cucumbers in Small-Scale Soilless and Hydroponics Systems

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Residential and small-scale commercial food production can take many forms. Traditional home gardens that utilize native soil may be the most common, but interest in growing vegetables is not limited to those with suitable outdoor and in-ground sites. In many cases, a gardener may not have access to a plot of soil, or the soil may be of such poor quality that growing in the ground is not an option. Soilless production and hydroponics are options for many and enable small-scale vegetable production where traditional gardens would be impossible.

The growing systems and techniques involved in soilless growing can enable those in urban areas with small spaces, a sunny patio, or a range of other locations and situations to enjoy growing their own food. Growing plants without using soil has been done for many years, but the science and practice of these methods continues to develop and expand opportunities for commercial growers and gardeners alike.

This educational publication has been prepared in a cooperative effort between University of Tennessee Extension and University of Florida Cooperative Extension systems to provide information and an introduction to these hydroponic practices and techniques specifically for gardeners, students, youth and other non-commercial growers.

Growing Systems

Overview

Hydroponic fruiting crops can be grown in complete, ready-to-use purchased kits, or in systems personally assembled or constructed. These multiple or single self-contained bucket, bag and slab systems were discussed in the first publication in this series, [W 844-A An Introduction to Small-Scale Soilless and Hydroponic Systems](#). Benefits of small complete systems include the ease of setup and potential for customer support. However, the price does tend to be higher than purchasing basic components and constructing a small system. In addition to price and construction time, also consider production potential, management requirements and versatility.

Another area of concern is how easily nutrient solution can be accessed, monitored, adjusted and changed. Also think through how easily the system can be cleaned between crops. The reliability of the system

components (pumps, lines, etc.) as well as the ease of replacing components and availability of replacement parts are also important. Reuse of system components is a factor as well since buckets (Figure 1) are more expensive to purchase initially but will last for several crops. Plastic bags or slabs are priced lower but likely need to be replaced for every crop or two.



Figure 1. Ripe hydroponic tomatoes. University of Florida image.

Recirculation of nutrient solution is common for shorter-term leafy crops, and sometimes these systems are termed closed. Open systems, or feed to drain, are common for commercial fruiting crop hydroponics because providing optimum nutrient levels is simpler and pathogen risks are lower when the nutrient solution is only used once. However, on a small scale, closed systems can be used for fruiting crops to reduce solution use and make the systems easier to operate in a range of locations.

Some of the biggest challenges for hydroponic gardeners occur when they try to establish and grow larger fruiting crops in systems best used for leafy crops, including nutrient film and floating beds. These systems can be challenging in terms of room for root growth, plant support and nutrient management. Some compact tomato or pepper plants can be grown in tower systems, but keep in mind that light and nutrient

requirements are higher for these crops than for the leafy plants in the same system. Additionally, fruiting crops are grown for longer seasons than leafy crops, so they are at a higher risk for root diseases being spread by recirculating nutrient solutions. Beyond these cautions, this publication does not focus on the merits of specific systems and suppliers. Rather, the focus is on the basics of nutrient solution management and fruiting crop production because these practices are essential regardless of the production system chosen.

Production potential

Production times and yields vary for the different fruiting crops. Tomatoes may be three to four months old (90-120 days) before first fruit ripen, but harvest can continue for several months if plants are properly maintained. In commercial settings, soilless beefsteak tomato plants may produce a pound or two of harvested fruit per plant per week after they start bearing with optimum light conditions. During short days and low light during the winter months, weekly tomato yields will likely be less than 1 pound per plant. Conditions are often not as consistently optimum, so yields are generally lower.

Cucumbers reach first harvest quickly (30-50 days) but are usually harvested for weeks rather than months. Cucumber yields are often described by fruit per plant rather than weight. A productive seedless cucumber plant could produce 15 to 60 fruits per plant depending on type, size and season. Smaller fruited cucumber varieties have become very popular in recent years. Often multiple cucumber crops are grown each year. In fact, cucumber cultivars are even developed for different seasons of growing.

