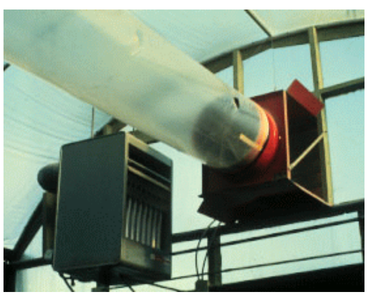

COMMERCIAL PRODUCTION OF VEGETABLE TRANSPLANTS

UNIVERSITY OF GEORGIA
EXTENSION

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Commercial Production of Vegetable Transplants

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Is Growing Greenhouse Transplants for Me?

W. Terry Kelley

Greenhouse grown containerized transplants is an increasingly popular way to establish vegetable crops. Compared to field-grown transplants, greenhouse transplants have several advantages. They can be produced earlier and more uniformly than field-grown plants. Their growth can be controlled more easily through fertility and water management and they can be held longer and harvested when needed. Because containerized plants are less crowded and healthier; stockier plants can be produced. Finally, container-grown greenhouse plants have a media-enclosed root ball, which retains moisture and root integrity at transplanting, reducing transplant shock. Transplants often result in better stands and earlier harvests; factors, which can increase profits to offset additional production costs associated with transplanting. However, if crops are lost due to frosts or other factors, replanting further increases production costs.

If you plan to use transplants, you may purchase them from a reputable transplant grower or grow them yourself. In deciding if you should grow vegetable transplants, consider (1) your overall operation, (2) the economic feasibility of growing the number of transplants you need, (3) your management skills and the availability of investment capital, (4) the specific vegetable transplants you intend to grow, and (5) the time and other resources you can spend on transplant production.

First determine if this operation fits your total business scheme. Production of greenhouse transplants is very management and resource intensive. Do you have the time, knowledge, management skills and financial resources necessary to do the job well? Start-up costs for growing greenhouse transplants are generally high. If you cannot devote sufficient resources to transplant production, it will be an extremely risky venture.

Second, weigh the risks and benefits of growing transplants. Potential problems can range from diseases and pests to structure and equipment failure. Crop management is much more intensive and less forgiving. An entire crop can be lost in a matter of days. Problems in the greenhouse can be transferred to the field and poorly grown transplants can become a liability after they are transplanted in the field.

Growers of greenhouse transplants generally fall into one of three categories: (1) producers of transplants solely for commercial sale, (2) growers of transplants for personal use, and (3) growers of transplants for their own operations as well as for commercial sale. The time that must be devoted to the production of greenhouse transplants depends on the category in which a grower falls. Since the third category is merely a hybrid of the other two, categories one and two are discussed.

If you grow transplants for sale, consider if the operation will be profitable. There must be a sufficient market for transplants just as for any other commodity. There is also the possibility that your customers may hold you responsible if their crop fails. Growers producing transplants for themselves have the same investment and loss potential risks. They may also have the added cost of buying scarce, expensive replacement plants if the crop fails. There are advantages, however, to growing your own plants. You know the crop history and variety as well as if the plants are free of diseases, insects and weeds. Contamination of your farm with pests from imported plants is also avoided. Successful vegetable producers who grow their own transplants can have healthy plants when they need them.

Once the risks, benefits and feasibility of growing transplants are determined, then decide if you want to proceed. For further discussion on the economics of growing greenhouse transplants, refer to the section entitled "The Economics of Growing Transplants in a Greenhouse."

Containers and Media

W. Terry Kelley and George E. Boyhan

Containers

The production of containerized vegetable transplants has changed dramatically in the past several years. Most container-grown vegetable transplants were produced in peat-based containers, but now the vast majority are grown in hardened plastic or polystyrene (Styrofoam) containers. Generally, peat containers, clay pots, peat pellets, fiber blocks and plastic pots are not used for mass production. Therefore, discussion here is limited to polystyrene and plastic types.

Since both plastic and polystyrene containers are a considerable financial investment, most are reused many times. Because of reuse, containers must be properly sanitized after each use or disease problems are likely to occur.

Most containers are sterilized using a 10 percent chlorine bleach solution. Problems sometimes arise when chlorine rinses are used. If polystyrene containers are not aerated properly, chlorine can soak into crevices and cause toxicity in future plantings. Use proper rates and throughly rinse with water after washing to reduce the possibility of toxicity.

Unlike polystyrene containers, plastic containers do not have the small pores and crevices that may harbor disease organisms and soak up residual chlorine. Plastic containers have edges, however, that can be difficult to clean and may provide a suitable environment for pathogens. Plastic containers are usually made up of two parts: a reusable plastic tray or flat with inserts of various sizes and/or configurations. The inserts are typically used only once.

Numerous types (shapes, sizes and configurations) of containers are available. Select the type that best fits your system. Plastic and polystyrene containers most often come in straight row arrangements. Polystyrene containers normally have inverted pyramid-shaped cells that taper toward the bottom. They may have cell sizes as small as 0.8 inch square or as large as 6 inches square. The number of cells in a container depends on the cell size. They may have from 12 to 338 cells per container. A polystyrene tray with a 1½-inch cell size has 128 cells, while a tray with a 2½-inch cell size has 72 cells.

Cells in plastic trays are arranged similarly and hold the same volume of soil as the same size polystyrene cells. Since plastic cell walls are thinner, plastic trays typically have more cells per tray than similar polystyrene containers. For example, cell media volume of a 512-cell plastic container is roughly equal to the media volume of a similar sized 338-cell polystyrene container.

More recently, single piece plastic flats are being used in transplant production (Figure 1, page 24). These flats are typically larger than standard flats (11" x 22") with a size of 13" x 26". They have greater rigidity than the inserts used with 11" x 22" flats. These single piece flats are reusable like polystyrene containers, but are considered more durable and easier to clean. As with polystyrene and plastic inserts, a variety of sizes are available.

Different plant species require differing amounts of space, nutrients and water. Certain cell sizes are more suitable for some plant species than others. Larger cells hold a greater volume of media, which enables them to retain more water and nutrients. Therefore, transplants growing in larger cells require less frequent watering and fertilizing. This helps reduce the likelihood of moisture or nutrient stress. Also, larger-celled containers normally produce stockier and earlier plants. Because of larger root volume, these plugs experience less transplant shock in the field. Proper watering is more critical with larger sized cells however, especially in the early stages when over-watering can be a real problem resulting in a greater chance of root disease development.

Generally, smaller cells are used for plants such as cabbage, broccoli, cauliflower, collard, kale and lettuce. Trays with 1 to 1½-inch cells are well suited for producing transplants of these crops. These trays generally have from 200 to 338 cells per tray. Use larger cell sizes, 1½ to 2½ inches, for production of tomato, pepper, watermelon, muskmelon, cucumber and squash transplants. These trays generally have from 72 to 200 cells per tray.

Some containers have round cells that may be in offset rows. There are no particular advantages or disadvantages to this arrangement. In situations where plants need additional room to grow, these containers may be used. However, containers with a larger cell size will serve the same purpose.

Other than sanitation difficulties, there are few disadvantages to plastic or polystyrene trays. Plants can sometimes be difficult to remove from them, particularly if roots grow through the bottom of the tray or into crevices. Transplants can be more easily removed if they are moistened prior to transporting to the field. This will also help reduce stress if there is a delay in transplanting. The trays are easy to handle, however, in a number of greenhouse setups.

Media

Generally, a commercially prepared soilless media is used for containerized transplant production. This media must be free of insects, pathogens, nematodes and weed seeds. Most commercial mixes and components for commercial mixes meet these criteria.

Media have different properties that vary according to the contents. Be careful to choose a media best suited for the intended use. For instance, several media are available specifically for starting transplants from seed. Generally, they contain finer shredded peat particles than media used for bedding plants or potting soil. Check the media description or ask the sales representative which media best suits your purpose. Select a media that drains well and provides good aeration but still has moderate water-holding capacity.

Media are available with starter nutrients (charged) or without starter nutrients (non-charged). Although either type can be used, many growers prefer a non-charged media so they can add their own starter solutions and know for sure the fertility levels are correct. Also, growers using non-charged media know the exact amounts of nutrients plants have received (provided they have precisely monitored fertilizer application/injection).

Georgia law requires media sold in this state to be labeled according to contents. According to the way they are formulated, nutrient content of charged mixes varies. Some may contain only major nutrients while some may include a mixture of trace elements as well. Growers can get customized mixes by special order (contract) with a commercial formulator.

Some charged mixes contain slow-release fertilizer that provides nutrients to plants after seed germination. Media with slow-release nitrogen is generally not recommended since it may eliminate the option of withholding nitrogen to control plant growth. It is essential to know the concentrations of all the nutrients in a media for effective fertilizer management.

