

An Introduction to the Production of Containerized Vegetable Transplants¹

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Introduction

This publication introduces the first-time transplant grower to the multiple factors involved in growing vegetable transplants. Many production practices are learned through the process of trial and error; therefore, the grower is encouraged to operate on a small scale until an efficient management style is developed.

Most vegetable crops can be grown from transplants, but only a few are traditionally grown in this manner. A "good" transplant is usually defined by consumer specifications. Differences in consumer preference may require distinct management techniques for the transplant crop. For example, home gardeners may favor robust, succulent plants, while commercial farmers may select more hardened plants. No simple procedure can be followed in growing vegetable transplants, and only through experience can you begin to produce a consistent product.

In general, a "good" vegetable transplant should be stocky, green, and pest-free with a well-developed root system. Once transplanted, the plant should

tolerate environmental challenges and continue growth to optimum yield. Overly hardened or under-fertilized transplants may not establish quickly, which can lead to delayed maturity and reduced yields. The "ideal" technique for growing transplants would be to raise the plant from start to finish by slow, steady, uninterrupted growth and with minimal stress. Since ideal growing conditions rarely exist, plant growth may need to be controlled through the manipulation of water, temperature, and fertilizer.

This bulletin will cover some of the many topics that need to be considered in the production of vegetable transplants. Subjects will include greenhouses, soilless media, containers, seed, irrigation, fertilization, shipping, and crop specifics.

Greenhouses

Location

The transplant production facility should be located away from farming areas. Vegetable fields are a frequent source of insects and diseases that can easily find their way to the transplant production facility. The site should be level and well drained and

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have ready access to an abundant supply of quality water. The greenhouse should be located a sufficient distance from surrounding trees or buildings to prevent shadows during the day. Other important considerations concerning greenhouse location include (1) orientation (east supplies more overall light, north-south supplies more uniform light), (2) availability of labor, (3) good proximity shipping routes, (4) easy access to utilities, (5) local zoning and tax laws, and (6) room for expansion.

Structure

Most vegetable transplant greenhouses in Florida are a modified Quonset-style, with metal trusses and metal or wooden sidewall support structures covered with polyethylene film (life expectancy = 3 years). The movable sidewalls (often called curtains) can be moved down (opened) to allow cross ventilation or up (closed) to conserve heat and provide protection from wind and rain. This style of construction can be used when cooling systems are too expensive for the production budget.

The roof of the house is generally double-layered polyethylene inflated with a small fan to reduce chafing on the trusses. An inflated roof is also important because, by maintaining constant tension on the polyethylene, the tearing action of the wind is reduced. Algae and particulate matter may build up on the outer surface of the polyethylene with time, but they may be removed by gently scrubbing the surface with a mild soap and water solution.

The front and rear walls of the house are generally constructed of a more rigid material, such as fiberglass or polycarbonates, for strength. End-wall doors should be large enough to allow the passage of such bulky materials as bales of soilless mix and wheelbarrows.

Greenhouse construction costs can run from \$1 to \$5 per square foot of house space depending on accessories. For more in-depth information on greenhouse construction specific to Florida, please refer to Jones (1991) or to books devoted solely to greenhouse operation and management (e.g., Nelson, 1985 or Langhans, 1980).

Irrigation Equipment

Two types of irrigation are presently in use in Florida vegetable transplant production: overhead, and ebb and flow (or ebb and flood). Overhead irrigation can be accomplished simply by using a garden hose. However, serious plant house growers rely on automated watering systems for uniformity of application. These machines require electricity and come as ground or elevated track models. Both units irrigate via a boom system, which can be equipped with an additional boom for pesticide application.

Ground irrigation units occupy about 9-12 square feet of walkway and are generally positioned at one end of the greenhouse upon completion of watering. Ground units are constructed in such a way that the grower must step through the unit when walking through the greenhouse. Elevated irrigation units provide all the options of ground units except that during power outages they are harder to operate manually. Exposed portions of the elevated unit should be padded to avoid head injury. Ebb and flow irrigation is accomplished by building modified troughs or pools in which the growing trays are floated (styrofoam trays perform best). The troughs can be easily constructed with wooden planks. A four-sided structure should be pressed into a sand floor or partially filled with sand. The "floor" of the trough should be sloped to facilitate drainage to one end for emptying. A liner of heavy gauge plastic will serve to hold the water. The sand beneath the liner will reduce the tendency for punctures. This system requires a high velocity pump to facilitate filling and emptying and a reservoir into which the irrigation water can be pumped.

Plants that are given unrestricted access to water exhibit unruly and uncontrolled growth, which leads to transplants that are difficult to plant and establish. Therefore, ebb and flow systems should allow for daily water removal and should be equipped with some support structure on which the growing trays can come to rest and drain properly.

Benches

Florida vegetable transplant greenhouses do not use traditional benches. In fact, the structure that

supports the growing container (flat or tray) is dictated by the type of irrigation used.

For overhead irrigation, growers use the T-rail system for bench construction. On either side of the central walkway are rows of square posts, about 3 feet tall, topped with strips of extruded aluminum in the shape of a "T" (much as angle iron is in the shape of an "L"). The flats of containers are slid between (and supported by) pairs of the T-rails (See Figure 1.)

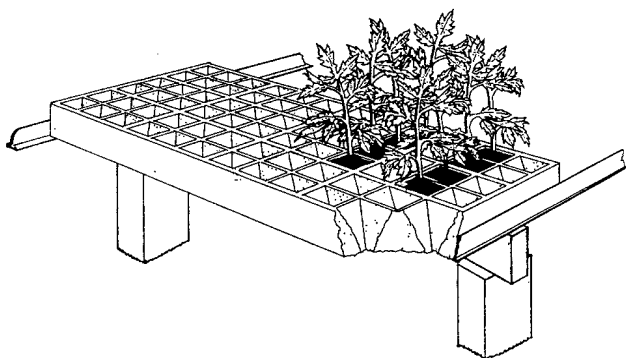


Figure 1. The T-rail system of bench construction is used for overhead irrigation. The T-rails are strips of extruded aluminum in the shape of the "T" that are attached to the tops of square posts. Flats of containers are slid between and supported by pairs of the T-rails.