Broad estimates of yield can help determine what size system is needed. For example, if the hydroponic system contains space for six plants, then harvests of 3 or more pounds of beefsteak tomatoes per week could be estimated for the late spring through mid-fall months if plants are well-managed. Many factors influence production, so these values are only guides. Over time, the most accurate estimates will be derived from your own records.

Location

Many small-scale hydroponic or soilless systems can produce well in backyard, educational or small commercial greenhouses. Additionally, outdoor production is possible for some systems that are more weather resistant. Whatever the location, natural light of eight hours or more is best for fruiting crops. Adequate light levels are critical for fruiting vegetable crops. When light levels are less than needed, plants may continue to grow, but fruiting will be reduced. Air movement is also needed to support photosynthesis and reduce the infection potential for leaf diseases, which is especially important for crops grown for several months. Make sure the site does not experience high levels of reflected light and heat buildup that could stress plants and reduce productivity.

Soilless and hydroponic production can also be practiced indoors with the use of supplemental lighting. However, production is more costly when lighting and ventilation systems are needed. It also requires knowledge of necessary light levels, duration and equipment. The discussion here focuses on sites with natural light.

Common Fruiting Crops

Tomatoes

Tomato is the most commonly grown soilless vegetable crop, and there are a wide range of types and cultivars. Beefsteak tomatoes are generally the most common, but there are many others — cherry, grape (Figure 2), plum, and roma or paste tomatoes, as well as cluster or tomato-on-vine (TOV) that are the clusters of several tomatoes still attached to the stems.

Tomato cultivars have been developed specifically for greenhouses. Even when growing in a small greenhouse where productivity may not be the main criterion, these cultivars are good choices because they are more resistant to diseases common in greenhouses, like leaf mold and powdery mildew. If the soilless system is used to grow tomatoes outdoors, greenhouse tomato cultivar disease resistances may not be as useful.



Figure 2. A small grape tomato being produced on an indeterminate plant in a soilless system. Bumgarner image, use courtesy of CropKing Inc.

Taste, productivity and growth habit are important as well. Most greenhouse cultivars are indeterminate, meaning they continue to produce leaves and grow vertically while producing fruit. They have been developed to bear consistently for several months. Many home gardeners and commercial field producers grow determinate cultivars that bear over a shorter period of time and do not continue to produce new stems and leaves along with fruit for the whole crop. Both indeterminate and determinate crops can be grown in hydroponic systems, but there are differences in harvest periods and plant management. Indeterminate plants are the focus here.

There are two different cropping calendars for indeterminate greenhouse, hydroponic tomatoes. The more northern schedule has transplants seeded in December or January that enables harvest to begin in mid- to late spring. Fruit are harvested through the summer and the crop continues to produce into the fall. Low production and disease pressure often determine when to stop picking and remove the crop from production. In more southern areas, seeds are sown in or around August and come into production in the late fall. They are harvested through the winter and spring to avoid having plants in the greenhouse in the hottest part of the summer. In Tennessee, both cropping calendars are possible. In Florida, the fall-to-spring cycle is more common, but additional lighting may be useful in both sites to get the best production during the winter.

Cucumbers

Cucumber is a rapidly growing crop that can fit well in small-scale soilless production systems. In small systems, it is possible to grow cucumbers on the same fertilizer solution as tomatoes. Garden-type seeded cucumbers can be grown in soilless systems if there are bees present to carry out pollination. However, greenhouse cucumber varieties are resistant to common diseases in greenhouses and are seedless, so they do not require pollination. In fact, greenhouse cucumbers do not usually have male flowers. So, if these cultivars are grown outdoors with other cucumber types, bees can pollinate seedless cucumber flowers and they will no longer be seedless. There are also seedless cucumbers for outdoor production, which can be grown in greenhouses and the seeds may be cheaper for home growers. Cucumbers are typically grown in three to five crops per year.

Peppers

Bell peppers can be grown in soilless systems on a similar schedule to tomatoes. Growing peppers to full-colored fruit maturity can be easier in greenhouses and hydroponic systems because they are more protected from moisture extremes, insects and diseases than outdoors. However, large bells are challenging to manage because fluctuations in light, temperature and nutrients can reduce yield. When conditions are not optimum, peppers often drop blooms or small fruit instead of producing mature fruit. Small bells (Figure 3) and various types of hot peppers can be less challenging to manage and provide a more consistent harvest.