There are many sources and kinds of media. Desirable prepackaged media are generally light-weight, well drained, well aerated, and hold moisture and nutrients well. The basic constituents of media are peat moss, perlite, vermiculite and a wetting agent. Other ingredients such as washed granite sand and processed bark ash can also be found in some mixes. Perlite is a processed volcanic mineral that provides good drainage to the media while holding air in the rooting zone. Most of the water from perlite stays on the surface of the particles, making it readily available to plants. Vermiculite is a mica-type mineral that can hold large amounts of air, water and nutrients.

Media with finely ground perlite, vermiculite and peat moss are best for starting vegetable transplants. Peat-lite mixtures, containing only peat moss and perlite, are not acceptable because the media is too coarse. Media without these components may not provide the needed nutrient and water-holding capacity to produce acceptable transplants. Additional ingredients are at the grower's discretion.

Although prepackaged media may be available in different sizes (Figure 2, page 24), it is usually shipped in bags or bales of either 3 or 4 cubic feet. The number of trays that can be filled by a bag/bale of media varies according to tray size and cell volume. Prices of media also vary according to contents, size of bags/bales and quantity of media purchased. We recommend transplant growers purchase commercially available media from a reputable company with an established quality control program.

It is possible for growers to mix their own soilless media. This requires additional time, labor and management, and any actual cost savings will likely be minimal. Except in special situations, commercially prepared media is preferred over home mixing.

Do not use field soils for growing containerized plants. Field soils generally drain poorly and are often contaminated with diseases and weed seed. Even though this soil can be treated to help control pest problems, soil treatment is labor-intensive, costly and does nothing to improve soil drainage.

Selecting an appropriate media is especially important when growing transplants using the float system. Media containing clumps and large particles are not recommended for float production. In the float system, plants are irrigated by water drawn from the surface of the water reservoir through holes in the bottom of the tray into the media-filled cells. For this to occur, the media must form a continuous column from the bottom to the top of the cell. Because large particles prevent media from completely filling cells, they create air pockets. Cells containing air pockets do not take up water properly and stay too dry for good plant growth – "dry cells." The media must have enough water-holding capacity to allow capillary action to draw up the water to the roots, but it must be porous enough to allow sufficient gas exchange.

Transplant Production Systems

George E. Boyhan and Darbie M. Granberry

The two transplant production systems used by Georgia transplant growers are (1) containerized production in protective structures (greenhouses, cold frames and hotbeds) and (2) in-ground transplant production in the open field (commonly referred to as field transplant production).

Container-Grown Plants in Greenhouses

This system is the most intensive and produces the earliest plants. During the past decade, major Georgia transplant growers have shifted from field to greenhouse production. This trend is expected to continue. Consequently, the value of field-grown transplants will continue decreasing and the value of greenhouse-grown containerized transplants will continue increasing.

Containerized greenhouse plants can be grown using the conventional "rail" (sometimes called "rack") system or the "float" system.

Rail System: In the rail system, rows of rails, usually aluminum T-rails, are precisely spaced to support the trays (flats) on each end (Figure 3, page 24). In this system, often referred to as the "Speedling System," trays have drainage holes in their bottoms and plants are watered and fertilized from above, usually by an overhead boom. Georgia transplant growers began using the rail system in the 1970s and used it almost exclusively until introduction of the float system in the late 1980s. Although interest in the float system is increasing, the rail system is still the most popular greenhouse transplant production system in Georgia.

Growers also use various other types of benches, that support trays at various heights. There are even moving benches available that use space more efficiently since only one isle is needed that can be created anywhere in the greenhouse as the tables are rolled out of the way. Some operations put flats directly on the ground. Usually this is on a concrete floor that will often have in-floor heating.

Float System: With the float system, growers fill polystyrene (Styrofoam) trays with media and then seed them. Trays are then irrigated and placed in a warm environment. After seeds germinate, trays are placed on a reservoir of water where they "float," either continuously or intermittently, until they are ready to go to the field. Soluble fertilizer is dissolved in the water and, as plants float, they take up water and nutrients (fertigation) from the reservoir. The float system requires less labor and management for irrigation and fertilization. Another advantage is that foliage does not get wet during irrigation. This can help reduce the incidence and severity of foliar diseases. If water in the reservoir becomes contaminated with disease-causing organisms, however, disease problems can be difficult to control (see "Disease Management" section).

One of two water management systems may be used for float production of transplants. They are the intermittent float system (sometimes called ebb and flow) and the continuous float system. The intermittent float system costs more to build and operate. Water is pumped into the reservoir to float and subsequently irrigate the plants for a brief period. Then the water is pumped or drained back into a holding tank. In the continuous float system, the water remains in the reservoir the entire time.

The float system appears to have potential for vegetable transplant production, but it has not been fully vetted for this purpose. Several kinds of vegetable transplants, including eggplant, tomato, pepper, cabbage, broccoli, cauliflower, pumpkin and squash have been produced using the float system. In some cases, such as seedless watermelon production, this type of system is not suitable since these seed need to be germinated in moist but not wet media. There is evidence that this system produces transplants more quickly than the conventional method, but the plants do not do as well upon transplanting. At this time, we do not recommend this system other than for experimental purposes.

Although the continuous float system is successfully used for tobacco transplant production, the intermittent float system may be better for vegetable transplant production. Growers experimenting with the float system are encouraged to try the intermittent float system first.

Whether one uses the float system or the rail system, the major advantage of producing transplants in greenhouses is that temperatures can be controlled and moderated for earlier, less stressed transplants.

Field Production of Bare-Root Plants

Because there is no overhead cost for protective structures, field production is the least expensive way to produce transplants. However, there are two significant restraints to field transplant production: (1) unpredictable frosts limit production of transplants for the early spring (2) soil type is critical, heavy clay soils are unsuitable for this type of production. Field-grown transplants have traditionally been used for early spring plantings in the northeastern United States and for late spring and summer plantings in the South (Figure 4, page 24). Virtually all Vidalia onions are produced as field grown transplants, however, most are produced for on-farm use with very few available for resale.

Site Selection and Soil Preparation: Field production sites should receive full sunlight but be protected from strong winds by windbreaks. The soil should be well drained and free of perennial weeds, nematodes and diseases that may adversely affect transplant growth. When selecting a site, consider the prior crop and prior herbicide applications.

Do not use land containing residues of potentially damaging "carry over" herbicides. If there is any doubt, carefully check labels of previously applied herbicides (see "Weed Management" section for information on weed control and herbicide use).

If possible, seed transplants on new ground. Otherwise, select land that grew crops suitable in a vegetable rotation. Use the following list to help select the best possible rotation crop:

1st choice: Pasture or sod
2st choice: Grain crop
3st choice: Cotton
4st choice: Soybeans
5st choice: Peanuts
6st choice: Transplants or the same vegetable crop

Since seed are planted directly into field soil, prepare the soil well to ensure that it is free of clods and debris. Deep-turn (moldboard plow or switch plow) the soil to bury litter. Use a rotary tiller or similar implement to form a smooth, raised bed free of clods. Raised beds warm up quicker in the spring and also help prevent flooding. The best soils tend to be sandy or sandy loams in nature. This type of soil when moistened is ideal for harvesting (pulling) the plants. Heavier soils such as clays make this process more difficult or impossible.

Liming and Fertilization: Base lime and fertilizer rates on soil analysis. Deep plowing on Coastal Plain soils (south Georgia) often brings acid subsoil to the surface. So take soil samples after plowing so lime recommendations are adequate. A soil pH in the range of 6.0 to 6.5 is desirable. For best results, incorporate recommended lime two to three months before planting. Apply and incorporate recommended fertilizer 7 to 10 days before seeding. Monitor transplants closely as they grow and, if needed, apply top dressings of 15 to 30 lb nitrogen per acre. Currently specific fertilizer recommendations for field grown transplant production are only available for Vidalia onions. For other listed crops (Table 1) plan on using to ½ the recommended rates for the entire crop.

Seeding and Irrigation: Plant seed close together in narrow rows (Table 1). Seed to the same depth you would for crop production (about two to three times the diameter of the seed). After seeding, water the bed uniformly to a depth of 2 inches. Keep the top ½ inch of soil moist until plants emerge. This may require several irrigations per day during hot, dry weather. Applications at 10 a.m., 2 p.m. and 4 p.m. are often used. Frequent irrigations during hot weather not only supply water for growth but also help lower soil temperatures and cool young plants.

Table 1. Spacing for Field Seeding Transplants

Crop	Inches between Rows	In-Row Spacing Inches between Plants
Broccoli	6-9	1
Cabbage	6-9	1
Cauliflower	8-9	1
Collard	6-9	1
Onion	4-6	0.125-0.5
Pepper	9-12	5
Tomato	9-12	5

After seedlings emerge, irrigate beds more thoroughly. If possible, wet the soil to a depth of 6 inches. Be careful not to injure or wash away small plants with excessive water force and do not "drown-out" transplants by allowing water to pond on the soil. Let the soil surface dry between irrigations. To help harden transplants, reduce irrigation and allow the soil to dry slightly during the five to seven days before pulling.