For ebb and flow irrigation or bottom watering facilities, growers use different tray support systems. Guide wires that extend through the walls of the trough are often used. These are anchored to I-beams outside the trough and tightened via turnbuckles. A series of such wires are spaced appropriately to prevent the growing trays from falling into the trough. Other support structures such as PVC pipe racks or cinder blocks and hog wire can also work well in smaller systems. When designing an inrack system, care should be taken to limit the possibility of puncturing the liner.

Heating

Greenhouse heating is needed less in Florida than anywhere else in the continental U.S. Heat buildup within the house from sunlight during the day may be enough to provide sufficient warmth on most nights (especially in South Florida). However, it is

important to have a source of heat if it becomes necessary. Portable propane or kerosene heaters can be used, but uniform heat distribution within the house with this equipment is poor. An overhead unit, connected to a polyethylene tube for balanced heat distribution throughout the greenhouse, is worth the investment. Do not undersize the heating unit in an effort to save money. The minimum temperature necessary to provide adequate plant protection during freeze emergencies is, of course, crop dependent; however, most crops can tolerate 50°F for 2-3 hours.

Media

Because of the difficulty of achieving the correct proportions of the various elements (peat, perlite, vermiculite, fertilizer, etc.) of a self-prepared medium, new growers are encouraged to use a commercial, preblended, soilless mix. Otherwise, uneven distribution of these ingredients may have an effect on germination and subsequent seedling growth, leading to size variability in the transplants.

Condition of the media is important when considering containerized production. Because soilless mixes with bark or peat moss with twigs contain large elements that permit gaps in the cell (i.e.; incomplete filling), they are not appropriate for small-cell vegetable transplant production. Commercial vegetable mixes can be obtained from local agricultural product supply houses.

Soilless mixes vary widely. Many include a micronutrient "charge," and all contain a surfactant to improve the wetting capabilities of the medium. Wetting agents degrade rapidly (in 3-6 months); therefore, you should only order sufficient media to complete a planting cycle. Most soilless mix companies will change their standard mix to conform to grower specifications. For example, some growers may want granular phosphorus, lime, or specific fertilizers added.

Once seeded, the planting container may be top-dressed with vermiculite. Vermiculite reduces moisture loss from evaporation and large shifts in media temperature, which provides a more stable germination environment. Some mixes allow you to grow "drier" or "wetter" according to your special

needs. Quantity and frequency of water application will change the physical (pore space) and chemical (pH) properties of the mix, which may or may not have a negative effect on plant growth. Crop management will likely change if you switch mixes.

Containers

The time-honored method of "pricking" seedlings from heavily seeded flats and transplanting them into a final container will produce a high quality plant and normal yields (Marr & Jirak, 1990). Although some transplant production houses in Florida use this technique, it is quite labor intensive. Seeding directly into the container that is to be sold to the customer is more typical in today's market.

Tray or Flat Composition

There is a wide variety of materials used for transplant production trays, ranging from styrofoam to various plastics. Tray quality will depend on the compositional strength necessary for the growers' needs. Containers other than styrofoam or plastic (clay, wood, peat pots, etc.) are not recommended for large-scale commercial production, essentially because of shipping costs.

Disposable vacuum-molded plastic trays or "cell packs" appear to be the norm in the bedding plant industry. The finished transplant is sold or shipped in these containers, an option not usually available with styrofoam or injection-molded trays because of their higher cost. In Florida, transplants grown for the enormous local vegetable industry are shipped in the tray, and the trays are returned for reuse once the seedlings are transplanted into the field.

Age cracks in older styrofoam trays allow fertilizer and disease organisms (McGovern et al., 1993) to penetrate the tray. These "pockets" of fertilizer or disease may lead to uneven growth or even plant death within the tray. Root damage may also occur when roots that penetrate the styrofoam in search of fertilizer are later "pulled." Vacuum-molded plastic inserts have recently been made available to alleviate the age-crack phenomenon.

Drainage

The hole in the bottom of the tray should be large enough to allow good drainage when watering from overhead, and provide good capillarity (upward movement of water through the spaces within the soilless mix) when using ebb and flow irrigation. The physical properties of soilless mixes are extremely important when considering drainage. Over the 4-6 week time frame of transplant production, some soilless mixes may compact. Compaction may lead to waterlogging of the medium, which reduces the oxygen supply reaching the roots. Lack of oxygen can lead to physiological problems such as root hair loss and spindly growth. These conditions emphasize the need for good drainage within the plug.

The Tray Cell

The trend in most commercial Florida transplant houses is toward more cells per tray (or smaller cells), thus increasing production while reducing the need to build more houses. While maximizing the number of cells per tray, tray designers also strive to maximize plug volume.

Cell size is generally a matter of economics. In crops such as onions or lettuce, where plants per acre number in the tens of thousands, flats with small cells are preferred because more plants can be grown in less space. The effects of cell size on yield in the field vary (Hall, 1989; Vavrina et al., 1993). Despite these findings, larger cells are recommended for longer cycle vegetable transplants (>5 weeks) such as peppers (Weston, 1988) and tomatoes (Weston & Zandstra, 1986), while smaller cells may be the better choice for shortcrops (<4 weeks). In shortcrops, root growth may not completely fill a large cell, and damage may occur when "pulling," as soil falls away and exposes roots.

Different cell shapes within the tray are available, including the inverted pyramid, the truncated cone, the bullet, and assorted beveled shapes.