Eggplant

Eggplant can be a desirable medium-length crop that fruit at a younger age than tomatoes and peppers. While there are greenhouse eggplant cultivars, a range of cultivars for home production can also be grown. One of the largest assets of greenhouse production of eggplants is reduced pest damage (such as flea beetles). However, eggplants are favored host plants for spider mites in a greenhouse environment.



Figure 3. Red baby bell peppers in a soilless system. Bumgarner image, use courtesy of CropKing Inc.

Table 1. Fruiting crop table to estimate timing and crop calendars

	Tomato	Cucumber	Pepper
Number of crops per year and typical calendar	One Winter harvest — July seeding. August transplanting for fall-to-spring harvest. Summer harvest — December seeding, January transplanting for spring-to-fall harvest.	Three to five New cucumber seedlings are started when older plants begin to slow in production.	One Winter harvest — July seeding. August transplanting for fall-to-spring harvest. Summer harvest —December seeding. January transplanting for spring-to-fall harvest.
Time from seeding to transplant	2-4 weeks	2-3 weeks	6-8 weeks
Time from transplant to harvest	7-10 weeks	4-6 weeks	10-12 weeks

Nutrient Solution Basics

Source water

Well water and municipal water can both be used successfully, but it is best to send a water sample to a public or commercial lab to determine the levels of pH, sodium, chloride, as well as micro and macronutrients. Issues with a poor-quality water source can be more damaging in soilless systems because there is no soil to act as a buffer and the plant roots are often directly bathed in the solution.

High levels of sodium and chloride can be a concern due to salt stress (75 parts per million is often used as an upper limit). For this reason, do not use water that has gone through a water softener because softeners remove minerals that cause hardness (such as calcium, magnesium) and replace those ions with sodium. A water source with high salt levels may need to be treated (reverse osmosis) or diluted with another source to reduce potential issues with high sodium levels (Figure 4).

Nutrient solutions for soilless systems are often based on the source water, which can contain a range of dissolved minerals. Some of these minerals are plant nutrients that can be used, but nutrients could be present in larger quantities than plants require. High levels of carbonate can interfere with solution formulation, pH management or nutrient uptake by the plant.



Figure 4. High levels of sodium in the source water can lead to blossom drop (A) or fruit issues, such as blossom end rot (B). Bumgarner images, use courtesy of CropKing Inc.

Fertilizer materials

Use only fertilizers designed for hydroponic systems because they vary based on the growing system. For example, calcium and magnesium may be present in higher quantities in a hydroponic fertilizer than in fertilizers for use in soil or potted greenhouse crops. Also, most hydroponic fertilizers contain all micronutrients, which is less common in fertilizers for soil growing. To prevent clogging in pumps and irrigation systems, it is also important to use greenhouse-grade fertilizers because they are completely soluble and do not contain filler materials common in fertilizers designed for soil.

Hydroponic fertilizers are generally formulated in either a dry/granular or liquid form. Dry fertilizers are often the most cost effective. They can be purchased as a premixed product or as individual fertilizers that are combined in specific ratios based on source water. Liquid fertilizers are often premixed and not specific for source water. They are simple to use in small hydroponic systems, but are difficult to adjust to specific source water conditions. If you have poor water quality, such as high pH or carbonates, a custom mix is an option, but often such mixes are not required on a small scale. While mixing your own fertilizer can be cost effective, most small-scale producers use premixed products for convenience.

Managing Nutrient Solutions

Fertilizer use in soilless systems

Dry or granular fertilizers can be used in one of two ways in soilless systems. They can be added in known quantities directly to a known volume of water to create a nutrient solution provided to and used directly by plants. We often refer to this as a feed strength solution. Fertilizers can also be used to mix concentrated solutions. Using dry or granular fertilizers to create liquid fertilizer concentrates is essentially creating a mixture similar to the liquid fertilizers discussed below. Mixing concentrates that can be used as a source repeatedly can be a time and cost-efficient method that can also be more accurate than using dry fertilizers directly (liquid volumes can be measured more quickly and accurately than weights). Many fertilizers have instructions for either method.