Frost Protection: Transplants growing in the field are especially susceptible to frost damage. Although they increase production costs, spun-bonded polyester row covers provide limited protection (a few degrees) from cold weather. These wide, lightweight covers can be laid directly over transplants prior to injurious cold temperatures. Continuous overhead irrigation also provides limited cold protection, but do not use center pivot systems in this fashion. They are not strong enough to withstand the ice that will build up and they do not supply continuous water over the entire crop.

Cold Frames and Hotbeds: Cold frames are constructed close to the ground (usually 1 to 3 feet high). They can be constructed of a number of materials including wood, PVC pipe, concrete, etc., and can have a variety of coverings including polyethylene film, rigid plastic, or glass. Hotbeds are similar but have an internal source of heat, usually buried heating cables. Seed may be planted directly into the ground or into containers placed inside the cold frame or hot bed.

Very few of Georgia's vegetable transplants are produced in cold frames and hotbeds. They are sometimes used when relatively small numbers of transplants are needed. If you need additional information on using cold frames and hotbeds for transplant production, contact your local county extension office.

Water and Fertilizer Management for Production of Containerized Transplants

Darbie M. Granberry and George E. Boyhan

Water Management

You may wish to pre-moisten peat-based media, which can be difficult to wet when completely dry and in fact may require the use of a surfactant to wet initially. After the flats are filled with media and seeded, irrigate to provide moisture for seed germination. Keep media moist but not soggy during germination. Over-watering encourages seed rot and often causes poor seedling vigor or seedling death. Keeping soils too dry during germination can prevent or delay germination and cause erratic stands.

Seed need adequate levels of oxygen and water during germination; hence, proper water management is crucial. Media selection is an important part of managing root zone moisture level. Monitor seedlings regularly to maintain optimum soil moisture. Sub-irrigation with float or intermittent float systems can result in too much water, and overhead irrigation can result in dry spots if not properly designed and maintained.

After germination, irrigate whenever the surface of the media becomes dry. To prevent over-watering, let the top inch of media dry between irrigations. When irrigating from above, continue applying water until it drips from the bottom of the flats. This will ensure that each flat is adequately watered and will also help prevent the accumulation of fertilizer salts in the media. Schedule irrigations early in the day so foliage will dry before nightfall. If leaves are still wet at sundown, they will probably stay wet all night. Moisture on leaves tends to increase disease incidence and severity.

Seedless watermelon are extremely difficult to germinate and various methods have been proposed to improve germination, including scarification of seed and careful control of media moisture. Never saturate media with water; this appears to reduce germination and final stand. Typically, media will be pre-moistened so it is damp but not wet. Triploid seed are sown in this media and the temperature is maintained above 70 degrees F, particularly at night. Often these flats or trays are stacked and wrapped in pallet plastic to maintain high temperatures. No additional water is required for 48 to 72 hours, at which time they are unwrapped and placed in the greenhouse benches. Light watering to maintain moisture is sufficient until seedlings emerge. Overwatering can reduce germination by more than 50 percent.

As plants grow and as temperatures increase, more water is needed. Monitor crop growth regularly and irrigate before seedlings become stressed from lack of moisture. Dry, hot weather greatly increases water requirements while cool, cloudy conditions reduce water needs.

As time for taking plants to the field nears, apply slightly less water to help harden-off transplants so they can better withstand the stress of transplanting. Never allow media to become completely dry, however. Adequate water is absolutely necessary for optimum growth of vegetable transplants. Manage irrigation frequencies and durations carefully.

Float System

If the media lacks sufficient moisture when the trays are first placed on the reservoir, overhead irri-gation may be required (for the first irrigation) to settle soil and adequately wet the mix. In continuous float systems, the media should "draw up" and hold sufficient moisture until the flats are removed from the reservoir. With intermittent float systems, trays should be floated until all the cells are moist. This usually takes about 40-60 minutes. Then withdraw the water until the next irrigation. Do not use float systems for seedless watermelon production.

Rail System

Overhead irrigation is used with the rail system. There are several ways to water from overhead. Most containerized transplants are irrigated with automated, mobile systems that have nozzled booms suspended over the flats (Figure 5, page 24). The boom travels the length of the house during an irrigation cycle. Properly maintained automated systems save labor, apply water and fertilizer uniformly, and can double as a pesticide applicator. For transplant production on a smaller scale, a stationary (solid-set) system with mist nozzles can be used. Stationary systems are fairly inexpensive and can be constructed relatively easily. Space nozzles precisely to maximize uniform distribution of water, fertilizer and pesticides. Hand watering is the most labor intensive and least uniform of all systems and is usually practical only when growing a relatively small number of transplants. When watering by hand, water all cells uniformly. Non-uniform water distribution results in non-uniform growth. Although hand watering may seem less expensive at first, the additional labor costs and reduced transplant value due to poor uniformity make it more expensive than many realize.

Effective water management is crucial to the production of quality transplants. Irrigation systems must be well planned, adequately designed, correctly installed and properly maintained.

Water Quality

Poor quality irrigation water can cause problems for greenhouse transplant growers. To prevent or mitigate water quality problems, test your water before you begin production. Maintain elements, soluble salts and alkalinity within desirable ranges (Table 2).

The cost of periodic water testing is insignificant compared to the cost of the problems it can help prevent. How often should testing be done? That depends on the frequency and severity of past problems. If you have had water quality problems, test your water frequently until you are sure they have been solved. If you change water sources, test the new water source before you use it.

Low or high pH water can change the media pH and affect fertilizer availability and nutrient uptake. In general, water with a pH of 5 to 7 is desirable. Depending upon the alkalinity level, water with a pH above 7 may cause problems, A high pH in combination with high alkalinity is more of a concern than a high pH in combination with a low alkalinity.

High levels of soluble salts can injure plants. Because salt impairs root function, affected plants may wilt, even when the soil is moist. Soluble salt concentrations are estimated by measuring the electrical conductivity (EC). For more information on water quality and sampling, contact your county extension office.

Fertilization

Container-grown plants are usually fertilized with soluble fertilizer, which has been dissolved in a stock solution (Figures 6 and 7, page 24). This stock solution is metered into the irrigation lines and mixed with water during application. The application of fertilizer and water through the irrigation system is called fertigation. If a charged media (contains fertilizer) is used, fertigation is usually delayed one or two weeks. Otherwise, begin fertigation when the first true leaf begins to develop. During fertigation, apply nutrient solution until it runs out the bottoms of the flats. This ensures that all plants are adequately fertilized (assuming the nutrient concentration is correct). In addition, this helps prevent salt injury by leaching residual fertilizer salts from the media.

When growing transplants, keep in mind that the biggest plant is not always the best. In fact, it could be the most undesirable. The fertilizer program must be effectively managed to grow stocky, sturdy, medium-green plants that transplant and grow well in the field. Consider your market when fertilizing. Some markets (such as the retail bedding plant trade) may desire larger, darker green transplants. Production of plants of this type usually requires slightly higher fertility levels. To successfully grow quality transplants, manage the fertility program throughout production carefully.

To help manage crop fertility, measuring EC can be helpful in determining how much fertilizer to use, when to apply it, and when to reduce its use. Inexpensive electrical conductivity meters are available from greenhouse suppliers and are a useful tool in managing crop fertility. EC is expressed as millimhos (1000 micromhos) per centimeter (mMohos/cm). Electrical conductivity readings up to 0.75 mMhos/ cm indicate low soluble salts and little or no risk of salt injury. Readings of 1.00 to 2.00 mMhos/cm are usually safe. However, as the EC reaches 2.25 mMhos/cm, the potential for salt injury increases. You should carefully monitor EC and take corrective action if levels exceed 2.25 mMhos/cm based on the saturation extraction method (see below). If levels get too high, reduce fertilizer applications or concentrations; leach soluble salts from the media with clean (containing no fertilizer) water and switch to fertilizers with a low salt index.