Cleaning

Transplant trays should be cleaned and sterilized before reuse to avoid a buildup of soilborne diseases such as damping-off. Adequate cleaning can be

achieved by washing trays with soap and water, followed by a chemical dip in either a quaternary ammonium (2-5%) or a sodium hypochlorite (1-2%) solution for at least 20 minutes, rinsing in clean water, and allowing trays to dry thoroughly before reuse. Steam sterilization at 160-180 for 40-60 minutes is the most effective method of combatting trayborne diseases (McGovern et al., 1993); however, purchasing sterilization equipment may be costly, and excessive temperatures and run times in the steam process can "melt" styrofoam trays. Additionally, steam sterilization causes the styrofoam bead structure to separate, accelerating age cracks and resulting in fissures that young roots can penetrate. These roots often tear off during plug removal. Cleaning styrofoam trays with the steam sterilization process will result in a tray life of 4-5 uses, while nonsteam cleaning methods enable approximately 20 uses.

Tray Inserts

Tray deterioration due to steam sterilization has led to the design of vacuum-molded plastic tray inserts to extend styrofoam tray life. These inserts fit inside a standard styrofoam tray, cost about 80 cents each, and have a life expectancy of about two years. Inserts can be steam sterilized in the styrofoam trays without damage, provided that sterilization temperatures are not excessive.

Seed

"Good seed doesn't cost, it pays!" This old adage applies doubly in vegetable transplant production. Poor germination or vigor can result in the loss of plant size uniformity within the tray, overall greenhouse productivity, and revenue. Quality seed insures good germination, rapid emergence, and vigorous growth. Poor quality seed results in "skips" or excessive seeding to compensate for poor stand establishment, both of which diminish profitability. Purchase only high quality seed that is certified disease-free or treated to reduce the risk of contamination by disease-causing organisms.

Primed Seed

Priming (enhancing) good seed can improve seed quality and vigor (Perkins-Veazie & Cantliffe,

1984; Argerich & Bradford, 1989). Primed seed is biologically altered through the addition of just enough water (and sometimes plant growth regulators) to allow the seed to undergo the early stages of germination without the radicle emerging from the seed coat. In the "primed" state, seeds germinate more rapidly and emerge more uniformly over a greater range of temperatures, soil moisture conditions, and/or various stresses. This results in greater vigor, uniformity, and rapid establishment.

Priming technology was developed to overcome germination and emergence problems in field plantings caused by adverse conditions such as cold soil, too much soil moisture, etc. However, enhanced-seed use in the greenhouse can be very cost effective as well by alleviating the need to "play catch-up" within an order or flat as a result of uneven emergence (i.e., all plants are of the same physiological age when shipped and relatively uniform in size). Rapidness of emergence means production programs (fertilizer, pesticides, etc.) can be quickly implemented. The reduction in wasted space from poor germination and the reduced labor for thinning overseeded orders or combining flats to increase plant percentage in the tray allow better production scheduling.

The added cost for priming ranges from a few cents to several dollars per 1,000 seeds. Seedless watermelon seed is usually the most expensive to prime, while carrots are generally the least expensive.

Pelleted and Coated Seed

Pelletization is a technology that uses a material such as clay to enlarge small or irregularly shaped seed and to make it spherical for ease in mechanical seeding. Pelletizing increases speed of seeding and singulation within the flat (one seed per cell); with the use of color coding it also can be used for variety identification. Pelletization was once thought to reduce seed oxygen availability in waterlogged soils (Durrant & Loads, 1986), however, this problem has been alleviated with newer formulations.

Coated seed refers to a new technology that was designed to reduce dust and worker exposure to pesticides. These coatings are highly water permeable

and are sprayed on the seed. The application of fungicides and fertilizers incorporated in the coating gives the grower additional benefits (Hummel, 1991).

Seed Germination

Of the many factors that influence germination, water and temperature affect seed performance the most. Extremes in either of these factors can result in poor germination (Ellis & Roberts, 1981; Perry, 1982). Different seed lots sown in the same environment may not act alike. Wheeler and Ellis (1992), after studying onion seed quality, seedling emergence, and seed/seedbed interactions, reported that fluctuations in the seedbed environment were the most important factors in determining final seedling emergence.

For best results, a "controlled" temperature room should be used for germination. Such rooms are insulated to allow for heating or cooling according to the specific germination needs of the seed. This technique reduces fluctuations in temperature and moisture that can occur in an open house. Room design should allow fork-lift access for moving trays on pallets, if large-scale production is anticipated.

High Temperature Effects

In tropical crops, such as tomato and pepper, high soil temperatures (>95°F) that occur in summer or fall production can suppress germination via a process called thermoinhibition. These seeds will readily germinate when the soil temperatures drop below the inhibitory level.

Conversely, seeds of lettuce and celery undergo a different high temperature condition called thermodormancy. When soil temperatures get too high for germination in these crops, a true dormancy occurs. Upon return to a more favorable soil temperature, seeds of these crops will still not germinate until the conditions of the high temperature dormancy are satisfied, a physiological process that is not well understood (Valdes & Bradford, 1985; Perkins-Veazie & Cantliffe, 1984).

Planting Depth

In most commercial facilities, flats are automatically filled with soilless mix, "dibbled" or pressed to a depth of about 1/4 inch, seeded, then covered with soilless mix or vermiculite. Proper planting depth is more important for seeds with minimal food storage reserves (cabbage family) and those that need light for germination (lettuce, celery). Variable planting depth can result in problems such as uneven stands and "leggy" plants.

Fertilization

High levels of fertilizer can reduce and delay germination in some vegetable crops (Vavrina et al., 1992), though most growers prefer some fertilizer in their mix. In general, vegetable crops will not need fertilization until after the expansion of the first true leaf. The inherent fertility of the peat (a component of the soilless mix) can carry the crop further than one might anticipate. Therefore if a nutrient charge is added to the medium prior to germination, the salt index level of this charge should be very low. High salt levels can cause complications in germination and early growth.