Premixed liquid fertilizers are very common in the hydroponics marketplace. They contain dissolved minerals and are added to source water in precise amounts. Instructions can be given in volume of fertilizer liquid added per volume of source water, such as ounces per gallon. Liquid fertilizers can also be mixed based on dilution ratios. An example would be a 1:100 dilution ratio of concentrate to water. This would mean that 1 gallon of fertilizer concentrate added to 99 gallons of source water would create 100 gallons of nutrient solution.

Keep in mind that if you use a single-use (or feed-to-drain) system to grow fruiting crops, fertilizer solution use will be much higher than for a leafy crop system. Mixing solutions at the correct strength to feed the crops directly can become cumbersome. Blending fertilizer concentrates in batches that can be used for several days or weeks may be more time efficient and accurate. There are often differences in the ratios of nutrients for leafy and fruiting crops. It is best to separate leafy and fruiting crops in growing systems so that the correct fertilizers or concentrations of fertilizer can be used for each crop.

Nutrient solution delivery (irrigation) in soilless fruiting crop systems

Nutrient solutions are often delivered differently to fruiting crops than in the leafy crop systems. Whether growing in perlite in buckets, rockwool slabs, or peat/coconut coir in slabs or upright bags, irrigation is delivered through feed lines and drip stakes that are placed close to the root system. Drip irrigation is completed in cycles and is not continuous.

A continuous flow of nutrient solution will lead to root growth that clogs the drain lines and plants that may have a poor balance of vegetative to reproductive growth. This is one of the most common mistakes made by novice hydroponics growers.

As an example, in perlite systems, it is common to start transplants on feeding cycles that run every 30 to 60 minutes. Cycles can be closer together as the weather gets warmer, but keep in mind that frequent feed cycles increase the volume of feed solution used if the system is not recirculating. These cycles are timed so the substrate does not completely dry out, but also provide good aeration and prevent waterlogging. The drainage speed of the substrate as well as the environment impact the timing of watering cycles. Plants grown in perlite and clay pebbles need to be watered more often than those in peat or coconut coir, and warmer conditions require more frequent watering.

It is common for systems to have automatic timers that turn the pumps on and off. In larger systems, nutrient solution is often only used once before being discarded or re-treated (feed-to-drain systems). This is done to optimize nutrition and sanitation. In small systems, fruiting crops can be grown with recycled solution. These small systems are combinations of the reservoir of a recirculating lettuce system and the timer and timed delivery of a feed-to-drain system. Irrigation is delivered on set cycles, but the drainage from the buckets or bags is collected and reused. In these systems, it is important to closely manage the pH and electrical conductivity (EC, which is the total concentration of dissolved materials in the solution) and change the tanks at regular intervals (every one to two weeks) to prevent nutrient imbalances and reduce disease risk.

Managing electrical conductivity (EC) in soilless vine crop nutrient solutions

Small-scale hydroponic growers often mix nutrient solutions based on fertilizer label directions without being able to test the concentration of the final solution. This practice can work, but keep in mind that fertilizer instructions are based on an average for various crops and source water. If the water has many dissolved minerals already present, mixes can be far from ideal.

So, it can be quite useful to be able to test the concentration of all minerals and nutrients in solution, using one of two common methods. First, samples can be tested in a lab to determine each nutrient in solution. A good practice is to send a solution sample to a lab periodically, but the time and expense often prevents this from being done frequently. The second common method to describe the total amount of dissolved ions in solutions (from fertilizers and source water) is to measure electrical conductivity (EC). Measuring EC provides a good sense of the overall fertilizer strength and is a simple way to estimate if nutrient solutions are mixed correctly.

Handheld devices can be purchased to measure EC in solutions (Figure 5). Often these units are combined with pH probes (discussed below) to provide multiple-use handheld tools. With proper testing and confirmation, fertilizers can be mixed to target ECs that provide specific nutrients based on the ratio of nutrients in the fertilizer. So, while EC does not indicate the level of an



Figure 5. These are small handheld pH and EC meters that can be a useful addition to a hydroponic growing system.

individual nutrient at a given moment, it can be used to prevent serious errors in mixing and guide management of solution during growth.