Table 2. Desirable Ranges in Irrigation Water without the Addition of Fertilizer.[a]

Material	Range	Material	Range
Sulfates (SO_4)	<50 ppm	Nitrate (NO3)	<5.0 ppm
Phosphorus (P)	0.005-5 ppm	Copper (Cu)	<0.2 ppm
Potassium (K)	0.5-10 ppm	Sodium (Na)	<50 ppm
Calcium (Ca)	40-100 ppm	Aluminum (Al)	<5.0 ppm
Magnesium (Mg)	30-50 ppm	Molybdenum (Mo)	<0.02 ppm
Manganese (Mn)	0.5-2 ppm	Chloride (Cl)	<100-150 ppm
Iron (Fe)[b]	2-5 ppm	Fluoride (F)	<0.75 ppm
Boron (B)	<0.5 ppm	Electrical Conductivity	<0.75 mMhos/cm
Zinc (Zn)	1-5 ppm	Alkalinity	0.75-1.3 meq/l CaCO3[c]
Hardness	100-150 mg CaCO3/l	SAR[d]	2 meq/l

[a] The sumbol < denotes "less than." Excerpted from a presentation at the Ohio Florists' Short Course, July 9, 1984, by Dr. John C. Peterson. Supplied by Maurice Watson, Ohio Agricultural Research Center - Research Extension Analytical Laboratory, as well as from a University of Tennessee extension publication PB 1617, Irrigation Water Quality for Greenhouse Production.

[b] If hard water (>150 mg CaCO3/l) is present, iron above 0.3 ppm can cause problems.

[c] 1 meq/l CaCO3 = 50 mg/l CaCO3, 1 mg/l = 1 ppm.

[d] SAR - Sodium absorption ratio. If Na is more than 40 ppm and SAR is more than 2, then Ca and Mg availability will be limited.

There are several different methods used for extracting a sample for determining EC. These include the saturation extraction method (SEM), Virginia Tech Extraction Method (VTEM), the 1:2 (media: water), and the 1:5 (media:water). The 1:2 and 1:5 extraction methods require air-dry samples, so they will not be discussed here. The saturation extraction method requires about 200 cc of media sample, which is then saturated with water. Distilled or deionized water is added until the surface just glistens with water. This is allowed to sit for 1.5 hours before vacuum filtration is used to collect the solution from the media for measurement. This is the method used by the University of Georgia's Soil Testing Laboratory.

The VTEM or pour-through method uses distilled or deionized water, which is poured through the media and collected. The media should be at or near capacity. This is achieved by watering the material throughly 2 hours before the extraction is attempted. For a flat, about 200 ml of distilled or deionized water is used to collect 50 ml of leechate solution. This may require several attempts to determine the optimum amount of water to apply to result in 50 ml of leechate. The VTEM method will almost always result in a lower reading than the SEM method. Table 3 lists methods of converting between the two, but note that this is just an approximation and your results may differ significantly.

Table 3. Converting between SEM and VTEM electrical conductivity (mMohos/cm).*

To Convert from:	Multiply by:	Add:	To Convert to:
VTEM	0.20	0.32	SEM
SEM	2.76	0.40	VTEM

* From *The How-to and Why of Four Medium Extraction Methods Used for Soluble Salts and pH Measurements*. Univ. of Fl. Environ. Horticulture Dept. Bul. 340.
1 mMoho/cm = 1 milliSiemens/cm (mS/cm) = 1 deciSiemens/m (dS/m).
1 mMoho/cm = 1,000 micromohos/cm (mMohos/cm)

Nutrient Concentrations

The amount of fertilizer needed at any given time depends on the kind of vegetable transplants being grown, the frequency of fertilizer applications, the stage of growth, the growing environment, and the amount (if any) of fertilizer in the media. As a general rule, the more often plants are fertigated, the lower the required nutrient concentration for any given fertigation.

Overhead Fertigation

If you plan to fertilize with every watering, begin with N concentrations in the 30 to 50 ppm (parts per million) range and modify the concentration as needed. Use higher rates for tomato, pepper and Cole crops and lower rates for cucurbits (watermelon and squash, etc.). Use higher rates when temperatures are high (late spring and summer) and lower rates when temperatures are cooler. Remember, fertilizer requirements may vary substantially with crop and growing conditions. If N levels above 50 ppm are applied daily, transplants are probably being over fertilized. If plants are fertilized one to three times per week, apply a more concentrated fertilizer solution. For example, if fertigation is scheduled only once a week, N concentrations of 250 to 300 ppm may be required.

If concentrations are above recommended levels, they can cause excessive growth, lowering transplant quality. Highly concentrated nutrient solutions are often phytotoxic (sometimes called "hot") and may burn the foliage, injure the roots or even kill plants. If a hot solution is accidentally applied, leach with clear water thoroughly after fertilization to wash the fertilizer off the leaves and from the substrate.

Subirrigation — Float System

Research in Florida with the intermittent float system (ebb and flow) indicates that a concentration of 30 to 45 ppm N (subirrigated once daily for 30 minutes) produces the best transplants.

EC can also be used to determine the approximate total dissolved solids (TDS) in a fertilizer solution as ppm. Start with a baseline reading of your water. For example, your water may have a reading of 0.25 mMohos/cm, which will have to be subtracted prior to calculating the ppm. For approximate conversion of EC to ppm of TDS use the following calculations:

ppm = EC x 670 (for 0.9 - 1.9 mMohos/cm)
ppm = EC x 700 (for 2.0 - 2.8 mMohos/cm)

Remember, if you are reading an EC of 1.5 mMohos/cm and your water has an EC of 0.25 mMohos/cm, subtract the 0.25 mMohos/cm from the 1.5 mMohos/cm before calculating the ppm of TDS. In this case, 838 ppm TDS. Table 4 gives approximate ranges for comparing nitrogen, TDS and EC. The TDS can be helpful in determining if your system is working correctly. Is my proportioner correctly diluting my stock solution prior to applying it to the plants, or have I correctly measured the fertilizer in the stock solution?

Table 4. Guidelines for Comparing Nitrogen, Total Dissolved Solids (TDS), and Electrical Conductivity (EC).*

Nitrogen (ppm)	TDS (ppm)	EC (mMohos/cm)
50	450-550	0.6-0.7
50-75	550-600	0.6-0.7
75-100	600-800	0.7-0.9
100-125	800-1,100	0.9-1.8
125-200	1,100-1,600	1.8-2.2

* From the *Greenhouse Tomato Handbook*. Mississippi State Univ. Publ. 1828.

Formulations

Types and analyses of fertilizers used in transplant production vary among growers. Choose and use fertilizers very carefully. Do not use potentially phytotoxic formulations that may not be intended for vegetable transplants. For overhead application, select fertilizers formulated to be used over the top of young plants and carefully control fertilizer rates to avoid injuring plants.

It is also very important that the formulations used for making stock solutions or for mixing directly into irrigation water be 100 percent soluble in water. Otherwise, you cannot be certain of the strength of the concentration or the total amount of nutrients applied. Table 5 lists some fertilizers and the amounts needed to make 50 ppm and 100 ppm nutrient solutions.

If concentrated stock solutions are to be used in a siphon system, be careful that $CaNO_3$ is not mixed in concentrated form with a phosphorus material. Calcium phosphate precipitates can occur. Other common incompatibilities include sulfates and calcium, phosphates and iron. This can be taken care of by preparing separate stock solutions for the incompatible materials. In addition, greenhouse grade $CaNO_3$ should be used since it is formulated to dissolve in water.

Please Note: Use only water-soluble fertilizer formulations to make nutrient solutions. If materials containing phosphorus (such as 12-12-12 and 20-20-20) are used, remember that the nutrient solution will contain phosphorus as well as nitrogen and potassium.

Example: If 3 ounces of ammonium nitrate and 4 ounces of potassium nitrate are dissolved in 100 gallons of water, the resulting nutrient solution will contain 100 ppm nitrogen and 100 ppm potassium.

Table 5. Ounces of Selected Fertilizer Materials Required per 100 Gallons of Water for 50 ppm and 100 ppm Nitrogen and Potassium.

	Oz./100 Gal. Water	
Fertilizer Material	**50 ppm N and K**	**100 ppm N and K**
Ammonium Nitrate and Potassium Nitrate	1.5 2.0	3.0 4.0
Sodium Nitrate and Potassium Nitrate	2.7 2.0	5.3 4.0
Calcium Nitrate and Potassium Nitrate	2.7 2.0	5.3 4.0
Urea and Potassium Nitrate	1.0 2.0	2.0 4.0
12-12-12	5.25	10.5
15-0-15, 15-15-15	4.25	8.5
20-20-20, 20-10-20	3.2	6.3

Source: *Knott's Handbook for Vegetable Growers*, Third Edition. 1988. O.A. Lorenze & D.N. Maynard. New York: John Wiley & Sons.

Scheduling Applications

Growers with automated watering systems usually prefer to apply fertilizer with each irrigation. This works very well because no one has to keep track of which irrigations are also to be fertigations. In addition, applying fertilizer during each irrigation cycle supplies nutrients frequently and reduces the likelihood of a deficiency developing.