Water

A moist but well-drained medium is best for maximum germination. A controlled temperature germination room, where the flats are stacked on pallets, conserves moisture, which precludes the necessity of additional watering. Seedless watermelons are especially sensitive to over-watering (see crop specifics below).

Irrigation

Knowing when to water is generally determined by experience. An accomplished grower can determine when to water by picking up a tray and judging the amount of moisture by hand weighing. Water requirements change as plants grow and with varying weather conditions. Seeds should be kept moist but not soaking wet, as saturated plugs generally have less oxygen (oxygen is very important during germination). Generally for established transplants, water should be applied only when the surface of the medium is dry to the touch. Excessive

watering leads to succulent plants with restricted root growth.

Water Quality

Water quality is an often overlooked but extremely important factor in growing vegetable transplants. Water should have a pH of 6.0-7.0, be low in organic particulate and dissolved salts, and possibly be chlorinated (1ppm chlorine) to reduce bacterial contamination (Frink & Bugbee, 1987). Chlorination is difficult without a proper monitoring system, and over- or under-chlorination can be disastrous. High carbonates and bicarbonates in the water will result in rapid upward pH swings in the plug, which eventually will cause nutrient deficiencies (particularly iron [Fe] and boron [B]). Water quality should be checked by a reputable lab before attempting transplant production and then at least yearly to insure continued quality. Basic water-quality standards can be found in Table 1.

Overhead Irrigation

A standard technique in both the bedding plant and vegetable transplant industries is to water until "run through" is achieved. This means to apply enough water so that each cell of the flat has sufficient water to allow some of it to drain out of the bottom. This technique attempts to saturate each cell, which in turn provides for more uniform growth within the flat (i.e., growth differences due to an inequality of water between neighboring cells are reduced).

Ebb and Flow Irrigation

With ebb and flow irrigation (see "Irrigation Equipment"), the duration of tray contact with the water is dependent on the wetting characteristics of the soilless mix. A rule of thumb is to allow water contact with the trays for 30-60 minutes, then hand weigh the trays to determine if they are saturated. If you determine that more water is needed, allow the trays to continue to float until saturated. However, continuous flotation of vegetable transplants may result in loss of height control, as unrestricted access to water will lead to rampant growth. (See additional comments on continuous flotation under "Root Pruning.")

Plant Height

Water management is the major technique used to control plant height, but too little or too much water will result in problems. Plastic trays tend to stay wetter than styrofoam trays, so controlling height in a plastic tray may require more attention. Under cloudy conditions, maintaining low soil moisture is preferred, as plants will tend to become "leggy" in low light conditions.

Disease

Overhead irrigation should be done in the morning, if possible, to allow the foliage to dry before night. Prolonged periods of wet foliage encourage disease. Chlorination (1-2 ppm chlorine) is suggested for ebb and flow systems to reduce bacterial and fungal contamination.

Root Pruning

When roots in overhead irrigation get sufficiently long and grow out of the tray through the drainage hole, they prune naturally upon exposure to the air. Pruning occurs because air actually dehydrates or dries out the roots. Branch roots will then begin growing in the soilless mix of the plug. In a continuous float system, however, root growth goes unchecked (Leskovar et al., 1994). Sometimes, even if the water source is removed daily, the humidity of the air space beneath the trays may be high enough to support root growth. This mat of roots extending below the tray interferes with shipping and handling, and if mechanically removed, it leaves numerous sites for disease entry. Upon "pulling" the plants, further damage may occur, resulting in greater die-back after transplanting. Therefore, a continuous float system for vegetables is not advised. Additionally, the flotation troughs should be sufficiently deep (>8 inches) to allow for good air flow to dissipate the humidity after drainage.

Fertilization

The goal in vegetable transplant production is to produce a sturdy, compact plant that when transplanted will establish and grow quickly and produce an optimum yield. A good rule of thumb is to begin fertilization only after the first true leaf has expanded to 1/2 to 3/4 inches in length.

Excessive fertilization, especially early in transplant growth, will result in "leggy" plants that may defoliate and establish slowly in the field. Minimal fertilization will result in stunted plants with retarded growth in the field. Proper fertilization directly impacts field performance.

No fertilizer formula or prescribed application is available that covers all transplant crops or all environmental conditions. Growers generally develop their own blends and application schedules. Some growers like to have phosphorus, lime (Ca), some starter nitrogen (N), and micronutrients provided in the soilless mix. Others prefer to dispense all nutrients through liquid fertilization to provide for "greater control" of plant growth. Good vegetable transplant crops can be produced using either method. The method selected depends on specific growing needs. For example, should leaching of fertilizer be necessary to slow excessive growth, liquid fertilizers are more easily washed out of a mix than are granular forms.

Slow release N sources are not generally used for vegetable transplants, since plant height is difficult to control with constant N. Usually, a single application of a full-complement micronutrient package provides all the elements required for seedling growth.

Fertilizers used for liquid applications should be 100% soluble in water. Rate of application depends on nozzle size and trolley speed in automatic watering systems. Frequency of fertilizer application varies from grower to grower. Some systems deliver 250-400 ppm N once weekly or 125ppm N twice weekly; however, 30ppm N of a totally water-soluble fertilizer applied at every watering should meet most crop nutrient demands (Vavrina & Hochmuth, 1994). Generally, summer-and fall-grown transplants should receive more frequent, lower-rate feedings (e.g., 30 ppm), while winter- and spring-grown transplants can receive fewer, higher-rate feedings. Amounts of fertilizer needed per 100 gallons of water to give 50 and 100 ppm N solutions are given in Table 2.

Fertilization, watering, temperature, and sunlight each are important components in controlling plant height. The grower's ability to be flexible in fertilizer application schedules will usually result in plants of greater acceptability for commercial use.

Other Production Considerations

There are a number of other conditions and practices that should be considered in the production of containerized transplants.