Most fruiting crops are grown during much of the season with EC levels of 2.0 to 3.0 milli-Siemens (mS, which is also equivalent to mmhos) per centimeter. If solution is recirculated in small fruiting crop systems, it is especially important to measure and manage EC using handheld meters and adding source water (to lower EC) or additional fertilizer concentrate to maintain appropriate EC levels. Additionally, tank changes may need to be done more often for fruiting crops than for leafy crops in a recirculating system because the larger plants take up nutrients more rapidly, which can lead to quicker nutrient imbalances.

Managing pH in soilless vine crop nutrient solutions

pH is a measurement that determines the acidity or alkalinity of a solution. Maintaining appropriate pH levels enables nutrients to be taken up most efficiently by plants. Measurement and management of pH is an area that is critical to successful soilless production, and there are two common methods to monitor pH.

- Handheld pH meter. These small electronic meters contain electrodes that can assess the pH of a solution quickly and efficiently (Figure 5). However, they can be a bit costly (\$80 and up) and are only accurate as long as properly calibrated.
- Colorimetric (color changing) indicator solutions. Dyes can be purchased that turn specific colors at given pH levels. Adding a few drops of these indicator solutions to a sample of nutrient solution and correlating the color to a pH chart can be a simple and inexpensive system of assessing pH (if you are not red-green color blind).

Nutrient solution pH for fruiting crops is usually delivered in a range (often 5.5 to 6.0 pH) that will maintain nutrients in the most available forms for plant uptake. Depending on the source water, acidic or basic materials may need to be added to the solution to reach the appropriate pH. Dilute acid or base solutions can be purchased and mixed to raise or lower pH.

Initial adjustment of pH when mixing nutrient solutions is all that is needed in feed-to-drain systems, but regular attention is needed to maintain pH and EC levels if a recirculating system is being used. Nutrient uptake by the plant and interaction of the solution with air can rapidly change pH. The ability to resist changes in pH is known as the buffer capacity, and source water differs in its buffer capacity due to dissolved ions. Some source water may react quickly to acid or bases that change pH while others may react slowly. So, when adjusting pH, it is important to add acidic or basic materials slowly to prevent overshooting the target. Over time, you will become more comfortable with how your water reacts to pH changes and will be able to approximate how much adjustment will be needed.

Growing Transplants

Substrate

Most fruiting crops are started in cubes or plugs and grown for a few weeks before being placed in the growing system to continue growing to maturity. Growing cubes made of peat, coir, rockwool and foam are commonly used, but they are generally larger than those used for leafy crops. A cube that is at least 1.5-by-1.5 inches is recommended. Larger blocks (3-inch or 4-inch cubes) can also be used as a second transplant step. Transplants can also be produced in an identical fashion to transplants that would be started for the garden, so don't feel as if rockwool or foam blocks are essential. Transplants grown in a loose, pathogen-free, soilless mix (typical bedding plant materials) in a seedling tray can also be transplanted into substrates in buckets, bags or slabs.

Seeding and germination conditions

For fruiting crops, most seeds are larger than leafy crops and are generally seeded into evenly moist cubes or plugs placed in solid seeding trays for germination. This allows the water solution to be delivered from the bottom for young seedlings. An additional 10 to 15 percent of cubes should be seeded to allow for varied germination rates of seeds. This also allows for some selection at transplanting and enables only the most uniform seedlings to be transplanted.

After placing seeds in the cubes, ensure that the cubes are evenly moist but not saturated. Usually one-fourth inch of water in the tray is sufficient. Using clear water for the first few days after seeding can be fine, but using nutrient solution is important as soon as germination occurs. For the first few days after seeding, the nutrient solution will not be necessary since seeds are just germinating. However, it is best to use water that is in the appropriate pH range. This water or solution will need to be checked frequently for pH levels as they can change quickly and lead to poor growth in seedlings.

For tomatoes and many warm-season crops, ideal germination conditions are between 75 F and 85 F. Follow recommendations for the crop and cultivar you are using, and keep in mind that low, high or inconsistent temperatures can dramatically reduce germination percentage. Heat mats can be used to increase temperatures during germination if needed. High temperatures (higher than 90 F) can reduce germination, so do not allow trays or pads to receive direct sunlight in warm seasons to prevent higher than optimum temperatures. It may be best to germinate seeds indoors or in a shaded area during warm periods, but remove them from shaded areas as soon as germination begins.