It is not necessary to apply fertilizer with every irrigation, however. Growers who do not use automated watering systems choose to fertigate every couple of days or even less often. Since soilless media contains little, if any, residual fertilizer, schedule fertigations so that plants are fertilized at least once per week. Fertilizer concentrations in the fertigation water should be around 250 to 300 ppm for plants that are fertilized only once a week. Also, fertilizer rates may need adjusting according to the weather. As temperature increases, growth and fertilizer needs can increase. During extended cloudy periods, reduce fertilizer to prevent plants from becoming too tall and leggy. Applications of fertilizer and water can be reduced five to seven days before pulling to harden-off the plants.

Timing is critical in transplant production. Plants must be ready when the appropriate time for planting occurs. Table 6 lists the approximate number of weeks required to produce these vegetables to transplant size. Other factors such as light levels, greenhouse temperature, watering and fertility affect production time. In addition, hardening-off plants is critically important and is accomplished by lowering the temperature and/or decreasing the amount of water. However, do not harden cucurbits by temperatures <55 degrees F. Exposure to cold temperatures can reduce the yield potential of cucurbits.

Table 6. Estimated Production Time for Selected Vegetables

Crop	**Production Time (weeks)**
Broccoli	5-7
Cabbage	5-7
Collards	5-7
Cucumber	2-3
Eggplant	5-7
Cantaloupe	3-5
Pepper	5-7
Squash	2-4
Tomato	5-7
Watermelon	3-5

Adapted from *Knott's Handbook for Vegetable Growers, 4th Edition*. D.M. Maynard & G.J. Hochmuth. 1997.

Insect Management

Stormy Sparks, Extension Entomologist

Field grown transplants are subject to a variety of insect-related problems. These problems are compounded when producing transplants for sale, particularly if the transplants will be shipped out of Georgia, because regulations are involved. Contact the Georgia Department of Agriculture for information on specific transplant certification regulations (http://agr.georgia.gov/portal/site/AGR/). If you need help locating the State Department of Agriculture office nearest you, contact your county extension office for the address. If you plan to ship transplants into other states, be aware of any regulations such as insect quarantines or regulations specific to those states — before you plant. Some state regulations require preventive actions that cannot be implemented after planting.

Soil insects can reduce transplant yields rapidly by destroying seed prior to germination or killing the seedlings at any stage of development. Soil fumigants can reduce potentially damaging populations of whitefringed beetle larvae, white grubs, wireworms and other soil insects that are present at the time of land preparation. Incorporation of a soil insecticide is advised, even in fumigated fields, if they have a history of soil insect problems.

Transplant crops seeded during late fall or winter are at risk of attack from the seedcorn maggot regardless of fumigation practices. The most effective control of seedcorn maggot is a soil insecticide incorporated during land preparation or applied at planting.

Monitor foliar insect pests from plant emergence until harvest. Most foliar pests can be controlled when initial infestations are detected. Insecticides labeled for field production can be used on field grown transplants unless use on transplants is specifically prohibited by the label. Refer to the Georgia Pest Management Handbook (available through your local county Extension office or http://www.ent.uga.edu) for current field recommendations. Read the product label thoroughly for any additional restrictions. Pay special attention to certain insects that present problems for transplant production in pepper, tomato, cabbage, collard, broccoli or onion (Figure 8, page 24).

Pepper and tomato are attacked by seedling thrips that may transmit tomato spotted wilt virus (TSWV). Control of thrips with conventional insecticides is not effective in preventing the transmission of TSWV. However, products with anti-thrips feeding properties, such as imidacloprid, combined with insecticides specific for virus carrying species of thrips, can reduce the problem. If treatments are made for this purpose, begin spraying immediately after transplanting and continue during the first four to six weeks as long as thrips are migrating into the field.

Yellow “sticky traps” can be used to monitor intensity of thrips migration. Transplanting into metallic-silver reflective plastic mulch has been shown to reduce TSWV. It is also helpful to destroy transplant beds immediately after pulling or if abandoned. This helps reduce the amount of virus available for transmission as well as reducing the build up and movement of thrips. To reduce cosmetic injury by thrips, apply an insecticide every five to seven days when moderate populations (one thrips per plant) can be found or damage is observed.

Aphids transmit several virus diseases to pepper and tomato. Use virus resistant varieties when practical. On susceptible varieties, treat when winged adult aphids are found on more than 5 percent of the plants.

Pepper weevil is a serious pest of pepper. Weevil eggs are deposited in fruiting forms (buds and small pods are preferred). Do not allow transplants to begin blooming before pulling. Transplants pulled before fruiting are less likely to carry weevils into the field, as only adults will be present. Application of an effective insecticide one or two days before pulling, as a preventive treatment, will reduce the potential for movement of adults into the field. Destroy transplant beds immediately after pulling or if abandoned to reduce weevil reproduction.

Cabbage, collard and broccoli can be attacked year-round by diamondback moth (DBM) caterpillars. The diamondback moth caterpillar can be highly resistant to conventional insecticides and has the ability to rapidly become resistant to newly registered insecticides. Biological insecticides are effective treatments. Pay careful attention to insecticide rotation and resistance management with DBM. Make applications for controlling DBM when the larvae are detected. Even if no larvae are found, preventive applications are frequently made prior to pulling as a precaution, especially when plants are to be shipped out of state.

Onions are subject to injury from seedcorn maggot and other soil insects during fall production. Apply a soil insecticide for prevention.

Greenhouse Transplants

Insect problems in greenhouse operations are exacerbated by the limited number of insecticides available for greenhouse use. Current regulations allow use of insecticides on registered crops in greenhouses unless greenhouse use is prohibited on the label. Certain labeled insecticides, due to toxicity or formulation, may not be suitable for greenhouse use even though no greenhouse prohibition is present. Check with an experienced greenhouse grower or your local county extension agent prior to using a new insecticide.

Avoid soil insect pest problems by using sterile media. Sanitizing and fumigating greenhouses between plantings helps reduce early problems with aphids, whiteflies, thrips, seedcorn maggot and fungus flies. Screening is useful for exclusion of many pests such as aphids, leaf miners, diamondback moth, armyworms, pepper weevil, seedcorn maggot and other larger flying insects. For maximum efficacy, screening must be carefully maintained and entryways into the greenhouse should be carefully guarded from pest entry as well. Screening is not as successful in preventing the entry of smaller insects such as thrips and whiteflies. Also, screen tends to increase temperature inside the greenhouse and may increase cooling costs.

Insecticide Resistance Management

While pesticide use is frequently required in transplant production in order to produce marketable transplants, give special attention to resistance management, particularly in greenhouse production. Within the closed environment of a greenhouse, selection for resistance can occur rapidly because most, if not all, of the pest population is exposed to each treatment. With multiple applications of a single class of insecticides, a population of pests capable of surviving exposure to all related insecticides can rapidly develop. If this occurs in transplant production, the resistant insect populations are moved with the transplants to the field. If the same class of insecticide is then used in the field, only the susceptible "wild" population is controlled and the resistance problem is maintained.

To avoid or delay resistance problems, use insecticides with different modes of action in a rotation. Ideally, the length of rotation is based on the specific pest's biology so successive generations are not exposed to insecticides with the same mode of action. So if you are targeting control at an insect with a two-week life cycle, use one class of insecticides for two weeks, and then avoid all related insecticides with a similar mode of action for the next two weeks. Also follow this rotation as the plants are transplanted to the field, with insecticides used during transplant production avoided during early field production.

Disease Management

David B. Langston, Jr., Extension Plant Pathologist

Field Transplants

The reduction in demand for bare-root plants has caused a reduction in the acreage of field grown transplants. Loss to plant diseases has always been a major limiting factor for field transplants because of the close spacing of young plants and increased susceptibility due to the succulence of seedlings. Eradication and avoiding soilborne pathogens in plant beds are the principle means by which disease losses can be reduced.

You can use several cultural practices to reduce pathogen inoculum levels in plant beds prior to seeding. Rotate plant beds to avoid buildup of pathogens or to avoid areas where problem diseases have been know to exist. Litter destruction and deep turning will reduce inoculum levels in seedbeds used continuously. Finally, probably the most effective cultural disease management decision is to use only high quality, disease-free seed from reputable sources. Many transplant diseases can be seed transmitted, thus circumventing most disease management practices transplant growers may use. Information about pathogen screening, fungicide and insecticide seed treatments, and where the seed were produced should be available. Always record lot numbers of seed you purchase in case disease problems arise.

Soil fumigation is the most common way to reduce losses to soilborne diseases and nematodes in field transplant production. This can be achieved through subjecting the soil to extreme heat or by treating the soil with chemical fumigants. The main objective of sterilization is to rid the soil of all living organisms that may attack young seedlings. Current practices, however, cannot completely kill all soil organisms.

Sterilizing the soil with heat can be achieved by treating the soil with hot steam or by using soil solarization. Solarization heats the soil by using clear plastic mulch, which allows the sun to heat the soil while the plastic keeps the heat from escaping. For heat sterilization to be effective, the soil must have adequate moisture for proper heat transfer and should be heated to approximately 180 degrees F for one to four hours.