Sanitation

Strict sanitary practices should be followed in the greenhouse and following crop removal from the house. Do not touch plants unless necessary. Alcohol spray bottles should be available (and used frequently) to sterilize hands if plants and flats need to be handled. Use only clean tools and uncontaminated or sterilized materials when filling flats. Spray growing areas with bromine or chlorine solutions (according to label specifications) after production to sanitize benches, walkways, and so forth.

Transplant materials (containers, media, seed, trays, fertilizers, etc.) should be stored separately from pesticides and growth regulators. Vapors from these compounds can contaminate transplant items and be absorbed by styrofoam trays. Ventilation systems should be shut off when field spraying occurs adjacent to the greenhouse (e.g., for weed control). Intake fans and windows can allow herbicide drift to damage the transplants.

Environmental Conditions

Extended periods of leaf or soil wetness can lead to disease, so avoid over-watering. Foliage should be dry by nightfall. Ventilate the house to keep relative humidity down and, if necessary, provide air movement to dry plants. Do not grow summer crops (e.g., tomatoes, watermelons) and winter crops (e.g., cabbage or lettuce) in the same greenhouse at the same time. Conditions such as temperature that are ideal for one crop may result in slowed or accelerated growth for the other crop.

Plant Pests

Judicious use of registered fungicides and insecticides will reduce the chances of pests developing chemical resistance. Transplant consumers should be made aware of the pesticide program used while growing the transplants to help in

developing their own pesticide strategies for the field.

If soilborne diseases are a particular problem, consider purchasing a suppressive medium. Suppressive media usually contain biological control organisms that subdue or even eliminate the effects of certain soil diseases such as *Pithium* spp.

No fungicides are specifically registered for use in ebb and flow systems (see notes on chlorination under "Irrigation: Disease").

Transplant Age

The "ideal age" for finished vegetable transplants has eluded researchers for decades. For example, good commercial yields of tomatoes have resulted from transplants ranging in age from 2 to 13 weeks (Vavrina & Orzolek, 1993). Studies conducted with broccoli, pepper, and watermelon have shown similar results (Lamont, 1992; Weston, 1988; Vavrina et al., 1993).

Perhaps the key to productivity in vegetable transplants resides not in age, but in the quality of the transplant. Providing plants with adequate resources to maintain appropriate growth in a limited space may be all that is necessary.

Transplanting in the Greenhouse

The practice of germinating seedlings in flats and transplanting them to containerized trays is a time tradition. In general, this process is best accomplished when the first true leaf is 1/4 to 1/2 inch long. "Prick" the plants from the flat using a small tool (pot stake, small knife, dibble, or similar tool) to support the hypocotyl section of the stem and adjacent root system. Transfer the seedling to the new container (with a well-drained medium) and set slightly deeper than originally grown to support the stem. Shade may be required to protect newly "spotted" (transferred) seedlings from wilting. Water lightly.

The plug transfer method involves transferring a small plug to a larger plug (Marr & Jirak, 1990). Less damage occurs with such a technique. Either transplant procedure is labor intensive and may not be warranted in large-scale operations, since quality

transplants can be grown in containerized trays from seed to maturity.

Plant Height

Growers have no legal chemical tool available for controlling plant height. Certain plant growth regulating chemistries can accomplish height control (Vavrina & Armbrester, 1990), but at this time none is registered with the Environmental Protection Agency (EPA) for use on vegetable crops. Plant height can be controlled to a certain extent by the judicious use of water and fertilizer. Only with experience can one learn when to withhold water and fertilizer for height control, as either method can greatly reduce the quality of the plant.

Hardening

Most transplants will be sufficiently hardened for field setting if strict measures are applied to maintain plant height, particularly under Florida growing conditions. However, additional hardening can be accomplished by either increasing the light intensity, reducing the irrigation inputs, or lowering the greenhouse temperatures by 5-10°F. Experienced growers may manipulate or reduce fertilizer inputs to achieve hardening. This technique is not advised for the novice grower for reasons of quality loss. Growers should slowly harden plants by letting them acclimate to "new" conditions, beginning about one week before anticipated sales. Over-hardening can result in slow field establishment and reduced yield.

Shipping

Shipping factors such as mechanical injury, environmental conditions, and length of storage can affect plant vigor and establishment. Mechanical injury most often occurs if the plants are pulled from the trays and packed in boxes. Leskovar and Cantliffe (1991) reported that tomato transplants shipped in the tray yielded more extra-large fruit than did transplants pulled from the tray and packed in boxes.

Risse et al. (1985) found densely packed transplants did not fare as well as loosely packed transplants both in field survival and yield. Furthermore, plants held at 50°F had greater field survival than did plants held at 70°F or higher.

Exposure to ethylene can also damage vegetable transplants. Ethylene is a plant hormone that when present at high levels can cause leaf drop, root decay, senescence, or loss of chlorophyll. Sources of ethylene gas include the exhaust of propane-powered forklifts and heaters and senescing (overripe) fruits and plants.

Individual Crops

Summary information concerning growing of the following crops can be found in Table 3.

Cole Crops

Hot-water treated seed should be used for all cole crops to combat seedborne diseases, specifically black rot. Coldframes may be used to grow and harden cole crops in northern climates; however, excessively cold temperatures cause "bolting" (premature flower stalk production) in these plants (Fontes et al., 1967; Guttormsen & Moe, 1985b).

Cold temperatures are always associated with bolting, but plant age (Guttormsen & Moe, 1985a), variety, and light conditions (Moe & Guttormsen, 1985) also play a role. When cole crop transplants are exposed to lower temperatures, there is an increased likelihood they will bolt in the field. As cole crop transplants advance in age (from 1 to 5 weeks), the ability to receive the chilling stimulus (i.e., be "programmed" for premature flowering usually increases. For example, 1- to 2-week-old transplants exposed to 38°F are less likely to field-bolt than are 4- to 5-week-old transplants. In general, if cole crops are raised at temperatures above 50° (optimum 70 - 80°F), bolting in the field will not be a problem. It is also important to note that Chinese cabbage, kohlrabi, and mustard seed can receive the chilling stimulus (later resulting in field-bolting), so refrigeration below 50°F of these seed is not advised.