After germination is complete and seed leaves (cotyledons) are apparent, a dilute nutrient solution should be added. Often seedlings are started on a half-strength solution (0.5-1.0 mS/cm) for the first few days and are gradually increased to between 1.0 and 1.5 mS/cm at transplanting.

Transplanting and Growing Out

Transplanting

Although it can vary, transplanting can occur around three to four weeks after seeding. Larger and older transplants are possible with larger cubes (crop support may be needed for these larger cubes). Transplants for soilless production are often a similar size to what would be planted in a traditional garden. Look for the same types of stocky seedlings with strong green color and no insect or disease issues. Place the young transplant in the substrate and be sure to cover the surface of the transplant cube. It is important to install drip irrigation quickly (especially in perlite and clay pebbles) to prevent the young plant from drying out (Figure 6). Timed irrigation cycles may be a little more closely spaced for a few days after transplanting.



Figure 6. A young tomato plant that was recently transplanted. This image shows the plastic twine clipped to secure and support the plant. Bumgarner image, use courtesy of CropKing Inc.

Environmental conditions for plant growth

Tomatoes and other warm-season crops prefer daytime temperatures in the 70s. Growth will be slowed when temperatures reach above the mid-80s. High temperatures and/or fluctuating temperatures also create the potential for fruit quality issues, such as blossom end rot. These issues are more common when the water movement carrying calcium through the plant and fruit is out of balance with water being lost through transpiration to the air.

Fruiting crops require consistently strong light to produce well and reduce disease risks. In the brightest and warmest parts of summer, shading may be needed to reduce heat and prevent heat buildup. At other times of the year, full sun is needed. Winter light levels are often insufficient for optimum growth and productivity and can limit high yields. However, small-scale growers may choose to accept slower growth and lower production in their fruiting crops in exchange for fresh produce in the off-season or to accommodate school calendars. Steps taken to control the nutrient solution or environmental conditions can often increase growth, productivity and quality. However, no amount of solution management or plant training can replace sunlight.

Plant Training

Plant support and training

Support of fruiting crops is essential for health and productivity. So, your growing area will need to have overhead wires or bars that can allow plants to be trained and managed vertically. Tomatoes, cucumbers, peppers and eggplants all will be trained vertically using plastic twine (other natural string fibers may break down during the crop cycle). Plastic twine for tomatoes can be tied to the top horizontal wire, but using a spool or bobbin (Figure 7) that can release more string, as described below, can be easier to manage and maintain over a longer period of time. Plastic clips (Figure 6 and Figure 8) are used to secure the main stem to the vertical string.



Figure 7. A bobbin used to hold extra twine and secure a vining crop to the overhead support wire. This image also shows a saddle that hangs from the support wire to prevent damage to a tender cucumber stem. Bumgarner image, use courtesy of CropKing Inc.

Most indeterminate tomatoes are trained to a single main stem, which typically has three leaves between each flower/fruit cluster. At each of the leaf axils, lateral branches form, but should be removed to maintain a single stem plant. These lateral branches (known as suckers) are removed for the life of the plant. Maintaining plants to a single main stem keeps their size manageable and helps the plant balance energy invested in leaf and stem growth versus fruit growth. This practice

should be done often (approximately weekly) so that large suckers do not need to be removed. Removing them can damage the plant, create large wounds, and waste plant energy.



Figure 8. A tomato plant showing the plastic twine and clip to secure the vine to the plant and two leaf axils where “suckers” were removed. A cluster support is also shown that supports the cluster by securing it to the twine. Bumgarner image, use courtesy of CropKing Inc.

Cucumbers are also trained vertically to twine, and most side branches are also removed to keep the plants more manageable (Figure 9). One of the challenges of managing cucumbers is the growth of tendrils. These are often removed to prevent them from attaching to other plants and support wires and creating problems in management. One or more flowers are produced and will form fruits at each leaf axil (site where leaves connect to main stem; Figure 7 and Figure 9). Cucumbers are fast growing and are often allowed to produce fruit until the main stem reaches the top support wire, at which point the stem loops over the support and is allowed to grow back down to the floor to extend harvest periods.