Few soil fumigants are available that deliver broad-spectrum control of diseases, insects, weeds and nematodes. Two fumigants that are available are methyl bromide and metam sodium. Methyl bromide is applied as a gas under a plastic tarp and provides effective control of a broad range of organisms. Methyl bromide, however, is very expensive and is scheduled to be phased out by the year 2005. Metam sodium is a water-soluble fumigant that is usually applied as a soil drench. It has a much narrower range of activity when compared to methyl bromide. Both materials are very hazardous to humans and should only be applied by experienced applicators.

Plant population and fertilization can have a significant impact on seedbed plant diseases. If over-crowding occurs, air circulation is decreased, which favors disease development. Over-fertilization with nitrogen will cause lush, succulent growth of seedlings, which makes them more susceptible to disease.

Once beds are seeded, take other precautions to manage diseases. Monitor plant beds daily to detect disease problems so the appropriate, labeled fungicides and/or bactericides may be applied. Refer to the *Georgia Pest Management Handbook* or contact your local county extension agent for specific chemical recommendations.

Greenhouse Transplants

Greenhouse transplant production is the most popular and widely used method of producing high quality vegetable transplants. However, the warm, humid conditions inside greenhouses provide an ideal environment for the development of most diseases. Previously mentioned disease management practices such as using disease-free seed and avoiding over-fertilization and over-watering pertain to greenhouse disease management.

Sanitation is critical in greenhouse transplant disease control because there are very few fungicidal and bactericidal compounds labeled for greenhouse use. Start by using clean water and transplant trays and sterile potting media. Disinfesting greenhouse structures and trays is a must. Disinfestants commonly used are products containing sodium hypochlorite (5.25 percent, diluted 1:9), formalin (37 percent, diluted 1:18), phenol products (e.g., Lysol), and quaternary ammonium compounds. Each of these compounds has specific strengths and weaknesses, so investigate those most applicable to your situation. Combinations of disinfectants may be used to cover a broad range of potential pathogens. Roguing or destroying diseased seedlings is often prudent and a necessary sanitation practice to keep other plants in the same greenhouse from becoming infected.

Reducing greenhouse humidity is an effective disease management option available to greenhouse operators. Most diseases caused by fungi and bacteria thrive in moist, humid conditions. Humidity can be reduced in the greenhouse by using open-mesh benches (which allow air to flow through benches), opening vents to expel humid air out of the greenhouse, and forcibly exhausting air by using fans.

Once diseases have been observed affecting greenhouse transplants (Figure 9, page 24), fungicides and/or bactericides may be applied to suppress continued disease spread. Examples of fungicides labeled for use in greenhouses are EBDCs (ethylenebisdithiocarbamates – ex. Dithane, Mancozeb), chlorothalonil (Bravo, Echo, Terranil, etc.) and Botran. Several copper compounds (e.g., Kocide, Top Cop) and antibiotics (streptomycin) may be used to manage greenhouse bacterial diseases. Use the *Georgia Pest Management Handbook* or contact the local county extension agent for information on currently labeled products.

A Word about Float Systems

Many growers use float systems to produce vegetable transplants. This greenhouse system uses Styrofoam trays floated in water, which eliminates the need for overhead watering. All aforementioned disease management practices used in greenhouse transplant production are appropriate for float systems.

The lack of overhead watering may reduce free moisture on foliage, which favors development of most diseases. However, condensation often still occurs, providing conditions favorable for disease. Using horizontal air flow fans can help reduce this problem.

Another problem with float systems is that some diseases can easily be transmitted through the water used to float the trays, therefore emphasizing the need for clean facilities and non-contaminated water. Completely clean facilities between each crop using a commercial grade greenhouse cleaner such as Green-Shield (n-alkyl dimethyl benzyl ammonium chloride solution), ZeroTol (hydrogen dioxide solution), or bleach solution.

Weed Management

Stanley Culpepper, Extension Weed Scientist

Managing weeds is critical for successful green-house or field production of quality vegetable transplants. Weeds compete with seedling vegetables for light, nutrients, water and space. Weeds can also harbor harmful insects and diseases, including nematodes, that can severely damage the present or preceding crop. Because many vegetable transplants are grown in a very confined space, weeds may also prevent thorough spray coverage of foliage and reduce the effectiveness of pesticide applications.

Greenhouse or Sheltered Transplants

Weeds in transplant greenhouses or shelters can be easily controlled by a variety of methods. For transplants grown in containers such as seedling trays or flats, sterile media and certified seed help prevent most weed problems. Most commercial plant growing media are certified as to purity from weed seeds. If a large bed is needed and natural soil is used, fumigate (see "Fumigation") to reduce or eliminate disease/nematode problems. Proper fumigation will also control most weed problems (nutsedge control may be inadequate).

Wind-blown seed is a potential source of weed contamination in seedling transplants. This problem can occur if greenhouses or sheltered areas are exposed to open air for a substantial amount of time. Wind-blown seed can be especially troublesome for fall grown transplants since many of the composite weeds mature and produce seed (wind-blown) during this time. Although these weed seeds may not germinate while in the greenhouse or shelter, they often germinate once they are transported to the field, since weed seed dormancy is often broken through various environmental changes. Weed seeds brought into the field with transplants often germinate very close to the transplant, which makes mechanical removal nearly impossible. Control weeds from wind-blown seed by using screens or other excluding devices that prevent them from reaching transplants.

Weed seed contamination can also come from within the greenhouse. Weeds will grow under greenhouse benches or along the edges of greenhouse walls and may seem harmless to the transplants. However, many of these weedy species such as Oxalis (yellow wood sorrel) possess unique seed dispersal mechanisms: this particular species can eject seeds up to 15 feet when the seed capsule is bumped or dries out. In addition, wind-borne seeds of many other species have the potential to reach the transplant crop. Weeds in greenhouses or shelters can disseminate seed to transplant media and are generally a nuisance. However, the most important reason for controlling these weeds is to reduce disease and/or insect pressure. Many weeds create a major source of transplant infection/infestation by harboring plant pests.

Most weeds growing inside greenhouses or shelters (not in transplant containers or media) can be controlled by periodic mechanical or chemical weeding. Generally, a non-selective herbicide such as glyphosate is effective and will also reduce subsequent contamination by weed seed if applied before seed set. It should be noted, however, that non-selective herbicides such as glyphosate should not be used when under production, but should be reserved for use between production cycles.

Residual herbicides can be very effective, but currently there are no residual herbicides labeled for greenhouse use. Avoid contamination of transplant media with treated greenhouse soil. Although there are effective means to control weeds in greenhouses/ structures, remember that weeds are best controlled by preventive measures that exclude the introduction of weed seeds. Where weed seeds are a continual problem, clean up the area and cover it with mulch.

Emerged weeds in transplant containers or media are generally hand pulled. This can be done when transplanted in the field if weeds are not too large.

Fumigation

Fumigation is a common practice for many vegetable transplant growers. Although expensive and labor intensive, proper fumigation controls most soil-borne pathogens, nematodes, and many weeds. Several gaseous, liquid or granular compounds are labeled for soil fumigation. However, most fumigants (regardless of application form) react with soil moisture to form a toxic gas. This gas kills organisms by impairing their ability to respire or breathe. Most soil fumigants are non-selective toxins that kill all organisms (seeds, nematodes, disease causing bacteria/fungi, worms, mammals, etc.) that come in contact with the gas. All soil fumigants are very toxic and should be handled with extreme caution.

Successful fumigation depends on several factors including soil moisture, soil temperature, plant residue, and soil cover or seal. To be effective, fumigant gas must penetrate throughout the soil profile before escaping to the atmosphere. Soil incorporation of fumigants is necessary to provide thorough coverage and to reduce losses due to volatilization. Incorporation equipment should leave the soil well tilled and free of clumps. Good soil moisture (near field capacity) will also help retain the gas in the soil. Although drier soil may allow more rapid movement of the gas throughout the soil profile, much of the gas can be lost to the air. In addition, many fumigants require water for conversion of the liquid or granular form into a gas. Temperatures above 50 degrees F are required for this process.

Large quantities of plant residue (weeds, crop debris, etc.) decrease fumigant performance because of decreased penetration. Many disease organisms and nematodes are harbored in these residues and can be controlled. A soil cover (usually plastic mulch) generally improves the efficacy of most fumigants and may even be required for some. If a cover is required, leave it on the soil for the recommended period of time before removal. Although some fumigants provide good control without soil covers, they require a firm soil surface to prevent volatilization. This can be accomplished by packing the soil with a heavy roller during or immediately after incorporation of the fumigant. Overhead irrigation immediately after application may also help "seal in" the fumigant by forming a crust layer on the surface.