Premature head formation ("buttons" or small heads) in broccoli has often been blamed on "old" transplants. Recently, Lamont (1992) reported that age alone does not influence broccoli head weight or diameter. Broccoli transplants of 31 weeks, held in standard container trays, yielded similarly to transplants grown in only six weeks. Although these data cannot be directly extrapolated to other cole

crops, one may question similar thinking about cauliflower. Cole crops can be grown successfully in both the spring and fall. Brussels sprouts, however, should be grown in the fall since frost improves firmness and flavor. Summer transplant production of cole crops is often subject to extremes in soil temperature, so shade cloth and strict control for adequate moisture may be necessary to insure optimum germination. Shade cloth should be removed before plants become spindly. Adequate boron (B) is suggested for cole crops since deficiencies in B may result in hollow heart (in broccoli and cabbage), unacceptable curd formation (in cauliflower), and other maladies. However, this does not mean additional boron loading in the transplants is necessary. A single application of a general micronutrient package should provide all of the B required for seedling growth.

Cucurbit Crops

Cucurbits such as cucumbers and squash are generally direct-seeded in the field because this method is often more cost-effective than using transplants. This is not the case with watermelon and muskmelon. With these crops, transplants are recommended to shorten the time from planting to market. Root damage in cucurbits is the number one cause of transplant loss, so care should be taken to reduce such damage. These crops traditionally spend the least amount of time in the greenhouse of any transplant crop. Cucumbers, for example, generally require less than three weeks from seed to setting. The higher temperatures needed to grow these crops tend to produce a "leggy" plant, which complicates field setting, so shorter greenhouse times are recommended. Cucurbit transplants should be field set with a maximum of two (true) leaves and before the plant gets much larger than a silver dollar in diameter. Cucurbits are fleshy, succulent plants, and the rigors of the natural environment (heat, cold, wind, abrasion, and so on) easily take their toll on "leggy" plants.

Seedless Watermelon

Of the cucurbits, the hardest to grow is the triploid (seedless) watermelon. Seedless watermelons are inherently weaker than standard watermelons, so extra care needs to be taken with this

crop. With the high cost of seedless watermelon seed, germination should be high (preferably over 90% emergence), so one seed per container or cell should be sown. Growers should never grow more than one plant per container because the plants will stretch in competition for light.

For seedless watermelon, the medium should be moist but not wet when seeding (saturate, then drain for 24 hours). Seed should be sown 1/4 to 1/2 inch below the medium surface. Seedless watermelons may drown if over-watered before or during the germination phase. This is because these seeds have more air space (which can fill with water) within the seed coat. The containers should not be irrigated again until the vermiculite (or soil surface) is dry and the soilless medium is barely moist. This practice requires experience and is used to reduce hypocotyl stretch during the germination stage. Hypocotyl stretch refers to excessive growth of the node between the root and the cotyledons (seed leaves). Excessive growth (stretch) in this area will result in spindly plants that are difficult to transplant and are more susceptible to wind damage. Low moisture should be maintained in the medium until the cotyledons are fully expanded and the first true leaf is 1/2 to 3/4 inch in diameter. Once true leaves develop, a fertilization program should be begun.

One difficulty with seedless watermelon is that the seed coat often adheres to the cotyledons, resulting in deformed seedlings. To rectify this phenomenon, the pointed end of the seed should be planted either up or at a 45° angle to the surface of the tray. This will cause the radicle (first root) to emerge and hook downward. The increased drag placed on the seed coat from the resulting "hook-shaped" radicle during emergence will usually free the coat from the seed (Maynard, 1989). Planting seed in this orientation will increase the time necessary to hand seed a flat, which may add to your production cost. A common problem in watermelon transplants is "rattailing." If seeds are planted too shallow, the radicle will push out of the soil and expose a portion of the root to the air. This condition produces a weak plant. Planting seed at an appropriate depth prevents this condition.

Many hybrid watermelon varieties flower during the four week stay in the greenhouse, unlike their open-pollinated counterparts. Since these new hybrids have been bred for increased productivity, this "problem" may become more prominent in the future as we increase our use of hybrid watermelons. Preliminary research has shown that these "seedling" male flowers do not affect subsequent field production.

Solanaceous Crops

Production procedures for all members of the Solanaceae are similar (see Table 3); however, several differences are worth mentioning. Pepper and eggplant seeds germinate more slowly than do tomato, therefore, these crops are excellent candidates for seed priming. Primed seeds of pepper and eggplant germinate in 2-4 days, as opposed to the 7-10 days required under ideal conditions with nonprimed seed. This should advance production scheduling by at least one week. Pepper seed is more variable than tomato and eggplant in terms of emergence and growth. Pepper varieties are much more diverse (bell, banana, hot, to name a few), and even cultivars within a specific type can vary widely in emergence time.

None of the solanaceous crops can tolerate low temperatures. Below 50°F all growth stops, and chilling injury can occur with prolonged exposure. Eggplant and pepper grow more slowly than tomato, so slightly higher night growing temperatures are preferred. Jalapeno pepper varieties are extremely variable in their growth. Some jalapeno varieties may require much more time in the greenhouse than do bell pepper to attain sufficient growth before going to the field. Baret al. (1990) have reported that the larger the pepper is at transplanting, the earlier the crop yields, but total fruit yield (after several harvests) was unaffected by a range of greenhouse nutritional regimens.

Irrigation scheduling is more critical in pepper and eggplant than in tomato. By virtue of their physiology, pepper and eggplant will react more quickly to deficits in irrigation and recover more slowly. Neither eggplant nor pepper recover readily from any serious shock or stunting.