Peppers and eggplants are also trained to twine suspended from top wires with lateral branches removed. However, peppers and eggplants are often allowed to grow two leaders. At each branch, peppers and eggplants generally produce two branches in a “V.” At the base of the plant and the first V, both branches are allowed to grow and the strongest or most desirable stem is selected to maintain two growing points. This means that peppers and eggplants in hydroponic systems will need twice as many bobbins with twine as are needed with indeterminate tomatoes.

Plant management practices

There are two important management practices common for tomato production in soilless systems. The first is called leaning and lowering. Because of the continued growth from the main stem, the tomato plants will soon reach the top horizontal wire. To maintain growth and harvest, the growing point can be lowered. This means that more twine is released gently from the bobbin or spool and the growing point is moved (leaned) along the wire. Extra twine is then released to lower the plant gently. The movement along the top horizontal wire creates the space to lower the plant without cracking the stem. Leaning and lowering is often done once a week, but the frequency varies depending on the crop and the environment. Cherry, grape and roma tomatoes tend to be more leggy and sometimes require more frequent leaning and lowering.

To maintain sanitation and balance the plant’s energy needs, older leaves are removed (often right before leaning and lowering). Knowing

how many and when to remove leaves is important. Leaf number can be a general indicator, and it is common to have 10-14 leaves on plant at a time. This can vary by tomato type. Another useful metric is to consider where the ripening cluster of fruit is located on the plant. Leaves below the most mature cluster are typically removed because they provide little nutritional benefit to developing fruit once that fruit begins to ripen. Another indicator is where the leaning and lowering places the lower leaves. It is not desirable to have leaves on the floor, so those can be removed. A top horizontal wire of adequate height will help keep leaves from touching the floor.



Figure 9. *Young cucumber plants growing up the twine support line. Fruit can be observed at leaf axils. University of Florida image.*

Leaning and lowering is less common for cucumbers because it is time consuming and they grow quickly. The stems of peppers and eggplant are too brittle for such practices, so these plants are trained vertically until they reach the support wire.

Pollination

Tomatoes, eggplants and peppers require pollination, while seedless cucumbers do not. The use of bumblebees for pollination is standard in commercial houses, but they are generally not used in smaller greenhouses because the smallest bumblebee hives contain a colony that is too large. The high number of bees will damage flowers as they visit repeatedly. Hives can be costly when only a few plants are present;

thus, hand pollination is most cost effective and reasonable on a small scale. Commercial pollinators can be purchased or even an electric toothbrush can be used. Pollination should be done three to four times a week and is most effective when humidity is 60 to 80 percent. Thus, pollination generally is done during the middle of the day. If fruiting crops are outdoors, wind helps with pollination, and pollinators will be able to access the plants.

Harvest and Storage

Harvest when fruit are ripe to optimize flavor and visual quality. In tomato, fruit are fully ripe in physiological terms at 20 percent or greater color. However, most growers harvest at 60 to 80 percent red color. Cucumbers can be harvested at nearly any stage desired by the grower. Fruit should not be allowed to remain on the plant too long because it can reduce the energy plants can invest in younger and developing fruit. Peppers are harvested when they reach preferred color. Eggplants are often harvested before seeds fill to have a better texture. A key indicator for eggplant is harvesting while the skin retains a strong glossy appearance.

Tomato, eggplant and cucumber are all chilling sensitive below 50 F. To prevent chilling injury and advance ripening, fruit can be stored around 55 F to 60 F. Warmer temperatures will increase respiration and decrease shelf life. Peppers can be stored slightly cooler (45 F) if needed to extend shelf life. For all these fruits, preventing water loss by storing at high relative humidity is recommended (>95 percent). This is especially true of the thin-skinned seedless cucumber. Often water loss is so rapid and damaging in cucumbers that they are individually wrapped soon after picking. Smaller seedless mini cucumbers do not lose water through the skin as quickly and therefore are less likely to need to be wrapped.



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