Although proper fumigation effectively controls many weeds, selective weed control is often observed. In general, most small-seeded species such as lambsquarters, pigweeds, crabgrass, Florida pusley, etc., are controlled. Larger-seeded weeds such as morning glories, sicklepod, Florida beggarweed, Texas panicum and nutsedges are often not controlled. As a rule-of-thumb, large seeds (>1-2 mm thick at narrowest point) and weed seeds having hard seed coats are more likely to survive fumigation. All seeds germinating at the time of treatment will be killed.

Effective fumigation requires two to seven days, depending on the fumigant as well as environment and soil conditions (refer to product label). After fumigation, a waiting period is required for the soil to aerate for an adequate length of time. The length of time needed for aeration will vary and depends on whether or not the soil was covered. A waiting period of 10 to 21 days after cover removal is required for soil covered during fumigation. Soils not covered during fumigation generally need less time. Some fumigants may require tillage to help remove the fumigant gas. It is critical to allow all fumigant gases to escape before planting to avoid crop injury and stand losses. In addition, take great care when working recently fumigated soils, especially when removing soil covers, because the gases are extremely toxic to humans.

Field-Grown Transplants

Transplants produced in the field are subject to the same weed pressures as crop plants grown in the field. In many cases, weed control techniques will be the same. There are some differences, however, with certain species.

Many field transplant beds are fumigated. This provides a good degree of weed control (see "Fumigation" section above). A pre-plant incorporated or pre-emergence herbicide treatment may be necessary, however, and a non-selective herbicide can be used to control emerged weeds before seedling emergence. Consult the *Georgia Pest Management Handbook* for a listing of vegetable crops and the herbicides recommended for use in specific vegetables.

Germinating seedlings are more susceptible to herbicide injury than transplants. Therefore, if you apply an herbicide before transplant emergence, make certain it is labeled for that crop and for direct-seeded application. For example, oxyfluorfen is successfully used for weed control in transplanted onions. If oxyfluorfen is applied as a preemergence treatment to direct-seeded onions, however, severe crop injury or death will occur.

The seedbed should be well prepared and free of weeds. Prior to seeding, weeds are usually controlled by tillage, but they may also be controlled using a non-selective herbicide. Black plastic film mulch makes good soil covers for fumigation and also provides nearly complete weed control (except for nutsedge).

By using good field selection and appropriate control methods, you can successfully prevent and control weeds in transplant fields (Figure 10, page 24). Mechanical cultivation provides good control of weeds between rows and also covers most small weeds in the row. In addition, flame cultivation may be an option; however, its merits have not been fully evaluated in vegetable production. Flame cultivation involves the use of a propane fed flame directed at weeds for control. Biological weed control is generally not an option with vegetables due to the short growing season; by the time the biological agent controls the weed, the damage to the crop is irreversible.

A non-selective herbicide for weed control in row middles is an option in several vegetable crops. Avoid herbicide contact with the crop, especially when a translocatable or systemic herbicide is applied. Application with shielded spray or hooded equipment substantially reduces the risk of crop contact.

Chemical weed control is often limited in vegetables and is constantly changing from year to year. Consult the *Georgia Pest Management Handbook* for recommendations and refer to product labels for use restrictions.

Greenhouse Structures and Site Selection

Paul E. Sumner, Extension Engineer

The basic purpose of a greenhouse is to provide a reliable enclosure in an environment favorable to plant growth.

Location and Orientation

Proper greenhouse location and orientation are very important for successful transplant production and should maximize uniform sunlight. In southern latitudes, the ridge should run north south. Avoid placing the greenhouse near objects (trees, buildings, etc.) east, west or south, which will shade the house. A distance equal to at least three times the height of an object should separate it from the greenhouse. Place the greenhouse where it is sheltered from northerly and northwesterly high winds. The soil at the site must be well drained and surface water must not run into the house. Use drain tile if necessary.

Locate the greenhouse near adequate and reliable sources of utilities such as electricity, water and gas. Provide good access roads, parking, and turnaround areas, which are crucial for any commercial operation. Locate head houses or supporting facilities on the north side. Plan construction so the greenhouse can be expanded in the future.

Types of Greenhouse Structures

Gable, curved roof and Quonset are the three basic types of greenhouse structures. A gutter-connected greenhouse is more efficient to heat than a single greenhouse because of less surface area. The structural strength of a greenhouse should be strong enough to withstand local wind (70 mph) and snow (12 p.s.f) loads (snow loads in north Georgia only). Most commercially available houses are constructed of galvanized steel tubing (Figure 11, page 24).

An adequate foundation should support the structure. Use the minimum number (or size) of overhead structural members to maximize light penetration. A clear-span design allows for easy working and equipment maneuverability. Use wide, high doors as necessary for equipment and crop operations.

Wood Types, Life, and Preservative Treatment

Wood is commonly used to construct benches, doors and structural frames for greenhouses (Figure 12, page 24). Since its life and durability are important for long-term usage, proper species and/or treatment are valuable in initial construction. The typical life of untreated wood in contact with the ground is about two to three years and is generally considered unsuitable for this application.

Properly treated wood has a much longer life than most untreated species and does not interfere with normal construction, painting or management procedures. Oil borne preservatives such as creosote and penta are not recommended due to toxicity to plants and covering materials. Use the water-borne salt-type preservatives, which are just as effective, readily available and suitable for greenhouses.

Since brush-on treatment is ineffective for long-term protection, it is not recommended. Only use commercially "pressure" treated wood. The expected life of pressure treated wood is 20 to 40 years.

Southern yellow pine and Douglas fir are most often treated, but other softwood species and some hardwood can be effectively treated.

Greenhouse Coverings

One of the most important parts of a greenhouse facility is the covering. Since sunlight is generally the limiting factor in wintertime greenhouse production, a covering that transmits maximum sunlight in the plant growth spectrum is essential. Physical durability and optical stability are other critical factors. Several covering materials are available. These include glass, fiberglass, polyethylene, acrylic, polycarbonate and polyester film. For more information on greenhouse covering materials see Georgia Extension Service Bulletin 910, Hobby Greenhouses (available from your county extension office).

Much work has been done on modern green-house design and construction. Greenhouse cooling has improved with high ceiling construction and, throughout the house, mist systems that also reduce energy costs. Greenhouse designs that incorporate insect exclusion screening have reduced or eliminated insect problems. Ventilation systems that keep plants dry as well as cooling the greenhouse reduce or eliminate the incidence of disease.

Greenhouse Heating and Cooling

Paul E. Sumner, Extension Engineer

Greenhouse cooling has been improved with high ceiling construction and, throughout the house, mist systems that also reduce energy costs. Greenhouse designs that incorporate insect exclusion screening have reduced or eliminated insect problems. Ventilation systems that keep plants dry as well as cooling the greenhouse reduce or eliminate the incidence of disease.

Heating

Any heating system that provides a uniform temperature without releasing toxic fumes to the plants is acceptable for heating a greenhouse (Figure 13, page 24). Energy sources suitable for heating greenhouses include natural gas, LP gas, fuel oil, wood and electricity. Convenience, investment and operating costs are important considerations when selecting a heating system for your greenhouse. Savings in labor could justify a more expensive heating system with automated controls. Proper ventilation is essential for all systems, except electrical. Incomplete combustion of petroleum products produces ethylene gas that can cause loss of plants. Greenhouse heater requirements depend upon the amount of heat loss from the structure. Heat loss from a greenhouse usually occurs by three simultaneous modes of heat transfer: conduction, convection and radiation. The heater requirement for a greenhouse is calculated by combining all three as a coefficient in a heat loss equation. For more information on greenhouse heater sizing see Georgia Extension Service Bulletin 792, Greenhouse Heating, Cooling and Ventilation (available from your county extension office).

Ventilation and Evaporative Cooling

As the outdoor temperature rises, additional air is needed to keep inside temperatures desirable for plant growth. Outside air is usually warm enough by this time to be admitted through doors or other openings at plant level. Fans may be added or combined with a cooling pad for use in evaporative cooling. In fact, air may be pulled through the pad with or without water in the pad. During warm periods, enough air needs to be pulled from the house to provide a complete air exchange every 60 seconds. Hook fans to a thermostat or humidistat to provide proper temperature and humidity.

If summer temperatures exceed acceptable levels and cannot be corrected with reasonable air ventilation rates, evaporative cooling is an alternative. A fan and pad system, using evaporative cooling, eliminates excessive heat and adds humidity. This reduces plant moisture losses, plant wilting and the demand for irrigation.

An evaporative cooling system moves air through a screen or spray of water so that water evaporates. About 1,000 BTUs of heat are required to change 1 pound of water from liquid to vapor. If the heat for evaporation comes from the air, the air is cooled. Evaporation is greater when air entering the system is dry, that is, when the relative humidity is low. Low humidity favors evaporation of more water and enhances cooling.