Research on tomato transplants is abundant since this vegetable is perhaps the most widely grown from transplants. Melton and Dufault (1991a) reported nitrogen (N) to be the driving force in tomato transplant growth and recommended at least 225 ppm N per week. They noted phosphorus (P) was only minimally involved and potassium (K) did not impact the growth parameters measured. Widders (1989) found higher tomato growth rates five days after field setting when higher N rates (350 ppm) were used in the plant house. Historically, it has been believed that tomato transplants should be grown and maintained at temperatures of 80°F or above. Dufault and Melton (1990) and Melton and Dufault (1991b), while investigating the impact of cold temperatures on recently set or stored tomato transplants, found tomato seedlings exposed to warm days (79°F) and cold nights (36°F) had no decrease in earliness, yield, or quality.

Bugbee and White (1984) reported that in hydroponically grown tomatoes optimum root growth during the first four weeks occurred in the range of 77-86°F. In weeks five and six, the best root growth occurred in the range of 68-77°F. While these temperature regimes are "ideal" for tomato roots, they need not be rigidly adhered to in the production of tomato transplants.

Lettuce

In contrast to field-seeded lettuce, transplanted lettuce provides a uniform, complete stand that establishes quickly in competition with weeds and leads to an earlier crop. Furthermore, in the spring, long-day light conditions contribute to the bolting of lettuce, so timely establishment of transplants can reduce the incidence of this production problem. Crisphead lettuce, grown predominantly in California, typically spends 28 days in the greenhouse and 28 days in the field. Leafy types mature earlier, though four weeks in the greenhouse is still a good rule of thumb.

The seed of older varieties of lettuce requires light to germinate. With most of the newer commercial lines, light is not a requirement. For the light-requiring varieties, seed should be sown shallow (<1/16 inch) to allow for the action of light. While adequate germination occurs under normal daylight

conditions, continuous supplemental light (300 footcandle, cool-white fluorescent light) can hasten establishment. Supplemental lighting can improve lettuce transplant quality by increasing plant mass (Masson et al., 1991a,b), but the benefit of supplemental lighting in the greenhouse does not lead to yield increases in the field (e.g., pounds per acre or size of head). Due to the large number of plants per acre required for commercial lettuce production, it may be necessary to plant these crops in very small cells; otherwise, greenhouse space will be used inefficiently. Establish lettuce at 70-75°F early (weeks I and 2), then drop the temperature 5-10°F for the remaining time (if possible). Lettuce can be grown in the same greenhouse as the cole crops.

Onion

Onion transplants can also be containerized. Due to the large number of plants per acre (often >50,000) required for commercial production, it is necessary to grow onions in small cells. Onions, like celery, will remain in the greenhouse longer (10-12 weeks) than most other crops. This fact should be considered if space limitations exist.

After germination (75°F), best results will be produced by growing onions at cooler temperatures (i.e., 50°F at night and 60-70°F during the day). Harden onions by further lowering the growing temperature (40-45°F at night) and reducing water. Onions can be grown with the cole crops as well. The tips of older onion leaves often yellow. This appears to be a normal occurrence and generally poses no problem if a proper fungicide program is in place to prevent secondary fungal infection of this tissue. Onion roots are poor at best, so over-watering can cause more harm than good. Onion leaves can be clipped, like tobacco, to about four inches to prevent the tops from becoming tangled and to later facilitate planting. If onion transplants harbor disease, the clipping process can disperse it. Care must be taken to minimize the spread of disease through good sanitation practices and judicious use of fungicides. Onions are not tolerant of high salt, so do not over-fertilize.

Celery

Celery seed requires continuous light for best germination. Seed germinates slowly and, therefore, is an excellent candidate for priming. Primed celery seed should advance the production schedule of this crop by one week. Most celery seed provided by reputable seed companies will be certified Septoria-free which alleviates the need for further seed sanitation procedures. Septoria-free indicates that this foliar disease is not likely to occur. Germination percentage is generally low in celery, but seed companies should provide seed of 90% germination.

After seed is sown, keep soilless mixes moist, but not waterlogged. Presoaking the seed may produce a better stand (Nonnecke, 1989). Supplemental lighting can increase plant mass in the greenhouse, but yields are not increased in the field (Masson et al., 1991a,b).

Seed germination research has found that alternating celery germination temperatures from 77°F during the day to 59°F at night produces the best results. Growing temperatures of 55°F or greater lessens bolting incidence. Accordingly, low temperature hardening predisposes celery to bolting. Trimming tall plants is acceptable and hardens plants as well (exercise care to avoid spreading disease).

Summary

Throughout this document it has been stressed that experience is the best teacher. Skilled transplant growers experiment with different planting media, seed, fertilizer, etc., until they develop efficient and profitable production guidelines. These growers will acknowledge, however, that their guidelines are subject to change because growing plants is a dynamic process. Every crop presents differing seed lots, weather conditions, insect and disease pressures, and even customer specifications. Add to these constraints subtle changes in water quality, medium constituents, and fertilizer/irrigation calibration, and one can see that no two transplant crops are the same.

The grower can reduce his/her margin of error in the transplant crop by remembering a few simple principles:

1. Buy quality seed. A good end product begins with the best quality seed. Cutting corners on seed costs will inevitably lead to greater production costs down the line.

2. Resist the temptation to over-water. Excessive irrigation can give rise to many problems, including seed and root rots, "leggy" plants, foliar diseases, poor root development, and nutrient deficiencies.

3. Fertilize judiciously. Apply small amounts of fertilizer more frequently during warmer weather, larger amounts less frequently in cool weather. Learn to fertilize (and irrigate) according to weather patterns, not just by routine.

4. Walk the greenhouse daily. Subtle changes that occur in growth, management, or disease/insect pressure can often be detected through casual observation of the plants.