Natural Ventilation

Greenhouses can be ventilated using side (Figure 14, page 24) and ridge (roof) vents (Figure 15, page 24), which run the full length of the house. These vents can be opened as needed to moderate greenhouse temperatures. Vent size is important. Ridge vents should be about one-fifth the floor area and the side vents should be the same size. Ridge vents should open above the horizontal position to provide about a 60-degree angle to the roof. Most of these vents are manually operated.

When used in combination, side and ridge vents result in thermal gradients that create circulation due to warm air rising. Houses with only side vents depend upon wind pressure for ventilation and usually do not ventilate as well. To improve ventilation of such houses, orient them to maximize wind flow through the house.

The Economics of Growing Vegetable Transplants in a Greenhouse

Greg Fonsah, Extension Economist

Plants represent only a small portion of the total cost of growing vegetables. Healthy, disease free plants are necessary to produce good yields of high quality. Because of the benefits of using containerized transplants, more growers are considering growing their own transplants in greenhouses. Growers need to determine if it is better to "grow their own" or to purchase greenhouse-grown plants from commercial plant growers. Transplant production in greenhouses requires close supervision and management. Producing transplants within a closed environment means many management decisions must be made before they are put into practice.

For illustrative purposes, a cost estimate is presented for a direct seeded rail system. Table 7 shows the total investment estimate, for this example, per rail house at about $44,870.32. The investment estimates for a float house would be almost $7,000 less. Table 8 shows operating costs of about $5,844.46 per crop in the rail house. Since seed costs vary greatly by vegetable and hybrid vs. non-hybrid, seed costs are not included in the tables.

Table 9 shows total annual costs – amortization and operating. For one crop in the rail house, amortization is $4,235.44 or $9.98 per thousand plants. For two crops, annual amortization would not change, but amortization per 1,000 plants would be half. This results in a savings of $4.99 per thousand plants. Operating costs per crop would be about the same for each crop – $5,844.46 or $13.86 per thousand plants. Total costs would be $23.84 per thousand.

Table 10 shows how total cost per 1,000 plants varies with different number of cells per tray and with number of crops grown per year. One crop produced in trays with 242 cells would be about $27.79 per thousand. As cells per tray increase, cost per 1,000 declines to about $22.46. At two crops per year, costs range from $20.83 to about $18.16 per 1,000.

Table 7. Estimated Investment and Annual Costs for Direct Seeded Rack Greenhouse.

Number of Houses	1
Per House (30' x 148')	
No. Styrofoam Trays	1,570
No. Cells per Tray	338
No. Cells per House	530,660
Percentage Cells w/Plants	0.80
Total Plants per House	424,528
Total Plants, All Houses	424,528
No. Crops to Be Grown	1
Total Plants per Year	424,528

Item	Unit	No. Units	Cost/Unit	Total Costs ($)	Your Farm
Investment Outlays:					
Site Preparation	Ea.	1.00	1,000.00	1,000.00	
House Kit	Kit	1.00	14,210.22	14,210.22	
Styrofoam Trays	Ea.	1,570.00	1.60	2,512.00	
T-Rail & Frames	Ea.	1.00	2,574.20	2,574.20	
Irrigation System	Ea.	1.00	3,698.48	3,698.48	
Seeder	Ea.	1.00	4,500.00	4,500.00	
Well & Pump	Ea.	1.00	3,500.00	3,500.00	
P.T. 2x6 Lumber	Ea.	16.00	6.92	110.72	
Door	Ea.	1.00	200.00	200.00	
Concrete	Yd.	5.50	65.00	357.50	
Electrical Service (professionally wired)	Ea.	1.00	7,500.00	7,500.00	
Gas Hook-Up	Ea.	1.00	1,200.00	1,200.00	
Erect Greenhouse	Hr.	256.00	13.70	3,507.20	
Total Investment Costs				$44,870.32	$

Table 8. Estimated Investment and Annual Costs for Direct-Seeded Rack Greenhouse.

Item	Unit	No. Units	Cost/Unit	Total Costs ($)	Your Farm
		ANNUAL OPERATING COSTS PER CROP			
Potting Medium	cu. ft.	314.00	1,000.00	1,962.50	
Tray Replacement	%	31.4	1.60	314.00	
Seed (seed cost excluded)	thou.	530.66	0.00	0.00	
Fertilizer (20-20-20)	lb.	60.00	0.65	39.00	
LP Gas	gal.	800.00	1.16	928.00	
Electricity	Kwh	400.00	0.08	32.00	
Repairs	dol.	44,870.32	0.01	448.70	
Taxes (40%)	dol.	20,395.80	0.02	407.92	
Replace Plastic Cover	dol.	0.25	1,511.00	377.75	
LABOR:					
Seeding	trays	1,256.00	0.40	502.40	
Removing Trays	hr.	8.00	6.50	52.00	
Management	hr.	70.00	6.50	455.00	
INTEREST ON:					
Operating Costs	dol.	5,202.71	7.00%	364.19	
Other					
Pest & Weed Control					
TOTAL OPERATING COSTS				$5,844.46	$

Table 9. Total Cost of Plant Production.

No.	Amortization/Cost	Notes	Amount (USD)
1.	Annual Amortization of Investment:		$4,235.44
	Years Life	20.00	
	Interest Rate	7.00%	
1a.	Annual Amortization per 1,000 Plants		$9.98
2.	Total Annual Operating Costs		$5,883.46
2a.	Operating Costs per 1,000 Plants		$13.86
3.	Total Annual Costs per House		$10,118.90
4.	Costs per 1,000 Plants	LESS SEED	$23.84

Table 10. Costs* per 1,000 Plants with Various Cell Sizes and Number of Crops Grown.

	COST (USD) BASED ON NUMBER OF CROPS		
NUMBER OF CELLS PER TRAY	1	2	3
242	27.79	20.83	18.50
288	25.57	19.71	17.76
338	23.84	18.85	17.18
392	22.46	18.16	16.73

*Excluding seed cost.

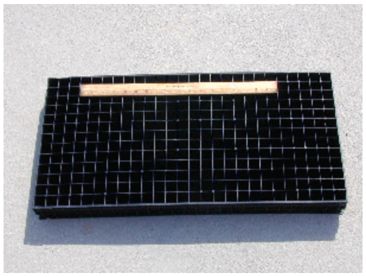

Figure 1. One-piece hard plastic flat.

Figure 2. Transplant growing media ready for trays is usually in bags.

Figure 3. Aluminum T-rails are usually used to support transplant trays.

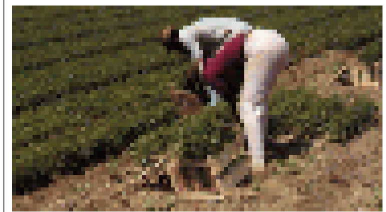

Figure 4. Pulling and packing field-grown transplants requires much hand labor.

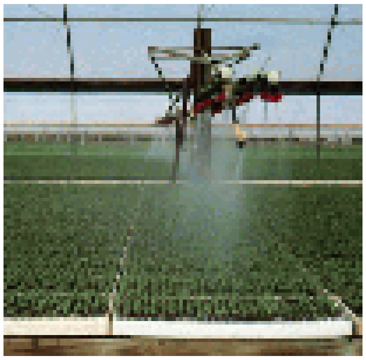

Figure 5. A "nozzled" boom irrigating transplants as it moves down the length of the greenhouse.

Figure 6. Commercial fertilizer formulations for preparing nutrient solutions.

Figure 7. A nutrient stock solution prepared using a commercially-available soluble fertilizer formulation.

Figure 8. The sweetpotato whitefly can be an especially troublesome insect pest in transplant greenhouses.

Figure 9. Transplants grown under Georgia's plant certification program are routinely inspected.

Figure 10. A weed-free transplant field resulting from a good rotation coupled with appropriate cultural practices and the use of recommended herbicides.

Figure 11. Galvanized steel tubing is often used in constructing greenhouses to be used for transplant production. Steel tubing facilitates maximum light transmittance.

Figure 12. Only lumber treated with a recommended preser-vative should be used in green-house construction. Overhead structural components made of wood do not allow as much light penetration as steel components.

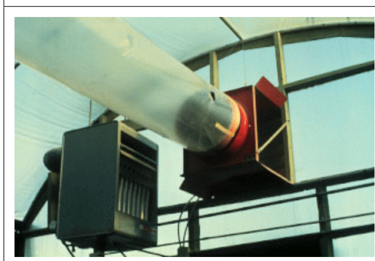

Figure 13. A forced-air heater used in conjunction with a fan-jet air distribution system helps maximize uniform heat distribution throughout the greenhouse.

Figure 14. Side vents are needed to achieve good natural ventilation.

Figure 15. Roof vents are needed to achieve good natural ventilation.

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