Ultimately, the success or failure of the transplant crop depends on the grower. Only through close supervision of the plants can you be aware of the signals that a problem is arising. However, through diligent observation and attention to detail, successful transplant crops can occur with greater frequency.

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Table 1. Desired water quality for problem-free irrigation.

| Type of Problem | |
|--|--|
| Salinity | |
| Electrical Conductivity* (EC) (dS/m) or Total Dissolved Solids (TDS) (mg/liter) | Less than 0.75 Less than 480 |
| Permeability | |
| Low EC (dS/m) or Low TDS (mg/liter) Sodium Adsorption Ratio ** (SAR) | More than 0.5 More than 320 Less than 6.0 |
| Toxicity of Specific Ions to Sensitive Crops | |
| Root Absorption | |
| Sodium (evaluated by SAR) Chloride (mg/liter) Boron (mg/liter) | SAR less than 3 Less than 70 1.0 |
| Foliar Adsorption (sprinkler irrigation) | |
| Sodium (mg/liter) Chloride (mg/liter) | Less than 70 Less than 100 |
| Miscellaneous | |
| NH ₄ ⁺ & NO ₃ ⁻ -N (mg/liter) HCO ₃ ⁻ (mg/liter) pH | Less than 5 Less than 40 Normal range: 6.5-8.0 |
| <p>*EC: 0.00-0.25-pure, very little risk of injury 0.25-0.75-normal, little risk of injury 0.75-2.00-acceptable, increasing potential of soluble salt damage 2.00-up-high potential for soluble salt damage</p> <p>**SAR = Na divided by the sq. root of (Ca + Mg)</p> | |
| <i>Source: Water Quality, 1985</i> | |

Table 2.

| Fertilizer Material | Oz./100 Gal. Water | |
|---|--------------------|------------|
| | 50 ppm | 100 ppm |
| Ammonium nitrate & Potassium nitrate | 1.5 2.0 | 3.0 4.0 |
| Sodium nitrate & Potassium nitrate | 2.7 2.0 | 5.4 4.0 |
| Calcium nitrate & Potassium nitrate | 2.7 2.0 | 5.4 4.0 |
| Urea & Potassium nitrate | 1.0 2.0 | 2.0 4.0 |
| 12-12-12 | 5.25 | 10.5 |
| 15-0-15, 15-15-15, 15-30-15 | 4.25 | 8.5 |
| 20-20-20, 20-10-20, 20-0-20 | 3.2 | 6.3 |
| <i>Source: Lorenz & Maynard, 1988</i> | | |

Table 3. Specific information for the production of vegetable transplants in containerized cells

| Crop | Cell Size (Dia. in inches) | Seed Required for 10,000 Transplants | Seedling Depth (in.) | Optimum Germination Temperature | Days to* Germination | Optimum Growing Temperature | | pH** tolerance | Time Required in Weeks for a Marketable Transplant |
|------------------|----------------------------|--------------------------------------|----------------------|---------------------------------|----------------------|-----------------------------|------------------|----------------|--|
| | | | | | | Day (IF) | Night (OF) | | |
| Broccoli | 0.8-1.0 | 2 oz. | 1/4 | (IF) 85 | 4 | 60-70 | Night (OF) 50-60 | 6.0-6.8 | 5-7 |
| Brussels Sprouts | 0.8-1.0 | 2 oz. | 1/4 | 80 | 5 | 60-70 | 50-60 | 5.5-6.8 | 5-7 |
| Cabbage | 0.8-1.0 | 2 oz. | 1/4 | 85 | 4 | 60-70 | 50-60 | 6.0-6.8 | 5-7 |
| Cauliflower | 0.8-1.0 | 2 oz. | 1/4 | 80 | 5 | 60-70 | 50-60 | 6.0-6.8 | 5-7 |
| Celery | 0.5-0.8 | 1 oz. | 1/16-1/8 | 70 | 7 | 65-75 | 60-65 | 6.0-6.8 | 10-12 |
| Collards | 0.8-1.0 | 2 oz. | 1/4 | 85 | 5 | 60-70 | 50-60 | 5.5-6.8 | 5-7 |
| Cucumber | 0.5-0.8 | 1 1/4 lb. | 1/2 | 90 | 3 | 70-75 | 60-65 | 5.5-6.8 | 2-3 |
| Eggplant | 1.0 | 4 oz. | 1/4 | 85 | 5 | 70-80 | 65-70 | 5.5-6.8 | 5-7 |
| Lettuce | 0.5-0.8 | 1 oz. | 1/8 | 75 | 2 | 55-65 | 50-55 | 6.0-6.8 | 4 |
| Muskmelon | 1.0 | 1 1/4 lb. | 1/2 | 90 | 3 | 70-75 | 60-65 | 6.0-6.8 | 4-5 |
| Onion | 0.5-0.8 | 3 oz. | 1/4 | 75 | 4 | 60-65 | 55-60 | 6.0-6.8 | 10-12 |
| Pepper | 0.5-0.8 | 7 oz. | 1/4 | 85 | 8 | 65-75 | 60-65 | 5.5-6.8 | 5-7 |
| Squash | 0.5-0.8 | 3 1/4 lb. | 1/2 | 90 | 3 | 70-75 | 60-65 | 5.5-6.8 | 3-4 |
| Tomato | 1.0 | 3 oz. | 1/4 | 85 | 5 | 65-75 | 60-65 | 5.5-6.8 | 5-7 |
| Watermelon | 1.0 | 3 1/4 lb. | 1/2 | 90 | 3 | 70-80 | 65-70 | 5.0-6.8 | 3-4 |

Other crops can be grown as transplants by matching seed types and growing according to the above specifications (examples: endive=lettuce). Sweet corn can be transplanted, but tap root is susceptible to breakage.

*Under optimum germination, temperatures. Primed seed will germinate more rapidly than unprimed seed under most conditions.

**Plug PH will increase over time with alkaline irrigation water.

Source: Adapted from Lorenz & Maynard, 1988